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भारत सरकार

GOVERNMENT OF INDIA

विद्युत मंत्रालय

MINISTRY OF POWER

केन्द्रीय विद्युत प्राधिकरण

CENTRAL ELECTRICITY AUTHORITY

(आई.एस.ओ. 9001:2008)

(ISO 9001:2008)

PTCC MANUAL

2010 EDITION

विद्युत एवं दूरसंचार समन्वय समिति (पीटीसीसी)

POWER AND TELECOMMUNICATION CO-ORDINATION COMMITTEE(PTCC)

PTCC MANUAL

2010

CENTRAL ELECTRICITY AUTHORITY
NEW DELHI

Executive Summary

The new edition of PTCC Manual relates to the protection of the telecommunication lines against the adverse effects of electricity lines. Section 160 of the Electricity Act, 2003 gives directions about the Protection of Telegraphic, Telephone and Electrical Signaling. It states that "Every person generating, transmitting, distributing, supplying or using electricity shall take all reasonable precautions in constructing, laying down and placing his electric lines, electrical plant and other works and in working his system, so as not injuriously to affect, whether by induction or otherwise, the working of any wire or line used for the purpose of telegraphic, telephone or electric signaling communication, or the currents in such wire or line."

The same provisions about the safety of Telecommunication circuits existed in the earlier Indian Electricity Act also. During All India Power Engineers' Conference held in 1949, it was recognized that the subject of co-existence of Power & Telecommunication System involves considerable amount of specialized study and it was recommended to the Central Government for formation of Central Standing Committee for coordination of Power and Telecommunication Systems. On the basis of their recommendation, a standing committee was formed by the Central Government in May, 1949 by the name of "Central Power & Telecommunication Co-ordination Committee"(PTCC). Since its inception in 1949, the composition of Central PTCC has been revised twice by the Govt of India, first reconstitution was done in 1982 and the second in 2001 vide Ministry of Power resolution dated 11th April, 2001 making Chief Engineer (LD&T) CEA & CGM (Inspection Circle) BSNL as Chairman of the Committee in alternate years. The other members of the Committee are from Power, Telecommunication, Railways and Defense. The Committee reviews the PTCC norms periodically in the context of the technological and infrastructural changes and safety standards at par with the international level which allows the problem to be treated with greater precision. Since this committee is 60 years old, the manual contains some historical information about PTCC and important decisions taken by the Central PTCC.

Due to rapid expansion of Power and Telecommunication Sectors, it became necessary to decentralize the Central PTCC for carrying out the processing of PTCC cases upto 33 kV at state level. Accordingly on the recommendation of Central PTCC, the Central Govt in 1968 constituted a State Level PTCC in each state. During the conference of Chairman State Electricity Boards in January 1978, the processing of power line cases up to 132 kV level was also entrusted to SLPTCC. The latest re-constitution of SLPTCC was notified by Ministry of Power vide letter dated 14.03.2001.

For the co-existence of all these service sectors it becomes very important to lay norms, guidelines and code of practice to mitigate any danger or disturbance on the telecommunication circuits. The PTCC Manual gives all the necessary instructions, directions, procedures and codes of practice to be followed to avoid any conflict of interest in location of power lines and telecom installations.

The main features of the revised PTCC manual are summarized as follows:

- Important decisions taken by Central PTCC.
- Procedure to apply for PTCC route approval.
- Flow chart depicting the various stages involved in PTCC route clearance.
- Revised Time Limits for various stages involved in PTCC clearance.
- Method to calculate Induced Voltages.
- A new chapter on calculation of Mutual Coupling (MC). The two examples of M.C calculations have been reproduced from the CCITT Directives.
- Ready Reckoner for calculation of Mutual Coupling.
- Code of practice for laying of Underground Power Cables upto 220 kV in proximity with U/G telecommunication cables.
- Setting up of Re-Engineering Supervisory Committee.
- Screening factor of underground cables used by BSNL.
- Latest postal addresses of all the sixteen zones of Indian Railways along with their jurisdiction.
- Latest postal address of all the DET's (PTCC) along with their jurisdiction.

The PTCC Manual will help both Power and Telecommunication Utilities of Public/State/Private sectors to achieve the goal of mutual and safe co-existence. The Manual will also facilitate expeditors PTCC clearances for erecting the Power Transmission Lines and Communication network.

सत्यमेव जयते

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SEWA BHAWAN, R.K. PURAM
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MESSAGE

The electrical energy being clean and the most convenient form of energy, having preference over other forms of energy, is a vital input for the economic development of the country. Along with the development of the transmission network of power sector, the development of telecommunication network, railway network and communication work of Defense sector also plays a major role at every stage of development of a nation. In order to provide interference free, economical and quality services of power and telecommunication, Government of India constituted a Central Standing Committee namely Power & Telecommunication Co-ordination Committee (PTCC) for addressing the Inter-Sector Telecommunication interference related issues amongst Power, Telecommunication, Railway and Defense Communication.

PTCC had been in existence since last 60 years and played a vital role in resolving technical issues, evolving standards and ensuring safe co-existence among various Power and Telecom Operators. I am pleased to know that new Edition of PTCC Manual has been brought out by Central PTCC after due diligence, deliberations and consultation with all the stakeholders.

I hope that the revised version of PTCC Manual would serve a useful guideline for all the utilities and other stakeholders for expediting the PTCC clearances for power lines and telecommunication network.

July, 2010

(GURDIAL SINGH)

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Message from Member(GO&D),Central Electricity Authority

Recognizing the need for coordination amongst the electrical and communication systems, a Power and Telecommunication Co-ordination Committee (PTCC) has been constituted by the Government of India comprising members from Power Utilities, Telecommunication, Railways and Defense. The objective of the Committee is to ensure the safety to telecommunication equipment and precious human lives of personnel working in the concerned organizations as also those working in the close vicinity of power transmission lines. The Committee has made significant contribution since its inception.

The aggregate length of 220 kV and above transmission lines in the Country was 1,92,535 circuit-kilometers at the end of 10th Plan. The transmission system development during the 11th Plan envisages formation of the National Grid. Additional transmission lines likely to be added in the transmission network would be of the order of 95,000 and 1,80,000 circuit-kilometers during 11th and 12th Plan respectively for evacuation of power from new generating stations to the load centers. This would enable increase in inter-regional transmission capacity to 32,650 MW by the end of 11th Plan and 75,000 MW towards the end of 12th Plan. There would also be a huge expansion due to additional intra-State transmission and distribution network in each State in the Country. Timely development of transmission network, inter-alia, requires various clearances to the projects including PTCC. The Central PTCC has continued to play a vital role in facilitating accord of PTCC route approval for the expansion of networks of Power, Telecommunications, and Railways.

The PTCC have issued guidelines and manuals from time to time for preparation of proposals for clearance. The norms are periodically reviewed by the Committee to affect changes in line with the technological advancements and bringing safety standards at par international level. The present edition of the manual has been finalized in consultation with all stakeholders and taking into consideration the advancements since its last edition. The manual incorporates revised method for calculation of mutual coupling, code of practice for laying of underground cables in proximity with communication cables, simplified procedure for coordination of power lines with telecommunication cables and guidelines for processing PTCC cases.

The PTCC Manual edition, 2010 would serve as a useful reference for framing proposals and enable expeditious clearance to infrastructure development projects in the field of Power, Telecommunication and Railways which contribute significantly to economic growth of the Country.

JULY 2010

(S.M.Dhiman)
Member(GO&D)
CEA

स्वहित एवं राष्ट्रहित में ऊर्जा बचाएं
Save Energy for Benefit of Self and Nation

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(भारत सरकार का उद्यम)
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गोपाल दास
अध्यक्ष एवं प्रबंध निदेशक

Gopal Das
Chairman & Managing Director

MESSAGE

I am pleased to note that the innovative edition of PTCC MANUAL 2010 is ready for release. There have been significant changes in PTCC activities over the years and a genuine requirement of a revised PTCC manual tailored to today's needs was felt essential, which, I am sure, is getting fulfilled by this edition.

The past few years have witnessed a vast boom not only in new Telecom installations but also in the Power and Railway sectors including the advent of metro operations in North and thus the role and importance of PTCC has enhanced manifold in settling disputes and cases requiring protection issues. I am also delighted to notice that the waiting period for PTCC clearances has reduced considerably keeping in tune with today's pace of activities.

I would like to appreciate the painstaking efforts by PTCC by bringing "Zero Unguarded Power Crossings" which has resulted in achieving nil incidences in fatal/non-fatal accidents to Outdoor/line staff/Phone Mechanics of BSNL. Statistics show that there have been significant improvements to Telecom Installations from induction current, earth potential rise, etc., due to the consistent efforts of PTCC by providing appropriate protection.

The PTCC Manual 2010 has been given minute attention to details and I am sure it will remain as a testimonial for many times to come. All necessary prerequisites have been addressed in which the following procedures require special mention:

- Simplified procedure for co-ordination of Power Lines upto 33KV
- Step-by-step procedure for PTCC clearance of power Lines of 66KV & above
- Low frequency induction and procedure for conducting its test
- Protection from Earth Potential Rise

I am sure that this manual will be a very handy tool for Telecom, Power, Railways & Defense wing personnel and I take this opportunity to congratulate Central Electricity Authority and Inspection Circle for making sincere efforts in bringing out this 3rd edition of PTCC Manual 2010.

(GOPAL DAS)

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MINISTRY OF POWER
सेवा भवन, रामाकृष्णा पुरम
SEWA BHAWAN, RAMAKRISHNA PURAM

नई दिल्ली-110066, दिनांक :
NEW DELHI-110066, Dated :

Message from Chief Engineer(LD&T) & Chairman Central PTCC

The infrastructure sectors like Power, Railway and Telecommunication plays an important role in the development at every stage of economic development in the country. During All India Power Engineers Conference held in 1949, it was recognized that for protection of telegraphic, telephone, and electrical signaling, the specialized studies required to compute the impact of induced voltages due to the proximity of Power and Telecommunication network. On the recommendation of the conference, Government of India constituted a Central Power and Telecommunication Coordination Committee (PTCC) in May 1949. The Central PTCC comprises of Members from Power, Telecom, Railways and Defense and is an excellent multi sector synergy forum.

The Central PTCC had been playing an important role in resolving technical issues, evolving standards and ensuring safe co-existence among various Power and Telecom operators. The Committee reviews the PTCC norm periodically in the context of technological and infrastructural changes and safety standards at par with International level.

The procedures and formats for processing of PTCC case had been well laid down. However, with time the advent of new technology in the field of telecommunication and power sector, the revision of PTCC manual (1995 edition) became imperative. The revised PTCC Manual has been prepared after getting the input from the stakeholders, through Central PTCC deliberations and getting comments from others by placing on CEA website.

The effort through PTCC Manual is to ensure that all the stake holders of Power, Telecommunication and Railways follow the procedures and complete the processing in time without any difficulty and delay, thereby eliminating the chances of any cost escalation of the project. The newly revised PTCC manual will work as a torch-bearer for all the stake holders especially for Central PTCC whose primary objective is to ensure the provision of safety aspects involved right from the conception stage.

I hope the revised PTCC document would provide useful reference in expediting and resolving the issues related for PTCC route approval and would facilitate to achieve the goal of mutual and safe co-existence of the various entities/stake holders in the business of Power and Telecommunication.

(A.K.Aggarwal)
Chief Engineer(LD&T)&
Chairman Central PTCC

JULY 2010

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MESSAGE FROM CGM, INSPECTION CIRCLE, JABALPUR

In view of tremendous growth in Power and Telecom Sectors in the last 10 years, large no. of power proposals were processed by PTCC and route approvals were issued. The PTCC manual 1995 edition is referred by the Power and Telecom Officers, has now been revised. Also a new chapter on mutual coupling calculation as per CCITT directives has been added in the new PTCC Manual 2010.

The field engineers, both from Power and Telecom sectors as well as Railways and Defence will be highly benefited from the new Manual 2010, as it contains detailed procedure for calculation of Induced Voltage and standards for crossing of all categories of power lines from LT, HT to EHT (i.e.) 230 v to 765kv.

It is also worth noting that important decisions taken on various Central PTCC up to October '09 has been included the PTCC Manual 2010.

I take this opportunity to congratulate all the officers from Central Electricity Authority (LD & Telecom) and from Inspection Circle in bringing out the comprehensive PTCC Manual 2010 in time, and wish them all success in their future endeavour.

(JAMUNA PRASAD)
Chief General Manager,
Inspection Circle, Jabalpur

सत्यमेव जयते

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नई दिल्ली-११० ००१

GOVERNMENT OF INDIA
MINISTRY OF RAILWAYS
(RAILWAY BOARD)
NEW DELHI-110001

MESSAGE

It is a great pleasure to see that CEA is publishing a new PTCC Manual. PTCC has played a major role in strategically working towards coordinating the safety issues between power and telecom sector resulting in unhindered growth in both power and telecom infrastructure of the country.

Railways being one of the members of PTCC, plays a vital rote in PTCC approvals as the railway telecom lines for train operations reach far and remote locations of the country. The boom in power sector is also pushing growth in far and remote places of the country. For sustained high rate of growth for the country, it is important that both power and telecom infrastructure providers of the country make an all out effort to work together. The new PTCC manual will take care of the growth of the country's infrastructure by simplifying procedures and making necessary adjustments to balance speedy approval delivery in line with the growth targets keeping in view the human safety.

I wish all the members of PTCC will make the best use of the new revised manual for rendering a great service to the nation in helping speedy infrastructure building.

12/8/10

(R.C. Agrawal)
Additional Member (Telecom)
Ministry of Railways
(Railway Board)

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Message from GM, Inspection Circle, BSNL & Secretary (Telecom) Central PTCC

In view of the overall economic development of the nation, the development of the country’s infrastructure and hence expansion of Power, Telecom and Railways network becomes very crucial. With the increasing number of HV and EHV power transmission lines and Telecom & Railway lines being laid in the country, the role of PTCC becomes extremely important in safeguarding the personnel of the concerned departments and also the common man.

The new PTCC Manual 2010 edition is an improvement of the currently existing PTCC Manual 1995 edition, which provides additional information that will expedite the PTCC route approval procedure by improving the understanding of the engineers of various departments concerned with the PTCC process.

I would like to congratulate all the officers of the LD&T Division of CEA, Inspection Circle, BSNL and concerned Railway authorities in bringing out this latest edition of the PTCC Manual and wish them all the best in all their future endeavours.

(G.C.Manna)
General Manager
Inspection Circle,
Jabalpur

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NEW DELHI-110066, Dated :

Acknowledgement by Director(PTCC) CEA & Secretary(Power) Central PTCC

I, sincerely thank Chairman CEA, Member (GO&D) CEA, CMD BSNL, Chief Engineer (LD&T) CEA, Addl. Member (Telecom) Railway Board and CGM (Inspection Circle) BSNL and GM (Inspection Circle) BSNL for their message and acknowledging the PTCC Manual as a valuable book on PTCC activities. The messages will definitively inspire and enthuse the readers about their role, responsibilities and their contribution to be made towards PTCC.

It gives me pleasure to place the manual in the hands of the all users/stake holders for frequent reference required for PTCC route approval / clearance and other related activities. Although most of the chapters have been bases upon the earlier version, several parts and sections have been re-written or newly introduced. I have been guided by the feedback received by innumerable engineers from Power Sector, Telecom Sector and Indian Railways across the country.

All the members of the Central PTCC deserve a special mention for their support and encouragement. I also wish to acknowledge the valuable contribution from all the members of the Sub-Committee formed to revise the PTCC Manual. My sincere thanks to all those persons directly or indirectly associated with this PTCC Manual.

I shall be grateful to the readers who point out errors and omissions which, inspite of all care might have been there. Suggestions for improvement & further enhancement of the scope of the manual are co-cordially invited.

JULY 2010

(D.K.Malik)
Director PTCC &
Secretary (Power)
Central PTCC

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CHAPTER-I

CHAPTER I

Brief Description of the Set-Up and Activities of the Power and Telecommunication Coordination Committee (PTCC)

1.0 Introduction

The importance of the co-ordination between power and telecommunication lines in India was brought to the forefront by the increasing number of situations of parallelism experienced immediately after independence. It was felt that, with further progress in the development plans for electric power and telecommunication, there would be a continually increasing number of such cases.

Both the power and communication engineers gave considerable thought to the subject and it was taken up for discussion in the All India Power Engineers Conference held in New Delhi in February 1949. It was recognized that the subject involved considerable amount of specialized study and that the task of finding solutions to co-ordination problems that might arise from time to time as well as to evolve general co-ordination methods can be better dealt with by a committee of Power and Telecommunication Engineers.

2.0 Formation of the PTCC

The All India Power Engineers Conference held in February 1949 discussed the problems in considerable detail and recommended to the Central Government the formation of a Central Standing Committee for co-ordination of Power and Telecommunication Systems. The recommendation of the conference was given effect to in resolution No.EL.II-151 (7) dated at New Delhi, the 30th May 1949 from the Government of India, Ministry of Works, Mines and Power, amended by corrigendum No.ELII-157 (7) dated 29th August 1949. The Resolution is reproduced as Appendix I to Chapter I.

3.0 Functions of the Committee

3.1 The terms of reference and the functions of the Committee are indicated in detail in the circular letter dated 19th September 1949, issued by the erstwhile Ministry of Works, Mines and Power to the various State Governments etc. separately at Appendix II to Chapter I.

3.2 The Rules of Business of the Central Standing Committee for co-ordination of power and telecom lines adopted during the PTCC meeting on 24th March 1972 are reproduced in Appendix III to Chapter I.

4.0 Membership of the Committee

4.1 The Committee initially consisted of 10 members representing the Central Electricity Commission, the then Post and Telegraph (P&T) Department, the

Electricity Branch of the Punjab, Public Works Department (PWD) and the Civil Aviation Directorate (Technical Officers) and the Ministry of Finance, the then Ministry of Works, Mines and Power and the Ministry of Communications. Although the Power & Telecommunication Coordination Committee (PTCC) was initially constituted for one year, the Ministry of Natural Resources and Scientific Research vide their Letter No. EL.II-15 (9) dated 15th February 1952 decided that it would continue to function until further orders. There have been some changes in the membership of the Committee from time to time. The co-option of members from the Railway Board in the PTCC was recommended by the 11th Plenary Session of the PTCC held in December 1965 in view of the large number of parallelism cases arising from the electrification of Railways. The Deputy Director (Telecom), Railway Board was then nominated to the Committee. A representative of the Wireless Adviser to the Government started attending the Committee meetings from 1961 onwards. Representatives of various State Electricity Boards took part in meetings of the Committee from 1967 onwards. The meeting of the Committee held in April 1975 recommended changes in the composition of the PTCC to make it more functional and the present membership of the Central PTCC is based on the Government of India, Ministry of Energy's notification No. 3/1/2001 - Trans dated 11th April 2001 reproduced in Appendix IV to Chapter I.

4.2 The meeting held on 10th August 1973 suggested that the PTCC should hold meetings at the regional centers so as to ensure effective participation and involvement by the State Electricity Boards / Power Utilities and local Committees thus enabling the members of the PTCC to have first-hand knowledge of the problems faced at regional levels. This was unanimously agreed to.

4.3 In the Central PTCC meeting held in Hyderabad in February 1977, it was decided to have these meetings on a quarterly basis covering all the four regions in a year and including the concerned representatives in each region. During discussions between Secretaries, Ministry of Energy and Ministry of Communications and their concerned officers held in New Delhi in May 1977, it was decided that a high level committee composed of Member, Telecom Board; Member, Central Electricity Authority (CEA); and other officers would be established to resolve important policy aspects and other pending matters of Power Telecom Co-ordination. A few meetings of the Committee have since taken place.

5.0 Meeting of the PTCC

5.1 The first meeting of the Committee was held on 28th and 29th June 1949, when certain decisions on the conduct of business of the PTCC were taken. It was decided to have two kinds of meetings, viz. Plenary and Technical.

Plenary Meeting

This would deal with constitutional, administrative and financial aspects of co-ordination work and ratify all resolutions of the Technical Meeting. All the representatives of the Ministries and the technical members would be present at these meetings.

Technical Meeting

This would deal with technical questions relating to co-ordination and communicate decisions in specific cases to the parties concerned. Any recommendations having repercussions on financial and legal matters would be referred to the Plenary Meeting.

The procedure for modifying any existing technical standard and issuing new technical directives was considered and it was decided that self-contained Committee Papers will be prepared in each case and circulated in advance to all members.

5.2 The Committee suggested that the principles in choosing a particular co-ordination method should be:

(i) On the basis of the least cost to the Country consistent with the proposed measures being technically sound and efficient.

(ii) That the least cost will take into account the first cost as well as the capitalized value of recurring maintenance cost.

(iii) That whether the remedial measures are carried out on the power line or communication line, the apportionment of costs as between the participating parties and Governments will be worked out in each case with due regard to the existing law and established practice.

5.2 Ever since its inception to the end of 1971, there have been 23 Technical Sessions and 24 Plenary Sessions of the PTCC. Subsequent to 1971, combined meetings have been held and a total of 89 such meetings have taken place during the period from March 1972 to January 2009.

6.0 Activities of the PTCC

A summary of the main activities of the PTCC is given below along with extracts of important decisions of the Committee topic wise for information.

6.1 Field Experiments, Studies and Reports

6.1.1 The first set of field experiments was carried out by the PTCC at Amritsar in 1949 on the 132 kV line between Jallandhar and Amritsar to determine the effects on the neighbouring Delhi-Amritsar carrier telephone lines. The tests were conducted with a view to determine the mutual coupling between the power and communication lines and the extent of shielding from induction afforded by the use of earth conductors. Tests were also conducted in Mumbai in November 1949 to study the interference from the 22 kV Kalyan – Vikhroli line of the Tata Power Company on the Kalyan – Mumbai trunk telephone lines. The tests were aimed at determining the shielding exerted by the electrified railway tracks paralleling the power and communication lines. The shielding effects of earthed conductors on a transmission line were experimentally studied in September 1950 on the 66 kV DC line from Coimbatore to Tirupattur. This test formed a part of the survey undertaken by the PTCC on the use of high conductivity wires for reduction of induction. The Committee published reports of the above tests.

6.1.2 The Committee also published a report giving details of the methods of measurement of earth resistivity for the use of power and communication engineers in India, enabling them to choose, under given circumstances, the most practicable method for assessing the earth resistivity in any given area for purposes of interference calculations.

6.1.3 The Committee deputed the two Joint Secretaries, Shri V.R. Raghavan (Power) and Shri B. Sivananda Rau (Telecom) to USA, Sweden, Canada, Switzerland and England in 1951 to make a joint study of the status of the problem of co-ordination between power and communication services in these countries. The object of the deputation was to study the principles and practices followed in those countries for mitigating the induction problem and to examine how similar problems can be tackled in India. After hearing the report of the Joint Secretaries, the PTCC passed a Resolution, at its meeting held in February, 1952 that although practices in / of foreign countries cannot be readily adopted in India, the Committee should make an intensive investigation to improve co-ordination practices in India and for this purpose, carry on systematic research work relating both to low frequency and noise induction. The Committee recommended to the Government that funds should be placed at its disposal as required for the purpose.

6.1.4 Regarding soil resistivity values, the Secretaries reported to the Committee, in its meeting held in May 1953, that deduction of soil resistivity from induction tests showed close agreement with measurements made with earth testing meggar, provided the electrode spacing adopted for the latter were sufficiently high (150 feet or above) and the measurements were made at frequent intervals of the order of a mile.

6.1.5 The Committee at the meeting held on 25th January 1974 adopted a Resolution recommending that a study team comprising representatives from the then Power Wing (PW) of Central Water & Power Commission (CW&PC) and P&T Department be sent abroad to study the latest techniques in regard to inductive co-ordination in other countries, since the last study team was sent more than 24 years back and in view of the considerable advances in other countries in the field. In the meeting held on 3rd September 1974, it was decided to include a representative from the Railways also in this Study Team.

6.1.6 During the year 1978, a joint team of four officers from the CEA, the then P&T Department and Railway Board was deputed to Switzerland, France and Sweden to study the practices relating to co-ordination in those countries. The reports of the Study Team prepared separately by the Officers of the Central

Electricity Authority/Railway Board and the then P&T Department were discussed so as to make suitable modifications wherever necessary in the existing Indian practices relating to PTCC.

6.1.7 The PTCC at its meeting held in September 1978 appointed a sub-Committee consisting of representatives from the Central Electricity Authority (CEA), the then P&T and the Railway Board to go into the problem of interference to telegraph circuits from power lines. A copy of the recommendations of the sub-Committee is given at Appendix V to Chapter I. The important finding was that conversion of earth return telegraph circuits to metallic return is called for only when the interference current as computed exceeds 1/10th of the telegraph current. This recommendation has been accepted by the PTCC and clearances are being issued on this basis.

6.1.8 A Sub-Committee was formed to study the noise due to paralleling power lines on telecom and railway communication circuits and in the meeting held on 29th October 1987, it was informed that the report of the Sub-Committee be circulated and in future noise problems should be sorted out directly by discussion among Central Electricity Authority (CEA), Department of Telecommunications (DoT) and Railways as required. The report of the Sub-Committee is given at Appendix VI to Chapter I.

6.1.9 Effect of Single/Double phase power lines for railway traction purpose on paralleling communication lines was under discussion in Central PTCC. A Sub-Committee was formed to study the problem and suggest remedial measures. In the meeting held on 5th March 1992, it was informed by the Sub-Committee that there will be no electro-magnetically induced voltage due to normal working of these power lines but, however, each individual case would be given to PTCC clearance based on its merits.

6.2 Codes of Practices

6.2.1 The Committee discussed the technical considerations involved in the transposition of power lines and the procedure adopted in various foreign countries and passed a Resolution to the effect (in its meeting in February 1952) that so far as interference to telecom lines is concerned, the transposition on power lines are not necessary.

6.2.2 The Committee, at its meeting held in February 1952 considered the regulations in regard to the structural arrangements to be provided at the crossing between power and telecom lines vis-à-vis the practices in some foreign countries and appointed a sub-committee to draft a suitable code. The draft submitted by sub-committee was considered in the meeting held in November 1953 and it was proposed that the draft suitably reworded, be submitted to the Committee members for approval. In the light of the comments and information received regarding practices in other countries the draft code was revised and presented to the session held in March 1955. The Committee ratified the same for final printing and issued to all concerned. Revisions to the Code of Practice were made in 1963 and 1974. A copy of the present code is available in Chapter VI of this manual.

6.2.3 In the meeting held in October 1963, the committee agreed to incorporation of the clause regarding the crossing of telecom lines with power lines having a pair of telecom lines on the same support in the PTCC Code of Practice.

6.2.4 In the meting held on 8th March 1976 at New Delhi the matter regarding power line to be on one side of the road was discussed and it was agreed that in open country, where there are power or telecom lines, the first entrant could choose one side of the road. However, when next line is to be erected by the same party on the same route, it should as far as possible, be erected on the same side, where the first line existed. In case of difficulty, it may be sorted out between the power and telecommunication authorities by mutual consultation.

6.2.5 A sub-committee was formed to finalize the norms for PTCC clearance of HVDC power lines. In the meeting held on 12th February 1987, it was decided that HVDC lines might be processed on the lines of norms finalized by the sub-committee. Actual observations would be taken when $\pm$500 kV Delhi – Rihand power line is commissioned and if necessary, modifications to the norms would be made. The norms for PTCC clearance of HVDC lines circulated vide CEA, New Delhi letter No. 19/117/87-PTCC dated 3rd February 1987 are at Appendix VII to Chapter I.

6.2.6 Finalization of Code of Practice for laying of underground Power Cables in proximity of Telecom Cables was under discussion in Central PTCC and in the meeting held on 29th October 1987, it was decided to follow the recommendations based on the minutes of the meeting held between Delhi Electric Supply Undertaking (DESU) and Department of Telecommunication (DoT) on 23rd March 1987. These recommendations are given in Appendix VIII to Chapter I.

6.2.7 In the meeting held on 14th June 1990, the draft Code of Practice on Earth Potential Rise (EPR) near sub-stations was approved and it is now included in Chapter VIII of this manual.

6.2.8 In the meeting held on 16th February 1995 at Bhopal, it was reiterated that in principle the erection/ laying of lines by Power and Telecom authorities along road should be restricted to either side of the road to avoid close proximity.

6.3 Protective Devices

6.3.1 The installation of Gas Discharge (GD) Tubes was first proposed by the Committee on February1952 as a measure of protection of the telecom lines affected by induction. In its meeting held in September 1952, the Committee discussed the quotation received for GD tubes and the maintenance work involved in the use of GD tubes and the reliability of their performance. It was decided that

(i) The purchase of the tubes be expedited;

(ii) The routine testing equipment for maintenance of GD tubes be purchased at the same time; and

(iii) That a careful record of the performance of the tubes over a period of time be maintained.

6.3.2 In the meeting held in March 1955, the Committee was informed that a trial consignment of NGC 3303 GD tubes had been received from M/s. Ericsson and that a limited number of short-circuit relay protectors used in America had also been obtained. These were to be tried in some known locations of severe induction. In the meantime, it was suggested that tests on these devices be conducted in co-operation with Indian Institute of Science. It was proposed that GD tubes be installed on telephone lines exposed to the Ganga canal grid lines and the SC relay protectors on the carrier alignment paralleling the Bangalore-Davangere 66 kV line. A detailed log of the faults on the power lines and the behavior of the protective devices on the telecom lines were suggested.

6.3.3 The meeting held in January 1959 reviewed the investigations carried out at the Indian Institute of Science on the suitability and operational characteristics of various protective devices. The meeting held in February, 1960 considered the report of tests on protective devices further and recommended the uses of GD tubes in view of their suitability both as regard protective level as well as life as established by the tests.

6.3.4 In the meeting held in February, 1961, the Chairman stated that it was very essential for the Telecom Department to carry sufficient stock of GD tubes since they were required in connection with cases of parallelism with power lines on which large sums of money were spent and the commissioning of which should not be delayed on account of lack of GD tubes for protecting the affected telecom lines. In the same meeting, the question of shortage of power contact protectors was also discussed and the Chairman wanted the Telecom Department to always keep sufficient stock of these protectors. In case of difficulty in finding adequate supplies of protectors, it should be permissible to adopt double guarding in order not to delay the energization of power lines.

6.3.5 In the meeting held in October 1963, the Committee decided that the earth resistance for power contact protectors may be 10 ohms instead of 1 ohm or lower as decided earlier.

6.3.6 The meeting held on 21st October 1972 expressed serious concern at the increasingly high levels of induction on telecom lines and strongly recommended that this problem should be studied in detail. Methods other than the provision of GD tubes, such as installation of sectionalizing transformers also deserved consideration.

6.3.7 High voltage limit for protection with GD tubes was under examination and in the meeting held on 7th April 1983, it was intimated that instructions were issued to DE's (T) (PTCC) to clear the cases on the basis of revised formula for installation of GD tubes. This is as per the discussions held at the high level meeting convened by Secretary (P) on 23rd September 1982, wherein it was decided that the revised formula of clearance with 20 GD tubes would be used presently. The 20 GD tubes formula was accepted by Department of Telecom vide their letter No. 130-21/83-TPL (TX) dated 6th August 1983 and is illustrated in Appendix IX to Chapter I.

6.4 PTCC Route Approval

6.4.1 Instances where the then Mysore Electricity Department erected and energized their HT lines without the approval of the PTCC were brought to the notice of the Committee in 1955, which requested the Government of India to draw the attention of the Mysore Government to the position which was in contravention of Section 32 of the Indian Electricity Act, 1910. Similar action was taken in the case of the Bareily – Haldwani 66 kV line put up by the Sharda Hydel authorities in Uttar Pradesh.

6.4.2 The meeting held in January 1959 suggested the preparation of a set of directives and graphs which would enable Telecom field officers to tackle cases of parallelism involving power lines upto 11 kV.

6.4.3 In the meeting in February 1961, the Chairman clarified that the approval of the PTCC was only in regard to the route of the line and that any conditions laid down by the PTCC had to be complied with before permitting the energization of the line by the local telecom authorities. It was also pointed out that as per Indian Electricity (I.E.) Rules, it was incumbent on the Power authorities to give an advance notice prior to energization of the line which should enable the local telecom authorities to take actions to ensure that the conditions, if any, stipulated by the PTCC have been complied with before energizing the line.

6.4.4 In the meeting held on 21st October 1972, the representatives of the Telecom Department pointed out that it would not be possible to give approval on the basis of data furnished by Power authorities in regard to telecom lines with application for power lines. Certain data might be overlooked when information thereon is furnished by State Electricity Boards.

6.4.5 The meeting held on 25th January 1974 decided that the Joint Secretary (Power) and Joint Secretary (Telecom) of Central PTCC should co-ordinate and prepare a detailed procedure for reference of cases to the PTCC taking into account the requirements of the Railways. A copy of the procedure was prepared and circulated to all concerned in July 1974. In the meeting held on 3rd September 1974, the attention of State Electricity Boards and P&T was drawn to the stipulation that the questionnaire and other data relating to power parallelism should be furnished to the PTCC at the survey stage of the power or telecom lines so as to provide adequate time for obtaining the required data and processing the cases for approval. Procedure for clearance of power and telecom cases is detailed in Chapter III of this manual.

6.4.6 The meeting held on 21st October 1972 appointed a sub-committee to recommend the stage at which cases for approval of the route of transmission lines should be referred to the PTCC, the time-limit within which they should be processed and the time that must elapse before energization of the route after approval is given. Another sub-committee further reviewed the recommendations of the sub-committee. The final recommendations were accepted for implementation in the meeting held on 24th February 1982. **‘**

On the recommendation of Central Electricity Authority the time limits for various steps involved in PTCC clearance were further revised vide **Chief General Manager, T&D Circle, Jabalpur Letter No.TD/LP-2012/General Dated 30.12.2009 and are reproduced in Appendix X to Chapter I.**

6.4.7 The meeting held on 1st July 1977 ratified the proforma for PTCC route approval. In the meeting held on 8th May 1981, it was decided to add an additional clause in the PTCC route approval certificate, to the effect that the energization of Extra High Tension (EHT) power lines would not be held up for want to installation of GD tubes on telecom lines when the induced voltage are in the range of 430 to 650V. This is because GD tubes in this range are recommended as additional protection at their own cost by DoT, although the accepted PTCC safe limit is 650V for EHT power lines i.e. 66 kV and above. Proforma of Route Approval is given in Appendix XI to Chapter I.

6.4.8 In the meeting held on 30th October 1979, it was decided that for route approval cases of power lines involving double circuits the induced voltage calculations should be made considering the double circuit alignment even when only one circuit was initially erected.

6.4.9 In the meeting held on 24th February 1979, it was decided that while referring the tap lines, Power authorities should indicate the details of the PTCC approval for the main line. Wherever route approval particulars are not available full details of main line should be submitted along with the proposal for approval of tap lines.

In the meeting held on 29th September 1988, it was agreed that if the proposal for main line is also received along with the tap lines, the clearance of tap lines would be expeditiously done after examination without waiting for the clearance of main line as far as possible. However, the clearance of the main line would be decided subsequently, if it was possible to delink the main line case with that of tap line and whatever protections would be needed on the telecom line would be provided on the existing principles of later entrant etc.

In the meeting held on 11th November 1991, the State Electricity Board representatives expressed their difficulties to furnish the details of the long existing main lines while seeking clearance of Loop-In-Loop-Out (LILO) / Tap lines. Relaxation in the matter was considered and it was said that only those cases where induction effect appears dangerous on preliminary examination, the complete main line details may be called for and the case examined in detail.

6.4.10 It was decided in the meeting held on 29th July 1983 that the route approval for power cables would continue to be issued on lines similar to those for overhead power lines taking into account the Screening Factors due to power and telecom cables in computing the induced voltages.

6.4.11 In the meeting held on 16th February 1995, it was reiterated that in principle all the proposals for PTCC clearance should be submitted in advance at the survey stage in order to give sufficient time for processing the cases for approval.

6.5 Low Frequency (LF) Induction

6.5.1 The Committee considered the question of modifying the existing limits relating to LF induction at the meeting held in May 1953 but was not inclined to permit any general relaxation of the existing rules. It was felt that cases, which prove to be extremely difficult, should be considered individually and decided on their own merits.

6.5.2 At its meeting held in March 1955, the Committee noted that the CCIF had agreed to raise the limit of maximum permissible low frequency induction to 650V in the case of high tension lines of high security. The Committee decided that this recommendation be adopted in India and for this purpose all EHT lines (66 kV and above) may be considered as belonging to the category of high security lines subject to the following notes:

(a) In addition to conforming to certain minimum requirements in respect of mechanical strength, electrical insulation, geography of the region etc., lines of high security shall be equipped with protective devices and circuit breakers so that the total duration of an earth fault current shall be within 0.2 seconds in the majority of the cases and shall in no case exceed 0.5 seconds.

(b) The CCIF recommendations raising the limit of longitudinal induction to 650 volts do not in general apply to cases of signaling circuits of railway systems and the value of 430 volts would be in force for such circuits.

(c) The 10th Plenary Session held on 15th March 1955 decided to adopt the CCIF recommendations regarding electrostatic induction also, i.e., there is a danger / risk if under normal operating conditions of an AC traction line with earth return through Rail or as a result of an accidental earth fault on one phase of an aerial power circuit of a single phase line or of a three phase line with neutral point normally insulated, the discharge current to earth of the two wires in parallel of an open wire telephone line through an impedance of negligible value exceeds 15 milliamps (RMS).

6.5.3 The question was further discussed in the meeting held on 15th June 1956 and the following recommendations were made:

(i) Except in the case of block signal and train wires and other similar circuits on which line-clear signals are passed, the (revised) limit of 650 volts may be applied for Railway circuits such as administrative control, railway through, traffic control, deputy control etc.

(ii) For control and deputy control circuits on which operating personnel would be working continuously, the operator's telephone set should be fitted with suitable acoustic shock absorbers in addition; proper protective devices like gas and carbon arrestors may be fitted on the circuits wherever they enter an office.

(iii) In all cases of parallelism involving railway circuits, the overall parallelism may be examined keeping in view a maximum permissible limit of 650 volts provided that in no block section within the total stretch of parallelism, the low frequency induction in any circumstances exceeds 430 volts.

(iv) For the purpose indicated in (iii), a reference will be made to the concerned Railway authorities as also to the Deputy Director (Telecom), Railway Board and their views obtained before the route of the high security HT line is approved by the Committee.

6.5.4 The question of protection for telecom lines in cases of heavy induction was discussed in Technical Session held on 2nd December 1964. It was decided that where the induced voltage is so high as to warrant provision of GD tubes at close intervals, other remedial measures such as cabling or adoption of microwaves etc. might be considered. Such individual cases should be put up before the Committee. In the Technical Session held on 5th January 1967, the question of conducting LF tests for induction was considered and it was decided that State Levels Units can be entrusted with this work when possible and the results sent to the Central Committee.

6.5.5 In the meeting held on 24th February 1982, it was agreed to that 'successive infeed' method on three phase lines will be adopted for LF test as it will enable more number of readings to be taken. The detailed test procedure is given in Chapter VII of this manual.

6.6 Co-ordination Measures

6.6.1 The March 1955 meeting considered the question of directives to field officers to decide cases of parallelism involving HT lines below 11 kV. A sub-committee was appointed to examine this question and suggest measures of co-ordination in such cases. This question of joint use of poles for power and telecom lines was also discussed and it was suggested that joint use may be tried in some cases and based on experience gained, suitable directives could be formulated.

6.6.2 In the meeting held in September 1957, the Chairman desired that in regard to all the cases where the induced voltages on the communication lines are found to be dangerous and where remedial measures are proposed to be taken on the communication lines, the danger involved should be specifically brought to the notice of the local communication authorities. Further, a list of all such cases should be maintained with a view to checking the progress of the remedial measures that are taken.

6.6.3 In the Technical Session held on 6th May 1971, the question of recommendations regarding ‘statutory’ provision in respect of power and telecom co-ordination was discussed at length. It was unanimously agreed that before making mandatory provision, it was essential to take necessary steps to make the working of the PTCC more efficient so that cases were cleared quickly. The Plenary Session held on 7th May 1971, decided that all cases disposed off by the State Level Committees be presented before the PTCC for formal approval.

6.6.4 In the meeting held on 3rd September 1974, at New Delhi, it was recommended that in view of the large number of accidents to telecom personnel due to deficiencies on LT leads and service loops, SDO of the P&T Department and AE of Electricity Board should meet every month and besides discussing the deficiencies and irregularities they should also have a joint inspection of the concerned section for taking suitable remedial action.

6.6.5 The meeting held on 11th April 1975 considered the question of additional staff to deal with PTCC work and passed a Resolution that an officer each of the rank of AE may be attached to Member (Power) and Member (Telecom) of the State Level PTCC for different items of work relating to the PTCC. The Committee desired that Electricity Boards should provide in their line estimates, necessary provision for protection of all power crossings and a certificate to that effect should be endorsed on the estimate.

6.6.6 In the meeting held on 7th April 1983, it was intimated that the State Electricity Boards would be advised by Central Electricity Authority to accede to requests for power shut down from Telecom field units at appropriate levels, if danger to human life was involved in connection with their maintenance work. This issue has to be dealt on humanitarian grounds.

6.6.7 While discussing about construction of power/telecom lines without PTCC approval and energization of power lines without energization certificate in the meeting held on 6th November 1986, it was decided that Electrical Inspector of the State has to ensure that the Indian Electricity Rules and Indian Electricity Act, based on which these rules were made, were observed in practice. They can grant permission for energization of lines only after satisfying that provisions on rules are met. The comments of Secretary, Central Electricity Board in this connection is given in Appendix XII to Chapter I.

6.7 Induced Voltage Calculations

6.7.1 In the meeting held in February 1961, the question of taking the value of fault resistance in computations of fault current as recommended by CCITT was considered. The Chairman suggested that the practice of not taking the resistance erred on the conservative side and may be continued except where the procedure led to serious difficulties. This was further discussed in January, 1967 meeting and it was decided that for parallelism which did not terminate in a sub-station 20-ohms fault resistance can be taken. In respect of parallelism terminating at substations, 20-ohms fault resistance may be taken provisionally pending further investigations.

6.7.2 In view of the very large number of cases processed by the Central PTCC, the question of further decentralization of PTCC cases was discussed in the meeting of the Chairman of SEB's held in January, 1978 and it was recommended that cases of power lines up to and including 132 kV would be handled by the SEB's themselves and concerned Regional DET (PTCC). (Refer para 6.10.1 of this chapter) Cases of power lines of 220 kV and above would be processed by the Central PTCC. Accordingly, guidelines were prepared by the Central Electricity Authority for computation of induced voltages and circulated to the SEB's. The nominees of Electricity Boards/Power Utilities are also been briefed where necessary about the procedure for computation during their visits to the CEA office.

6.7.3 In the meeting held on 23rd October 1980, it was agreed that the cases of inter-state lines of 132 kV and below would be handled by Central Electricity Authority in view of procedural difficulties in dealing with different states.

6.7.4 In the meeting held on 26th September 1984, members were informed about the ready reckoner for computation of mutual coupling prepared by Rajasthan State Electricity Board (RSEB) and duly checked by Central Electricity Authority.

6.7.5 In the meeting held on 14th June 1990, representative of Central Electricity Authority intimated that the computation of induced voltage is already being done in CEA and the programs for computation of Mutual Coupling (MC) and Fault Current (FC) calculations are available for supply to the interested organizations on consultancy basis. Regarding computerization of maps etc he assured to examine it in consultation with Department of Telecommunications.

6.8 Licensing Very High Frequency (VHF) & Power Line Carrier Communication (PLCC) Facilities

6.8.1 The question of licensing VHF and PLCC facilities required by power systems was discussed in Plenary Meeting held on 9th December 1955 and the Committee resolved that:

(i) The Ministry of Communication be requested to pursue a liberal policy of granting licenses to power supply undertakings for providing communication facilities required for operation and maintenance of power systems.

(ii) The power supply undertakings, while forwarding applications to the Telecom Department for obtaining licenses for their own communication facilities, should endorse a copy to the PTCC for examination of technical matters and recommendations to DG Telecom.

(iii) The Ministry of Communication is requested to reconsider the stipulation regarding taking over the communication network of the power supply authority, while granting licenses to Power authorities for operating their communication facilities.

(iv) The question of royalties and fees payable by the power supply undertakings may be a matter of negotiation between the Ministry of Communication and the party concerned.

The procedure for granting licenses for PLCC systems was further discussed in the Plenary Meeting on 28th January 1959 and it was decided that Power authorities should refer all cases to the PTCC, who in consultation with the Wireless Adviser, would forward it with their recommendations to the DG Telecom.

6.8.1 The Committee felt that PLCC cases would not come strictly within the purview of the PTCC and as such lists of PLCC cases need not be put up before future Committees. The Committee ratified the instructions already issued to state level committees.

6.8.3 In the meeting held on 8th May 1981, it was intimated that Telecom Directorate had issued instructions and Central Electricity Authority concurred with them according to which-

(i) In cases where detailed survey for the power line is to be completed the PTCC should be intimated along with the PLCC application that a power line is to be constructed between these places and details shall be furnished after survey.

(ii) In cases, where PLCC is to be superimposed on a power line not referred to the PTCC, the same has to be referred to the PTCC before applying for PLCC frequency allocation.

In cases of lines constructed prior to the formation of PTCC, it was decided in the meeting that in such instances, the PLCC case would be regularized through PTCC but the frequency allocation should not be held up on this account.

6.9 Apportionment of Costs

6.9.1 In the 23rd Plenary Session of the PTCC held on 6th January 1967, the financial aspects of co-ordination measures were discussed at length. It was decided that the later entrant in the field should pay the initial cost of protective measures recommended by the PTCC + 15% towards spares.

6.9.2 The question of apportionment of costs for protection of railway block circuits against induction from power lines under fault conditions has been under the consideration of the PTCC from 1972 onwards. The following is a chronological record of the case:

(i) PTCC meeting on 24th March 1972 sets up working group of Railways and the then P&T to discuss the issue.

(ii) Meeting of Working Groups on 25th August 1972. No agreement reached.

(iii) PTCC meeting of 21st October 1972 decided to revive the Working Group.

(iv) Meeting of Working Group on 28th March 1973. Agreement not possible.

(v) PTCC meeting on 10th August 1973 discussed the issue again and decided as follows with the Railway representative dissenting:

(a) The PTCC will concern itself to giving route approvals in all cases (whether Telecom or Railway owned) by providing protective measures to conform to the voltage limits specified by CCITT.

(b) In case any using Department wants additional protective measures to meet the special needs of its own, such Departments would have to adopt suitable measures at their own cost.

(c) In respect of block circuits leased from Telecom, the Telecom authorities would indicate the required details in the route map. In respect of Railway-owned circuits, however, such details would be obtained from the local authorities. A reference will be made to the Railways before route approvals only in cases where even after adopting standard protective measures, it is not possible to bring down the induced voltages to the levels prescribed by the CCITT.

(vi) Matter reviewed in the PTCC meeting on 25th January 1974, which reiterates the decision as at (v), with the Railway representatives not being in agreement with it.

6.9.3 The question of apportionment of costs between Power and Telecom (Telecom/Railway) authorities for re-engineering of circuits affected by newly laid power lines has been under discussion between the CEA and the Telecom Board based on the report of the PTCC Study Team referred to in Para 6.1.6. The Telecom Board then accepted the principle of cost apportionment in such cases on the basis of 2/3 and 1/3 share between Power and Telecom authorities. A copy of the Telecom Board's letter dated 18th July 1981 in this regard is at Item I in Appendix XIII to Chapter I.

The apportionment of cost of re-engineering was further revised vide . ADG (ML), Department of Telecommunications, New Delhi Letter No.10-11/92-ML dated 25th May 1992. The same is reproduced at Appendix XIII to Chapter I.

6.9.4 In case, the interference current on Earth Return Telegraph Circuit exceeds the prescribed limit of 1/10th of the working current on account of electrostatic or electromagnetic induction due to the cumulative effect of various power lines, then it was agreed in the Central PTCC meeting held on 29th July 1983 that the later entrant contributing to making the limit being exceeded would be liable to pay for the conversion of earth return to metallic return even though the contribution due to that particular power line by itself may not exceed 1/10th of the working current.

6.9.5 After detailed discussion in the meeting held on 17th November 1983 at Ernakulam, it was decided that the old cases of power and telecom lines not yet cleared by the PTCC should be regularized. The concerned field authorities were requested to take action accordingly. As regards the question of later entrant for the purpose of protection measures etc, the date of reference of the case to the PTCC should be the deciding factor. Chairman suggested that, wherever the records of clearance were not available in the case of existing telecom/power lines, the date of construction should be the deciding factor. If the records were not available in spite of best efforts, LF tests should be conducted and the cost of protection should be shared by both the parties concerned on 50:50 basis.

6.9.6 A decision about the basis for deciding the later entrant was taken in the meeting held on 20th February 1984 for the purpose of cost apportionment. Accordingly-

(i) From 17th November 1983 onwards the date of reference to the competent PTCC authority will be the basis for cost apportionment for re-engineering and protective measures to telecom lines in respect of new lines proposed or constructed and

(ii) In all old cases of DoT and power lines prior to 17th November 1983, actual date of construction/modification involving LF induction will be the basis for the cost apportionment for re-engineering and protective devices.

6.9.7 A high level meeting was held on 4th May 1992 in connection with apportionment of costs of re-engineering with apportionment of costs of re-engineering between representatives of DoT and DoP and the minutes circulated vide DoT letter No.10-11/92-ML dated 25th May 1992 were given at Item-II in Appendix XIII to Chapter I.

6.9.8 In the meeting held on 16th February 1995 at Bhopal, Director (ML) readout the guidelines approved by DoT based on the recommendations of the high level committee on methodology for obtaining payment of re-engineering charges towards affected telecom circuits/lines from Power authorities. DoT, New Delhi letter No. 10-11/94-ML dated 30th January 1995, containing these guidelines is included in Appendix XIV to Chapter I. It was decided to settle all pending and future re-engineering cases based on these guidelines.

6.10 State Level Power & Telecommunication Coordination Committee (SLPTCC)

6.10.1 A proposal for the formation of Sub-Committee to deal with power lines of voltage up to and including 33 kV which is now upto 132 kV) was considered in the Technical Committee meeting held on 5th January 1967. Considering that large lengths of 11, 22 and 33 kV power lines have to be constructed on top priority basis in the context of the five year plans, the PTCC felt that creation of Sub-Committees at State Level is warranted to handle problems of co-ordination in regard to sub-transmission lines. The PTCC accordingly recommended to Government the formation of State Level Committees in each of the States comprising representative each from the office of the General Manager, Telecom and Chief Engineer, State Electricity Board of the respective states. These Committees will dispose off parallelism cases of power lines up to 33 kV (which is now upto 132 kV) in their respective states in accordance with a 'simplified procedure' drawn up and furnish to the Central Committee a quarterly progress report about the co-ordination cases processed by them. The PTCC felt that this active association of power and telecom interests would remove the bottlenecks existing at present.

6.10.2 The meeting of the Committee held on 25th January 1974 agreed to the proposal of the Railways for inclusion of their representatives in the various State Level Committees. It was also decided in the meeting held on 3rd September 1974 that during the interval between two PTCC meetings, at least one case may be taken up for detailed tests and investigation. The JS (P) and JS (T) would submit the reports of such tests to the PTCC for further action.

6.10.3 In the meeting held on 21st March 1980 at Jabalpur, it was decided that the completion of protection works for the cases for which Central PTCC issues route approval might be discussed in the State Level PTCC meetings. It was decided that the minutes of State Level PTCC meetings would also be endorsed to Central Electricity Authority, New Delhi.

6.10.4 In the meeting held on 26th September 1984, it was decided that AE (PTCC) of T&D Circle would continue to be the Secretary for State Level PTCC. In the 58th Central PTCC meeting held on 25th February 1993 decisions were taken about frequency of State Level PTCC meetings and additional functions to be performed by State Level PTCC so as to make it more effective. The revised present composition of State Level PTCC and its functions are given in Appendix XV to Chapter I.

6.10.5 In the meeting held on 24th January 1990, it was clarified that the decisions of Central PTCC are binding on State Level PTCC and since DET's (PTCC) are attending all State Level PTCC meetings; they should ensure that no adverse/contradictory decisions are taken at State Level PTCC meetings.

6.10.6 In the meeting held on 16th February 1995 at Bhopal, the matter for up-gradation of Chairmanship of State Level PTCC was discussed and it was felt that there was no such necessity and the present system was found to be working satisfactorily. However, Members were of the view that as at the Central level, at the State level also a high level co-ordination body may be constituted, wherever necessary, with the GM on telecom side and CE on power side to settle those cases which remain unresolved even after two State Level PTCC meetings.

6.11 Co-ordination with Railways

6.11.1 The Railway Board has been writing to the PTCC ever since stating that the decisions of the PTCC are not acceptable to it and that the Electricity Boards pay for all protective measures which the Railways consider necessary for ensuring that the block circuits are protected from induction. The matter has been discussed again with the Railway Board by officers of the Central Electricity Authority to ascertain the types of block circuits and the extent to which they are affected by induction. It is seen that there are nearly 25 types of block instruments of which a few can withstand induction up to 430V, a few can be modified to withstand low levels of induction and a few cannot tolerate any induction.

6.11.2 The above decisions have been modified at a High Level meeting at the level of Members of P&T Board; Member of CEA, Director (Signals) of Railway Board and other concerned officers, which was held in December 1976 to discuss the problems relating to protection of Railway Telecom and Block Circuits. A copy of the minutes indicating the decisions is in Appendix XVI to Chapter I.

6.11.3 Application of Screening Factor due to Rails in induced voltage calculations for Railway telecom and block circuits was under discussion in several Central PTCC meetings and finally a decision was taken in the meeting held on 12th February 1987 that unity screening factor due to rails will be applied only for the Railway block circuits.

6.11.4 AC Immunity levels of Railway block instruments were circulated by Railways vide Director Telecom (Railway Board) New Delhi letters, (i) No.77/W3/TCM/2/Meeting dated 3rd April 1978 and (ii) No. 90/Telecom/PTCC/P/1 dated 25th May 1993, which are included in Appendix XVII to Chapter I.

6.12 Guidelines For Laying Power Cables of voltage more than 33 kV in Proximity With Telecom Cables

6.12.1 A sub-committee comprising the members from CEA, T & D Circle, BSNL, Jabalpur, AP Telecom Circle, TN Telecom Circle, TNEB and APTRANSCO was set up by the Central PTCC during its 73rd Central PTCC Meeting held on 5th August 1999 at Aurangabad to prepare interim guidelines for laying the power cables of voltage more than 33 kV in proximity with telecom cables. The Committee framed the guidelines and submitted them to the Central PTCC for its approval and acceptance for the use of Power and Telecom sectors. The Central PTCC approved and accepted the guidelines and they were circulated with the Minutes of the 82nd Central PTCC meeting held at Lucknow on 26th February 2004. These guidelines have been given in Appendix – XVIII to Chapter I.

6.13 Summary of important points required to be followed before forwarding the PTCC proposal.

6.13.1 This information is given as Appendix- XIX to chapter – I

6.14 Formation of Protection/Re-engineering Supervisory Sub-committee.

6.14.1 In the 89th Central PTCC meeting held at Aurangabad held on 23rd January 2009, the Central PTCC had accepted the proposal of CEA for formation of a Sub-committee to scrutinize the re-engineering estimates. The Supervisory committee should work to bring uniformity in the scope of equipment required for re-engineering and cost aspects thereof. The Chairman, Central PTCC, advised that in order to make this Supervisory Committee most effective it should include the member from the affected power utility, he will also be the convener of the meeting. He proposed that there should be three permanent members of this Supervisory Committee

1. Director (PTCC), CEA,
2. AGM (PTCC) T&D Circle, Jabalpur. (Now T&D Circle is renamed as Inspection Circle)
3. Director (Telecom), Railway Board.

He further proposed that there shall be two/three floating members in the Sub-committee which will be as follows:

1. Member from the affected power utility whose re-engineering proposal is to be scrutinized by the Sub-Committee.
2. A Member from the agency who has given the re-engineering estimate. It will be either BSNL or Railways.
3. Any other party which is directly affected by this re-engineering estimate.

Chairman Central PTCC further said that whenever required the meeting of the above committee has to be convened by the affected power utility.

6.15 Forwarding of PTCC proposal by Private Parties. (Other than Central/State Power utilities)

In the 90th Central PTCC Meeting held at Bangalore on 30.10.09 the members of the Central PTCC decided that all the proposals (220kv and above) for PTCC route approval from the private parties, which are to be processed by CEA be sent directly to CEA for processing. It was also decided that while applying for PTCC route approval the private parties shall also submit a copy of the MoU/ Agreement between them and Central/State power transmission utilities.

6.16. PTCC route approval for the LILO of power line or Tapping/Tee off of the main power line, submitting the reference vide which the PTCC approval of the main line was accorded.

In the 90th Central PTCC Meeting held at Bangalore on 30.10.09 the members of the Central PTCC decided that in future Route approval reference for main line should not be insisted upon whenever a proposal for new tap/LILO line is forwarded for PTCC route approval. However the power authorities should categorically state in the Questionnaire that the Main line is approved by PTCC.

6.17 Marking of telecom circuits that are less than 5 km in length and more than 2 km away from the proposed Power Line.

In the 91st Central PTCC Meeting held at Trivandrum on 8th June 2010, it was decided by the committee that while forwarding the telecom details for PTCC route approval of Power Lines, BSNL will not mark those telecom circuits which are less than 5 km in length and more than 2 km away from the proposed power line.

> If you talk to a man in a language he understands, that goes to his head. If you talk to him in his language, that goes to his heart.
> -Nelson Mandela

CHAPTER-II

CHAPTER II

Various Committees Connected With Power & Telecommunication Coordination

1.0 After its inception in 1949 all cases for PTCC clearance were being referred to the Central PTCC. The work at the Central level increased enormously due to the enormous spurt in both the Power and Communication sectors. The clearance of 11 kV lines was entrusted to DE's (T) of the Telecom Department on the basis of guidelines prepared by the Central PTCC. It was necessary to further decentralize the work relating to lines up to 33 kV. Accordingly, State Level Committees were set up in 1968 with representation from the Power and Telecom sides. A 'Simplified Procedure' for issue of clearance in such cases was prepared by the Central PTCC.

2.0 With the increasing complexities in matters connected with PTCC clearance and the problems posed by large financial outlays incurred in re-engineering of telecom lines, it was decided in 1977 to have an informal High Level Committee of the Members from the CEA and the then P&T Board to go into cases not settled by the PTCC.

3.0 In view of the increasing tempo of transmission line construction, it became difficult for the CEA to process all cases of lines beyond 66 kV. As decided by the conference of Chairman of State Electricity Boards in January 1978, the work relating to computation of induction from power lines of 66 kV, 110 kV and 132 kV was decentralized w.e.f. June 1978. Officers nominated by SEB's specifically for the purpose started dealing with these cases in conjunction with the Regional DE's (T) PTCC who issued route approvals on behalf of Central PTCC. In February 1979 the Central PTCC decided that State Level PTCC's would discuss all cases of lines up to 132 kV.

4.0 Summing up, the various Committees involved in PTCC matters are as follows:

(i) The informal High Level Committee comprised of the Member (G&O) of CEA and Member (TD) of Telecom Board meeting at intervals by mutual consent.

(ii) Central PTCC with nominees at present as indicated in Appendix IV to Chapter I, meeting 4 times a year. The CE (LD&T), CEA/CGM, T&D Circle, DoT chair the meetings in alternate years.

(iii) State Level PTCC's with nominees at present as indicated in Appendix XV to Chapter I. The SE from State Electricity Board and Director (Telecom) from DoT chair the meetings in alternate years. Meetings are held generally every month but not later than a quarter. The Chairmanship is fixed by mutual consent.

5.0 High Level Committee

5.1 Composition

In a few cases like upper limit of voltage for GD tubes, cost apportionment etc. where no consensus could be arrived at in the Central PTCC, such cases are discussed at the level of Secretary (Power) or Chairman/Member, CEA assisted by other officers from Ministry of Power/ CEA and Secretary (Communication) or Members from the Telecom Board assisted by other officers from the Telecom side. Officers of appropriate level from the Railways are also invited when there are issues involving them.

5.2 Central Standing Committee

In the high level meeting between representatives of Department of Telecom and Department of Power on re-engineering held on 4.5.1992 at New Delhi, it was decided that the Central Standing Committee should be revived so that it could look into such estimates which have resulted in delay in settling re-engineering cases. It will consist of two representatives from DoT and Two from CEA, Director (ML), DoT will be the convener of the committee. Minutes of the said meeting are available at Sl.No. II in Appendix XIII to Chapter I.

6.0 Central PTCC

6.1 Composition

As per Appendix IV to Chapter I.

6.2 Functions

As already indicated in Chapter I, basic function could be summarized as:

(i) To consider all matters relating to the adverse effect of power lines on telecom lines.

(ii) To consider specific cases of route approval of power lines exceeding 33 kV and telecom lines. Computations of induced voltages for lines over 33 kV and up to 132 kV are done by SEB's and for lines of 220 kV and above by the Central Electricity Authority.

(iii) To consider and adopt new protective measures to minimize the cost of protection.

6.3 Frequency of Meetings

Generally once in three months.

7.0 State Level PTCC

7.1 Composition

The present membership of the State Level PTCC consists of officers of Junior Administrative Grade from the concerned SEB, Telecom Circle, Railways and Defense. It is as per Appendix XV to Chapter I.

7.2 Functions

The main functions of the Committee are as under:

(i) To review the progress of route approval cases of 11 kV lines dealt with by Telecom District Engineers.

(ii) To consider route approval cases up to service voltages of power lines upto and including 132 kV.

(iii) To consider re-engineering schemes for cases where induction exceeds the protection limit for GD tubes.

(iv) To co-ordinate and watch the progress of installation of protective measures and re-engineering works and issue of energization certificates on completion of protective works.

(v) To consider violation of PTCC regulations and take suitable corrective measures.

(vi) To discuss cases of power lines of 66KV and above held up for PTCC clearance.

(vii) Other additional functions detailed in Appendix XV to Chapter I.

7.3 Frequency

The meeting is generally to be convened once a month but not later then once in 3 months in any case and the Chairmanship is mostly by rotation between the SEB/DoT representatives.

8.0 Formation of Protection/Re-engineering Supervisory Sub-committee.

In the 89th Central PTCC meeting held at Aurangabad held on 23rd January 2009 the Central PTCC had accepted the proposal of CEA for formation of a Sub-committee to scrutinize the re-engineering estimates.

Composition of the Protection/ Re-engineering Supervisory Sub-committee.

The Supervisory Committee shall consist of three permanent members

1. Director (PTCC), CEA,

2. AGM (PTCC) T&D Circle, Jabalpur.
3. Director (Telecom), Railway Board.

There shall be two/three floating members in the Sub-committee which will be as follows:

1. Member from the affected power utility whose re-engineering proposal is to be scrutinized by the Sub-Committee.
2. A Member from the agency who has given the re-engineering estimate. It will be either BSNL or Railways.
3. Any other party which is directly affected by this re-engineering estimate.

Functions of the Supervisory Committee

The Supervisory committee should work to bring uniformity in the scope of equipment required for re-engineering and cost aspects thereof. The Chairman, Central PTCC, advised that in order to make this Supervisory Committee most effective it should include the member from the affected power utility; he will also be the convener of the meeting.

It was also decided that whenever required the meeting of the above committee has to be convened by the affected power utility.

> Adaptability is not imitation. It means power of resistance and assimilation.
> -Mahatma Gandhi

CHAPTER-III

CHAPTER III

Procedure for Clearance of PTCC Cases of Power and Telecommunication Lines

SECTION A

POWER TRANSMISSION LINES (INCLUDING) POWER CABLES

1.0 Important

1.1 Each power line is to be examined with respect to all the telecom lines inclusive of long distance cables, coaxial cables, railway circuits etc.

1.2 The cases of 11 kV lines are processed and approved by the respective divisional Engineer Telegraphs/Telephones. Induced voltage calculations are done by the DE's Telegraphs/Telephones as the case may be.

1.3 The cases above 11KV and up to 33KV lines are processed by the SDE (PTCC) of T&D Circle whose office is located at the office of Chief General Manager Telecom. Induced Voltage calculations are made by the said SDE (PTCC)

1.4 Induced voltage calculations of lines of 33KV DC and above and up to 132KV are done by the nominated officers of the respective Electricity Boards/Power Utilities. Induced voltage calculations above 132 kV are done by the Central Electricity Authority. Cases are processed by the DET (PTCC) concerned. In case of DC lines, strung initially as Single Circuit, PTCC clearance is not required again in case the computation is done on Double Circuit basis initially itself. In such cases only the DoT is to be informed.

1.5 The recommendations of the Railways are incorporated in respect of the railway block circuits in the Route Approval Certificate irrespective of the induced voltage.

1.6 Maximum safe limits of LF induction are 430V and 650V from ordinary and high reliability power lines respectively as per CCITT. The Indian PTCC has adopted these limits for power lines up to 33 kV and for 66 kV and beyond respectively.

1.7 Single Wire Earth Return Telegraph Circuits affected will be converted as per the relevant decision of the PTCC.

1.8 The PTCC Route Approval itself is not a clearance for energization and separate clearance will have to be obtained from the Railways/Telecom Authority maintaining the same.

2.0 Power Lines Exceeding 132 kV

2.1 In the case of power lines of 220 kV and above, the application for clearance of the route is processed by the Central PTCC. The application for PTCC clearance is to be accompanied by the following documents:

(i) Questionnaire Number 1 as per proforma at Appendix 1 to Chapter III duly filled in with all relevant details.

(ii) A route map of the proposed power line (with terminal stations prominently marked) drawn to a scale of 1”=1 mile or 1 cm =0.5 km. The route map should depict all topographical details including railway lines, rivers, canals and important roads and other landmarks like towns, villages with names etc. on either side of the proposed power line up to 8 kms.

(iii) Where there is close parallelism, the scale of the route map should be larger in order to compute the mutual coupling between the two lines accurately.

(iv) Statement showing the soil resistivity in the area covered by the line measured by the four electrode method with an inter-electrode spacing of 50 meters, measurements being taken at every 2 or 3 kms along the length of the line.

(v) Single-line diagram of the electrical layout of the relevant portion of the power system with details as in the questionnaire.

(i) In the case of tap or spur lines, distances of the tap point from either of the end sub-stations should be clearly marked.

2.2 Copies of all the documents are to be sent to:

(i) Director (PTCC), PTCC Directorate, LD & T Division, Central Electricity Authority, NREB Complex, Katwaria Sarai, New Delhi110016.

(ii) Concerned DET (PTCC) of DoT as per addresses given below (with two additional copies of route map).

- **For Northern Region**
  (UP, Uttaranchal, Rajasthan, Haryana, Punjab, HP, J&K, Delhi etc.)

  Divisional Engineer (T),PTCC, Northern Region, Inspection Circle, Bharat Sanchar Nigam limited,469, 4th Floor, kidwai Bhawan, Janpath, New Delhi-110001.

- **For Eastern Region**
  (Orissa, Bihar, Jharkhand, Assam, West Bengal and states in the NE Region)

DET (PTCC), Eastern Region, Inspection Circle,BSNL, 83/1A, Vivekananda Road, 7th Floor, Kolkata 700006.

- **For Western Region**
  (Maharashtra, Gujarat, MP, Chhattisgarh, Goa, Diu & Daman)

  DET (PTCC), Western Region, Inspection Circle, BSNL, 'D' Wing, 3rd floor, Administrative Building, Telecom Complex, Juhu-Tara Road, Santa Cruz (W), Mumbai 400054.

- **For Southern Region**
  (Karnataka, Kerala, Tamilnadu, Andhra Pradesh)

  The Divisional Engineer (T),PTCC, Inspection Circle, Southern Region, Bharat Sanchar Nigam Ltd.,1st Floor, Raj Bhavan Telephone Exchange No.26, Sardar Patel Road, Guindy, Chennai – 600 032.

2.3 Copies of route map are also to be sent to:

(i) The local DET of the Telecom Department (two copies) with a request to mark the telecom lines involved and forward the same to the DET (PTCC) concerned; if more than one DE (T) is involved, additional copies to be sent to other DE's (T) concerned.

(ii) The SDE (PTCC), O/o CGM (Telecom), of the Circle concerned-One copy.

(i) GM (S&T) of the Railways concerned (four copies) with a request to mark their telecom lines involved and forward one copy thereof to the Director (PTCC), Central Electricity Authority, New Delhi and one copy to the concerned DET (PTCC).

(The address of all the zones of the Railways along with their jurisdiction is given in Appendix III of this chapter)

(iv) GM (Projects) and GM (Maintenance)-Two copies each.

(ii) Army Signals in case of border areas-Two copies.

2.4 The final PTCC clearance would be issued by the DET (PTCC) concerned on behalf of Central PTCC, after receipt of the induced voltage computations and Railways' recommendations.

2.5 The State Electricity Boards/Power Utilities will keep a liaison with the DoT/Railways to ensure that the protective measures are provided in time.

NOTE: THE ABOVE PROCEDURE IS DEPICTED IN A FLOW CHART ANNEXED AT THE END OF THIS CHAPTER.

3.0 POWER LINES OF 33KV D/C AND ABOVE UPTO 132 kV D/C

3.1 In these cases the application for clearance of the route is to be processed by the State Electricity Board concerned, which is to designate a suitable officer and the DET (PTCC) as per 2.2(ii) above. The application for PTCC clearance is to be accompanied by the documents mentioned in 2.1 above. The route map is to cover 8 KM. on either side of power line for 66 kV and above and 5 KM. for 33 kV lines.

3.2 Copies are to be sent to the officers as in 2.2 above except that instead of Director (PTCC), CEA mentioned therein, the officer designate in the Electricity Board/Power Utility is to be contacted.

3.3 Copies of the route map are to be sent to the officers mentioned at 2.3 above.

3.4 The final PTCC clearance would be issued by the DET (PTCC), concerned on behalf of Central PTCC.

NOTE: THE ABOVE PROCEDURE IS DEPICTED IN A FLOW CHART ANNEXED AT THE END OF THIS CHAPTER.

4.0 POWER LINES OF ABOVE 11KV UPTO 33 kV S/C

Detailed instructions are available in the booklet 'Simplified Procedure for Co-ordination of Power lines up to and including 33 kV with Telecom lines' detailed in Chapter IV of the Manual. The route map to cover 5 kms. on either side of power line for 33 kV and 22 kV. The route approval of all these cases is issued by the State Level PTCC.

5.0 POWER LINES OF 11 kV

The clearance is to be obtained from the local DET of the Telecom Department as per procedure given in the 'Simplified Procedure' mentioned in 4.0 above. This does not cover SWER power lines, regarding which separate guidelines are issued. The route map to cover 3 kms. on either side of power line for 11 kV.

SECTION B

FOR THE USE OF BSNL/ MTNL/ RAILWAY/ DEFENSE

1.0 IMPORTANT

1.1 All telecom lines in the vicinity of the proposed power route would be marked distinctly to scale on the route map received from the power authorities. It is not enough to indicate a portion of the line only.

1.2 Not only the crossings but also the complete alignment of the telecom line, as actually in existence or planned, should be marked on the line route map to same scale. The stations, which the telecom line connects, should be clearly indicated and the entire portion falling on the route map should be shown.

1.3 L-14 diagrams should accompany the route map. No abbreviations or code words should be used but full name of stations should be shown.

1.4 Along with the route map on which the telecom lines have been marked as indicated above, the details in full of all the circuits working on the telecom alignments giving the discontinuity points and route lengths, should be furnished.

1.5 The DET should furnish the telecom details, L-14 index etc. through the respective SDE (PTCC) to the DET (PTCC) concerned.

Note: The telecom details should be supplied to:

(i) The DET (PTCC) concerned within 2 months of receipt of the route map and should be complete.

(ii) The information regarding telecom particulars should be given in the proforma complying with all the points in the check sheets.

1.6 After receipt of the route approval, the Telecom/ Railway authorities concerned shall arrange for the necessary protection expeditiously and intimate compliance to the Member (P) and Member (Telecom) of State Level PTCC and the Organization issuing the route approval. Member (Telecom) of concerned Telecom authority would then issue the energization approval for the power line. For computing the interference current on the earth return telegraph circuits, the following details are to be supplied in case of single-wire earth return telegram circuits.

(i) Average height of telecom wire above ground in meters.

(ii) Number of line conductors excluding the telegraph wire under consideration, which are not insulated from earth.

(iii) Whether phantom has been employed for the telegraph circuit.

(iv) Length of telegraph section and separation from power line.

(v) Details of telegraph apparatus including normal operating current and voltages.

SECTION C

TELECOM LINES

For the use of officers of Department of Telecommunications and Railway Board while submitting the applications for Route Approval in case of new Telecommunication Lines

1.0 Important

1.1 The route of all the Trunk lines, Junction lines, Long Distance PCO lines, Telegraph Circuits, Railway Circuits and Coaxial Cables should be referred to PTCC for Route Approval.

1.2 Each Circuit is to be studied for the effect of induced voltages from all the paralleling power lines, in the vicinity (for 11 kV lines up to 3 kms 33 kV lines up to 5 kms and above 33 kV lines up to 8 kms.)

1.3 All power line crossings should be as per the PTCC Code of Practice.

1.4 PTCC Route Approval itself is not a clearance. **Provision of all protection is a MUST for energization.** The protective measures should be carried out during construction.

2.0 Procedure

2.1. The application for PTCC clearance is to be made at the survey stage itself. As the effect of the induced voltage is to be calculated with respect to all the power transmission lines, running parallel to the proposed telecom/railway lines, the case should be submitted to the respective DET (PTCC) and others concerned, i.e. Executive Engineer of the concerned Electricity Board/Power Utility and to the Director (PTCC), CEA, New Delhi. The approval will be issued by DET (PTCC) after the receipt of all induced voltage calculations.

2.2 The route of the proposed telecom line should be marked on a topographical map to the scale of 1”=1 mile or 1 cm=0.5 km. The route map should show topographical details including all railway lines, rivers, canals and important roads and other landmarks like towns, villages with names etc. on either side of the proposed telecom line up to 8 kms. The route of all the power lines also should be marked on the map.

(i) All Railway Stations falling on the map portion of the line should be physically located on the map and marked with names.

(ii) Care should always be taken to be as far away from the power lines as possible while fixing the telecom line route. Where, however, there is close parallelism in certain sections, the scales of the route map should be larger than 1”=1 mile in order to compute the mutual impedance between the two lines accurately for that particular section.

2.3 The application for PTCC approval is to be accompanied by the following documents:

(i) A Questionnaire Number 2 as per proforma at Appendix II to Chapter III duly filled in with all relevant details.

(ii) Statements showing the soil resistivity in the area covered by the line measured by four electrode method with an inter-electrode spacing of 50 meters, measurements being made at every 2 or 3 kms along with the length of the line.

(iii) The L-14 diagram of the proposed telecom alignment.

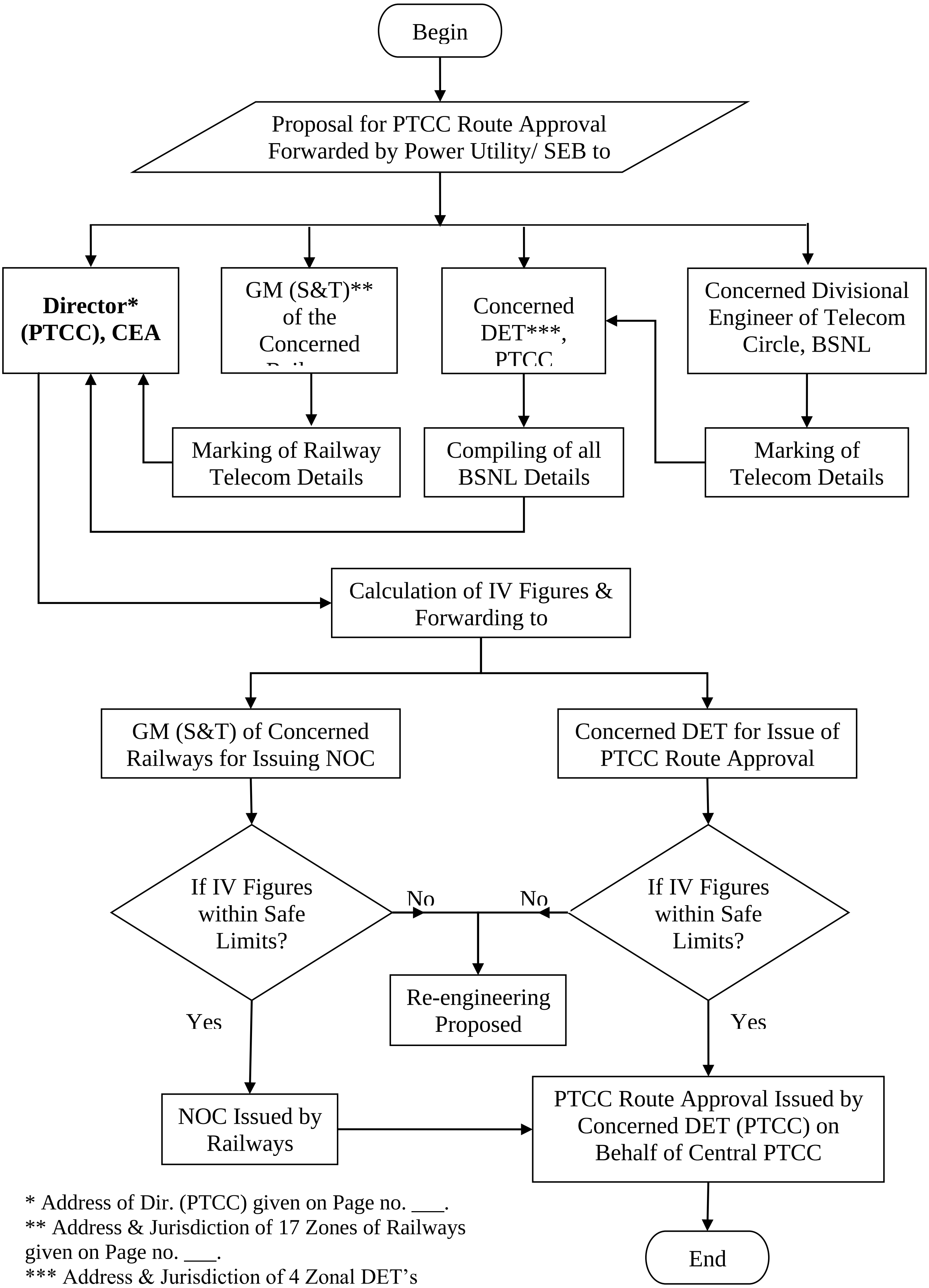
(iv) The details of the circuit likely to work on the telecom lines (use of codes and abbreviation should not be made).

(v) The number of crossings and the angle of crossings with power line with location details.

2.4 Copies of all the documents as above (plus four additional copies of the route map) to Member (Power) of State Level PTCC for marking the power details. The later will get the power lines marked and send to SDE (PTCC) for lines of 33 kV S/C and below and to Director (PTCC) CEA, New Delhi, for lines of 220 kV and above. For the power lines of other voltages, the computations are done by the SEB. The results in all cases are sent to the DET (PTCC) concerned for necessary action to examine and issue the PTCC Route Approval.

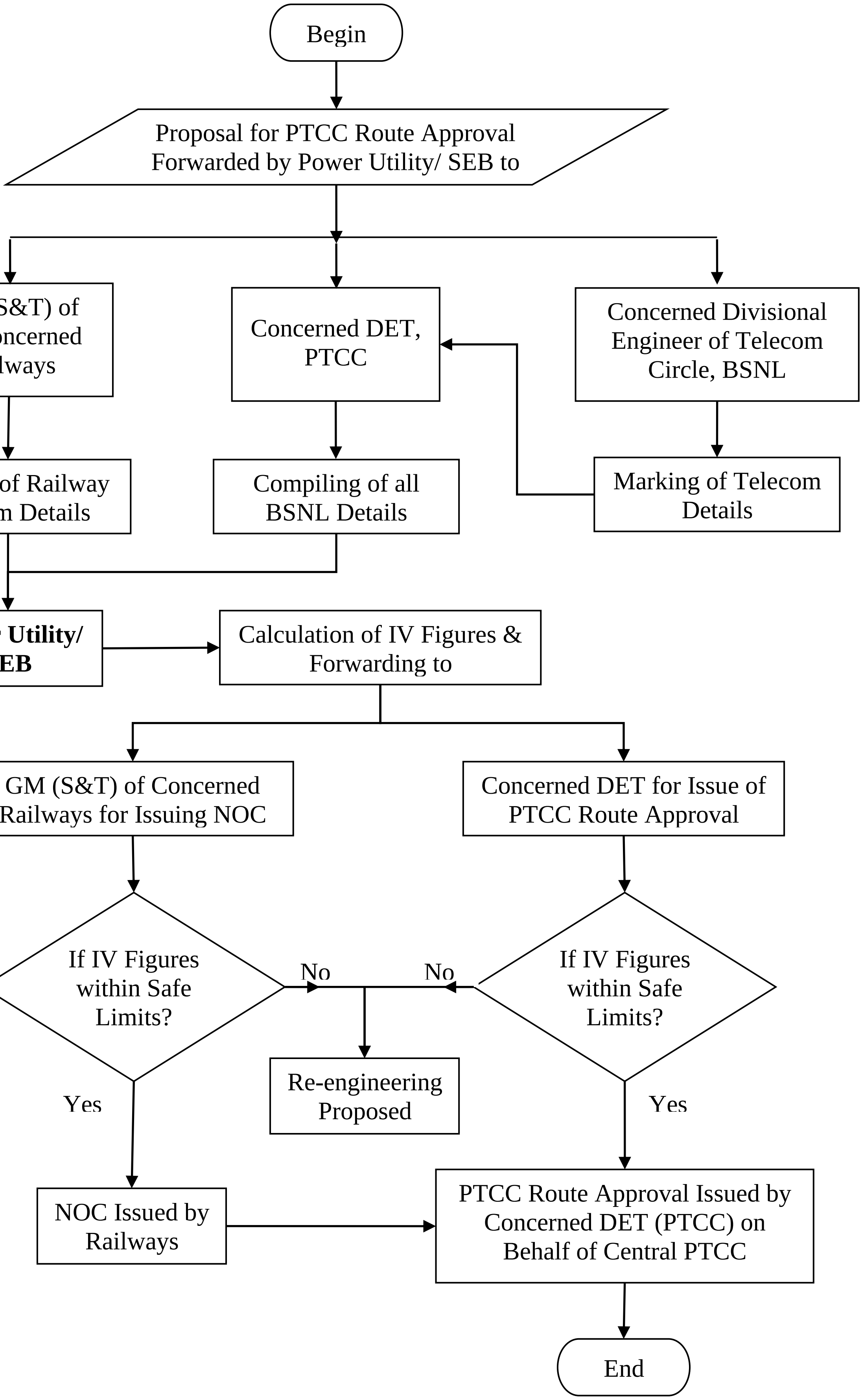
It is easy to perform a good action, but not easy to acquire a settled habit of performing such actions.
-Aristotle

Flowchart for the Processing of PTCC Route Approval of Power Lines, 220kV and above



* Address of Dir. (PTCC) given on Page no. ___.
** Address & Jurisdiction of 17 Zones of Railways given on Page no. ___.
*** Address & Jurisdiction of 4 Zonal DET's (PTCC) are given on Page no. ___.

Flowchart for the Processing of PTCC Route Approval of Power Lines, 132kV and below



CHAPTER-IV

CHAPTER IV

Simplified Procedure for Co-ordination of Power Lines of voltage level up to 33 kV with Telecommunication Lines

1. Introduction

Power and telecommunication lines constitute essential lifelines of any community. Very often they will have to follow the same road or railway alignment and thus will have to exist close to each other. Any high voltage power line sets up in its vicinity electric and magnetic fields. Communication circuits coming under the influence of these fields will experience extraneous induction. The extraneous induction under certain conditions may introduce noise in communication circuits and/or cause danger to communication equipment or personnel. Therefore it is very essential that whenever power and telecommunication lines have to take rights of way close to each other, suitable co-ordination measures are effected to derive maximum benefits from both the systems. The specific co-ordination principle to be adopted, depends on the operating conditions of the two systems. In this country, the power systems are operated with their neutrals effectively grounded. The communication lines are generally of the overhead open wire type. With such systems, earth return currents on power circuits caused during asymmetrical faults on power lines can induce dangerously high voltages on the communication circuits. Therefore, the Power & Telecommunication Co-ordination Committee (PTCC) has based the Power and Telecommunication Co-ordination in this country on the principle of low frequency induction. It may be mentioned that with the co-ordination based on low frequency induction and the limits given in Para 2 being adhered to, the requirements in respect of noise interference are taken care of.

2. Principle of low frequency inductive coordination

The principle of low frequency inductive co-ordination essentially involves the determination of the induced voltage on the communication circuits under single line to ground fault conditions on the power line and limiting the induced voltages in the different sections to the prescribed limits. The prescribed limit for parallelism with power lines up to and including 33 kV is 430 volts.

3. This simple graphical method for examination of power and telecommunication lines; parallelisms for purposes of co-ordination is divided into five parts as under:

Part I Gives graphs for determining separation necessary between power and telecommunication lines, to keep the induction within the prescribed limit (430V). This separation is referred to as minimum safe separation.

Part II Gives graphs showing S/S_m vs Induced Voltages (in units of 430V), for estimating induced voltages where the minimum safe separations prescribed in Part I cannot be achieved in practice. This will enable provision of necessary protection on telecommunication circuits.

Part III Gives details about use of protection measures to be adopted in cases of voltages exceeding the prescribed limits.

Part IV Gives method of estimation of induced voltage where tap lines, more than one power line and extensions to existing power lines are involved.

Part V Explains the step-by-step procedure for examination of individual cases of parallelism.

4. In the preparation of this procedure, it has been assumed that the power lines would be essentially radial ones i.e. the sources of supply would be only at one end. This assumption is justified, as the bulk of the power lines in this voltage category would be operated in this manner. Infinite bus has been assumed at nearest extra high voltage grid sub-station at which the voltage level of 11, 22 or 33 kV is created. This assumption is also justified as the error creeping in by neglecting the system impedances behind the extra high voltage bus is insignificant. Further, the error if any, would be on the safe side. In the preparation of the graphs for estimation of fault currents, a fault resistance of 20 ohms in conformity with the recommendation of the latest CCITT directives has been taken into account. For estimating mutual coupling between power and telecommunication lines, Carson curves have been used.

Part I

To Determine Minimum Safe Separation Necessary Between Power and Telecommunication Lines to Keep the Low Frequency Induction within the Prescribed Limit of 430 Volts

1. Plate 1 (a and b) in Appendix III to Chapter IV gives a set of graphs for determining minimum safe separation i.e. the separation necessary to keep the low frequency induction within the prescribed limit of 430 volts. For these curves the abscissa represents the product of fault current in amps causing the induction and length of parallelism in kms, while the ordinate represents the minimum safe separation in meters. The soil resistivity is a parameter and separate curves have been given for soil resistivity of:

(i)	1,000 Ohms-cm.	(ii)	3,000 Ohms-cm
(iii)	5,000 Ohms-cm	(iv)	7,500 Ohms-cm
(v)	10,000 Ohms-cm	(vi)	15,000 Ohms-cm
(vii)	20,000 Ohms-cm	(viii)	50,000 Ohms-cm
(ix)	1,00,000 Ohms-cm		

2. For using the curves in Plate 1, knowledge of fault current on the power circuit causing the induction is necessary. This can be determined for any situation from the graphs given in Plates 2(a) to 2(c) in Appendix III to Chapter IV. For using the graphs given in Plates 2 (a) to 2(c), the following basic information of the power circuit is necessary:

(a) Voltage class of the power line - 11, 22, or 33 kV.

(b) Size of conductor used for the power line.

(c) Total capacity of the step-down transformer in MVA at the main grid sub-station creating the voltage of the power line.

(d) Distance of the point of fault (end of parallelism) from the main grid sub-station in kms.

3. For 11 kV lines the effect of the capacity of the main step-down transformer is insignificant and hence only the conductor size is the parameter in the graphs given in Plate 2(c). Conductor size of 0.03 sq.in.cu.eq. ACSR, 0.04 sq.in.cu.eq. ACSR and 0.06 sq.in.cu.eq. ACSR only have been covered, being popular sizes.

The capacity of the main step-down transformer has some effect in the case of 22 kV and 33 kV lines. Hence, in Plates 2 (a) & 2 (b) graphs have been drawn for the capacities of step-down transformer, viz.5 MVA and 30 MVA for each of the sizes of conductor. The curve for

K = 30 MVA

can be used for all cases where the capacity of the step-down transformer exceeds 30 MVA. Similarly the curve for

K = 5 MVA

can be used for transformer capacities of 5 MVA and below. For values of transformer capacities between 5 MVA and 30 MVA, suitable interpolation should be made.

4. In practice in any parallelism section the separating distance between the power line and the telecommunication line will not be same throughout. In such cases it is necessary to determine the average separation. The method to be adopted for determining the average separation is given in Appendix I to Chapter IV.

5. A knowledge of the soil resistivity for determining safe separation in any situation is very essential. The soil resistivity at any place can be measured by means of the Evershed Earth Tester. The method of determining soil resistivity by means of Evershed Earth Tester is explained in Appendix II to Chapter IV.

6. Examples

The method of determining safe separation for any situation has been demonstrated by means of the following examples:

Example I

Figure 1 shows the schematic of a 33 kV S/C line using 0.06 sq.in.cu.eq. ACSR. At the main grid sub-station, at 'A', there are two numbers 4 MVA, 132/33 kV transformers. In the route of this power line, parallelism with communication circuits occurs in the section BC. Determine the safe separation. The soil resistivity of the place is of the order of 10,000 ohms/cm³.

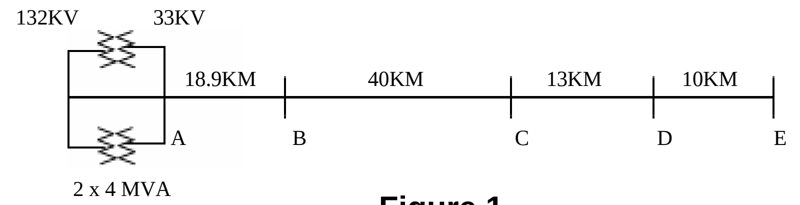


Figure 1

Voltage class of the power line	= 33 kV
Size of conductor	=0.06 sq.in.cu.eq. ACSR
Step-down transformer capacity	= 2x4 = 8 MVA
Distance of Point 'C (end of parallelism) from main step-down 'A'	= 58.9 kms

Referring to Plate 2(a), corresponding to the above conditions on the power circuit,

Fault current causing induction	= 230 Amps
Length of Parallelism	= 40 kms

Product of fault current and length Of parallelism = 230 x 40
= 9200 Amp kms

Referring to Plate 1 (a), the minimum safe separation, corresponding to soil resistivity of 10,000 ohm/cm³ for Amp Km of 9200, S_m = 720 meters

Example II

Figure 2 shows the schematic diagram of an 11 kV S/C line using 0.04 sq.in.cu.eq. ACSR. At the main grid sub-station there are two numbers 7.5 MVA, 132 / 11 kV transformers. In the route of this 11 kV power line, parallelism with communication circuits occurs in the section CD. Determine safe separation, if the soil resistivity of the region is of the order of 5,000 ohms/cm³.

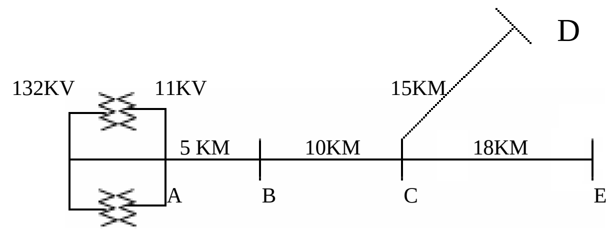


Figure 2

Voltage class of the power line	= 11 kV
Size of conductor	= 0.04 sq.in.cu.eq. ACSR
Step-down transformer capacity	= 2x7.5 = 15 MVA

Distance of point of fault (end of parallelism)
from main step-down transformer = 30 kms

Referring to Plate 2(c), corresponding to the above,
Fault current causing induction = 122 Amps
Length of Parallelism = 15 kms

Product of fault current and length of parallelism = 122x15
= 1830 Amp kms

From Plate 1(b), the minimum safe separation, corresponding to 1830 Amps kms and soil resistivity of 5000 ohms/cm³, S_m = 21.5 meters

NOTE: When separations required are very small, it is necessary to ensure that it is more than 1½ times the height of the power supports.

Example III

Figure 3 shows the schematic diagram of an electrical system. For the 11 kV S/C line, 0.03 sq.in.cu.eq. ACSR is used. At the grid sub-station creating 11 kV there are two numbers 1 MVA, 33/11 kV transformers. For power parallelism in section CE, determine safe separation. The soil resistivity in the region is about 20,000 ohms/cm³.

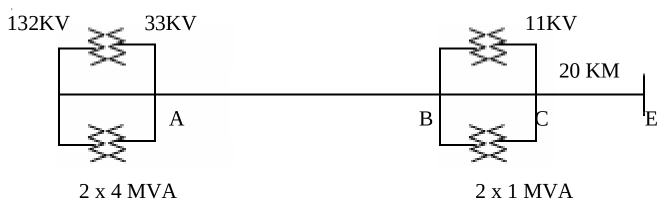


Figure 3

Voltage class of the power line = 11 kV
Size of conductor = 0.03 sq.in.cu.eq. ACSR
Step-down transformer capacity = 2x1 = 2 MVA

Distance of point of fault (end of parallelism)
from main grid sub-station = 20 kms

Referring to Plate 2(c), corresponding to the above,

Fault current causing induction = 142 Amps
Product of fault current and length of parallelism= 142x20
= 2840 Amp kms

From Plate 1(a), the minimum safe separation, corresponding to 2840 Amps kms and soil resistivity of 20,000 ohms/cm³, S_m= 130 meters

Part II

To estimate induced voltage on Telecommunication Circuits in situation where the average separation that can be maintained under field conditions, is less than minimum safe separation obtain from Plate1

Very often situations arise where the minimum safe separation as determined by Plate-1, cannot be maintained due to difficult terrain conditions or problems of maintenance. In such situations, the power and telecommunication engineers should investigate the maximum possible separation that can be maintained under the field conditions and determine the possible induction on the telecommunication circuit under that condition. This is required to determine the protective measures necessary for the telecommunication circuits. Plates 3 (a) to 3 (i) in Appendix III to Chapter IV give graphs for determining induction on telecommunication circuits for the separations other than the minimum values. In these graphs the abscissa of X-axis represents the ratio of the actual average separation that can be maintained under field conditions (S) to minimum safe separation (S_m) determined from Plate 1, while the ordinate or Y-axis represents the actual induced voltage in units of 430 volts. The Plates 3 (a) to 3 (i) cover graphs for various values of soil resistivity. In each of these graphs, the minimum safe separation (S_m), is a parameter.

The use of these graphs has been demonstrated by the following examples:

Example IV

In the case of Example I, if the field conditions limit the actual separation to 450 meters, determine the induction on the paralleling telecommunication circuit.

From Example I

S_m = Minimum safe separation
= 720 meters

S = Average separation that can be actually maintained
= 450 meters

$$\frac{S}{S_m} = \frac{450}{720} = 0.625$$

From Plate 3 (e), (for soil resistivity = 10,000ohms/cm³) corresponding to S_m = 720 meters and $S/S_m = 0.625$,

We get,
Induced Voltage = 1.53 x 430
= 656 Volts.

Example V

S_m = Minimum safe separation
= 130 meters

S = Actual separation that can be maintained
= 95 meters

$$\frac{S}{S_m} = \frac{95}{130} = 0.73$$

From Plate 3 (g), (for soil resistivity of 20,000ohms/cm³) corresponding to S_m =130 meters and S/S_m = 0.73,

We get,
Induced Voltage = 1.11 x 430
= 477 Volts.

PART III

Protection of Telecommunication Circuits in Cases of Voltages Exceeding the Prescribed Limits

In cases where the induced voltage on the telecom circuits, as determined from Plates 3(a) to 3(i) exceeds the prescribed safe limit of 430 volts, it is necessary to consider various protection measures so that the equipment installed and the personnel working on these circuits are not subjected to the influence of hazardous potentials.

One of the measures commonly adopted for protection is the use of three electrode Gas Discharge (GD) tubes. Two electrodes of the tube are connected to the wires of a telephone pair and the third electrode to the earth, through the earth cap. Under normal conditions, the telecom line is kept insulated. The gap breaks-down and the telecom line is virtually earthed, when induced voltage excess the pre-determined value (250V). Through the discharge path, the earth connection to the tube should be of very low resistance so that the voltage across the tube is restricted to safer values.

The following example illustrates the use of GD tubes to restrict the induction to safe values.

Example VI

In order to reduce the induced voltage of 656 volts to safe value in Example IV, determine the number of GD tubes to be installed on telecom line. The number of GD tubes is calculated as below:

$$\frac{\text{Induced Voltage}}{\text{Constant}} = \frac{656}{300}$$

`

= 2.2

= 3 (rounded off to the next higher digit).

Two GD tubes should be installed at the ends of telecom lines in the paralleling section and one in the middle of these two.

In case the number of GD tubes worked out are more than three, two of these should be fitted at each end of the paralleling section of the telecom lines and the rest of the GD tubes be fitted in between space at equal intervals.

GD tubes worked out by the above method should be fitted on all the telecom wires in the paralleling section.

PART IV

Estimation of Induced Voltage where
(a) Tap lines are involved;
(b) More than one power line in parallelism with DoT line; and
(c) Extensions arise to existing lines.

(a) Tap lines

The procedure for estimation of induced voltages on telecom lines paralleling tap lines is illustrated by Example II given under part I. Here, CD can be considered as a tap line branching off from the main line AE at C (Figure 2). Parallelism occurs in section CD and estimation of the induced voltage in this case is clarified by Example-II.

(b) More than one Power Line in Parallelism with DoT line

In all calculations of induced voltage, it is assumed that the faults on all the paralleling power lines do not occur simultaneously. With this assumption, it is possible to estimate the induction on a given section of telecom line due to different paralleling power lines individually. The final value of induced voltage to be considered is the severest of the estimated value of induced voltage due to the different power lines.

(c) Extensions Arise to Existing Lines

The estimation of induced voltage in cases where extensions arise to an existing line is illustrated by Example VII below.

Example VII

Let us consider that in Example I, in Part I, the line is extended to E for a distance of 10 Kms using the same conductor and that parallelism occurs in the section DE (Figure 1).

Distance of Point 'E' From step-down station 'A'	= 81.9 Kms
From Plate 2 (a), fault current	= 176 Amps
Length of parallelism	= 10 Kms
Product of fault current and length of parallelism	= 1760 Amp Kms

From Plate 1(b), for soil resistivity of 10,000 ohms/cm^3

Safe separating distance S_m	= 24 meters
Average separation	= S (say)

Average separation S can be calculated with the help of Appendix I to Chapter IV. After calculating average separation the ratio of average separation to safe separation S/S_m should be calculated and from this ratio induced voltage can be found out from the Plate 3(e) (for soil resistivity of 10,000 ohms/cm³).

PART V

Step by Step Procedure for Examination of Individual Cases

A. Procedure to be followed for New Power Line Constructions

The Executive Engineer or the SDO in-charge of the power line construction should carry out the following:

(a) Survey the route for investigating the maximum separations that field conditions permit. Once knowledge of separations that can be maintained in different portions is available, the average separation for the entire parallelism stretch can be estimated as per the procedure given in Appendix I to Chapter IV.

(b) Measure soil resistivity at a few places by means of Evershed Earth Tester. The method has been explained in Appendix II to Chapter IV. As many measurements as possible along the route should be taken for soil resistivity. In any case, it should not be less than three. There will be variation in the value of soil resistivity from point to point. The value to be chosen depends on the general trend. This has been demonstrated by means of an example below. It is important to measure the soil resistivity during the dry season.

Example VIII

The soil resistivity survey based on 160 feet or 50 meters inter-electrode spacing, reveals the following information.

Location of Measurem-ent	Meggar Reading (R)	Soil Resistivity (2πaR) Ohms/cm³
1	1.50	47,144
2	1.30	40,858
3	1.30	40,858
4	2.00	62,858
5	1.35	42,429
6	2.60	81,715

From the above survey, it can be concluded that this region is of a soil resistivity of 50,000 ohms/cm³.

(c) Calculate the value of fault current for a single line to ground fault on the power line at a point corresponding to the end of parallelism. For this purpose, use Plate 2(c) for 11 kV, Plate 2(b) for 22 kV and Plate 2(a) for 33 kV lines. The basic data of the power system required for calculation of fault current are:

(i) Operating voltage of the power line.
(ii) Conductor size of the power line.
(iii) Capacity of main step-down transformer.
(iv) The distance of the point of fault (end of parallelism) from the main step-down station.

(d) Determine the minimum safe separation necessary corresponding to:

(i) Soil resistivity
(ii) Product of fault current and length of parallelism.

(e) If the minimum safe separation obtained in (d) above is less than the average separation determined in (a) above, the route as surveyed can be adopted.

(f) If the minimum safe separation in (d) above is more than the average separation in (a) above, then estimate the induced voltage on telecommunication circuits from Plates 3 (a) to 3(i) corresponding to:

(i) Soil resistivity.
(ii) Safe separation.
(iii) Ratio S/S_m .

(g) Refer the proposals for the approval of the route of the power line to the State Level Power & Telecommunication Co-ordination Committee (SLPTCC). While referring the case, forward:

(i) A route map of the power line, drawn to a scale 1˝ = 1 mile or 1 cm = 0.5 kms, showing separations between the power line and telecommunication line also to the same scale.

(ii) Results of the calculations in (a) to (f) above.

B. Procedure for New Constructions in respect of Telecommunication Lines

The construction officer in-charge of telecommunication line construction should do the following:

(a) Survey the route for investigating the maximum separations that field conditions permit and prepare a route map showing the separations.

(b) Measure soil resistivity at new places by means of Evershed Earth Tester.

(c) Refer to Section C of Chapter III for further detailed procedure in respect of telecom lines.

A man who has committed a mistake and doesn't correct it is committing another mistake.

- Confucius

CHAPTER-V

CHAPTER V

Guidelines for Processing PTCC Cases of Power Lines 66 kV and above

1.0 The 'Simplified Procedure for Co-ordination of Power lines up to and including 33 kV with Telecommunication lines' detailed in Chapter IV is based on the following assumptions:

(i). That the power lines would be essentially radial i.e., the source of supply would be only at one end and

(ii). That an infinite bus could be considered at the nearest EHV sub-station where the voltage level up to 33 kV is created, thus neglecting the system impedance behind the EHV bus.

2.0 It will be clear that the above assumptions are not applicable in all cases. Even now, instances of 33 kV DC lines, which are not covered by the 'Simplified Procedure' are being referred to the Central PTCC. The following paragraphs, therefore deal with the methods which are to be adopted in order to estimate the low frequency induced voltages from power lines up to and including 132 kV, whether SC or DC, under Single-Line-to-Ground (SLG) fault conditions on the neighbouring telecommunication lines.

3.0 Three aspects are involved in the estimation of the induction:

(i). Determination of the mutual coupling between the power and telecommunication lines.

(ii). Determination of the effective fault current.

(iii). Determination of the induced voltage in the affected telecommunication section.

4.0 The detailed procedure in respect of each of the items in Para 3.0 is given below

4.1 Determination of the Mutual Coupling (MC) between the Power & Telecommunication Lines

4.1.1 Appendix I to Chapter IV of the 'Simplified Procedure' referred to in Para 1.0 above, has detailed a method for estimating the average separation between the power and telecom lines in any section of parallelism, where actual separation between them is not uniform. The method is applicable in any general case. Once the average separation has been arrived at, the mutual coupling between the two lines could be worked out on the basis of curves showing the Separation versus Mutual Impedance as in Plates 1 (A) to 1 (F) given in Appendix IV to Chapter V.

4.1.2 An illustration would explain the procedure. In Example IX of the 'Simplified Procedure' in Chapter IV, the average separation between the power and telecom lines has been worked out as 866 meters. For a soil resistivity of 10,000 ohms/cm³, the corresponding mutual impedance from Plate 1 (A) would be 0.034 ohms/km. The MC for a parallelism of 10 kms would then be 0.34 ohms.

4.1.3 Apart from the above, a graphical method is also available for the determination of the mutual coupling. The parallelism, in this case, is assumed to be made up of a large number of small sub-sections, in each of which the separation between the power and telecom circuits could be considered to be reasonably uniform.

4.1.4 At the beginning and end of each sub-section on the power line, vertical ordinates are erected from which the separation distance to the telecom line can be measured (Figure 1). The mutual impedance corresponding to these points for the relevant soil resistivity value is obtained from the curves in Plates 1 (A) to 1 (F). A curve is then drawn connecting the horizontal distances along the power line and the MC at each point to suitable scale. The mutual coupling for the section of parallelism involved is obtained by measuring the area bounded by the curves with the help of a planimeter. The actual coupling is calculated as follows:

MC = Area of the curve x Scale for distances along the horizontal axis x Scale for mutual coupling at each point x Planimeter Constant.

N.B. = If the scale along the horizontal axis is 1"=1 mile, the factor of 1760/1000 should be used to multiply the MC. If the scale is 1 cm = 0.5 kms, the factor is 500/1000 and so on).

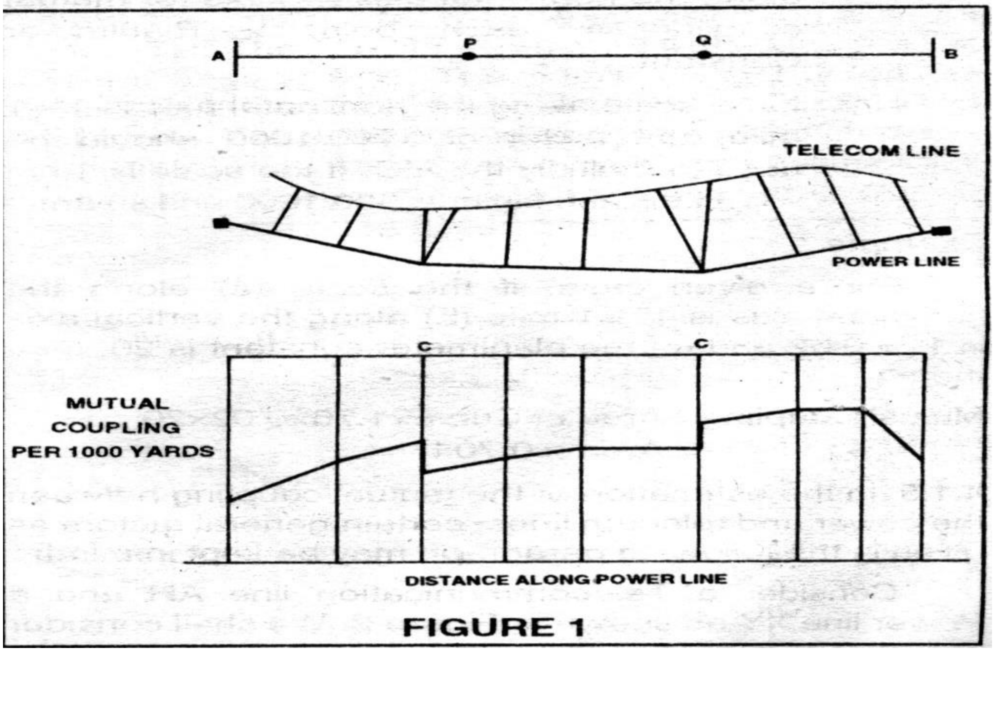


FIGURE 1

Example

For a given case, if the scale (a) along the horizontal axis is 1˝ = 1 mile (b) along the vertical axis is 1˝ = 0.02 and (c) the planimeter constant is 20, then the

Mutual Coupling = Area of Curve x 1.76 x 0.02 x 20
= Area x 0.704

4.1.5 In the estimation of the mutual coupling between the power and telecom lines, certain general factors as given in the following paragraph may be kept in mind:

Consider a Telecommunication line AH; and a Power line XY as shown in Figure 2. We shall consider only that part of the telecommunication line, which lies inside the zone in question i.e. the length BH. The telecommunication line, when approximated by a series of straight-line section, may present a parallel section (DE), oblique approaches (BC, CD, GH) or crossings (EFG). Each of the straight-line elements BC, CD, DE….. is then projected on the power line at bc, cd, de…. The electromotive force induced in each of the lengths BC, CD, DE by the corresponding lengths, bc, cd, de of the power line is calculated. The induced electromotive force is the sum of all these partial electromotive forces.

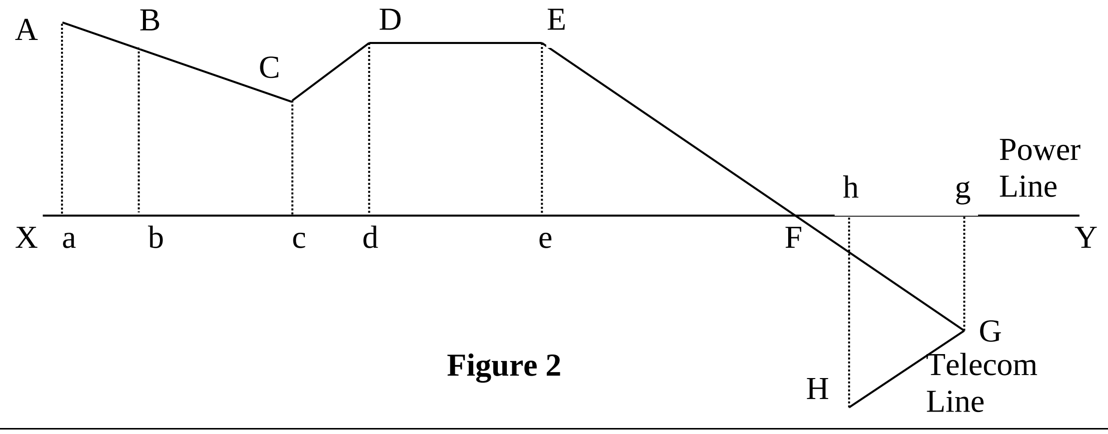


Figure 2

4.1.6 Method Proposed in CCITT Guide

Where the exposure between power and telecommunication lines is oblique, it can be considered as a parallel section having a distance between lines

$$d = \sqrt{d_1 d_2}$$

Provided that $1/3 < d_1/d_2 < 3$. If d_1/d_2 is outside these limits, the section MN is divided into two sections MP and PN so that d_1/d_2 lie between 1/3 and 3.

4.1.7 Crossings

For an approximate calculation, crossings can be disregarded when the angle exceeds 45^0. When the crossing angle is less than 45° the crossing is treated as a parallel section with a distance between lines of 6 meters. This empirical method introduces a maximum error of 10 to 15 % in the mutual coupling.

An example for treating the crossing is illustrated in Figure 3. On the Section MN of the telecom line, which crosses the power line, points M′ and N′ situated 10 meters from the power line are defined.

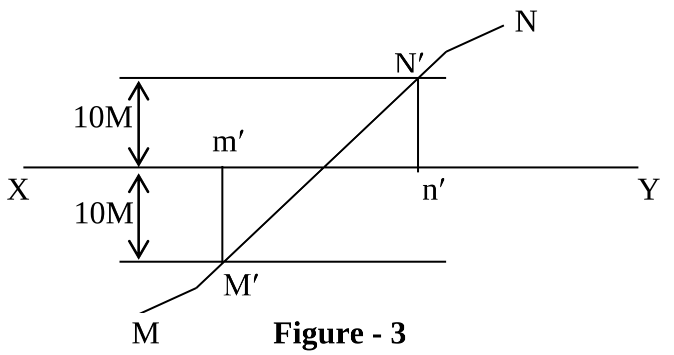


Figure - 3

The section MM′ and NN′ are treated as oblique exposures. Section M′N′ is ignored if $\alpha \geq 45^0$ section M′N′ is treated as a parallel section with a distance between lines as 6 meter if $\alpha < 45^0$.

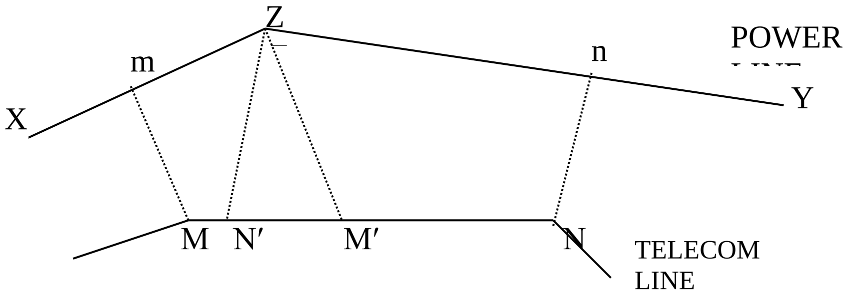
Note*:* If the telecom line has a bend inside the zone ± 10 meters around the electricity line, the crossing is considered as terminating at the level bend.

Notes:

(i) When the telecommunication line reverses its direction with respect to the power line (section GH in Figure 2), the electromotive forces induced in such sections are subtracted and must therefore be given a negative sign.

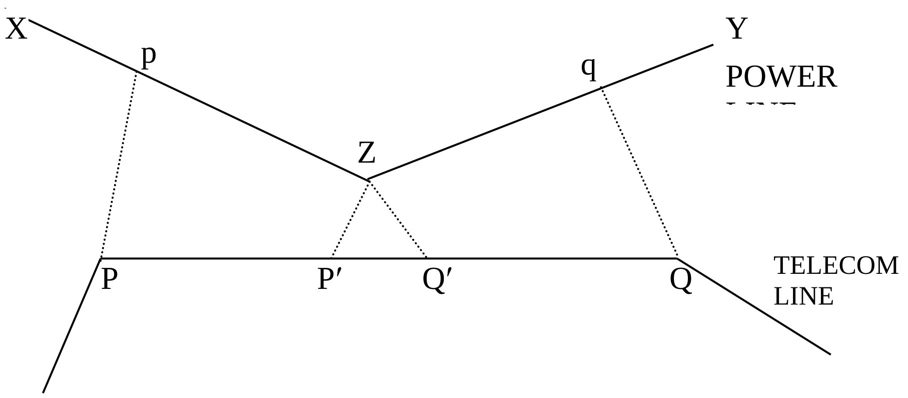
(ii) When the power line and the telecommunication lines converge as shown in Figure 4, the projection must be made as shown in this figure. The length N′M′ is subjected both to the induction from the line XZ and that from the line ZY. The electromotive forces induced in MM′ (by mZ) and in N′N (by Zn) must therefore be added.

(iii) When the power line and the telecommunication line diverge as shown in Figure 5, the projection must be made as shown in that figure. It is seen that the length P′Q′ is not subjected to any induction and it is merely necessary to add the electromotive forces induced in PP′ (by pZ) and in Q′Q (by Zq).



Note: The section N′M′ is induced twice i.e. by XZ and ZY. The induced emf in MM’ & NN’ are added.

Figure - 4



Note: The section P’Q’ is not counted. The induced emf PP’ & QQ’ are added

Figure - 5

4.2 Determination of the Effective SLG Fault Current

4.2.1 It is presumed that power engineers are generally familiar with the procedure for the estimation of fault current at any required point on a transmission line. The current is to be considered at the most unfavorable point in the exposure as regard induction. The following paragraphs cover some of the important points in regard to the determination of these currents.

4.2.2 The procedure outlined in the ‘Simplified Procedure’ would be applicable for radial or Single Circuit 33 kV lines, where an infinite bus could be considered at the nearest EHV sub-station. For power lines, which do not, fall in the above category the procedure is indicated in the subsequent paragraphs.

4.2.3 Consider that the line AB (Figure 6) is to be constructed and a telecom line is paralleling it in the section CD. The line AB is such that there is feed at both the ends A & B. The points C′ and D′ on the power line, through which ordinates to the telecom line would pass, are to be considered for evaluation of the SLG fault current. After these currents are estimated, it is necessary to work out the contribution at C′ from B and D’ from A. The more severe of these currents is to be considered for computation of the induced voltage.

4.2.4 For the evaluation of the fault current, an SLG fault study of the system on the digital computer or otherwise, considering the power system conditions which give the maximum current at the fault, taking into account lines and power stations, the construction of which has been approved, is required. From this study, it would be possible to obtain the SLG fault current at any required point. In this evaluation, a fault resistance of 20 ohms as permissible in the CCITT directives can be considered for intermediate points on the line.

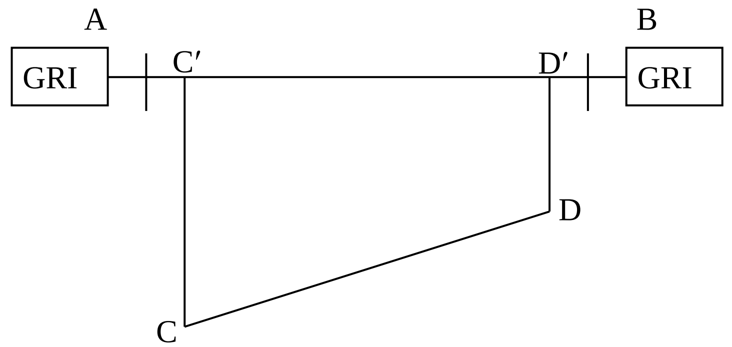


Figure - 6

4.2.5 In case a complete study of the system as mentioned above is not available, the necessary calculations have to be carried out by one of the following alternatives:

(i) If the fault levels at the end buses are obtained from the fault study and only the fault current at the intermediate points are not available therein, it would be possible to work out the same by the method given in Appendix I to Chapter V.

(ii) A judicious examination of the system will reveal the extent up to which the same is to be considered in the estimation of fault levels in the required line. This becomes necessary when the power system network in itself is complex and manual reduction of the same is time consuming and laborious. An infinite bus would then have to be considered at one or two suitable points in the network and thereafter the balance portion is reduced by star-delta transformation. In some cases, it would be evident that the power flow would only be (in one direction) from a nearby source of generation and a radial line from the same could be easily assumed. Illustrative examples are given in Appendix II to Chapter V.

(iii) By way of facilitating the manual calculations of fault current, the main principles are given in Appendix III to Chapter V.

4.2.6 After the estimation of the fault currents, curves showing the fault currents flowing in from both sides of the fault are drawn. Figure 7 gives an example of such a curve.

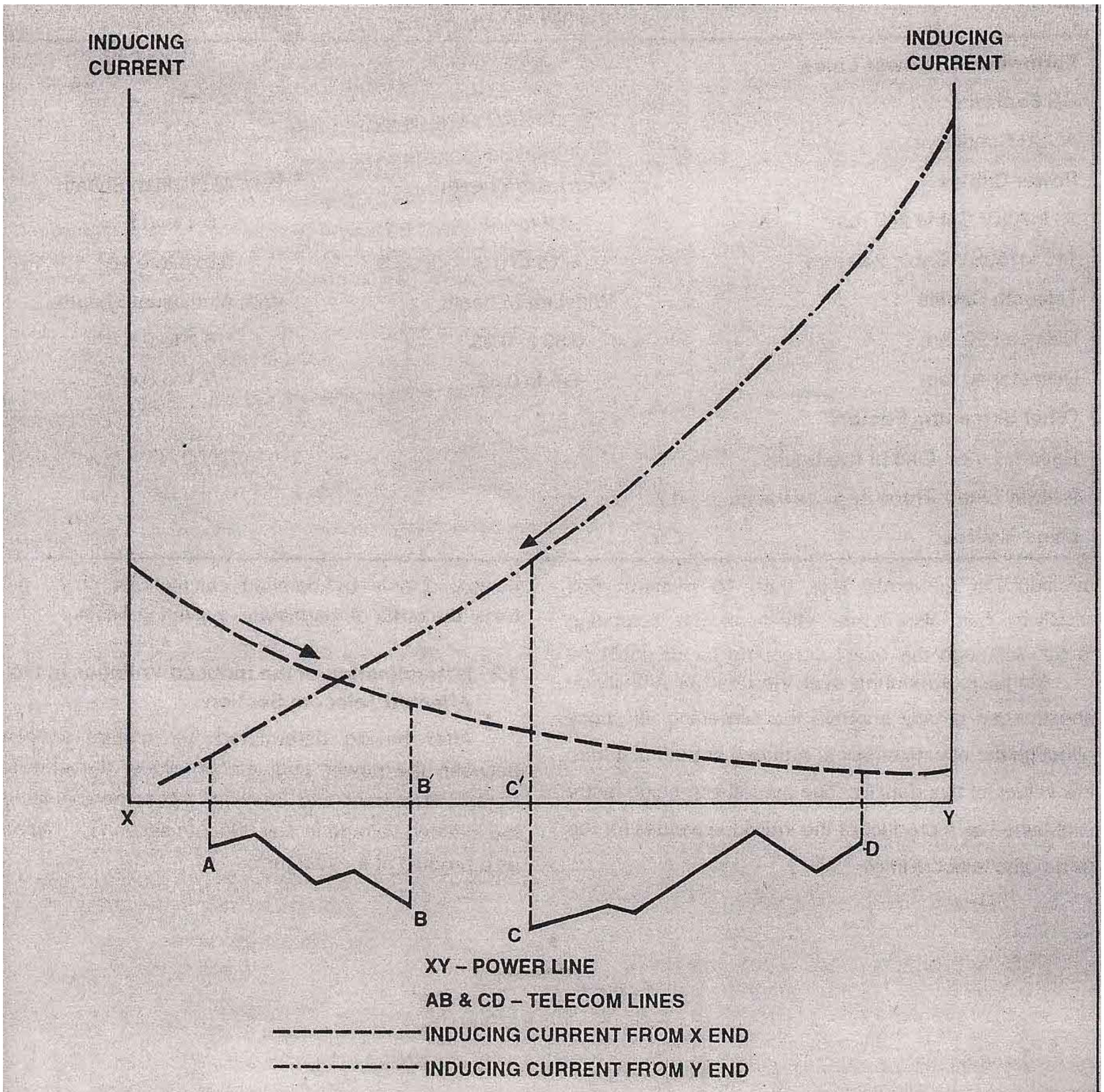


FIGURE 7

It can be seen from this figure that, in the case of the exposure AB, the least favorable point will be B′ with the inducing current coming from end x and in the case of exposure CD, the most unfavorable point will be C′ with the inducing current being from end Y.

4..7 Evaluation of Screening Factor

The Screening factor (k) takes into account the screening action of all earthed conductors in the immediate vicinity of both the inducing line and the affected telecommunication circuits (earth wire, rails etc) and in the case of power and/ or telecom cables, of the screening action of the sheath.

In regard to nearby conductors, their screening action is effective only if their resistance is low; and are well earthed at least at both their ends and if they are close to the inducing circuit or the circuit affected by induction (generally less than 10 meters). Soil resistivity has also some effect on the screening factor. Although the exact screening factor could be evaluated by detailed calculations or by field tests, the order of magnitude is given in Chapter-X.

Magnetic armoring over the Lead or Aluminum sheaths can greatly improve the screening efficiency although the effectiveness is reduced at both high and low values of flux density. The overall screening factor is obtained as a product of the individual values for the power and telecom lines.

4.5 Determination of the Induced Voltages in the Affected Telecom Section

After having determined the mutual coupling between the power and telecom lines, the effective SLG fault current and knowing the screening factor, the induced voltage in any telecom section is obtained as a product of these figures.

Our greatest glory is not in never falling, but in rising every time we fall.

- Confucius

CHAPTER-VI

CHAPTER VI

Code of Practice for the Protection of Telecommunication Lines at Crossings with Overhead Power Lines Other than Electric Traction Circuits

1.0 Introduction

1.1 The possibility of damage to telecommunication apparatus and injury to personnel due to accidental contacts between electric supply lines and telecommunication lines is an important consideration necessitating proper protective arrangements. Such contacts between power and telecommunication lines may result from falling tree limbs, improper sag of conductors, damaging acts by the public, structural failures, poor maintenance, wind storms and conductor failures due to lightning stroke, etc. Therefore, crossing of the power and telecommunication lines requires some consideration as they would be in close proximity in such situations. The objective of this Code is to set out measures to be adopted at crossings to avoid or reduce danger to personnel and telecommunication lines.

Rule 87 of the Indian Electricity Rules should be observed in respect of crossing of power and telecommunication lines.

(The Indian Electricity Rules will be replaced by the Safety Regulations prepared by CEA. The draft copy of the same is available on CEA website)

1.2 While the arrangements described in this Code are expected to offer a high degree of protection at reasonable cost, it is always advisable to route all future power and telecommunication lines so as to keep the number of crossings to the minimum possible under the circumstances.

1.3 All new constructions at crossing locations shall conform to the practices laid down in this Code. The existing arrangements at crossing need not be dismantled but should continue to be maintained till due for replacement.

1.4 Crossing situation not specifically covered by this Code should be referred to the PTCC for decision.

1.5 The principle that is followed by the PTCC in regard to the liability towards the cost of structural arrangements and the installation of necessary protective apparatus, etc has been that it should fall on the party who enters the field at a later date, irrespective of whether such work is carried out on the power or communication line. This is in conformity with the Indian Electricity Rules.

2.0 Classification of Power Lines

For the purposes of this Code, power lines are classified as below:

(i) Low and medium voltage distribution and service lines (voltage not exceeding 650 volts between phases).

(ii) High voltage lines, Category I (voltage exceeding 650 volts, but not exceeding 12 kV between phases).

(iii) High voltage lines, Category II (voltage exceeding 12 kV but not exceeding 36 kV between phases).

(iv) Extra high voltage lines (voltage exceeding 36 kV between phases)

Note: Lines with voltages of 36 kV (between phases) and below also come within Category (iv) provided they comply with the usual standards of construction and operation adopted for lines with voltage of 72.5 kV (between phases) and above. Such cases shall be referred to PTCC.

3.0 Crossings between Power and Telecommunication Lines

3.1 Disposition of Power and Telecommunication Wires

Except in the case of electric traction circuits, which are not covered by this Code, the power lines shall crossover the telecommunication lines.

Note 1: This arrangement is advantageous as power wires are generally of a heavier gauge than telecommunication wires and hence have a lesser possibility of breakage. Further, as telecommunication lines generally require more frequent attention for maintenance, operation and are subjected to frequent reconstructions, it would be convenient and would afford greater safety in working, if they are taken below the power lines.

Note 2: In unusual situation where it is considered that the most appropriate method will be to take the telecommunication line above the power line, the specific approval for each case shall be obtained from the competent authority responsible for the telecommunication system.

3.2 Angle of Crossing

The angle of crossing shall be as nearly a right angle as possible.

Note 1: If the angle of crossing were small, it would increase the context of dangerous proximity of the telecommunication lines with the power lines as a result of the possible whipping action of the broken power conductors.

Note 2: In exceptionally difficult situations, when the angle has to be below 60 degree, the matter should be reported to the competent authority in-charge of the telecommunication system which shall, if considered necessary, refer it to the PTCC for technical advice.

3.3 **Clearance**

Specific clearances to be provided between power lines, telecommunication lines, earth wire and earthed structures are indicated for each type of crossing under Paragraphs 4.0, 6.0, 8.0 and 9.0.

3.4 **Crossings over Telecommunication Lines**

Joints and other mechanical discontinuities should, as far as practicable, be avoided in the crossing and adjacent spans and at associated supports. If it is impracticable to avoid such joints, etc they should be of such a type and so made as to have strength substantially equal to that of the conductor in which they are placed.

Note: Clearances between telecommunication and power wires have an important bearing on the safety of persons working on the telecommunication lines and on the prevention of accidental contacts between telecommunication and power wires. It is essential therefore, to provide clearances as specified in this Code.

4.0 Joint Use of Poles at Crossing Locations

4.1 In all new constructions, whether of power lines or telecommunication lines, the possibility (except in cases of unusual difficulty) of joint use of poles for crossings between telecommunication lines and (a) low and medium voltage distribution and service lines and (b) high voltage lines, Category I, should be investigated and adopted.

Note 1: From the point of view of safety and structural considerations, the use of a common pole to support both the power lines and telecommunication lines for the crossings is an advantageous proposition.

Note 2: Where it becomes impracticable to adopt joint use of pole, the arrangements given in Para 6.0 or 7.0 shall be adopted, as the case may be.

4.2 The design strength and other mechanical features of the common support and fittings shall be in accordance with the standards and requirements of the Power supply authority or the Telecommunication authority whichever is more rigorous.

4.3 Adequate clearance shall be provided on the common pole to enable employees of either party to carry out maintenance work on their respective lines. The clearance provided on the jointly used pole shall not be less than the figures given in Table 1.

Note: Neutral wires on the power alignment shall be treated as power conductors for the purpose of this rule, in the case of multiple earthed neutrals that are not carried on insulators.

4.4 When the power lines carried on the jointly used pole are high voltage lines of voltage to earth 3,000 volts and above, power contact protectors (See Appendix I to Chapter VI) shall be installed at the crossing on all the exposed wires generally occupying the top bracket of the telecommunication line.

4.5 In order to minimize the maintenance work, a jointly used pole shall be used only for supporting the two crossing alignments. No apparatus or equipment such as switches, fuses, junction boxes etc shall be mounted on such a pole and no lines shall tee-off from it. There is however no objection to the installation of protectors or arrestors on the pole for the protection of telecommunication wires.

5.0 Guards

5.1 Guarding arrangements shall always be provided as and where prescribed in this Code.

5.2 Guarding arrangements will, ordinarily be carried out by the owner of the pole on which they are to be made. The owner will also be responsible for their efficient maintenance, the cost being met as indicated in Para 1.5.

5.3 Every guard shall be properly earthed at the terminal supports.

5.4 Guard wires shall have a breaking load of not less than 635 Kg (1400 lbs) and if made of iron or steel shall be galvanized. Every guard wire or cross-connected system of guard wires shall have sufficient current carrying capacity to avoid the risk of their fusing on coming into contact with any live power wire.

5.5 For the purpose of ensuring that any live wire coming in contact with the guard wires is rendered dead the net resistance to earth of the guard shall be low enough to give rise to an earth fault current of a magnitude which is at least twice the minimum, required to operate the protective system on the power circuit.

Table-1
Ref. para 4.0 (joint use of poles at crossings) Subpara 4.3

Location	Low and Medium Voltage Lines	High Voltage lines upto and including 7.2 kV	High voltage Lines above 7.2 kV and upto and including 12 kV
Minimum vertical clearance between the bottom most power cross-arm and fittings and the topmost communication cross-arm and fittings.	1220mm (4′0″)	1380mm (4′6″)	1980mm (6′6″)
Minimum vertical clearance between power and communication wires at the pole.	1380mm (4′6″)	1525mm (5′0″)	2130mm (7′0″)
Minimum vertical clearance between communication wires and ground wire on the power line.	1070mm (3′6″)	1070mm (3′6″)	1070mm (3′6″)

6.0 Crossings With Low And Medium Voltage Distribution and Service Lines

6.1 Where joint use of poles as laid down in Para 4.0 is not feasible, either of the two methods of crossing recommended below shall be adopted:

(a) Insulated weatherproof wires carried on effectively earthed steel bearer wires may be used for the power lines. The minimum factor of safety for the bearer wires shall be 2.5 based on the ultimate strength of the wire. The vertical clearance from the insulated wires to the telephone wires shall not be less than 760 mm (2′6″). Where this clearance cannot be maintained, PVC sleeving shall be provided on the telecommunication wires. In such cases the vertical clearance between the two lines shall not be less than 30 cms.

(b) Where bare wire is used for the power line, a guard shall be provided between the telecom line and power line as indicated in Figure 1 & 2, as the case may be. The guard shall be fixed either to the power line supports or to the telecom line supports.

6.2 Guards on Power Line Supports

The minimum vertical clearance between the guard wires and the telecommunication wires shall be 915 mm (3 ft). The guard shall be so arranged that lines drawn upwards from its outermost wires towards the center, at an angle of 45 degree to the vertical, will totally enclose the power wires as shown in Figure 1(b). Cross-lacing shall also be provided so as to cover a distance of at least 1830 mm (6 feet) on either side beyond the outer most crossing points of the wires of the telecommunication lines as shown in Figure 1(a).

6.3 Guards on Telecommunication Line Supports

The minimum clearance between the power wires (including neutral wires of the power circuit) and the telecom wires shall be 1220 mm (4 feet) as shown in Figure 2(a). In case the lowest wire on the power line is a ground wire, the minimum separation between the ground wire and the guard shall be 610 mm (2 feet). The minimum clearance between the guard wires and the telecommunication wires shall be 610 mm (2 feet). Cross-lacings shall be provided as shown in Figure 2(b).

7.0 Crossing With High Voltage Lines, Category-I

Where joint use of poles as laid down under Para 4.0 is not feasible, the arrangement in Para 8.0 shall be adopted.

8.0 Crossing With High Voltage Lines, Category-II

8.1 For the crossing span, the telecommunication alignment shall be taken close to the power pole to obtain increased vertical clearance between wires.

8.2 A light cantilever framework shall be fixed to the power support as indicated in Figure 3(a) and 3(b). The framework will be designed for each case depending upon the type of support used for the power line and the type of brackets on the telecommunication line.

8.3 In deciding the structural details for these crossings, provisions should be made for the possible erection of additional wires on the telecommunication line to meet future requirements. The clearances both horizontal and vertical, and between wires and supports shall conform to the standards shown in Figure 3(a) and 3(b).

8.4 In those cases where the poles of either of the lines cannot be or are not located near the crossing location, cradle guards on the power line shall be provided, the arrangement being similar to that in Para 6.2, but with clearances indicated in Figures 3(a) and 3(b).

8.5 Power contact protectors shall be installed on all the exposed wires generally carried on the topmost bracket by the telecommunication supports.

Note: The technical details of power contact protectors are described in the Appendix I to Chapter VI.

9.0 Crossing With Extra High Voltage Lines

9.1 No guarding arrangements are considered necessary in such cases.

9.2 The telecommunication line shall cross the power line as close to the power line supports as practicable.

9.3 The minimum clearances between the power wires and telecommunication wires shall be:

For lines of voltage above 36 kV upto and including 72.5 kV:	2440 mm (8′0″)
For lines of voltage above 72.5 kV upto and including 145 kV:	2740 mm (9′0″)
For lines of voltage above 145 kV upto and including 245 kV:	3050 mm (10′0″)
For lines of voltage above 245 kV:	3050 mm (10 feet) Plus 305 mm (1 foot) for every additional 33 kV or part thereof

10.0 Crossing With Power Lines Having Telecommunication Wires On The Line Supports Below The Power Line

10.1 Crossing should be so arranged that the telecommunication line passes close to a power pole to obtain increased vertical clearance between the wires of the two alignments.

10.2 A guard shall be provided both on the power supports as well as on telecommunication line, as per arrangements indicated in Fig. 4 (a) and 4 (b).

11.0 Safety Regulations prepared by CEA. (The draft copy of the same is available on CEA website)

SCHEDULE – V (of the draft safety regulations)

XV “**Safety requirements for overhead lines, underground cables and generating stations”**

Lines crossing or approaching each other and lines crossing street and road :

(1) Where an overhead line crosses or is in proximity to any telecommunication line, either the owner of the overhead line or the telecommunication line, whoever lays his line

later, shall arrange to provide for protective devices or guarding arrangements, in a manner **laid down in the Code of Practice or the guidelines prepared by the Power and Telecommunication Coordination Committee** and subject to the provisions of the following regulations:-

(2) When it is intended to erect a telecommunication line or an overhead line which will cross or be in proximity to an overhead line or a telecommunication line, as the case may be, the person proposing to erect such line shall give one month's notice of his intention so to do along with the relevant details of protection and drawings to the owner of the existing line.

(3) Guarding shall be provided where lines of voltage not exceeding 33kV cross a road or street.

> Great things are not done by impulse,but by a series of small things brought together.
> -Vincent Van Gogh

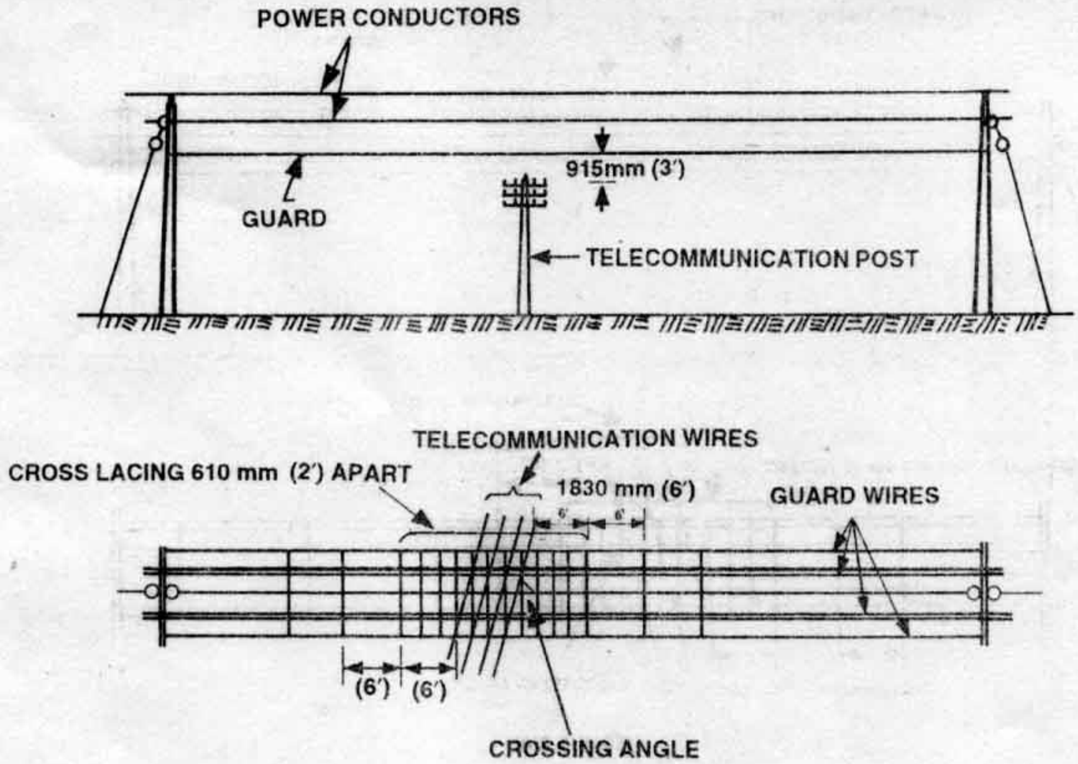
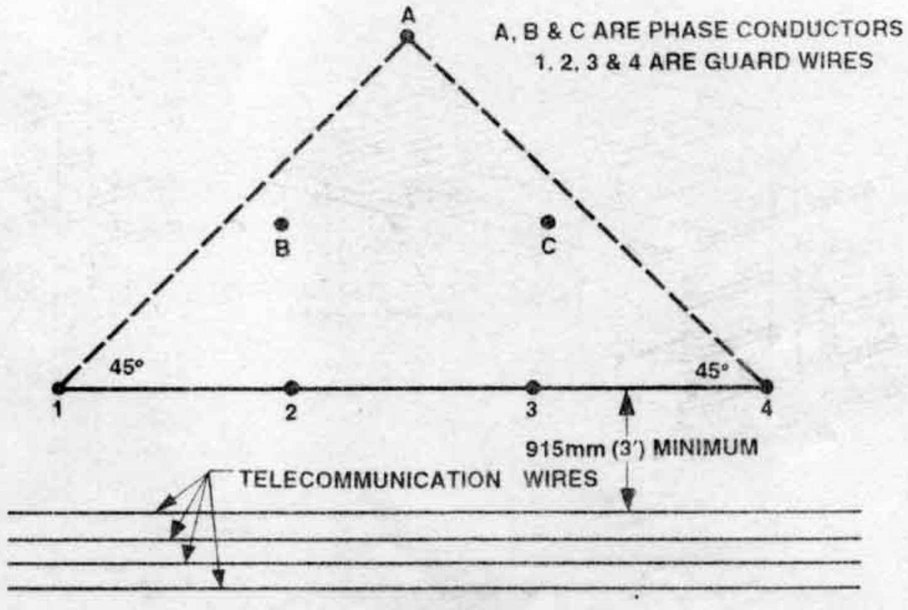


FIGURE 1(a)



SECTIONAL VIEW
FIGURE 1(b)

TYPICAL CROSSING PROVIDED WITH A GUARD ON POWER LINE SUPPORTS
FIGURE 1

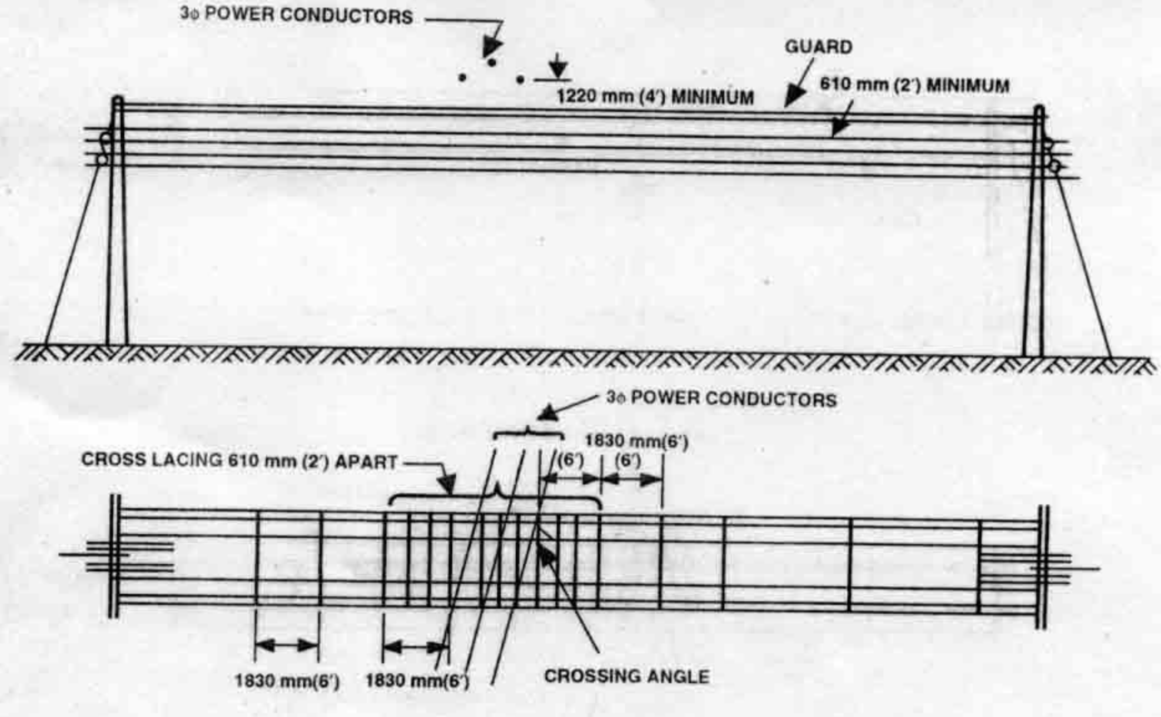
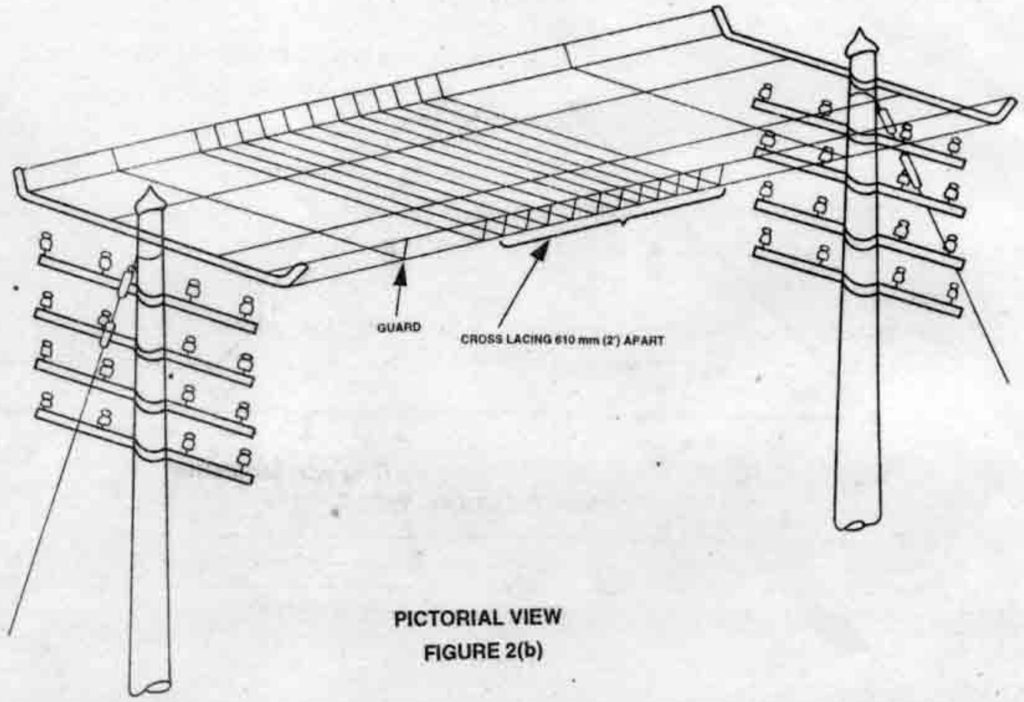


FIGURE 2(a)

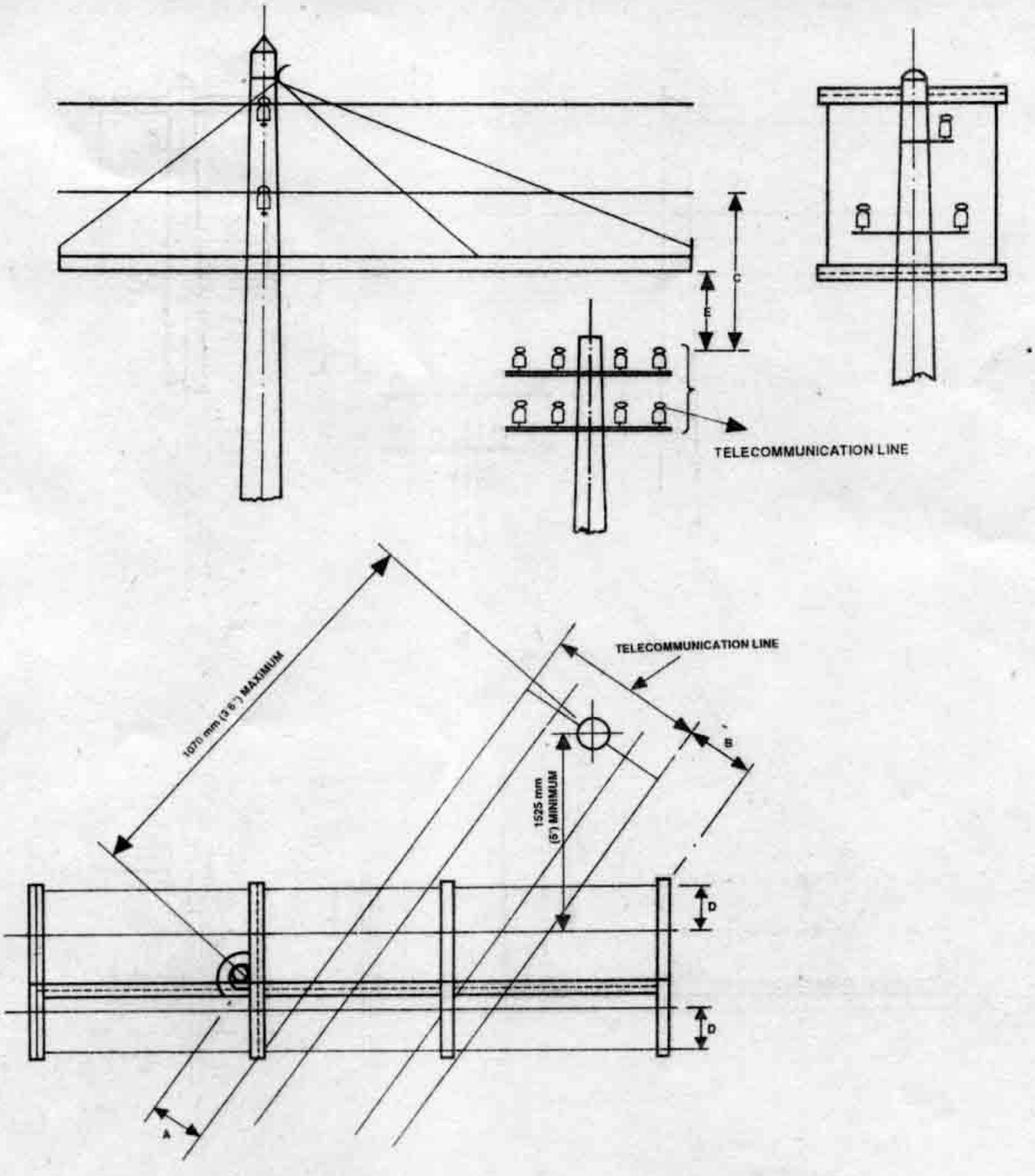


PICTORIAL VIEW

FIGURE 2(b)

TYPICAL CROSSING PROVIDED WITH A GUARD ON TELECOMMUNICATION LINE SUPPORTS

FIGURE 2



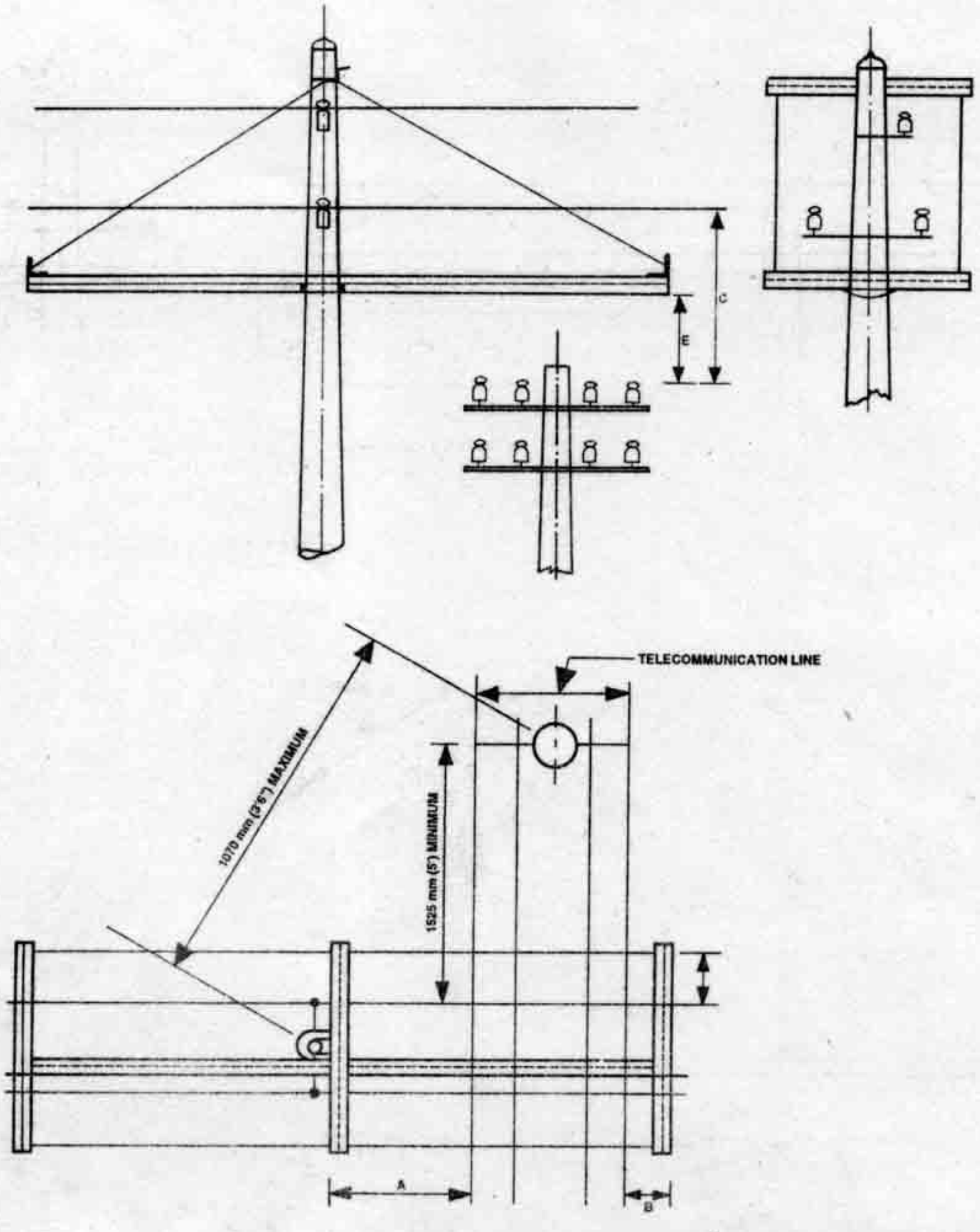
MINIMUM CLEARANCES

	A	B	C	D	E
7.2KV & BELOW	305 mm (1')	915 mm (3')	1380 mm (4' 6")	305 mm (1')	1070 mm (3' 6")
12KV	305 mm (1')	915 mm (3')	1525 mm (5')	305 mm (1')	1220 mm (4')
24KV	305 mm (1')	915 mm (3')	1680 mm (5' 6")	460 mm (1' 6")	1220 mm (4')
36KV	305 mm (1')	915 mm (3')	1830 mm (6')	610 mm (2')	1220 mm (4')

NOTE: SEE ALSO NOTES 1, 2, 3, & 4 OF FIGURE 3(b)

CANTILEVER GUARD AT OBLIQUE CROSSING

FIGURE 3 (a)

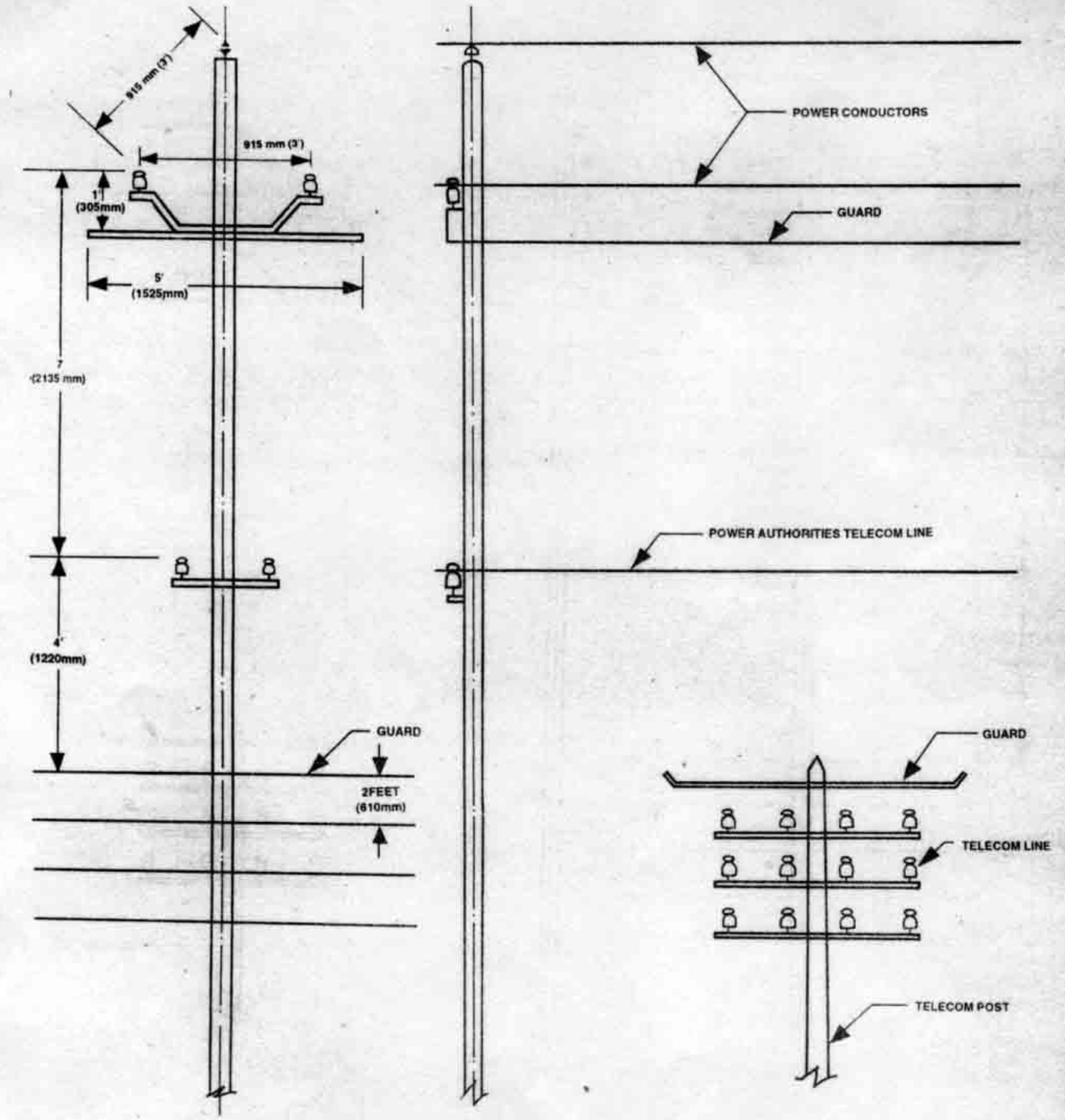


NOTE:

1. STRAIN POINT OF THE H.T. LINE AT THE CROSSING POLE SHOULD BE AVOIDED AS FOR AS POSSIBLE.
2. AT THE CROSSING A 'CATCH ARM' SHOULD BE PROVIDED SO THAT IN THE EVENT OF THE POLE FALLING DOWN, THE HT CONDUCTORS WILL NOT TOUCH THE TELEPHONE WIRES.
3. THE 'CATCH ARM' SHOULD BE CONNECTED TO THE GROUND WIRE, IF ANY OR IT SHOULD BE EARTHED PROPERLY BY SOME SEPARATE ARRANGEMENT.
4. ALL IRON SHOULD BE GALVANIZED.
5. FOR CLEARANCE A, B, C, D & E SEE FIGURE 3(a)

CANTILEVER GUARD RIGHT ANGLE CROSSING

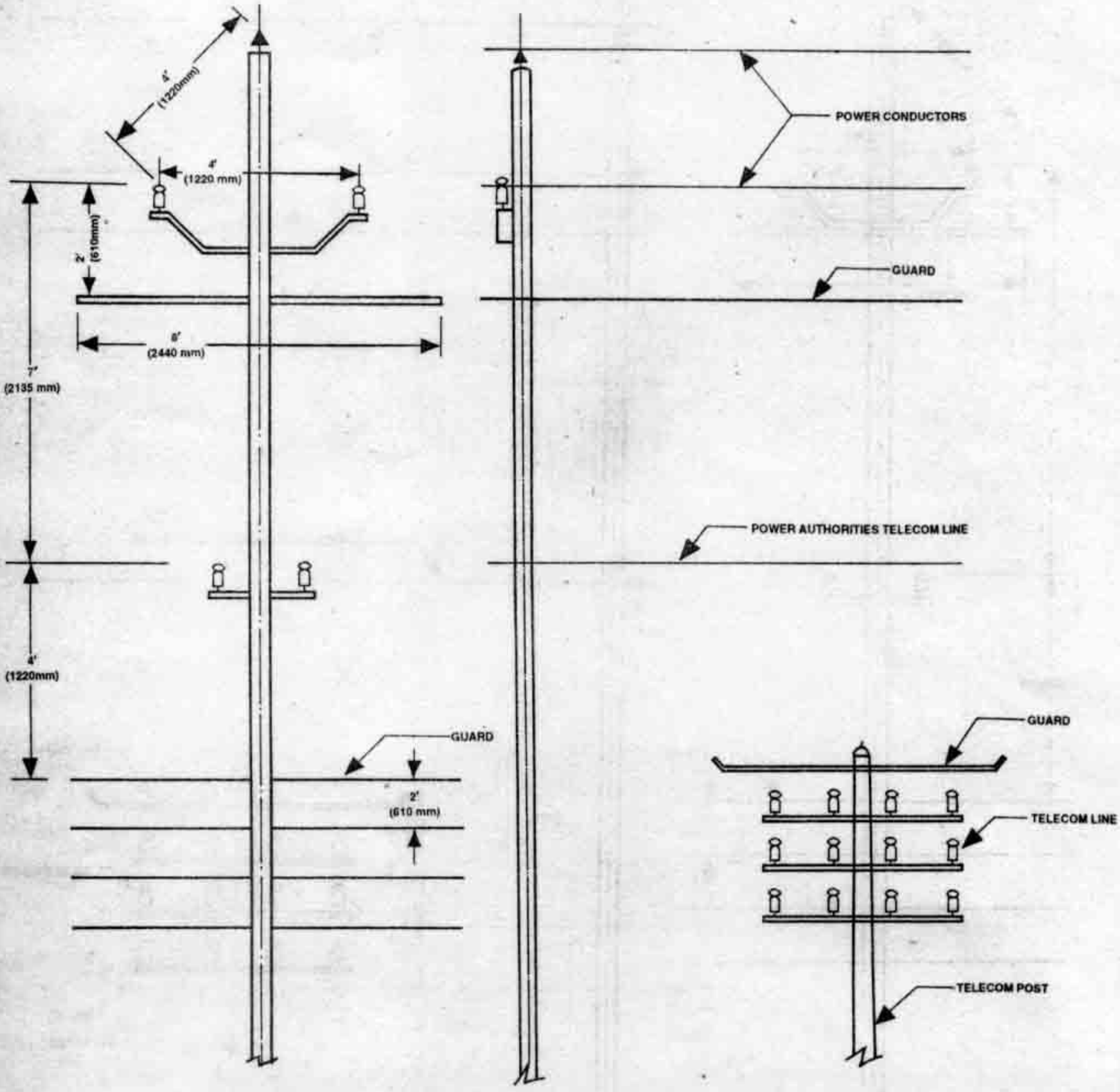
FIGURE 3 (b)



11 KV LINE

TYPICAL CROSSING ARRANGEMENT OF POWER LINE HAVING A COMMUNICATION PAIR ON THE SAME SUPPORT AND TELECOM LINE

FIGURE 4(a)



33 KV LINE

TYPICAL CROSSING ARRANGEMENT OF POWER LINE HAVING A COMMUNICATION PAIR ON THE SAME SUPPORT AND TELECOM LINE

FIGURE 4 (b)

CHAPTER-VII

CHAPTER VII
Low Frequency Induction Test

1.0 Introduction

The induced voltage on a telecommunication line during an earth fault on the power line is given by the expression:

$$V = M \times I$$

Where V is induced voltage in Volts,
I is Earth Fault Current in Amps and
M is Mutual Coupling in Ohms between Power line and telecom line

The value of Mutual Coupling (MC) depends upon the distance between the power and telecom lines, the length of parallelism, the fundamental frequency of the power supply and the soil resistivity of that area. The mutual coupling between paralleling power and telecom lines is theoretically calculated or computed with the help of Carson's Curves. There is always an amount of uncertainly in the theoretically computed values of MC on account of unreliability in soil resistivity data collected and unawareness of possible effective screening offered by various metallic conductors in the vicinity.

In order to arrive at a more accurate value of MC, Low Frequency (LF) Induction test may be conducted by injecting 50 Hz low value earth currents in the power line and measuring the corresponding values of induced voltages on the paralleling telecom line. However, owing to the huge costs involved in making arrangements and conducting such test, it may be considered when there is any ambiguity in either the soil resistivity values or effective screening factors considered in theoretical calculations or variance in actual positions of telecom or power lines from the marking on the maps and the induced voltages calculated on paralleling telecom lines happen to be very high necessitating re-engineering of either power or telecom lines.

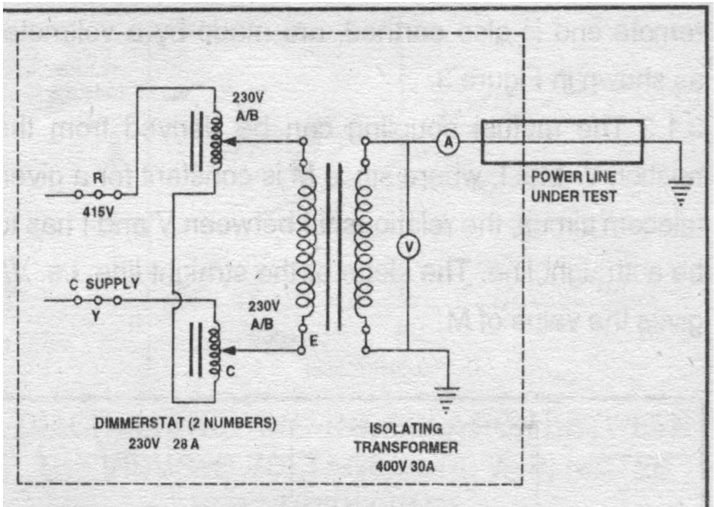
2.0 Procedure

The Low frequency Induction test procedure may be divided into three parts as under.

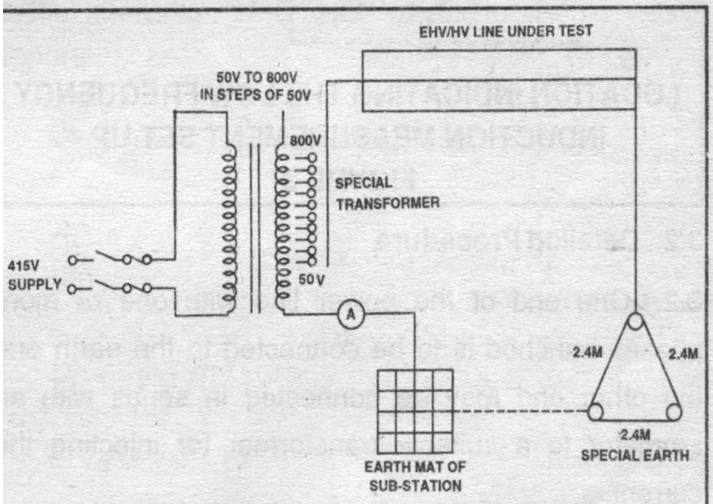
(i) Preparation for the test.

(ii) Conduction of the test.

(iii) Interpretation of test results



LOCATION INDICATING THE CURRENT INJECTION SET UP ON POWER LINE
FIGURE 1

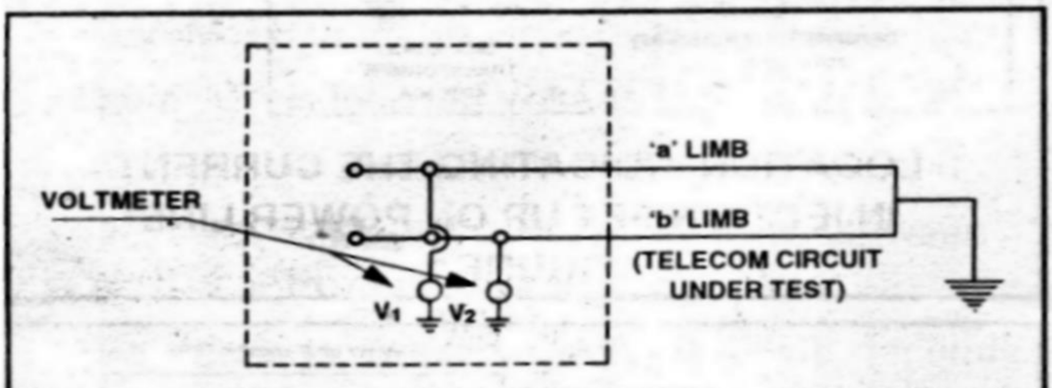


LOCATION INDICATING THE CURRENT INJECTION SET UP ON POWER LINE
FIGURE 2

2.1 Preparation for the Test

2.1.1 General

DET (PTCC) of the region and the SDE (PTCC) of T&D Circle at the Telecom Circle Headquarters may do overall co-ordination with different agencies involved such as Power, Telecom, Railways, Defense etc in preparation for the test. Either a meeting among the representatives of the different agencies should be separately convened or in any State Level PTCC meeting the tentative date/period for the LF Induction test should be decided and intimated to all concerned.



LOCATION INDICATING THE LOW FREQUENCY INDUCTION MEASUREMENT SET UP
FIGURE 3

2.1.2 Telecom Lines

The telecom lines involved in parallelism with the power lines on which testing is proposed should be tested thoroughly and if there is any high resistance or low insulation fault, the same should be removed by the Telecom authority in-charge of these lines. A certificate to the effect that the involved telecom lines are in good condition and the line resistances are within prescribed limits should be given by the Telecom Authority accordingly to the concerned SDE (PTCC)/ DET (PTCC) before the due date of testing.

2.1.3 Power Lines

The Power authority in-charge of the involved power line should also get the power line tested so as to ensure that it is free from low insulation and other faults and a certificate to that effect accordingly should be given to SDE (PTCC)/ DET (PTCC) before the due date of testing.

2.1.4 Soil Resistivity

SDE (PTCC)/ DET (PTCC) should arrange for a joint measurement of soil resistivity along the proposed power line at three or four test location so as to verify the data considered in theoretical calculations. In case of large variations in practically measured values from theoretically considered values, the soil resistivity should be got re-measured for every 2 to 3 kms to arrive at the actual value of soil resistivity. Procedure for measurement of soil resistivity is detailed in Appendix II to Chapter VII.

The soil resistivity data, thus obtained would be useful in analyzing the large variations, if any, in the induced voltage values arrived at by LF induction test from those calculated theoretically.

2.1.5 Instruments

Following is the list of important instruments to be checked and kept ready for testing by the concerned Power and Telecom authorities.

(i) Suitable transformers for injecting current in power line. Autotransformer is preferred.

(ii) Ammeters along with current transformer, if required, to cover the range for the experiment.

(iii) Voltmeters preferably digital type along with suitable rotary switch and connecting wires for connecting to telecom lines and earth.

(iv) Suitable connecting wires for connecting power lines to the transformer and through rotary switch and ammeter to earth.

2.1.6 Other Arrangements

Effective earthing for the power and telecom lines should be prepared and kept ready before the testing. The testing locations should be identified and arrangements for inter-communication facility between testing parties and transportation of men & material should be arranged by the concerned Power & Telecom authorities.

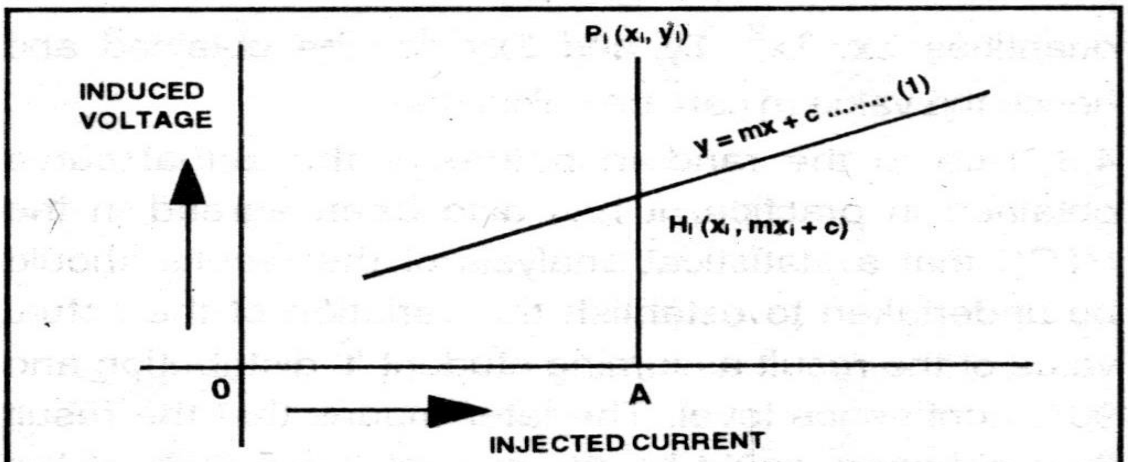


DIAGRAM SHOWING THE RELATION BETWEEN THE INDUCED VOLTAGE IN T/L Vs INJECTED CURRENT IN P/L

FIGURE 4

3.0 Conduction of the L.F Test

3.1 Theory

For conduction of LF test the test set-up as shown in Figure 1 may be used. The arrangement enables injection of currents up to 25 Amps, 400 V on the power line, the far end of which is earthed after bunching all the three conductors together. The isolating transformer is to segregate the earthing current on the line under test from affecting the power supply.

In case, with the above test set-up it is not possible to drive even 8 Amps of current over and above the minimum current required to overcome the stray voltage, the test set-up as shown in Figure 2 may be used. Here a special transformer, with 415 V winding on primary side and the secondary side having various tapings from 50 to 800 V in steps of 50V with a current driving capacity of 40 Amps, is used. The secondary voltage is impressed on the particular power line under test after bunching all the three phases. At the other end the three phases are bunched and earthed.

3.1.1 For earthing either the grid mat of the sub-station is used or a separate earth is prepared by driving a set of 3 numbers of 2.6M standard earth electrodes forming an equilateral triangle of 8 ft into the earth. Tower earth should not be used for this purpose. A similar earthing arrangement is made for the communication line under test. Measurements either limb to earth, on paralleling telecom line, whose remote end is also earthed, are made by a voltmeter as shown in Figure 3.

3.1.2 The mutual coupling can be derived from the relation V= M x I where M is constant for a given telecom circuit, the relationship between V and I has to be a straight line. The slope of the straight line i.e. V/ I gives the value of M.

3.2 Detailed Procedure

3.2.1 One end of the power line with one or more phases bunched is to be connected to the earth and the other end may be connected in series with an ammeter to a suitable transformer for injecting the current.

3.2.2 Each wire of the telecom line should be isolated and one end may be connected to the earth. The other end is the testing end, where each limb may be connected through a suitable rotary switch to the voltmeter and earthed.

3.2.3 To overcome the effect of stray voltages due to other power lines in the vicinity, Central PTCC has recommended successive in feed from 3 phase line in its meeting held on 24.2.1982. It will enable more number of readings to be taken. Current may, therefore, be injected in the power line successively from three different phases RY, YB and BR and the corresponding induced voltages in each limb of the telecom lines may be measured by means of rotary switch and voltmeter. It is preferable to have 10 to 12 readings in between the minimum and maximum current which may be possible to inject. No test will be valid if the number of readings taken is less than 8 (including

‘Zero’ current reading). The amount of current injected in the power line should be sufficient to overcome the static voltages already existing on the telecom line due to the presence of any other power lines in the vicinity. Feeding current should be 0 to 30A but in no case it should be less than 8A over and above the minimum current required to overcome the stray voltages. If necessary, the length of power line under test may be suitably restricted to the extent of length of parallelism for this purpose. If the static voltages on paralleling telecom line continue to be high and there happens to be limitation as regards the current being fed on power line, shutting down of the other effecting power lines in the vicinity may be considered.

3.2.4 Induced voltage should generally increase with the increase in injecting current. In case where the induced voltage decreases with the increase in the injecting current, which may be due to the effect of other sources in the vicinity, it is suggested that the observation in such cases should be repeated.

4.0 Interpretation of Test Results

4.1 The respective current and corresponding induced voltage readings on each limb of telecom line for each phase are noted and tabulated. Average of induced voltage readings of both limbs is calculated for each telecom line. Actual Induced Voltage is arrived at as follows:

$$\text{Actual Induced Voltage } Y = \sqrt{\frac{V_1^2 + V_2^2 + V_3^2}{3} - V_0^2}$$

Where V_0 is induced voltage measured without injecting any current in power line.

V_1,V_2 & V_3 are induced voltages measured with current injected successively in power line from RY,YB and BR phases.

Alternatively the direction of current flow may be reversed (Reversal of Current Flow method) to overcome the stray voltages in which case the Actual Induced Voltage is given by:

$$\text{Actual Induced Voltage } Y = \sqrt{\frac{V_1^2 + V_2^2 +}{2} - V_0^2}$$

Where V_0 is induced voltage measured without injecting any current in power line

V is the induced voltage measured with current injected successively in one direction and

V_2 the induced voltage measured with injected current reversed by 180 degree.

4.2 Theoretically, the relationship between the inducing current & the induced voltage should be a straight line as explained in 3.1.2 above. However, due to possible experimental errors such as inaccuracies in the meters, imperfect earthing etc, such an ideal curve is hardly achieved in practice. Recourse is, therefore taken to the best curve fitting method, whereby the nearest ideal straight line of the form y = mx + c is evolved. In this equation 'm' would give the slope of the straight line, which in this case would be the mutual coupling value.

The term 'best fit' is interpreted in accordance with Legender's Principle of Least Square which consists in minimizing the sum of the Squares of the deviations of the actual values given by the line of best fit.

Considering the fitting of a straight line

$$y = mx + c \qquad \ldots\ldots\ldots\ldots\ldots\ldots \quad (1)$$

to a set of n points (x_i,y_i), where i = 1,2……..n, the equation (1) represents a family of straight lines for different values of the arbitrary constants m and c. The value of m and c should be determined so that the equation (1) can be the line of best fit.

Let $P_i(X_i,Y_i)$ be any general point in the scatter diagram shown in Figure 4. P_{iA} is drawn perpendicular to X-axis meeting the line (1) in H_i. Abscissa of H_i is x_i and since H_I lies on (1) its ordinate is (mx_i+c). Hence the co-ordinates of Hi are (x_i, mx_i+c).

$P_iH_i = P_{iA} - H_{iA}$

$= y_i - (mx_i+c)$

is called the error of estimate or the residue for y_i. According to the principle of least square the values of m and c are to be determined so that

$$E = \sum_{i=1}^{n}\left(P_iH_i\right)^2 = \sum_{i=1}^{n}\left(y_i - mx_i - c\right)^2$$ is minimum

From the principle of maxima and minima the partial derivation of E with reference to m and c should vanish separately, i.e.,

$$\frac{dE}{dc} = 0 = -2\sum_{i=1}^{n}\left(y_i - mx_i - c\right)$$ and

$$\frac{dE}{dm} = 0 = -2\sum_{i=1}^{n}\left(y_i - mx_i - c\right)$$

$$\sum_{i=1}^{n} y_i = nc + m\sum_{i=1}^{n} x_i$$

or $\sum y = nc + m\sum x$ ....(2)

$$\sum_{i=1}^{n} x_i y_i = c\sum_{i=1}^{n} x_i + m\sum_{i=1}^{n} x_i^2$$

or $\sum xy = c\sum x + m\sum x^2$ .... (3)

From equation (2)

$$c = \frac{\sum y - m\sum x}{n}$$ .... (4)

Substituting value of c in equation (3):

$$\sum xy = \left[\frac{\sum y - m\sum x}{n}\right]\sum x + m\sum x^2$$

$$= \frac{\sum x\sum y - m\left(\sum x\right)^2 + mn\sum x^2}{n}$$

Thus,

$$m = \frac{n\sum xy - \sum x\sum y}{n\sum x^2 - \left(\sum x\right)^2}$$ .... (5)

From n number of observations for current injected in the power line x_i Amps and corresponding induced voltages observed on the telecom line y_i volts all the quantities Σx, Σx², Σy and Σxy can be obtained and hence the value of m can be calculated.

4.3 Due to the random nature of the actual curve obtained in practice, it has also been agreed in the PTCC that a statistical analysis of the results should be undertaken to establish the variation of the actual value of the result assuming standard ‘t’ distribution and 90% confidence level. The later means that the result then obtained would be the correct value 90% of the time. Statistical table showing standard ‘t’ distribution is given at Appendix I to Chapter VII. For a number of readings, degree of freedom to be considered is n-2 and the value of ‘t’ for 90% confidence is given in Table at Appendix I to Chapter VII. The mutual coupling arrived at should be corrected for 90% confidence as shown below:

From Equation 5:

Mutual Coupling (MC) $= m \pm t_{n-2}\sqrt{\frac{\sum y^2 - c\sum y - m\sum xy}{n-2} \times \frac{n}{n\sum x^2 - \left(\sum x\right)^2}}$

(for 90% confidence)

5.0 Example

Name of power line: 132 kV D/C Jassore to Dehra
Name of telecom line: Narpur – Rehan
LF induction test was conducted and the readings as shown in Table 1 have been recorded.

From Table 1 various quantities are calculated as given in Table 2.
Average of induced voltage readings with ‘0’ Amps current

$$V_0 = \frac{2.6 + 1.15 + 1.1 + 1.1}{4} = 1.48V$$

Table 1

Phase	Sl. No.	Feeding Current In Amps.	Induced Voltage in Volts		Average Induced Voltage in Volts
			Limb-1	Limb-2	
YB	1	0	2.5	2.7	2.6
	2	4	2.6	2.7	2.65
	3	8	3.6	3.7	3.65
	4	9.6	4.5	4.6	4.55
	5	11.2	5.4	5.4	5.4
	6	12.8	6.2	6.2	6.2
	7	14.4	6.7	6.7	6.7
	8	15.2	6.8	6.8	6.8
	9	16.0	7.0	7.0	7.0
RY	1	0	1.2	1.1	1.15
	2	4	3.6	3.6	3.6
	3	8	3.9	3.9	3.9
	4	9.6	5.0	5.0	5.0
	5	11.2	5.9	5.9	5.9
	6	12.8	6.6	6.6	6.6
	7	14.4	7.2	7.2	7.2
	8	15.2	7.6	7.6	7.6
	9	16.0	7.6	7.6	7.6
	1	0	1.1	1.1	1.1
BR	2	4	4.1	4.1	4.1
	3	8	5.1	5.1	5.1
	4	9.6	5.9	5.9	5.9
	5	11.2	6.7	6.7	6.7
	6	12.8	7.6	7.6	7.6
	7	14.4	8.1	8.2	8.15
	8	15.2	8.2	8.3	8.25
	9	16.0	8.5	8.5	8.5
	1	0	1.1	1.1	1.1

Table 2

Injecting Current in Amps. (x)	Induced Voltage In Volts			$Y = \frac{\sqrt{V_1^2 + V_2^2 + V_3^2}}{2} - V_0^2$	xy	x^2	y^2
	YB (V1)	RY (V2)	BR (V3)				
0	-	-	-	1.48	0.00	0.00	2.19
4	2.65	3.6	4.10	3.17	12.68	16.0	10.05
8	3.65	3.9	5.10	3.99	31.92	64.0	15.92
9.6	4.55	5.0	5.90	4.96	47.62	92.2	24.60
11.2	5.40	5.9	6.70	5.84	65.41	125.4	34.11
12.8	6.20	6.6	7.60	6.66	85.25	163.8	44.35
14.4	6.70	7.2	8.15	7.22	104.0	207.4	52.13
15.2	6.80	7.6	8.25	7.43	112.9	231.0	55.21
16.0	7.00	7.6	8.50	7.58	121.3	256.0	57.46

From Table 2 Column 1 $\sum x = 91.2$
From Table 2 Column 5 $\sum y = 48.33$
From Table 2 Column 6 $\sum xy = 581.07$
From Table 2 Column 7 $\sum x^2 = 1155.84$
From Table 2 Column 8 $\Sigma y^2 = 296.03$

From Para 4.2, equation 5: $m = \frac{n\sum xy - \sum x \sum y}{n\sum x^2 - \left(n\sum x\right)^2}$

$$= \frac{9 \times 581.07 - 91.2 \times 48.33}{9 \times 1155.84 - (91.2)^2}$$

$= 0.394$

From Para 4.2, equation 4: $c = \frac{\sum y - m\sum xy}{n}$

$$= \frac{48.33 - 0.394 \times 91.2}{9}$$

$= 1.378$

Applying correction as per Para 4.3 above

Number of readings n = 9
Degree of freedom = 9-2=7

Value of 't' for 90% confidence from Table at Appendix 1 to Chapter VII, i.e. t_{n-2} =1.89

Thus,

$$\text{Mutual Coupling MC)} = m \pm t_{n-2}\sqrt{\frac{\sum y^2 - c\sum y - m\sum xy}{n-2} \times \frac{n}{n\sum x^2 - \left(\sum x\right)^2}}$$

$$= 0.394 \pm 1.895\sqrt{\frac{296.03 - 1.378 \times 48.33 - 0.394 \times 581.07}{7} \times \frac{9}{9 \times 1155.84 - (91.2)^2}}$$

$$= 0.394 \pm 1.895\sqrt{0.06995 \times 0.004316}$$

= 0.394 ± 1.895 × 0.0174
= 0.394 ± 0.033
= 0.427 or 0.361

In case the theoretically computed value of MC is greater than 0.427 then higher of the values, i.e., 0.427 should be taken as final value for mutual coupling. If the theoretically computed value is between 0.427 and 0.361 then that may be taken as final value for mutual coupling.

6.0 Precautions

While conducting the LF induction test following precautions may be taken for ensuring accuracy in test results.

(i) It may be ensured that the distance between the power line earth point and telecom line earth points are atleast 3 kms.

(ii) Length of conductors connecting the telecom line from earth up to the paralleling length should run perpendicular to the direction of parallelism.

(iii) The voltmeter used for measurement of induced voltages should have Z_{in}= 10 Mega Ohm or more.

(iv) The test should be arranged only during the dry season.

Accident is the name of the greatest of all inventors.
- Mark Twain

CHAPTER-VIII

CHAPTER VIII

Code of Practice for Protection from Earth Potential Rise

1.0 Introduction

When an earth fault occurs in a power system, some of the fault current returns via the earth, through the earthing system (e.g., earthing of towers and power sub-stations etc). This current raises the potential of the earthen system with respect to a remote earth for the duration of the fault. This is known as 'Earth Potential Rise'. During such a fault, due to the transfer of potential between the EPR areas and outside points, by conductors of telecom circuits and other metallic structures etc, serious hazard may result to telecom installations, telecom personnel and customers.

1.1 Locations Prone to EPR

The following are the locations where Earth Potential Rise may occur:

(i). Areas near power sub-stations earthing system.
(ii). Areas near pole mounted sub-station (transformer) on low voltage system.
(iii). Areas near power line towers having earth electrodes.

1.2 Factors Affecting EPR

Following factors are to be considered for assessment of hazard due to EPR.

- Type of power network
- Fault current level
- Power grounding system (Earth resistance)
- Soil resistivity
- Local conditions

Power networks are classified according to the technique used in connecting the neutral point to ground. The grounding network affects both the level and duration of the fault current.

According to CCITT directives:

(i) In case of networks of which the neutral point is earthed directly or through low impedance, the rise in earth potential must be considered and its value must be calculated or measured for the highest value of the current flowing to earth through the earthing system of the electrical installation.

(ii) In case of network of which the neutral point is earthed through an arc suppression coil without additional devices for clearing faults, it is not necessary to consider the rise in earth potential as the current flowing through the earthing system is limited to a very low value by the arc suppression coil.

(iii) When the neutral point is earthed through an arc suppression coil with additional device for clearing the faults, the earth potential needs to be considered only in those generating stations or sub-stations, where the device is fitted and should be determined as in (i) above.

It can be assumed that the additional device operates only rarely and does not justify the whole of a system protected in this way being regarded as if all the neutral points were permanently earthed.

(iv) In case of network of which the neutral point is isolated the rise in earth potential is to be considered only in case of network of large extent, which may give rise to a very large capacity current in the fault (more than several hundred amperes); further the rise in potential occurs only in neighborhood of the fault and in consequence, there is no need to consider it in the case of generating stations or sub-stations, except when the fault occurs within the station.

2.0 EPR Limits and hazard zone

The EPR contours which define hazard zone for the telecom plants are as given below:

Sl. No.	Type of Telecommunication Plant	Type of Power System	
		High Reliability Lines	Other Lines
1.	Terminal apparatus, joints, cabinets, pillars, manholes, pits, poles	650V	430V
2.	Telephone exchanges	430V	430V
3.	Cables (a) Metal Sheathed	650V	430V
	(b) Plastic insulated and plastic sheathed, PIJF cable	7 kV	7 kV

2.1 Zone of EPR

The zone of EPR near an earthing system varies from some tens to some thousands of metres, depending on soil resistivity, layout of the earth electrode, power network, fault current levels and other local conditions. The zone of EPR in urban areas is small compared to rural areas. Only EPR zones having potential higher than the values given above in 2.0 are considered as dangerous.

The power supply authority will in all cases be able to provide the value of the earthing system fault current at any location, the resistance of the earthing system and the soil resistivity of the area. It can also supply the data regarding the magnitude of EPR and the extent of hazard zone occurring at these fault locations.

Measurements and calculations of EPR zone are normally done by Power authorities. In order to ensure the safety of telecom assets and personnel, Telecom authorities should ascertain the EPR hazard zone from the concerned Power authorities.

3.0 Measurement of EPR Zone

3.1 Theoretical Formula for Measurement of EPR zone

The distance X in meters at which the EPR may rise to a value E_x can be determined from the formula.

$$X = \frac{\rho l}{2\pi Ex} \text{ metres}$$

Where,
ρ = Soil resistivity in ohm meter.
L = Fault current in Amps.
E_x = EPR voltage (limit as specified in 2.0 above for a particular telecom installation).

Above formula gives good results only in case of simple earthing systems such as single electrode earthing systems. As the area of earthing system increases the error increases rapidly.

For larger earthing systems the more practical formula would be

$$Ex = \frac{E_{max} \times D}{(d + D)} = \frac{IR \times D}{(d + D)}$$

Where E_x = The potential at radial distance ‘d’ from the perimeter of the earth mat in volts.

I = the maximum fault current through the earth mat in Amps.
R = the measured resistance of the earth mat in ohms.
D = Half the diagonal distance of the mat in meters.
d = Distance in meters from the perimeter of the earth mat.

In those cases, when the earth mat is not essentially rectangular in shape, the value of 'D' should be half length of the diagonal of a square, having the same area as that enclosed by the irregular earth mat.

Substituting the EPR voltage limit for E_x the distance 'd' of that voltage contour from the perimeter of the earth mat in meters can be calculated from the above formula.

Example

As given by the Power authorities for a power sub-station.
R = 1 ohm

Note: The value of earth resistance of a sub-station is normally less than 1 ohms; however this may vary depending on the size of the sub-station. The exact value of earth resistance can be obtained from Power authorities.

I = 5 kA (after considering necessary screening factors).

Dimensions of earth mat = 20x25 meters.

Solution

Half the diagonal distance of earth mat

$$D = \frac{\sqrt{20^2 + 25^2}}{2} = \frac{32}{2} = 16\ metres$$

E_x = 430 V (for a telephone exchange as per Para 2.0)

$$\therefore E_X = \frac{IR \times D}{(d + D)}\ or\ d + D = \frac{IR \times D}{E_X}$$

d + 16 = $\frac{5000 \times 1 \times 16}{430} = \frac{80000}{430}$

= 186.046 (say 187 meters)

d = 187 – 16 = 171 meters

Conclusion
The effective EPR zone is 171 meters from the perimeter of the earth mat of the given power sub-station.

3.2 Practical Measurement of EPR Zone

In theoretical formula uniform earth resistivity is assumed. In practice however the earth resistivity is rarely uniform and equi-potential contours around an earthing system are often distorted away from the postulated circular shape for the hemispherical electrode because of the rectangular shape of the station earthing system and other earthed conductors such as metallic sheathed cables, water or gas pipes etc buried in the earth in the vicinity. For an accurate determination of a particular EPR hazard zone, a practical test is therefore necessary, which has to be conducted by Power authorities and co-ordinated by Telecom authorities.

Where the calculations by above formula indicate that there is a border line problem or if there is a doubt about the reliability of the parameter values used in the calculation, the hazard zone may be determined by practical measurements.

Because of the costs involved, practical measurements cannot be made in each and every case under consideration and it may be more economical instead to institute protective measures suggested in the following paras.

4.0 Protection Measures

4.1 Co-ordination with Power authorities

(i) By proper co-ordination with power authorities at various levels, it may be ensured that the earth resistance of the power earthing systems is maintained within limits and they are installed as far away as possible from the telecom installations and cables, so that the effect of EPR is not there on the telecom circuits. It should also be ensured by Power authorities that the protective systems operate properly and fault tripping timings are maintained within limits.

(ii) In case of new installations the effective zone of influence of EPR may be ascertained from concerned Power authorities so as to ensure safe separation at the initial stage itself.

4.2 Minimum Separation for Telecom Cables in the Soil

In the absence of other experiences, local measurement or calculated values of EPR, the following minimum separations in soil between telecom cable with a metal sheath in direct contact with the soil and a high voltage power earthing system should be observed.

Separation in soil (in meters) between telecom cables and high voltage earthing systems beyond which no calculation or measurement is necessary:

Earth Resistivity in Ohm Meters	Power Network System with		Location
	Isolated Neutral or Arc Suppression Coil	Directly Earthed Neutral	
< 50	2	5	Urban
	5	10	Rural

50 - 500	5	10	Urban
	10	20	Rural
500 - 5000	10	50	Urban
	20	100	Rural
	10	50	Urban
	20	100 – 200*	Rural
*200 meters in areas with extremely severe soil conditions i.e. 10,000 ohm meters			

In the case of tower earthing, half the above distances can be used, if the power lines include earth wires.

Where the local situations do not permit such separation, the telecom cables should be provided with insulation, for example by placing the cables in insulated plastic tubes in the hazard zone or using plastic sheathed cable. When the magnitude of hazard is extremely high, optical fiber cables or radio relay systems may be used instead of metallic cables.

4.3 **Telephone Exchanges**

Telephone exchanges should not be installed where the maximum EPR at the site of the exchange is greater than 430 volts.

In case of telephone exchanges, which include a distribution sub-station, providing the power requirements for the telecom equipment, every effort should be made to obtain EPR figure less than 430 volts for all categories of HV earth systems, if necessary by directly coupling all earth systems (including the reinforcing mesh which forms part of the building structure) and supplementing existing earth systems with deep driven earth electrodes. It may be practicable to feed power to the sub-station through an underground metallic sheathed cable with a supplementary earth system and surge diverters (lighting arresters) at the transition point between overhead and underground power construction. Where, despite these measures it is not possible to achieve a figure of EPR below 430 volts the sub-station earth system should be removed to a location, which ensures EPR not greater than 430 volts.

4.4 Telecom Circuits Within/Passing Through the EPR Hazard Zone

Within the power system earthing hazard zone the telecom circuits should be provided in plastic insulated and unscreened plastic sheathed cable laid in rigid PVC conduit. To isolate the circuits from remote earth, all conductors should be provided with isolating links within the boundary. Accessible metal parts such as metal sheathing, frames, boxes etc must be connected to the earthing systems.

If there is PABX in the hazard zone, the earthing of PABX should be common to the power system earth. The telecom circuits should have isolating transformer.

Location of cable joints, terminals, pillars, cabinets, etc, which require personnel to work, should be avoided in the hazard zone. If it is unavoidable, a warning sign should be fixed and special work practices should be followed.

Telecom circuits should not be protected for the purposes of mitigation of induced voltage due to power system earth faults by using GD tubes between the conductors and earth in the hazard zone as this results in the transfer of earth potential rise to the telecom circuits when the protectors fire.

It may prove desirable in some cases to change the underground to overhead construction. In such cases or wherever overhead construction is felt desirable in EPR hazard zone, only wooden poles should be used.

When it is essential to provide a telephone connection within the EPR zone, the following precautions should be taken:

(i) The post carrying DP box from which drop-wire is drawn to provide telephone connection should be located outside the EPR boundary of 430V.

(ii) Self-supporting drop-wire without support of GI wire should be used.

(iii) If necessary, the drop-wire should be supported on wooden poles within the EPR zone.

(iv) Inside the building the drop-wire should be taken through PVC pipes to the telephone instrument.

(v) Rosette should be installed on an ebonite plate fixed on the wall.

(vi) The telephone instrument should be placed on a wooden table, which in turn should be placed on a rubber mat so that a person using the telephone also stands on the rubber mat.

(vii) The wire drawn from rosette to telephone instrument at any point should not touch any portion of the building.

(viii) Battery eliminators should not be used while providing plan 103 facility in the building.

The purpose of all these precautions is to prevent the telephone instrument, its user and connecting link etc from coming in contact with hazardous voltage.

4.5 Precautions for Working Staff in EPR Hazard Zone.

When working on telecom circuits in hazard zone, telecom staff should insulate themselves from the earth by standing on an insulating mat having a specified insulation capable of withstanding voltage of at least 15 kV for one minute. Where practicable, insulated tools, gloves and footwears should also be used.

Wherever isolating links are provided for telecom circuits, the telecom staff should remove these links before attending to any work on the circuits.

5.0 Conclusion

In case of existing telecom network wherever necessity arises, the details with respect to EPR will be obtained from concerned Power authorities and the matter referred to Power & Telecommunication Co-ordination Committee (PTCC) for suggesting necessary protective measures. For all new constructions, due consideration should be given to the safety limits and aspects explained above so as to ensure the safety of telecom assets and personnel.

References:

(i) PTCC code of practice for the protection of personnel and equipment against earth potential rises caused by high voltage power system faults, issued vide Director (ML), DoT, New Delhi letter No. 10-11/89-ML dated 10th May 1989.

(ii) APT booklet on EPR.

(iii) Introductory manual on co-ordination of Power & Telecom Systems (Australia).

> We always love those who admire us;we do not always love those whom we admire.
>
> -Francois De La Rochefoucauld

CHAPTER-IX

CHAPTER – IX

Mutual Coupling Calculations as per CCITT Directives

In this chapter two examples on calculation of Mutual Coupling have been reproduced from the CCITT Directives. These examples contain all type of complexities involved in calculation of MC and are easy to understand.

> After climbing a great hill, one only finds that there are many more hills to climb.
>
> -Nelson Mandela

Practical examples of the calculation of voltages induced in telecommunication circuits by electricity lines

Example 1

Consider the case of a 225-kV 3-phase electricity line AB, with earthed neutral. The line is fitted throughout its length with an earth wire having a resistance $R = 0.05\ \Omega/\text{km}$.

Consider also a telecommunication line ab consisting of bare overhead wires.

The respective geographical positions of these two circuits are given at a scale of 1/50 000 in the diagram below (Figure 12).

1. ASSUMPTIONS

1.1 Soil resistivity ρ

The soil resistivity in the zone of the telecommunication circuit was evaluated at $\rho = 50\ \Omega\cdot\text{m}$ (paragraph 3.2.1 of the application guide). This value has been used for all the following calculations.

1.2 Inducing current J

The organization operating the power line gave an inducing current of $J = 4.5$ kA determined for the most unfavourable case, which is that of a phase-to-earth fault at point D, with the inducing current coming from substation A (paragraph 3.2.2 of this guide).

1.3 Screening factor k

As the electricity line AB is provided throughout its length, and in particular on the section under consideration, with an earth wire of resistance $R = 0.05\ \Omega/\text{km}$, we shall assume a screening factor $k = 0.6$ (paragraph 3.2.3 of this guide).

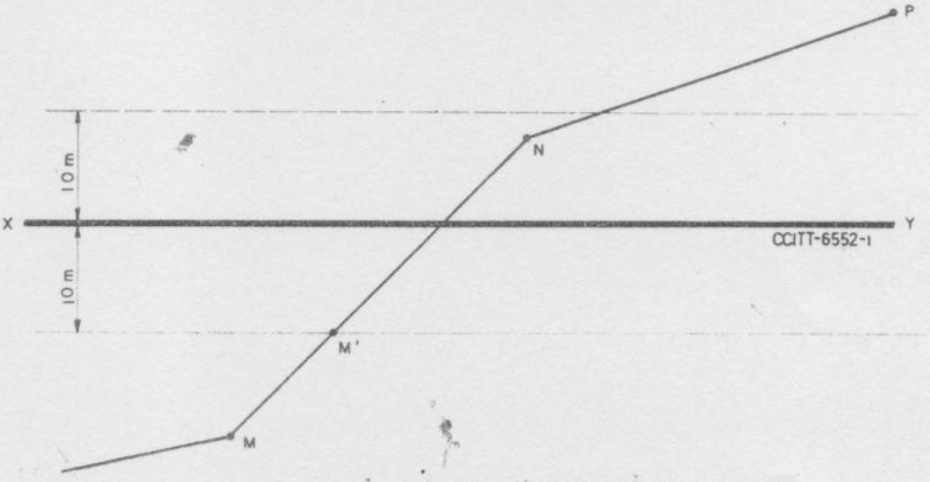
1.4 Exposure

Considering the value of the soil resistivity in the area under consideration, it seems useless to take into consideration the effects of induction beyond a distance of *3 km* on each side of the electricity line. If one observes the routes of the line in a zone thus defined, one can see (Figure 12) that the whole of the telecommunication line ab is included in this area, and consequently it is affected, throughout its entire length, by the induction phenomena caused by the line AB (section 2 of this guide).

2. BREAKDOWN OF THE TELECOMMUNICATION CIRCUIT INTO ELEMENTAL SECTIONS

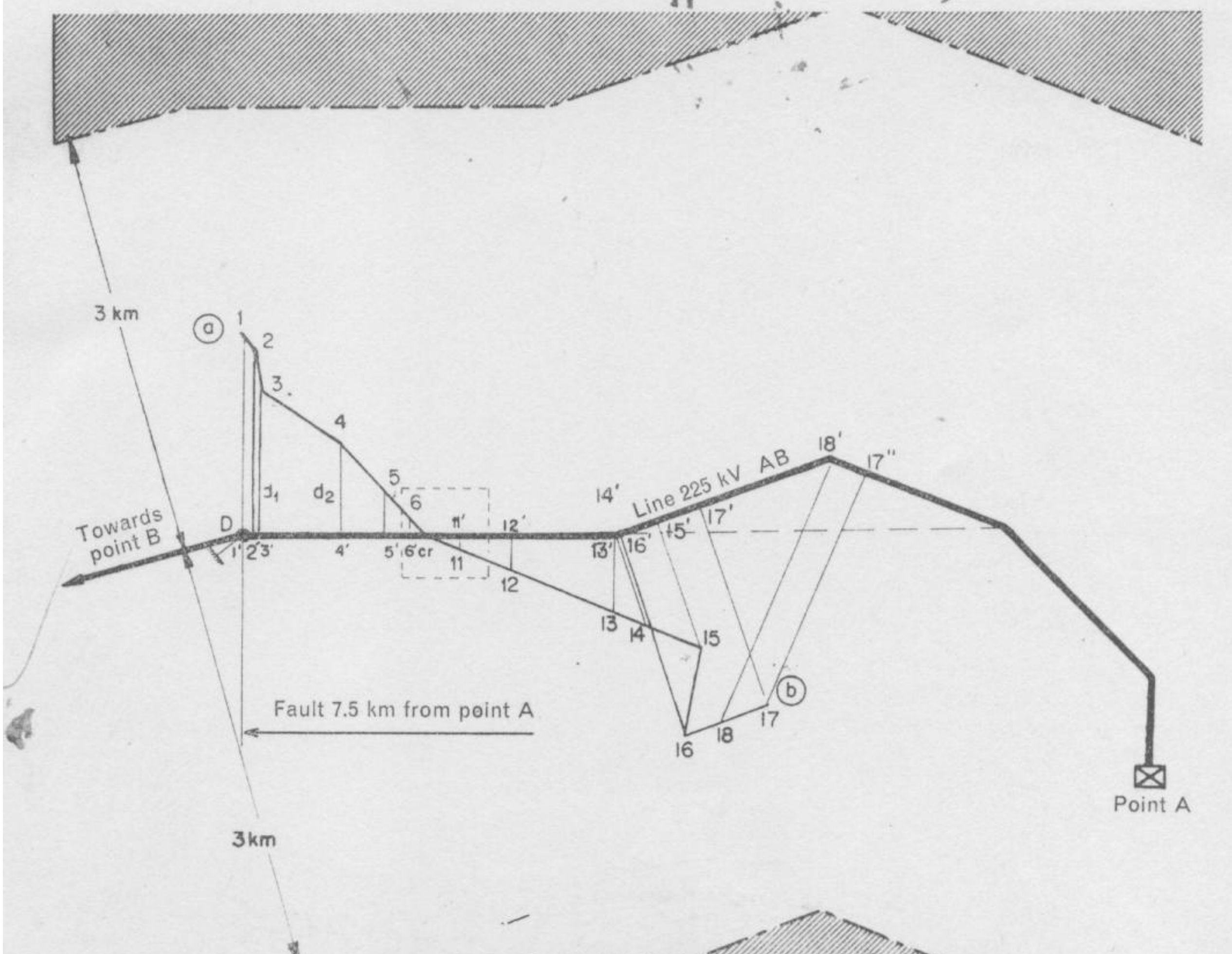
2.1 First of all, each of the angular points of the telecommunication circuit is projected on to the electricity line (Figure 12: 1, 2, 3, 4, 15, 16, 17).

2.2 On each side of the crossing C_r of the two circuits, which receive a special treatment, two points 8 and 9, at a distance of 10 m from the electricity line, are determined on the telecommunication line (Figure 13: 8 - 8′ = 9 - 9′ = 10 m).



The sections MM′ and NP are considered as oblique exposures
The section M′N is considered as a crossing

FIGURE 11



Scale: 1/50 000 1 mm = 50 m
FIGURE 12

2.3 All the straight-line parts of the telecommunication circuit are, where appropriate, divided into elemental sections such that in all cases:

$$\frac{d_1}{d_2} \leqq 3 \qquad \text{if} \qquad d_1 > d_2$$

$$\frac{d_2}{d_1} \leqq 3 \qquad \text{if} \qquad d_2 > d_1 \, .$$

Thus in our example, points 5, 6, 7, 10, 11, 12 and 13 are determined and are in turn projected on to the electricity line (Figures 12 and 13).

Notes. —

1. The section 13 - 14 is not taken into account, for it has no possible projection on the electricity line.

2. The section 15 - 16, which represents a reversal with respect to the arbitrarily chosen positive direction, will therefore receive an induction which will appear negatively in the following calculations.

3. The section 16 - 17 has two possible projections on to the power line, which presents a converging angle at this point. Consequently, this part of the circuit will receive two inductions:

— one over its whole length from the section 16′ - 17′ of the electricity line,

— the other over the portion 18 - 17 from the section 18′ - 17″ of the electricity line (Figure 12).

The resultant induced electromotive forces will therefore be added together.

2.4 Figure 13 shows the region of the crossing (an enlargement of the area in Figure 12 enclosed by a dotted line). It can be seen that the crossing forms two angles α and α'.

The intersection is treated as a parallel section with distance between lines d = 6 m and length 1, equal to the projection 8′ - 9′ of the segment contained in the zone of 10 metres around the power line (paragraph 3.3.3 of this guide).

$$l = 8' - 9' = 0.033 \text{ km}$$

These values are given in the summarizing table.

SUMMARIZING TABLE

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10
Elemental sections	d_1 m	d_2 m	$d = \sqrt{d_1 d_2}$ m	l km	MμH/km ρ = 50 Ω.m	Ml +	Ml −	Ml Total	k
1-2	1400	1300	1349	0.070	33	2.3			↑
2-3	1300	1030	1156	0.025	42	1.1			
3-4	1030	650	816	0.560	74	41.4			
4-5	650	270	419	0.305	160	48.8			
5-6	270	90	156	0.144	320	46.1			
6-7	90	30	52	0.048	530	25.4			
7-8	30	10	17.5	0.016	740	11.8			
Cr 8-9	6	6	6	0.033	940	31			0.6
9-10	10	30	17.5	0.049	740	36.3			
10-11	30	90	52	0.147	530	77.9			
11-12	90	270	156	0.440	320	140.8			
12-13	270	530	378	0.640	172	110			
14-15	650	950	786	0.300	77	23.1			
15-16	950	1485	1188	0.260	42		10.7		
16-17	1485	1485	1485	0.490	26	15.3			
17-18	1775	2000	1885	0.250	15.5	3.9			↓
						615.2	10.7	604.5	0.6

3. DRAWING UP OF THE SUMMARIZING TABLE

All the data thus defined are used to complete columns 1 to 5 of the table. We have in succession:

Column 1 = Numbers of elemental sections (Figures 12 and 13).

Columns 2 and 3 = Distances in metres d_1 and d_2 to the electricity line from the ends of the sections.

Column 4 = The geometric mean of these distances.

Column 5 = The length in kilometres of the projection of the sections on to the power line.

Column 6 can easily be completed by using Figure 5 of the application guide (paragraph 3.2.1) which gives directly the value M of the mutual inductance in μH/km as a function of the distance d defined in column 4 and the soil resistivity ρ which is in the present example $50\,\Omega\cdot$m.

The figures in column 7 are obtained by multiplying together the values appearing in columns 5 and 6.

Note that the value obtained for the section 15 - 16, in which the direction of the telecommunication line is reversed, appears as a negative in column 8 which is reserved for this purpose.

The totals appear at the bottom of columns 7, 8 and 9.

The screening factor k, which is the same for the entire circuit, appears in column 10.

4. FINAL RESULT

The electromotive force induced in a telecommunication circuit by an electricity line is given by the equation:

$$e = 2\pi f\, Ml\, J\, k\, 10^{-3} \quad \text{(Section 3.2 of this guide).}$$

For the example given, we have:

$f = 50$

$Ml = 604.5$

$J = 4.5$

$k = 0.6$

Hence:

$$e = 2 \times 3.14 \times 50 \times 604.5 \times 4.5 \times 0.6 \times 10^{-3} = 515 \text{ volts.}$$

Notes. —

1. As regards the crossing, it may be noted that the induction in the segment 8 - C_r could have been ignored, as the angle is slightly greater than 45° (paragraph 3.3.3 of the application guide). This would have given an error of 6 volts in the calculation of the total induced voltage, which is quite negligible.

2. To be completely accurate, one would have to calculate the induced electromotive forces e_1, e_2, e_3, etc., on each of the elemental sections and then obtain the sum of these electromotive forces in accordance with section 3.1 of the present guide.

In the two examples considered, the sum of the factors Ml was taken and multiplied once only by the inducing current. This more rapid method of effecting the calculation is valid in the large majority of cases in order to obtain an approximate value.

Example 2

Consider a 3-phase 225-kV electricity line XY with an earthed neutral. The line is fitted with an earth wire over the section XL of its length of resistance $R = 0.5\,\Omega$/km.

Consider also a telecommunication line xy consisting of three parts:

— An overhead section of bare wires (1 to 5).

— A section of underground cable with a lead sheath and two layers of tape (5 to 11).

— An overhead section of self-supporting plastic cable (11 to 19).

The respective geographical positions of these two circuits are shown in Figure 14 on a scale of 1/50 000.

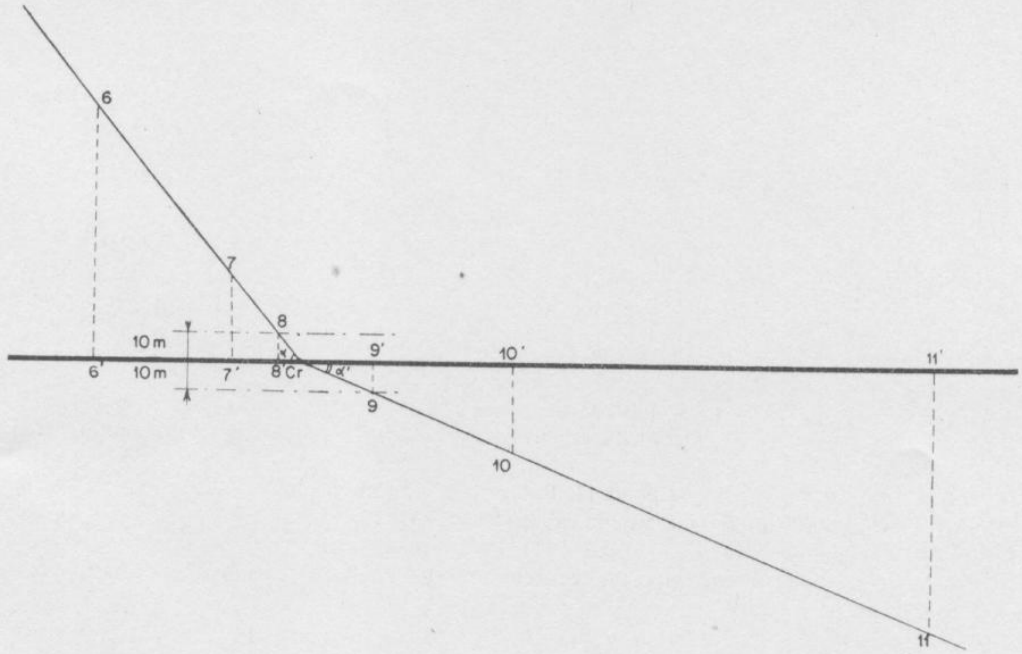


FIGURE 13

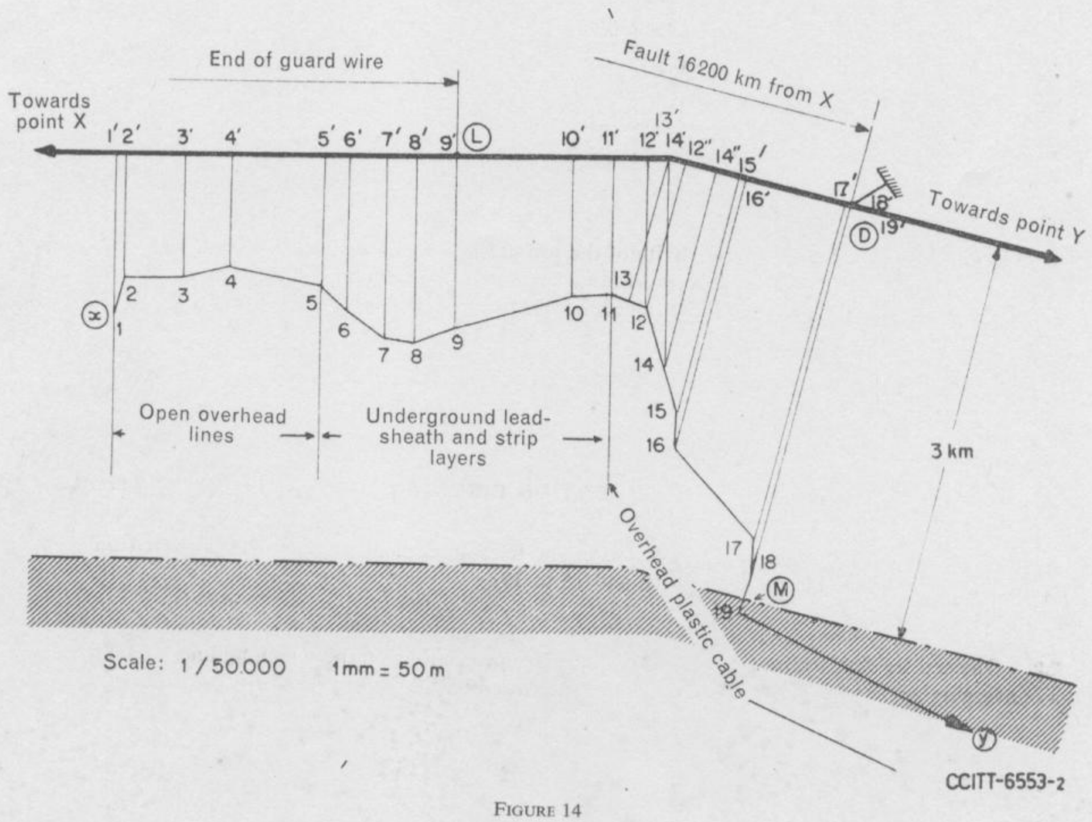


FIGURE 14

1. ASSUMPTIONS

1.1 Soil resistivity ρ

The soil resistivity in the zone of the tèlecommunication circuit was evaluated at $\rho = 100\,\Omega\cdot\text{m}$ (section 3.2.1). This value was used for all the following calculations:

1.2 Inducing current J

The organization operating the electricity line gave an inducing current $J = 6.12$ kA, determined for the most unfavourable hypothesis of a phase-to-earth fault located at point D, with the current coming from sub-station X (section 3.2.2).

1.3 Screening factors k_n

The electricity line is fitted with an earth wire of resistance $R = 0.5\,\Omega/\text{km}$ up to point L. We shall therefore assume for that part of the circuit lying between point 1 and point 9 a screening factor $k_{1.9} = 0.75$.

However from point 5 up to point 11, the telecommunication circuit, which consisted of bare overhead wires, changes to an underground cable with lead sheathing and two strip layers. This type of cable has a screening factor $k_{5.11} = 0.5$. This means that between point 5 (start of underground cable) and point 9 (end of earth wire) the two screening factors combine to give an overall screening factor equal to their product:

$$k_{5.9} = 0.75 \times 0.5 = 0.375$$

Beyond point 11, the circuits consist of overhead cable in a plastic covering which does not have any screening effect, i.e. the screening factor is $k_{11.y} = 1$.

We shall therefore have the following screening factors in turn:

— Segments 1 to 5: $k_{1.5} = 0.75$

— Segments 5 to 9: $k_{5.9} = 0.75 \times 0.5 = 0.375$

— Segments 9 to 11: $k_{9.11} = 0.5$

— Segments 11 to y: $k_{11.y} = 1$

(see section 3.2.3).

1.4 Exposure

In view of the value of the resistivity of the soil in the area considered, it seems sufficient to take into consideration the induction effects inside a zone of 3 km around the electricity line. We shall therefore disregard the portion of the telecommunication circuit situated beyond point M (see section 2).

2. DIVISION OF THE TELECOMMUNICATION CIRCUIT INTO ELEMENTAL SECTIONS

2.1 First of all each of the angular points of the telecommunication circuit is projected on to the electricity line (Figure 14: points 1 to 12 and 15 to 19).

2.2 One can see that section 11 - 12 has two possible projections on the screening line, which presents a converging angle at this point. This part of the circuit will therefore receive two inductions:

— one throughout its length from section 11′ - 12′ of the electricity line,

— the other over its portion 13 - 12 from the portion 13′ - 12″ of the electricity line.

The resultant induced electromotive forces will therefore be added together.

The same applies to section 12 - 14 which will receive the following inductions:

— one throughout its length from portion 12′ - 14′ of the electricity line,

— another, also throughout its length from the portion 12″ - 14″ of the electricity line.

Here again, the resultant induced electromotive forces will be added.

2.3 Since the section 18 - 19 is perpendicular to the electricity line, it will not be subject to any electromagnetic induction effects.

3. DRAWING UP OF THE SUMMARIZING TABLE

All the data thus defined can be used to fill columns 1 to 5 of the table; we have in turn:

— Column 1 = Numbers of the elemental sections (Figure 14).

— Columns 2 and 3 = Distances in metres d_1 and d_2 to the electricity line from the ends of the sections.

— Column 4 = The geometric mean $d = \sqrt{d_1 d_2}$.

— Column 5 = The length l in kilometres of the projection of the sections on the power line.

Column 6 is completed by using Figure 5 of this Guide, which gives directly the value M of the mutual inductance in μH/km as a function of the distance d defined in the end column 4 and the resistivity of the soil, which is 100 Ω·m in the example being considered.

225 kV Line XY
Circuit xy

Col. 1	Col. 2	Col. 3	Col. 4	Col. 5	Col. 6	Col. 7	Col. 8	Col. 9	Col. 10
Elemental sections	d_1 m	d_2 m	$d = \sqrt{d_1 d_2}$ m	l km	M μH/km $\rho = 100\ \Omega\cdot m$	Ml +	Ml Total	k	Mlk Total
1-2	1200	940	1064	0.070	82	5.7		↑	
2-3	940	940	940	0.440	96	42.2		0.75	
3-4	940	850	895	0.330	102	33.6		↓	
4-5	850	990	915	0.650	100	65.0	146.5	× 0.75	= 109.9
5-6	990	1165	1072	0.180	82	14.8		↑	
6-7	1165	1350	1251	0.280	64	17.9		0.375	
7-8	1350	1400	1375	0.220	57	12.5		↓	
8-9	1400	1270	1336	0.270	58	15.6	60.8	× 0.375	= 22.8
9-10	1270	1010	1131	0.850	75	63.7		↑ 0.5	
10-11	1010	1000	1005	0.300	88	26.4	90.1	↓ × 0.5	= 45.0
11-12	1000	1100	1049	0.250	82	20.5		↑	
12-13	1100	1120	1110	0.120	75	9.0			
12-14	1100	1575	1316	0.150	60	9.0			
12-14	1120	1540	1318	0.240	60	14.4		1	
14-15	1540	1860	1694	0.160	40	6.4			
15-16	1860	2090	1971	0.040	30	1.2			
16-17	2090	2600	2340	0.740	21	15.5		↓	
17-18	2600	2780	2694	0.040	16	0.6	76.6	× 1	= 76.6
									254.3

The values in column 7 are obtained by multiplying the values appearing in columns 5 and 6 together.

Since the electricity line and the telecommunication line have different screening factors depending on the zones considered, these screening factors are given opposite the sections involved (column 9).

Column 8 contains the total values of the induction coefficients of the zones concerned, and column 9 the corresponding screening factors. In column 10 are given the final values of the induction coefficients with their respective screening factors (product $M\,l\,k$).

The final total appears at the bottom of column 10.

4. FINAL RESULT

The electromotive force induced in the telecommunication circuit by the electricity line is expressed by the equation:

$$e = 2\pi f \; M\,l\,J\,k \; 10^{-3}$$

where:

$$f = 50$$

$$Mlk = 254.3$$

$$J = 6.12$$

hence:

$$e = 2 \times 3.14 \times 50 \times 254.3 \times 6.12 \times 10^{-3} = 489 \text{ volts.}$$

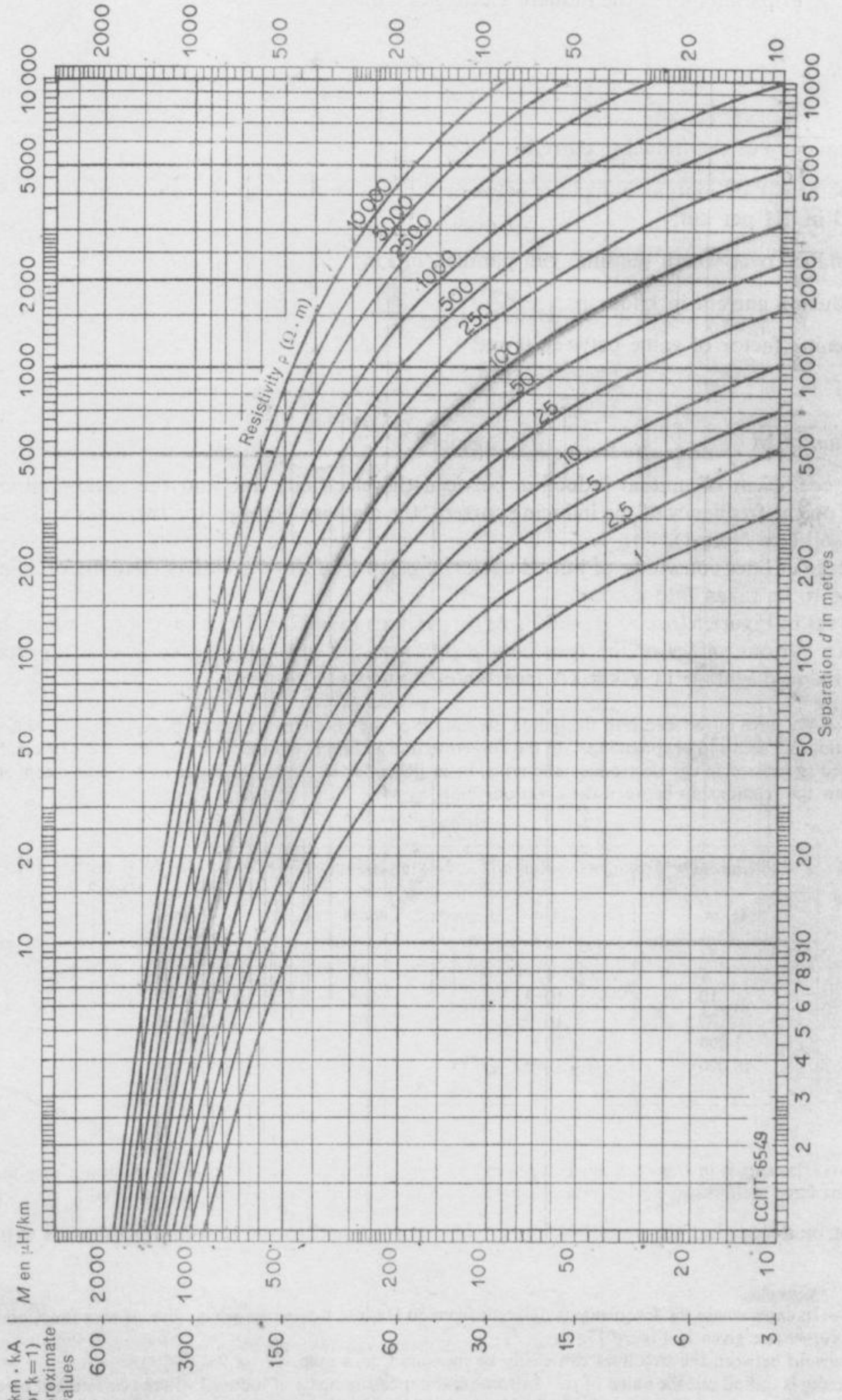


FIGURE 5

Mutual inductance M in μH/km for f = 50 Hz as a function of the separation d (in metres) and resistivity ρ (in Ω·m).

CHAPTER - X

Approximate value of Screening Factors at Fundamental Frequency (50 Hz), as per CCITT Recommendations.

Approximate values of screening factors at fundamental frequency

Screening factor of	**Screening factor**
Earth wires of high voltage lines	
a) single earth wire	
- DC resistance < 0.1 Ω/Km	0.55 – 0.7
- DC resistance < 0.5 Ω/Km	0.65 – 0.75
- DC resistance < 1.0 Ω/Km	0.8 – 0.9
b) double earth wire (the DC resistance hereunder relates to the resulting value of the two earth wires in parallel	
- DC resistance < 0.1 Ω/Km	0.4 – 0.4
- DC resistance < 0.5 Ω/Km	0.15 – 0.75
- DC resistance < 1.0 Ω/Km	0.8 – 0.9
High voltage cables	
a) Lead sheath cable	
- 30-70 kV, 240 mm^2	0.2 – 0.4
- 110-150 kV, 240 mm^2	0.15 – 0.3
- 275 kV, 60 mm^2	0.01 – 0.25
- 400 kV, 1000 mm^2	< 0.2
a) Aluminium sheath cable	
- 30-70 kV, 240 mm^2	
- 110-150 kV, 240 mm^2	0.1 – 0.2
- 275 kV, 60 mm^2	0.07 – 0.15
- 400 kV, 1000 mm^2	0.04 – 0.1
	< 0.05
Telecommunication cables	
a) Lead sheath cable	
- diameter 20 mm	0.85 – 0.95
- diameter 40 mm	0.6 – 0.85
b) Aluminium sheath cable	
- diameter 20 mm	0.2 – 0.6
- diameter 40 mm	0.1 – 0.4

Electrified railway lines		
Number of tracks	Number of lines of rails through which the induced currents are returned	
1	1	0.61
1	2	0.44
2	the two outer lines	0.44
2	4	0.28

As per decision taken in the 90th Central PTCC Meeting held at Bangalore on 30th October 2009, the Screening Factor of Unscreened / PIJF Underground Communication cable is to be considered as 0.5.

> Do not go where the path may lead, go instead where there is no path and leave a trail.
>
> \- Ralph Waldo Emerson

CHAPTER - XI

CHAPTER XI

Information about Electrical Inspectors and Statutory Provisions
(As per the Electricity Act 2003)

I Appointment of Chief Electrical Inspector and Electrical Inspector

(1) The Appropriate Government may by notification, appoint duly qualified persons to be Chief Electrical Inspector or Electrical Inspectors and every such Inspector so appointed shall exercise the powers and perform functions of a Chief Electrical Inspector or Electrical Inspector under this Act and exercise such other powers and perform such other functions as may be prescribed within such areas or in respect of such class of works and electrical installations and subject to such restrictions as the Appropriate Government may direct.

(2) In the absence of express provision to the contrary in this Act or any Rule made thereunder, an appeal shall lie from the decision of a Chief Electrical Inspector or an Electrical Inspector to the Appropriate Government or if the Appropriate Government, by general or special order so directs to an Appropriate Commission.

A. ADDRESSES OF STATE ELECTRICAL INSPECTORS

1. Chief Electrical Inspector,
Government of Andhra Pradesh,
Stone Building,
Mint Compound,
Hyderabad – 500 004.

2. Chief Engineer, Zone – II,
Public Works Department,
Government of Arunachal Pradesh,
Itanagar – 791 111.

3 Chief Electrical Inspector-cum-Adviser,
Government of Assam,
R.G. Barooah Road, Rajgarh Link,
Road No. 1, (Opp. Commerce College),
Guwahati – 781 003.

4 Senior Electrical Inspector,
Government of Bihar,
Patna.

5. Chief Electrical Inspector,
Government of Gujarat,
IMP Department,
Dwarkesh Building, 3rd Floor, Khanpur,
Ahmedabad – 380 001.

6. Chief Electrical Inspector,
Government of Haryana,
SCO No. 85-86,
Sector No. 17-D,
Chandigarh – 160 017.

7. Chief Electrical Inspector,
Bakshi Cottage,
Long Wood,
Shimla – 171 001.

8. Chief Electrical Inspector,
Governemnt of Kerala,
Housing Board Building,
Santhinagar,
Trivandrum – 695 001.

9. Chief Electrical Inspector,
Government of Karnataka,
K.R. Circle, P.B. No. 5148,

KEB,Multistoried Building,
Bangalore – 560 001.

10. Chief Engineer (ES) &
Chief Electrical Inspector,
Government of Madhya Pradesh,
Satpura Bhavan, 3rd Floor,
Bhopal – 462 004.

11. Chief Engineer (Electrical)
Government of Maharashtra,
6th Floor, Bandra (East),
Kurla Compelx
Administrative Building,
Mumbai- 400 051.

12. Chief Engineer (Power),
Governemnt of Manipur,
Electricity Department,
Imphal – 795 001.

1. Senior Electrical Inspector,
Government of Meghalaya,
Lower Lachumiera,
Shillong – 795 001

14. Chief Engineer Power &
Electricity Department,
Government of Mizoram,
Aizwal – 796 001.

15. Chief Engineer,
Electricity Department,
Nagaland,
Kohima – 797 001.

16. Chief Electrical Inspector,
Government of Orissa,
3rd Floor, Heads of Deptt. Building,
Bhubaneswar – 751 001.

17. Chief Electrical Inspector,
Government of Punjab,
Patiala.

18. Chief Electrical Inspector,
Government of Rajasthan,
Subhas Marg ‘C’ Scheme,
Jaipur – 302 001.

19. Chief Electrical Inspector,
Government of West Bengal,
Directorate of Electricity,
1, Karish Mukherjee Road,
Kolkata – 700 020.

20. Chief Electrical Inspector,
Electrical Inspectorate,
Thiru, Vi. Ka. Industrial Estate,
Guindy,
Chennai – 600 032.

21. Director Electrical Safety,
Vidyut Khand II,
Behind Pick-up Building,
Gomtinagar,
Lucknow – 226 010.

B. ADDRESSES OF CENTRAL ELECTRICAL INSPECTORS

I. Head Office

Chief Electrical Inspector
Central Electricity Authority
Sewa Bhawan, R.K. Puram,
New Delhi-110066.

II. Regional Offices

(1) Superintending Engineer,
Regional Inspectorate Office,
Room No.324, NRPC Building
SSJ Marg, Katwaria Sarai,
New Delhi-110016

(2) Superintending Engineer,
Regional Inspectorate Office,
Shastri Bhavan,
Chennai 600006

(3) Superintending Engineer,
Regional Inspectorate Office,
WRPC Building, Plot No. F-3
MIDC Area, Central Road,Marol,
Andheri East,
Mumbai-400093.

(4) Superintending Engineer
Regional Inspectorate Office,
Zorem Nongrim Hills
Shillong

(5) Superintending Engineer
Regional Inspectorate Office (East)
ERPC Building, 14, Golf Club Road,
Tollyguange,
Kolkata-700033.

Whenever you see a successful person you only see the public glories, never the private sacrifices to reach them.
-Greg Evans

EXTRACTS OF IMPORTANT CLAUSES FROM THE ELECTRICITY ACT, 2003

SECTION 159

Protection of Railways, Highways, Airports and Canals, Docks, Wharfs and Piers

No person shall in the generation, transmission, distribution, supply or use of electricity, in anyway injure any railway, highway, airports, tramway, canal or water-way or any dock, wharf, or pier vested in or controlled by a local authority, or obstruct or interfere with the traffic on any railway, airway, tramway, canal or water-way.

SECTION 160

Protection of Telegraphic, Telephonic and Electrical Signaling

(1) Every person generating, transmitting, distributing, supplying or using electricity (hereinafter referred to as the "operator") shall take all reasonable precautions in constructing, laying down and placing his electric lines, electrical plant and other works and in working his system, so as not injuriously to affect, whether by induction or otherwise, the working of any line used for the purpose of telegraphic, telephone or electric signaling communication, or the currents in such wire or line.

(2) Where any difference or dispute arises between the operator and the telegraphic authority as to whether the operator has constructed, laid down or placed his electric lines, electrical plant or other works, or worked his system, in contravention of sub-section(1), or as to whether the working of any wire, line or current is or is not injuriously affected thereby, the matter shall be referred to the Central Government and the Central Government, if it is of the opinion that the wire or line has been placed in unreasonable proximity to the electric lines, electrical plant or works of the operator after the construction of such lines, plant or works, may direct the operator to make such alterations in, or additions to, his system as may be necessary in order to comply with the provision of this section, and the operator shall make such alteration or additions accordingly:

Provided that nothing in this sub-section shall apply to the repair, renewal, or amendment of any electric line or electrical plant so long as the course of the electric line or electrical plant and the amount and nature of the electricity transmitted thereby are not altered.

(3) Where the operator makes default in complying with the requirements of this section, he shall make full compensation for any loss or damage incurred by reason thereof, and, where any difference or dispute arises as to the amount of such compensation, the matter shall be determined by arbitration.

Explanation:- For the purposes of this section, a telegraph line shall be deemed to be injuriously affected if telegraphic, telephonic or electric signaling communication by means of such line is, whether through induction or otherwise, prejudicially interfered with, by an electric line, electrical plant or other works or by any use made thereof.

SECTION 161

Notice of Accidents and Inquiries

(1) If any accident occurs in connection with the generation, transmission distribution, supply or use of electricity in or in connection with any part of the electric lines or electrical plant of any person and the accident results or is likely to have resulted in loss of human or animal life or in any injury to a human being or an animal, such person shall give notice of the occurrence and of any such loss or injury actually caused by the accident, in such form and within such time as may be prescribed, to the Electrical Inspector or such other person as aforesaid and to such other authorities as the Appropriate Government may by general or special order direct.

(2) The Appropriate Government may, if it thinks fit, require any Electrical Inspector, or any other person appointed by it in this behalf, to inquire and report:-

(a) as to the cause of any accident affecting the safety of the public, which may have been occasioned by, or in connection with the generation, transmission, distribution, supply or use of electricity, or

(b) as to the manner in, and extent to which the provisions of this Act or rules and regulations made hereunder or of any license, so far as those provisions affect the safety of any person, have been complied with.

(3) Every Electrical Inspector or other person holding an inquiry under sub-section (2) shall have all powers of a civil court under Code of Civil Procedure, 1908 for the purpose of enforcing the attendance of witnesses and compelling the production of documents and material objects, and every person required by an Electrical Inspector be legally bound to do so within the meaning of section 176 of the Indian Penal Code.

SECTION 164

Exercise of Powers of Telegraph Authority in Certain Cases

The Appropriate Government may, by order in writing, for the placing of electric lines or electrical plant for the transmission of electricity, or for the purpose of telephonic or telegraphic communications necessary for the proper co-ordination of works, confer upon any public officer, licensee or any other person engaged in the business of supplying electricity under this Act, subject to such conditions and restrictions, if any, as the Appropriate Government may think fit to impose and to the provisions of the Indian Telegraph Act, 1885, any of the powers which the telegraph authority possesses under that Act with respect to the placing of telegraph lines and posts for the purposes of a telegraph established or maintained by the Government or to be so established or maintained.

Accomplishment is easiest when we work the hardest, and it is hardest when we work the easiest.

-Anonymous

APPENDIX
To
CHAPTER - I

Appendix I to Chapter I

(Refer Para 2.0)

No.EL.II-151 (7) dated 30th May 1949,
Amended by EL.II-141 (7) dated 29th August 1949

RESOLUTION

The Government of India have given careful consideration to the problems of interference between power and telecommunication lines and installations and are of the opinion that measures should now be taken to resolve the conflict of interests in regard to the location and working of power and telecommunication lines and installations, which, either exist at present or may arise in the future, with the increasing development of electric power and telecommunication facilities in India.

Both power and telecommunication services are essential to the life of the community, and in the interest of satisfactory and economical service, the Power and Communication authorities should jointly evolve agreed general methods of co-ordination. In individual cases, where general coordination methods are considered insufficient, special measures should be devised to meet the situation in order to prevent or at least minimize the effects of interference.

The Government of India have, therefore, decided to constitute a Central Standing Committee of Co-ordination of power and telecommunication lines.

2. Composition of the Committee

The Committee will consist of the following:

(i) Shri N.N. Iyengar, Chairman, Central Electricity Commission

(ii) Shri H.R. Bhatia, Project Engineer East, Punjab Electricity Branch.

(iii) Shri V.R. Raghavan, Project Officer, Central Electricity Commission.

(iv) Shri H.N. Shrivastava, Additional Chief Engineer, P&T Directorate.

(v) Shri B.S. Rau, Director of Telegraphs (External Plants), P&T Directorate.

(vi) Shri M.B. Sarwate, Director of Communications, Civil Aviation Directorate.

(vii) Shri K.V. Venkatachalam, Deputy Secretary, Ministry of Communication.

(viii) Shri A.C. Bose, Deputy Secretary, Ministry of Finance (Communication).

(ix) Shri S. Neelakantam, Deputy Secretary, Ministry of Works, Mines and Power.

(x) Shri S. Venkataraman, Deputy Secretary, Ministry of Finance.

The above committees may co-opt additional members as may be necessary from time to time, nominate a Joint Secretary each from the Central Electricity Commission and the Posts and Telegraphs Directorate. The headquarters of the Committee shall be at Delhi and the Posts & Telegraphs Directorate will provide secretariat assistance. The terms of office of the members will be one year.

3. Functions of the Committee

The Committee shall:

(i) Study the existing rules and regulations issued on the subject by competent authorities and suggest that modifications, if any, are called for in the light of present day researches and developments and international practices.

(ii) Initiate and undertake scientific and field studies associated with the problem of co-ordination.

(iii) Examine and study all individual co-ordination cases and recommend measures to be undertaken.

4. For carrying out the above functions, the Committee may seek the assistance of the Engineering Branches of the Posts and Telegraphs Department, the Engineering Departments of the Central and Provincial Governments and other scientific organizations in India, such as, the Indian Institute of Science, Bangalore and the Council of Scientific and Industrial Research, New Delhi, in carrying out various field studies and experiments.

5. In order that field tests and investigations may be carried out by various scientific bodies and the Posts and Telegraphs Department on behalf of the Committee, it is recommended that the Central, Provincial and State Governments whose co-ordination problems are to be considered, should provide in their annual budgets necessary lump sum grants for the purpose.

ORDER

ORDERED that this Resolution be communicated to all provincial Governments, all Chief Commissioners, the Ministries of the Government of India (including Joint Secretaries, Ministry of Finance, Defense Division, I&C Division and Communications Division). The Cabinet Secretariat, the Prime Minister's Secretariat and the Private and Military Secretaries to his Excellency the Governor General.

ORDERED so that the Resolution be published in the Gazette of India, for general information.

Sd/-
(B.K. Gokhale)
Secretary

Appendix II to Chapter I

(Refer Para 3.1)

Government of India
Ministry of Works, Mines & Power

No.EL.II-151 (7) **Dated, New Delhi, the 19th September 1949**

From : Shri S. Neelakantam,
Dy. Secretary to the Govt. of India.

To,
All Provincial Governments, Chief Commissioners and State Governments.

Subject: Co-ordination between Power & Telecommunication Systems.

Sir,

I am directed to invite the attention of all Provincial Governments etc to the Resolution of the Government of India, in the Ministry of Works, Mines and Power No. EL.II-151 (7) dated the 30th May 1949, constituting a Central Standing Committee on co-ordination of Power & Telecommunication systems. This Committee has commenced its labours and in its first meeting held in New Delhi on the 11th August, 1949 has formulated the general procedure and principles which it will adopt. The Committee has already begun the task of examining the problems of Co-ordination of Power and Telecommunication systems and of carrying out detailed scientific investigations with a view to evolve satisfactory solutions to them. In this work, the Committee will generally be guided by the recommendations of the 'Comite Consultatif Internationale Telephonique a grande distance'. It is, however, felt that situations may arise where rigid application of the recommendation of the CCIF cannot be enforced without causing considerable inconvenience either to Power or Communication authorities. Such cases will be examined in the light of field experiments and recent data available in the other countries. The Committee proposes to deal with these individual problems as they arise and in this connection, has formulated the following general points for its guidance.

(a) In any interference situation, the Committee will give careful consideration to the various possible methods of reducing the interference to the permissible limits and recommend to the parties concerned that method which involves the least cost to the country (irrespective of the system on which these measures are carried out) consistent with the proposed measures being technically sound and efficient.

(b) The least cost mentioned in Item (a) above will take into account the first cost as well as the present value of the increase or decrease in the recurring maintenance costs.

(c) Whether the remedial measures are carried out on the power line or on the communication line, the apportionment of the cost as between the participating parties and/or Governments will be worked out in each case with the due regard to existing laws and established practice.

2. It is expected that the rapid development of power and communication services in the country is likely to give rise to a large number of difficult interference situations. In order not to hold up the progress of these important projects, it is urgently necessary to find acceptable solutions to the problems.

3. Accordingly, in order to facilitate and expedite decisions in the case of any new transmission lines or modifications to the existing lines, it is requested that the co-ordination committees is apprised of the intentions of the Provincial Governments, Licensees etc. in regard to schemes for the construction of transmission and distribution lines together with all relevant details required for the construction of the question. All Provincial Governments, State Governments, etc, are therefore requested to advise the heads of their respective Electricity Departments to forward to:

(a) The Joint Secretary (Power), Power Telecommunications Co-ordination Committee, Central Electricity Commission, Shimla and also to-

(b) The Joint Secretary (Telecommunications), Power Telecommunications Co-ordination Committee, P&T Directorate (Development Branch), Eastern Court, New Delhi.

Particulars asked for in the enclosed questionnaire of all transmission line schemes, which are either under construction or have been projected. Further, the Electrical Inspectors of the Provincial Governments may also be requested to instruct the Electricity Supply Licensees to take similar action in respect of transmission lines being constructed by them. In the case of those states where there are no Electrical Inspectors, the State Governments may directly advise the Electricity Supply Licensees in their jurisdiction in regard to this matter.

4. The Provincial and State Electricity Departments or Electricity Licensees desiring information regarding telegraph or telephone installations in their areas may consult the local Divisional Engineers Telegraph or the Directors of Telegraphs.

Yours faithfully,

Sd/-
(S. Neelakantam)
Deputy Secretary to the Government of India

Appendix III to Chapter I

(Refer Para 3.2)

Rules of Business of the Central Standing Committee for Co-ordination of Power and Telecommunication Lines (Adopted in the Central PTCC Meeting held on 24.03.72)

2. The Government of India has constituted a body called Central Standing Committee of Co-ordination of Power and Telecommunication lines, hereafter referred to as the Power and Telecommunication Co-ordination Committee (PTCC) under Resolution No. II-151 (7) dated 30.5.1949, generally to exercise such functions and duties as assigned and in such manner as prescribed by the Government and in particular to:

   (i) Study the existing rules and regulations issued on the subject by competent authorities and suggest what modifications, if any, are called for in the light of present day researches and developments and international practices.

   (ii) Initiate and undertake scientific and field studies associated with the problem of co-ordination.

   (iii) Examine and study all individual co-ordination cases and recommend measures to be undertaken.

   (iv) To consider and make recommendations to Government on all matters concerned affecting power and telecommunication systems.

3. The PTCC hereby makes the following Rules of Business in order to facilitate its working and carrying out its functions and duties.

4. **Short Title**

   (i) These may be called the Rules of Business of the Power and Telecommunication Co-ordination Committee.

   (ii) They shall come into force with immediate effect.

   (iii) Any acts done by the PTCC hereafter would be considered to have been done under these Rules.

Part I

5. **Definitions**

   In these Rules unless the context otherwise requires:

   (i) PTCC means the Power and Telecommunication Co-ordination Committee.

(ii) Chairman means the Chairman of the PTCC.

(iii) Vice- Chairman means the Vice-Chairman of the PTCC.

(iv) Member means Member of the PTCC nominated by Government of India

(v) CWPC (PW) means Central Water & Power Commission (Power Wing) while P&T means Posts and Telegraphs Department.

(vi) Joint Secretary (Power) means Joint Secretary of the PTCC and Joint Secretary (Telecom) means Joint Secretary of the PTCC respectively from CWPC (PW) and Post and Telegraph.

(vii) Meeting means meeting of the PTCC.

6. All other works and expressions used herein and not defined specifically shall have the meanings respectively assigned to them in the Indian Telegraphs Act 1885, the Indian Electricity Act 1910 and the Indian Electricity (Supply) Act 1948.

Part II

The PTCC and its Secretariat

7. Composition

(i) The PTCC shall comprise of all the members nominated to it by the Government of India from time to time.

(ii) The PTCC has the option to co-opt additional members as may be necessary from time to time.

(iii) The Deputy Director (PTCC) of the CWPC (PW) and the Divisional Engineer (Telegraphs) of Posts and Telegraphs Department will be the Joint Secretary (Power) and Joint Secretary (Telecom) respectively of the PTCC.

8. Headquarters of the PTCC

(i) The PTCC shall have its headquarters at New Delhi provided that in the interest of the work, the Central Government may shift the headquarters in part or full to any other place within the Union of India.

(ii) The power side of the PTCC would be attached to the CWPC (PW) and the telecommunications side to the P&T Department.

9. Tenure of the PTCC and election of its Chairman and Vice-Chairman

The tenure of the present PTCC will be two years commencing from 1st April 1972. The nominees of CWPC (PW) and P&T in alternate years by rotation will hold the offices of Chairman and Vice-Chairman for one financial year. The PTCC can extend the term of the Chairman and Vice-Chairman, if they otherwise continue to be members of the PTCC.

10. Functions of the Joint Secretaries

Joint Functions

(i) Obtaining data regarding specific proposed power parallelism cases in the standard questionnaire from together with fault current calculations

(ii) Preparation of draft approval in specific cases after scrutiny and submission to the PTCC for decision. (Normally, the concurrence of the two Joint Secretaries should be sufficient to issue the clearance based on approved practices)

(iii) Collaboration with foreign bodies and Indian Power Administrations for collection of statistical and engineering data on the subject. In this matter wherever and when necessary, the advice of Regional Communication and Power Engineers will be availed of to assist in the investigation of special problems and the collection of technical data.

(iv) Maintenance of the accounts for their respective divisions for each financial year.

(v) Follow-up action on the decisions of the PTCC.

(vi) Issuing of instructions on behalf of the PTCC for research work and field tests.

(vii) Arrangements for publication of Technical Reports.

Functions of Joint Secretary (Power)

(i) Arranging to get necessary and relevant data in regard to power lines and systems together with values of earth resistivity measurements from the field units.

(ii) Calculation of induction in individual cases and safe separating distances in specific instances for cases of lines of 220 kV and above.

Functions of Joint Secretary (Telecom)

(i) Obtaining necessary and relevant data in regard to all telecommunication lines involved in cases referred to the PTCC from field units.

(ii) Checking the calculations carried out by the Joint Secretary (Power) and communication of route approvals in individual cases.

11. Meetings of the PTCC

(i) The PTCC shall hold its meetings as frequently as possible but not less than once is six months.

(ii) The meetings of the PTCC may be convened at any place within the Union of India. Generally the meetings are taking place once in a quarter.

(iii) The meetings shall be convened by the Joint Secretary attached to the wing to which the Chairman belongs, with the approval of the Chairman.

(iv) The Chairman or in his absence, the Vice-Chairman, will preside over the meetings of the Committee. In the absence of both the Chairman and Vice-Chairman at a PTCC meeting, the members present shall elect a Chairman from among the members present who will preside over the same and conduct its business.

(v) Notice of not less than a month shall be given to members regarding the meetings. A tentative agenda shall also be circulated along with this notice. Extraordinary meetings can be convened at short notice, if necessary.

(vi) The Agenda notes of the meeting shall be prepared by the Joint Secretary convening the meeting and circulated at least a fortnight in advance. The minutes of the meeting shall be drafted by the Joint Secretary convening the meeting and approved by the Chairman of the meeting before being circulated to all members.

Part III

12. Work of the PTCC

The PTCC shall carry out the functions already outlined in Para 1. For carrying out these functions, the Committee may seek the assistance of the Engineering Branches of the P&T Department, the Engineering Departments of the Central and State Governments, State Electricity Boards and other Scientific Organizations and Institutions in India like the IIT's, IISc, Bangalore, Council of Scientific and Industrial Research, New Delhi, in carrying out field tests and experiments.

13. Examination of line co-ordination cases

(i) Cases referred to the PTCC shall be got examined by the Joint Secretary (Power) as outlined at 9 above [after getting such data as necessary from the Joint Secretary (Telecom) and State Electricity Boards etc] and he shall communicate the results of his examination together with suggestions regarding any protective measures necessary to the Joint Secretary (Telecom). The Joint Secretary (Telecom) shall then issue the approval after considering these results. The details of Railway owned alignments shall be communicated to the Joint Secretary (Telecom) by GM (S&T) concerned.

(ii) A list of cases approved as in (i) above shall be put up for information at the earliest meeting following.

(iii) If specific cases warrant the advice of the PTCC, the details of such cases shall be put up to the PTCC for suitable decision, by circulation, if necessary.

(iv) Where considered necessary, the Joint Secretary (Power) or (Telecom) shall arrange for necessary field experiments to be conducted, after getting the proposal approved by the Chairman or in his absence, the Vice-Chairman.

(v) In the interest of expeditious disposal of cases, the PTCC may delegate its functions, in respect of cases up to a specific level to State Level Co-ordination Committee.

(vi) The procedure for incurring expenditure relating to the PTCC shall be in accordance with the directives issued from time to time by the Government of India (The existing directives are reproduced as Annexure A).

(vii) The budget for PTCC for each year shall be subject to approval at the meeting.

(viii) An Annual Report of the work of the PTCC may be prepared and put up to Government of India every year.

Annexure A

I. Copy of letter No. EL.II-151 (26) dated the 18th January 1954 from Shri K.L. Saxena, Under Secretary to the Government of India, Ministry of I&P, New Delhi to the Chairman, Central Water and Power Commission (Power Wing), New Delhi.

Subject: **Sanction for incurring expenditure on Power and Telecommunication Co-ordination Committee work.**

Sir,

I am directed to convey the sanction of the President to the acceptance by the Central Water & Power Commission (Power Wing) of the debit raised by the Deputy Accountant General, Posts and Telegraphs for an amount equal to 50% of the actual expenditure incurred by the Power and Telecommunication Co-ordination Committee during the year 1954-55. The expenditure will be adjusted against the head '47 – Miscellaneous Departments, A.2 CW&PC (PW). A.2 (4)-Other Charges'.

The Sanction of the President is also accorded to the acceptance by the Commission of similar debits for one half of the actual expenditure incurred by the Power & Telecommunication Co-ordination Committee during 1955-56 and to be incurred in future years.

The above sanction is subject to the condition that the expenditure would not exceed the budget provision in any year of account.

II. Copy of letter no. EL-387 (1) dated the 28th June 1956 from the Under Secretary to the Government of India, Ministry of I&P, New Delhi to the Joint Secretary (Power), PTCC, CWPC (PW), New Delhi.

Subject: **Delegation of enhanced financial powers to the Chairman, Power & Telecommunication Co-ordination Committee.**

Sir,

I am directed to convey the sanction of the President to the delegation of the following financial powers for incurring expenditure within the budget provision, to the Chairman of the Power and Telecommunication Co-ordination Committee.

(a) **Cash Expenditure**

Up to the limit of Rs. 10,000/- (Ten thousand only) for any single item. For expenditure greater than the aforesaid amount, the normal Posts and Telegraphs Departmental procedures for sanction for such expenditure should be followed.

(b) **Expenditure under stores** to the extent of the amount sanctioned in the budget.

(c) **Salary of Staff employed carrying out experimental investigations in connection with the Power and Telecommunication Co-ordination Committee work** subject to the following limitations.

(i) Staff for maximum period of one year, each individual drawing a total salary of not more than Rs.300/- per month, and

(ii) The salary paid to any individual shall not exceed that admissible to a Government servant of equivalent rank.

III. Copy of letter No.III-387 (8) dated the 9th June 1952 from Shri G.D. Kshetrapal, IAS, Deputy Secretary of the Government of India, Ministry of Irrigation & Power, New Delhi to Chairman, CWPC (PW), New Delhi.

Subject: Procedure for incurring expenditure relating to the Power and Telecommunication Co-ordination Committee.

Sir,

I am directed to say that the President has been pleased to decide that from the year 1958-59 the actual estimated expenditure approved by the Power & Telecommunication Co-ordination Committee will be provided in the Budget of the Central Water and Power Commission under a separate sub-head, and the Power and Telecommunication Co-ordination Committee will be debited to the Posts and Telegraphs Department through the Accountant General, Central Revenues.

2. It will also be necessary for the Additional Chief Engineer, Jabalpur (Posts and Telegraphs Department) to incur certain small items of expenditure such as printing of stationery, railway freight for transporting apparatus for purposes of field tests etc. any such items of expenditure incurred in the Posts and Telegraphs Department may be transferred monthly to the Accountant General, Central Revenues, Nagpur for debit against Central Water and Power Commission. As far as possible, no expenditure need be incurred by the Posts and Telegraphs Department towards the end of the year, so that the clearance of the remittance items with Accountant General, Central Revenues in March Preliminary Account itself may be facilitated, leaving sufficient time for the re-debit of 50% of the expenditure to the Posts and Telegraphs Department in the March Final or Supplementary Accounts. The Additional Chief Engineer (Posts and Telegraphs), Jabalpur will also intimate to the Central Water and Power Commission to the particulars of expenditure as and when incurred in advance of the usual monthly debits referred to above. He will also furnish to the Central Water and Power Commission an estimate of the expenditure to be incurred annually for inclusion in the budget of the Central Water and Power Commission by the date specified by the latter.

Appendix IV to Chapter 1

(Refer Para 4.1)

Notification for re-organization of Central PTCC

(To be published in the Gazette of India, Part–I, Section–I)

Government of India

Ministry of Power

No.3/1/2001-Trans **New Delhi, the 11th April 2001**

Resolution

In partial modification of the Ministry of Power's Resolution No.7/5/82 – Trans dated 9th August 1982, it has been resolved to reconstitute the Central Standing Committee of Co-ordination of Power and Telecommunication Co-ordination Committee as detailed below:

Composition of the Committee

1.	Chief Engineer (LD & T), Central Electricity Authority,New Delhi	Chairman In Alternate Years
2.	Chief General Manager, T&D Circle Bharat Sanchar Nigam Ltd (BSNL) Jabalpur	
3.	Director (PTCC), Central Electricity Authority,New Delhi	Secretary (Power)
4.	Deputy General Manger, T&D Circle BSNL, Jabalpur	Secretary (Telecom)
5.	Director (Telecom), Railway Board New Delhi	Member
6.	Jt. DDG (ML), Ministry of Communication	Member
7.	Chairman/ Co-Chairman of SLPTCC	Member
8.	Director (GP), Ministry of Communication	Member
9.	Representative of Deptt. of Power	Member
10.	A representative from the Army Headquarters	Member
11.	DDG(NE), TEC, BSNL, Hyderabad	Member
12.	DET (PTCC), T&D Circle, BSNL	Member

2. The Headquarters of the Committee shall be at Delhi and the TEC, Department of Telecom will provide Secretariat assistance.

3. Functions of the Committee

The Committee shall:

(i) Study the existing rules and regulations issued on the subject by competent authorities and suggest modifications, if any, as called for in the light of present day researches and developments and international practices.

(ii) Initiate and undertake scientific and field studies associated with the problem of co-ordination.

(iii) Examine and study all individual co-ordination cases and recommend measures to be undertaken.

4. For carrying out the above functions, the Committee may seek the assistance of the Engineering Branches of the Bharat Sanchar Nigam Ltd. (BSNL), the Engineering Departments of the Central and State Governments and other Scientific Organizations in India, such as the Indian Institute of Science, Bangalore and Council of Scientific and Industrial Research, New Delhi in carrying out various field studies and experiments.

5. In order that field tests and investigations may be carried out by various scientific bodies and the Bharat Sanchar Nigam Ltd (BSNL) on behalf of the Committee, it is recommended that the Central and State Governments, whose co-ordination problems are to be considered, should continue to provide in their budgets necessary lump-sum grants for the purpose.

Sd/-
(J. Vasudevan)
Additional Secretary to the Government of India

O R D E R

Ordered that this Resolution be communicated to all State Governments, National Thermal Power Corporation, National Hydro Electric Power Corporation, the PGCIL, the Central Electricity Authority, all Regional Electricity Boards, all the Ministries of the Government of India, The Prime Minister's Office, the Secretary to the President, the Planning Commission and the Comptroller and Auditor General of India

Ordered also that the Resolution be published in the Gazette of India.

Sd/-
(P.I.Suvrathan)
Joint Secretary to the Government of India

The Manager,

Government of India Press,
Faridabad

Copy to**:**

1. PS to Minister of Power/ PS to Minister of State for Power/PS to Secretary(P)/ PS to SS(P) / PS to AS(P) / JS(FA) / JS(H) / JS(Th & A) / JS(IPC) / JS(PP&EA) /US(Coord), Ministry of Power.
2 The Chairman, Central Electricity Authority, New Delhi (10 Copies)
3. The Member (PS), Central Electricity Authority, New Delhi.
4. The Chief Engineer, LD&T Division, Central Electricity Authority, New Delhi
5. The CMD, NTPC, Scope Complex New Delhi.
6. The CMD, NHPC, Faridabad.
7. The CMD, POWERGRID, New Delhi.
8. The Member Secretary, WREB, Plot No. F-3, MIDC Area, Marol, Andheri (E),Mumbai – 4000093.
9. The Member Secretary, NREB, Katwaria Sarai, New Delhi.
10. The Member Secretary, NEREB, Nogrimbah Road, Laitumkhrah, Shillong – 703003.
11. The Member Secretary, SREB, No. 29, Race Course Cross Road, Bangalore – 560029.
12. The Member Secretary, EREB, 14 Golf Club Road, Tollygunge, Calcutta

Sd/-
(Mrs. Renu Sarin)
Desk Officer (Trans)

Appendix V to Chapter 1

(Refer Para 6.1.7)

Record of Discussions of the Sub-Committee to Examine the Conversion of Earth Return Telegraph Circuits to Metallic Return

A meeting of the above sub-committee was held on 25th January 1979 and the following were present:

(i) Shri A.K. Das, Joint Director, Telecom (G), Railway Board, Rail Bhavan,New Delhi.

(ii) Shri S.C. Buch, Ex-Engineer (PLCC), Gujarat Electricity Board, Old Padra Road, Vidyut Nagar, Baroda.

(iii) Shri C.S. Nehete, Ex-Engineer (PTCC), MSEB, Dr. Ambedkar Road, Mumbai.

(iv) Shri N.C. Gupta, Director (Maintenance), Northern Telecom Region, Kidwari Bhavan, New Delhi.

(v) Shri N.V. Krishnaswami, Deputy Director (PTCC), CEA, New Delhi.

Shri Arvind, ADG, DGP&T joined the discussions later.

1. The members of the Sub-Committee expressed the view that its report should be based on CCITT Recommendations which are:

   (i) For open-wire single wire earth return telegraph circuits – 430V for ordinary and 650V for high security power lines against danger during SLG fault condition on the power line.

   (ii) Interference is caused to the operation of the system (telegraph) when the r.m.s. value of the current from the external sources due to electrostatic or electromagnetic induction passing through one of the receivers exceeds 1/10th of the telegraph current flowing under steady state conditions of the power line.

2. The tripping times for different voltage categories of power lines indicated by the Power side representatives are as follows:

11 kV, 22 kV, 33 kV, 66 kV, 110 / 132 kV	:	0.20 to 0.50 Seconds
220 kV, 400 kV	:	0.10 to 0.15 Seconds

3. The details of the telegraph instruments used by P&T and Railways in India as per information furnished by Railways and P&T are as follows:

Type of Instrument	DC Resistance of Coils	Working Current
(i) Dubern Sounder	2 coils each of 250 ohms Normally both the coils are connected in series but in case of fault one coil is also used.	12 to 15 mA
(ii) BPO Polarized Sounder	2 coils each of 250 ohms Both connected in series.	12 to 15 mA
(iii) BPO Relay	2 coils each of 100 ohms The coils are wound differentially.	5 mA
(iv) Teleprinter	2 coils each of 240 ohms.	(i) 35 to 45 mA under single current working (ii) 20 to 35 mA with double current working
N.B.: (a) The duration of one pulse is in the range of 13.3 to 20 ms. for teleprinter telegraph circuit depending upon speed of operation. (b) The width of the signal element for the instrument at (i), (ii) & (iii) depends upon the speed of operation of the signaller.		

4. The induction during SLG fault condition may constitute hazards to the personnel as well as equipment. The clearance time for such faults on the different categories of power lines have been indicated in Para 2. During the time the fault persists on the power line, induction on the telegraph line would continue. Apart from this, the working of the telegraph circuit will also be disrupted in case the induced current in the circuit exceeds 1/10th of the normal operating current of the telegraph instruments during such faults. Under this condition, the following are the likely effects:

(i) Hazards to the personnel.
(ii) Hazards to the equipment.

Against hazards to the personnel and equipment the normal protective devices as applicable to the other affected telecom lines may suffice.

The P&T and Railway representatives stated that the telegraph circuit would not be available during the pendency of the fault on the power line in case the induced current in the circuit exceeds 1/10th of the normal operating current of the telegraph instrument. On a specific query from Shri S.C. Buch, it was indicated by the P&T and Railway representatives that in case of circuit having metallic return and arresters subjected to induction more than spark-over voltage of the arresters, the circuit will be lost during the pendency and the fault when the current through the telegraph circuit exceeds 1/10th of the telegraph current.

5. Interference

Due to their asymmetric nature, the earth return telegraph circuits are more susceptible to interference. As per CCITT, interference is caused to the operation of the system (telegraph) when the rms value of the current from the external sources due to electrostatic or electromagnetic induction passing through one of the receivers exceeds 1/10th of the telegraph current flowing under steady state condition of the power line. For consideration of this aspect, induction (electrostatic and/or electromagnetic) during normal operation of the power line will have to be computed. In case the induced current exceeds 1/10th telegraph current as indicated above, the following protective measures may have to be taken:

(i) Conversion of earth return, to metallic return symmetrical circuit.

(ii) In case, conversion of earth return to metallic return on overhead lines does not bring down the level of induced current to less than the prescribed limit, other methods such as use of shielded cables, change of route etc may have to be considered.

Note: Procedure circulated with Agenda for Central PTCC Meeting No. 81-82/3 held at Chandigarh on 26th November 1981 by Central Electricity Authority, New Delhi.

Conversion of Railway Train Wire Circuits into Metallic Return

1. Introduction

Train wire is a single wire earth return telegraph circuit used by Railway Department. It is a non-continuous circuit working on station-to-station basis (as contrast to railway control circuit which is a continuous circuit looped at every station). Due to the short length of this circuit (the length depending upon the distance between the two consecutive Railway Stations), the Railway Department uses only 12 V operating battery.

2. Procedure adopted for conversion of SWER Telegraph circuits to metallic return

As per the recommendations of the sub-committee for examining the conversion of SWER telegraph circuits to metallic return, the conversion should be done in the following cases.

If the interfering current from a power line under its normal working condition exceeds 1/10th of the normal operating current of the telegraph circuit, the telegraph circuit should be converted to metallic return. This should be examined for electromagnetic and electrostatic inductions.

(i) Electrostatic Induction

If the weighted separation between the power and telecom line for the total length of parallelism for the telegraph circuit under examination exceeds the separation obtained from the formula,

Separation $'a' = \frac{1}{12}\sqrt{E \times S}$ for 50 c/s inducing frequency

Where,
E = Service voltage of the power line in volts and
S = Length of telecom line in kilometers involved in exposure,

the telegraph circuit is not required to be converted to metallic return.

In the case of railway train wire circuits, generally the electrostatic induction is within safe limits.

(ii) Electromagnetic Induction

The mutual coupling of the telegraph circuit under examination (for full length of parallelism) is multiplied by the maximum residual unbalanced current of the power line. This value should not exceed $1/10^{th}$ of the normal operating voltage of the telegraph circuit. (The inducing current and the operating current, if desired, can be obtained by dividing these voltages by the impedance of the telegraph circuit).

In the case of train wire circuits, metallic conversion is often required on account of electromagnetic induction.

(iii) Maximum residual unbalanced currents for different categories of power lines are given as below:

Category of Power Line	Load In MW	Effective Line Current In Amperes	Maximum Unbalanced Residual Current 1.5% of Effective Line Current in Amps.
400 kV S/C	500	902	13.5
230/220 kV D/C	300	984	14.76
230/220 kV S/C	150	492	7.38
132 kV S/C	50	273	4.095
132 kV D/C	100	546	8.19
110 kV S/C	50	328	4.92
110 kV D/C	100	656	9.84
66 kV S/C	12.5	137	2.055
66 kV D/C	25	274	4.11
33 kV S/C		200	3.00
Note: In case of 33 kV S/C power line, line current in each phase is being confirmed in each individual case.			

3. Some typical cases in which train wire circuits are required to be converted to metallic return are given below:

Sl. No.	Name of Power Line	Name of Train Wire Section	Length of Paralleli-sm in Miles	Mutual Coupli-ng	Maximum un-balanced Residual Current in Amps	Disturbing EM Volt on Train Wire Current	Permissib-le EM Volt
1.	Singrauli – Kanpur 400KV S/C	1. Billi R/S -Phaprakund	6.64	0.216	13.5	2.916	1.2
		2. Phaprakund -Mangardaha	3.75	0.658	13.5	8.883	1.2
		3. Mangardaha -Mirchandhri	4.28	0.471	13.5	6.358	1.2
		4. Mirchandhri -Churki	9.2	0.793	13.5	10.705	1.2
2.	Ring Main line around Jallandhar 66 kV D/C	5. Jallandhar -Pathankot	24.2	0.448	4.11	1.841	1.2
3.	Nakodar – Nurmahal 33 kV D/C	6. Nakodr -Nurmahal	11 Km	0.8	3.0	2.4	1.2

4. Conclusion

It will be seen that in the above cases, the maximum electromagnetic voltage is 10.7V. The cases range from 400 kV to 33 kV power lines (i.e. can occur in every category of the power line). To avoid the conversion in majority of cases, the only remedy is to increase the circuit impedance by adding a resistance between the sounder and earth and increasing the battery voltage to maintain the same operating current. The following table can illustrate the case.

Operating Battery Voltage	Working Current (15 to 25 mA Mean Value 20mA)	Initial Circuit Resistance 500 ohms for Sounder Plus 100 ohms for Line and Earth at Both Ends In Ohms	Additional Resistanc-e in ohms	Net Total Resistan-ce in ohms	Permissible Electromagn-etic Induction Volts for 10% of the Operating Current.
12 V	20mA	600	Nil	600	1.2 V
24 V	20mA	600	600	1200	2.4 V
36 V	20mA	600	1200	1800	2.6 V
48 V	20mA	600	1800	2400	4.8 V
60 V	20mA	600	2400	3000	6.0 V

Appendix VI to Chapter I

(Refer Para 6.1.8)

Copy of Central Electricity Authority, New Delhi Letter No. 19/109/89/PTCC Dated 17th November 1989

Subject: Noise Sub-committee Report.

Dear Sir,

As you are all aware that the Central PTCC in its meeting held at Bhubaneshwar on 29.7.1983 set up a Sub-committee to go into the problem of noise interference due to power line on paralleling communication circuits and suggest remedial measures. The Sub-committee carried out studies and conducted a few tests during its period and submitted a report. The same is enclosed herewith for your kind perusal. Based on the report Chairman, Central PTCC, in the meeting held at Chennai on 29.10.1987 suggested that this Committee may be wound up. He further suggested that in future such problems should be sorted out directly by discussions among Central Electricity Authority, Department of Telecom and Railways as and when required.

Yours faithfully,
Sd/- (D.P. Sinha)
Director (Telecom & PTCC)

Enclosure to Central Electricity Authority, New Delhi Letter No. 19/109/89-PTCC dated 17th September 1989

Report of the Noise Sub-Committee (1983-87)

Introduction

The problem of noise interference due to power lines on railway communication circuits was first reported from Southern Region way back in 1981. This noise was related to the two-phase operation of 11 and 22 kV power lines of Tamil Nadu Electricity Board. A study team investigated the problem and carried out tests on the affected circuits during 21st and 23rd April 1981. It was observed that the noise on communication circuits increased due to two-phase operation of the power lines. The Central PTCC, therefore, requested Tamil Nadu Electricity Board to discontinue the two-phase operation of the power lines wherever there were noise problems on communication circuits. Since then, there were representations from the Department of Telecommunication about noise interference in communication circuits due to power lines/cables and they have been insisting that some standards be laid for limiting noise due to power lines. The power side requested Department of Telecom to cite specific examples where noise interference was observed so that they could be studied, where the noise problem arose due to power line operation in the vicinity. However, no specific cases were referred for a long time even though there was increasing insistence from Department of Telecom for the study of the noise interference problem. Taking cognizance of this demand from Department of Telecom, the Central PTCC at its meeting held at Bhubaneswar on 29th July 1983 set up a Sub-Committee to go into the problem and suggest remedial measures. The constitution and terms of reference of the Sub-committee are annexed.

Meetings of the Sub-Committee

The first meeting of the Sub-committee was convened on 10th November 1983 at New Delhi to consider the cases referred by DET, PTCC, Northern Region, even though there was no noise interference in these cases except that there were some standing voltages on certain communication circuits as reported by DoT. A detailed discussion on the methods of calculations of noise interference based on the formulae enumerated in CCITT Directives was carried out and it was decided that the calculations would not yield any reliable and practicable results. However, the Committee felt that though there were no reported cases of noise interference, some appear to exist. Hence, it was decided to investigate specific cases, if any, reported to the Sub-committee.

Field Test

The Noise Sub-committee in its second meeting held on 30th July 1986 decided to carry out actual noise measurements on Janakpuri-Najafgarh junction cable where interference due to noise was reported by DET, PTCC Northern Region. Shut down from the Najafgarh Sub-station was to be arranged with the help of DESU to carry out the tests.

After making required arrangements including arrangement of shut down of 11 kV feeders, actual noise measurements were carried out on certain pairs of the cable on 20th August 1987 at Najafgarh exchange. Representatives of Central Electricity Authority, TRC & DoT participated in the measurements.

It was decided to take noise measurements on the same 11 numbers of pairs on which noise was earlier noticed by DET, PTCC, Northern Region. These 11 numbers of pairs were identified by DoT for noise measurement and were got opened from Janakpuri end. To simulate terminating impedance of 600 ohms, it was decided to connect to each pair a telephone set which has a nominal impedance of 600 ohms. It was proposed to measure the psophometric noise with a psophometer and both weighted and flat noise observations were to be recorded.

Procedure

Before starting the measurement all the 11 kV feeders emanating from Najafgarh S/S were shut-off and psophometric noise was measured on the selected 11 numbers of pairs. On a pair 4/5/12, when the psophometer was connected the needle started shaking violently and no steady measurement was possible. The pair was later detected to be ‘open’. Each of the pair was accordingly checked for continuity and it was found that in all 5 pairs were open and therefore declared 'Faulty'. Steady observations on the psophometer were recorded for remaining 6 numbers of pairs. The psophometric noise was recorded on each of the 'healthy' pairs again after all the 11 kV feeders had been switched ON from Najafgarh S/S.

Observations

The set of observations recorded, both weighted and flat are annexed. It may be seen that the psophometric noise on different pairs vary from 0.2 to 90 mV when the 11 kV supply is OFF and 0.3 mV to 120 mV when the 11 kV supply is ON. This large variation in the psophometric noise for different pairs of the same cable indicates different characteristics of each pair of the cable under measurement.

As can be seen from the observations, the psophometric noise on the junction cable increased from 0.1 to 30 mV for different pairs and in one case it actually decreased by 0.8 mV.

Conclusion

From the observations recorded for Janakpuri-Najafgarh junction cable it is seen that the pairs under measurement are totally unbalanced. This is brought out by widely differing psophometric noise on different pairs even when the 11 kV feeders were OFF. The measurements on pair 4/6/27 are highly revealing, as the psophometric noise is observed to be 2.5 mV when the power lines were OFF and 1.7 mV when the power lines were ON. This decrease appears possible only due to the high stray capacitive effect of the pairs with respect to earth. It is suspected that water/moisture might have seeped in the cable, resulting in stray earth capacitances, thus unbalancing the different pairs within the same cable. The most perfectly balanced pair comes out to be 4/5/10 pair for which measured psophometric noise when power lines are OFF is 0.2 mV and when power lines are ON is 0.3 mV, the variation being well within the permissible limits. The noise being observed appears purely due to fault in the cable pairs due to seepage of water or some similar reasons creating unbalance. It may be significant to note that the same pairs (which were tested now) were got tested for psophometric noise by DET, PTCC in December 1984 and he detected Noise. In the meeting held on 30th July 1986 he further stated that the Noise had disappeared after the investigation but had reappeared. Since monsoon rains do set in around that time of the year, the rain water might have seeped in the cable again, unbalancing the pairs, thus, creating psophometric noise. There had been no change as far as surrounding power lines are concerned to warrant any variation in the noise levels. This clearly shows that the condition of this junction cable is not good and the noise notified is only due to the faulty cables and not due to induction from power lines.

Observations Recorded at Najafgarh Exchange on 20th August 1987 from 1100 Hrs to 1500 Hrs.

BEFORE SHUT DOWN				AFTER SHUT DOWN (only 11 kV feeder off)			
Sl. No.	Cable Pair No.	Psophometer Reading		Sl. No.	Cable Pair No.	Psophometer Reading	
		Weight-ed	Flat			Weight-ed	Flat
(i)	4/5/10	0.3 mV	0.3mV	(i)	4/5/10	0.2 mV	0.5 mV
(ii)	4/5/12	-faulty-	-	(ii)	4/5/10	-	--
(iii)	4/5/17	3.5 mV	3.5 mV	(iii)	4/5/17	2 mV	2.25 mV
(iv)	4/5/39	6 mV	6 mV	(iv)	4/5/39	5 mV	5 mV
(v)	4/6/2	-faulty-	-	(v)	4/6/2	-	-
(vi)	4/6/3	10 mV	10 mV	(vi)	4/6/3	6 mV	6 mV
(vii)	4/6/19	-faulty-	-	(vii)	4/6/19	-	-
(viii)	4/6/21	-faulty-	-	(viii)	4/6/21	-	-
(ix)	4/7/7	1.7 mV	2.5 mV	(ix)	4/6/27	2.5 mV	2.5 mV
(x)	4/7/7	0.12 V	0.12V	(x)	4/7/7	0.09 V	0.09 V
(xi)	4/7/12	-faulty-	-	(xi)	4/7/12	-	-

Annexure

Terms of Reference of the Noise Sub-Committee.

1. The levels of Noise under conditions of normal operation from power lines of the open wire type on telecommunication lines and cables. The Sub-committee would study the existing international regulations in this regard particularly the CCITT directives and examine limits, which could be laid down under Indian conditions.

2. Similar study in respect of underground power cables. The immediate problem is in regard to the limits to be tolerated from such cables.

3. The protective measures that can be adopted on the power lines as well as telecommunication lines to bring down the existing level of noise to the specified limits.

4. Aspects of cost sharing with regard to protective measures.

Appendix VII to Chapter I

(Refer Para 6.2.5)

Minutes of the Sub-Committee Meeting For Information of Norms For PTCC Clearance of HVDC Lines

(Circulated vide C.E.A., New Delhi Letter No. 19/117/87-PTCC dated 3rd February 1987)

The meeting of the Sub-committee for formation of norms for PTCC clearance of HVDC lines was held on 2nd February 1987 in the office of the undersigned. The list of the participants is enclosed.

1. Details of the smoothing Reactors provided on each pole of the DC line (already furnished by NTPC) were discussed. It was shown from the calculations that the fault currents are limited to within 1.4 kA/m Sec. It was further clarified that the above value is much lower than the transient currents occurring during ground faults on AC transmission lines. Hence, it was logically concluded that there is no possibility of any hazard due to induced voltage during ground fault conditions.

2. The maximum allowable levels for the longitudinal induced noise voltage due to DC line harmonics on a parallel telecom line at a lateral distance of 1 kilometer from the DC line, based on stringent requirements was tentatively agreed as:

For Bipolar Operation	10 mV/km
Monopolar Metallic Return	20 mV/km
Monopolar Earth Return	30 mV/km

The above values were as suggested by the consultants M/s Hydro Quebec.

The above values for the bipolar and monopolar modes have also been used as a criterion in several cases as mentioned clearly in Reference (1) and have been taken as guiding values and design criteria for other HVDC lines.

3. It was decided that the actual values of induced voltage would be measured after construction of the Rihand – Delhi HVDC line and the need for relaxation of the above norms could be examined at that stage.

4. As regards the transverse voltages on the telecom line, it was decided that the same could be examined separately at a later date depending on requirements.

Sd/- (D.M. Rao)
Deputy Director (PTCC)

Reference (1): DC Filter Design Methods for HVDC Systems-R.H. Lasseter etc. at IEEE Transactions on Power Apparatus and Systems Vol. PAS-96 No. 2 March/April 1977.

Members present at the meeting of the Sub Committee to evolve norms for PTCC clearance of HVDC lines.

(ii) Telecommunication Research Center

(a) Shri Tej Singh, Asstt. Director (SE)

(ii) NTPC

(a) Shri M.Barat, Engineer (T)
(b) Shri R.S. Moni, Engineer (PS-HVDC)
(c) Shri Rebati Dass, Engineer (PS-HVDC)

(iii) Central Electricity Authority

(a) Shri D.M. Rao, Dy. Director (PTCC)
(b) Shri Ram Swarup, Dy. Director (PTCC)
(c) Shri D.K. Malik, Asstt. Director (PTCC)

Appendix VIII to Chapter I

(Refer Para 6.2.6)

Recommendations Based On the Minutes of the Meeting Held between Delhi Electric Supply Undertaking (DESU) and Department Of Telecommunications Held on 23rd March 1987

1. (i) Para 6.3.2, Page 16 of IS: 1255/1983

Due to various practical difficulties, particularly the aspect of pushing up the cost of laying of cables in case of increased depths, depths as proposed by Telecommunication Department, are not accepted. The existing depths as provided on Page 16 of IS: 1255 may stay.

(ii) For Road crossing of all Cables.

The cable shall be laid through the adequate size of pipes crossing the road.

Along the roadside concrete covers with marking on all cables of 11 kV and above shall be provided. (The present practice is that for 11 kV cables bricks are provided to cover the cable, which is considered not an efficient and durable arrangement).

2. (i) Para 6.3.3 – Clearance

In Delhi it may be difficult to obtain proposed clearance of 0.6 meters between Power Cable and Telecommunication Cable due to pressure on space allocated for routes to provide various underground services, hence it may not be possible to achieve. However, in other places in India wherever it could be achieved should be provided. Accordingly, it was agreed that Para on Clearances should be reworded as under:

- Power Cable to communication cable — Preferably 0.6 meters but not less than 0.3 meters at any point.

- For identification of the underground cable provision for route markers should be made suitably to read as under

- Route Markers – Suitable route markers/indicators indicating disposition of the cable be provided.

Note: Para 6.3.2 and 6.3.3 of IS: 1255/1983 is reproduced below for ready reference.

6.3.2 Depth

The desired minimum depth of laying from ground surface to the top of cable is as follows:

High voltage cables, 3.3 kV to 11 kV rating	: 0.90 m
High voltage cables, 22 kV, 33 kV rating	: 1.05 m
Low voltage and control cables	: 0.75 m
Cables at road crossings	: 1.00 m
Cables at railway level crossings (measured from bottom of sleepers to the top of pipe)	: 1.00 m

6.3.3 Clearance

The desired minimum clearances are as follows:

Power Cable to power cables	:	Clearance not necessary; however, Larger the clearance better would be current carrying capacity.
Power cables to control cables	:	0.20 m
Power cable to communication cable	:	0.30 m
Power cable to gas/water main	:	0.30 m

Inductive influence on sensitive control cable on account of nearby power cables should be checked.

Appendix IX to Chapter I

(Refer Para 6.3.7)

Protection of Telecommunication Line from High Induced Voltage with Gas Discharge (GD) Tubes by using 20 GD Tubes Formula

1.0 Introduction

Owing to vast expansion in Power & Telecommunication sectors number of power lines happen to run parallel to telecommunication lines. Telecommunication lines, therefore, need to be protected from low frequency induction in the event of single line to ground fault on paralleling power lines when the induced voltage exceeds the prescribed safe limit of 430 volts. Telecom personnel working on these circuits and the equipment installed need also to be protected from the influence of hazardous potentials.

One of the measures commonly adopted is the installation of Gas Discharge (GD) Tubes on telecom lines in paralleling section. Under the normal conditions, the telecom line is kept insulated from earth by it. When the induced voltage exceeds the striking voltage of the GD tube, it conducts and offers low resistance path to earth, bringing down the induced voltage to safe limits.

Dividing the induced voltage by 300 volt and rounding them off to next higher number generally arrive at the number of GD tubes installed. One GD tube each is installed at both ends and the remaining are placed at equidistance intermediate points on telecom line in the paralleling section. This procedure is adopted where the induced voltages are in the range of 430 to 2000 volts. When the induced voltage is 2000 volt or more then the number of GD tubes is to be arrived at by using 20 GD tubes formula.

2.0 Formula

As per 20 GD tubes formula, the number of Gas Discharge Tubes required to be installed on telecom line for protection against induced voltage can be calculated as under:

(a) For high reliability power line (more than 33 kV): $650 \geq \frac{E}{N}\left[1+\sqrt{\frac{10N}{Z}}\right]$

(b) For low reliability power line (up to 33 kV) : $430 \geq \frac{E}{N}\left[1+\sqrt{\frac{10N}{Z}}\right]$

Where E = Induced Voltage in volts.
N = Number of Gas Discharge Tubes required
Z = Total Impedance of effected portion of telecom line in ohms.

Again $Z = Z_0 \times L$

where Z_0 is Impedance per kilometer of telecom line in ohms per km.

L is Length of parallelism in km.
Z_0 is in ohms per km. for different wires:

5 AWG ACSR	0.65 ohms/km
7 AWG ACSR	0.704 ohm/km
300 lbs/mile copper	0.66545 ohms/km
242 lbs/mile copper weld	0.89 ohms/km
300 lbs/mile iron wire	1.522 ohms/km
100-lbs/mile-iron wire	4.27 ohms/km

The above cited formula was accepted by Department of Telecommunications vide DG P&T letter No. 130-21/83-TPL (TX) dated 6th August 1983.

3.0 Limitations

3.1 This formula should be applied only in such cases where the induced voltage is 2000 V or above.

3.2 By applying this formula, the maximum number of Gas Discharge Tubes, which could be permitted to be installed on a telecom line for protection against induced voltage, is restricted to 20 (Twenty) only. Provision of more than 20 GD tubes on a telecom line leads to degradation of 'Quality of Speech' including increase in 'Cross-talk'.

If the number of GD tubes exceeds 20, it becomes a case of re-engineering in which either the affected telecom lines are to be shifted to a safer distance to bring induced voltage within permissible limit or media of communication is to be changed.

3.3 Since increase of Noise and Cross-talk up to installation of 20 GD tubes is within permissible limits as tested by TRC, New Delhi, Department of Telecommunications, Government of India, has permitted the use of 20 GD tubes for protection because power sector were vehemently pressing for increase of induced voltage limit from 2000 to 6000 V.

4.0 Example

DANTEWALA	-	SUKMA LINE
1 pair	-	5 AWG

Length of parallelism with high reliability power wire = 35.18 miles

Induced voltage on telecom line due to high reliability power line = 2430 volts

Calculation for ascertaining requirement of GD tubes to bring induced voltage within permissible limits.

$$650 = \frac{E}{N}\left[1 + \sqrt{\frac{10N}{Z}}\right]$$

$$Z = Z_0 \times L$$

Line Impedance Z_0 = 0.65 ohm/km.

L = 35.18 x 1.6 kms.

Z = 35.18 x 1.6 x 0.65

$$650 = \frac{2430}{N}\left[1 + \sqrt{\frac{10N}{35.18 \times 1.6 \times 0.65}}\right]$$

$$\frac{65}{243} = \frac{1}{N}\left[1 + \sqrt{\frac{10N}{56.288 \times 0.65}}\right]$$

$$0.2674 = \frac{1}{N}\left[1 + \sqrt{\frac{10N}{36.5872}}\right]$$

$$[0.2674 - 1]^2 = \frac{10N}{36.5872}$$

$$0.071556N^2 + 1 - 0.535N = 0.2733196N$$

$$0.0716N^2 - 0.8083N + 1 = 0$$

$$N = \frac{0.8083 \pm \sqrt{0.6533 - 0.2864}}{0.1432}$$

$$N = \frac{0.8083 \pm \sqrt{0.3699}}{0.1432}$$

$$N = \frac{1.4140}{0.1432} = 9.8747$$

Say, 10

Substituting for N

$$\frac{2430}{10}\left[1 + \sqrt{\frac{10 \times 10}{35.18 \times 1.6 \times 0.65}}\right]$$

$$243\left[1+\sqrt{\frac{100}{36.5872}}\right]$$

=243 9(1+ 1.6532)

= 644.73685

Say, 645 Volts

Thus number of GD tubes required to be fitted on telecom line to bring induced voltage within permissible limits = 10 (Ten) only.

Appendix X to Chapter I

(Refer Para 6.4.6)

Subject: 'Time Limit' for Various Steps Involved in PTCC Clearance

Reference: Revision of Time Limits for various stages involved in PTCC clearance.

Chief General Manager, T&D Circle, Jabalpur Letter No.TD/LP-2012/General Dated 30.12.2009.

With mutual consent between CEA and Inspection Circle, BSNL the time limits for various stages involved in PTCC clearance have been revised. These recommendations are given below. It is requested that the concerned field units of BSNL Circle/Power Utilities/Railways may kindly adhere strictly to these time limits forthwith and thereby ensure speedy clearance of cases referred to Power and Telecommunication Co-ordination Committee.

A. For obtaining PTCC route approval

(i) For Approval of 11 kV Lines – Approval by the respective DE's (Telecom)

(a) 4 weeks if the power line proposal pertains to single case.
(b) 5 weeks if the cases are referred in-group.

(ii) For 22 kV/33 kV Power Lines – Approval by the State Level

(a)	Furnishing the telecom details by P&T/ Railway/Army etc.	4 weeks
(b)	Examining cases and computing the Induced Voltage (IV) calculations and forwarding the same to Railways, if required.	2 weeks
(c)	Forwarding recommendations by Railways	2 weeks
(d)	Final examination and issue of certificate	1 week

(iii) For 33 kV D/C and above up to 132 kV Power Lines (Central Cases)

(a)	Furnishing telecom details by P&T/ Railway/Army	6 weeks

(b)	Scrutinizing the details, preparing copies & forwarding to concerned Electricity Board by DET PTCC.	1 week
(c)	Furnishing I.V. calculations by Electricity Board and endorsing copies to all concerned	6 weeks
(d)	Furnishing recommendations by Railway /Army	2 weeks
(e)	Final examination & Issue of certificate	2 weeks

(iv) For Approval of Power Lines above 132 kV (Central Cases)

(a)	For furnishing telecom details by P&T/Railways/Army.	8 weeks
(b)	Scrutinizing the details, preparing additional copies and forwarding to Joint Secretary Power.	1 weeks
(c)	Furnishing Induced Voltage calculation by Joint Secretary Power & endorsing copies to all concerned.	6 weeks
(d)	Furnishing recommendations by Railways/ Army.	2 weeks
(e)	Final examination and issue of certificate	2 weeks

(iii) For approval of Cases from P&T/Railway/Army for the construction of Telecom Lines, laying Coaxial Cables etc.

(a)	For marking and furnishing power line details of various categories of power lines separately to the AE (PTCC) (up to 33 kV) to the concerned Electricity Board authority (for cases of 33 kV D/C and above up to 132 kV) and to the Joint Secretary (Power), C.E.A. (for cases above 132 kV)	10 weeks
(b)	Computing Induced Voltage calculation by AE (PTCC)/Electricity Board/Joint Secretary (P).	6 weeks
(c)	Furnishing recommendations by Railways/ Army	2 weeks
(d)	Final examination and issue of certificate	2 weeks.

B. For protective works after the PTCC approval

(a)	For quoting the charges and furnishing Estimate	4 weeks
(b)	Arrangement for payment	4 weeks
(c)	Execution of protective works by P&T	10 weeks
(d)	Execution of protective works by Railways	6 weeks

Notes:

1 In general, the time schedule recommended for the various functions shall not apply to cases where re-engineering is involved. Even for such cases the appropriate authorities may quote the reasonable time required for the re-engineering.

1. The period for implementing the protective works has been recommended assuming the essential materials for those works would be available in reasonable time.

2. If the protective works are to be undertaken by the Department or Agencies other than the Unit submitting the proposal, every attempt should be made for speedy completion of the protective works. However, energization shall not take place if the protections are not completed.

3. The time limits prescribed are indicative only and may vary depending upon the length of Power line.

C. For watch and monitoring

- Cases below 33 kV: - Necessary monitoring and watching would be done by the respective State Level PTCC Committees.

- The Standing Sub-committee will examine badly delayed cases of 33 kV D/C and above.

- Information pertaining to such cases would be called for in the prescribed form from the various DET's (PTCC) for review by the Sub-committee.

PROFORMA

Appendix XI to Chapter I

(Refer Para 6.4.7)

Government of India
Power & Telecommunication Co-ordination Committee

No………… Date…………

Certificate of Approval to the Route of Extra High Tension (EHT) Power Line / Telecommunication Line

Approval of the Power & Telecommunication Co-ordination Committee is hereby conveyed to the route of …………………………….EHT Line/Telecommunication Line/Cable particulars of which are given in Annexure I.

The approval is for the route only and is subject to the following conditions.

1. The approval is based on the Power system/Telecom system conditions' details as reported by the Power supply authority/Telecom authority at present. Any changes either to Transmission line or the Power system or the paralleling telecommunication lines which are likely to alter the low frequency induction from the estimated at present should be reported to PTCC for its prior approval.

2 The Power and Telecommunication authorities shall be required to adopt such measures as may be recommended by PTCC for counteracting any interference that might arise when the EHT line is in normal operation.

3. Each crossing should satisfy the condition as laid down in Para 6 -10 of PTCC Code of Practice for crossings.

4. The angle of crossing shall be 90 degree but in no case less than 60 degree.

5. The power line shall be equipped with protective switchgear such that the duration of earth current shall be as short as possible but never exceeding 0.5 seconds.

6. The power line shall be energized within a mutually acceptable time limit after obtaining a Certificate from concerned Telecom and/or Railway authority regarding completion of provision of all protective measures as recommended by PTCC and also under specific clearance from the Telecom and/or Railway authority maintaining the Telecom system.

7. The energization of Extra High Tension power lines would not be held up for want of installation of GD tubes on telecom lines when the induced voltages are in the range of 430 to 650 V.

8. The telecom line shall be commissioned within a mutually acceptable time after completing provision of all protective measures as recommended by PTCC and also after obtaining a specific clearance from Power authority, if certain measures as recommended by PTCC are to be carried out on power system.

9. The later entrant in the field shall bear entire cost of providing GD tubes and their fitting as recommended by PTCC including 15% spares and/or any other protective measures as recommended by PTCC.

10. The route approval shall be subject to special condition as laid down under Annexure II.

DET(PTCC)
Power & Telecommunication Coordination Committee.

Note:

(i). Proforma for Annexure I, separate for Power Lines and Telecommunication lines is given in the following pages. For Cables, the same proforma may be used with suitable modifications, where necessary.

(ii). Special conditions, if any, may be separately listed and enclosed as Annexure II.

Annexure I
(For Power Lines)

1. (a) Name of the Power Supply authority seeking approval
   (b) Reference number & date:
   (c) Probable date of energization:

2. (a) Name of the power line:
   (b) Route map number & date:
   (c) Operating voltage:
   (d) Length of HT line:
   (e) Number of circuits:

3. (a) Names of paralleling telecom lines:
   (b) Length of parallelism:

4. Average value of earth resistivity in the region:

5. Whether LF test necessary:

6. Fault Current & induced voltages etc:

Sl. No	Name of the Telecom Line/Circuit	Length of Parallelis-m in kms	Maximu-m Fault Current in Amps	Mutual Couplin-g in Ohms	Net Induced Voltage in Volts	Safe Separatin-g Distance in Metres

Annexure I

(For Telecom Lines)

1. (a) Name of the Telecom authority seeking approval:
   (b) Reference number & date:
   (c) Probable date of energization:

2. (a) Name of the telecom line:
   (b) Route map number & date:
   (c) Length of telecom line:

3. (a) Names of paralleling power lines:
   (b) Length of parallelism:

4. Average value of earth resistivity in the region:

5. Whether LF test necessary:

6. Fault current & induced voltages:

Sl.No.	Name of the Telecom Line/Circuits	Length of Parallelism in kms.	Mutual Coupling in Ohms	Estimate-d Fault Current in Amps	Likely Inductio-n in Volts.

Appendix XII to Chapter 1

(Refer Para 6.6.7)

Comments of Secretary, Central Electricity Board

(Circulated as Annexure VII to Agenda for Central PTCC Meeting Held at Jaipur on 6th November 1986)

1. Section 32 of the Indian Electricity Act 1910, stipulates that every person generating, transmitting, supplying or using energy shall take all reasonable precautions in constructing, laying down and placing his electric supply lines and other works and in working the system so as not to injuriously affect whether by induction or otherwise the working of any wire or line used for the purpose of telegraphic, telephonic or electric signaling communications or the currents in such wire or line.

   The disputes arising out of contravention of the above mentioned provisions contained in Section 32(1) are required to be referred to the Central Government who may direct the owners of the power line to make such alterations and additions which may be necessary for the compliance of these provisions, provided that the telecommunication lines were already in existence prior to the coming of the power lines.

   In cases of default in complying with the provisions of this Section, the owners of the power lines shall make full compensation for any loss or damage incurred by reason thereof.

2 Rule 87 of the IE Rules 1956 provides for compliance with the Code of Practice or the guidelines prepared by Power and Telecommunication Co-ordination Committee. It has been further stated that all works to be done by or under Rule 87 shall be carried out to the satisfaction of the Inspector.

   Section 47 of the IE Act 1813 provides for punishment for non-compliance with the provisions of Section 32 except where the Court is of the opinion that the case was one of emergency and that the offender complied with the provisions of the Section as far as was reasonable in the circumstances. Similarly, penalty for breach of Rule 87 pertaining to compliance with the regulations of PTCC has been stipulated in Rule 141 of the IE Rules. It may, however, be pointed out that the provisions of Rule 87 of the IE Rules can be relaxed by the State Government or the Central Government as the case may be to such an extent and subject to such conditions as it may think fit.

   The above-referred list of power lines erected/energized without PTCC approval includes cases, which are more than 10 years old. No information is available in respect of the following points:

   (i) Whether the concerned Electrical Inspector has given approval without ensuring compliance with the provisions of Rule 87;

(ii) Whether in any particular case the State Government/Central Government had granted relaxation from the enforcement of the provisions contained in Rule 87;

(iii) Whether in each of the cases under reference the telecommunication lines were in existence prior to the coming up of the power lines and the dates of erection of both the power lines as well as telecommunication lines.

After ascertaining in each of the cases that the provisions of Section 32 had not been complied with and for which a reference had not been received from the Telecommunication Department, the Central Government may direct the owner of the power lines to comply with the provisions of Section 32 of the IE Act read with Rule 87 of the Indian Electricity Rules.

Launching of prosecution against the defaulting persons can also be taken recourse to, if considered necessary.

Appendix XIII to Chapter I

(Refer Paras 6.9.3 and 6.9.7)

I. Copy of Director (RD), Department of Telecommunications, New Delhi Letter No. 131-13/81-tpl (tx) dated 18.7.1981.

To

Shri V.V. Rao
Chief Engineer (PS)
Ministry of Energy
Department of Power
West Block No.2, R.K. Puram
New Delhi 110022.

Subject: Sharing of cost for re-engineering scheme between State Electricity Boards/ C.E.A./ other Undertakings dealing with construction and / or operation of power lines and P&T Department.

With reference to your letter No. 19/96086-PTCC dated 17th April 1980, on the subject, conveying your concurrence to our proposals, I am to intimate you that the P&T Board, in meeting no. 3 of 1981-82 held on 15th June 1981, has approved the following proposals:

(i) In cases in which the telecommunication circuits are required to be protected by installation of GD tubes, shifting/re-routing of open wire lines, substitution in part with underground cable pairs, the cost of protective measures may be borne by the later entrant in the field as per the practice being following at present.

(ii) In cases where it becomes necessary to remove the open wire lines altogether and provide circuits on other media like underground symmetrical cable, coaxial cables/microwave, UHF or other radio systems, the Electricity authority shall pay the 2/3rd portion of costs of such protective measures, and P&T shall bear 1/3rd portion of the cost.

(iii) Past cases will not be re-opened.

(iv) This is for your information and further necessary action.

Sd/-
(K.Radhakrishnan)
Director (RD)

Copy to:

2. Shri N. V. Krishnaswami, Director Telecom, C.E.A., B6-7/19, DDA Shopping Center, Safdarjung Enclave, New Delhi 110016.

II. Copy of ADG (ML), Department of Telecommunications, New Delhi Letter No.10-11/92-ML dated 25th May 1992

Subject: Minutes of the meeting held between Department of Telecommunications and Department of Power on re-engineering on 4th May 1992 at 14.30 Hours in Committee Room, Sanchar Bhavan.

Kindly find enclosed herewith minutes of the above meeting for your kind information and necessary action.

Sd/-
ADG (ML)

Enclosures

Minutes of the meeting held in the Committee Room in Sanchar Bhavan, New Delhi at 14.30 hours on 4th May 1992 between Department of Telecommunications and Department of Power (Central Electricity Authority) on re-engineering cost towards affected telecom circuits/lines.

A meeting was held between the representatives of Central Electricity Authority, New Delhi and Department of Telecommunications, New Delhi on the representation of the Power sector for reviewing the sharing formula for the re-engineering cost of the affected Telecom circuits/lines. The following participated in the meeting:

DoT Side

S/Shri
(1) D.B. Sehgal, DDG (ML)
(2) N.C. Gupta, DDG (RN)
(3) D.Swaminathan, Director (ML)
(4) Ms. Rune Ghosh, Director (FAI)
(5) B.C. Bhat, ADG (F-I)

C.E.A Side

S/Shri
(1) D.P. Sinha, CE (LD&T), C.E.A
(2) D.M.Rao, Director PTCC
(3) Harish C.Arora, Dy. Director
(4) Neeraja Mathur, Dy. Dir.
(5) Ram Swarup, Dy. Dir.
(6) D.K. Malik, Asstt. Dir.

Shri D.B. Sehgal, DDG (ML) welcomed all the participants and requested Shri D.P. Sinha, Chief Engineer, Central Electricity Authority to give brief on the need for re-examination of the sharing of re-engineering costs. Shri Sinha, CE, Central Electricity Authority outlined how the sharing formula between the Power sector and the Telecom sector towards re-engineering charges was evolved. In earlier times, the technology available for replacement was generally by like by like systems; therefore, the entire cost of re-engineering was borne by the later entrant due to whom re-engineering was necessitated. Subsequently, as technology improvement resulted in induction of new types of equipments in place of the existing open wire lines, a steady increase in the re-engineering cost was observed. On the representation of the Power sector, the issue was examined in detail by DoT and the Power sector authorities in 1981 and a decision was taken that the total cost of re-engineering will be borne in the ratio of 2:1 by the Power Sector and DoT. Further, due to induction of the latest technologies like digital microwave systems and optical fibre systems, the Power sector feels that the re-engineering cost has shot-up tremendously and in certain cases even exceeded the cost of the new power line. It has also been observed by the Power Sector that while re-engineering DoT is providing large capacity systems in place of open wire lines having 3/8/12 channel systems. The additional capacity is being used by DoT for meeting its future growth requirements and thus, the Power sector is being made to bear the developmental cost of DoT plans. He requested DoT to reconsider the whole issue on the lines suggested by the Power sector i.e. Power sector may pay prorata cost in the ratio of the system capacity of the old system vis-à-vis the total capacity of the new system.

DDG (ML) while appreciating the concern of the Power sector made it amply clear to them that they should not just look at the re-engineering estimate presented by DoT in isolation. They should appreciate that had the Power sector erected the alignment in a different route thereby avoiding the necessity for re-engineering the extra cost that would have been involved should also form a factor in deciding the cost of the re-engineering estimate presented by DoT. He emphasized that it was not always possible to replace by open wire line by a radio/cable system of exactly the same capacity. We should find out the best and the most economical technical solution and having capacity as close to the system to be replaced as possible. The cost of this system should be born fully (100%) by concerned Electricity Authority. However, if DoT combines its future requirements and wants to install a system of much higher capacity, Power sector may pay the notional cost of replacement by the nearest possible technically suitable system. He in fact drew the attention of the Power sector to the railway electrification work wherein also large scale re-engineering was involved. He pointed out that the Railways bear 100% re-engineering charges and in addition permit DoT to make use of the excess capacity on the medium wherever available for which no compensation need to be paid to the Railways.

DDG (RN) pointed out that the present sharing formula was arrived at after detailed consideration by both the Telecom and Power sectors including drawing parallels from other telecom administrations. There may be a few exceptional cases where the opinion of the two organizations may differ with regard to the best solution. Such cases can be considered by Standing Committee consisting of officers from both DoT and Power sector for which already instructions exist. Instead of resorting to the above mechanism to solve the problem it should not be our endeavor to re-open the issue of the sharing formula for the re-engineering cost, which was arrived at after careful consideration by both the parties.

The Chief Engineer, CEA agreed with the above suggestions and proposed that the Central Standing Committee should be revived immediately so that it could look into such estimates, which have resulted in this situation. He once again reiterated that this issue is to be resolved expeditiously before the next Central PTCC meeting, which is likely to be held in the month of June/July, 1992. It was decided that the Central standing Committee will consist of two representatives from DoT and Two from CEA, Director (ML), DoT will be convener of the Committee.

Appendix XIV to Chapter 1

(Refer Para 6.9.8)

Government of India
Ministry of Communication
Telecom Commission
(ML Section)

No. 10-11/94-ML **New Delhi the 30th January 1995.**

To
(1) All Chief General Managers, Telecom Circles
(2) The Chief General Manager Maintenance, New Delhi/Mumbai/Kolkata/Chennai
(3) The Chief General Manager, T&D Circle, Jabalpur
(4) All Chief General Managers, Telecom Projects
(5) The Chief General Manager, Task Force, Guwahati/Shimla.

Subject: Methodology for obtaining payment of re-engineering charges from Department of Power towards affected telecom circuits/lines.

The question of obtaining the re-engineering charges from Department of Power has been under consideration for sometime in this office. It has now been decided, in consultation with the CEA that the following criteria will have to be adopted while claiming re-engineering charges from the Department of Power.

2. To protect affected DoT systems working on overhead alignment due to induction from power lines, the following procedures are adopted:

(i). Protection through GD tubes without shifting alignment;
(ii). Shifting/re-routing of existing alignment with or without GD tubes;
(iii). Substitution in part with underground cable pairs; and
(iv). In case where it becomes necessary to remove the open wire lines altogether, the existing system may be replaced by other viable system.

In the first, instance, efforts should be made strictly in the order given above. If none of them are viable, then action may be initiated for replacement by nearest technically feasible small capacity system.

(i) In case from 2 (i) to 2 (iii) above the existing procedure for re-engineering charges will be continued between DoT & Department of Power (as is being followed presently)

(ii) In case of 2 (iv) above if the nearest equivalent capacity system is installed in place of the existing system, the following least cost technically viable options will be adopted.

(a) In case of replacement by narrow band radio system (VHF/UHF) limited to 6/10 channels as the nearest technically feasible small capacity systems, 100% of the cost of Equipment+100% of the cost of the Tower or Mast as the case may be +25% enhanced charges on the cost of Equipment & Tower or Mast as the case may be (to cover transportation, installation, establishment, land, building, A/C plant, motor vehicles, testing etc) will have to be charged from Power Utility.

(b) In case of narrow band radio systems (UHF) limited to 30 channels as the nearest technically feasible small capacity systems, 66% (2/3rd) of the cost of the Equipment, +66% (2/3rd) of the cost of the Tower or Mast as the case may +25% enhanced charges on the cost of Equipment & Tower or Mast as the case may be (to cover transportation, installation, establishment, land, building, A/C plant, motor vehicles, testing etc) will have to be charged from Power Utility.

(c) In case of replacement by PCM cable system under re-engineering work, 66% (2/3rd) of the cost of the equipment and cable + 50% enhanced charges (to cover transportation, cable laying, tools, testing etc) will have to be charged from Power Utility.

(d) In case, if DoT wants to utilize the higher capacity system for future development in telecom networks, such as optical fibre cable systems, 2 GHz M/W system etc, the notional cost of the technically feasible system as mentioned in Para 3 (ii) (a) (b) and (c) above, whichever will be lower, will be charged from Power Utility and DoT will be free to plan any higher system as per its requirement.

(e) Estimates once accepted and paid for, will not be revised.

(f) When the amount of payment towards re-engineering charges is equal to or less then Rs.50 lacs, the mode of payment will be as per Para 1 (I to iv) of the enclosed Annexure as applicable and the entire amount to be paid in one installment only.

(g) When the amount involved is more than Rs.50 lacs the mode of payment will be as per separate notification modifying the previous reference no. 130-12/86-TPL(TX) dated7.7.1987 (as per Annexure).

This issues with the concurrence of Internal Finance vide their Diary No. 178/95-FA-I dated 20.1.1995. This supersedes all the orders issued in this regard earlier. This will be effective from the date of issues of orders.

Sd/-
(D. Swaminathan)
Director (ML)

Copy to:

(i). All DDG's, Telecom Commission, New Delhi.
(ii). Shri D.P.Sinha, CE (LD&T), CEA, Sewa Bhawan, RK Puram, New Delhi.
(iii). Director (FA-I), Telecom Commission, New Delhi.
(iv). Guard File.

Annexure

No. 10-11/94-ML **Dated at New Delhi, 30th January 1995.**

To

(1) All Chief General Manager, Telecom Circles
(2) All Chief General Managers, Maintenance
(3) The Chief General Manager, T&D Circle, Jabalpur
(4) All Chief General Manager, Telecom Projects
(5) The Chief General Manager, Task Force, Guwahati/Shimla

Previous Reference: 130-12/86-TPL (TX) dated 7.7.1987 amended as below:

1. In partial modification to the order already issued on the above subject, the following alternatives are suggested by which the payment can be made to DOT in all such re-engineering cases.

   (i) Cash payment
   (ii) By Demand draft.
   (iii) By Cheque if the payment is made by Government agency like Department of Power, Public Sector Undertaking like NTPC etc.
   (iv) In case of Electricity authorities/State Electricity Boards, the payment mode can be either as per (i) and (ii) above or through a nationalized bank under irrevocable letter of credit in favor of Department of Telecom for relevant installment.

2. The authorization in such case to pay the amount in four phases as suggested in the earlier circular mentioned above holds good namely.

   (iii) 25% of the estimated cost to be released initially as first installment.

   (iv) Next 35% should be released as second installment as soon as the equipment is ordered.

   (v) Next 30% should be released as third installment after the supplies are affected and erection starts.

   (vi) Balance 10% should be released during erection, commissioning.

3. It is requested that all the pending cases may also be reviewed in the light of the above-mentioned decisions and settled expeditiously, where the Electricity Department wants to make payment in installments. The cases already settled are not to be re-opened.

Sd/-
(D.Swaminathan)
Director (ML)

Appendix XV to Chapter 1

(Refer Para 6.10.4)

State Level Power and Telecommunication Co-ordination Committee

Government of India
Central Electricity Authority
Power Communication Engineering Division
NREB Complex, Katwaria Sarai
New Delhi 110016.

No. PCE/1/2001-PTCC/334 – 66 Dated: 20th March, 2001

To,

CE's (Transmission), SEB's

Sub: Membership of the Re-constituted State Level PTCC

Sir,

In pursuance of the decision taken in the 75th Central PTCC meeting held at Bangalore on 9th November, 2000 the membership of the SLPTCC has been modified. The Ministry of Power have conveyed their approval vide letter No. 3/1/2001-Trans. Dt. 14th March, 2001 for the revision of the membership of the newly constituted SLPTCC as detailed below:

(i). GM (Telecom) of concerned Telecom Circle, BSNL
(ii). Chief Engineer (Transmission) of the concerned SEB's/ State Power Transmission Corporations
} Chairman in alternate years

(iii). DGM (Telecom) who deals with PTCC matters of the Telecom Circle } Secretary (SLPTCC) Telecom Sector

(iv). SE/DGM, who deals with PTCC matters of the State Power Utility) } Secretary (SLPTCC Power Sector

.

(v). EE of Power Utility / SDE (PTCC), T & D Circle BSNL - Co-ordination Secretary

(vi). Other members from Power Sector:

(i). Zonal SE/ EE in-charge of PTCC
(ii). Representative from any other Central/ State Power Trans. Corporation
(iii). Chief Electrical Inspector or his authorized representative from state

(vii). Other Members from BSNL

(i). AGM (Plg) in charge of PTCC, BSNL
(ii). DET (PTCC), BSNL of the concerned region

(iii). Any other representative of BSNL as special invitee, as required.

(viii). DSTE of Zonal Railway
(ix). Army representative of the Area

You are therefore requested to revise the nominations of your officers to SLPTCC in accordance with the above constitution and communicate the same to all concerned.

The brief functions of the SLPTCC are annexed.

Yours faithfully,
Sd/-
(Ram Swarup)
Director (PTCC)
Tel. No. 6565183

Copy forwarded for information to:

Chief General manager, T & D Circle, Bharat Sanchar Nigam Limited, Sanchar Vikas Bhawan, Residency Road, Jabalpur, 482001 with a request that a similar notification may please be issued at your end to all the CGM of Telecom Circle of BSNL.

Sd/-
(Ram Swarup)
Director (PTCC)
Tel. No. 6565183

II. Frequency

As per the decision taken in 58th Central PTCC meeting held at Darjeeling on 25.2.1992 the State Level PTCC meetings should be held as frequently as possible but not later than a quarter/3 months. In Telecom Circles where large number of unguarded power crossings are pending and more electrocution accidents occurred, the meetings in those circles should be convened more frequently In order to decide any emergency cases, special State Level PTCC meetings can also be requisitioned and the power of requisition of such meetings is vested with Chairman State Level PTCC.

III. Functions

As per decision taken in 58th Central PTCC meeting held at Darjeeling on 25th February 1993 in addition to the present business or transaction, following items must be deliberated on regular basis in State Level PTCC meetings, with all participants participating at desired level.

(a) Position of unguarded power crossings, including LT crossings and non-standard electric service leads should be discussed in every meeting as to how many were added, how many rectified and a continuous monitoring is done and further targets fixed for rectification.

(b) All the PTCC cases both at State and Central level, which are delayed beyond the fixed time limits specified in PTCC manual must be discussed, reasons for delay analyzed and targets fixed case by case.

(c) All re-engineering cases must be discussed deliberating on all possible reasonable schemes based on existing guidelines and decisions taken. In case of any disagreement by any party, same should be recorded and in the form of any agenda item the case should be sent to Central PTCC with all details of enabling Central PTCC to take further decision in the mater.

(d) All cases of payment of costs, completion of protection works and energization approval must be discussed and targets fixed and continuous monitoring is done.

(e) Matters concerning Railways should be recorded and intimated to Railways with a copy to Director (Telecom), Railway Board, New Delhi.

(f) All fatal and non-fatal accident cases should be discussed in the meetings and based on reports the responsibility should be fixed and the implementation of remedial measures monitored to avoid recurrence of accidents.

Appendix XVI to Chapter 1

(Refer Para 6.11.2)

MINUTES OF THE MEETING HELD ON 10-12-1976 TO DISCUSS PROBLEM S RELATING TO PROTECTION OF RAILWAY TELECOM AND BLOCK CIRCUITS

A meeting was held in the P&T Board room on 10-12-1976 to discuss problems relating to protection of Railway Telecom and Block Circuits consequent to induction from power lines. The following were present

P&T Board

Shri S.N. Ranganathan	Member (TD)
Shri H.J. Mirchandani	Member (TO)
Shri P.A. Sankarnarayan	GM, T&D Circle, Jabalpur
Shri T.S. Subramanian	Director (TRC)
Shri M.N. Mathur	DDG (ML)
Shri T.V. Srirangan	Addl. Director (TRC)
Shri B.N. Iyenagar	Dy. Director (TRC)
Shri B.R. Baliga	Asstt Director (TRC)

CEA

Shri S.S. Murthy	Member (Power Systems)
Shri N.V. Krishnaswamy	Jt. Secretary (Power), PTCC

Railway Board

Shri Laljee Singh	Director (Signal)
Shri A.K. Das	Jt. Director (Telecom)

2. Opening the discussion Shri Laljee Singh of Railway Board mentioned that Railways presently are having circuits leased from P&T as well as owned by the Railways themselves. He mentioned that though in 1955-56 the PTCC had decided on a limit of 430 V induction in respect of railway block circuits and a representative from Railways was also present when the decision was taken, considerably further development has taken place and it is now found that the railway block circuits are getting affected by such induced voltages. In this connection, he gave details about the different types of block instruments being used by the Railways. While some of these instruments do not get affected by induced voltages up to 430V other types are not so. These instruments are still capable of giving further service. Shri Laljee Singh stated that Railways are going in for standardization of the block instruments and will be providing as far as possible only those, which are capable of withstanding 430V AC induction for the future installations. However, in respect of existing block circuits conversion of earth return circuits and replacement/modification of instruments have become necessary as a result of these induced voltages.

He gave instance of 19 cases in which the Railways had computed additional expenditure, recurring as well as non-recurring for the extra protection required in the block circuits over and above the stipulation given in PTCC approval. While in most of these cases the cost ranges from about Rs. 170 to about Rs. 69,000, there was one case where the expenditure was estimated at Rs. 1.53 lacs non-recurring and Rs. 322 recurring. Shri Laljee Singh mentioned that the PTCC should take note of these and incorporate adequate protective measures in respect of railway block circuits while giving route approvals.

3. Shri Laljee Singh had a doubt whether the PTCC before giving clearance gets all the information regarding the railway alignments specially those operated by Railways. It was clarified by Joint Secretary (Power) that this information is obtained by the PTCC Secretaries and the line drawings also go to Railways directly. This arrangement was considered satisfactory.

As far as the telecom circuits used by Railways on alignments either rented out from the P&T or owned by them the present protective measures as recommended in PTCC clearance is satisfactory, only the cost of such measures are to be borne by the later entrant. It was also clarified that the Joint Secretary Telecom of the PTCC is at present looking after all the telecom circuits, which are disturbed as a result of power induction. The main problem was that the block circuits are presently being considered as equivalent to telecom lines and only the protective measures for the telecom lines are prescribed for the block circuits also. However, the block circuits in many cases cannot withstand the voltages, which are being prescribed for the telecom lines. While the PTCC gives clearance for block circuits, it is necessary to ensure that the protective measures to be additionally provided on the block circuits are also specified, in consultation with Railway Board. It is not clear in the clearance given by the PTCC as to who will fit in the additional protective measures and who will bear the cost. The additional cost which the Railways will have to bear on a number of routes already cleared by the PTCC was also submitted during the discussion and it was found that in most cases it was a few thousands of rupees. Taking all these facts into consideration the following principles were decided for future clearance in respect of railway circuits.

4. (i) For new railway lines, Railways will provide, as far as possible block instruments, which can stand the voltages permissible for telecom lines. Initially from considerations of economy, they provide only earth return circuits which have to be changed to metallic return circuits if and when power parallelism problem arises.

(ii) The present practice in regard to issue of PTCC clearance for communication circuits may be continued and the protective measures for the railway communication circuits may be similar to those prescribed by the P&T for their own communication circuits. Cost of such measures is to be borne by later entrant.

(iii) Wherever the railway electrification has been carried out, the paralleling railway circuits (including block circuits) can be cleared as for telecom lines without additional protective measures being prescribed for the block circuits subject to the condition that the induced voltage does not exceed 430V. In case the induced voltage exceeds 430V, case has to be coordinated and discussed with Railway Board for a decision.

(iv) For existing alignments which are also carrying block circuits, the PTCC clearance will be given along with the additional protective measures as recommended by the Railway Board required for the block circuits and the cost for the same is to be borne by the later entrant i.e. the Electricity authorities. Approximately one time capital cost to be borne by the later entrant will be intimated to PTCC later if required.

(vii) Shri Krishnaswamy of the CEA pointed out that this procedure of incorporating the additional protective measures prepared for block circuits might increase the time delay in giving route approvals. Shri A.K. Das promised that a time limit can be given for obtaining information and Railways would adhere to this time limit.

5. Of late many cases are arising wherein the normal protective measures like re-routing the telecom or power lines or mitigating induction by GD tubes are not sufficient. In such cases re-engineering of the telecom circuits by media other than open wire lines has to be resorted to. There is no clear procedure up till now as to how the re-engineering proposal will be framed and finally accepted by the Telecom and Power authorities. DDG (ML) stated that this has been discussed internally in the Telecom Directorate and the proposed new procedure is as follows.

As soon as it is established that re-engineering is required, the PTCC will call for a meeting of the concerned GMsP, GMsM and Circle GM and GM T&D Circle and a representative from the Power authorities. Whenever railway circuits are involved concerned Railway representatives will also be called for attending the meeting. In this meeting the probable solution will be discussed and the GMsP/Railway representative will be asked to prepare the re-engineering proposals with alternatives and approximate cost. The proposal would be framed within a specified time frame and would be sent to DDG (ML) in P&T Directorate and also to power authorities and to Railway Board. The time frame for framing the proposal will be decided in this meeting itself depending upon the urgency and other factors. This will be examined in the Directorate and Railway Board along with the time frame for implementation of the proposals and forwarded to the Power authorities for acceptance. This procedure should be tried out henceforth. After the appropriate re-engineering proposals are finalized, the formal clearance will be given by the PTCC.

6. The present cases of re-engineering are often becoming quite difficult to decide and implement because the cases are generally referred to DG P&T at an advanced stage. Member (D) requested all concerned that proposal should come to PTCC at the survey stage itself so as to provide adequate time for examination, re-engineering and implementation.
NO.10-23/72-ML Vol. II (Part I) dated at New Delhi April 1977, Copy forwarded to all concerned.

Sd/-
(N.C. Gupta)
Asstt. Director General (ML)

NOTE: With reference to the procedure for finalizing the re-engineering schemes in Para 5 above Director (RD), DOT, New Delhi vide his DO 130-12-85-TPL (TX) dated 10th October 1985 addressed to DGM, T&D Circle, Jabalpur clarified that in order to curtail the delay, the new re-engineering schemes may also be finalized by telecom Circles in consultation with Telecom Projects and concerned Power authorities and on the basis of estimated cost, re-engineering charges may be claimed from concerned Power authorities

Appendix XVII to Chapter 1

(Refer Para 6.11.4)

Government of India (Bharat Sarkar)
Ministry of Railway (Rail Mantralaya)
(Railway Board)

No.77/W3/TCM/2/Meeting **New Delhi, dated 3rd April 1978**

The General Manager (S&T)
All Indian Railways

Subject: PTCC route approval for Power Lines up to and including 132 kV lines.

At present the power lines up to 33 kV are being dealt with at the State Level PTCC but it has been decided now that henceforth all cases of route approval right up to 132 kV (inclusive) will be decentralized with effect from 1st June 1978. In other words, General Manager (S&T), Railways, will have to deal with these cases up to and inclusive 132 kV instead of Railway Board. The procedure will be as follows (to be effective from 1st June 1978).

The route map in 4 copies will be sent from the State Electricity Board authorities to the concerned Railways who will have to furnish the telecom details to the State Level Power Member. The later will calculate the induced voltage on the affected block and telecom circuits and send the same to the Railway authorities. The Railways authorities in turn will have to examine and furnish the recommendations for protective measures on railway block circuits (in the same way as the Railway Board furnishes the same with a copy to the Railways) to the following:

(1) For cases up to 33 kV to AE PTCC of the State;

(2) For cases beyond 33 kV up to 132 kV (inclusive) to:

(a) Joint Secretary (Telecom), PTCC, Room No.478 Khurshid Lal Bhawan, New Delhi-110001 for Northern Region cases;

(b) Divisional Engineer Telegraphs, PTCC, O/o General Manager Telecom Maharashtra Circle, GPO Building, Walchand Hirachand Marg, Fort, Mumbai-400001 for Western Region cases;

(c) Division Engineer Telegraphs, PTCC, O/o General Manager Telecom, Eastern Region, Taher Mansion, 5th Floor, B-Bentick Street, Kolkata-700001 for Eastern Region cases; and

(d) Division Engineer, Telegraphs, PTCC, Southern Region, 100/101, Walajah Road, Chennai-600002 for Southern Region cases.

who will issue route clearance incorporating the Railway's recommendations of protective measures to be provided by Railway/P&T. As for the protective measures on railway communication circuits whether owned or maintained by Railways or P&T, the standards followed by P&T will be adopted for railway, telecom circuits as well. Protective measures on railway telecom circuits on that basis will be incorporated by Joint Secretary (Telecom)/DET PTCC's in the route approval. The cost of all the protective measures will be borne by the later entrant in the field.

A copy of the recommendations for protective measures on railway block circuits is also enclosed herewith for the guidance of Railways.

For re-engineering and any other complicated cases, the matter may be referred to or discussed with Joint Director, Telecom (G), Railway Board. The target for furnishing the telecom details etc. should continue to be the same as is prevalent at present i.e.

(a) The telecom details should be furnished to Member (Power) State Level PTCC within one month from the date of receipt of route maps from State Electricity Board.

(b) The recommendations for protective measures should be furnished within 10 days from the date of receipt of calculated induced voltage from the Member (Power), State Level PTCC;

(c) The estimate for the cost (to be paid by the State Electricity Board authorities) should be sent to State Electricity Board within one month from the date the route clearance from PTCC, is received; and

(d) The work of provision of protective measures on receipt of the estimated cost should be completed as early as possible and thereafter clearance for the energization of power line should be issued to State Electricity Board authorities.

For cases above 132 kV the procedure at present being followed will continue.
This letter may please be acknowledged.
Encl: as above.

Sd/-
(A.K Das)
Joint Director, Telecom (G)

Copy to:

1. The Joint Secretary (Power), PTCC, West Block No. II, R.K. Puram, New Delhi 110022. He is requested to advise all the State Electricity Board authorities to ensure 4 copies of the route maps with railway tracks and principal stations to be sent to the concerned Railways and advice Power Members to furnish the induced voltage on railway block and communication circuits to the concerned Railways.

2. (a) The Joint Secretary (Telecom), PTCC, Room No. 478 Khurshid Lal Bhavan, New Delhi 110001.

(b)The Divisional Engineer Telegraphs, PTCC, O/o The G.M. Telecom, Taher Mansion, Eastern Region, 5th Floor, B-Bentick Street, Kolkata-1.

(c) The Divisional Engineer Telegraphs, PTCC, O/o GM Telecom Maharashtra Circle, GPO Building, Walchand Hirachand Marg, Fort, Mumbai - 400001.

(d) The Divisional Engineer Telegraphs, PTCC, Southern Region, 100/101, Walajah Road, Chennai- 600002.

for information. They are requested to ensure that no route clearance to the cases is issued without Railways' approval has been received or Railways' recommendations have been incorporated.

Sd/-
(A.K. Das)
Joint Director, Telecom (G)

NOTE:

(i). Address at Sl. No. 1 above may now be read as given 2.2(i) of Section-A of Chapter III.
(ii). Addresses of regional DET's (PTCC) given at Sl. No. 2(a), (b), (c) and (d) above and in the main body of the letter may now be read as given in 2.2 (ii) of Section-A of Chapter III.

Recommendations

For Protective Measures against Induced Voltages on Different Types of Block Instruments in Use in Indian Railways

1. Neale's Token Instrument and Neale's Tablet instruments with the characteristics similar to Neale's Token in respect of 3-position Relay and Tock Magnet & Neale's 'D'Type.

(a) For induced voltage not exceeding 430 V no special precaution is necessary.

(b) For induced voltages exceeding 430 V metallic return and appropriate Gas Discharge tubes are to be provided.

2. Western Railway Type Single Line Tablet Instrument

This instrument is immune up to 75V AC induced voltages and cannot be used where it is expected to have more than 75 V AC induced voltages.

3. Carson Double Line Block Instruments.

Induced AC voltages exceeding 125 V result in unsafe condition and hence cannot be used where induced voltages are likely to exceed 125V.

4. Siemen's Tokenless Block Instruments.

This instrument can stand induced AC voltages up to 210 AC r.m.s with the following modification:

(a) Condenser C2 of the frequency converter card disconnected and

(b) All the lightning dischargers provided within the instrument must be removed and lightning dischargers having voltage rating not less than 350 V provided externally between each line and earth. This provision of limit of 350 V will also apply to lightning dischargers if any provided by P&T Department on the line.

This instrument is not considered suitable for use in AC electrified section.

5. SGE Double Line Block Instrument

As in Sl. No. 1.

6. Kyosan Tokenless Block Instrument

Since the induced voltage of the order of 38 V Single Phase AC causes distortion and mutilation of the codes and can cause unsafe condition, this type of block instrument is not considered to be immunized against AC induced voltage beyond 30V.

(Note: Immunity level was modified subsequently vide Railway Board letter No. 90/Telecom/PTCC/P/1 dated 25.5.1993, given on next page).

7. Diado Double Line Block Instruments.

This block instrument is safe for installation on circuits where AC induced voltage does not exceed 24 V rms

8. Diado Single Line Tokenless Block Instruments

Without modification this instrument can safely stand induction up to 74V 50 cycles AC induced voltages. For induced voltages up to 650V AC the following modification is to be made:

A-3 position polarized relay of the type used in Neale's token or SGE double line block instrument is to be interposed in the line circuit and the existing line relay (NR Relay) fed from local battery through the contacts of polarized relay. Also the line condensers C1 & C2 each of the microfarad capacity with a voltage rating of 160V are to be replaced by condensers of equal capacitance but with a voltage rating of 1000V Standard gas dischargers will also have to be provided for the lines.

9. Podanur Make Single Line Tokenless Block Instrument (Push Button Type)

This instrument is only suitable for use in non-AC electrified sections. This instrument is safe for use in block circuits subjected to maximum induction 650V r.m.s. 50 cycles AC from neighboring power line provided the existing DC blocking condenser in the telephone circuits is replaced by a one rated for 1000V DC for non AC section only (non AC electrified).

10. Tyres Tablet Token Instrument No. 7

Tests indicate that the instrument is not safe for induced voltages higher than 150V AC

11. Neale's Voucher Block Instrument

This instrument is safe for induced AC voltages up to 430V. This instrument is not suitable beyond 430V.

12. Thcobald Token Instrument

It has been found that the instruments can withstand induced AC voltage up to 430V without any unsafe failure.

13. Syko's Lock and Block Instruments

It is considered that the Syko's lock and block instrument is safe with induced voltage up to 15V only. In view of this low value of the induced voltage, which the instrument can withstand, it is desirable not to use this instrument on sections where any induced voltage may be expected.

14. Rest of the types of single line and double line block instruments are not safe for use in sections having AC induced voltages.

15. Maximum acceptable limit of induced voltage due to power parallelism is up to 2000V on railway block and communication circuits subject to the specific limitations mentioned above.

The cases of induced voltages above these limits should be treated as re-engineering cases and each such case should be treated separately in consultation with the Railway Board.

II. Copy of Director Telecom (Railway Board) New Delhi Letter No. 90/ Telecom/ PTCC/ P1 dated 25th May 1993.

To
General Manager (S&T)
All India Railways
Director General (Telecom)
RDSO, Lucknow.

Subject: AC Immunity Level of Block Instrument.

Reference: This office letter No. 77/W3/TCM/2/Meeting dated 3rd April 1978.

Railway Board vide above referred letter circulated the AC Immunity levels of various block instruments. Please add the following in the list already circulated vide above referred letter.

Block Instrument : Kyosan Tokenless Push Button.

Immunization Level : 650 V AC with modification similar to Podanur's Tokenless Single line block instrument as mentioned in Item 9 of the above referred letter.

Sd/-
(S.C. Sharma)
Director (Telecom)

Copy to :

1. Director (PTCC), PTCC Directorate, Central Electricity Authority, West Block-2,Wing-1, Ground Floor, RK Puram New Delhi 110066.
2. The Chief General Manager, T&D Circle, Department of Telecommunications, Sanchar Vikas Bhavan, ResidencyRoad, Jabalpur 482001.
   With enclosure of Railway Board's letter No. 77/W3/TCM/2/Meeting dated 3.4.1978 (in 4 pages) for information and necessary action.

Sd/-
Director (Telecom)

Appendix XVIII to Chapter I

(Refer Para 6.12.1)

Guidelines for Laying Underground Power Cables Greater Than 33 kV in Proximity with Telecom Cables

Para 2.11 of Minutes of 82nd Central PTCC Meeting held at Lucknow regarding power cables of more than 33 kV.

The guidelines for laying of underground power cables greater than 33 kV in proximity with the telecommunication cables framed by the Central PTCC has been accepted by the Central Electricity Board in its 39th Meeting held in December 2002. The same are reproduced below for information and reference.

Sl.No.16

Agenda Item No.	:3.39.2002
Name and address of the Proposer	:Shri G. Kesava Rao Chief Engineer (LD & T) Division, CEA
Existing Rule No.	:87-relating to PTCC

and

Sl. No. 22

Agenda Item No.	:9.39.2002
Name and address of the Proposer	:Shri P.K. Khindri Chief General Manager Department of Telecommunications Training & Development Circle, Jabalpur
Existing Rule No.	:87- A (New Rule)

The above two proposals were clubbed for discussion. The proposers explained the reasons for the amendments and stated that the existing specification of the Bureau of Indian Standards covers cables only up to 33 kV rating. The PTCC (All India) was constituted in 1949 with joint participation of the Central Electricity Authority, Ministry of Communication, Ministry of Railways, Ministry of Defense, BSNL & SEB's and meets regularly at intervals of six months. It has constituted a sub-committee in which CEA is also a member. The sub-committee had approached the Bureau of Indian Standards for inclusion of "PTCC Guidelines" in the existing specification of BIS. However the BIS has not accepted.

Shri Mukherjee, BIS, Shri Ram Swarup, Director, Central Electricity Authority, Shri Panigrahi, DDG, Dept. of Telecommunications, Shri Subramanian, CEI to Government of Tamil Nadu, Shri Jain, Director(Technical), HVPNL, Shri Durairaj, Chief Engineer (Planning), TNEB, Shri Vaishnav, CEI to Government of Gujarat, and Shri Aggarwal, Chief Engineer(EI), CEA, participated in the detailed discussions and gave their view points. Shri Jain, Director (Technical), HVPNL has stated that clearance of 0.3m up to 33 kV rating shall be retained as per existing BIS. He also opined that 0.6 m clearance between power cables greater than 33 kV and telecom cables may be adopted and proposed amendment 87(b) can be covered under rule 87A. Subsequent to the discussions the following modifications to the proposed amendments are accepted;

(i) Suitable coverage to underground power cables in the form of changed heading in the form of Rule 87A to be made.

(ii) The value of minimum clearance for underground power cables to be kept as 0.3 meters for 33 kV and less and 0.6 meters for 33 kV and above.

(iii) Power cables greater than 33 kV to be laid at a minimum depth of 1.2 meters.

Appendix XIX to Chapter I

(Refer Para 6.13.1)

I. Separate Questionnaire for referring HT and EHT power line to be used.

II. Marking of Telecom Details for power line proposal:

Capacity of Power Line	**Telecom assets to be marked**
HT (High Tension power line)	
11 kV	3 Kms on either side **of proposed power line**
22 kV	5 Kms on either side **of proposed power line**
33 kV SC (Single Circuit)	5 Kms on either side **of proposed power line**
EHT (Extra High Tension power line)	
33 kV DC (Double Circuit	8 Kms on either side **of proposed power line**
66 kV SC and above	8 Kms on either side **of proposed power line**

Power cable should have the shortest length of parallelism with BSNL cables. When high voltage cables 11 kV and above, **has a parallelism exceeding 0.8 Km** with BSNL cable should be marked in the topo map for suitable recommendation, which implies power cables of length less than 0.8 Km need not be marked in the topo map. Hence for many power proposals of length less than 0.8 Km, Telecom details need not be called for, which considerably eases the work of both BSNL and EB authorities

III. Various Level of PTCC meeting:

Sl.No.	**PTCC meeting**	**Frequency/Periodicity**
1	Central level	Once in six months
2	State level	Once in three months
3	SSA/Telecom District	Once in three months
4	Divisional Level	Once in two months
5	Sub divisional level	Once in a month

IV. Precedure for clearance of Power and Telecom circuits by PTCC

1. Submission of Quesstionaire in the standard proforma with Topo Map supplied by Survey map of India to the concerned authority.

2. Processing by competent authority and calculation of Induced voltage on paralleling telecom circuits.
3. Issue of Route Approval Certificate (RAC)
4. Issue of Crossing Approval
5. Submission of Form F by concerned GM BSNL
6. Issue of Energisation approval

IV.2. Processing by competent authority and calculation of Induced voltage on paralleling telecom circuits etc .

2.1. The power proposal from Chief Engineer , SEB for erection of 33 kV DC and above with topo map (2 copies) to be submitted to DE PTCC, Respective SSA Head, Respective Railways and STRC/NTRC This proposal should contain Soil Resistivity data and Earth potential Rise Report(EPR). In case the proposed power line comes under two states, proposal to be submitted to both the states of concerned authority.

2.2 The concerned field units mark all the Exges, cables.

2.3 After scruitinising the telecom details sent by the SSA's and forwarded to the concerned SEB authorities for Low frequency Induction.

2.4 Similarly the concerned railway will also mark their railway telecom details and sent it for the concerned SEB for Low frequency Induction.

2.5 DE PTCC and Railway authority get back induced voltage report from the SEB.

2.6 DEPTCC will issue Route Approval Certificate (RAC) on receipt of NOC from Railway and STR with due recommendations.

2.7 When the route approval certificate is received from the DET, PTCC, T&D Circle, the following points may be checked up by the concerned authority

(a) Whether GD tube protection is recommended to any telecom assets and if so at whose cost it is to be carried i.e., BSNL or SEB.

(b) Whether any EPR zone limits are specified.

2.8 Submission of inspection report

Ensure the following points in the Inspection Report:

a) The items which are not applicable may be struck off.
b) GD Tube protection work, wherever done, is to be indicated in the concerned Annexure.
c) The number of crossings mentioned in the Inspection Report may be reconciled with that in the SEB proposal.
d) The form "F" is to be countersigned by GM/DGM as the case may be.
e) Even if there is no telecom crossing involved with a powerline, the Inspection form is to be submitted by the SSA to confirm it.

2.9 Wherever defects/deficiencies are noted, appropriate action may be taken. Fulfilling all the points the energisation approval will be issued by the

IV. 3. Issue of Route Approval Certificate (RAC) , Crossing Approval (CA) and Energisation Approval (EA)

3.1 Table on issue of RAC, CA,EA

Sl No	Type of Work	11 kV	22/33KVSC	33KV DC / 66KV/ 110KV/ 132 kV	220KV/ 400KV	Telecom
1.	Proposal to be submitted to	DET Concerned	SLPTCC	DET, PTCC T&D Circle		DET, PTCC T&D Circle
2.	**Processing and issue of RAC by**	**DET Concerned**	**SLPTCC**	**DET, PTCC T&D Circle**		**DET PTCC T&D Circle**
3.	Calculation of I.V done by	DET Concerned	SLPTCC	SEB	Central Electricity Authority, New Delhi (CEA,ND)	SSA(11KV) SLPTCC (22/33KV) SEB(>33KV DC) CEA(220KV & above)
4.	Crossing Approval issued by	**DET Concerned**	**Head of SSA**	**CGMT,concerned Circle**		
5.	Energisation Approval issued by	**DET Concerned**	**Head of SSA**	**CGMT,concerned Circle**		

Crossing Details

In addition to the Crossing details given in the PTCC manual through light on the following points.
"Angle of crossing of Power Overhead line with Railway Overhead line".

VII. Safety measures:

Reporting of Electrocution accidents:

The course of action to be taken on electrocution accident cases and procedure for submission of various PTCC reports etc for speedy disposal of electrocution cases is given hereunder.

Any accident either Fatal or Non fatal occurred in the SSA's should be reported to the circle office as well as Electrical Inspector by Telegram / FAX (within 24/48 hours) by the Head of the SSA after confirming that the accident has occurred due to power lines only.

Processing Cases of Electrocution Accidents

As soon as the information is received about the occurrence of an electrocution accident the controlling officers have rush to the spot. Preliminary welfare measures in the victim are to be arranged most expeditiously.

Then following step by step action is to be taken.

1. Telegraphic intimation is to be given to the concerned Electrical Inspector of the District and Chief Electrical Inspector to the respective State Govt. **within 24 hours in case of a Fatal Accident / 48 hours in case of Non Fatal Accident** along with 44 A Proforma & Written report. Also a telephonic message should be given to the Electrical Inspector, SDE PTCC, Circle office, DE PTCC, T&D Circle and concerned ADE, SEB.

2. The accident spot and surrounding areas are to be surveyed and all evidences are to be recorded by SDE concerned . A preliminary report and Part-1 report are then to be submitted to circle through of Head of SSA **within one Week** of occurrence of accident. Part-I contains

    a. Name and designation of the person involved
    b. Date of occurrence of accident

c. Nature of injury (extent of disablement) and medical report on the cause of the injury.
d. Welfare measures taken

    1. Whether the injured person was visited in the Hospital
    2. Whether any financial or other help was given to injured or his family.

3. A joint inspection has to be carried out by SDE and ADE of SEB and the report signed by both and should be submitted to circle office **within four weeks** along with Part-II report, Medical / Post-Mortem and Police report (FIR).

4. Electrical Inspector will conduct an enquiry on the accident. SDE should pursue with the Electrical Inspector for sending his report early.

5. Departmental Enquiry will be conducted by circle office and SDE PTCC of T&D circle may be co-opted.

6. Complete settlement of welfare measures such as (a) Compensation under W.C. Act (b) DCRG (c) Pension and (d) Employment should be completed **within eight weeks** of occurrence of the accident.

All reports submitted to the circle office should be personally signed by concerned GM of the SSA who should satisfy that action on all points has been completed as per the instructions.

Procedure for reporting cases of electrocution accidents and formats are enclosed herewith (Enclosure-V)

6 Reasons for Accidents:

1. Unguarded power crossings:

Providing proper guarding at unguarded power crossing with telecom lines to avoid accidental contact and to prevent consequent hazards to telecom personnel and equipment. Field units should hold periodical meetings with EB at different levels and should have time bound programme for deduction of all UGPC's and providing proper guardings. No new lines should be commissioned without completing the guarding work wherever the telecom line crosses the electric wire.

2. Non using protective Devices:

The second line of defense is by way of providing personal protective devices to the staff for their use while handling telecom installations. These protective devices are classified under two categories.

a. **Basic safety devices**

i. Neon Tester
ii. Rubber Gloves (Type-I) IS 4770
iii. Safety Belt (DOT Spec) S/QP-104A, DT/6.10.77
iv. Insulated Tools
v. Rubber Shoes – IS 3755
vi. Helmet (Yellow colour) IS 2925

are to be provided.

b. **Additional safety devices:**

i. High voltage Tester RL No: 170110
ii. Artificial Resuscitator.

3. Improper supervision & working on the line without Power shut down:

Power shut down should be taken while handling the telecom installations in the vicinity of exposed power installations and work is to be carried out with proper supervision.

4. Other General Protective measures:

i. Periodical patrolling of lines is to be ensured so that all PTCC violations such as UGPC's, worn out electric service leads etc are noticed and immediate follow up action is taken to get them rectified.
ii. Sub Divisional and Divisional and State level PTCC meetings are to used to record PTCC violations and monitor the progress of their rectification.
iii. Handling of telecom installations in stormy weather conditions should be avoided.
iv. All new power and telecom lines should be referred to PTCC at the survey stage to ensure necessary protection to telecom installations.
v. If noise or induction is noticed on any existing telecom circuit, the matter has to be immediately reported to PTCC for examination and suggestion on necessary protection.

Training and Education:

The efficiency of safety orientation not only lies in provision of safety devices but also in educating and training the personnel about their utility, usage and maintenance. Demonstration, lectures, training courses and workshops in PTCC aspects have to be arranged to make safe working a habit for telecom personnel.

Administration have issued rulings and regulation from time to time, which have to be implemented by the staff. Stringent measures have to be adopted to avoid lapse on the part of the staff in implementing the safety programme.

Development of Safety programme:

Statistics of electrocution accidents are collected every year and reviewed. It helps in deciding the remedial measures to avoid recurrence of accidents. It also helps in finalizing guidelines for future safety programmes. Development of safety engineering measures based on the feed back from the field is, thus, a continuous process for betterment of safety.

Conclusion:

The safety measures described above are largely preventive in nature and seek reasonable protection to telecom installations and personnel. The cooperation of the power authorities is equally essential in ensuring the overall safety of telecom installations and personnel.

> Fall seven times and stand up eight.
> - Japanese Proverb

APPENDIX
to
CHAPTER – III

Appendix I to Chapter III

(Refer Para 2.1 (I) of Section A)

QUESTIONNAIRE 1

Government of India
Power & Telecommunication Co-ordination Committee
(To be answered by the Authorities In-charge of Power System while Applying for PTCC Route Approvals.)

1.0 Please supply data of the power system as per details below:

1.1 Key diagram (single line) of the electrical layout of the relevant portions of the power system, indicating the number, voltage ratings, capacities, etc. of the various power apparatus. Indicate also by DoTted lines the extension proposed ultimately or through the current Five Year Plan.

Note: By relevant is meant all the power stations, which under normal operating conditions will feed into a fault occurring within or outside the parallelism section as well as all lines on which such fault current would flow.

1.2 Data on the characteristics of equipment, viz. generators, transformers, reactors, synchronous condensers, earthing transformers, etc. installed in the system as per enclosed annexure (transient reactance figures should be given for all rotating machines).

1.3 Please state if the neutral points of the power system are (i) insulated, or (ii) earthed. If the latter, please indicate the type of earthing, e.g. solidly earthed, earthed through Peterson coils, earthed through resistance or reactance. Give also full particulars.

2.0 Please supply the following data in respect of the particular power line for which approval is sought.

2.1 Name.

2.2 Operating voltage and number of circuits.

(i) Length.

(ii) Conductor/Earth wire size and material.

2.4 If it is a top or spur line, the length of the tap and the distance of the tapping point from the end sub-stations should be clearly indicated.

2.5 Is the power line bussed at any intermediate sub-stations? If so, please give details.

2.6 Will the power line initially be charged at some lower voltage?

2.7 Probable date of commencing the construction.

2.8 Probable date of commissioning.

2.9 Date by which approval is desired.

3.0 Please supply a route map showing the proposed alignment of the power line and the paralleling telecommunication lines in the area, drawn to a scale of 1 cm = 0.5 kms. or 1" = 1 mile. All topographical details including all railway lines, rivers, canals and important roads up to 8 kms. on either side of the proposed power line may also be drawn to the scale. The railway stations should be located on the map and named.

Note 1: If the proposed line is an extension of the existing line, which had not been referred to the Committee previously a similar route map of the existing line, should also be supplied along with the route map of the proposed line.

Note 2: A copy of the route map with telecom circuits marked be also sent to local DOT authorities and Railway authorities, requesting them to confirm the telecom circuit and also indicate the points of discontinuity in the telecom circuits to both the Joint Secretaries of the committee.

3.1 Number and date of the route map showing the proposed alignment.

4.0 Sketch or sketches or supports showing the conductor and group wire arrangements of the transmission line together with an indication of the sizes and materials of the various wires.

5.0 Please indicate the protective device adopted for the line. In respect of lines protected by circuit breakers, please furnish also the type of the lines and relaying proposed and the total time (Breaker and Relay) for clearance of ground faults on the line with normal relay settings.

6.0 Please indicate the soil resistivity in the area covered by the line. The soil resistivity should be measured by the four electrode method using an inter electrode spacing of 50 meters (150 feet). The measurements may be made at every 2 or 3 kms. along the length of the line.

7.0 Please indicate the number of crossings between the proposed alignment and the telecommunication lines involved and state if the crossing arrangements will be provided in accordance with the code of Practice for Crossings issued by the Power and Telecommunication Co-ordination Committee.

8.0 EPR details of End substations-

Name of Substation :
New / Existing :
Diagonal distance of earth mat in meters :

Maximum fault current of Substation in Amps :
Earth mat resistance in Ohms :

9.0 Main line particulars in the case of LILO/ tapline :

9a Whether any Railway lines are existing within 8 kms. on either side of the power line:

10.0 While applying for route approvals of the Committee, the above particulars should be furnished to:

(i) Director (PTCC), Central Electricity Authority, Load Despatch & Telecommunication Division, PTCC Directorate, NREB Building, Shaheed Jeet Singh Marg, Katwaria Sarai, New Delhi 110016.

(ii) DET (PTCC) concerned.

Place: Signature:
Date: Name:
Designation:

N.B.: For computing the interference current from the power line on the single wire earth return telegraph circuits, indicate the maximum load current for which the power line has been designed.

Annexure to Appendix I

Please furnish the characteristics of the various power apparatus as under:

1. Synchronous Machines (Generators, Synchronous Condensers)

S.No.	Name of the Power Station or Sub-station	Rating in kVA	Transient Reactance (Percentage Reactance on its own Base)
1. 2. 3.			

2. TRANSFORMERS

Sl. No.	Name of Power Station or Sub station	High Voltage Winding	Medium Voltage Winding	Low or Tertiary Winding	Percentage Reactance**		
		KV Connec-tions	KV Connec-tions	KV Connec-tions	HV/V	MV/LV or Tertiary	HV/LV or Tertiary
1. 2. 3.							

*(1) In the case of star connections, please state clearly whether the neutral is effectively grounded.

(2) In the case of windings connected delta, please indicate whether it would be operated with isolated neutral or grounded through earthing transformers.

**(3) The MVA base to which these values relate should be clearly specified.

3, REACTORS

S.No.	Name of the Power House or Sub-station	Rating	Percentage Reactance (on its own Base)
1. 2. etc.			

4. EARTHING TRANSFORMERS

S.No.	Name of the Power House or Sub-station	Current Rating (Short-time)	Voltage	Time Rating	Percentage Reactance (on the short-time Rating)
1. 2.					

etc.					

Appendix II to Chapter III

(Refer Para 2.3(I) of Section C)

QUESTIONNAIRE 2

Government of India
Power & Telecommunication Co-ordination Committee

(To be answered by the Authorities in-charge of Telecommunication Line while Applying for PTCC Route Approval)

Section a (1)

1.0 Please supply the following data in respect of the particular telecom line for which approval is sought:

2.01 Name

2.02 Route-length

2.03 Probable date of commencing the construction.

2.04 Probable date of commissioning

2.05 Date by which approval is desired.

2.06 Please supply a route map showing the proposed route of the telecom line and also the existing/proposed power lines in the area drawn to a scale of 1"=1 mile or 1 cm=0.5 kms. Topographical details including railway lines, rivers, canals and important roads up to 8 kms. on either side of the proposed telecom line should also be drawn on the map.

2.07 Number and date of the route map.

2.08 Sketch or sketches of L-14 diagram of the proposed alignment.

2.09 Details of the circuits likely to work on the proposed line with discontinuity points and route lengths.

2.10 Please indicate the soil resistivity in the area covered by the proposed line. The soil resistivity should be measured by the four electrode method using an inter electrode spacing of 50 meters. The measurements may be made at every 2 or 3 kms. along with the length of the line.

2.11 Please indicate the number of crossings and angle of crossings between the proposed telecom alignment and the power lines and give a certificate that the crossing arrangement will be made in accordance with the Code of Practice for Crossings issued by PTCC.

2.12 Additional information as per Para 1.6 item (i) to (v) of Section B in Chapter III, for telegraph circuits.

Date: Signature and Designation of Telecom/Railway
Authority
Place:

(To be furnished by the SEB)
Section a (2)

2.0 Please supply the following data in respect of the power lines existing or proposed on either side of proposed telecom line (up to 8 kms. for 66 kV and above, 5 kms. for lines above 11 kV and up to 33KV and 3 kms. for lines up to 11KV).

2.1 Name of the power line/lines.

2.2 Operating voltage and number of circuits of power line/lines.

2.3 Length of power line/lines.

2.4 Whether the route(s) of power line/ lines has/ have been approved by PTCC? If yes, please indicate approval certificate number and date.

2.5 The designation and address of the officer in-charge of the power line/lines.

Date: Signature and Designation of Officer of SEB/
Deptt
Place:

Section b (1)
(Applicable to Coaxial Cables)

1.01 Name of the coaxial cable route.

1.02 Route length

1.03 (a) Number of coaxial tubes.
(b) Size of the coaxial tubes.
(c) Maximum frequency used on the coaxial conductors.
(d) Details of interstice pairs.
(e) The characteristic curves of screening factor for the proposed coaxial cable.

1.04 Probable date of commencing the construction.

1.05 Probable date of commissioning.

1.06 Date by which approval is desired.

1.07 Please supply the route map showing the proposed route of the coaxial cable to enable the Power authorities to mark the existing/proposed power lines in the area, drawn to the scale of 1” = 1 mile or 1 cm = 0.5 kms. Topographical details including railway lines, rivers, canals and important roads up to 8 kms. on either side of the proposed coaxial cable route should also be drawn up on the map.

1.08 Number and date of the route map.

1.09 Please indicate the soil resistivity of the area covered by the proposed coaxial cable route. Soil resistivity should be measured by the four electrode method using the inter electrode spacing of 50 meters. The measurement may be made at every 2 or 3 kms. along with length of the route.

1.10 Please indicate the screening factor characteristics for the coaxial cable.

Date: Signature and Designation of Telecom/ Railway
Authority
Place:

(To be furnished by the SEB/Power Utility)
Section b (2)

2.0 Please supply the following data of the power lines existing or proposed on either side of the proposed coaxial cable route (up to 8 kms. for 33 kV DC and above, 5 kms. for lines above 11KV and up to 33 kV SC and 3 kms. for lines up to 11KV.)

2.1 Name of the power line/lines.

2.2 Operating voltage and number of circuits of power line/line.

2.3 Length of the power line/lines.

2.4 Whether the route of power line/lines has been approved for the PTCC. If yes, please indicate the approval certificate number and date.

Date: Signature and Designation of Officers of SEB/ Department
Place:

(Applicable for Armored OF Cables)

QUESTIONNAIRE FOR ARMORED OFCABLE

1. Name of OFC route :

2. Route length :

3. Probable date of commencement of construction :

4. Probable date of commissioning :

5. Date by which approval is desired :

6. Please supply route map showing the proposed armored OFC route *indicating all jointing location*s in the map. The scale of the map should be 1” = 1 mile or 1cm = 0.5 km and should be written in the map. Topographical details including Railway lines, rivers, canals, and important roads, upto 8 kms. on either side of the proposed cable should also be drawn. There should be a 8 km. spacing on either side of the OFC in the map. :

7. Please indicate the soil resistivity in the area covered by the proposed OFC. The soil resistivity should be measured by the four electrode method

using an inter electrode spacing of 50 meters. The measurements may be made at every 2 or 3 kms. along the length of the line. :

Date Signature and Designation of
Place Telecom Authority

To be submitted to DET PTCC

1. Questionnaire – 1 copy

2. Route map with the following details – 3 copies
   a) Mark the OF cable route in the map so as to have 8 km spacing on either side of the cable.
   b) Indicate the joint locations in the map.
   c) Write the names of the terminals of the OFC route. In case of spur routes, name of the tapping point location should be given.
   d) Write the scale of the map in the map itself.

3. Value of induced voltage on the OFC due to 11 kV power lines.

4. Soil resistivity data

To be submitted to SDE PTCC, Inspection Circle, o/o CGM Telecom

1. Questionnaire – 1 copy

2. Route map with the following details – 1 copy
   a) Mark the OF cable route in the map.
   b) Indicate the joint locations in the map.
   c) Write the names of the terminals of the OFC route. In case of spur routes, name of the tapping point location should be given.
   d) Write the scale of the map in the map itself.
   e) Get all 33 kV SC/ 22 kV power lines, existing as well as proposed, within 8 kms. on either side of the power line marked in the map by Electricity authorities.
   f) Indicate transformer capacities and type/ gauge of the conductor and name of the terminals for each power line route on the map.
   g) Following certificate in the map signed by Electricity authorities:
   Certified that all 22 kV / 33 kV SC power lines, existing as well as proposed, within 8 kms. on either side of the power line have been marked in the map.

3. Soil resistivity data.

Appendix III to Chapter III
(Refer Para 2.3(I) of Section C)

ADDRESS OF ALL THE ZONAL RAILWAYS ALONG WITH THEIR POSTAL ADDRESS AND JURIDICTION FOR FORWARDING THE ptcc PROPOSAL.

Rly/Hq	Divisions	Designation	BSNL Phone	Fax No.	Address
Central Railway, Mumbai	Mumbai, CSTM, Bhusawal, Nagpur, Pune, Solapur.	CSTE	022-22620354	22659564	CSTE's Office, Central Railway, Annexe Building, 3rd Floor, Chattarpati shivaji Terminus, Mumbai - 400 001
Eastern Railway, Kolkata	Howarah, Sealdah, Asansol, Malda.	CSTE	033-22200444	22202112	CSTE's Office, 3rd Floor,Eastern Railway, Fairlie Place, 17, N.S. Road, Kolkata - 700 001.
Northern Railway, New Delhi	Delhi, Firozpur, Lucknow, Moradabad, Ambala.	CSTE	011-23386569	23304181	CSTE's Office, Room No.409, Northern Railway, Baroda House, New Delhi - 110 001.
Northeast Railway, Gorakhpur	Izzatnagar, Lucknow, Varanasi.	CSTE	0551-2201846	2203147	CSTE's Office, N.E. Rly. Hd. Qrs. Gorakhpur - 273012.
Northeast Frontier Railway, Guwahati	Alipurduar, Katihar, Lumding, Rangia, Tinsukia.	CSTE	0361-22570594	22570594	CSTE's Office, 1st Floor, N.R. Rly. Hd. Qrs. Maligaon, Guwahati - 781 011.
Southern Railway, Chennai	Chennai, Madurai, Palghat, Tiruchchirapalli, Trivandrum.	CSTE	044-25353800	25330177	CSTE's Office, Southern Railway, Hd. Qrs., Park Town, Chennia - 600 003

South Central Railway, Secunderabad	Secunderabad, Hyderabad, Guntkal, Guntur, Nanded, Vijaywada.	CSTE	040-27824755	27833193	CSTE's Office, Room No.720, S.C. Railway, Rail Nilayam, Secunderabad - 500 371
South Eastern Railway, Kolkata	Adra, Chakradharpur, Kharagpur, Ranchi	CSTE	033-24392373	24392203	CSTE's Office, 3rd Floor, New Annexure Bldg., S.E. Railway, 43, Garden Reach Road, Kolkata - 700 043.
Rly/Hq	**Divisions**	**Designation**	**BSNL Phone**	**Fax No.**	**Address**
Western Railway, Mumabi	Mumbai, Ahmedabad, Bhavnagar, Rajkot, Ratlam, Vadodara	CSTE	022-22082812	22002232	CSTE's Office, 5th Floor, Station Bldg., Churchgate, Western Railway, Mumbai - 400 020.
East Central Railway, Hajipur	Danapur, Dhanbad, Mughalsarai, Samastipur, Sonpur.	CSTE	06224-2677066	2677088	CSTE's Office, E.C. Railway, Hajipur - 844 101.
East Coast Railway, Bhubaneshwar	Khurda Road, Samalpur, Waltair.	CSTE	0674-2303347	2303508	CSTE's Office, B-1, Rail Vihar, Chandrasekharpur, Bhubaneshwar - 751 023.
North Central Railway, Allahabad	Allahabad, Agra, Jhansi.	CSTE	0532-2617535	2560050	CSTE's Office, North Central Railway, Allahabad - 211 001.
North Western Railway, Jaipur	Jaipur, Ajmer, Bikaner, Jodhpur.	CSTE	041-2220204	2221955	CSTE's Office, North Western Railway, Jaipur -302006.
South Western Railway, Hubli	Hubli, Bangalore, Mysore.	CSTE	0836-2364916	2364906	Head Quarter Office, S.W. Railway, Club Road, Keshwa Puri, Hubli - 580 023.

South Eastern Central Railway, Bilaspur	Bilaspur, Nagpur, Raipur.	CSTE	07752-237053	237053	CSTE's Office, South East Central Railway, Bilaspur - 495 004.
West Central Railway, Jabalpur	Jabalpur, Bhopal, Kota	CSTE	0761-2677066	2677088	Hd. Qrs. Office, West Central Railway, Jabalpur - 482 001.
Railway Board, Rail Bhawan, New Delhi		CSTE	011-23388504	23304690	Room No.124, Rail Bhawan, Raiseena Road, New Delhi - 110 001.

> Individual commitment to a group effort – that is what makes a team work, a company work, a society work, a civilization work.
>
> \- Vince Lombardi

APPENDIX
to
CHAPTER – IV

Appendix I to Chapter IV
(Refer Para 4 in Part I)

Procedure for Estimating Average Separation Between Power and Telecommunication Lines in Any Parallelism Section

In practice the routes of the power line and the paralleling telecommunication line will be such that the exposure in the entire stretch of parallelism will not be uniform. Consider any parallelism section, as for instance, the one shown in Figure 4. The power line can be deemed to be made up of a large number of small sub-sections. Let d_1, d_2….. d_n be the lengths of the various sub-sections. With respect to these small sub-sections, the exposure between power and communication circuits can be reasonably assumed to be uniform. In other words, the separating distance between the two systems can be assumed to be uniform with respect to this sub-section. Let S_1, S_2….. S_n be the separating distances corresponding to the sub-section d_1, d_2….. d_n respectively.

S = Equipment weighted average separation for the entire parallelism section.

$$D = d_1 + d_2 + d_3 + \cdots\cdots + d_n$$

= Total length of parallelism.

Then we can write

$$\frac{d}{\sqrt{S}} = \frac{d_1}{\sqrt{S_1}} + \frac{d_2}{\sqrt{S_2}} + \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \frac{d_n}{\sqrt{S_n}}$$

The method of determining equivalent average separation for any parallelism section is explained in Example IX. In Figure 5 values of $1/\sqrt{S_n}$ for various values of S_n have been given to facilitate quick calculation.

Example IX

In the case of Example I, survey of route reveals that separations, as given in the adjacent Table, can be maintained in the different stretches of the parallelism. Determine the induced voltage on the telecommunication circuits if the soil resistivity of the region is 10,000 ohms/cm^3.

Sl. no. of the Section	Length of the Section (d_n) in Km	Separating Distance between the Power and Telecom Line (S_n) in Km	$\sqrt{S_n}$	$d_n/\sqrt{S_n}$
1 First	0.611	0.52	0.721	0.847
2 Next	0.644	1.003	1.001	0.643
3 Next	0.620	1.167	1.081	0.574
4 Next	0.828	1.370	1.170	0.707
5 Next	0.909	1.405	1.186	0.765
6 Next	0.885	1.222	1.106	0.800
7 Next	0.740	1.062	1.031	0.717
8 Next	0.724	0.921	0.961	0.753
9 Next	6.800	0.796	0.892	7.623
10 Next	3.830	0.776	0.881	4.347
11 Next	1.400	0.865	0.930	1.505
12 Next	1.167	0.986	0.994	1.174
13 Next	1.367	0.974	0.988	1.384
14 Next	1.407	0.883	0.941	1.495
15 Next	0.885	0.725	0.852	1.039
16 Next	5.510	0.684	0.827	6.660
17 Next	0.885	0.632	0.796	1.110
18 Next	0.885	0.532	0.730	1.211
19 Next	0.644	0.442	0.665	0.968
20 Next	2.350	0.442	0.665	3.534
21 Next	0.418	0.684	0.828	0.505
22 Next	0.442	0.958	0.980	0.451
23 Next	1.207	1.282	1.132	1.065
24 Next	0.644	1.679	1.295	0.497
25 Next	0.941	2.140	1.463	0.643
26 Next	1.167	2.770	1.665	0.700
27 Next	2.090	2.870	1.695	1.232
	40.000			42.949

d = 40 Kms

$$\frac{d_1}{\sqrt{S_1}} + \frac{d_2}{\sqrt{S_2}} + \text{.........................} = 42.429$$

Let S = Average separation, then $\frac{40}{\sqrt{S}} = 42.949$

Therefore Average Separation, S = 0.866 Kms or 866 meters.

As the actual average separation is more than minimum safe separation (720 meters) vide example I, the induction is less than 430 volts.

Appendix II to Chapter IV

(Refer Para 5 in Part I)

MEASUREMENT OF SOIL RESISTIVITY

The soil resistivity at any place can be measured by means of Evershed Earth Tester.

The earth tester has four terminals marked P1, P2, C1 & C2 and four similar electrodes are driven into the ground at equal distances of 50 meters, in the region where the soil resistivity is to be determined (should be driven at least 3 to 4 feet). Let us Designate these four electrodes as A, B, C and D. A and D (extreme electrodes) should be connected to C1 and C2 of the meggar. The electrodes B and C (the middle ones) should be connected to P1 and P2. By operating the meggar handle continuously at a uniform speed, we can read the electrode resistance 'R' on the meggar scale. The soil resistivity is given by the equation

$$\rho = 2\pi aR$$

Where

ρ = Soil resistivity in ohm/Cm^3.

R = Meggar reading in ohms.

A = Distance between two electrodes in Cms.

Note: (1) Generally, in Evershed earth meggars, the reading as obtained on the meggar will have to be divided by 10 or 100, depending upon the setting on the meggar.

(2) For further details Appendix II to Chapter VII may also be referred.

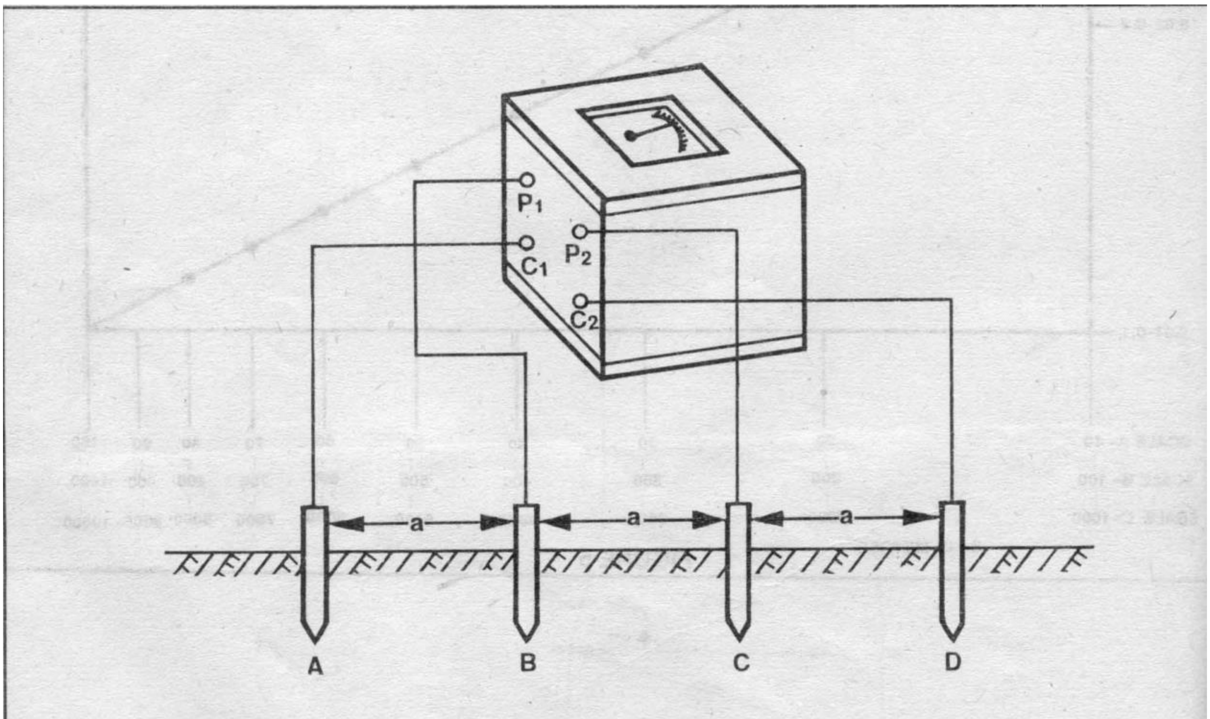


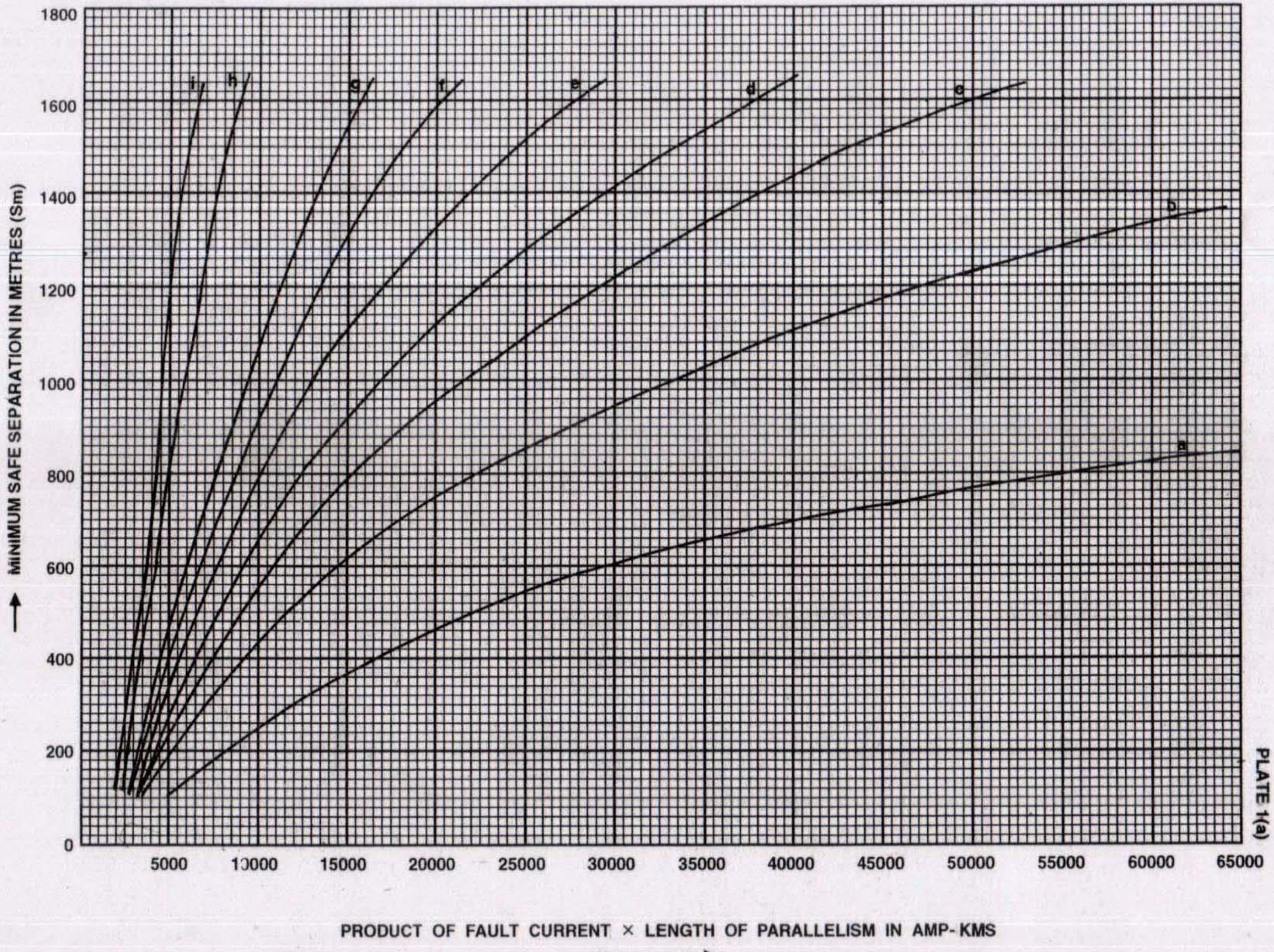
FIGURE 6

Appendix III to Chapter IV

(Refer Paras 1 and 2 of Part 1 and First Para of Part II)
PLATES 1(a), 1(b), 2(a), 2(b),2(c) and 3(a) to 3(i)

Teamwork is the fuel that allows common people to attain uncommon results.
- Andrew Carnegie

PLATE 1(a)



GRAPH SHOWING MINIMUM SAFE SEPARATION REQUIRED BETWEEN POWER AND TELECOM LINES FOR INDUCTION WITHIN LIMITS

(a) ρ = 1000 Ω/Cms^3
(b) ρ = 3000 Ω/Cms^3
(c) ρ = 5000 Ω/Cms^3
(d) ρ = 7500 Ω/Cms^3
(e) ρ = 10000 Ω/Cms^3
(f) ρ = 15000 Ω/Cms^3
(g) ρ = 20000 Ω/Cms^3
(h) ρ = 50000 Ω/Cms^3
(i) ρ = 100000 Ω/Cms^3

MINIMUM SAFE SEPARATION WHERE Sm IS FROM 0 TO 100 METRES

PLATE 1(b)

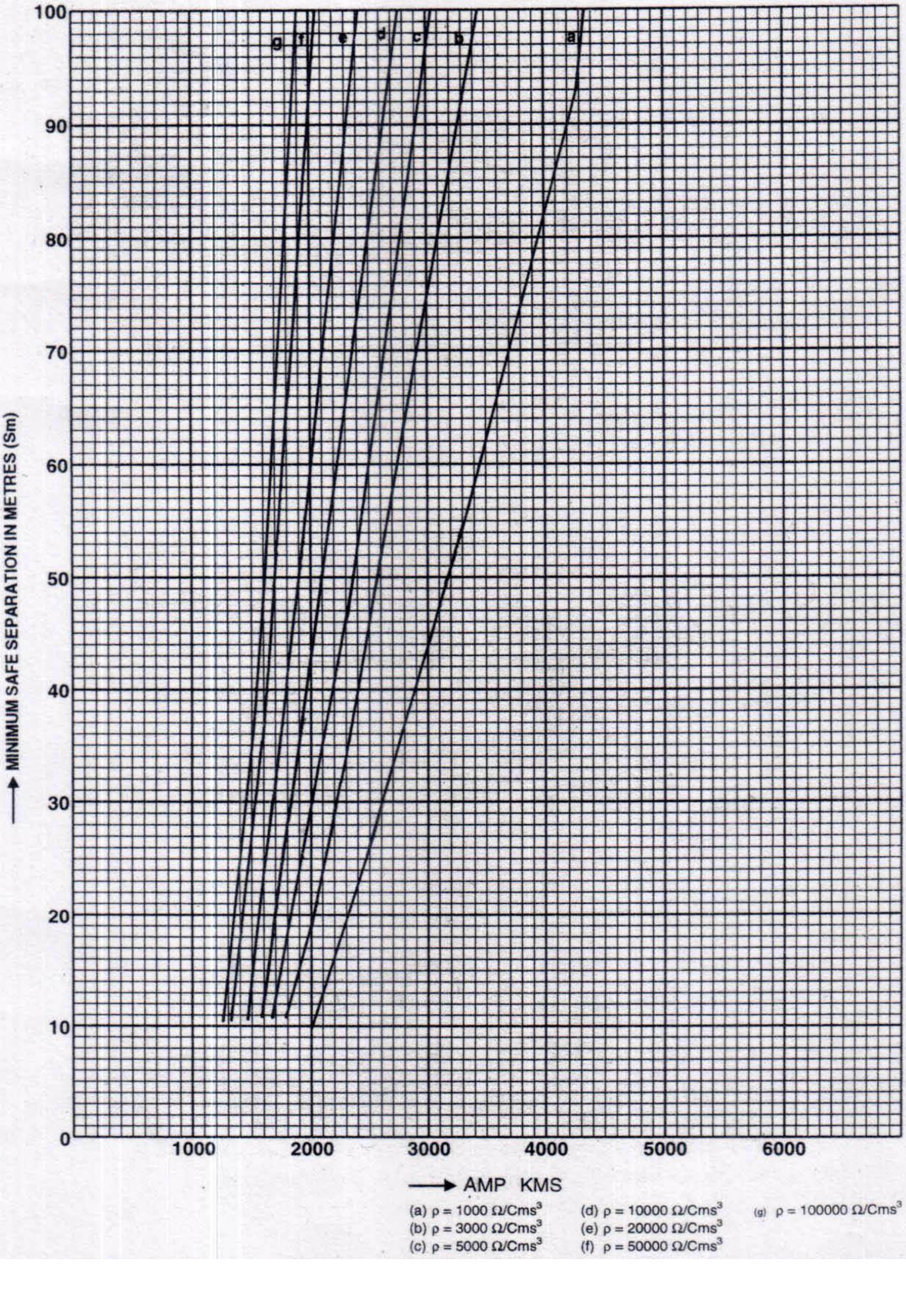
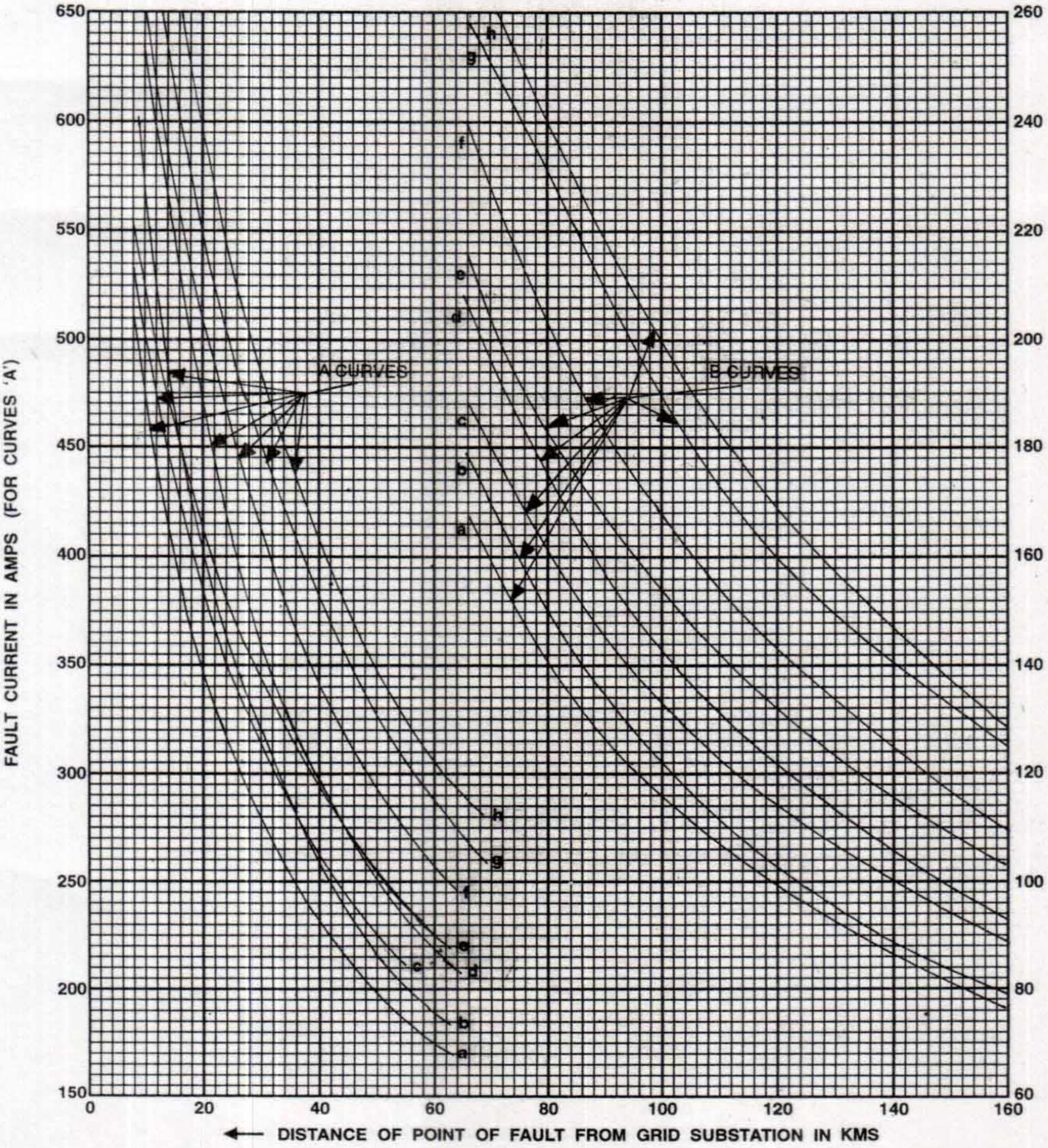


PLATE 2(a)

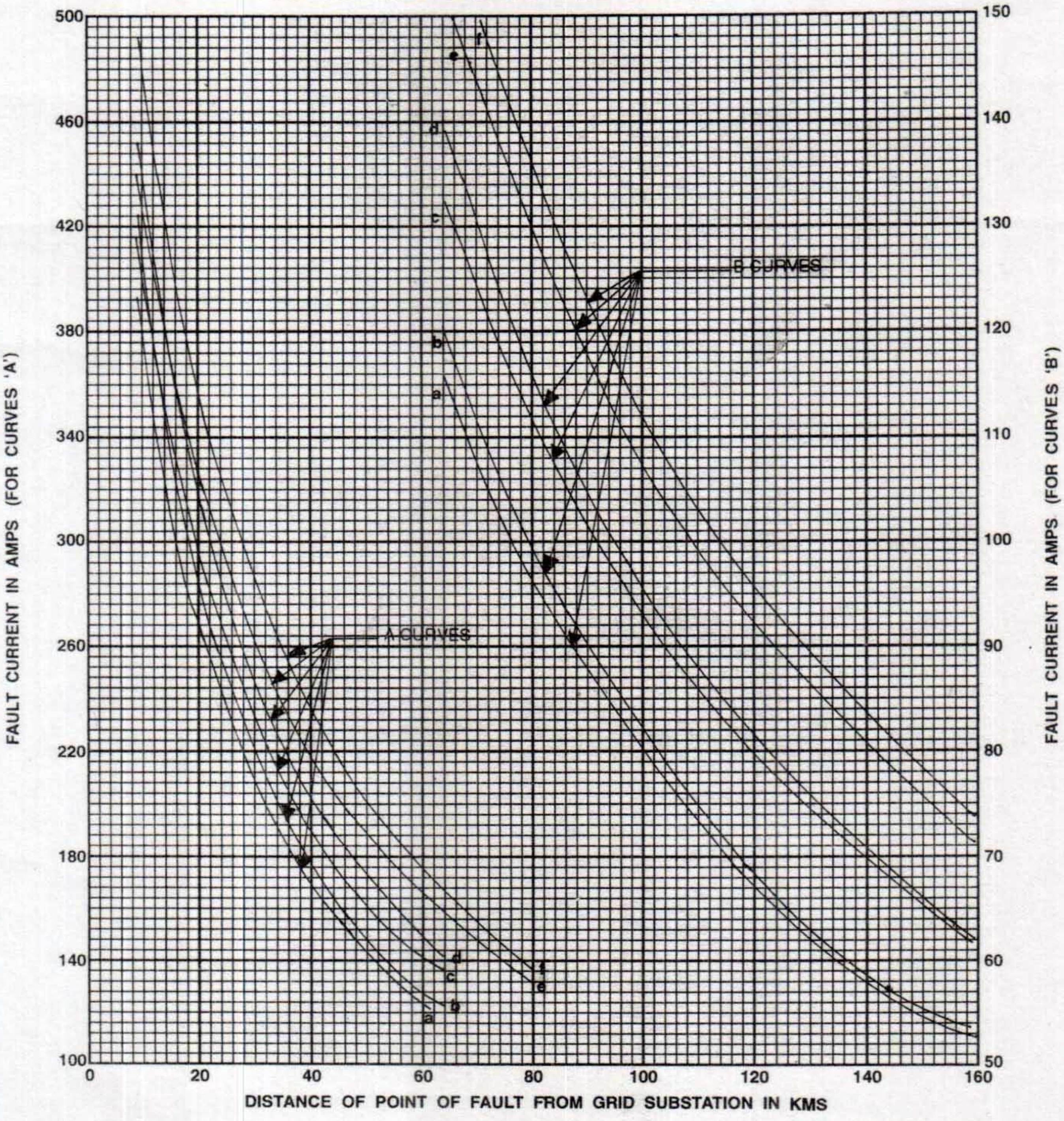
CALCULATION OF FAULT CURRENT FOR 33KV SYSTEM FOR STEPDOWN TRANSFORMERS OF 5 AND 30MVA CAPACITIES



(a) 0.03 ACSR (K = 5)
(b) 0.03 ACSR (K = 30)
(c) 0.04 ACSR (K = 5)
(d) 0.04 ACSR (K = 30)
(e) 0.06 ACSR (K = 5)
(f) 0.06 ACSR (K = 30)
(g) 0.10 ACSR (K = 5)
(h) 0.10 ACSR (K = 30)

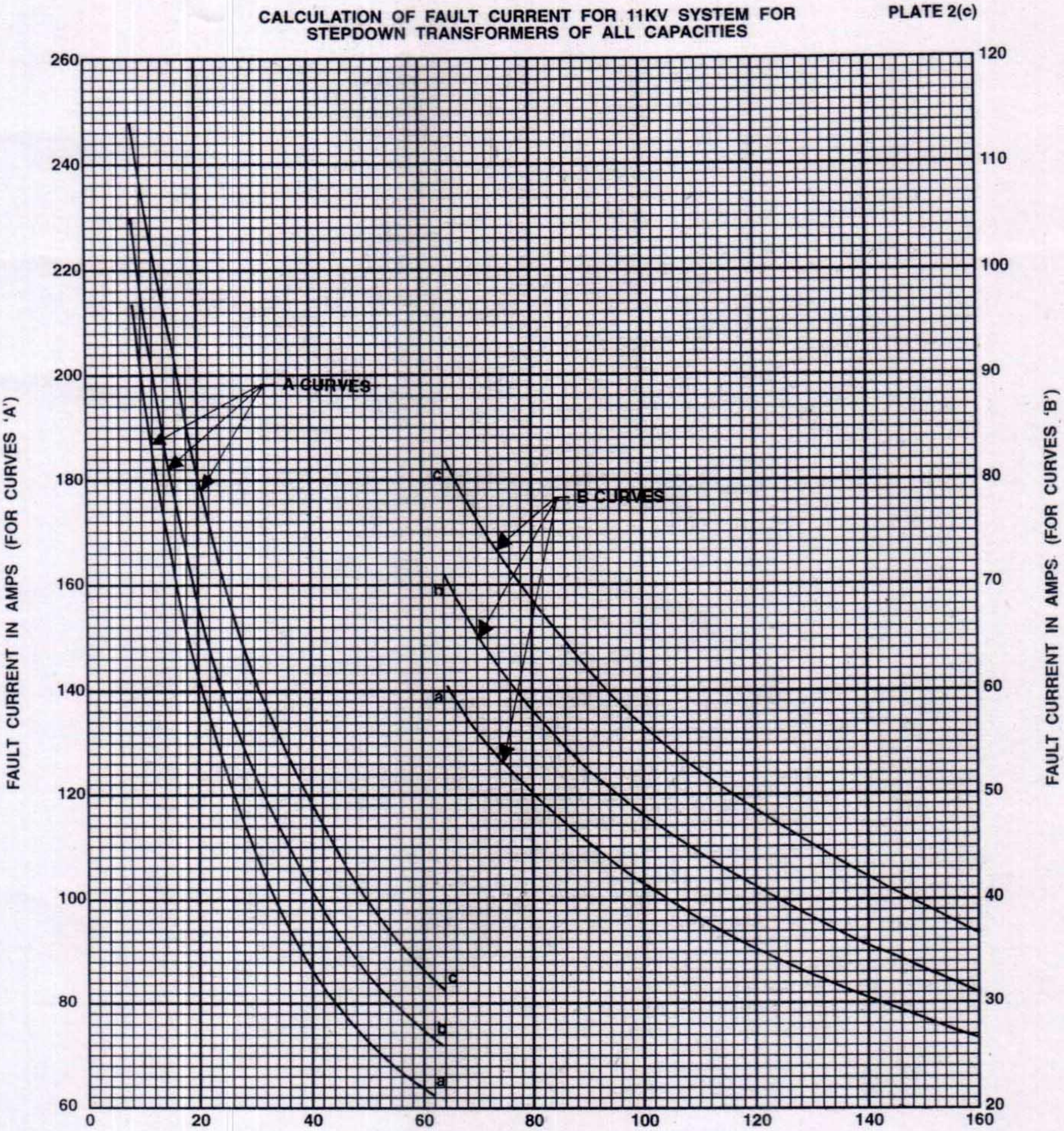
CALCULATION OF FAULT CURRENT FOR 22KV SYSTEM FOR STEPDOWN TRANSFORMERS OF 5 AND 30MVA CAPACITIES

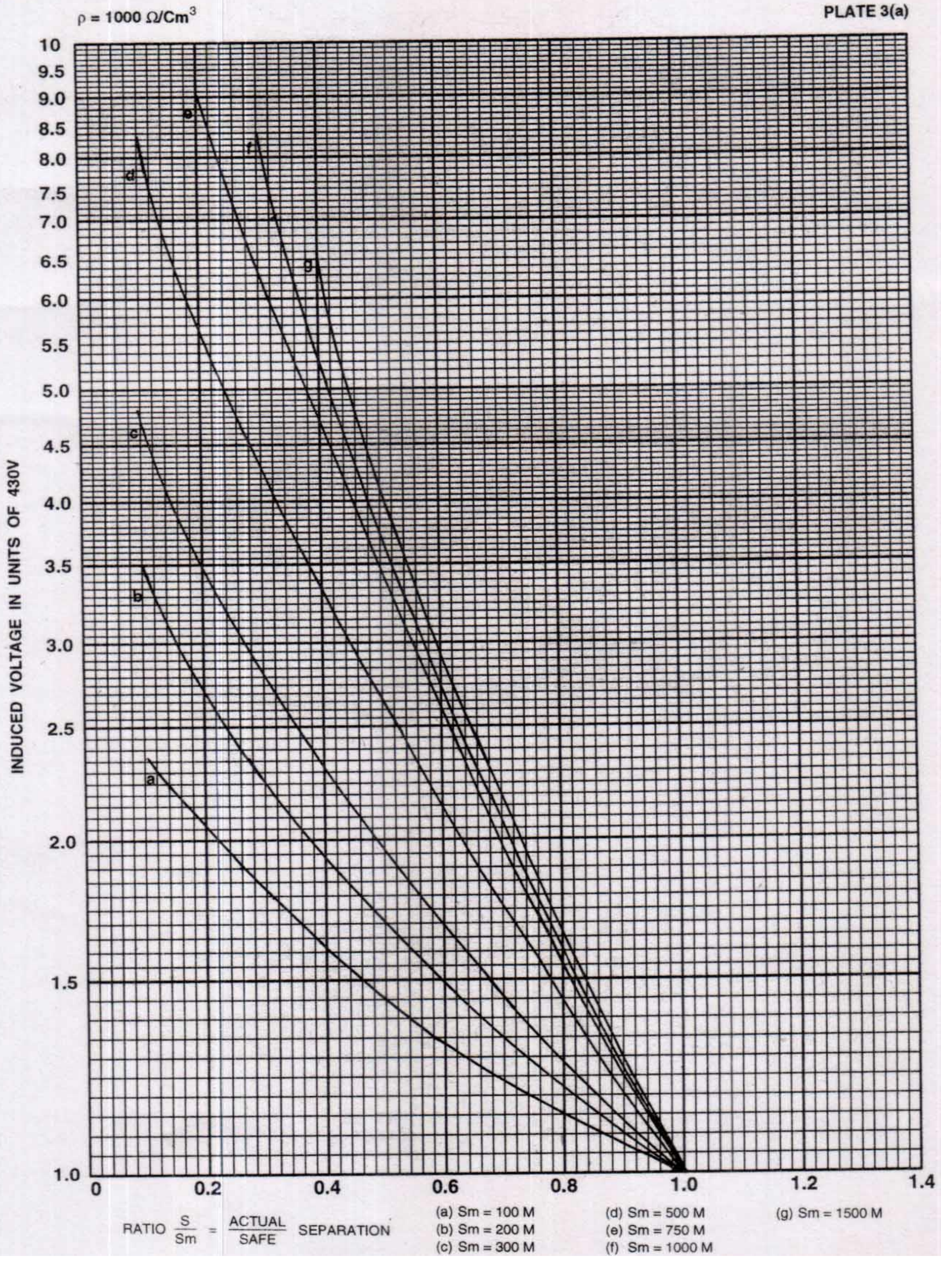
PLATE 2(b)

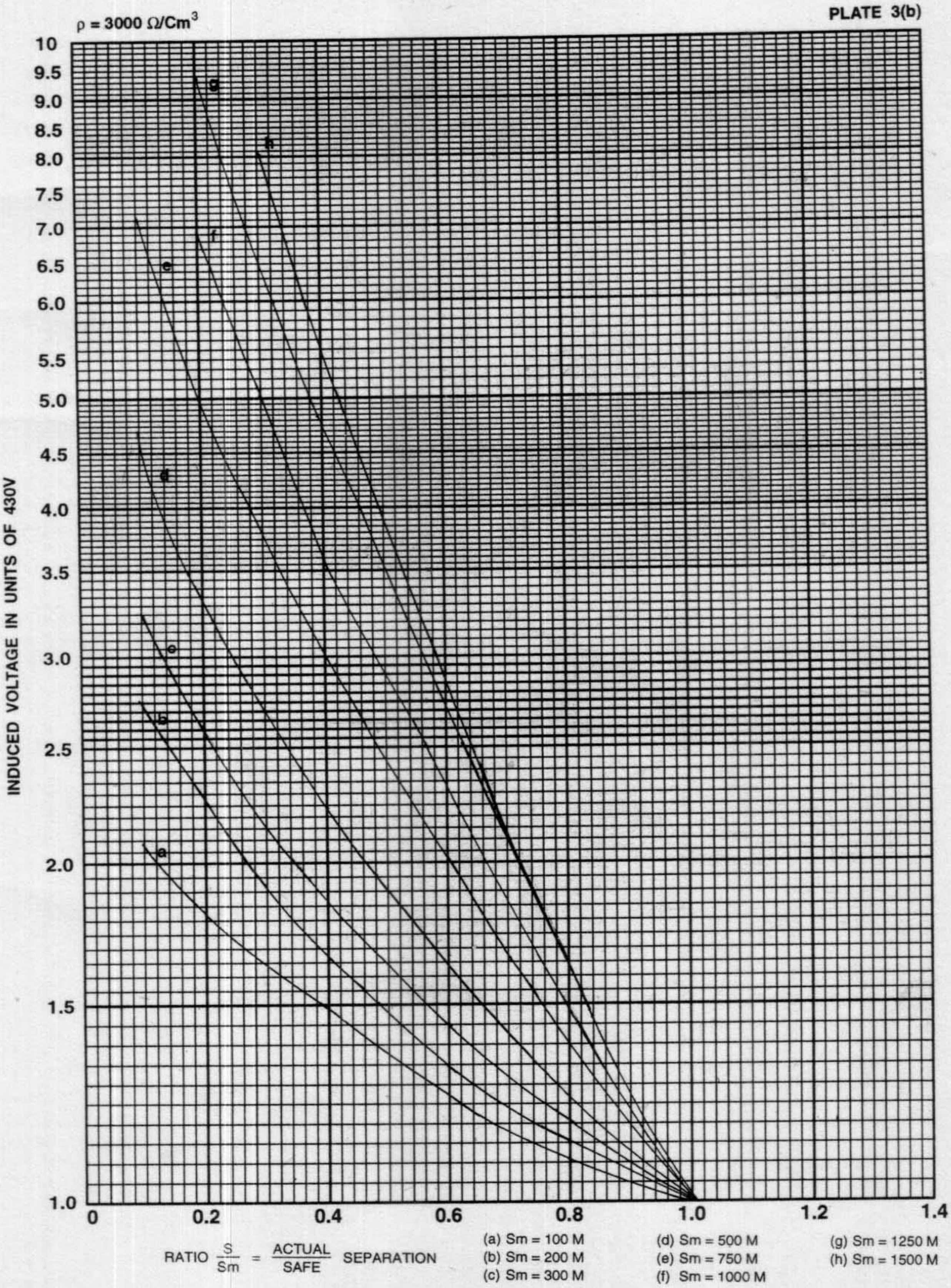


(a) 0.03 ACSR (K = 5) (b) 0.03 ACSR (K = 30)
(c) 0.04 ACSR (K = 5) (d) 0.04 ACSR (K = 30)
(e) 0.06 ACSR (K = 5) (f) 0.06 ACSR (K = 30)

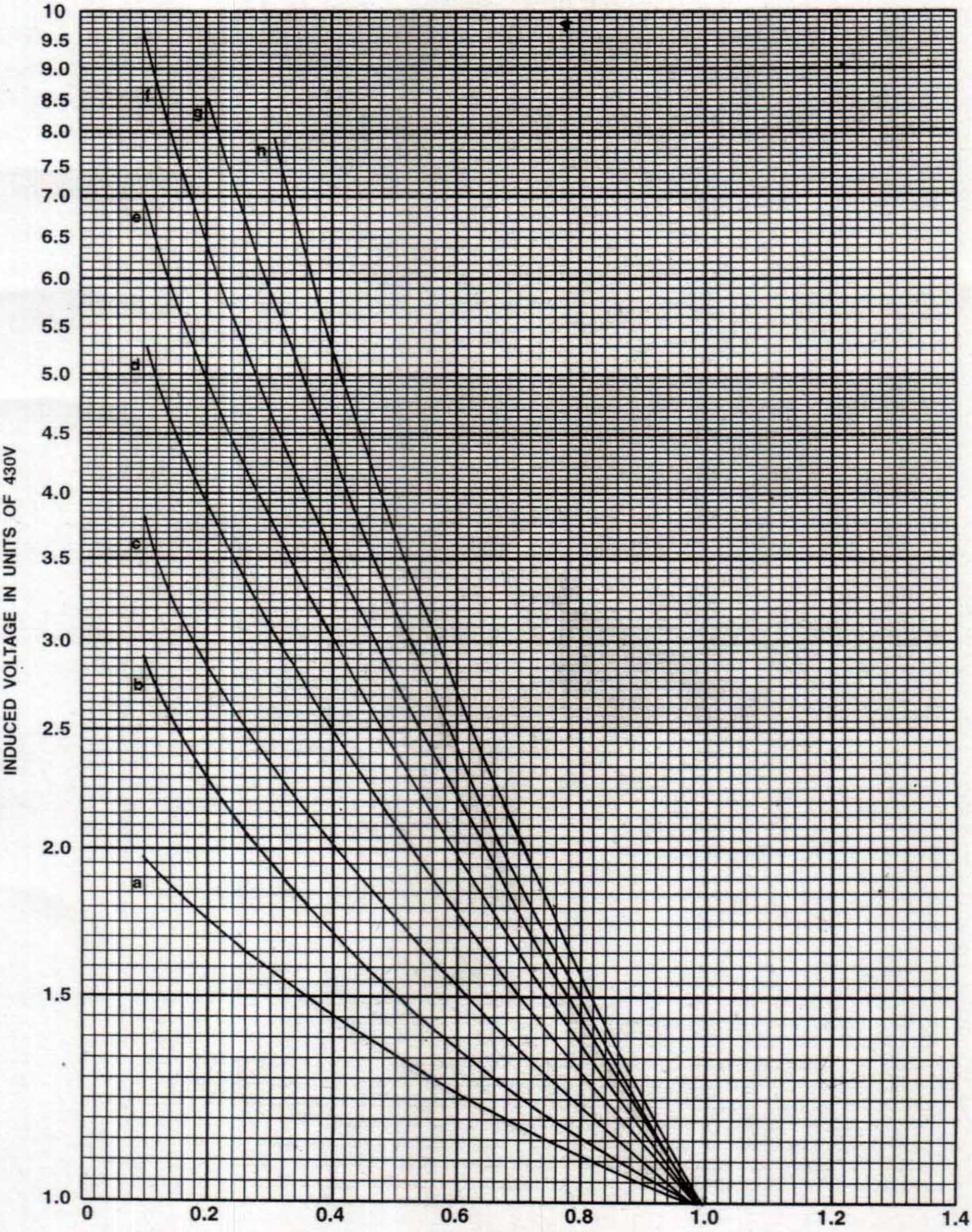
PLATE 2(c)


CALCULATION OF FAULT CURRENT FOR 11KV SYSTEM FOR STEPDOWN TRANSFORMERS OF ALL CAPACITIES
FAULT CURRENT IN AMPS (FOR CURVES 'A')
FAULT CURRENT IN AMPS (FOR CURVES 'B')
A CURVES
B CURVES
a
b
c
260
240
220
200
180
160
140
120
100
80
60
120
110
100
90
80
70
60
50
40
30
20
0
20
40
60
80
100
120
140
160
DISTANCE OF POINT OF FAULT FROM GRID SUBSTATION IN KMS
(a) 0.03 ACSR
(b) 0.04 ACSR
(c) 0.06 ACSR


ρ = 1000 Ω/Cm³
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
a
b
c
d
e
f
g
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1500 M


ρ = 3000 Ω/Cm3
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
a
b
c
d
e
f
g
h
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M

ρ = 5000 Ω/Cm³



RATIO $\frac{S}{Sm} = \frac{\text{ACTUAL}}{\text{SAFE}}$ SEPARATION

(a) Sm = 100 M
(b) Sm = 300 M
(c) Sm = 500 M
(d) Sm = 750 M
(e) Sm = 1000 M
(f) Sm = 1250 M
(g) Sm = 1500 M
(h) Sm = 2000 M

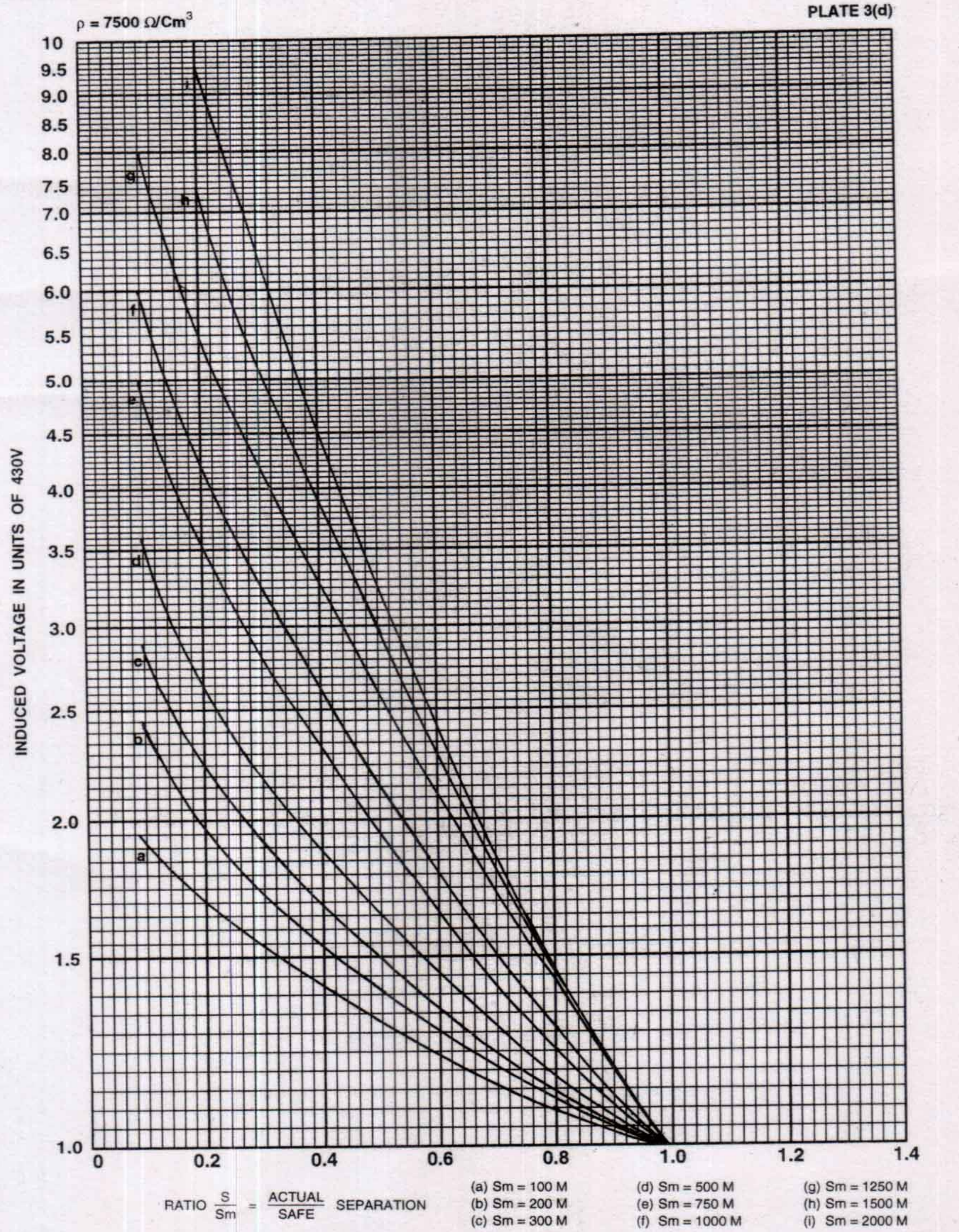
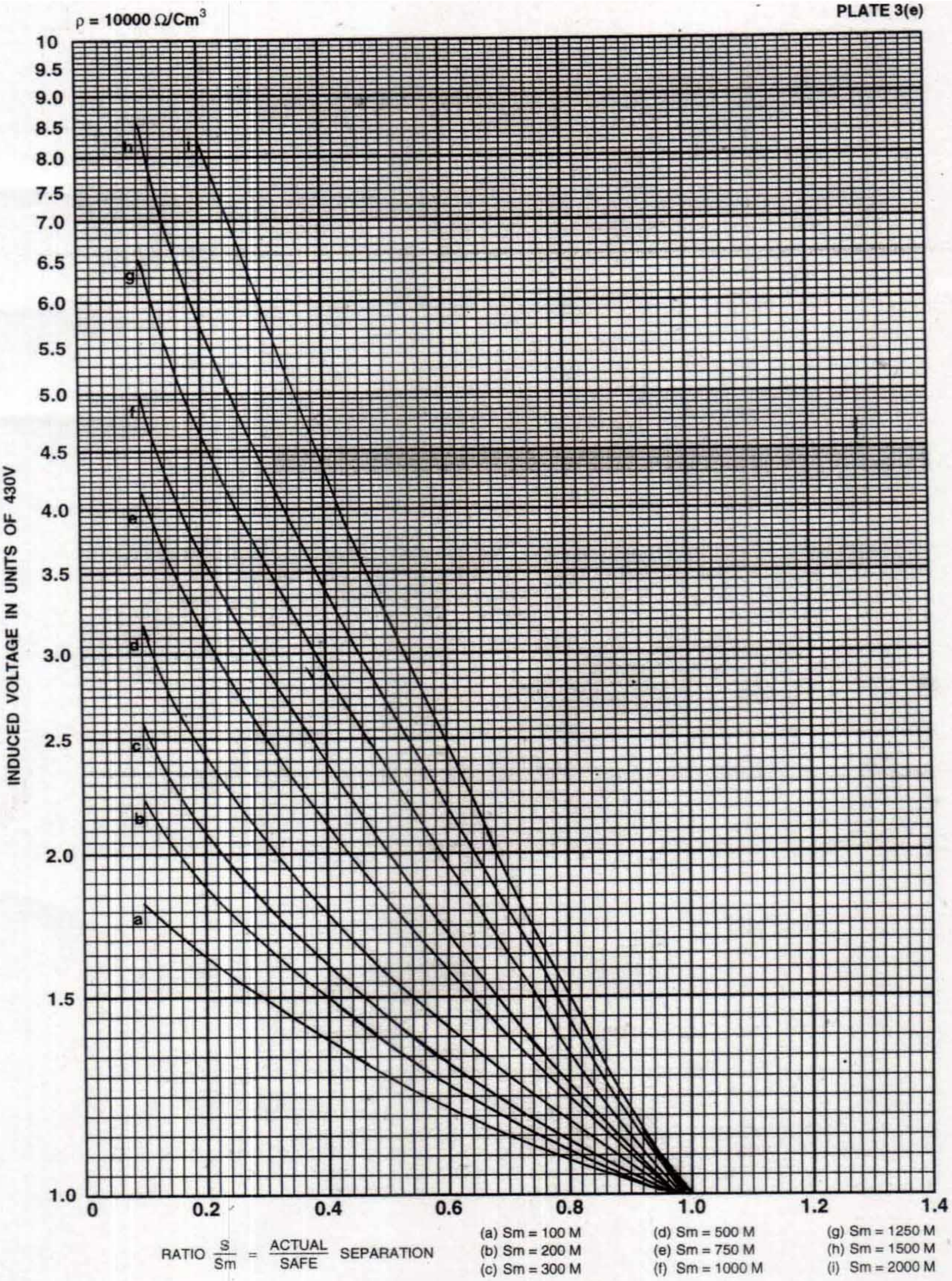
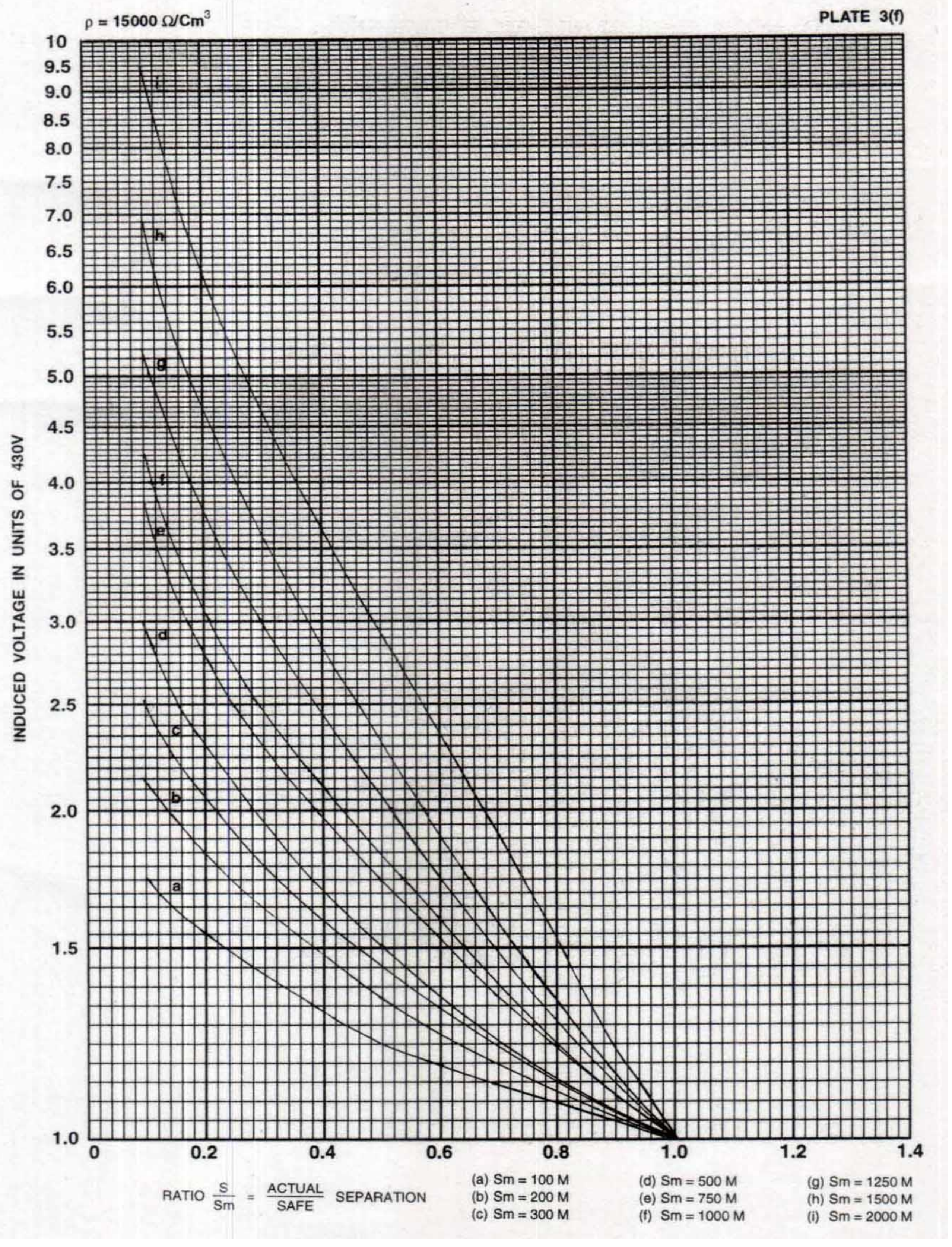
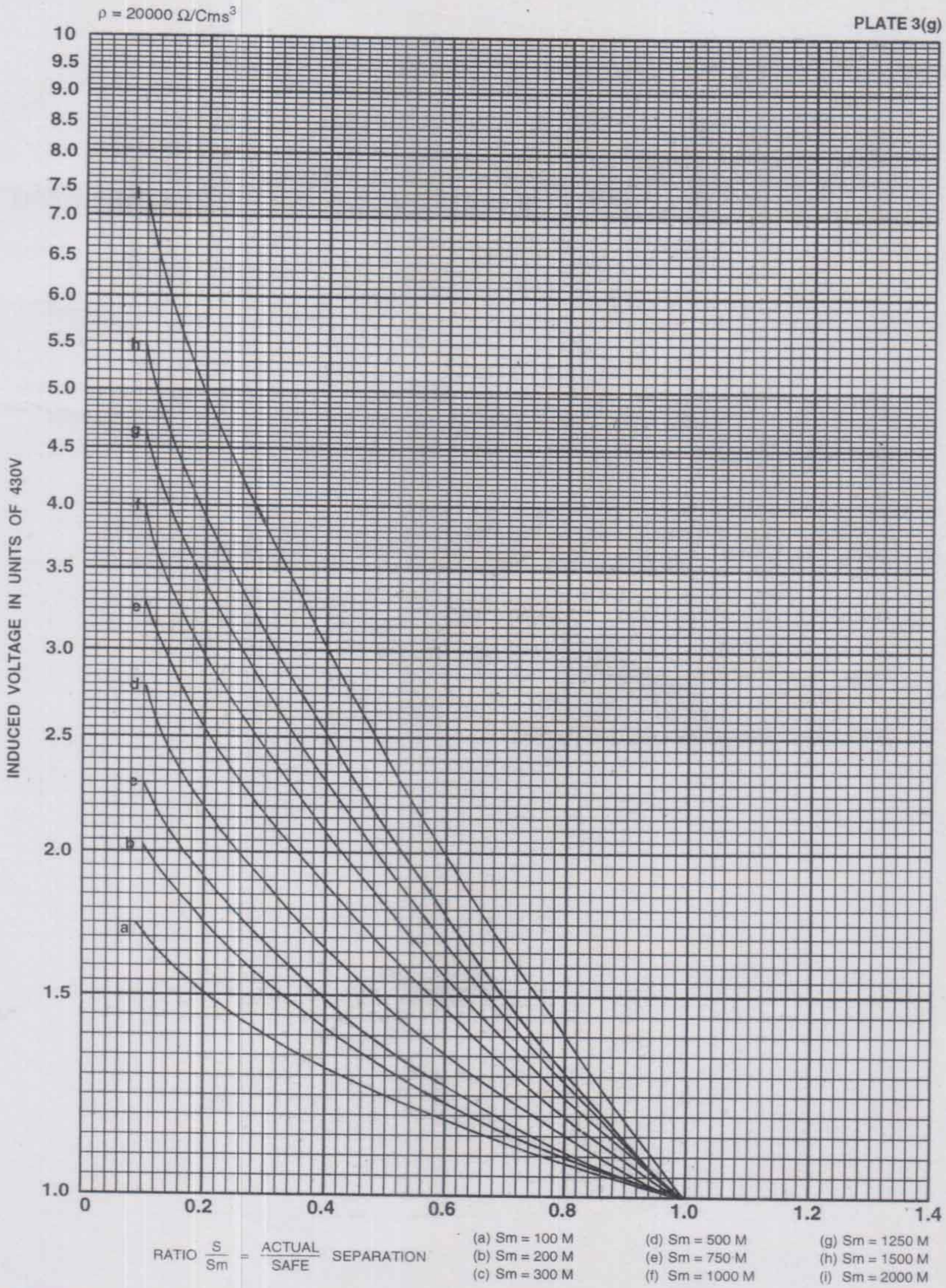


PLATE 3(d)
ρ = 7500 Ω/Cm3
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
a
b
c
d
e
f
g
h
i
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M
(i) Sm = 2000 M

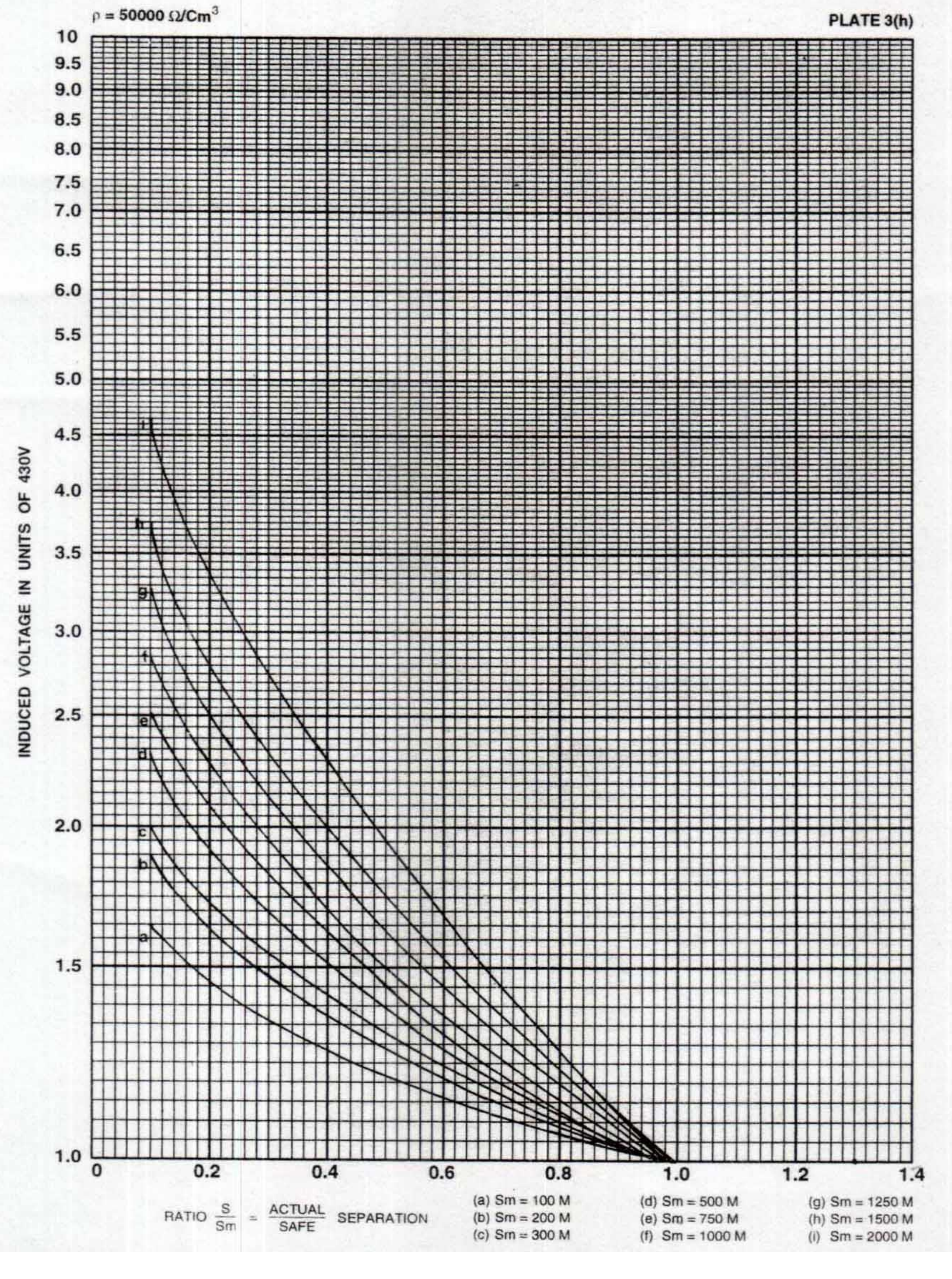

ρ = 10000 Ω/Cm3
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
h
i
g
f
e
d
c
b
a
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M
(i) Sm = 2000 M



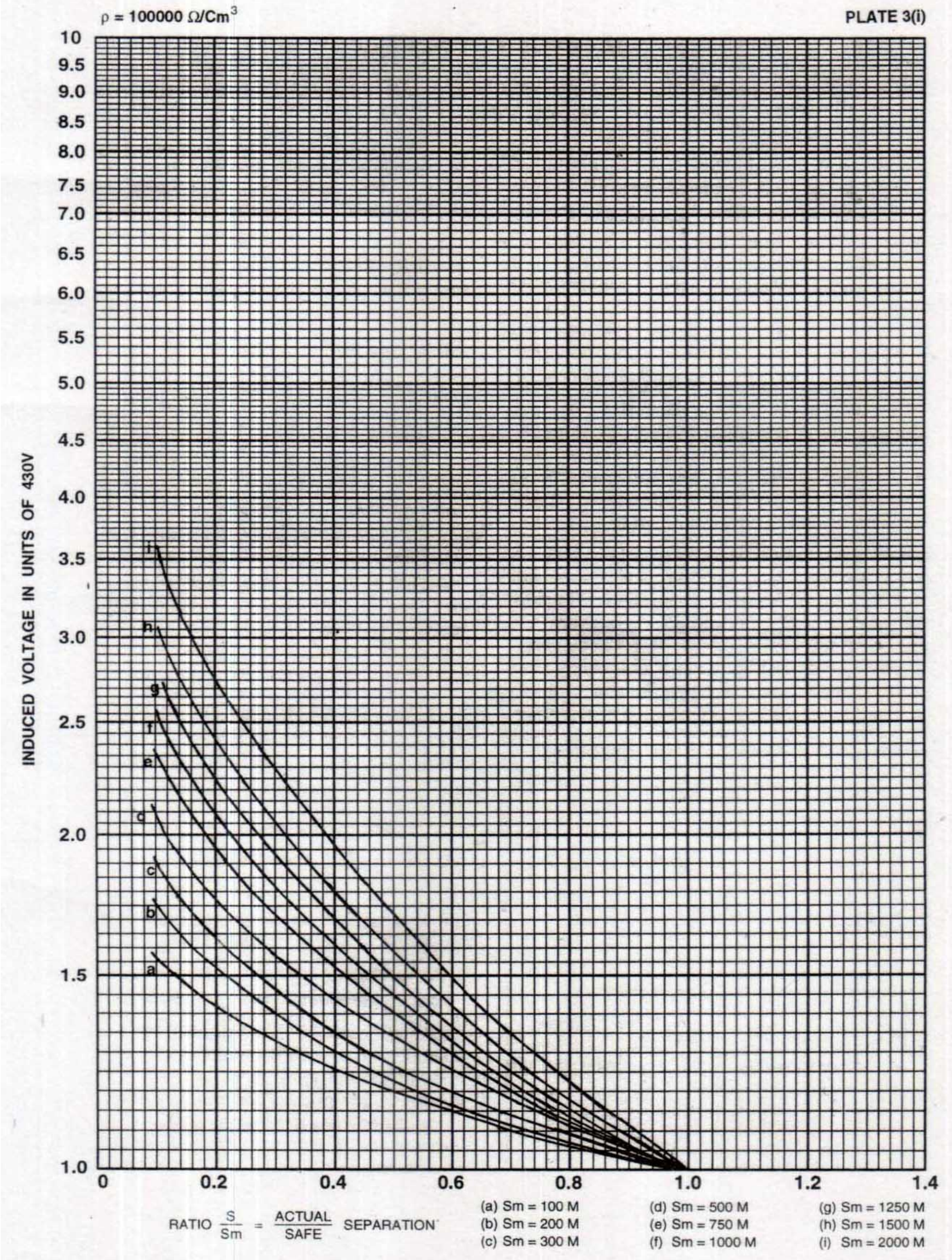
ρ = 15000 Ω/Cm³
PLATE 3(f)
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
i
h
g
f
e
d
c
b
a
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M
(i) Sm = 2000 M



ρ = 20000 Ω/Cms3
PLATE 3(g)
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
a
b
c
d
e
f
g
h
i
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M
(i) Sm = 2000 M



ρ = 50000 Ω/Cm³
PLATE 3(h)
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
a
b
c
d
e
f
g
h
i
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M
(i) Sm = 2000 M


ρ = 100000 Ω/Cm3
INDUCED VOLTAGE IN UNITS OF 430V
10
9.5
9.0
8.5
8.0
7.5
7.0
6.5
6.0
5.5
5.0
4.5
4.0
3.5
3.0
2.5
2.0
1.5
1.0
0
0.2
0.4
0.6
0.8
1.0
1.2
1.4
a
b
c
d
e
f
g
h
i
RATIO S/Sm = ACTUAL/SAFE SEPARATION
(a) Sm = 100 M
(b) Sm = 200 M
(c) Sm = 300 M
(d) Sm = 500 M
(e) Sm = 750 M
(f) Sm = 1000 M
(g) Sm = 1250 M
(h) Sm = 1500 M
(i) Sm = 2000 M

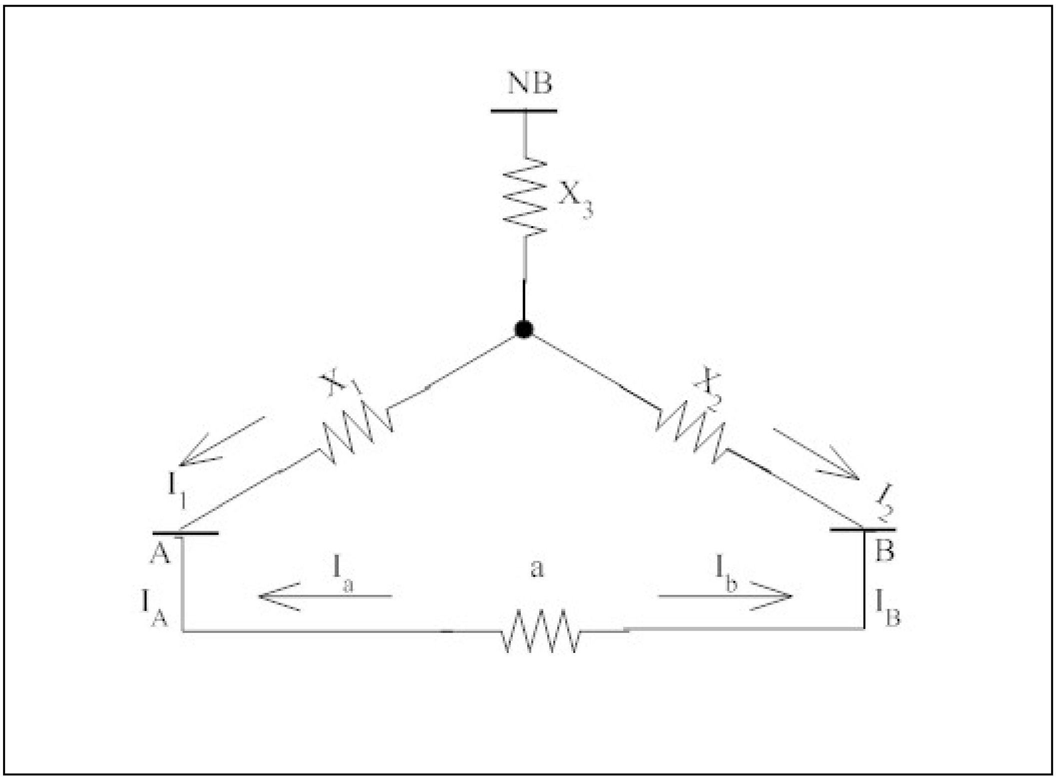
APPENDIX
to
CHAPTER – V

Appendix I to Chapter V

[Refer Para 4.2.5 (i)]

Procedure to Calculate Fault Currents At Intermediate Points between Buses from Level Studies

Positive and zero sequence impedances of the line A-B under examination can be calculated from the data supplied with the case referred. By successive reduction of the network, it reduces to the form shown in Figure 8. The values of the impedances X1, X2 and X3 are to be determined. The fault study will give fault levels at buses A & B and the contribution of current through the line under examination.



For fault at bus A, the following data is available for the study,

I_A = Total fault current

I_a = Fault current through the line A-B.

I_1 = I_A – I_a = Fault current through other lines and transformers etc., connected to the bus A.

A = Impedance of the line A-B

The fault impedance Z_A at bus A, which includes the impedance of the line A-B also could then be determined.

Similarly, for fault at bus B,

I_B = Total fault current.

I_b = Fault current through A-B.

$I_2 = I_B - I_b$ = Fault current through other lines and transformers etc, connected to the bus B.

Z_B = Fault impedance at bus B including that of line A-B.

Then,

(i) $Z_A = X_3 + \frac{X_1(X_2+a)}{X_1+X_2+a}$ [As X_1 & (X_2+a) are in parallel for fault at A].

(ii) $Z_B = X_3 + \frac{X_2(X_1+a)}{X_1+X_2+a}$ [As X_2 & (X_1+a) are in parallel for fault at B].

(iii) $I_a = \frac{X_1}{X_1+X_2+a}$ for fault at A

(iv) $I_b = \frac{X_2}{X_1+X_2+a}$ for fault at B

By solving equation (iii) & (iv)

$$X_1 = \frac{I_a I_B}{(I_1 I_2 - I_a I_b)} \times a$$

$$X_2 = \frac{I_A I_b}{(I_1 I_2 - I_a I_b)} \times a$$

Substituting the values of X_1 and X_2 in (i) or (ii)

$$X_3 = Z_A - \frac{I_1 I_a I_B}{I_A (I_1 I_2 - I_a I_b)} \times a$$

$$= Z_A - \frac{I_1}{I_A} \times X_1$$

or $$X_3 = Z_B - \frac{I_2 I_b I_A}{I_B (I_1 I_2 - I_a I_b)} \times a$$

$$= Z_B - \frac{I_2}{I_B} \times X_2$$

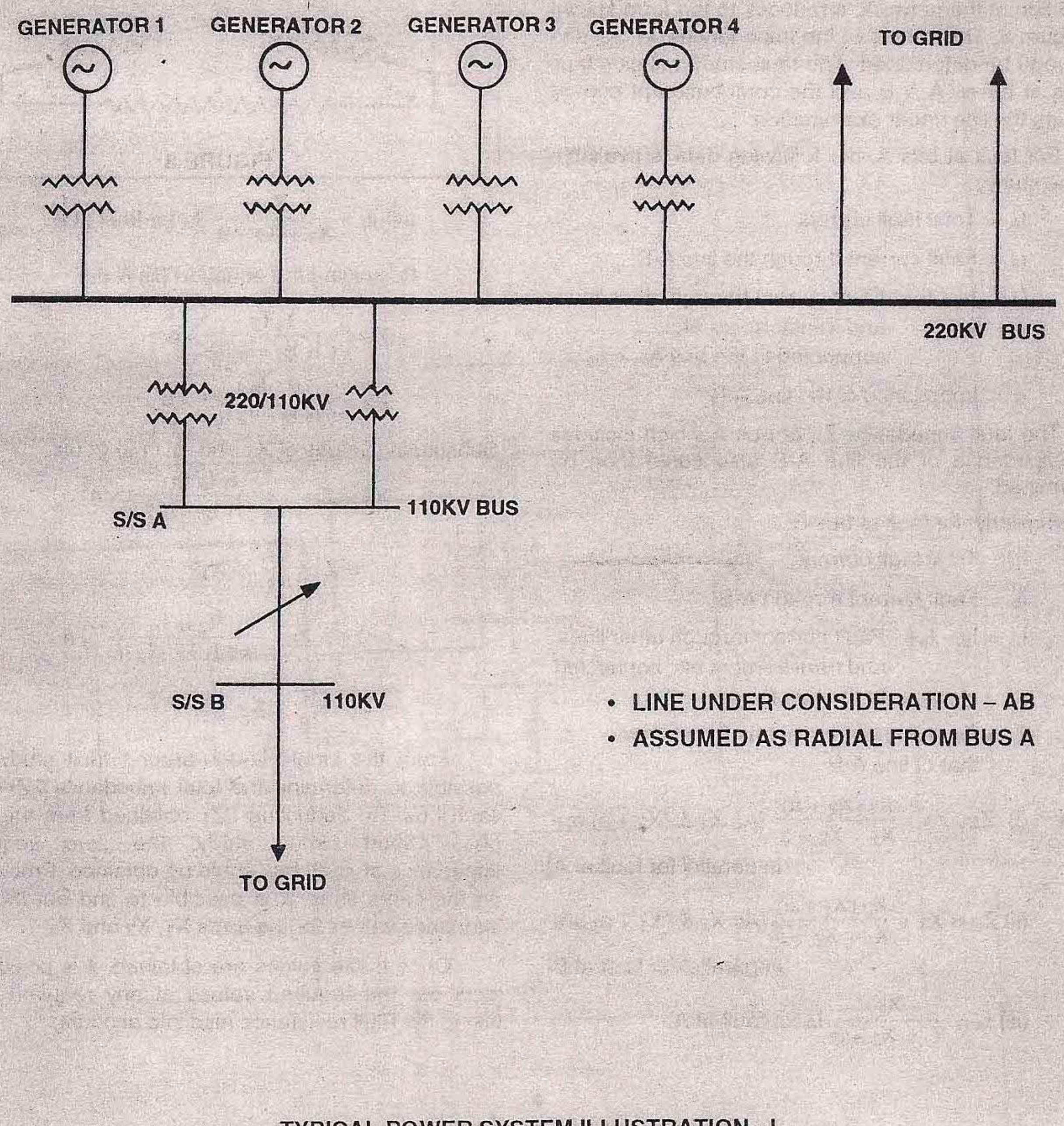
From the single line-to-ground fault study, it is possible to determine the total impedance $2Z_1+Zo$ at each bus. By deducting $2Z_1$ obtained from the three-phase short circuit study, the zero sequence impedance at each bus could be obtained. Proceeding on the same lines, it is possible to find out the zero sequence values for the arms X_1, X_2 and X_3.

Once these values are obtained, it is possible to work out the required values at any required point, taking the fault resistances also into account.

Appendix II to Chapter V

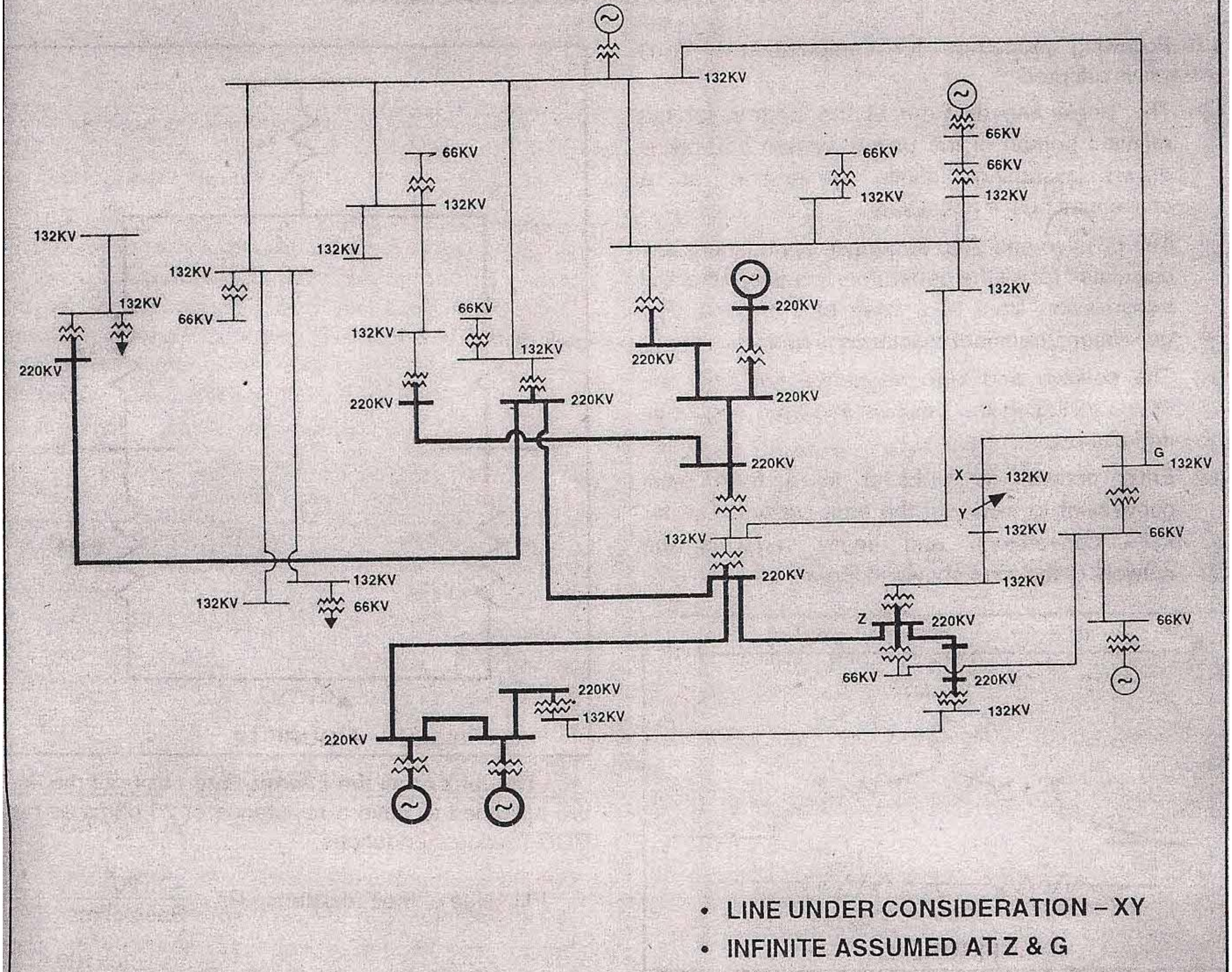
[Refer Para 4.2.5 (ii)]

Typical Power System Illustrations



TYPICAL POWER SYSTEM ILLUSTRATION - I

FIGURE 9



TYPICAL POWER SYSTEM ILLUSTRATION - II

FIGURE 10

Appendix III to Chapter V

[Refer Para 4.2.5 (iii)]

Computation of Fault Currents

1.0 Following procedure for computation of fault currents is adopted:

(i) The single line diagram of the system for the relevant portion of the power system network is drawn assuming infinite generation at a convenient bus, if necessary.

(ii) The positive and zero sequence impedances are calculated for all the generators, transformers and transmission lines to a base of 100 MVA (for generators, transient reactance is taken).

(iii) The positive and zero sequence networks are drawn including the positive and zero sequence impendence.

(iv) Each network is reduced to a form most convenient to work out the fault currents by star delta conversions and finally reducing the network to the form shown in Figure 11.

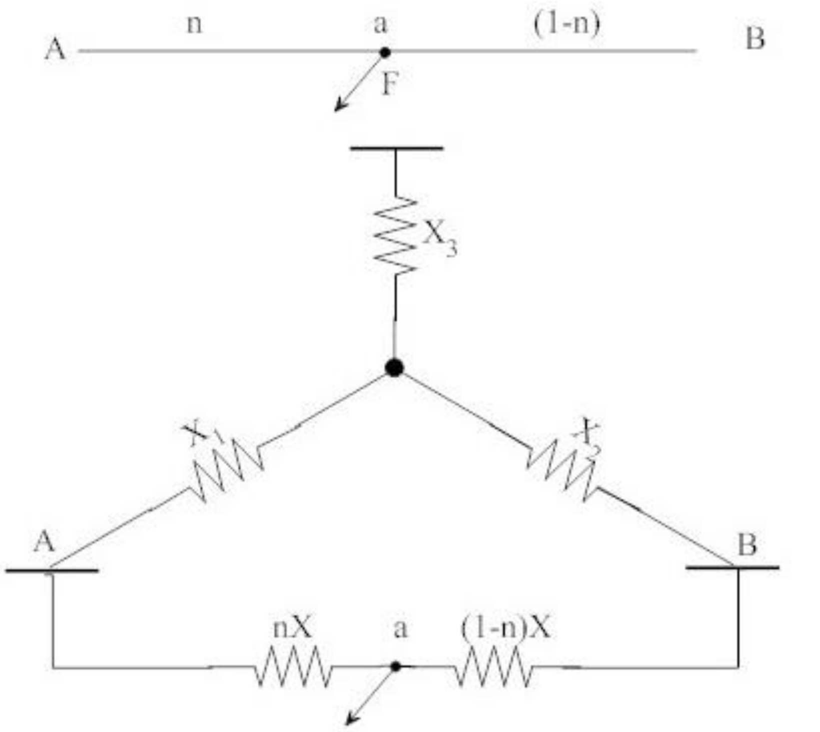


Figure 11

1.1 For Single Circuit Lines

When, considering the fault at point (a), the impedance will be given by

$$X_a = X_3 + \frac{(X_1 + nx)\left[X_2 + (l - n)x\right]}{X_1 + X_2 + lx}$$

Where X	is impedance/mile or impedance/Km of the line
l	is length of the line in miles or Kms.
n	is distance of the fault from bus A in miles or Kms.

The network is reduced to the form shown in Figure 12.

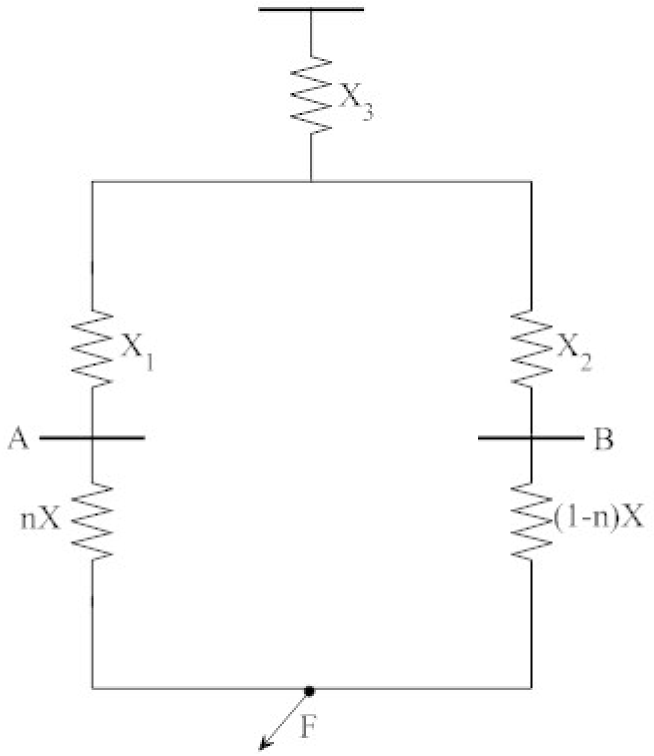


Figure 12

The fault at all the intermediate points of the line is assumed to have a resistance of 20 ohms as per CCITT recommendations.

PU value of fault resistance $R_F = \frac{20}{\text{Base Ohms}}$

Percentage value $R_F = \frac{20 \times 100}{\text{Base Ohms}}$

$$\text{Where} \quad \text{Base ohm} = \frac{(\text{Base Voltage in KV})^2}{\text{Base MVA}}$$

To account for this resistance in zero sequences network, it is necessary to add $3R_F$ to the zero sequence networks. Therefore, the total zero sequences impedance will be:

$$Z_0 + 3R_F = Z_0 + \frac{3 \times 20 \times 100}{\text{Base ohms}}$$

$$\text{Total fault impedance} \quad \vec{Z_T} = \overrightarrow{(Z_1 + Z_2 + Z_0)} + \left[\overrightarrow{\frac{6000}{\text{Base ohms}}} \right]$$

$$\text{Since } Z_1 = Z_2, \vec{Z} = \overrightarrow{(2Z_1 + Z_0)} + \overrightarrow{\left(\frac{6000}{\text{Base ohms}} \right)}$$

$$|Z_T| = \sqrt{(2Z_1 + Z_0)^2 + \left(\frac{6000}{\text{Base ohms}} \right)^2}$$

$$\text{Fault current } I_F = \frac{3 \times \text{Base Amps} \times 100}{Z_T}$$

1.2 For Double circuit Lines

This study requires knowledge of effective positive sequence and zero sequence impedance of the grid corresponding to the point of fault on one of the circuits of the DC line including the mutual impedance of the two circuits. This can be obtained by suitably representing the concerned double circuit line and the positive or zero sequence network of the grid.

1.2.1 Positive Sequence Network

The representation of a double circuit line in positive sequence network is as shown in Figure 13

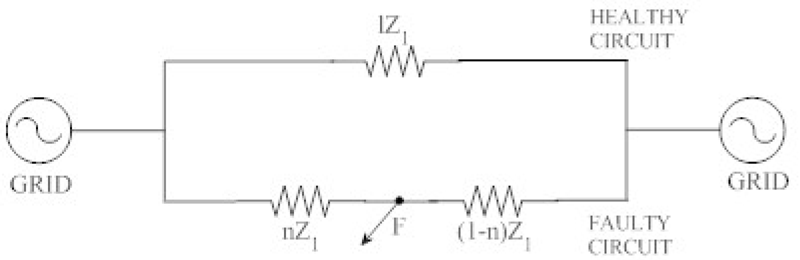


Figure 13

1.2.2 Zero Sequence Network

The effective impedance of any double circuit line comprises two components viz self-impedance per circuit plus mutual impedance due to the second circuit. The mutual impedance is represented by Zm and can be known from standard tables. Another factor required is 'K' which is the difference of self-impedance and mutual impedance and can also be obtained from standard tables. The representation of the line in zero sequence networks is given in Figure 14.

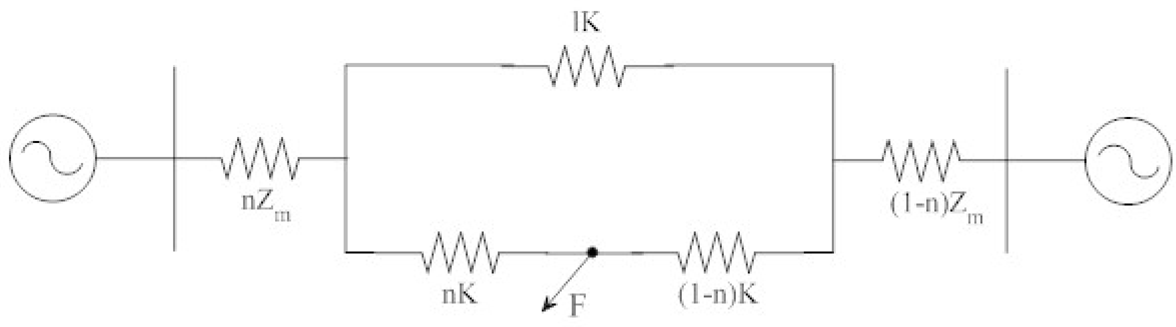


Figure 14

For knowing the total fault current, it is preferable to reduce the delta formed by impedance $(X_2 + nZm)$, IK and $X_3 + (l - n)$ Zm into equivalent star as shown in Figure 15.

X_{1y}, X_{2y}, X_{3y} are the impedance of the equivalent star

Now $$Z_0 = (X_1 + X_{1y}) + \frac{(X_{2y} + nK)(X_{3y} + (1-n)K)}{X_{2y} + X_{3y} + IK}$$

Now $Z = Z_1 + Z_2 + Z_0$

$= 2Z_1 + Z_0$

$$Z_T = \sqrt{(Z)^2 + (Z_{FR})^2}$$

$$I_F = \frac{3 \times \text{Base Amps} \times 100}{Z_T}$$

$$I_A = I_F \frac{(X_{3y} + (1-n)K)}{X_{2y} + X_{3y} + IK}$$

and $I_B = I_F \dfrac{\left(X_{2y} + nK\right)}{X_{2y} + X_{3y} + lK}$

For knowing the effective fault current for the section PQ of the line involved in parallelism with the telecommunication line shown in Figure 16, it is necessary to know the current contributions from buses A and B under fault conditions at points P and Q. For the fault at point P, only the current from bus B flows through the section PQ and for the fault at Q current from bus A flows through PQ. The effective current will be higher of these currents flowing through PQ

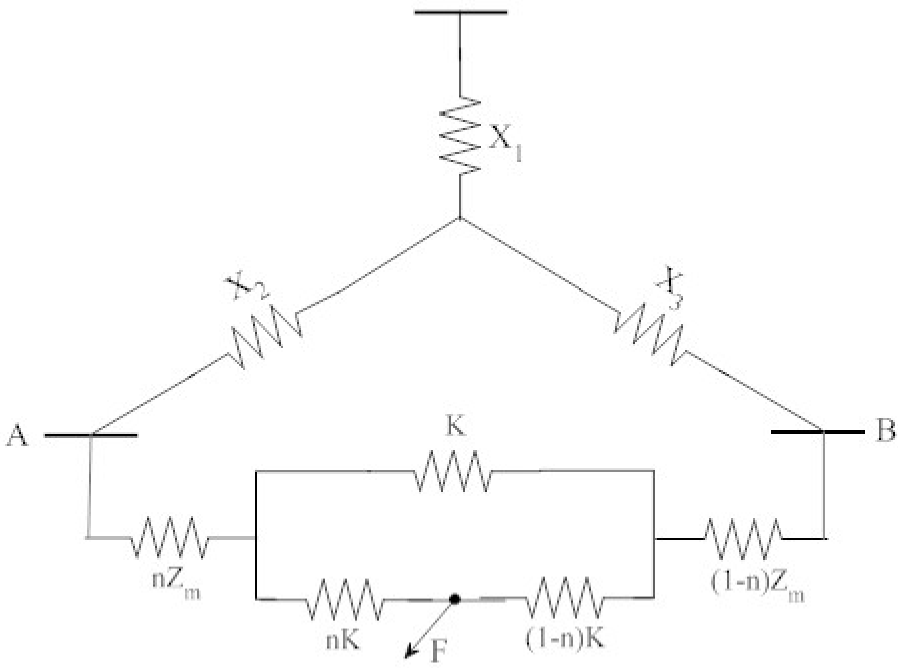


Figure 15 (a)

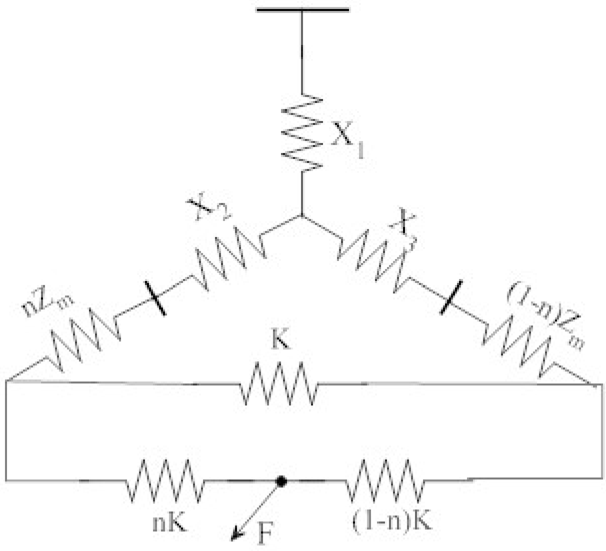


Figure 15 (b)

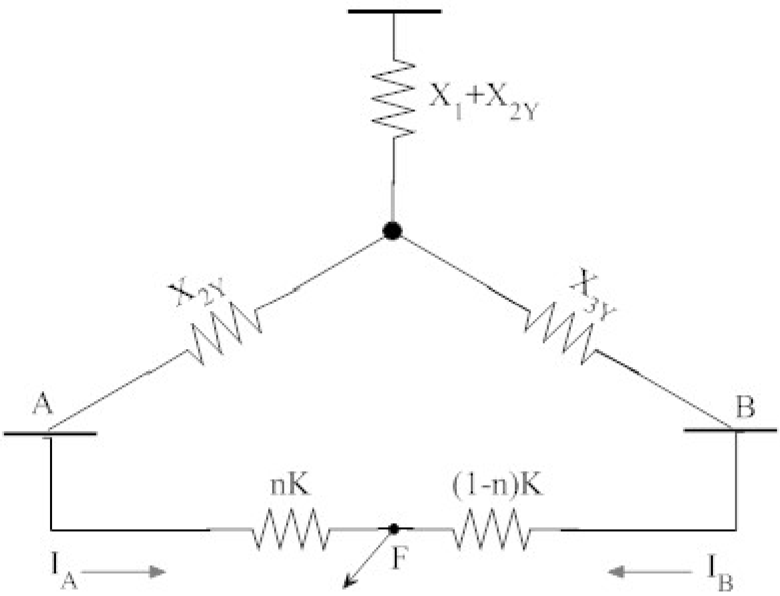


Figure 15 (c)

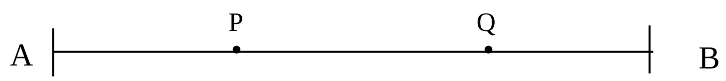


Figure 16

Annexure I to Appendix III of Chapter V

A Summary of Important Formulae and Values Used in Fault Current Calculations

BASE: 100 MVA

Base Voltage in kV	Base Amps	Base Ohms
400	144.3	1600.00
230	251.0	529.00
220	262.4	484.00
132	437.4	174.20
110	524.9	121.00
66	874.8	43.56
33	1750.0	10.89
22	2624.0	4.84
11	5249.0	1.21

Per Unit Quantities

(i) Base current in Amps. = $\dfrac{\text{Base KVA}}{\sqrt{3}\times\text{Base Voltage in KV}}$

(ii) Base impedance $= \dfrac{\left(\text{Base voltage in KV}/\sqrt{3}\right)^2\times 1000}{\left(\text{Base KVA}/3\right)}$

$$= \frac{\left(\text{Base voltage in KV}\right)^2\times 1000}{\text{Base KVA}}$$

$$= \frac{\left(\text{Base voltage in KV}\right)^2}{\text{Base MVA}}$$

(iii) Per unit impedance $= \dfrac{\text{Actual impedance in ohms}}{\text{Base impedance in ohms}}$

$$= \frac{\text{Actual impedance in ohms}\times\text{Base KVA}}{\left(\text{Base voltage in KV}\right)^2\times 1000}$$

(iv) For changing per unit impedance on a given base to per unit impedance on a new base, the following equation is used.

$$\text{Per unit } Z(\text{new}) = \text{Per unit } Z\ (\text{given}) \times \left[\frac{\text{Base KV given}}{\text{Base KV new}}\right]^2 \times \left[\frac{\text{Base KVA new}}{\text{Base KVA given}}\right]$$

(v) $\text{Short circuit MVA} = \sqrt{3} \times (\text{nominal KV}) \times I_{SC} \times 10^3$

(vi) Impedance $Z = \dfrac{\left(\text{nominal KV}/\sqrt{3}\right) \times 1000}{I_{SC}}$ ohm

$$Z = \frac{(\text{nominal KV})^2}{\text{Short circuit MVA}} \text{ ohm}$$

Converting to per unit value:

$$Z = \frac{(\text{nominal KV})^2}{\text{Short circuit MVA}} \times \frac{\text{Base MVA}}{(\text{Base KV})^2} \text{ per unit}$$

$$= \frac{\text{Base MVA}}{\text{Short circuit MVA}} \text{ per unit}$$

$$= \frac{I_{base}}{I_{SC}} \text{ per unit}$$

$$= \frac{I_{base}}{I_{SC}} \times 100\%$$

(vii) $I_{SC} = \dfrac{I_{base}}{Z\%} \times 100$

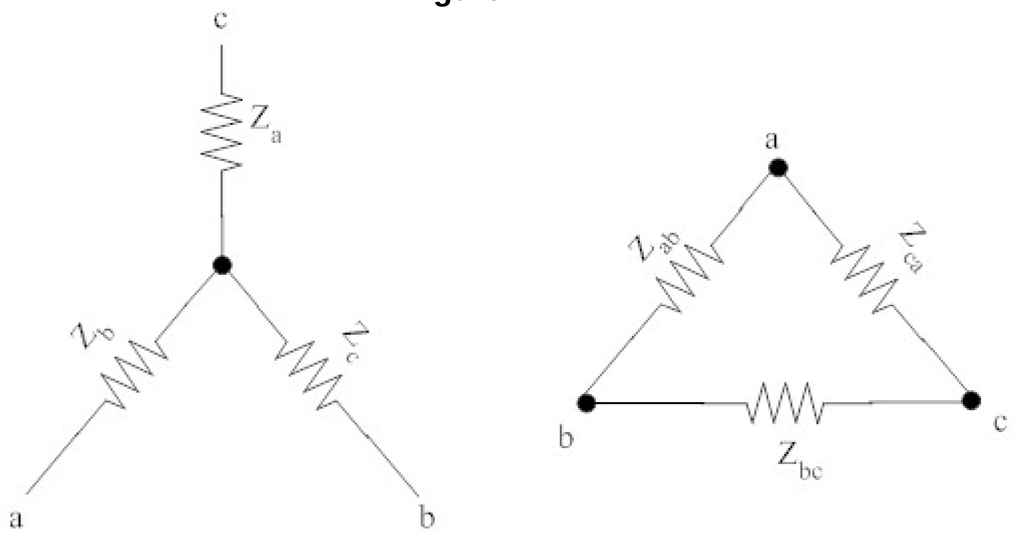
(viii) For single line to ground faults, the neutral current is 3 times the phase current.

$\therefore$ I_{sc} for SLG faults $= \dfrac{3 \times I_{base} \times 100}{Z\%}$ Amps

Annexure II to Appendix III (Chapter V)

STAR DELTA TRANSFORMATION

Figure 17



Star Delta Conversion

$$Z_{ab} = \frac{Z_a Z_b + Z_b Z_c + Z_c Z_a}{Z_c}$$

$$Z_{bc} = \frac{Z_a Z_b + Z_b Z_c + Z_c Z_a}{Z_a}$$

$$Z_{ca} = \frac{Z_a Z_b + Z_b Z_c + Z_c Z_a}{Z_b}$$

Delta Star Conversion

$$Z_a = \frac{Z_{ab} Z_{ca}}{Z_{ab} + Z_{bc} + Z_{ca}}$$

$$Z_b = \frac{Z_{ab} Z_{bc}}{Z_{ab} + Z_{bc} + Z_{ca}}$$

$$Z_c = \frac{Z_{ca} Z_{bc}}{Z_{ab} + Z_{bc} + Z_{ca}}$$

Appendix IV to Chapter V

(Refer Para 4.1/1)

PLATES 1(A) to 1(D)

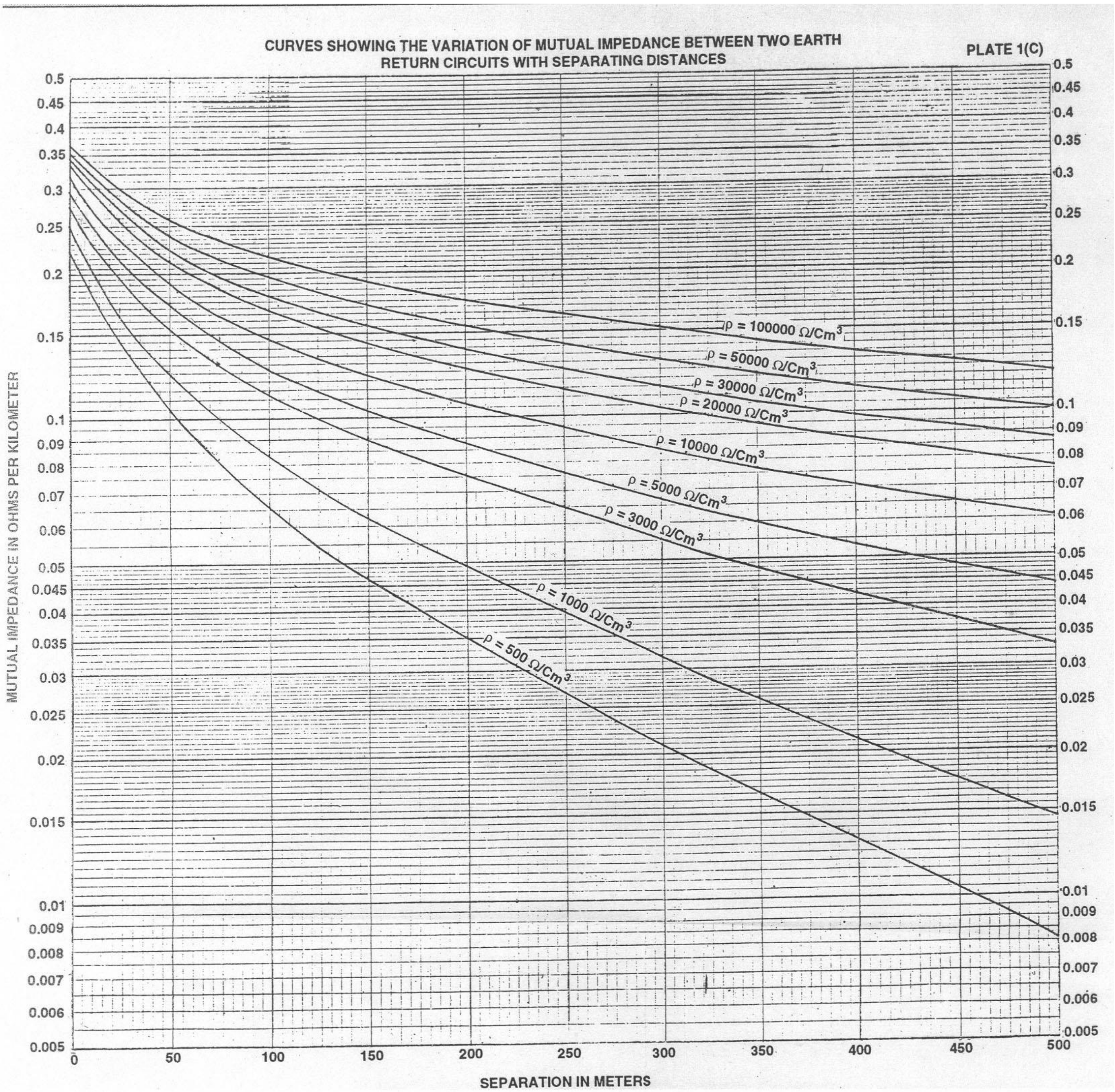

CURVES SHOWING THE VARIATION OF MUTUAL IMPEDANCE BETWEEN TWO EARTH RETURN CIRCUITS WITH SEPARATING DISTANCES
PLATE 1(C)
MUTUAL IMPEDANCE IN OHMS PER KILOMETER
SEPARATION IN METERS
ρ = 100000 Ω/Cm³
ρ = 50000 Ω/Cm³
ρ = 30000 Ω/Cm³
ρ = 20000 Ω/Cm³
ρ = 10000 Ω/Cm³
ρ = 5000 Ω/Cm³
ρ = 3000 Ω/Cm³
ρ = 1000 Ω/Cm³
ρ = 500 Ω/Cm³
0.5
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.09
0.08
0.07
0.06
0.05
0.045
0.04
0.035
0.03
0.025
0.02
0.015
0.01
0.009
0.008
0.007
0.006
0.005
0
50
100
150
200
250
300
350
400
450
500

PLATE 1(A)

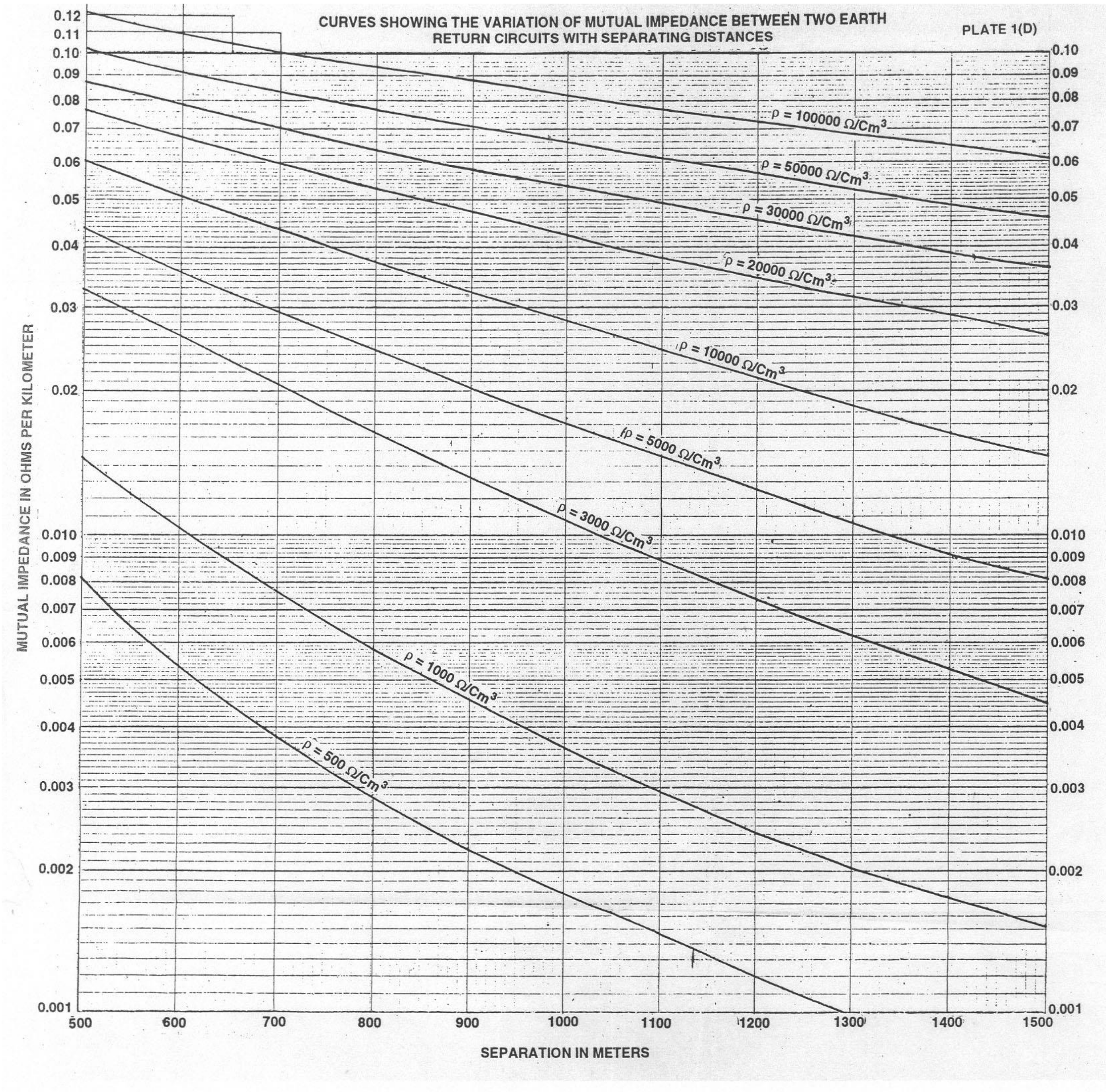

CURVES SHOWING THE VARIATION OF MUTUAL IMPEDANCE BETWEEN TWO EARTH RETURN CIRCUITS WITH SEPARATING DISTANCES
PLATE 1(D)
MUTUAL IMPEDANCE IN OHMS PER KILOMETER
SEPARATION IN METERS
ρ = 100000 Ω/Cm³
ρ = 50000 Ω/Cm³
ρ = 30000 Ω/Cm³
ρ = 20000 Ω/Cm³
ρ = 10000 Ω/Cm³
ρ = 5000 Ω/Cm³
ρ = 3000 Ω/Cm³
ρ = 1000 Ω/Cm³
ρ = 500 Ω/Cm³
0.12
0.11
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
500
600
700
800
900
1000
1100
1200
1300
1400
1500

PLATE 1(B)

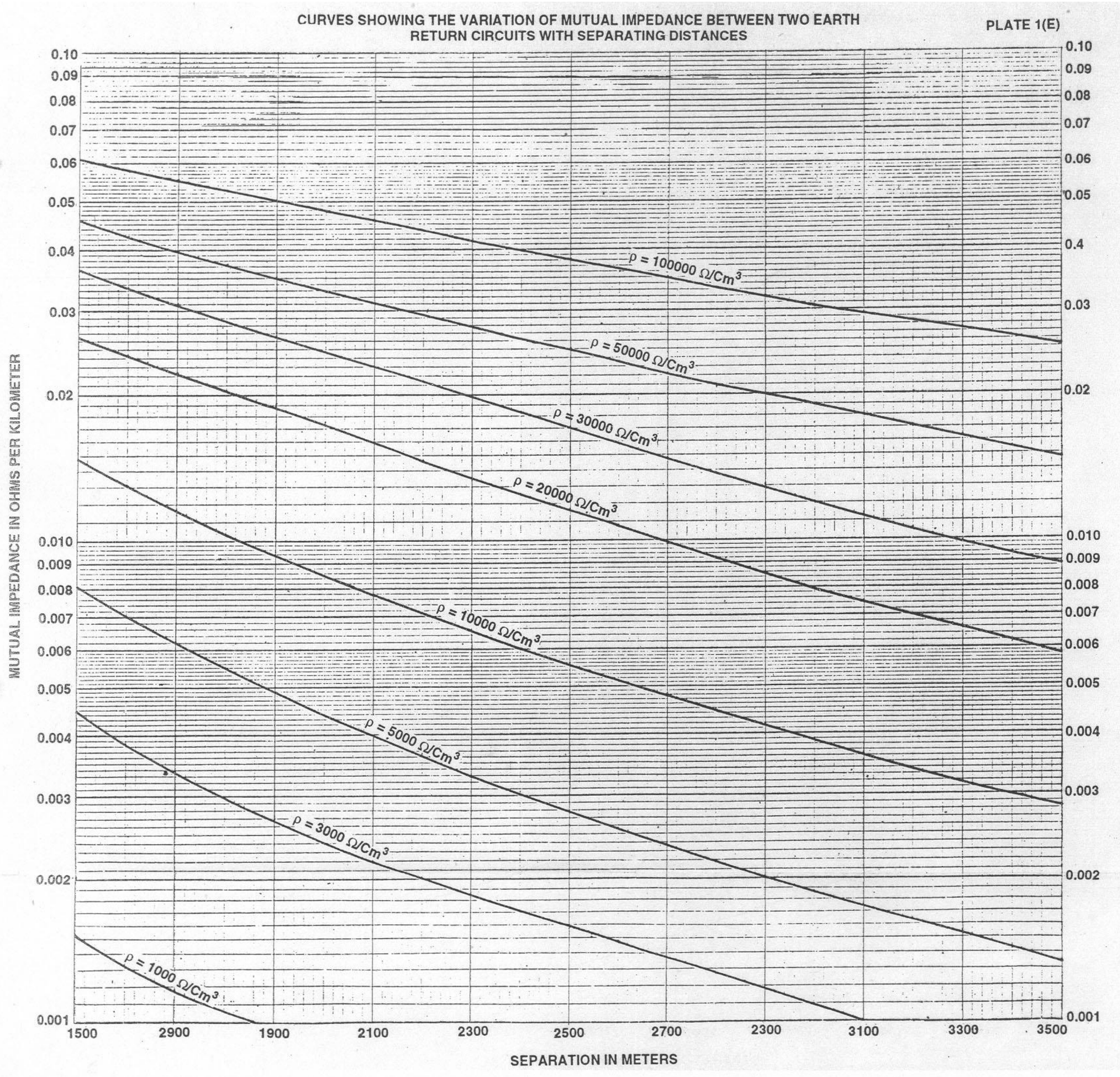

CURVES SHOWING THE VARIATION OF MUTUAL IMPEDANCE BETWEEN TWO EARTH RETURN CIRCUITS WITH SEPARATING DISTANCES
PLATE 1(E)
MUTUAL IMPEDANCE IN OHMS PER KILOMETER
SEPARATION IN METERS
ρ = 100000 Ω/Cm³
ρ = 50000 Ω/Cm³
ρ = 30000 Ω/Cm³
ρ = 20000 Ω/Cm³
ρ = 10000 Ω/Cm³
ρ = 5000 Ω/Cm³
ρ = 3000 Ω/Cm³
ρ = 1000 Ω/Cm³
0.10
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.010
0.009
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
1500
2900
1900
2100
2300
2500
2700
2300
3100
3300
3500

PLATE 1(C)

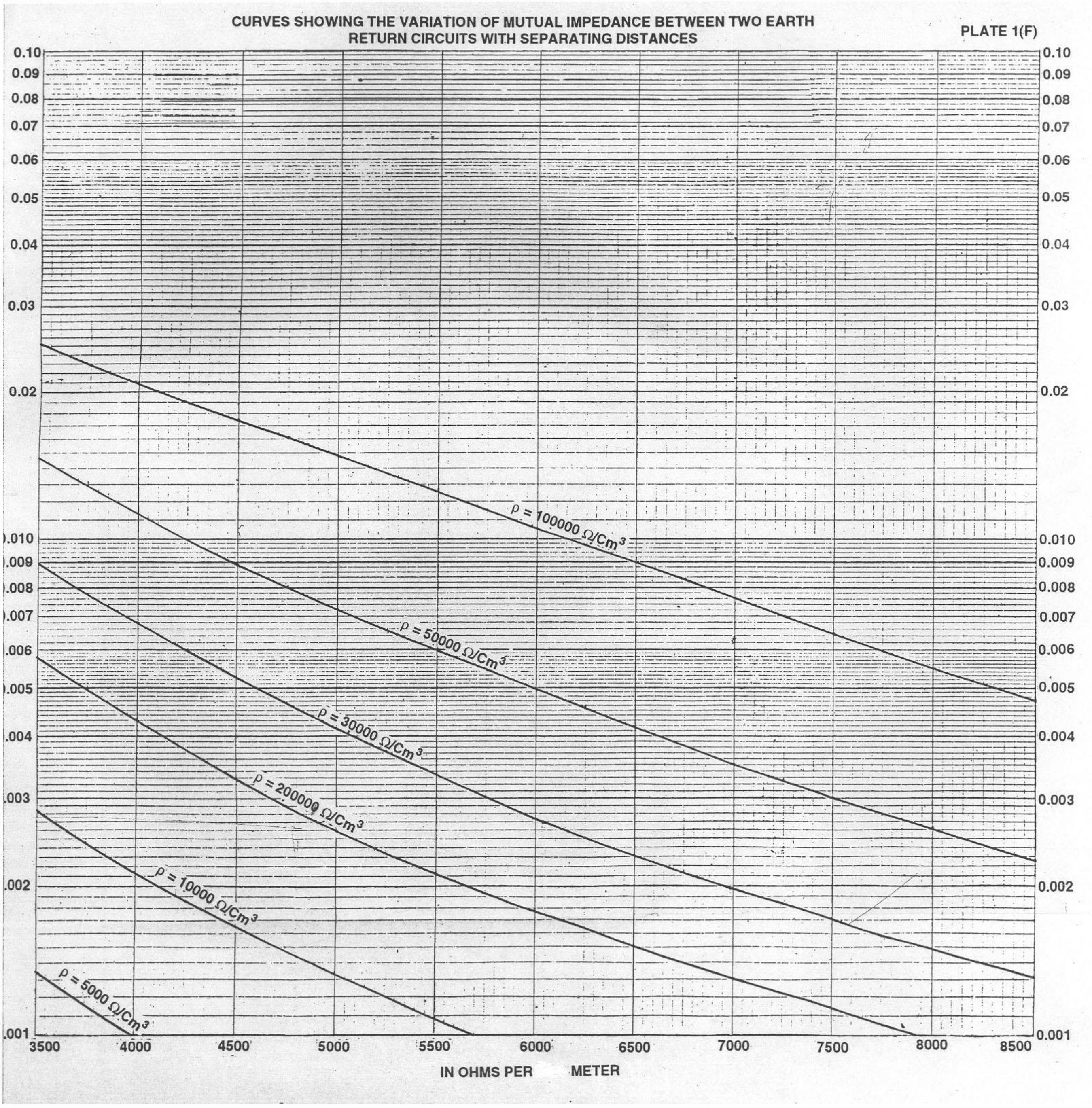

CURVES SHOWING THE VARIATION OF MUTUAL IMPEDANCE BETWEEN TWO EARTH RETURN CIRCUITS WITH SEPARATING DISTANCES
PLATE 1(F)
ρ = 100000 Ω/Cm³
ρ = 50000 Ω/Cm³
ρ = 30000 Ω/Cm³
ρ = 200000 Ω/Cm³
ρ = 10000 Ω/Cm³
ρ = 5000 Ω/Cm³
IN OHMS PER METER

PLATE 1 (D)

Soil Resistivity

Chart indicating maximum separation distance between power and telecom lines at the end of parallelism considering 8 Kms range of either side of power line.

Sl No.	Soil Resistivity in Ohms/cm3	Separation between Power & Telecom lines (as per map scale)		Mutual impedance in Ohms/KM	Remark
		1 cm=500Mts	*In meters*		
1.	2.	3.	4.	5.	6.
1.	250	0.83	415	0.005	
2.	500	2.58	1290	0.001	
3.	1000	3.72	1860	0.001	
4.	2000	4.92	2460	0.001	
5.	2500	3.20	1600	0.0031	
6.	3000	6.20	3100	0.001	
7.	5000	8.0	4000	0.001	
8.	7500	9.40	4700	0.001	
9.	10000	11.40	5700	0.001	
10.	15000	13.4	6700	0.001	
11.	20000	15.90	7950	0.001	
12.	25000	16.00	8000	0.00116	
13.	30000	16.00	8000	0.00148	
14.	50000	16.0	8000	0.0026	
15.	100000	16.0	8000	0.0055	
16.	250000	16.00	8000	0.0142	
17.	500000	16.00	8000	0.0243	
18.	1000000	16.00	8000	0.0375	

SOIL RESISTIVITY IN OHMS /CM^3 -250 Ohms/Cm^3

Safe Separation in meters	Mutual impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual impedance in Ohms/KM
5	-	160	0.0270	315	0.0095
10	0.1730	165	0.0259	320	0.0091
15	0.1500	170	0.0249	325	0.0088
20	0.1350	175	0.0238	330	0.0086
25	0.1225	180	0.0229	335	0.00835
30	0.1100	185	0.0219	340	0.0081
35	0.1020	190	0.0211	345	0.0078
40	0.0935	195	0.0205	350	0.0076
45	0.0870	200	0.01955	355	0.0074
50	0.0815	205	0.0190	360	0.0073
55	0.0765	210	0.0184	365	0.0070
60	0.0720	215	0.0178	370	0.0067
65	0.0680	220	0.0172	375	0.0066
70	0.0640	225	0.0166	380	0.0064
75	0.0600	230	0.0161	385	0.00625
80	0.0570	235	0.0156	390	0.0060
85	0.0540	240	0.0151	395	0.0057
90	0.0515	245	0.0147	400	0.0056
95	0.0485	250	0.0142	405	0.0054
100	0.0460	255	0.0137	410	0.0052
105	0.0440	260	0.0134	415	0.0050
110	0.0420	265	0.0130		
115	0.0400	270	0.01255		
120	0.0381	275	0.0122		
125	0.0362	280	0.0118		
130	0.0349	285	0.0115		
135	0.0332	290	0.0112		
140	0.0320	295	0.0107		
145	0.0308	300	0.0104		
150	0.02925	305	0.0101		
155	0.0281	310	0.0097		

SOIL RESISTIVITY IN OHMS /CM^3 -500 Ohms/Cm^3

Safe Separation in meters	Mutual impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2025	160	0.0440	315	0.0194
10	0.1850	165	0.0428	320	0.0190
15	0.1700	170	0.0415	325	0.0185
20	0.1570	175	0.0403	330	0.0181
25	0.1450	180	0.0392	335	0.0177
30	0.1360	185	0.0380	340	0.0173
35	0.1270	190	0.0370	345	0.0169
40	0.1180	195	0.0360	350	0.0165
45	0.1120	200	0.0350	355	0.01615
50	0.1050	205	0.0340	360	0.0158
55	0.0980	210	0.0332	365	0.0154
60	0.0930	215	0.0324	370	0.0151
65	0.0880	220	0.0315	375	0.01475
70	0.0840	225	0.03075	380	0.0144
75	0.0810	230	0.0300	385	0.0141
80	0.0770	235	0.0290	390	0.0138
85	0.0740	240	0.02825	395	0.0135
90	0.0710	245	0.0275	400	0.0132
95	0.0680	250	0.0268	405	0.01285
100	0.0660	255	0.0260	410	0.0126
105	0.0630	260	0.02545	415	0.0123
110	0.0610	265	0.02475	420	0.0121
115	0.0580	270	0.0241	425	0.01175
120	0.0565	275	0.0235	430	0.0115
125	0.0540	280	0.0229	435	0.01125
130	0.0525	285	0.0225	440	0.01095
135	0.0510	290	0.0218	445	0.0107
140	0.0490	295	0.0213	450	0.01045
145	0.0478	300	0.0208	455	0.0102
150	0.0462	305	0.02035		
155	0.0450	310	0.0198		

SOIL RESISTIVITY IN OHMS /CM^3 -500 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
460	0.0099	730	0.0035	1040	0.00166
465	0.00964	740	0.0034	1050	0.00162
470	0.0094	750	0.0033	1060	0.0016
475	0.0092	760	0.0032	1070	0.0156
480	0.0089	770	0.0031	1080	0.00153
485	0.00875	780	0.00301	1090	0.0015
490	0.0085	790	0.00294	1100	0.00148
495	0.0083	800	0.00286	1110	0.00144
500	0.00815	810	0.0028	1120	0.00141
510	0.0078	820	0.0027	1130	0.00139
520	0.0074	830	0.00266	1140	0.00136
530	0.0071	840	0.00259	1150	0.00134
540	0.0067	850	0.00252	1160	0.0013
550	0.00645	860	0.00247	1170	0.00128
560	0.0062	870	0.0024	1180	0.00126
570	0.0060	880	0.00234	1190	0.00123
580	0.00575	890	0.00229	1200	0.0012
590	0.0055	900	0.00222	1210	0.00118
600	0.00535	910	0.00218	1220	0.00116
610	0.0052	920	0.00212	1230	0.00113
620	0.0050	930	0.00209	1240	0.00111
630	0.0048	940	0.00203	1250	0.00109
640	0.0046	950	0.00199	1260	0.00107
650	0.0045	960	0.00195	1270	0.00105
660	0.00432	970	0.0019	1280	0.00103
670	0.0042	980	0.00186	1290	0.001
680	0.0041	990	0.00182		
690	0.00393	1000	0.00179		
700	0.00381	1010	0.00175		
710	0.0037	1020	0.00171		
720	0.0036	1030	0.00169		

SOIL RESISTIVITY IN OHMS /CM^3 -1000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2270	190	0.0517	375	0.02335
10	0.2075	195	0.0500	380	0.0229
15	0.1910	200	0.0490	385	0.0224
20	0.1750	205	0.0480	390	0.0220
25	0.1640	210	0.0470	395	0.0215
30	0.1535	215	0.0460	400	0.0212
35	0.1445	220	0.0450	405	0.02075
40	0.1370	225	0.0440	410	0.02035
45	0.1300	230	0.0430	415	0.0200
50	0.1240	235	0.0420	420	0.0195
55	0.1180	240	0.0410	425	0.0192
60	0.1135	245	0.0402	430	0.0188
65	0.1085	250	0.0393	435	0.0185
70	0.1040	255	0.0385	440	0.0181
75	0.1000	260	0.0378	445	0.0178
80	0.0960	265	0.0370	450	0.0175
85	0.0920	270	0.0360	455	0.0172
90	0.0890	275	0.0352	460	0.0168
95	0.0860	280	0.0347	465	0.0165
100	0.0830	285	0.03385	470	0.0162
105	0.0807	290	0.0330	475	0.0159
110	0.0780	295	0.0324	480	0.01506
115	0.0760	300	0.0318	485	0.01503
120	0.0735	305	0.0310	490	0.0150
125	0.0715	310	0.03035	495	0.0148
130	0.0690	315	0.0297	500	0.0145
135	0.0675	320	0.0290	510	0.0140
140	0.0655	325	0.0284	520	0.0136
145	0.0637	330	0.0278	530	0.0131
150	0.0635	335	0.02725	540	0.0128
155	0.0610	340	0.0267	550	0.0122
160	0.059	345	0.02625	560	0.0119
165	0.0580	350	0.0257	570	0.0115
170	0.0565	355	0.0252	580	0.0111
175	0.0550	360	0.0248	590	0.01075
180	0.0538	365	0.0243	600	0.0104
185	0.0525	370	0.0238	610	0.0100

SOIL RESISTIVITY IN OHMS /CM^3 -1000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
620	0.00975	1010	0.00355	1400	0.00175
630	0.0094	1020	0.00346	1410	0.001725
640	0.0092	1030	0.0034	1420	0.0017
650	0.0089	1040	0.00332	1430	0.00168
660	0.0086	1050	0.00326	1440	0.00166
670	0.0084	1060	0.0032	1450	0.00163
680	0.0081	1070	0.00312	1460	0.0016
690	0.0079	1080	0.00308	1470	0.00159
700	0.00765	1090	0.003	1480	0.00157
710	0.0074	1100	0.00295	1490	0.00154
720	0.0072	1110	0.0029	1500	0.001525
730	0.0070	1120	0.00283	1520	0.00148
740	0.0068	1130	0.00278	1540	0.00144
750	0.0066	1140	0.00273	1560	0.0014
760	0.00645	1150	0.00269	1580	0.00136
770	0.0063	1160	0.00261	1600	0.00132
780	0.00613	1170	0.00258	1620	0.001285
790	0.00595	1180	0.00251	1640	00.00126
800	0.0058	1190	0.0248	1660	0.00123
810	0.00565	1200	0.00242	1680	0.00120
820	0.0055	1210	0.00239	1700	0.00118
830	0.0054	1220	0.00234	1720	0.00115
840	0.00525	1230	0.0023	1740	0.001125
850	0.00512	1240	0.00227	1760	0.0011
860	0.0050	1250	0.002215	1780	0.00108
870	0.0049	1260	0.00219	1800	0.00106
880	0.00476	1270	0.00214	1820	0.00104
890	0.00467	1280	0.0021	1840	0.00102
900	0.00455	1290	0.00207	1860	0.0010
910	0.00445	1300	0.00203		
920	0.00432	1310	0.0020		
930	0.00423	1320	0.00198		
940	0.00415	1330	0.00194		
950	0.00408	1340	0.0019		
960	0.00398	1350	0.00188		
970	0.0039	1360	0.00185		
980	0.0038	1370	0.00182		
990	0.0037	1380	0.00180		
1000	0.00362	1390	0.00187		

SOIL RESISTIVITY IN OHMS /CM^3 –2,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2450	205	0.0590	405	0.0295
10	0.2250	210	0.0575	410	0.0290
15	0.2100	215	0.0565	415	0.0285
20	0.2000	220	0.0555	420	0.0280
25	0.1860	225	0.0540	425	0.0270
30	0.1760	230	0.0535	430	0.0272
35	0.1670	235	0.0525	435	0.0268
40	0.1600	240	0.0520	440	0.0262
45	0.1525	245	0.0510	445	0.0260
50	0.1470	250	0.0500	450	0.0255
55	0.1400	255	0.0490	455	0.0250
60	0.1340	260	0.0480	460	0.0247
65	0.1270	265	0.0470	465	0.0242
70	0.1200	270	0.0460	470	0.0239
75	0.1150	275	0.0455	475	0.0235
80	0.1100	280	0.0447	480	0.0231
85	0.1070	285	0.0440	485	0.0228
90	0.1040	290	0.0432	490	0.0224
95	0.1000	295	0.0428	495	0.0222
100	0.0970	300	0.0420	500	0.0220
105	0.0950	305	0.0411	510	0.0210
110	0.0925	310	0.0402	520	0.0205
115	0.0900	315	0.0395	530	0.0201
120	0.0880	320	0.0390	540	0.0195
125	0.0860	325	0.0381	550	0.0190
130	0.0835	330	0.0374	560	0.0182
135	0.0820	335	0.0370	570	0.0179
140	0.0790	340	0.0361	580	0.0174
145	0.0775	345	0.0355	590	0.0170
150	0.0760	350	0.0350	600	0.0168
155	0.0735	355	0.0345	610	0.0161
160	0.0720	360	0.0340	620	0.0157
165	0.0715	365	0.0332	630	0.0152
170	0.0690	370	0.0330	640	0.0148
175	0.0675	375	0.0322	650	0.0143
180	0.0660	380	0.0320	660	0.0140
185	0.0640	385	0.0312	670	0.0137
190	0.625	390	0.0310	680	0.0133
195	0.0620	395	0.0304	690	0.0129
200	0.0600	400	0.0300	700	0.0125

SOIL RESISTIVITY IN OHMS /CM^3 –2,000 Ohms/Cm^3

Separation In Meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
710	0.0122	1140	0.0049	1640	0.00232
720	0.0118	1150	0.0048	1660	0.00228
730	0.0115	1160	0.0047	1680	0.00221
740	0.0113	1170	0.00465	1700	0.00216
750	0.0110	1180	0.0046	1720	0.0021
760	0.01070	1190	0.00435	1740	0.00203
770	0.0105	1200	0.0043	1760	0.00198
780	0.01025	1210	0.00425	1780	0.00193
790	0.0100	1220	0.0042	1800	0.00189
800	0.0098	1230	0.00412	1820	0.00183
810	0.0096	1240	0.00405	1840	0.0018
820	0.0094	1250	0.0040	1860	0.00177
830	0.00921	1280	0.00395	1880	0.00172
840	0.0090	1270	0.0039	1900	0.00170
850	0.0089	1280	0.00382	1920	0.00168
860	0.00862	1290	0.00378	1940	0.00164
870	0.00850	1300	0.00372	1960	0.00162
880	0.0084	1310	0.00369	1980	0.00158
890	0.0082	1320	0.00365	2000	0.00156
900	0.0080	1330	0.0036	2020	0.00153
910	0.0078	1340	0.00355	2040	0.00150
920	0.0077	1350	0.00348	2060	0.00148
930	0.0075	1360	0.00342	2080	0.00145
940	0.0074	1370	0.00335	2100	0.00143
950	0.00722	1380	0.0033	2120	0.00141
960	0.0071	1390	0.00326	2140	0.00138
970	0.00695	1400	0.0032	2160	0.00136
980	0.0068	1410	0.00316	2180	0.00133
990	0.0067	1420	0.00312	2200	0.00130
1000	0.0065	1430	0.00308	2220	0.00128
1010	0.0064	1440	0.00302	2240	0.00126
1020	0.00622	1450	0.0030	2260	0.00123
1030	0.00615	1460	0.00298	2280	0.00120
1040	0.0060	1470	0.00293	2300	0.00118
1050	0.00585	1480	0.0029	2320	0.00116
1060	0.00575	1490	0.00286	2340	0.001140
1070	0.00562	1500	0.00282	2360	0.001125
1080	0.0055	1520	0.0275	2380	0.0011
1090	0.0054	1540	0.00268	2400	0.00108
1100	0.0053	1560	0.00260	2420	0.00105
1110	0.0052	1580	0.00254	2440	0.00103
1120	0.0051	1600	0.00248	2460	0.001
1130	0.00498	1620	0.00240		

SOIL RESISTIVITY IN OHMS /CM^3 –2,500 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	---	200	0.0665	395	0.0371
10	---	205	0.0652	400	0.0368
15	---	210	0.0645	405	0.0361
20	0.2000	215	0.0635	410	0.0356
25	0.1880	220	0.0625	415	0.0351
30	0.1775	225	0.0615	420	0.0348
35	0.1690	230	0.0600	425	0.0342
40	0.1610	235	0.0590	430	0.0339
45	0.1550	240	0.0580	435	0.0334
50	0.1470	245	0.0570	440	0.0330
55	0.1425	250	0.0560	445	0.0325
60	0.1370	255	0.0550	450	0.0320
65	0.1320	260	0.0543	455	0.0319
70	0.1280	265	0.0530	460	0.0314
75	0.1235	270	0.0525	465	0.0310
80	0.1200	275	0.0515	470	0.0307
85	0.1150	280	0.0505	475	0.0301
90	0.1120	285	0.0500	480	0.0298
95	0.1085	290	0.0490	485	0.0294
100	0.1050	295	0.0485	490	0.0290
105	0.1020	300	0.0479	495	0.0287
110	0.0990	305	0.0470	500	0.0285
115	0.0960	310	0.0463	510	0.0274
120	0.0940	315	0.0458	520	0.0268
125	0.0915	320	0.0450	530	0.0260
130	0.895	325	0.0445	540	0.0252
135	0.0870	330	0.0440	550	0.0246
140	0.0850	335	0.0433	560	0.0240
145	0.0835	340	0.0427	570	0.0233
150	0.0815	345	0.0420	580	0.0228
155	0.0795	350	0.0416	590	0.0222
160	0.0775	355	0.0.410	600	0.0218
165	0.0760	360	0.0405	610	0.0211
170	0.0745	365	0.0400	620	0.0206
175	0.0735	370	0.0395	630	0.0200
180	0.0725	375	0.0390	640	0.0197
185	0.0700	380	0.0385	650	0.0192
190	0.0690	385	0.0380	660	0.0189
195	0.0680	390	0.0375	670	0.01845

SOIL RESISTIVITY IN OHMS /CM^3 –2,500 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0180	1070	0.00824	1460	0.00388
690	0.0177	1080	0.0081	1470	0.0038
700	0.01735	1090	0.00795	1480	0.0037
710	0.0170	1100	0.0078	1490	0.00365
720	0.0167	1110	0.0076	1500	0.0036
730	0.0163	1120	0.0075	1520	0.0035
740	0.0160	1130	0.00735	1540	0.0034
750	0.0158	1140	0.0072	1560	0.0033
760	0.0154	1150	0.00705	1580	0.0032
770	0.0151	1160	0.0069	1600	0.0031
780	0.0148	1170	0.068		
790	0.01455	1180	0.0066		
800	0.0143	1190	0.0065		
810	0.0140	1200	0.0064		
820	0.0138	1210	0.0063		
830	0.0135	1220	0.006195		
840	0.0132	1230	0.0060		
850	0.0129	1240	0.0059		
860	0.0127	1250	0.0058		
870	0.0124	1260	0.0057		
880	0.0121	1270	0.0056		
890	0.0119	1280	0.0055		
900	0.0116	1290	0.00535		
910	0.0114	1300	0.00525		
920	0.0112	1310	0.00515		
930	0.01095	1320	0.00505		
940	0.0107	1330	0.00498		
950	0.0105	1340	0.00487		
960	0.0103	1350	0.0048		
970	0.0100	1360	0.0047		
980	0.0098	1370	0.0046		
990	0.00965	1380	0.0045		
1000	0.0095	1390	0.0044		
1010	0.0093	1400	0.00435		
1020	0.0091	1410	0.00425		
1030	0.00895	1420	0.00419		
1040	0.00875	1430	0.0041		
1050	0.0086	1440	0.0040		
1060	0.0084	1450	0.00395		

SOIL RESISTIVITY IN OHMS /CM^3 –3,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2550	200	0.0755	395	0.0429
10	0.2530	205	0.0740	400	0.0421
15	0.2200	210	0.0730	405	0.0418
20	0.2070	215	0.0725	410	0.0411
25	0.1960	220	0.0715	415	0.0408
30	0.1850	225	0.0700	420	0.0401
35	0.1750	230	0.0685	425	0.0398
40	0.1670	235	0.0675	430	0.0391
45	0.1600	240	0.0670	435	0.0388
50	0.1540	245	0.0660	440	0.0382
55	0.1475	250	0.0650	445	0.0378
60	0.1435	255	0.0640	450	0.0372
65	0.1380	260	0.0630	455	0.0368
70	0.1335	265	0.0620	460	0.0363
75	0.1295	270	0.0610	465	0.0360
80	0.1250	275	0.0605	470	0.0354
85	0.1220	280	0.0590	475	0.0350
90	0.1185	285	0.0580	480	0.0345
95	0.1150	290	0.0570	485	0.0340
100	0.1125	295	0.0560	490	0.0338
105	0.1095	300	0.05502	495	0.0332
110	0.1070	305	0.0545	500	0.03295
115	0.1045	310	0.0540	510	0.0320
120	0.1020	315	0.0530	520	0.0313
125	0.0995	320	0.0520	530	0.0307
130	0.0975	325	0.0510	540	0.0300
135	0.0950	330	0.0500	550	0.0293
140	0.0930	335	0.0497	560	0.0286
145	0.0915	340	0.0490	570	0.0280
150	0.0890	345	0.0483	580	0.0273
155	0.0880	350	0.0479	590	0.0269
160	0.0865	355	0.0471	600	0.0261
165	0.0850	360	0.0468	610	0.0257
170	0.0835	365	0.0460	620	0.0250
175	0.820	370	0.0454	630	0.0244
180	0.0805	375	0.0450	640	0.0239
185	0.0790	380	0.0443	650	0.0231
190	0.0780	385	0.0439	660	0.0228
195	0.0770	390	0.0432	670	0.0221

SOIL RESISTIVITY IN OHMS /CM^3 –3,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0218	1070	0.0094	1460	0.00477
690	0.0211	1080	0.0092	1470	0.0047
700	0.0208	1090	0.0090	1480	0.0046
710	0.0201	1100	0.0089	1490	0.00453
720	0.0198	1110	0.00875	1500	0.0045
730	0.192	1120	0.0086	1520	0.00432
740	0.0188	1130	0.0084	1540	0.0042
750	0.0182	1140	0.00825	1560	0.00408
760	0.0179	1150	0.0081	1580	0.00395
770	0.0175	1160	0.00795	1600	0.00382
780	0.0170	1170	0.0078	1620	0.00371
790	0.0168	1180	0.00765	1640	0.00362
800	0.0164	1190	0.0075	1660	0.00352
810	0.0160	1200	0.0074	1680	0.00343
820	0.0157	1210	0.00725	1700	0.00335
830	0.0154	1220	0.0071	1720	0.00328
840	0.0150	1230	0.0070	1740	0.00319
850	0.0147	1240	0.00685	1760	0.0031
860	0.0144	1250	0.00675	1780	0.00303
870	0.0141	1260	0.0066	1800	0.00298
880	0.0138	1270	0.0065	1820	0.0029
890	0.0136	1280	0.064	1840	0.00283
900	0.0133	1290	0.0063	1860	0.00279
910	0.0130	1300	0.0062	1880	0.00272
920	0.01275	1310	0.0061	1900	0.00267
930	0.0125	1320	0.006	1920	0.0026
940	0.0122	1330	0.0059	1940	0.00255
950	0.0120	1340	0.0058	1960	0.0025
960	0.01175	1350	0.0057	1980	0.00245
970	0.0115	1360	0.0056	2000	0.0024
980	0.0112	1370	0.0055	2020	0.00236
990	0.0110	1380	0.0054	2040	0.00231
1000	0.0108	1390	0.00535	2060	0.00228
1010	0.0106	1400	0.00525	2080	0.00222
1020	0.0104	1410	0.00519	2100	0.0022
1030	0.0101	2100	0.0051	2120	0.00215
1040	0.0099	2120	0.0050	2140	0.00211
1050	0.0097	2140	0.0049	2160	0.00208
1060	0.0096	2160	0.00485	2180	0.00204

SOIL RESISTIVITY IN OHMS /CM^3 -3000 Ohms/Cm^3

Separation In Meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0020	2860	0.00122		
2220	0.00198	2880	0.00120		
2240	0.00194	2900	0.00118		
2260	0.00191	2920	0.00117		
2280	0.00188	2940	0.00115		
2300	0.00185	2960	0.00113		
2320	0.00182	2980	0.00111		
2340	0.00179	3000	0.00108		
2360	0.00177	3020	0.00107		
2380	0.00173	3040	0.0105		
2400	0.00171	3060	0.00104		
2420	0.00169	3080	0.00102		
2440	0.00167	3100	0.001		
2460	0.00164				
2480	0.00161				
2500	0.00159				
2520	0.00157				
2540	0.00154				
2560	0.00152				
2580	0.00150				
2600	0.00148				
2620	0.00145				
240	0.00143				
2660	0.00142				
2680	0.00139				
2700	0.00137				
2720	0.00135				
2740	0.00133				
2760	0.00132				
2780	0.00130				
2800	0.00128				
2820	0.00126				
2840	0.00124				

SOIL RESISTIVITY IN OHMS /CM^3 –5,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2730	205	0.0870	405	0.0525
10	0.2550	210	0.0850	410	0.0520
15	0.2380	215	0.0840	415	0.0515
20	0.2240	220	0.0830	420	0.0510
25	0.2130	225	0.0820	425	0.0505
30	0.2025	230	0.0805	430	0.0500
35	0.1940	235	0.0790	435	0.0495
40	0.1860	240	0.0780	440	0.0490
45	0.1790	245	0.0770	445	0.0485
50	0.1725	250	0.0765	450	0.0480
55	0.1660	255	0.0750	455	0.0477
60	0.1600	260	0.0740	460	0.0472
65	0.1550	265	0.0730	465	0.0469
70	0.1500	270	0.0720	470	0.0464
75	0.1450	275	0.0710	475	0.0460
80	0.1410	280	0.0705	480	0.0455
85	0.1375	285	0.0695	485	0.0450
90	0.1340	290	0.0685	490	0.0448
95	0.1300	295	0.0680	495	0.04435
100	0.1270	300	0.0670	500	0.0440
105	0.1240	305	0.0660	510	0.0430
110	0.1210	310	0.0650	520	0.0420
115	0.1190	315	0.0645	530	0.0410
1320	0.1160	320	0.0640	540	0.0400
125	0.1140	325	0.0635	550	0.0392
130	0.1125	330	0.0625	560	0.0385
135	0.1100	335	0.0620	570	0.0378
140	0.1075	340	0.0610	580	0.0370
145	0.1055	345	0.0600	590	0.0362
150	0.1040	350	0.05905	600	0.0355
155	0.1023	355	0.0590	610	0.0349
160	0.1000	360	0.0580	620	0.0340
165	0.0980	365	0.0575	630	0.0334
170	0.0960	370	0.0570	640	0.0329
175	0.0950	375	0.0565	650	0.0321
180	0.0935	380	0.0555	660	0.0317
185	0.0920	385	0.0550	670	0.0310
190	0.0905	390	0.0545	680	0.0304
195	0.0890	395	0.0540	690	0.0300
200	0.0880	400	0.0535	700	0.0294

SOIL RESISTIVITY IN OHMS /CM^3 –5,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
710	0.0289	1100	0.0147	1490	0.0082
720	0.0282	1110	0.0144	1500	0.00815
730	0.0279	1120	0.0142	1520	0.0079
740	0.0272	1130	0.0140	1540	0.00765
750	0.0269	1140	0.0138	1560	0.0074
760	0.0263	1150	0.0136	1580	0.0072
770	0.0259	1160	0.0134	1600	0.0070
780	0.0253	1170	0.01315	1620	0.00685
790	0.0250	1180	0.01300	1640	0.00665
800	0.0245	1190	0.0127	1660	0.0065
810	0.0240	1200	0.01255	1680	0.0635
820	0.0237	1210	0.0123	1700	0.0062
830	0.0231	1220	0.0121	1720	0.00605
840	0.0229	1230	0.0119	1740	0.0059
850	0.0223	1240	0.0117	1760	0.00575
860	0.0220	1250	0.0115	1780	0.0056
870	0.0216	1260	0.0114	1800	0.0055
880	0.0211	1270	0.0112	1820	0.00535
890	0.0208	1280	0.0110	1840	0.0052
900	0.0202	1290	0.0108	1860	0.0051
910	0.0200	1300	0.0106	1880	0.0050
920	0.0196	1310	0.0104	1900	0.0049
930	0.0192	1320	0.0102	1920	0.0048
940	0.0189	1330	0.0101	1940	0.0047
950	0.0186	1340	0.00995	1960	0.00457
960	0.0181	1350	0.0098	1980	0.0045
970	0.01795	1360	0.00965	2000	0.0044
980	0.0176	1370	0.00955	2020	0.0043
990	0.0173	1380	0.0094	2040	0.0042
1000	0.0170	1390	0.00925	2060	0.00415
1010	0.0168	1400	0.00915	2080	0.00405
1020	0.0166	1410	0.0090	2100	0.0040
1030	0.0163	1420	0.0089	2120	0.0039
1040	0.0160	1430	0.0088	2140	0.0038
1050	0.01580	1440	0.0087	2160	0.00375
1060	0.0156	1450	0.0086	2180	0.0037
1070	0.0153	1460	0.0085	2200	0.0036
1080	0.01505	1470	0.0084	2220	0.00355
1090	0.01485	1480	0.0083	2240	0.00348

SOIL RESISTIVITY IN OHMS /CM^3 –5,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2260	0.0034	3040	0.00181		
2280	0.00334	3060	0.00179		
2300	0.0033	3080	0.00177		
2320	0.00322	3100	0.00174		
2340	0.00318	3120	0.00172		
2360	0.0031	3140	0.00170		
2380	0.00307	3160	0.00168		
2400	0.00301	3180	0.00166		
2420	0.00298	3200	0.00163		
2440	0.00291	3220	0.00161		
2460	0.00287	3240	0.00159		
2480	0.00282	3260	0.00157		
2500	0.00278	3280	0.00155		
2520	0.00273	3300	0.00152		
2540	0.00269	3320	0.00150		
2560	0.00264	3340	0.00148		
2580	0.00260	3360	0.00147		
2600	0.00256	3380	0.00144		
2620	0.00251	3400	0.00143		
2640	0.00248	3420	0.00141		
2660	0.00243	3440	0.00139		
2680	0.00240	3460	0.00137		
2700	0.00237	3480	0.00136		
2720	0.00233	3500	0.00134		
2740	0.00230	3550	0.00131		
2760	0.00225	3600	0.00127		
2780	0.00221	3650	0.00123		
2800	0.00219	3700	0.00119		
2820	0.00215	3750	0.00116		
2840	0.00211	3800	0.00112		
2860	0.00208	3850	0.00108		
2880	0.00203	3900	0.00105		
2900	0.00200	3950	0.00102		
2920	0.00198	4000	0.00100		
2940	0.00195				
2960	0.00192				
2980	0.00189				
3000	0.00187				
3020	0.00184				

SOIL RESISTIVITY IN OHMS /CM^3 –7,500 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2800	200	0.0975	395	0.0615
10	0.2620	205	0.0965	400	0.0612
15	0.2485	210	0.0950	405	0.0610
20	0.2350	215	0.0940	410	0.0600
25	0.2230	220	0.0930	415	0.0590
30	0.2130	225	0.0920	420	0.0585
35	0.2040	230	0.0910	425	0.0580
40	0.1950	235	0.0890	430	0.0575
45	0.1870	240	0.0880	435	0.0570
50	0.1800	245	0.0870	440	0.0565
55	0.1730	250	0.0860	445	0.560
60	0.1675	255	0.0850	450	0.0554
65	0.1625	260	0.0835	455	0.0549
70	0.1580	265	0.0830	460	0.0540
75	0.1550	270	0.0820	465	0.0538
80	0.1500	275	0.0810	470	0.0535
85	0.1460	280	0.0800	475	0.0530
90	0.1420	285	0.0790	480	0.0525
95	0.1390	290	0.0775	485	0.0522
100	0.1360	295	0.0770	490	0.0520
105	0.1330	300	0.0760	495	0.0515
110	0.1310	305	0.0750	500	0.0510
115	0.1280	310	0.0740	510	0.0500
120	0.1265	315	0.0735	520	0.0490
125	0.1235	320	0.0725	530	0.0478
130	0.1215	325	0.0720	540	0.0470
135	0.1190	330	0.0710	550	0.0460
140	0.1170	335	0.0700	560	0.0450
145	0.1150	340	0.0690	570	0.0442
150	0.1130	345	0.0680	580	0.0434
155	0.1115	350	0.0670	590	0.0427
160	0.1100	355	0.0665	600	0.0420
165	0.1080	360	0.0660	610	0.0412
170	0.1065	365	0.0655	620	0.0408
175	0.1050	370	0.0645	630	0.0400
180	0.1040	375	0.0640	640	0.0395
185	0.1025	380	0.0630	650	0.0390
190	0.1010	385	0.0625	660	0.0382
195	0.0990	390	0.0620	670	0.0378

SOIL RESISTIVITY IN OHMS /CM^3 –7,500 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0370	1070	0.0200	1460	0.0114
690	0.0363	1080	0.01975	1470	0.0113
700	0.0360	1090	0.0194	1480	0.0112
710	0.0352	1100	0.0191	1490	0.0110
720	0.0347	1110	0.0188	1500	0.0109
730	0.0340	1120	0.0185	1520	0.0106
740	0.0335	1130	0.0181	1540	0.0104
750	0.0330	1140	0.0179	1560	0.0101
760	0.0325	1150	0.0176	1580	0.00995
770	0.0320	1160	0.0172	1600	0.0097
780	0.0314	1170	0.0170	1620	0.00945
790	0.0310	1180	0.0167	1640	0.0093
800	0.0305	1190	0.0163	1660	0.0091
810	0.0300	1200	0.0161	1680	0.0089
820	0.0295	1210	0.0158	1700	0.00875
830	0.0290	1220	0.0156	1720	0.00855
840	0.0286	1230	0.0154	1740	0.0084
850	0.0282	1240	0.0152	1760	0.0082
860	0.0278	1250	0.0150	1780	0.00805
870	0.0272	1260	0.0148	1800	0.0079
880	0.0269	1270	0.0146	1820	0.00775
890	0.0263	1280	0.0144	1840	0.0076
900	0.0260	1290	0.01425	1860	0.0074
910	0.0255	1300	0.0141	1880	0.00728
920	0.0251	1310	0.0140	1900	0.0071
930	0.0248	1320	0.0138	1920	0.00695
940	0.0243	1330	0.0135	1940	0.0068
950	0.040	1340	0.0133	1960	0.0067
960	0.037	1350	0.0132	1980	0.00655
970	0.0232	1360	0.0131	2000	0.00645
980	0.0229	1370	0.0129	2020	0.0063
990	0.0225	1380	0.0128	2040	0.0062
1000	0.0221	1390	0.0127	2060	0.0061
1010	0.0218	1400	0.0124	2080	0.0060
1020	0.0215	1410	0.0122	2100	0.0059
1030	0.0211	1420	0.0120	2120	0.00575
1040	0.0208	1430	0.0119	2140	0.00565
1050	0.0205	1440	0.0117	2160	0.0055
1060	0.02015	1450	0.0116	2180	0.0054

SOIL RESISTIVITY IN OHMS /CM^3 –7,500 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0053	2980	0.00279	4150	0.00138
2220	0.0052	3000	0.00273	4200	0.00134
2240	0.0051	3020	0.0027	4250	0.00130
2260	0.0050	3040	0.00267	4300	0.00128
2280	0.0049	3060	0.00262	4350	0.00124
2300	0.0048	3080	0.00259	4400	0.00121
2320	0.00475	3100	0.00255	4450	0.00118
2340	0.00467	3120	0.00250	4500	0.00115
2360	0.0046	3140	0.00248	4550	0.00112
2380	0.0045	3160	0.00243	4600	0.00108
2400	0.0044	3180	0.00240	4650	0.00105
2420	0.00432	3200	0.00238	4700	0.0010
2440	0.00429	3220	0.00235		
2460	0.00421	3240	0.00232		
2480	0.00415	3260	0.0023		
2500	0.00410	3280	0.00228		
2520	0.00400	3300	0.00224		
2540	0.00396	3320	0.0022		
2560	0.0039	3340	0.00219		
2580	0.0038	3360	0.00216		
2600	0.00375	3380	0.00213		
2620	0.00372	3400	0.00211		
2640	0.00368	3420	0.00209		
2660	0.00360	3440	0.00206		
2680	0.00355	3460	0.00203		
2700	0.00346	3480	0.00201		
2720	0.0034	3500	0.0020		
2740	0.00335	3550	0.00196		
2760	0.0033	3600	0.0019		
2780	0.00326	3650	0.00183		
2800	0.0032	3700	0.00178		
2820	0.00315	3750	0.00172		
2840	0.0031	3800	0.00168		
2860	0.00305	3850	0.00162		
2880	0.0030	3900	0.00158		
2900	0.00295	3950	0.00154		
2920	0.0029	4000	0.00150		
2940	0.00286	4050	0.00146		
2960	0.00282	4100	0.00141		

SOIL RESISTIVITY IN OHMS /CM^3 –10,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.2950	200	0.1065	395	0.0715
10	0.2750	205	0.1055	400	0.0710
15	0.2580	210	0.1040	405	0.0700
20	0.2450	215	0.1030	410	0.0695
25	0.2340	220	0.1020	415	0.0690
30	0.2240	225	0.1000	420	0.0685
35	0.2150	230	0.0990	425	0.0680
40	0.2065	235	0.0980	430	0.0675
45	0.1980	240	0.0970	435	0.0670
50	0.1910	245	0.0955	440	0.0665
55	0.1840	250	0.0940	445	0.0660
60	0.1780	255	0.0930	450	0.0655
65	0.1725	260	0.0920	455	0.0650
70	0.1675	265	0.0910	460	0.0645
75	0.1640	270	0.0900	465	0.0640
80	0.1600	275	0.0890	470	0.0635
85	0.1560	280	0.0880	475	0.0630
90	0.1525	285	0.0870	480	0.0625
95	0.1495	290	0.0860	485	0.0620
100	0.1465	295	0.0850	490	0.0615
105	0.1440	300	0.0845	495	0.0610
110	0.1410	305	0.0840	500	0.0605
115	0.1380	310	0.0830	510	0.0590
120	0.1360	315	0.0820	520	0.0580
125	0.1335	320	0.0810	530	0.0570
130	0.1310	325	0.0806	540	0.0562
135	0.1290	330	0.0795	550	0.0551
140	0.1270	335	0.0790	560	0.0542
145	0.1250	340	0.0780	570	0.0533
150	0.1230	345	0.0775	580	0.0525
155	0.1215	350	0.0768	590	0.0516
160	0.1190	355	0.0760	600	0.0509
165	0.1175	360	0.0755	610	0.0500
170	0.1160	365	0.07495	620	0.0490
175	0.1145	370	0.0740	630	0.0484
180	0.1130	375	0.0735	640	0.0478
185	0.1110	380	0.0730	650	0.0469
190	0.1100	385	0.0725	660	0.0460
195	0.1080	390	0.0720	670	0.0454

SOIL RESISTIVITY IN OHMS /CM^3 –10,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0448	1070	0.0257	1460	0.0152
690	0.0440	1080	0.0252	1470	0.0150
700	0.0435	1090	0.0250	1480	0.0149
710	0.0429	1100	0.0245	1490	0.0148
720	0.0421	1110	0.0241	1500	0.0147
730	0.0415	1120	0.0239	1520	0.0144
740	0.0410	1130	0.0236	1540	0.01405
750	0.0402	1140	0.0232	1560	0.0137
760	0.0396	1150	0.0230	1580	0.0133
770	0.0390	1160	0.0227	1600	0.01305
780	0.03825	1170	0.0223	1620	0.0128
790	0.0378	1180	0.0220	1640	0.0125
800	0.0372	1190	0.0217	1660	0.0122
810	0.0368	1200	0.0213	1680	0.0119
820	0.0361	1210	0.0210	1700	0.0116
830	0.0356	1220	0.0208	1720	0.0113
840	0.0350	1230	0.0204	1740	0.01105
850	0.0347	1240	0.0201	1760	0.01085
860	0.0341	1250	0.01995	1780	0.01055
870	0.0336	1260	0.0196	1800	0.0103
880	0.0331	1270	0.0193	1820	0.0101
890	0.03275	1280	0.0190	1840	0.0099
900	0.0322	1290	0.01885	1860	0.0097
910	0.0319	1300	0.01855	1880	0.0095
920	0.0313	1310	0.0183	1900	0.00935
930	0.0310	1320	0.0180	1920	0.0092
940	0.0304	1330	0.0178	1940	0.0090
950	0.0302	1340	0.0176	1960	0.0088
960	0.0298	1350	0.0173	1980	0.00865
970	0.0294	1360	0.0171	2000	0.0085
980	0.0290	1370	0.0169	2020	0.00835
990	0.0286	1380	0.0167	2040	0.0082
1000	0.0281	1390	0.0164	2060	0.0080
1010	0.0279	1400	0.0162	2080	0.0079
1020	0.0275	1410	0.01605	2100	0.0078
1030	0.0270	1420	0.0159	2120	0.0076
1040	0.0268	1430	0.0158	2140	0.0075
1050	0.0263	1440	0.0156	2160	0.00735
1060	0.0260	1450	0.0153	2180	0.0072

SOIL RESISTIVITY IN OHMS /CM^3 –10,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0071	2980	0.0391	4150	0.00196
2220	0.0070	3000	0.00386	4200	0.0019
2240	0.00688	3020	0.0038	4250	0.00187
2260	0.00678	3040	0.00376	4300	0.00181
2280	0.00662	3060	0.0037	4350	0.00178
2300	0.0065	3080	0.00365	4400	0.00173
2320	0.0064	3100	0.0036	4450	0.00169
2340	0.0063	3120	0.00355	4500	0.00165
2360	0.0062	3140	0.0035	4550	0.00162
2380	0.0061	3160	0.00345	4600	0.00158
2400	0.0060	3180	0.00342	4650	0.00154
2420	0.0059	3200	0.00338	4700	0.00150
2440	0.0058	3220	0.00332	4750	0.00148
2460	0.0057	3240	0.00328	4800	0.00144
2480	0.0056	3260	0.00323	4850	0.00141
2500	0.00553	3280	0.0032	4900	0.00138
2520	0.00545	3300	0.00317	4950	0.00136
2540	0.00538	3320	0.00311	5000	0.00133
2560	0.00530	3340	0.00309	5050	0.00130
2580	0.0052	3360	0.00305	5100	0.00127
2600	0.00513	3380	0.00301	5150	0.00125
2620	0.00507	3400	0.00299	5200	0.00122
2640	0.0050	3420	0.00295	5250	0.0012
2660	0.0049	3440	0.00291	5300	0.00118
2680	0.00484	3460	0.00289	5350	0.00115
2700	0.00478	3480	0.00287	5400	0.00113
2720	0.0047	3500	0.00283	5450	0.0011
2740	0.00464	3550	0.00276	5500	0.00108
2760	0.00458	3600	0.00268	5550	0.00106
2780	0.00450	3650	0.0026	5600	0.00104
2800	0.00445	3700	0.00251	5650	0.00102
2820	0.00438	3750	0.00244	5700	0.0010
2840	0.0043	3800	0.00238		
2860	0.00427	3850	0.0023		
2880	0.0042	3900	0.00225		
2900	0.00415	3950	0.0022		
2920	0.00410	4000	0.00213		
2940	0.00402	4050	0.00207		
2960	0.00398	4100	0.0020		

SOIL RESISTIVITY IN OHMS /CM^3 –15,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.3050	200	0.1170	395	0.0800
10	0.2900	205	0.1160	400	0.0790
15	0.2725	210	0.1150	405	0.0785
20	0.2550	215	0.1135	410	0.0780
25	0.2425	220	0.1120	415	0.770
30	0.2325	225	0.1110	420	0.0764
35	0.2250	230	0.1100	425	0.0755
40	0.2150	235	0.1080	430	0.0750
45	0.2075	240	0.1070	435	0.0748
50	0.2030	245	0.1050	440	0.0740
55	0.1960	250	0.1035	445	0.0735
60	0.1910	255	0.1020	450	0.0730
65	0.1860	260	0.1010	455	0.0725
70	0.1820	265	0.0990	460	0.0723
75	0.1780	270	0.0980	465	0.0720
80	0.1730	275	0.0970	470	0.715
85	0.1680	280	0.0960	475	0.0710
90	0.1650	285	0.0950	480	0.0705
65	0.1620	290	0.0940	485	0.0700
100	0.1575	295	0.0935	490	0.0695
105	0.1545	300	0.0930	495	0.0690
110	0.1515	305	0.0920	500	0.0685
115	0.1480	310	0.0910	510	0.0680
120	0.1460	315	0.0900	520	0.0670
125	0.1440	320	0.0890	530	0.0660
130	0.1420	325	0.0880	540	0.0650
135	0.1400	330	0.0875	550	0.0645
140	0.1376	335	0.0870	560	0.0638
145	0.1360	340	0.0865	570	0.0628
150	0.1340	345	0.0860	580	0.0620
155	0.1320	350	0.0855	590	0.0610
160	0.1310	355	0.0852	600	0.0600
165	0.1280	360	0.0850	610	0.0588
170	0.1260	365	0.0840	620	0.0580
175	0.1240	370	0.0835	630	0.0570
180	0.1230	375	0.0830	640	0.0560
185	0.1220	380	0.0825	650	0.0555
190	0.1200	385	0.0820	660	0.0548
195	0.1190	390	0.0805	670	0.0540

SOIL RESISTIVITY IN OHMS /CM^3 –15,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0530	1070	0.0327	1460	0.0214
690	0.0523	1080	0.0322	1470	0.0211
700	0.0515	1090	0.03195	1480	0.0210
710	0.0507	1100	0.0315	1490	0.0208
720	0.0498	1110	0.0312	1500	0.0205
730	0.0490	1120	0.0310	1520	0.0198
740	0.0485	1130	0.0307	1540	0.0194
750	0.0480	1140	0.0303	1560	0.0190
760	0.0472	1150	0.0301	1580	0.0186
770	0.0467	1160	0.0298	1600	0.01815
780	0.0460	1170	0.0296	1620	0.0178
790	0.0453	1180	0.0292	1640	0.0174
800	0.0448	1190	0.0290	1660	0.0170
810	0.0440	1200	0.0287	1680	0.0168
820	0.0437	1210	0.0283	1700	0.0164
830	0.0430	1220	0.0280	1720	0.0160
840	0.0425	1230	0.0278	1740	0.0157
850	0.0422	1240	0.0273	1760	0.0154
860	0.0419	1250	0.0271	1780	0.0152
870	0.0415	1260	0.0270	1800	0.0148
880	0.0410	1270	0.02675	1820	0.01455
890	0.0403	1280	0.0264	1840	0.0143
900	0.0400	1290	0.0260	1860	0.0140
910	0.0395	1300	0.0258	1880	0.0137
920	0.0390	1310	0.0255	1900	0.0134
930	0.0385	1320	0.0252	1920	0.0133
940	0.0380	1330	0.0250	1940	0.0130
950	0.0375	1340	0.02475	1960	0.0127
960	0.0371	1350	0.0245	1980	0.0124
970	0.0364	1360	0.0242	2000	0.0122
980	0.0360	1370	0.0240	2020	0.0119
990	0.0357	1380	0.0238	2040	0.0117
1000	0.0354	1390	0.0235	2060	0.0115
1010	0.0350	1400	0.02315	2080	0.0113
1020	0.0347	1410	0.0229	2100	0.0111
1030	0.0342	1420	0.0226	2120	0.0108
1040	0.0338	1430	0.0222	2140	0.0107
1050	0.0334	1440	0.0220	2160	0.0104
1060	0.0331	1450	0.0217	2180	0.0103

SOIL RESISTIVITY IN OHMS /CM^3 –15,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0100	2980	0.0055	4150	0.00283
2220	0.00995	3000	0.00542	4200	0.00277
2240	0.0098	3020	0.00540	4250	0.0027
2260	0.0096	3040	0.00538	4300	0.00264
2280	0.0095	3060	0.0053	4350	0.00257
2300	0.0094	3080	0.0052	4400	0.0025
2320	0.0093	3100	0.0051	4450	0.00243
2340	0.0091	3120	0.00505	4500	0.00235
2360	0.0090	3140	0.0050	5550	0.00229
2380	0.0088	3160	0.00495	4600	0.00223
2400	0.0087	3180	0.0049	4650	0.00219
2420	0.0085	3200	0.00485	4700	0.00212
2440	0.0083	3220	0.0048	4750	0.00208
2460	0.0082	3240	0.00475	4800	0.00205
2480	0.00805	3260	0.00469	4850	0.0020
2500	0.0079	3280	0.0046	4900	0.00196
2520	0.0078	3300	0.00455	4950	0.00192
2540	0.0077	3320	0.0045	5000	0.00189
2560	0.0075	3340	0.00445	5050	0.00184
2580	0.0074	3360	0.0044	5100	0.00180
2600	0.0073	3380	0.00436	5150	0.00176
2620	0.0072	3400	0.0043	5200	0.00172
2640	0.0071	3420	0.00425	5250	0.00168
2660	0.0070	3440	0.0042	5300	0.00164
2680	0.0069	3460	0.00415	5350	0.00162
2700	0.0068	3480	0.00405	5400	0.00159
2720	0.0067	3500	0.0040	5450	0.00157
2740	0.0066	3550	0.0039	5500	0.00154
2760	0.0065	3600	0.0038	5550	0.00152
2780	0.0064	3650	0.0037	5600	0.00149
2800	0.00635	3700	0.0036	5650	0.00147
2820	0.00630	3750	0.0035	5700	0.00144
2840	0.00625	3800	0.0034	5750	0.00142
2860	0.00620	3850	0.0033	5800	0.0014
2880	0.00610	3900	0.00323	5850	0.00138
2900	0.00605	3950	0.00314	5900	0.00135
2920	0.0058	4000	0.00305	5950	0.00133
2940	0.00565	4050	0.00298	6000	0.0013
2960	0.00558	4100	0.0029	6050	0.00128

SOIL RESISTIVITY IN OHMS /CM^3 –15,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
6100	0.00127				
6150	0.00124				
6200	0.00123				
6250	0.0012				
6300	0.00118				
6350	0.00116				
6400	0.00114				
6450	0.00112				
6500	0.0011				
6550	0.00108				
6600	0.00107				
6650	0.00103				
6700	0.00100				

SOIL RESISTIVITY IN OHMS /CM^3 -20000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.3165	200	0.1265	395	0.0880
10	0.3000	205	0.1250	400	0.0877
15	0.2825	210	0.1240	405	0.0870
20	0.2685	215	0.1225	410	0.0865
25	0.2560	220	0.1210	415	0.0860
30	0.2435	225	0.1200	420	0.0855
35	0.2340	230	0.1185	425	0.0850
40	0.2250	235	0.1175	430	0.0845
45	0.2175	240	0.1165	435	0.0840
50	0.2115	245	0.1150	440	0.0835
55	0.2050	250	0.1140	445	0.0830
60	0.2000	255	0.1130	450	0.0825
65	0.1950	260	0.1120	455	0.0820
70	0.1900	265	0.1105	460	0.0810
75	0.1860	270	0.1095	465	0.0802
80	0.1820	275	0.1085	470	0.0799
85	0.1780	280	0.1075	475	0.0790
90	0.1750	285	0.1060	480	0.0785
65	0.1710	290	0.1055	485	0.0780
100	0.1680	295	0.1048	490	0.0775
105	0.1650	300	0.1038	495	0.0770
110	0.1620	305	0.1025	500	0.0765
115	0.1600	310	0.1015	510	0.0758
120	0.1570	315	0.1005	520	0.0743
125	0.1545	320	0.1000	530	0.0738
130	0.1520	325	0.0990	540	0.0728
135	0.1495	330	0.0980	550	0.0720
140	0.1475	335	0.0975	560	0.0708
145	0.1450	340	0.0965	570	0.0700
150	0.1435	345	0.0955	580	0.0690
155	0.1415	350	0.0950	590	0.0680
160	0.1395	355	0.0940	600	0.0675
165	0.1375	360	0.0930	610	0.0665
170	0.1360	365	0.0925	620	0.0659
175	0.1345	370	0.0920	630	0.0650
180	0.1325	375	0.0910	640	0.0640
185	0.1310	380	0.0900	650	0.0634
190	0.1295	385	0.0899	660	0.0625
195	0.1285	390	0.0890	670	0.0620

SOIL RESISTIVITY IN OHMS /CM^3 –20,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0610	1070	0.039	1460	0.02725
690	0.0605	1080	0.0388	1470	0.0270
700	0.0598	1090	0.0383	1480	0.0268
710	0.0590	1100	0.0380	1490	0.0264
720	0.0580	1110	0.0377	1500	0.0262
730	0.0573	1120	0.0373	1520	0.0260
740	0.0568	1130	0.0370	1540	0.0255
750	0.056	1140	0.0367	1560	0.0250
760	0.055	1150	0.0362	1580	0.0246
770	0.0545	1160	0.0360	1600	0.0242
780	0.054	1170	0.0355	1620	0.0238
790	0.053	1180	0.0350	1640	0.0234
800	0.0528	1190	0.0349	1660	0.0230
810	0.052	1200	0.0345	1680	0.0226
820	0.0515	1210	0.03405	1700	0.0222
830	0.051	1220	0.03400	1720	0.0218
840	0.0504	1230	0.0335	1740	0.0214
850	0.050	1240	0.0332	1760	0.0210
860	0.0493	1250	0.03285	1780	0.0207
870	0.049	1260	0.0326	1800	0.0204
880	0.0484	1270	0.0322	1820	0.0200
890	0.0480	1280	0.0320	1840	0.0197
900	0.0472	1290	0.0318	1860	0.0193
910	0.0470	1300	0.0315	1880	0.0190
920	0.0461	1310	0.0312	1900	0.0188
930	0.0458	1320	0.0310	1920	0.0184
940	0.0451	1330	0.0308	1940	0.0181
950	0.0448	1340	0.0304	1960	0.0179
960	0.0442	1350	0.0301	1980	0.0176
970	0.0439	1360	0.0300	2000	0.0173
980	0.0432	1370	0.0297	2020	0.0170
990	0.0430	1380	0.0293	2040	0.0167
1000	0.0422	1390	0.0290	2060	0.0164
1010	0.0420	1400	0.0288	2080	0.0162
1020	0.0413	1410	0.0287	2100	0.0159
1030	0.0410	1420	0.0283	2120	0.0157
1040	0.0402	1430	0.0280	2140	0.01535
1050	0.0400	1440	0.0278	2160	0.0151
1060	0.0394	1450	0.0275	2180	0.0148

SOIL RESISTIVITY IN OHMS /CM^3 20,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0146	2980	0.008	4150	0.00394
2220	0.0144	3000	0.0079	4200	0.00383
2240	0.01415	3020	0.0078	4250	0.00373
2260	0.01395	3040	0.0077	4300	0.00363
2280	0.01375	3060	0.0076	4350	0.00354
2300	0.0135	3080	0.0075	4400	0.00345
2320	0.01335	3100	0.0074	4450	0.00336
2340	0.01315	3120	0.00732	4500	0.00327
2360	0.0129	3140	0.0072	4550	0.0032
2380	0.0127	3160	0.00715	4600	0.0031
2400	0.0125	3180	0.00705	4650	0.00303
2420	0.0123	3200	0.0070	4700	0.00296
2440	0.0122	3220	0.0069	4750	0.0029
2460	0.0120	3240	0.0068	4800	0.00282
2480	0.0118	3260	0.00672	4850	0.00277
2500	0.01165	3280	0.00665	4900	0.0027
2520	0.0114	3300	0.0066	4950	0.00265
2540	0.0113	3320	0.0065	5000	0.0026
2560	0.0111	3340	0.0064	5050	0.00253
2580	0.0109	3360	0.00633	5100	0.00248
2600	0.01075	3380	0.00624	5150	0.00243
2620	0.0105	3400	0.0062	5200	0.00239
2640	0.0104	3420	0.0061	5250	0.00233
2660	0.0102	3440	0.00603	5300	0.0023
2680	0.0100	3460	0.00595	5350	0.00225
2700	0.0099	3480	0.0059	5400	0.0022
2720	0.0975	3500	0.0058	5450	0.00217
2740	0.0096	3550	0.0056	5500	0.0212
2760	0.00948	3600	0.0054	5550	0.00208
2780	0.00935	3650	0.00525	5600	0.00204
2800	0.0092	3700	0.0051	5650	0.002
2820	0.0090	3750	0.00495	5700	0.00197
2840	0.0089	3800	0.0048	5750	0.001925
2860	0.0088	3850	0.00465	5800	0.0019
2880	0.00865	3900	0.0045	5850	0.00186
2900	0.00855	3950	0.0044	5900	0.00183
2920	0.0084	4000	0.00428	5950	0.0018
2940	0.00828	4050	0.00417	6000	0.00177
2960	0.00815	4100	0.00405	6050	0.00174

SOIL RESISTIVITY IN OHMS /CM^3 –20,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
6100	0.00171				
6150	0.00168				
6200	0.00166				
6250	0.00163				
6300	0.0016				
6350	0.00158				
6400	0.00156				
6450	0.00153				
6500	0.0015				
6550	0.00148				
6600	0.00146				
6650	0.00144				
6700	0.00141				
6750	0.0014				
6800	0.00138				
6850	0.00136				
6900	0.00134				
6950	0.00132				
7000	0.0013				
7050	0.00128				
7100	0.00127				
7150	0.00126				
7200	0.00124				
7250	0.00123				
7300	0.0012				
7350	0.00119				
7400	0.00117				
7450	0.00115				
7500	0.00114				
7550	0.00112				
7600	0.0011				
7650	0.00108				
7700	0.00107				
7750	0.00105				
7800	0.00104				
7850	0.00103				
7900	0.00101				
7950	0.0010				

SOIL RESISTIVITY IN OHMS /CM^3 –25,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation In Meters	Mutual Impedance in Ohms/KM
5		200	0.1350	395	0.0938
10		205	0.1330	400	0.0930
15		210	0.1305	405	0.0925
20	0.2675	215	0.1295	410	0.0920
25	0.2550	220	0.1270	415	0.0910
30	0.2450	225	0.1250	420	0.0900
35	0.2360	230	0.1245	425	0.890
40	0.2300	235	0.1230	430	0.0880
45	0.2230	240	0.1220	435	0.0879
50	0.2170	245	0.1200	440	0.0875
55	0.2125	250	0.1190	445	0.0865
60	0.2075	255	0.1180	450	0.860
65	0.2030	260	0.1172	455	0.0851
70	0.1985	265	0.1165	460	0.0850
75	0.1950	270	0.1150	465	0.0845
80	0.1910	275	0.1140	470	0.0835
85	0.1880	280	0.1138	475	0.0830
90	0.1850	285	0.1125	480	0.0825
65	0.1830	290	0.1115	485	0.0820
100	0.1800	295	0.1105	490	0.0815
105	0.1760	300	0.1100	495	0.0805
110	0.1740	305	0.1090	500	0.0800
115	0.1710	310	0.1075	510	0.0790
120	0.1680	315	0.1065	520	0.0780
125	0.1650	320	0.1060	530	0.0775
130	0.1630	325	0.1050	540	0.0765
135	0.1610	330	0.1045	550	0.0760
140	0.1585	335	0.1035	560	0.0750
145	0.1570	340	0.1020	570	0.0740
150	0.1550	345	0.1015	580	0.0735
155	0.1520	350	0.1010	590	0.0726
160	0.1500	355	0.1000	600	0.0720
165	0.1476	360	0.0987	610	0.0710
170	0.1460	365	0.0980	620	0.0705
175	0.1440	370	0.0975	630	0.0698
180	0.1420	375	0.0968	640	0.0690
185	0.1400	380	0.0960	650	0.0680
190	0.1385	385	0.0950	660	0.0678
195	0.1370	390	0.0945	670	0.0668

SOIL RESISTIVITY IN OHMS /CM^3 –25,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation In Meters	Mutual Impedance in Ohms/KM
680	0.0660	1070	0.0440	1460	0.0304
690	0.0653	1080	0.0435	1470	0.0300
700	0.0648	1090	0.0430	1480	0.0299
710	0.0640	1100	0.0428	1490	0.0296
720	0.0632	1110	0.0421	1500	0.0292
730	0.0626	1120	0.0420	1520	0.02915
740	0.0620	1130	0.0415	1540	0.0288
750	0.0613	1140	0.0410	1560	0.0285
760	0.0603	1150	0.0407	1580	0.0281
770	0.0600	1160	0.0400	1600	0.0277
780	0.0595	1170	0.0398	1620	0.02725
790	0.0590	1180	0.0394	1640	0.0270
800	0.058	1190	0.0391	1660	0.0267
810	0.0575	1200	0.0389	1680	0.02625
820	0.0570	1210	0.0383	1700	0.0260
830	0.0563	1220	0.0380	1720	0.0256
840	0.0553	1230	0.0378	1740	0.02515
850	0.0550	1240	0.0374	1760	0.0248
860	0.0545	1250	0.0372	1780	0.0244
870	0.0540	1260	0.0369	1800	0.0241
880	0.0532	1270	0.0365	1820	0.02385
890	0.0528	1280	0.0363	1840	0.0235
900	0.0522	1290	0.0360	1860	0.0232
910	0.0518	1300	0.0353	1880	0.0229
920	0.0510	1310	0.0350	1900	0.0226
930	0.0505	1320	0.0348	1920	0.02215
940	0.0500	1330	0.0343	1940	0.0219
950	0.0495	1340	0.0340	1960	0.0215
960	0.0490	1350	0.0337	1980	0.0212
970	0.0485	1360	0.0333	2000	0.0209
980	0.0480	1370	0.0330	2020	0.0206
990	0.0475	1380	0.0327	2040	0.0202
1000	0.047	1390	0.0323	2060	0.0200
1010	0.0465	1400	0.0321	2080	0.0196
1020	0.0460	1410	0.0320	2100	0.0194
1030	0.0455	1420	0.0317	2120	0.0191
1040	0.0450	1430	0.0313	2140	0.0189
1050	0.0446	1440	0.0310	2160	0.0186
1060	0.0442	1450	0.0308	2180	0.0183

SOIL RESISTIVITY IN OHMS /CM^3 –25,000 Ohms/Cm^3

Separation	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation In Meters	Mutual Impedance in Ohms/KM
2200	0.0180	2980	0.0105	4150	0.00498
2220	0.01775	3000	0.0104	4200	0.00485
2240	0.0175	3020	0.0102	4250	0.00471
2260	0.0173	3040	0.0100	4300	0.0046
2280	0.01705	3060	0.00985	4350	0.0045
2300	0.0168	3080	0.00972	4400	0.0044
2320	0.0166	3100	0.0096	4450	0.0043
2340	0.0164	3120	0.00945	4500	0.0042
2360	0.0162	3140	0.00935	4550	0.0041
2380	0.01595	3160	0.00923	4600	0.004
2400	0.01575	3180	0.0091	4650	0.0039
2420	0.0155	3200	0.0090	4700	0.00378
2440	0.0153	3220	0.00885	4750	0.0037
2460	0.01510	3240	0.00873	4800	0.0036
2480	0.0149	3260	0.0086	4850	0.0035
2500	0.0147	3280	0.00848	4900	0.00342
2520	0.0145	3300	0.00835	4950	0.00333
2540	0.0143	3320	0.00822	5000	0.00327
2560	0.01415	3340	0.00812	5050	0.00321
2580	0.01395	3360	0.0080	5100	0.00315
2600	0.0138	3380	0.0079	5150	0.0031
2620	0.01365	3400	0.00778	5200	0.003
2640	0.0134	3420	0.00765	5250	0.00292
2660	0.0132	3440	0.0755	5300	0.00286
2680	0.0130	3460	0.00745	5350	0.0028
2700	0.0128	3480	0.00732	5400	0.00275
2720	0.0127	3500	0.00730	5450	0.0027
2740	0.0125	3550	0.0071	5500	0.00264
2760	0.0123	3600	0.00696	5550	0.0026
2780	0.0122	3650	0.0068	5600	0.00254
2800	0.0120	3700	0.0066	5650	0.0025
2820	0.01185	3750	0.00647	5700	0.00244
2840	0.0117	3800	0.0063	5750	0.0024
2860	0.0115	3850	0.00618	5800	0.00235
2880	0.0113	3900	0.00605	5850	0.0023
2900	0.0112	3950	0.0059	5900	0.00227
2920	0.0110	4000	0.00575	5950	0.00222
2940	0.0108	4050	0.00526	6000	0.0022
2960	0.0107	4100	0.0051	6050	0.00212

SOIL RESISTIVITY IN OHMS /CM^3 –25,000 Ohms/Cm3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation In Meters	Mutual Impedance in Ohms/KM
6100	0.00209	8000	0.00116		
6150	0.00203	8050	0.00114		
6200	0.002	8100	0.00111		
6250	0.00195	8150	0.00109		
6300	0.0019	8200	0.00107		
6350	0.00186	8250	0.00104		
6400	0.00182	8300	0.00103		
6450	0.0018	8350	0.00101		
6500	0.00178	8400	0.001		
6550	0.00175				
6600	0.00172				
6650	0.0017				
6700	0.00169				
6750	0.00165				
6800	0.00163				
6850	0.0016				
6900	0.00157				
6950	0.00154				
7000	0.00152				
7050	0.0015				
7100	0.00148				
7150	0.00146				
7200	0.00144				
7250	0.00142				
7300	0.0014				
7350	0.00138				
7400	0.00137				
7450	0.00134				
7500	0.00132				
7550	0.0013				
7600	0.00129				
7650	0.00128				
7700	0.00125				
7750	0.0124				
7800	0.00122				
7850	0.00121				
7900	0.0119				
7950	0.00118				

SOIL RESISTIVITY IN OHMS /CM^3 –30,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separatio n in meters	Mutual Impedance in Ohms/KM
5	0.3280	200	0.1385	395	0.0990
10	0.3110	205	0.1370	400	0.0980
15	0.2970	210	0.1355	405	0.0975
20	0.2820	215	0.1350	410	0.0970
25	0.2700	220	0.1335	415	0.0965
30	0.2580	225	0.1320	420	0.0960
35	0.2480	230	0.1305	425	0.09505
40	0.2380	235	0.1290	430	0.0949
45	0.2310	240	0.1280	435	0.0940
50	0.2230	245	0.1270	440	0.0935
55	0.2170	250	0.1260	445	0.0930
60	0.2115	255	0.1250	450	0.0925
65	0.2060	260	0.1230	455	0.0922
70	0.2010	265	0.1220	460	0.0920
75	0.1965	270	0.1210	465	0.0910
80	0.1925	275	0.1200	470	0.0902
85	0.1890	280	0.1190	475	0.0900
90	0.1860	285	0.1180	480	0.0890
65	0.1825	290	0.1170	485	0.0885
100	0.1790	295	0.1160	490	0.0880
105	0.1770	300	0.1150	495	0.0875
110	0.1740	305	0.1140	500	0.0870
115	0.1715	310	0.1130	510	0.0860
120	0.1685	315	0.1120	520	0.0855
125	0.1660	320	0.1110	530	0.0842
130	0.1640	325	0.1100	540	0.0840
135	0.1620	330	0.1090	550	0.0829
140	0.1600	335	0.1080	560	0.0820
145	0.1575	340	0.1075	570	0.0810
150	0.1555	345	0.1065	580	0.0800
155	0.1540	350	0.1055	590	0.0792
160	0.1520	355	0.1050	600	0.0785
165	0.1500	360	0.1045	610	0.0780
170	0.1480	365	0.1035	620	0.0769
175	0.1465	370	0.1025	630	0.0760
180	0.1450	375	0.1020	640	0.0750
185	0.1440	380	0.1015	650	0.0740
190	0.1420	385	0.1005	660	0.0737
195	0.1400	390	0.1000	670	0.0725

SOIL RESISTIVITY IN OHMS /CM^3 –30,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0720	1070	0.0504	1460	0.0370
690	0.0710	1080	0.0500	1470	0.0369
700	0.070	1090	0.0497	1480	0.0366
710	0.0696	1100	0.0491	1490	0.0363
720	0.0690	1110	0.0490	1500	0.0362
730	0.0680	1120	0.0483	1520	0.0358
740	0.0675	1130	0.0480	1540	0.0351
750	0.0668	1140	0.0474	1560	0.0346
760	.0660	1150	0.0470	1580	0.0340
770	0.0653	1160	0.0467	1600	0.0334
780	0.0649	1170	0.0462	1620	0.0328
790	0.0640	1180	0.0460	1640	0.0322
800	0.0633	1190	0.0457	1660	0.0318
810	0.0629	1200	0.0452	1680	0.0313
820	0.0620	1210	0.0450	1700	0.0308
830	0.0618	1220	0.0447	1720	0.0303
840	0.0610	1230	0.0442	1740	0.0299
850	0.0602	1240	0.0440	1760	0.0294
860	0.0600	1250	0.0437	1780	0.0290
870	0.0591	1260	0.0431	1800	0.0285
880	0.0590	1270	0.0430	1820	0.0280
890	0.0582	1280	0.0427	1840	0.0277
900	0.0580	1290	0.0423	1860	0.0272
910	0.0571	1300	0.0420	1880	0.0269
920	0.0570	1310	0.0417	1900	0.0265
930	0.0563	1320	0.0414	1920	0.0260
940	0.0560	1330	0.0410	1940	0.0258
950	0.0555	1340	0.0408	1960	0.0253
960	0.0550	1350	0.0404	1980	0.0250
970	0.0546	1360	0.0400	2000	0.0247
980	0.0541	1370	0.0396	2020	0.0243
990	0.0539	1380	0.0392	2040	0.0240
1000	0.0533	1390	0.0390	2060	0.0237
1010	0.0530	1400	0.0387	2080	0.0233
1020	0.0525	1410	0.0383	2100	0.0230
1030	0.0520	1420	0.0380	2120	0.0228
1040	0.0517	1430	0.0379	2140	0.0223
1050	0.0511	1440	0.0376	2160	0.0220
1060	0.0510	1450	0.0372	2180	0.0218

SOIL RESISTIVITY IN OHMS /CM^3 30,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0213	2980	0.0122	4150	0.00626
2220	0.0210	3000	0.0120	4200	0.0061
2240	0.02075	3020	0.0118	4250	0.00595
2260	0.0204	3040	0.0117	4300	0.0058
2280	0.0200	3060	0.0115	4350	0.00566
2300	0.0198	3080	0.0114	4400	0.0055
2320	0.0195	3100	0.0112	4450	0.00538
2340	0.0191	3120	0.0111	4500	0.00524
2360	0.0189	3140	0.0109	4550	0.0051
2380	0.0186	3160	0.01075	4600	0.0050
2400	0.0183	3180	0.0106	4650	0.00487
2420	0.0180	3200	0.0105	4700	0.00475
2440	0.0178	3220	0.0104	4750	0.00464
2460	0.0175	3240	0.0103	4800	0.00453
2480	0.0173	3260	0.0101	4850	0.00442
2500	0.0170	3280	0.00995	4900	0.00432
2520	0.0168	3300	0.0098	4950	0.00422
2540	0.0165	3320	0.00975	5000	0.00414
2560	0.0163	3340	0.0096	5050	0.00404
2580	0.0160	3360	0.0095	5100	0.00396
2600	0.0158	3380	0.0094	5150	0.00388
2620	0.0156	3400	0.0093	5200	0.0038
2640	0.0154	3420	0.0092	5250	0.00371
2660	0.0152	3440	0.0091	5300	0.00363
2680	0.0150	3460	0.0090	5350	0.00356
2700	0.0147	3480	0.00895	5400	0.00349
2720	0.0145	3500	0.0089	5450	0.00341
2740	0.0144	3550	0.0087	5500	0.00334
2760	0.0142	3600	0.00842	5550	0.00328
2780	0.0140	3650	0.0082	5600	0.0032
2800	0.01375	3700	0.00795	5650	0.00314
2820	0.0136	3750	0.00775	5700	0.00308
2840	0.0134	3800	0.00752	5750	0.00301
2860	0.0132	3850	0.0073	5800	0.00295
2880	0.0130	3900	0.0071	5850	0.0029
2900	0.01285	3950	0.00695	5900	0.00284
2920	0.0127	4000	0.00675	5950	0.00278
2940	0.0125	4050	0.0066	6000	0.00272
2960	0.0123	4100	.0064	6050	0.00269

SOIL RESISTIVITY IN OHMS /CM^3 –30,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separatio n in meters	Mutual Impedance in Ohms/KM
6100	0.00264	8050	0.00147		
6150	0.0026	8100	0.00145		
6200	0.00255	8150	0.00143		
6250	0.0025	8200	0.00142		
6300	0.00247	8250	0.0014		
6350	0.00243	8300	0.00138		
6400	0.00238	8350	0.00136		
6450	0.00234	8400	0.00134		
6500	0.0023	8450	0.00133		
6550	0.00227	8500	0.00131		
6600	0.00223	8550	0.00128		
6650	0.0022	8600	0.00126		
6700	0.00216	8650	0.00123		
6750	0.00212	8700	0.0012		
6800	0.0021	8750	0.00118		
6850	0.00207	8800	0.00116		
6900	0.00203	8850	0.00115		
6950	0.0020	8900	0.00113		
7000	0.00197	8950	0.00112		
7050	0.00194	9000	0.0011		
7100	0.00191	9050	0.00108		
7150	0.00189	9100	0.00105		
7200	0.00187	9150	0.00102		
7250	0.00183	9200	0.001		
7300	0.0018				
7350	0.00178				
7400	0.00176				
7450	0.0173				
7500	0.00170				
7550	0.00168				
7600	0.00166				
7650	0.00163				
7700	0.00161				
7750	0.00158				
7800	0.00157				
7850	0.00154				
7900	0.00152				
7950	0.0015				
8000	0.00148				

SOIL RESISTIVITY IN OHMS /CM^3 –50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separatio n in meters	Mutual Impedance in Ohms/KM
5	0.3390	200	0.1550	395	0.1145
10	0.3230	205	0.1530	400	0.1135
15	0.3100	210	0.1520	405	0.1130
20	0.2960	215	0.1500	410	0.1120
25	0.2840	220	0.1490	415	0.1110
30	0.2720	225	0.1475	420	0.1105
35	0.2620	230	0.1460	425	0.1100
40	0.2530	235	0.1450	430	0.1095
45	0.2450	240	0.1440	435	0.1090
50	0.2390	245	0.1430	440	0.1080
55	0.2325	250	0.1420	445	0.1075
60	0.2265	255	0.1404	450	0.1065
65	0.2220	260	0.1395	455	0.1060
70	0.2175	265	0.1380	460	0.1053
75	0.2140	270	0.1370	465	0.1050
80	0.2100	275	0.1360	470	0.1045
85	0.2060	280	0.1350	475	0.1040
90	0.2030	285	0.1240	480	0.1030
65	0.2000	290	0.1330	485	0.1025
100	0.1960	295	0.1320	490	0.1020
105	0.1935	300	0.1310	495	0.1015
110	0.1900	305	0.1300	500	0.1005
115	0.1880	310	0.1290	510	0.1000
120	0.1850	315	0.1280	520	0.0992
125	0.1830	320	0.1270	530	0.0980
130	0.1800	325	0.1260	540	0.0970
135	0.1780	330	0.1250	550	0.0960
140	0.1760	335	0.1245	560	0.0950
145	0.1740	340	0.1235	570	0.0940
150	0.1720	345	0.1225	580	0.0930
155	0.1700	350	0.1215	590	0.0920
160	0.1675	355	0.1205	600	0.0912
165	0.1660	360	0.1200	610	0.0900
170	0.1640	365	0.1195	620	0.0897
175	0.1625	370	0.1185	630	0.0885
180	0.1610	375	0.1175	640	0.0880
185	0.1600	380	0.1165	650	0.0870
190	0.1580	385	0.1155	660	0.0862
195	0.1565	390	0.1150	670	0.0855

SOIL RESISTIVITY IN OHMS /CM^3 –50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.0845	1070	0.0622	1460	0.0468
690	0.0840	1080	0.0619	1470	0.0464
700	0.0830	1090	0.0617	1480	0.0461
710	0.0823	1100	0.0610	1490	0.0460
720	0.0820	1110	0.0608	1500	0.0459
730	0.0815	1120	0.0601	1520	0.0450
740	0.0805	1130	0.0599	1540	0.0443
750	0.0800	1140	0.0591	1560	0.0437
760	0.0793	1150	0.0590	1580	0.0430
770	0.0785	1160	0.0585	1600	0.0423
780	0.0780	1170	0.0580	1620	0.0418
790	0.0775	1180	0.0575	1640	0.0411
800	0.0765	1190	0.0570	1660	0.0406
810	0.0760	1200	0.0567	1680	0.0400
820	0.0755	1210	0.0561	1700	0.0395
830	0.0750	1220	0.0557	1720	0.0391
840	0.0740	1230	0.0551	1740	0.0385
850	0.0738	1240	0.0549	1760	0.0380
860	0.0730	1250	0.0542	1780	0.0376
870	0.0725	1260	0.0540	1800	0.0371
880	0.0720	1270	0.0535	1820	0.0367
890	0.0715	1280	0.0531	1840	0.0362
900	0.0710	1290	0.0529	1860	0.0359
910	0.0705	1300	0.0523	1880	0.0352
920	0.0700	1310	0.0520	1900	0.0350
930	0.0695	1320	0.0515	1920	0.0345
940	0.0690	1330	0.0512	1940	0.0341
950	0.0682	1340	0.0510	1960	0.0338
960	0.0680	1350	0.0503	1980	0.0332
970	0.0675	1360	0.0500	2000	0.0330
980	0.0670	1370	0.0495	2020	0.0326
990	0.0662	1380	0.0491	2040	0.0321
1000	0.0660	1390	0.0489	2060	0.0318
1010	0.0655	1400	0.0485	2080	0.0314
1020	0.0650	1410	0.0481	2100	0.0310
1030	0.0642	1420	0.0480	2120	0.0308
1040	0.0639	1430	0.0476	2140	0.0304
1050	0.0635	1440	0.0472	2160	0.0300
1060	0.0628	1450	0.0470	2180	0.0298

SOIL RESISTIVITY IN OHMS /CM^3 50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation In Meters	Mutual Impedance in Ohms/KM
2200	0.0294	2980	0.0191	4150	0.0104
2220	0.0290	3000	0.0190	4200	0.0102
2240	0.0288	3020	0.0187	4250	0.00993
2260	0.0284	3040	0.0185	4300	0.0097
2280	0.0281	3060	0.0183	4350	0.0095
2300	0.0278	3080	0.01815	4400	0.0093
2320	0.0275	3100	0.0180	4450	0.0908
2340	0.0271	3120	0.0178	4500	0.0089
2360	0.0269	3140	0.0176	4550	0.0087
2380	0.0265	3160	0.0174	4600	0.0085
2400	0.0261	3180	0.0172	4650	0.00835
2420	0.0260	3200	0.0171	4700	0.0082
2440	0.0257	3220	0.0169	4750	0.0080
2460	0.0253	3240	0.0167	4800	0.0078
2480	0.0251	3260	0.0166	4850	0.00765
2500	0.0249	3280	0.0164	4900	0.0075
2520	0.0247	3300	0.0162	4950	0.00735
2540	0.0243	3320	0.0161	5000	0.0072
2560	0.0241	3340	0.0159	5050	0.00708
2580	0.0238	3360	0.0157	5100	0.0069
2600	0.0235	3380	0.0156	5150	0.0068
2620	0.0232	3400	0.0154	5200	0.00668
2640	0.0229	3420	0.0152	5250	0.00655
2660	0.0227	3440	0.0151	5300	0.0064
2680	0.0224	3460	0.0150	5350	0.0063
2700	0.0221	3480	0.0148	5400	0.0062
2720	0.0219	3500	0.0147	5450	0.0061
2740	0.0217	3550	0.0143	5500	0.00598
2760	0.0214	3600	0.0139	5550	0.00586
2780	0.0211	3650	0.0136	5600	0.00575
2800	0.0210	3700	0.0132	5650	0.00565
2820	0.0208	3750	0.0129	5700	0.00555
2840	0.0205	3800	0.0125	5750	0.00545
2860	0.0203	3850	0.0122	5800	0.00535
2880	0.0201	3900	0.0119	5850	0.00525
2900	0.0200	3950	0.0116	5900	0.00515
2920	0.0198	4000	0.0113	5950	0.00505
2940	0.0196	4050	0.0110	6000	0.00495
2960	0.0194	4100	0.0107	6050	0.0049

SOIL RESISTIVITY IN OHMS /CM^3 –50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation In meters	Mutual Impedance in Ohms/KM
6100	0.0048	8050	0.00257		
6150	0.0047	8100	0.00253		
6200	0.0046	8150	0.0025		
6250	0.00453	8200	0.00246		
6300	0.00445	8250	0.00242		
6350	0.00438	8300	0.00239		
6400	0.0043	8350	0.00236		
6450	0.00422	8400	0.00231		
6500	0.00415	8450	0.00229		
6550	0.0041	8500	0.00225		
6600	0.0040				
6650	0.00395				
6700	0.00389				
6750	0.00382				
6800	0.00375				
6850	0.0037				
6900	0.00361				
6950	0.00356				
7000	0.0035				
7050	0.00344				
7100	0.0034				
7150	0.00335				
7200	0.0033				
7250	0.00324				
7300	0.0032				
7350	0.00314				
7400	0.0031				
7450	0.00305				
7500	0.0030				
7550	0.00295				
7600	0.00291				
7650	0.00288				
7700	0.00283				
7750	0.0028				
7800	0.00277				
7850	0.00272				
7900	0.00269				
7950	0.00264				
8000	0.0026				

SOIL RESISTIVITY IN OHMS /CM³ –1,00,000 Ohms/Cm³

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separatio n in meters	Mutual Impedance in Ohms/KM
5	0.3510	200	0.1750	395	0.1350
10	0.3370	205	0.1740	400	0.1346
15	0.3220	210	0.1725	405	0.1340
20	0.3100	215	0.1710	410	0.1330
25	0.3000	220	0.1700	415	0.1325
30	0.2900	225	0.1690	420	0.1320
35	0.2790	230	0.1670	425	0.1310
40	0.2700	235	0.1655	430	0.1305
45	0.2640	240	0.1650	435	0.1300
50	0.2575	245	0.1645	440	0.1290
55	0.2510	250	0.1630	445	0.1280
60	0.2460	255	0.1620	450	0.1275
65	0.2410	260	0.1605	455	0.1265
70	0.2375	265	0.1600	460	0.1260
75	0.2340	270	0.1580	465	0.1255
80	0.2290	275	0.1570	470	0.1250
85	0.2250	280	0.1560	475	0.1249
90	0.2220	285	0.1550	480	0.1235
65	0.2190	290	0.1545	485	0.1230
100	0.2155	295	0.1530	490	0.1225
105	0.2130	300	0.1520	495	0.1220
110	0.2100	305	0.1510	500	0.1215
115	0.2070	310	0.1500	510	0.1205
120	0.2050	315	0.1490	520	0.1195
125	0.2025	320	0.1480	530	0.1180
130	0.2000	325	0.1470	540	0.1165
135	0.1975	330	0.1460	550	0.1150
140	0.1950	335	0.1450	560	0.1140
145	0.1940	340	0.1445	570	0.1125
150	0.1915	345	0.1430	580	0.1110
155	0.1900	350	0.1420	590	0.110
160	0.1880	355	0.1410	600	0.1090
165	0.1855	360	0.1402	610	0.108
170	0.1845	365	0.1398	620	0.1075
175	0.1825	370	0.1390	630	0.1065
180	0.1800	375	0.1380	640	0.1050
185	0.1795	380	0.1370	650	0.1045
190	0.1775	385	0.1365	660	0.1040
195	0.1760	390	0.1360	670	0.1030

SOIL RESISTIVITY IN OHMS /CM^3 –1,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.1020	1070	0.0781	1460	0.0624
690	0.1010	1080	0.0778	1470	0.062
700	0.100	1090	0.0772	1480	0.0619
710	0.0995	1100	0.0768	1490	0.0615
720	0.099	1110	0.0762	1500	0.061
730	0.098	1120	0.076	1520	0.0605
740	0.0976	1130	0.0755	1540	0.0598
750	0.0968	1140	0.075	1560	0.059
760	0.096	1150	0.742	1580	0.0585
770	0.0958	1160	0.0740	1600	0.058
780	0.095	1170	0.0738	1620	0.0575
790	0.094	1180	0.0735	1640	0.0568
800	0.0937	1190	0.073	1660	0.0560
810	0.0930	1200	0.0724	1680	0.0556
820	0.0925	1210	0.072	1700	0.0552
830	0.092	1220	0.0718	1720	0.0546
840	0.0916	1230	0.071	1740	0.0541
850	0.0910	1240	0.0705	1760	0.0537
860	0.090	1250	0.0700	1780	0.0530
870	0.0896	1260	0.0698	1800	0.0526
880	0.089	1270	0.0694	1820	0.0521
890	0.0885	1280	0.0690	1840	0.0515
900	0.0880	1290	0.0686	1860	0.0510
910	0.0875	1300	0.0682	1880	0.0505
920	0.0870	1310	0.0680	1900	0.050
930	0.0862	1320	0.0678	1920	0.0498
940	0.0858	1330	0.0672	1940	0.0493
950	0.085	1340	0.067	1960	0.0488
960	0.0844	1350	0.0665	1980	0.0482
970	0.0838	1360	0.0660	2000	0.0478
980	0.083	1370	0.0659	2020	0.0473
990	0.0826	1380	0.0655	2040	0.047
1000	0.0820	1390	0.0650	2060	0.0465
1010	0.0815	1400	0.0648	2080	0.046
1020	0.0810	1410	0.0642	2100	0.0457
1030	0.0820	1420	0.0640	2120	0.0452
1040	0.798	1430	0.0638	2140	0.0449
1050	0.0790	1440	0.0635	2160	0.0445
1060	0.0785	1450	0.063	2180	0.0440

SOIL RESISTIVITY IN OHMS /CM^3 1,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0437	2980	0.0308	4150	0.0198
2220	0.0432	3000	0.0305	4200	0.0193
2240	0.0428	3020	0.0302	4250	0.019
2260	0.0424	3040	0.030	4300	0.0186
2280	0.0420	3060	0.0298	4350	0.0183
2300	0.0415	3080	0.0295	4400	0.018
2320	0.0411	3100	0.0293	4450	0.0177
2340	0.0408	3120	0.0291	4500	0.0174
2360	0.0404	3140	0.0290	4550	0.0171
2380	0.0400	3160	0.0288	4600	0.0168
2400	0.0398	3180	0.0286	4650	0.0166
2420	0.0393	3200	0.0284	4700	0.0163
2440	0.0390	3220	0.0281	4750	0.0160
2460	0.0388	3240	0.0280	4800	0.0158
2480	0.0383	3260	0.0278	4850	0.0156
2500	0.0380	3280	0.0275	4900	0.0153
2520	0.0378	3300	0.0273	4950	0.0150
2540	0.0373	3320	0.0271	5000	0.0148
2560	0.0370	3340	0.0270	5050	0.0146
2580	0.0368	3360	0.0268	5100	0.0143
2600	0.0363	3380	0.0265	5150	0.0141
2620	0.0361	3400	0.0263	5200	0.0138
2640	0.0358	3420	0.0261	5250	0.0136
2660	0.0355	3440	0.0259	5300	0.0134
2680	0.0351	3460	0.0257	5350	0.0132
2700	0.035	3480	0.0254	5400	0.0130
2720	0.0345	3500	0.0252	5450	0.0128
2740	0.0342	3550	0.0248	5500	0.0125
2760	0.0340	3600	0.0242	5550	0.0124
2780	0.0335	3650	0.0238	5600	0.0121
2800	0.0332	3700	0.0232	5650	0.0119
2820	0.0330	3750	0.0228	5700	0.0117
2840	0.0328	3800	0.0223	5750	0.0115
2860	0.0324	3850	0.022	5800	0.0113
2880	0.0321	3900	0.0216	5850	0.0111
2900	0.0319	3950	0.0211	5900	0.01035
2920	0.0317	4000	0.0208	5950	0.0107
2940	0.0313	4050	0.0203	6000	0.0105
2960	0.0310	4100	0.020	6050	0.0104

`SOIL RESISTIVITY IN OHMS /CM^3 –1,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
6100	0.0102	8050	0.0054		
6150	0.010	8100	0.0053		
6200	0.00983	8150	0.0525		
6250	0.0097	8200	0.00517		
6300	0.00958	8250	0.0051		
6350	0.0094	8300	0.005		
6400	0.00927	8350	0.00492		
6450	0.0091	8400	0.00485		
6500	0.009	8450	0.00478		
6550	0.00882	8500	0.0047		
6600	0.0087				
6650	0.00856				
6700	0.0084				
6750	0.0083				
6800	0.00815				
6850	0.008				
6900	0.0079				
6950	0.0775				
7000	0.0076				
7050	0.0075				
7100	0.00737				
7150	0.00725				
7200	0.0071				
7250	0.007				
7300	0.0069				
7350	0.00675				
7400	0.00665				
7450	0.00655				
7500	0.00645				
7550	0.00635				
7600	0.00625				
7650	0.00615				
7700	0.00605				
7750	0.00595				
7800	0.00585				
7850	0.00575				
7900	0.00565				
7950	0.0558				
8000	0.0055				

SOIL RESISTIVITY IN OHMS /CM^3 –2,50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.4250	200	0.1970	395	0.1615
10	0.3820	205	0.1960	400	0.1605
15	0.3600	210	0.1950	405	0.1600
20	0.3460	215	0.1940	410	0.1590
25	0.3300	220	0.1930	415	0.1580
30	0.3180	225	0.1910	420	0.1570
35	0.3080	230	0.1900	425	0.1565
40	0.3000	235	0.1890	430	0.1560
45	0.2900	240	0.1880	435	0.1555
50	0.2840	245	0.1870	440	0.1549
55	0.2770	250	0.1860	445	0.1540
60	0.2710	255	0.1850	450	0.1530
65	0.2650	260	0.1840	455	0.1520
70	0.2610	265	0.1830	460	0.1510
75	0.2570	270	0.1820	465	0.1500
80	0.2530	275	0.1810	470	0.1495
85	0.2490	280	0.1805	475	0.1490
90	0.2450	285	0.1800	480	0.1480
65	0.2425	290	0.1790	485	0.1475
100	0.2400	295	0.1780	490	0.1470
105	0.2370	300	0.1770	495	0.1460
110	0.2350	305	0.1765	500	0.1450
115	0.2330	310	0.1760	510	0.1440
120	0.2310	315	0.1750	520	0.1430
125	0.2290	320	0.1740	530	0.1420
130	0.2260	325	0.1730	540	0.1410
135	0.2250	330	0.1720	550	0.1405
140	0.2220	335	0.1715	560	0.1400
145	0.2200	340	0.1705	570	0.1390
150	0.2170	345	0.1700	580	0.1380
155	0.2150	350	0.1695	590	0.1370
160	0.2140	355	0.1685	600	0.1365
165	0.2120	360	0.1670	610	0.1360
170	0.2100	365	0.1665	620	0.1350
175	0.2070	370	0.1655	630	0.1340
180	0.2050	375	0.1650	640	0.1330
185	0.2040	380	0.1640	650	0.1320
190	0.2010	385	0.1630	660	0.1310
195	0.2000	390	0.1620	670	0.1305

SOIL RESISTIVITY IN OHMS /CM^3 –2,50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.1300	1070	0.1030	1460	0.0885
690	0.1295	1080	0.1025	1470	0.0882
700	0.1290	1090	0.1020	1480	0.08815
710	0.1280	1100	0.1015	1490	0.0881
720	0.1275	1110	0.1010	1500	0.08805
730	0.1270	1120	0.1000	1520	0.0880
740	0.1260	1130	0.0995	1540	0.0879
750	0.1250	1140	0.0990	1560	0.0870
760	0.1245	1150	0.0985	1580	0.0865
770	0.1240	1160	0.0980	1600	0.0860
780	0.1230	1170	0.0975	1620	0.0855
790	0.1220	1180	0.0970	1640	0.0845
800	0.1210	1190	0.0965	1660	0.0840
810	0.1205	1200	0.0960	1680	0.0835
820	0.1200	1210	0.0958	1700	0.0830
830	0.1195	1220	0.0955	1720	0.0823
840	0.1185	1230	0.0950	1740	0.0820
850	0.1180	1240	0.0945	1760	0.0813
860	0.1175	1250	0.0941	1780	0.0805
870	0.1165	1260	0.0940	1800	0.0800
880	0.1160	1270	0.0937	1820	0.0797
890	0.1150	1280	0.0930	1840	0.0790
900	0.1145	1290	0.0927	1860	0.0785
910	0.1140	1300	0.0925	1880	0.0780
920	0.1135	1310	0.0920	1900	0.0775
930	0.1125	1320	0.0919	1920	0.0770
940	0.1120	1330	0.0916	1940	0.0765
950	0.1110	1340	0.0914	1960	0.0760
960	0.1105	1350	0.0910	1980	0.0752
970	0.1095	1360	0.0908	2000	0.0750
980	0.1085	1370	0.0907	2020	0.0745
990	0.1080	1380	0.0906	2040	0.0740
1000	0.1075	1390	0.0905	2060	0.0735
1010	0.1070	1400	0.0902	2080	0.0730
1020	0.1065	1410	0.0900	2100	0.0723
1030	0.1055	1420	0.0895	2120	0.0720
1040	0.1050	1430	0.0893	2140	0.0715
1050	0.1040	1440	0.08890	2160	0.0710
1060	0.1035	1450	0.0888	2180	0.0703

SOIL RESISTIVITY IN OHMS /CM^3 2,50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0700	2980	0.0535	4150	0.0368
2220	0.0695	3000	0.0530	4200	0.0362
2240	0.0690	3020	0.0527	4250	0.0357
2260	0.0685	3040	0.0523	4300	0.0350
2280	0.0680	3060	0.0520	4350	0.0345
2300	0.0677	3080	0.0518	4400	0.0340
2320	0.0670	3100	0.0515	4450	0.0335
2340	0.0665	3120	0.0510	4500	0.0330
2360	0.0660	3140	0.0507	4550	0.0326
2380	0.09580	3160	0.0502	4600	0.0321
2400	0.0655	3180	0.0500	4650	0.0318
2420	0.0650	3200	0.0495	4700	0.0312
2440	0.0645	3220	0.0492	4750	0.0309
2460	0.0640	3240	0.0489	4800	0.0302
2480	0.0635	3260	0.0485	4850	0.0298
2500	0.0630	3280	0.0480	4900	0.0293
2520	0.0625	3300	0.0479	4950	0.0290
2540	0.0622	3320	0.0475	5000	0.0285
2560	0.0620	3340	0.0472	5050	0.0282
2580	0.0615	3360	0.0470	5100	0.0280
2600	0.0610	3380	0.0467	5150	0.0276
2620	0.0605	3400	0.0462	5200	0.0272
2640	0.0602	3420	0.0460	5250	0.0270
2660	0.0600	3440	0.0458	5300	0.0265
2680	0.0595	3460	0.0452	5350	0.0260
2700	0.0590	3480	0.0450	5400	0.0257
2720	0.0588	3500	0.0440	5450	0.0254
2740	0.0585	3550	0.0435	5500	0.0250
2760	0.0580	3600	0.0430	5550	0.0247
2780	0.0575	3650	0.0422	5600	0.0244
2800	0.0570	3700	0.0418	5650	0.0241
2820	0.0565	3750	0.0410	5700	0.0239
2840	0.0563	3800	0.0405	5750	0.0236
2860	0.0560	3850	0.0400	5800	0.0233
2880	0.0555	3900	0.0393	5850	0.0230
2900	0.0550	3950	0.0387	5900	0.0227
2920	0.0546	4000	0.0382	5950	0.0223
2940	0.0542	4050	0.0378	6000	0.0220
2960	0.0540	4100	0.0372	6050	0.0218

SOIL RESISTIVITY IN OHMS /CM^3 –2,50,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
6100	0.0215	8100	0.0139		
6150	0.0211	8150	0.0137		
6200	0.0209	8200	0.0136		
6250	0.0206	8250	0.0134		
6300	0.0202	8300	0.0133		
6350	0.0200	8350	0.0132		
6400	0.0198	8400	0.0131		
6450	0.0196	8450	0.0130		
6500	0.0193	8500	0.0128		
6550	0.0192				
6600	0.0190				
6650	0.0188				
6700	0.0185				
6750	0.0183				
6800	0.0180				
6850	0.0178				
6900	0.176				
7000	0.0173				
7050	0.0171				
7100	0.0169				
7150	0.0168				
7200	0.0166				
7250	0.0165				
7300	0.0163				
7350	0.0162				
7400	0.0160				
7450	0.0158				
7500	0.0157				
7550	0.0155				
7600	0.0154				
7650	0.0153				
7700	0.0151				
7750	0.0150				
7800	0.0148				
7850	0.0147				
7900	0.0145				
7950	0.0143				
8000	0.0142				
8050	0.0140				

SOIL RESISTIVITY IN OHMS /CM^3 –5,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separatio n in meters	Mutual Impedance in Ohms/KM
5	0.456	200	0.2230	395	0.1850
10	0.420	205	0.2220	400	0.1840
15	0.400	210	0.2200	405	0.1830
20	0.380	215	0.2180	410	0.1825
25	0.365	220	0.2170	415	0.1820
30	0.350	225	0.2160	420	0.1810
35	0.340	230	0.2150	425	0.1800
40	0.330	235	0.2130	430	0.1795
45	0.323	240	0.2120	435	0.1790
50	0.313	245	0.2100	440	0.1780
55	0.307	250	0.2085	445	0.1770
60	0.304	255	0.2070	450	0.1760
65	0.2955	260	0.2065	455	0.1755
70	0.2925	265	0.2060	460	0.1750
75	0.2875	270	0.2050	465	0.1745
80	0.2825	275	0.2040	470	0.1740
85	0.2775	280	0.2030	475	0.1735
90	0.2725	285	0.2020	480	0.1730
65	0.2700	290	0.2010	485	0.1725
100	0.2650	295	0.2000	490	0.1710
105	0.2625	300	0.1990	495	0.1705
110	0.2600	305	0.1980	500	0.1700
115	0.2575	310	0.1970	510	0.1690
120	0.2550	315	0.1960	520	0.1680
125	0.2500	320	0.1955	530	0.1670
130	0.2490	325	0.1950	540	0.1660
135	0.2475	330	0.1945	550	0.1650
140	0.2450	335	0.1940	560	.1640
145	0.2425	340	0.1925	570	0.1630
150	0.2400	345	0.1920	580	0.1620
155	0.2390	350	0.1915	590	0.1610
160	0.2375	355	0.1910	600	0.1600
165	0.2350	360	0.1900	610	0.1590
170	0.2325	365	0.1890	620	0.1585
175	0.2310	370	0.1880	630	0.1580
180	0.2300	375	0.1875	640	0.1570
185	0.2280	380	0.1870	650	0.1565
190	0.2260	385	0.1860	660	0.1560
195	0.2250	390	0.1855	670	0.1550

SOIL RESISTIVITY IN OHMS /CM^3 –5,00,000Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.1535	1070	0.1255	1460	0.1070
690	0.1525	1080	0.1245	1470	0.1065
700	0.1515	1090	0.1240	1480	0.1060
710	0.1505	1100	0.1230	1490	0.1055
720	0.1500	1110	0.1220	1500	0.1050
730	0.1495	1120	0.1215	1520	0.1045
740	0.1490	1130	0.1210	1540	0.1040
750	0.1485	1140	0.1205	1560	0.1030
760	0.1480	1150	0.1200	1580	0.1025
770	0.1475	1160	0.1198	1600	0.1015
780	0.1470	1170	0.1190	1620	0.1010
790	0.1460	1180	0.1185	1640	0.1000
800	0.1450	1190	0.1180	1660	0.0995
810	0.1440	1200	0.1175	1680	0.0985
820	0.1430	1210	0.1170	1700	0.0980
830	0.1420	1220	0.1165	1720	0.0970
840	0.1410	1230	0.1160	1740	0.0965
850	0.1405	1240	0.1155	1760	0.0960
860	0.1400	1250	0.1150	1780	0.0955
870	0.1395	1260	0.1145	1800	0.0945
880	0.1390	1270	0.1140	1820	0.0940
890	0.1385	1280	0.1135	1840	0.0935
900	0.1380	1290	0.1130	1860	0.0925
910	0.1370	1300	0.1125	1880	0.0920
920	0.1360	1310	0.1120	1900	0.0915
930	0.1350	1320	0.1115	1920	0.0910
940	0.1340	1330		1940	0.0905
950	0.1330	1340	0.1110	1960	0.0900
960	0.1320	1350	0.1105	1980	0.0895
970	0.1310	1360	0.1103	2000	0.0890
980	0.1305	1370	0.1100	2020	0.0885
990	0.1300	1380	0.1098	2040	0.0880
1000	0.1298	1390	0.1097	2060	0.0870
1010	0.1290	1400	0.1096	2080	0.0865
1020	0.1285	1410	0.1090	2100	0.0860
1030	0.1280	1420	0.1085	2120	0.0850
1040	0.1270	1430	0.1080	2140	0.0845
1050	0.1265	1440	0.1077	2160	0.0840
1060	0.1260	1450	0.1075	2180	0.0830

SOIL RESISTIVITY IN OHMS /CM^3 –5,00,000Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.0825	2980	0.0654	4150	0.0495
2220	0.0820	3000	0.0650	4200	0.0490
2240	0.0815	3020	0.0645	4250	0.0485
2260	0.0810	3040	0.0640	4300	0.0480
2280	0.0805	3060	0.0639	4350	0.0475
2300	0.0800	3080	0.0638	4400	0.0470
2320	0.0795	3100	0.0636	4450	0.0465
2340	0.0790	3120	0.0633	4500	0.0460
2360	0.0785	3140	0.0630	4550	0.0457
2380	0.0780	3160	0.0625	4600	0.0450
2400	0.0770	3180	0.0620	4650	0.0447
2420	0.0765	3200	0.0619	4700	0.0443
2440	0.0760	3220	0.0618	4750	0.0440
2460	0.0755	3240	0.0617	4800	0.0435
2480	0.0750	3260	0.0615	4850	0.0430
2500	0.0745	3280	0.0611	4900	0.0427
2520	0.0740	3300	0.0610	4950	0.0425
2540	0.0735	3320	0.0605	5000	0.0418
2560	0.0730	3340	0.0600	5050	0.0412
2580	0.0725	3360	0.0595	5100	0.0410
2600	0.0722	3380	0.0590	5150	0.0405
2620	0.0720	3400	0.0585	5200	0.0400
2640	0.0715	3420	0.0582	5250	0.0397
2660	0.0710	3440	0.0580	5300	0.0392
2680	0.0705	3460	0.0575	5350	0.0390
2700	0.0700	3480	0.0573	5400	0.0385
2720	0.0698	3500	0.0570	5450	0.0380
2740	0.0695	3550	0.0565	5500	0.0377
2760	0.0690	3600	0.0560	5550	0.0375
2780	0.0685	3650	0.0555	5600	0.0370
2800	0.0680	3700	0.0550	5650	0.0368
2820	0.0678	3750	0.0540	5700	0.0365
2840	0.0675	3800	0.0535	5750	0.0360
2860	0.0670	3850	0.0530	5800	0.0359
2880	0.0665	3900	0.0525	5850	0.0355
2900	0.0660	3950	0.0520	5900	0.0350
2920	0.0659	4000	0.0515	5950	0.0349
2940	0.0658	4050	0.0510	6000	0.0345
2960	0.0656	4100	0.0500	6050	0.0340

SOIL RESISTIVITY IN OHMS /CM^3 –5,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
6100	0.0338	8050	0.0241		
6150	0.0332	8100	0.0240		
6200	0.0330	8150	0.0239		
6250	0.0325	8200	0.0237		
6300	0.0322	8250	0.0234		
6350	0.0320	8300	0.0231		
6400	0.0318	8350	0.0230		
6450	0.0315	8400	0.0229		
6500	0.0312	8450	0.0226		
6550	0.0310	8500	0.0225		
6600	0.0305				
6650	0.0302				
6700	0.0300				
6750	0.0299				
6800	0.0295				
6850	0.0292				
6900	0.0290				
6950	0.0288				
7000	0.0285				
7050	0.0283				
7100	0.0280				
7150	0.0278				
7200	0.0276				
7250	0.0275				
7300	0.0272				
7350	0.0270				
7400	0.0269				
7450	0.0267				
7500	0.0265				
7550	0.0262				
7600	0.0260				
7650	0.0259				
7700	0.0257				
7750	0.0255				
7800	0.0251				
7850	0.0250				
7900	0.0249				
7950	0.0246				
8000	0.0243				

SOIL RESISTIVITY IN OHMS /CM^3 –10,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
5	0.47	200	0.2450	395	0.2055
10	0.45	205	0.2440	400	0.2050
15	0.427	210	0.2425	405	0.2040
20	0.41	215	0.2410	410	0.2025
25	0.395	220	0.2400	415	0.2015
30	0.38	225	0.2390	420	0.2010
35	0.368	230	0.2370	425	0.2000
40	0.357	235	0.2350	430	0.1990
45	0.348	240	0.2340	435	0.1985
50	0.34	245	0.2330	440	0.1980
55	0.332	250	0.2325	445	0.1970
60	0.324	255	0.2300	450	0.1960
65	0.318	260	0.2295	455	0.1950
70	0.313	265	0.2285	460	0.1949
75	0.310	270	0.2260	465	0.1940
80	0.305	275	0.2255	470	0.1930
85	0.300	280	0.2250	475	0.1925
90	0.295	285	0.2235	480	0.1920
65	0.291	290	0.2225	485	0.1910
100	0.290	295	0.2210	490	0.1905
105	0.287	300	0.2200	495	0.1900
110	0.281	305	0.2195	500	0.1895
115	0.277	310	0.2185	510	0.1890
120	0.2750	315	0.2175	520	0.1885
125	0.2730	320	0.2165	530	0.1880
130	0.270	325	0.2160	540	0.1870
135	0.266	330	0.2150	550	0.1850
140	0.265	335	0.2145	560	0.1840
145	0.2625	340	0.2140	570	0.1835
150	0.2610	345	0.2130	580	0.1830
155	0.2600	350	0.2120	590	0.1820
160	0.2575	355	0.2110	600	0.1815
165	0.2560	360	0.2100	610	0.1814
170	0.2550	365	0.2095	620	0.1810
175	0.254	370	0.2090	630	0.1805
180	0.2510	375	0.2080	640	0.1800
185	0.250	380	0.2075	650	0.1790
190	0.2480	385	0.2065	660	0.1785
195	0.24750	390	0.2060	670	0.1780

SOIL RESISTIVITY IN OHMS /CM^3 –10,00,000Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
680	0.1775	1070	0.1540	1460	0.1325
690	0.1770	1080	0.1530	1470	0.1320
700	0.1765	1090	0.1525	1480	0.1310
710	0.1760	1100	0.1520	1490	0.1305
720	0.1755	1110	0.1510	1500	0.1300
730	0.1750	1120	0.1505	1520	0.1290
740	0.1740	1130	0.1500	1540	0.1288
750	0.1735	1140	0.1495	1560	0.1285
760	0.1730	1150	0.1490	1580	0.1280
770	0.1725	1160	0.1485	1600	0.1275
780	0.1720	1170	0.1480	1620	0.1270
790	0.1710	1180	0.1475	1640	0.1265
800	0.1705	1190	0.1470	1660	0.1260
810	0.1700	1200	0.1465	1680	0.1255
820	0.1690	1210	0.1460	1700	0.1250
830	0.1685	1220	0.1455	1720	0.1248
840	0.1680	1230	0.1450	1740	0.1245
850	0.1670	1240	0.1440	1760	0.1240
860	0.1665	1250	0.1435	1780	0.1235
870	0.1660	1260	0.1430	1800	0.1230
880	0.1655	1270	0.1425	1820	0.1225
890	0.1650	1280	0.1420	1840	0.1220
900	0.1645	1290	0.1410	1860	0.1215
910	0.1635	1300	0.1405	1880	0.1205
920	0.1625	1310	0.1402	1900	0.1202
930	0.1620	1320	0.1400	1920	0.1200
940	0.1610	1330	0.1390	1940	0.1195
950	0.1600	1340	0.1385	1960	0.1190
960	0.1595	1350	0.1380	1980	0.1185
970	0.1590	1360	0.1375	2000	0.1175
980	0.1585	1370	0.1370	2020	0.1170
990	0.1580	1380	0.1365	2040	0.1165
1000	0.1578	1390	0.1360	2060	0.1160
1010	0.1575	1400	0.1355	2080	0.1155
1020	0.1570	1410	0.1350	2100	0.1150
1030	0.1560	1420	0.1345	2120	0.1145
1040	0.1550	1430	0.1340	2140	0.1140
1050	0.1548	1440	0.1335	2160	0.1135
1060	0.1545	1450	0.1330	2180	0.1130

SOIL RESISTIVITY IN OHMS /CM^3 –10,00,000Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
2200	0.1125	2980	0.0966	4150	0.67
2220	0.1120	3000	0.0962	4200	0.066
2240	0.1110	3020	0.0960	4250	0.0645
2260	0.1105	3040	0.0955	4300	0.0635
2280	0.1100	3060	0.0950	4350	0.0630
2300	0.1098	3080	0.0946	4400	0.0620
2320	0.1095	3100	0.0942	4450	0.0615
2340	0.1090	3120	0.0940	4500	0.0609
2360	0.1085	3140	0.0938	4550	0.0600
2380	0.1080	3160	0.0936	4600	0.0595
2400	0.1075	3180	0.0930	4650	0.0590
2420	0.1070	3200	0.0925	4700	0.0585
2440	0.1065	3220	0.0920	4750	0.0580
2460	0.1060	3240	0.0918	4800	0.0575
2480	0.1055	3260	0.0915	4850	0.0570
2500	0.1050	3280	0.0912	4900	0.0564
2520	0.1045	3300	0.0910	4950	0.0560
2540	0.1040	3320	0.0908	5000	0.0550
2560	0.1035	3340	0.0906	5050	0.0548
2580	0.1030	3360	0.0903	5100	0.0544
2600	0.1025	3380	0.0900	5150	0.0540
2620	0.1020	3400	0.0898	5200	0.0537
2640	0.1015	3420	0.0894	5250	0.0534
2660	0.1010	3440	0.0890	5300	0.0530
2680	0.1005	3460	0.0884	5350	0.0527
2700	0.1000	3480	0.0882	5400	0.0524
2720	0.0998	3500	0.0880	5450	0.0520
2740	0.0996	3550	0.0855	5500	0.0518
2760	0.0994	3600	0.0840	5550	0.0511
2780	0.0992	3650	0.0820	5600	0.0509
2800	0.0990	3700	0.0800	5650	0.0507
2820	0.0988	3750	0.0785	5700	0.0502
2840	0.0985	3800	0.077	5750	0.0500
2860	0.0980	3850	0.0755	5800	0.0498
2880	0.0979	3900	0.074	5850	0.0495
2900	0.0978	3950	0.072	5900	0.0492
2920	0.0973	4000	0.0715	5950	0.0490
2940	0.0970	4050	0.0695	6000	0.0485
2960	0.0968	4100	0.068	6050	0.0480

SOIL RESISTIVITY IN OHMS /CM^3 –10,00,000 Ohms/Cm^3

Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM	Separation in meters	Mutual Impedance in Ohms/KM
6100	0.0477	8050	0.0372		
6150	0.0475	8100	0.0370		
6200	0.0470	8150	0.0368		
6250	0.0469	8200	0.0365		
6300	0.0466	8250	0.0363		
6350	0.0462	8300	0.0360		
6400	0.0459	8350	0.0358		
6450	0.0457	8400	0.0355		
6500	0.0455	8450	0.0352		
6550	0.0450	8500	0.0350		
6600	0.0449				
6650	0.0446				
6700	0.0443				
6750	0.0440				
6800	0.0437				
6850	0.0434				
6900	0.0432				
6950	0.0430				
7000	0.0427				
7050	0.0423				
7100	0.0420				
7150	0.0418				
7200	0.0415				
7250	0.0412				
7300	0.0410				
7350	0.0408				
7400	0.0405				
7450	0.0402				
7500	0.0400				
7550	0.0396				
7600	0.0394				
7650	0.0390				
7700	0.0388				
7750	0.0386				
7800	0.0384				
7850	0.0382				
7900	0.0380				
7950	0.0377				
8000	0.0375				

LINE PARAMETER

Particulars of line	Type of Conductor	Conductor size in Copper Equivalent		Positive Sequence Reactance on 100MVA base in %age per Km/Circuit	Zero Sequence Reactance on 100MVA base in %age per Km/Circuit	Mutual reactance on 100MVA base in %age per Km
		Sq. M.M.	Sq. Inch			
220kV S/C	Zebra	258.10	0.04	0.085	0.255	----
220kV D/C	Zebra	258.10	0.04	0.081	0.265	0.10
132kV S/C	Panther	129.0	0.20	0.24	0.77	----
132 kV D/C	Panther	129.0	0.20	0.23	0.73	0.50
33kV S/C	Racoon	48.39	0.075	(3.90+j 3.52)	(5.26+ j 14.81)	----
33kV D/C	Racoon	48.39	0.075	(3.90+j 3.51	(5.26+j 14.52)	(1.36+j 10.49)

Cooperation is the thorough conviction that nobody can get there unless everybody gets there.

- Virginia Burden

APPENDIX
to
CHAPTER – VI

Appendix I to Chapter VI

(Refer Paras 4.4. and 8.5)

Power Contact Protectors

1. Operation

Power contact protectors (see Figure 5) are air gap arrestors connected between overhead telecommunication wires and ground. The arrester gaps are designed to breakdown at a voltage of 3,000 volts to possess a high current carrying capacity.

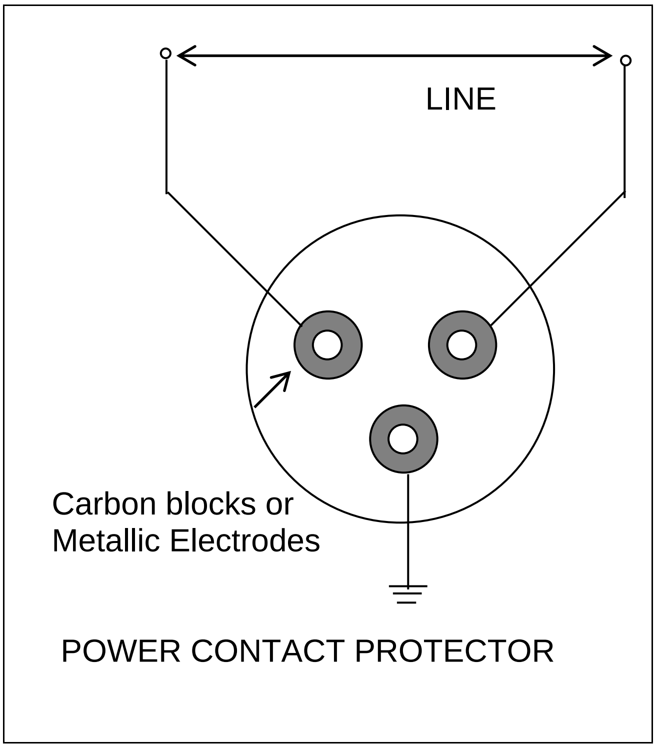
When wires of a telecommunication line on which these protectors are installed come in contact with a power wire of voltage to ground exceeding 3,000 volts, the protector gaps breakdown and provide a low impedance path to the power system fault current. Rapid de-energization of the power supply circuit, in the event of a power contact with the wires of the telecommunication line is thus rendered possible.

2. Installation

Power contact protectors shall be provided on exposed telecommunication lines involved in crossing with HT power lines referred to in Paras 4.4. and 8.5 of the Code. These protectors should be installed at the pole nearest to the crossing point on the exposed wires (i.e. all the wires carried on the top most bracket) of the telecommunication line.

3. Earthing of Power Contact Protectors

To ensure maximum possible protection to the telecommunication line, the protector earth resistance shall be as possible a figure of ten ohms or lower, as recommended for this purpose and it is very essential that the protector earth resistance should be periodically checked and maintained within this value, as far as possible.



POWER CONTACT PROTECTOR

Talent wins games, but team work and intelligence wins championships.

- Michael Jordan

APPENDIX
to
CHAPTER – VII

Appendix I to Chapter VII

(Refer Para 4.3)

Statistical Tables – Value of 't'

Degree of Freedom	Value of 't' in Percentage for the Confidence Interval					
	70	80	90	95	98	99
1	1.963	3.078	6.314	12.706	31.881	63.657
2	1.386	1.886	2.920	4.303	6.965	9.925
3	1.250	2.638	2.353	3.182	4.541	5.841
4	1.190	1.533	2.132	2.776	3.747	4.604
5	1.156	1.476	2.015	2.571	3.365	4.032
6	1.134	1.440	1.943	2.447	3.143	3.707
7	1.119	1.415	1.895	2.365	2.998	3.499
8	1.108	1.397	1.860	2.306	2.896	3.355
9	1.100	1.383	1.833	2.262	2.821	3.250
10	1.093	1.372	1.812	2.228	2.764	3.169
11	1.088	1.363	1.796	2.201	2.718	3.106
12	1.083	1.356	1.782	2.179	2.681	3.055
13	1.079	1.350	1.771	2.160	2.650	3.012
14	1.076	1.345	1.761	2.145	2.624	2.977
15	1.074	1.341	1.753	2.131	2.602	2.947
16	1.071	1.337	1.746	2.120	2.583	2.921
17	1.069	1.333	1.740	2.110	2.567	2.898
18	1.067	1.330	1.734	2.101	2.552	2.878
19	1.066	1.328	1.729	2.093	2.539	2.861
20	1.064	1.325	1.725	2.086	2.528	2.845
21	1.063	1.323	1.721	2.080	2.518	2.831
22	1.061	1.321	1.717	2.074	2.508	2.819
23	1.060	1.319	1.714	2.069	2.500	2.807
24	1.059	1.318	1.711	2.064	2.492	2.797
25	1.058	1.316	1.708	2.060	2.485	2.787
26	1.058	1.315	1.706	2.056	2.479	2.779
27	1.057	1.314	1.703	2.052	2.473	2.771
28	1.056	1.313	1.701	2.048	2.467	2.763
29	1.055	1.311	1.699	2.045	2.462	2.756
30	1.055	1.310	1.697	2.042	2.457	2.750
40	1.050	1.303	1.684	2.021	2.423	2.704
50	1.046	1.296	1.671	2.000	2.390	2.660
120	1.041	1.289	1.658	1.980	2.358	2.617
200	1.036	1.282	1.645	1.960	2.326	2.576

Appendix II to Chapter VII

(Refer Para 2.1.4)

Measurement of Soil Resistivity

1. Introduction

The study of the problem of low frequency electromagnetic induction between power and telecommunication lines involves knowledge of the resistivity of the earth. The mutual coupling between two earth return circuits depends upon the dispersion and distribution of the ground currents circulating in the circuits. This in turn is largely determined by the earth resistivity. Almost invariably the resistivity of the earth is far from uniform even within a local area and further all known methods of measurement of earth resistivity suffer from various limitations.

A general idea of the order of soil resistivity in any region may be had from the type of soil or geological structure in that area. A number of factors affect the soil resistivity such as moisture, nature and concentration of salts in the soil, temperature, seasonal variations etc. It is not possible to predict to a precise degree the resistivity to be expected in a given area or the electrode resistance at given site. In every case, it is necessary to carry out an actual measurement to determine the earth resistivity in a given area.

2. Method of Measurement

Several methods of measurement are known but each one suffers from one limitation or other, due to which the different methods are found to give sometimes widely divergent results.

A low frequency test is the most desirable method for determining the earth resistivity, since it gives an overall average figure for the area concerned. Experiments were conducted by the PTCC in the 50s to determine the suitability of different methods and electrode spacing to be used while collecting data of soil resistivity for low frequency induction calculations. The experiments established that the four-electrode method is the most suitable with large electrode spacing of 150 feet. The PTCC practice is therefore to collect soil resistivity data by using this method keeping an inter-electrode spacing of 50 meters.

3. Four-Electrode Method

Other methods include the use of a search coil but the general preference is for the ‘four electrode method’ explained below using the meggar earth tester.

The familiar earth testing meggar is an instrument, which can be conveniently used for carrying out the four-electrode method of measuring resistivity. It has a generator producing DC at 500 or 1000 volts with the current coils connected in series. The potential coil is mounted on the same shaft as the current coil and has a definite inclination to the latter. The terminals of the current coil and the potential coil are brought out to four independent terminals C1, C2 and P1, P2. Both the potential and current coils tend to rotate in the field of permanent magnet, when the generator is worked, the direction of the movement being opposite to each other. Therefore, when the instrument is connected to a test earth and the generator is worked, the position taken by the combined current-potential coil will be proportional to the ratio of V/I or the mutual resistance between the current and potential circuits.

The meggar is known to give fairly accurate results of earth resistivity. Where the average resistivity over a large area and depth are required, the electrode spacing has to be kept correspondingly high. While there should be no objection to keep such wide spacing with the meggar, the skin effect of the ground currents places a limitation on the spacing that can be used. The results with the meggar are reasonably reliable for electrode spacing up to about 150 to 200 feet.

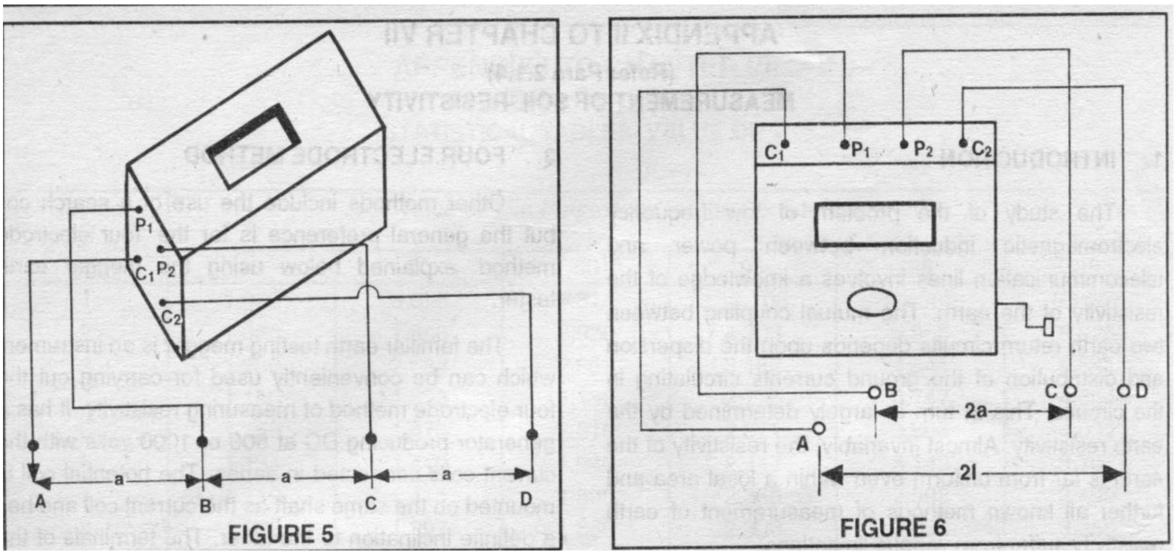


FIGURE 5   FIGURE 6

As indicated in Figure 5, the meggar earth tester has four terminals marked P1, P2, C1, C2 and four similar electrodes are driven into the ground at equal distances of 50 meters in the region where the soil resistivity is to be determined (should be driven about 1 meter depth). If these electrodes are designated as A,B,C, and D, the extreme electrodes A and D should be connected to C1 and C2 of the meggar. The electrodes B and C should be connected to P1 and P2. By operating the meggar handle continuously at uniform speed, we can read the electrode resistance ‘R’ on the meggar scale.

The soil resistivity is given by the equation

$$\rho = 2 \pi a R$$

Where
ρ = Soil resistivity in Ohms/cm³.
R = Meggar reading on Ohms.
a = Distance between two electrodes in Meters.

In one type of instrument currently available, the connections are made as in Figure 6 and the value of soil resistivity is evaluated from the formula.

$$\rho = R\pi \frac{(l^2 - a^2)}{2a} \quad \text{ohm meters}$$

Where
R = Resistance of ground as measured.
2l = Distance between electrodes A and D in the meters.
2a = Distance between electrodes B and C in meters.

The value in Ohm-cm can be obtained by multiplying the result by 100.

In all measurements of soil resistivity, it is necessary to see that these are carried out in the driest part of the year.

It's hard to beat a person who never gives up.
- Babe Ruth

Glossary

BSNL	**:**	**Bharat Sanchar Nigam Limited**
CEA	**:**	**Central Electricity Authority.**
CSTE	**:**	**Chief Signal and Telecommunication Engineer.**
DET	**:**	**Divisional Engineer Telegraph**
DoT	**:**	**Department of Telecommunication.**
EHV	**:**	**Extra High Voltage.**
GD Tube	**:**	**Gas Discharge Tube.**
IV	**:**	**Induced Voltage.**
L14 diagram	**:**	**Diagram depicting the telephone pole along with conductors.**
MC	**:**	**Mutual Coupling.**
MoP	**;**	**Ministry of Power.**
MTNL	**:**	**Mahanagar Telephone Nigam Limited.**
PCP	**:**	**Power Contact Protector**
PTCC	**:**	**Power and Telecommunication Co-ordination Committee**
SLG	**:**	**Single Line to Ground.**