



एकस्ट्रा हाई वोल्टेज पारेषण लाइनों के परीक्षित टॉवर
डिज़ाइनों का संग्रह
**COMPENDIUM OF TESTED TOWER DESIGNS
FOR EHV TRANSMISSION LINES**



भारत सरकार
Government of India
विद्युत मंत्रालय
Ministry of Power
केन्द्रीय विद्युत प्राधिकरण
Central Electricity Authority
नई दिल्ली
New Delhi

मार्च – 2018
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रविन्द्र कुमार वर्मा

अध्यक्ष

एवं भारत सरकार के पदेन सचिव

केंद्रीय विद्युत प्राधिकरण

संदेश

पारेषण लाइनें किसी भी देश के पारेषण प्रणाली की रीढ़ हैं और इनके द्वारा ही देश के एक क्षेत्र से दूसरे क्षेत्र में प्रचुर मात्रा में बिजली का पारेषण संभव है। टावर पारेषण लाइन का सबसे महत्वपूर्ण घटक है जो कंडक्टर को सपोर्ट करता है तथा जिस पर भिन्न प्रकार के स्टैटिक एवं डाइनेमिक बल कार्य करते रहते हैं। टॉवर का डिजाइन ऐसा किया जाना चाहिए कि वह इन सभी बलों को सहन करने के साथ विभिन्न पर्यावरणीय परिस्थितियों का भी सामना कर सके। अधिकांशतः यूटिलिटीज को विभिन्न कंडक्टर टाईप, वोल्टेज लेवल, विंड जोन, अल्टीट्यूड आदि के लिए टॉवर डिजाइन करने में समस्याओं का सामना करना पड़ता है। इन टॉवरों को उपयुक्त मानक के अनुसार डिजाइन की उपयुक्तता के लिए परीक्षण करना पड़ता है जिसमें अत्यधिक समय लगता है।

उपरोक्त बातों को ध्यान में रखते हुए विद्युत मंत्रियों की कान्फ्रेंस में यह निर्णय लिया गया कि ईएचवी पारेषण लाइन के स्वीकृत टॉवरों के डिजाइन का एक संग्रह तैयार किया जाएगा जो कि न केवल पावर यूटिलिटीज को अपनी आवश्यकतानुसार टॉवर चयन करने में मदद करेगा बल्कि नए टॉवर डिजाइन करने में लगे समय को बचाएगा जो कि काफी महंगा भी होगा।

मुझे "एक्स्ट्रा हाई वोल्टेज पारेषण लाइनों के परीक्षित टॉवर डिजाइनों का संग्रह" प्रस्तुत करते हुए अत्यन्त प्रसन्नता हो रही है। इस संग्रह में आई.एस 802: 2015 के अनुसार परीक्षित 66 केवी, 132 केवी और 220 केवी वोल्टेज लेवल की पारेषण लाइनों के टावरों, तथा आईएस 802: 1995 के अनुसार परीक्षित 400 के.वी, 765 के.वी, 1200 के.वी, ± 500 के.वी (डी.सी) और ± 800 के.वी (डी.सी) पारेषण लाइनों के टॉवरों के डिजाइन को सम्मिलित किया गया है।

मैं इस संग्रह को तैयार करने में योगदान प्रदान करने वाले के.वि.प्रा. और पीजीसीआईएल के सभी अधिकारियों का धन्यवाद करता हूँ। मुझे उम्मीद है कि यह संग्रह सभी पावर यूटिलिटीज को इन परीक्षित टॉवर डिजाइनों को पारेषण लाइनों में उपयोग करने हेतु प्रोत्साहित करेगा एवं इस प्रकार बचाए गए बहुमूल्य समय और लागत का उपयोग पारेषण प्रणाली में अन्य सुधार करने हेतु किया जा सकेगा।

(रविन्द्र कुमार वर्मा)



Ravindra Kumar Verma
Chairperson
& Ex-officio Secretary to
Government of India
Central Electricity Authority

MESSAGE

Transmission lines are the backbone of transmission system of any Country which allow transmission of large chunk of power from one part of the Country to the other part. Transmission tower is the most important component of any transmission line which supports the conductor and is subjected to various static & dynamic forces. The tower has to be designed to withstand not only all kind of forces but also different environmental conditions. Most of the times Utilities face problem in designing towers for various conductor configurations, voltage levels, wind zones, altitude etc. These towers have to be tested for suitability of design as per relevant Standards which is a time consuming job.

Keeping this in mind it was decided in the Power Minister's Conference that a compendium of approved tower design for EHV transmission lines be prepared which will help utilities to select towers as per their requirement rather than designing new towers each time and getting it tested which is both time consuming & costly affair.

I am pleased to present the **"Compendium of Tested Tower Designs for EHV Transmission Lines"**. This compendium includes tested towers design for transmission lines of 66 kV, 132 kV and 220 kV voltage class, as per IS 802 :2015 and 400 kV, 765 kV, 1200 kV, ± 500 kV DC and ± 800 kV DC towers, as per IS 802:1995.

I thank all the Officers of CEA and PGCIL who have been involved in preparation of this compendium. I hope this document would benefit all the utilities in inspiring them to adopt these tested tower designs thereby saving both time and cost which could be utilised for other improvements in the transmission system.

(RAVINDRA KUMAR VERMA)



प्रकाश मस्के
सदस्य (विद्युत प्रणाली)
एवं भारत सरकार के पदेन अपर सचिव
केंद्रीय विद्युत प्राधिकरण

प्रस्तावना

सभी पावर यूटिलिटीज के उपयोग के लिए 66 केवी और अधिक वोल्टेज के टॉवरों के परीक्षित टॉवरों का संग्रह लाना मेरे लिए एक अत्यन्त प्रसन्नता की अनुभूति है। विभिन्न वोल्टेज लेवल, कॉन्फिगरेशन, विंड जोन के टॉवरों के लिए डिजाइन का संकलन अथक प्रयास द्वारा ही संपूर्ण हुआ जो पारेषण लाइनों के निर्माण के समय और लागत के रूप में परिलक्षित होगा।

इस टॉवर डिजाइन के संग्रह में टॉवर डिजाइन, फाउंडेशन डिजाइन और 66 केवी, 132 केवी, 220 केवी, 400 केवी, 765 केवी, 1200 केवी और एचवीडीसी पारेषण लाइनों के लिए परीक्षित टॉवरों के विवरण के अध्याय सम्मिलित किए गए हैं। पावर यूटिलिटीज के आसान संदर्भ के लिए टॉवर डिजाइन के विभिन्न पैरामीटर्स एवं बेसिक डिजाइन सिद्धांत भी संग्रह में समाहित किए गए हैं। मुझे पूर्ण विश्वास है कि यूटिलिटीज को इन परीक्षित टॉवरों के संकलन की सहायता से समान पारेषण लाइन टावरों के डिजाइन एवं परीक्षण की पुनरावृत्ति की आवश्यकता नहीं रहेगी तथा इससे बहुमूल्य समय और धन की भी बचत होगी।

(प्रकाश मस्के)



Prakash Mhaske
Member (Power System) &
Ex-Officio Additional Secretary to
Govt. of India
Central Electricity Authority

FOREWORD

It is a matter of great pleasure to bring to you the Compendium of towers for transmission lines of 66 kV and above voltage class. An effort has been put to aggregate designs of towers for different voltage levels, configuration and wind zones which will result into the time & cost optimization of transmission lines.

This compendium consists of chapters on basics of tower design, foundation design and details of tested towers for 66 kV, 132 kV, 220 kV, 400 kV, 765 kV, 1200 kV and HVDC transmission lines. Basic designing principles and the various parameters of tower design have been included in the document for easy reference for the transmission utilities. I am certain that utilities will refer this compendium for tested towers which will not only help in avoiding duplication of work by various utilities in designing and testing of similar transmission line towers but also save lot of precious time & money.

(Prakash Mhaske)

PREFACE



The EHV transmission sector has made tremendous growth in recent past and as we are a fast growing economy, the same vigour is required in future too to make this critical infrastructure of transmitting energy in faster and most techno-economical manner. Even though the transmission lines consist of various components but the towers are perhaps most critical component in the transmission system which consumes lot of time & cost in designing & testing before it gets cleared for manufacturing. In a typical long line various type of towers have to be planned based on wind zone, reliability level, deviation angle and other site specific parameters. As such the techno-economic solution for utilities is to use the already available type tested towers.

Ministry of Power vide their letter no. F.No. 13/3/2016-OM dated 30.11.2016 forwarded the Minutes of Conference of Power, Renewable Energy and Mines Ministers of States/Union territories held on 7th & 8th October, 2016 at Vadodara, Gujarat, in which Hon'ble Union Minister of State (IC) of Power, Coal and Renewable Energy & Mines, Govt. of India had suggested (in point no. 90 of Minutes, in respect of Transmission) that CEA and PGCIL should prepare a compendium of approved designs so that these designs could be adopted by States.

In compliance to above, we have prepared the compendium which mainly consists of four chapters, the first chapter describes the fundamentals of tower design and summaries various technical factors for various voltage level designs in lucid and concise manner in tabular form. The second chapter deals with various types of tower foundation depending on specific site conditions. As tower foundation is important and integral part of any transmission line the same is very important and requires various soil parameters before selecting the foundation type.

As we all are aware that new Indian Standard has come in 2015 replacing 1995 version of IS:802, the tower being designed now has to comply latest IS. In third chapter, we have compiled the available PGCIL type tested tower design as per IS802:2015. As the revision in applicable standard is a recent development, there are only 18 number designs which are given in this chapter.

Even though revised IS has come in 2015, the type tested designs as per earlier IS are still relevant from the point of view of design experience and with minor modifications, the same could comply revised IS. The possibility of using such design with altered line parameters like span etc. could be explored by designers. As such, we have compiled type tested tower designs complying earlier IS in fourth chapter of this compendium. This chapter has good number of designs right from 1200kV AC to HVDC lines, 765kV and 400kV towers as well.

At the end, I thank CEA management particularly Shri P.S.Mhaske, Member (PS) for guiding at every step in preparation of this compendium. I also thank my colleagues Shri Gorakh Thakur, CE(TCD), Shri Neeraj Kumar, Director(TCD), Shri Y.K.Swarnkar, Director, Smt. Kavita Jha, Dy.Director and Asstt. Directors Shri Mohit Mudgal, Shri Faraz, Ms. Bhaavya Pandey, Shri Karan Sareen & WAPCOS engineers Shri Vijay Pal & Ms. Sippy Srivastava for working tirelessly for this compendium.

Special thanks to the management & officers of PGCIL for making available information of their type tested designs of towers without which we could not have achieved the goal of preparing this document. As the design is a dynamic process and design improvements have to be incorporated from time to time, I welcome the suggestions from state utilities on this compendium, so that we could improve upon it in future revisions of this document.

S. Srivastava
2/3/2018

March, 2018
New Delhi

(Sanjay Srivastava)
Chief Engineer
Power System Engg. & Technology Development
Central Electricity Authority



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CHAPTER – 1

TOWER DESIGN CRITERIA FOR TRANSMISSION

RAIPUR- WARDHA LINE





HVDC BISWANATH CHARIALI- AGRA LINE

CHAPTER - 1

TOWER DESIGN CRITERIA FOR TRANSMISSION LINES

1.1. BACKGROUND

Requirement of transfer of large quantum of power and reduction in losses and high cost of Right of Way (ROW) per kilo volt has necessitated use of extra high voltages for transmission lines. To transfer power at increased voltages the design, fabrication and construction of very tall and broad towers is required. Optimization of designs of towers results into the cost optimization of transmission lines.

The designing of tower and get it tested is long and expensive proposition. If designs tested by other utilities are made available, it will help in fast execution of transmission line projects. Use of previously designed and tested towers will save lot of time & money. Duplication of work by various utilities in designing and testing of similar transmission line towers can be avoided resulting saving of precious time of about 6-8 months.

Ministry of Power vide their letter no. F.No. 13/3/2016-OM dated 30.11.2016 forwarded the Minutes of Conference of Power, Renewable Energy and Mines Ministers of States/Union territories held on 7th & 8th October, 2016 at Vadodara, Gujarat, in which Hon'ble Union Minister of State (IC) of Power, Coal and Renewable Energy & Mines, Govt. of India had suggested (in point no. 90 of Minutes, in respect of Transmission) that CEA and PGCIL should prepare a compendium of approved designs so that these designs could be adopted by States. According, CEA has made this compendium wherein details of type tested EHV towers as per current and previous IS have been compiled.

IS 802(Part 1/ sec 1) "Use of structural steel in Overhead Transmission Line Towers- Code of Practice" on the basis of which the transmission line towers are designed in India has been revised in the year 2015. In the latest IS, there is revision in design concepts corresponding to angle towers as well as suspension towers. PGCIL vide their letter no. CC: ENGG:TL: dated 21.07.2017 informed that 191 tested tower designs are available with PGCIL, out of which 173 towers are designed according to IS 802(Part1/ Sec1) :1995 and 18 nos. towers are designed according to IS 802:2015(Part1/ Sec1). Various design parameters & single line diagrams have been provided in Chapter 3 & 4 this compendium for easy reference to transmission utilities.

Basic design principles and the various parameters of tower design and testing are being described in the document. The generally practiced values of these parameters are provided for the utilities for quick reference. As complete details of each tower is quite elaborate and voluminous, this document provides limited information about design of transmission towers. Once selection of type of tower is done, the concerned utilities may approach PGCIL for suitability of selected design and other terms & conditions. As the

codes and standards are updated with time, the utilities may refer latest edition of all Indian Standards and CEA regulations mentioned in the document.

Type tested design of towers provided in Chapter 3 & 4 are sole property of PGCIL and utilities wishing to use these designs should contact PGCIL for further modalities.

1.2 TRANSMISSION LINE TOWERS

The transmission lines are normally supported by lattice type towers with square base. Therefore, the reliability of these lines depends much on the reliability of the towers and their foundations. The towers support the conductor, insulators and earth wire and/or Optical Fiber Ground Wire and also help in maintaining vertical & horizontal Electrical clearances from the live conductor to ground (Phase clearance) and live conductor to live conductor (Phase to Phase Clearance). The ground clearance after accounting for maximum sag and maximum conductor temperature under no wind condition need to be maintained as per requirement of Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations 2010 (as amended).

The weight of a tower required for any specific application is influenced to a great extent by the selection of tower configuration, choice of steel structural for tower members, type of tower, types of connections, etc. On the basis of experience and designing skill, a tower designer can produce tower designs conforming to the governing specifications and bring about optimization in tower weight without sacrificing stability and reliability features of the finished tower, which are very important for structural reliability of a transmission line. This depends not only on the designs of tower and its foundation but also on the type of tower, development of structural arrangement of tower member, detailing of connections, quality of steel structural, accuracy in fabrication, proper soil investigations, use of foundations according to soil conditions at sites of tower installation, accuracy and adequate care in tower erection and stringing as well as proper maintenance of the erected towers.

1.3 STANDARDS

The Indian Standards mentioned below as amended up to date are applicable to the materials and process used in the manufacture of towers and tower accessories.



Sl. No.	Indian Standards (IS)	TITLE
1.	IS 2	Rules for rounding off numerical values
2.	IS 209	Specification for Zinc
3.	IS 278	Specification for Galvanised steel barbed wire for fencing
4.	IS 432	Mild steel & Medium tensile steel bars & hard drawn steel wire for concrete Reinforcement
5.	IS 456	Code of practice for plain & Reinforced concrete
6.	IS 802 (Part-1)	Code of practice for use of structural steel in overhead transmission line Towers : Material, Loads and permissible stresses
	Section-1-2015	Materials & Loads
	Section-2-2016	Permissible stress
7.	IS 802 -(Part II)-	Code of practice for use of structural steel in overhead transmission line : Fabrication, galvanising, inspection and packing
8.	IS 802-(Part-III)	Code of practice for use of structural steel in overhead transmission line : Testing
9.	IS 808	Specification for hot rolled steel beams, channels & Angle sections
	Part-V	Equal Leg angles
	Part-VI	Unequal Leg angles
10.	IS 1200	Method of measurement of Building and civil works
11.	IS 1367	Technical supply conditions for threaded fasteners
12.	IS 1573	Specification for Electroplated coatings for zinc on iron and steel
13.	IS 1893	Criteria for earthquake resistant design of structures
14.	IS 2016	Specification for Plain washers
15.	IS 2062	Specification for steel for general purpose
16.	IS 2551	Danger Notice plates
17.	IS 2629	Recommended practice for hot dip galvanising of iron and steel
18.	IS 2633	Method of testing uniformity of coating on zinc coated articles
19.	IS 3063	Specification for Single coil rectangular section spring washers for bolts, nuts and screws
20.	IS 3757	High strength structural bolts
21.	IS 4091	Code of practice for design and construction of foundations for transmission line towers and poles
22.	IS 4759	Specification for Hot dip zinc coating on structural steel and other allied products
23.	Is 5358	Specification for Hot dip galvanised coating on fasteners
24.	Is 5613	Code of practice for design, installation and

25.	(Part-2/Sec-1) IS 5613 (Part-2/Sec-2)	maintenance of overhead power Lines : Designs Code of practice for design, installation and maintenance of overhead power Lines: Installation and maintenance
26.	IS 5613 (Part 3/Sec-1)	Code of practice for design, installation and maintenance of overhead power Lines: Designs
27.	IS 5613 (Part 3/ Sec-2)	Code of practice for design, installation and maintenance of overhead power Lines: Installation and maintenance
28.	IS 6610	Specification for Heavy washers for steel structures
29.	IS 6639	Specification for Hexagonal bolts for steel structures
30.	IS 6745	Specification for Methods for determination of weight of zinc coating of zinc coated iron and steel articles
31.	IS 7215	Specification for Tolerance for Fabrication of steel structures
32.	IS 10238	Step bolts for steel structures
33.	IS 12427	Transmission tower bolts
34.		CEA (Measures relating to Safety and Electric Supply) Amendment Regulations 2014
35.	Publication No.19/N/700/196 3	Regulation for electrical crossings for Railway tracks.
36.	CBI&P Publication No. 290	Manual on Design of long span River Crossing Towers

1.4 TOWER GEOMETRY

Basic function of a tower is to carry conductors, earthwires, insulators, hardware, etc. and transfer loads coming on these to foundation safely in normal as well as extreme conditions. The conductors carry electric current which has its electric field depending on voltage of the line and tower geometry is chosen in such a way that all the electrical clearances are maintained in all conditions. A tower is mainly constituted of the following parts:

- Peak
- Cross Arm
- Cage
- Boom
- Tower Body, Extension

A general geometry has been shown in Figure-1 below:

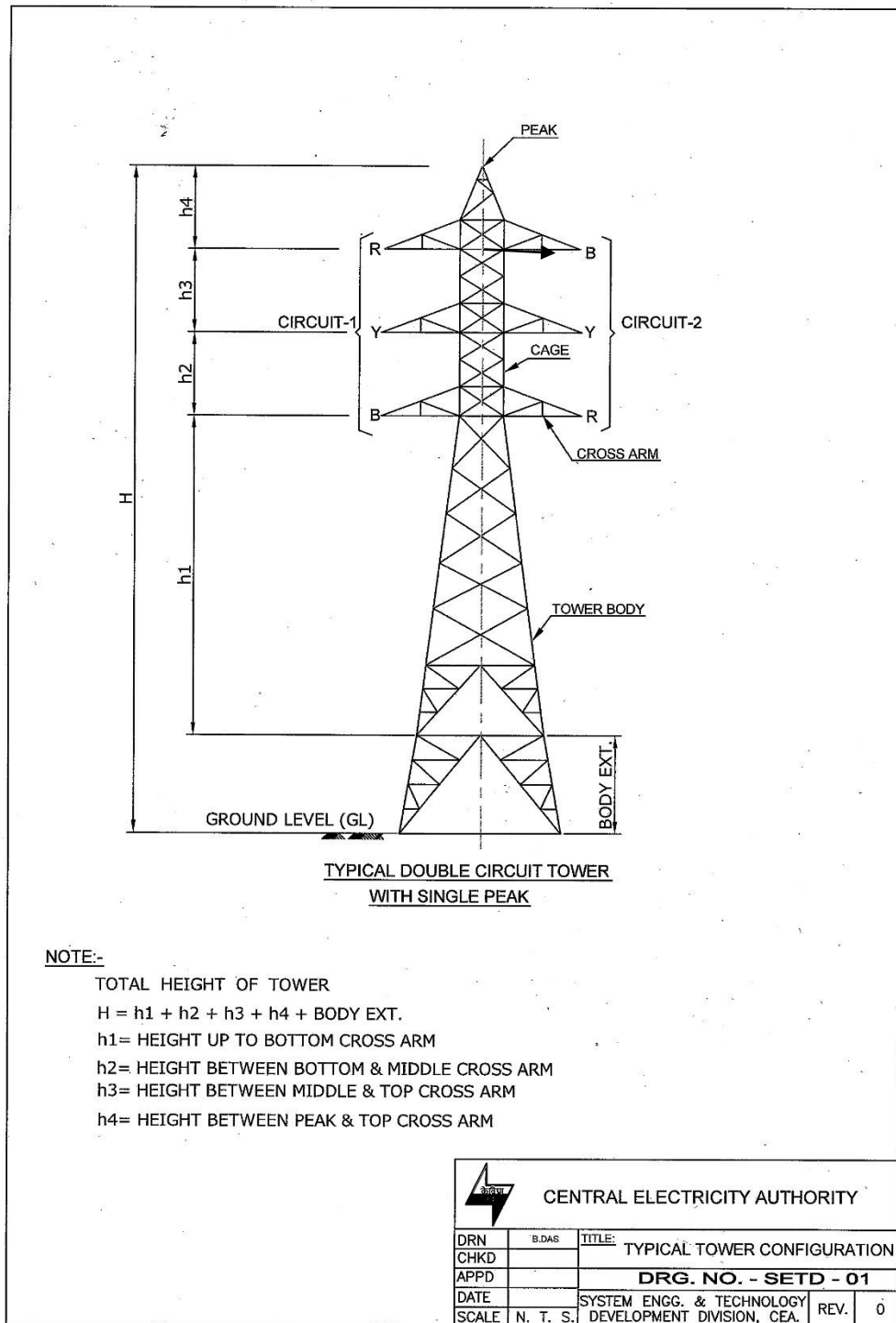
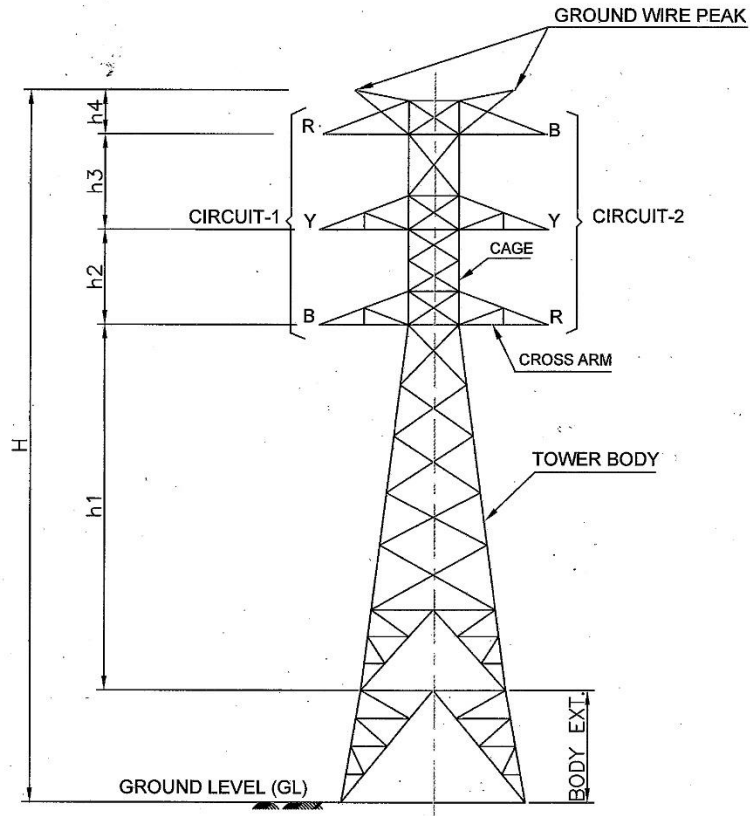


Figure-1



**TYPICAL DOUBLE CIRCUIT TOWER
WITH DOUBLE PEAK**

NOTE:-

TOTAL HEIGHT OF TOWER

$H = h1 + h2 + h3 + h4 + \text{BODY EXT.}$

$h1 =$ HEIGHT UP TO BOTTOM CROSS ARM

$h2 =$ HEIGHT BETWEEN BOTTOM & MIDDLE CROSS ARM

$h3 =$ HEIGHT BETWEEN MIDDLE & TOP CROSS ARM

$h4 =$ HEIGHT BETWEEN PEAK & TOP CROSS ARM



CENTRAL ELECTRICITY AUTHORITY

DRN	S.DAS	TITLE: TYPICAL TOWER CONFIGURATION	
CHKD		DRG. NO. - SETD - 02	
APPD		SYSTEM ENGG. & TECHNOLOGY	
DATE		DEVELOPMENT DIVISION, CEA.	REV. 0
SCALE	N. T. S.		

Figure-2

A brief description of each part of the tower is as under:

a) Peak

It is the portion of tower above the top cross arm. The peak is used to support the ground wire/OPGW through clamps. The height of the peak depends upon specified angle of shield and mid span clearance.

b) Cross-Arm

The function of a cross-arm is to support conductor. The number of cross arms depends upon number of circuits. The dimensions of a cross-arm depend upon the line voltage, type and configuration of insulator string, electrical clearance requirement, minimum framing angle from the requirement of mechanical stress distribution etc.

c) Cage

Cage is the portion between peak and tower body. The cross-section of cage is generally square and it may be uniform or tapered throughout its height depending upon loads. Cross-arms are connected to the cage.

d) Boom

It is generally a rectangular beam of uniform cross-section or tapered towards the middle of the beam, forms part of horizontal configuration towers. The boom is attached to the lower body and it supports power conductors.

e) Tower Body, Extension

Tower body is the main portion of the tower for connecting cage to the tower foundation or body extension or leg extension. It comprises tower legs inter-connected by bracings and redundant members. Tower body plays a vital role for maintaining required ground clearance of the bottom conductor of the transmission line.

1.5 CLASSIFICATION OF TOWERS

The towers may be classified as Suspension towers, Tension towers, Transposition towers & Special towers. Suspension and tension towers, as per IS 802 part 1 sec1 :2015, are further classified as given below in Table-I.

Table-I

a) Suspension towers (with I/V/Y suspension insulator strings):		
(1)	Tangent towers (0°) with suspension string	To be used on straight runs only
(2)	Intermediate towers (0° to 2°) with suspension string	To be used on straight runs and upto 2° line deviation
(3)	Light angle towers (0° to 5°) with suspension string	To be used on straight runs and upto 5° line deviation
NOTE:- In the selection of suspension tower either (2) above or a combination of (1) and (3) may be followed.		
b) Tension towers:		
(1)	Small angle towers (0° to 15°) with tension string	To be used for line deviation from 0° to 15° .
(2)	Medium angle towers (0° to 30°) or (15° to 30°) with tension string.	To be used for line deviation 0° to 30° or 15° to 30°
(3)	Large angle towers (30° to 60°) with tension string	To be used for line deviation from 30° to 60°
(4)	Dead-end towers with tension string	To be used as dead end (terminal) tower or anchor tower.
(5)	Large angle and dead end towers with tension string	To be used for line deviation from 30° to 60° or for dead-ends
NOTE:- In the selection of tension towers either (5) or a combination of (3) and (4) may be followed.		

c) Transposition towers:

In 400 kV and above AC transmission lines transposition towers are used to transpose the phase conductors in three sections in such a way that each phase by rotation occupies each of the three phase positions in a circuit. Generally, transposition of phases is required for the line length above 100 km or as per system study. While carrying out the transposition arrangements, availability of adequate electrical clearances must be ensured.

d) Special towers:

These towers are used at locations such as those involving long span river or valley crossings, creek crossings, etc. falling on the line route. These towers are specially designed to meet the site specific requirements.

e) Crossing gantry structures

Sometimes, existing power lines are to be crossed above the existing line by providing towers with required extension or from below by using low height Gantry structures. Existing lines from above are also crossed by removing the earth wire from existing line and providing diamond configuration of earth wire system.

1.6 TOWER EXTENSIONS

BODY EXTENSION

Body extension is used to increase the height of tower to achieve the required minimum ground clearance over road crossings, river crossings, ground obstacles etc. However, towers need to be planned and designed for this. Body extensions upto 9.0 m height in steps of normally 1.5 m may be used. The standard tower has K-bracing in the lower most panel to facilitate such arrangements. For body extensions having heights greater than 9 m (say 12, 15, 18, 21, 25 m etc.), the suitability of the loading of standard tower has to be checked by reducing the span length and/or angle of deviation. For lines traversing in hilly terrain, negative body extensions, wherein a portion of the tower body is truncated, can be used in tension towers from the consideration of economy.

LEG EXTENSIONS

Leg extensions are used either with anyone leg or combination of legs at locations where footings of the towers are at different levels. Leg extensions are generally used in hilly regions to reduce benching or cutting. However, towers need to be planned and designed for this. The alignment of leg extension is done with the first section of a tower. Installation of leg extension calls for high degree of expertise in tower erection. Leg Extensions are also used with negative and positive body extension in suspension and tension towers from the consideration of economy.

1.7 TOWER DESIGN

The loads at conductor and earthwire attachment points under different loading conditions viz. reliability conditions (normal condition), security conditions (broken wire condition), safety conditions, anti-cascading condition etc. (as per relevant IS or IEC Standards) considering various combinations of design temperatures, wind and snow loads is calculated and tower designs are developed accordingly.

The design of towers is generally based on the procedure and guide lines as out lined in IS-802 (Part-1/Section-1)- 2015. Statutory requirements laid down by the Central Electricity Authority (Measures relating to Safety and Electric Supply) Regulations 2010 as amended from time to time and by any other statutory body applicable to such structures are to be satisfied.

Various criteria and parameters are taken into consideration for designing of a tower. These parameters broadly include voltage class, type of configurations, type of tower, conductor type, number of sub-conductors in bundles, extension required as per application (body extension or leg extension), type and number of earthwire / OPGW, design span, wind zone, altitude etc. Detail of these parameters which are required to be specified for designing of towers is given below.

(a) Voltage Class : 66kV/132kV / 220kV / 400kV / 765kV/1150 kV A.C system & ± 500 kV, ± 800 kV D.C systems

(b) Type of Configuration

- No. of circuits : Single Circuit, Double Circuit, Multi Circuit (more than 2 circuits)
- Configuration of Conductors : Vertical / Horizontal / Delta
- Configuration of Insulators : Suspension (I / V / Y type) / tension
- Configuration of Earth wire : Single peak / Double peak

(c) Applicable Standard : Towers are designed as per provisions of IS 802 (Part-I/Sec1): 2015 & (Part-I/Sec2): 2016.

(d) Tower Type:

The selection of the most suitable types of tower for transmission lines depends on the actual terrain through which the line traverses. Any combination of the types of towers specified in Table-I is generally suitable for most of the lines. The angles of line deviation specified in Table-I are for the design span. The span may, however, be increased up to an optimum limit by reducing angle of line deviation, if adequate ground and phase clearances are available. In order to decide the tower type for a particular location, following information is required:

- Angle of line deviation on tower.
- Whether it is to be used as section tower or dead end tower.
- Sum of adjacent spans.
- Weight span on tower

(e) Extension to Towers : Refer Para 1.6.

(f) Conductor:



Physical attributes, such as dimension, weight etc., of conductor, no. of sub-conductors in bundle and bundle spacing being used for particular line is required to be provided for designing of tower.

Electrical and mechanical properties of commonly used conductors for up to 765 kV lines AC & ± 800 kV HVDC, ± 500 kV HVDC lines are given below:

Code Name of Conductor	ACSR "DOG"	ACSR "PANTHER"	ACSR "MOOSE"	ACSR "ZEBRA"	ACSR "BERSIMIS"	ACSR "LAPWING"
Voltage level	66 kV	132 kV / 110 kV	400 kV	765 kV, 220 kV	765kV, ± 500 kV HVDC	± 800 kV HVDC
No. of conductor / Phase	One	One	Two (Twin Bundle), Four (Quad bundle)	Six (Hexa Bundle)	Four (Quad Bundle)	Six (Hexa Bundle)
Stranding/ Wire diameter	6/4.72 mm Al+7/1.57 mm Steel	30/3.00 mm Al + 7/3.00 mm steel	54/3.53 mm Al +7/3.53 mm Steel	54/3.18 mm Al +7/3.18 mm Steel	42/4.57 mm Al +7/2.54 mm steel	45/4.78 m Al. +7/3.18 mm steel
Total sectional area	118.5 mm ²	261.5 mm ²	597 mm ²	484.5 mm ²	725 mm ²	863.13 mm ²
Overall diameter	14.15 mm	21.00 mm	31.77 mm	28.62 mm	35.05 mm	38.22 mm
Approx. Weight	394 kg/km	974 kg/km	2004 kg/km	1621 kg/km	2181 kg/km	2667 kg/km
Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km	0.14 Ohm/km	0.05552 Ohm/ km	0.06868 Ohm/km	0.04242 Ohm/km	0.0358 Ohm/km
Min. UTS	32.41 kN	89.67 kN	161.2 kN	130.32 kN	154 kN	188 kN
Modulus of elasticity	7747 kg/mm ²	8158 kg/mm ²	7034 kg/mm ²	7036 kg/mm ²	6322 kg/mm ²	7546 kg/mm ²
Co-efficient of linear	19.80×10^{-6} /deg. C	17.80×10^{-6} /deg C	19.30×10^{-6} / deg C	19.30×10^{-6} /deg C	21.20×10^{-6} /deg C	21.50×10^{-6} / deg C

Expansion						
Max. allowable temperature	85 deg. C	85 deg C	85 deg C	85 deg C	85 deg C	85 deg C

(g) Earthwire / Optical Ground Wire (OPGW):

The earthwire of appropriate size to cater to predicted & design fault currents and lightning are used. Generally, one earthwire is used for transmission lines up to 220 kV and two earthwires are used for transmission lines of 400 kV and higher voltage classes. Now days it is a common practice to use OPGW as earthwire for 132 kV and above voltage class lines. In case of 400kV and above voltage class lines, at least one out of two earthwires is OPGW and second earthwire . is either of galvanized stranded steel (GSS) or alternatively . ACSR or AACSR conductor type. Apart from providing protection from lightning, OPGW also serves as medium for communication and protection. Technical parameters for commonly used GSS Earthwire and OPGW are given below.

i. Earthwire

Voltage level	220 kV, 132 kV, 110 kV, 66 kV	765 kV, 400 kV, ±500 kV HVDC	±800 kV HVDC
No. of Continuous Earthwires	one	Two	Two
Stranding / Wire Diameter	7/3.15 mm	7/3.66 mm	7/4.5 mm
Total Sectional Area	54.55 mm ²	73.65 mm ²	111.33 mm ²
Overall diameter	9.45 mm	10.98 mm	13.5 mm
Approx. Weight	428 kg/km	583 kg/km	882 kg/km
Calculated d.c. resistance at 20 deg. C	3.375 Ohm/km	2.5 Ohm/km	1.66 Ohm/km
Min. UTS	56 kN	68 kN	106.2 kN
Modulus of Elasticity	19361 kg/mm ²	19361 kg/mm ²	19330 kg/mm ²
Co-efficient of Linear Expansion	11.5x10 ⁻⁶ / deg C	11.5x10 ⁻⁶ /deg C	11.5x10 ⁻⁶ /deg C

Max. allowable temperature	53 deg C	53 deg C	53 deg C
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ii. OPGW

Voltage level	765 kV, 400 kV, ± 500 kV HVDC
Stranding/Wire diameter	24 fibers
Total sectional area	80.2 mm ²
Overall diameter	12.5 mm
Approx. Weight	460 kg/km
Min. UTS	84 kN
Modulus of elasticity	13904 kg/mm ²
Co-efficient of linear expansion	14.3 x10 ⁻⁶ /deg C
Max. allowable temperature	53 deg C

Note: Mechanical and other properties of OPGW vary from Supplier to Supplier. Any other OPGW, which is compatible with Conductor/EW Suitable for the particular line, can be adopted, subject to meeting the limitations of Sag-tension values.

(h) Spans:

- (i) **Normal Span:** Normal design span, adopted in general, for various voltage level transmission lines is indicated below:

Voltage (kV)	Normal span (meters)
± 800 HVDC	350 to 450
± 500 HVDC	350 to 450
765 AC	350 to 450
400 AC	350 to 450
220 AC	325 to 400
132 AC	300 to 350



66 AC	200 to 300
-------	------------

(ii) Ruling Span

The Ruling Span is defined as the assumed uniform span that most closely resembles the variety of spans that are in any particular section of the line. The ruling span is used to calculate sag and clearances on the plan profile drawing, and it is necessary in structure spotting. When stringing the line, the general rule is that the spans in the line should not be more than twice the ruling span, or less than half of the ruling span

The ruling span is then calculated by the following formula.

$$LU = \sqrt{\frac{L_1^3 + L_2^3 + L_3^3 + \dots}{L_1 + L_2 + L_3 + \dots}}$$

Where LU= Ruling Span

L1, L2, L3, ----- etc. are different spans in a section (Tension location to Tension location)

Normal design span is considered as theoretical ruling span.

(iii) Wind Span

The wind span is the sum of the two half spans adjacent to the support under consideration. For normal Horizontal span this equals to Normal ruling span.

(iv) Weight Span

The weight span is the horizontal distance between the lowest point of the conductors on the two spans adjacent to the tower. Permissible weight span under normal and broken wire condition for different type of towers at various voltage levels in plain and hilly terrain is indicated below.

	Terrain / Tower Type	Permissible Weight Span (m)			
		Normal Condition		Broken Wire Condition	
		Max.	Min.	Max.	Min.
	765 kV				
(a)	Plain terrain				



	Suspension	600	200	360	100
	Small/Medium Angle	600	0	360	-200
	Large Angle	600	0	360	-300
(b)	Hilly Terrain				
	Suspension	600	200	360	100
	Small / Medium / Large Angle	1000	-1000	600	-600
	400 kV				
(a)	Plain terrain				
	Suspension	600	200	360	100
	Small/Medium Angle	600	0	360	-200
	Large Angle	600	0	360	-300
(b)	Hilly Terrain				
	Suspension	600	200	360	100
	Small/Medium/Large Angle	1000	-1000	600	-600
	220 kV				
(a)	Plain terrain				
	Suspension	525	200	315	100
	Small/Medium Angle	525	0	315	-200
	Large Angle	525	0	315	-300



(b) Hilly Terrain				
Suspension	525	200	315	100
Small/Medium/Large Angle	1000	-1000	600	-600
132 kV				
(a) Plain terrain				
Suspension	488	195	195	104
Small/Medium Angle	488	0	195	-200
Large Angle	488	0	195	-300
(b) Hilly Terrain				
Suspension	488	208	192	104
Small/Medium/Large Angle	960	-960	576	-576
66 kV				
(a) Plain terrain				
Suspension	375	163	150	75
Small/Medium/Large Angle	375	0	150	-150
(b) Hilly Terrain				
Suspension	375	163	150	75
Small/Medium/Large Angle	750	-750	450	-450
± 800 kV HVDC				
(a) Plain terrain				

	Suspension	550	200	330	100
	Small/Medium Angle	600	0	360	-200
	Large Angle	600	0	360	-300
	± 500 kV HVDC				
(a)	Plain terrain				
	Suspension	600	200	360	100
	Small/Medium Angle	600	0	360	-200
	Large Angle	600	0	360	-300

(i) RELIABILITY CONSIDERATIONS

Transmission lines shall be designed for the reliability levels given in Table below. These levels are expressed in terms of return periods in years of climatic (wind) loads. The minimum yearly reliability P_s corresponding to the return period, T is expressed as:

$$P_s = (1-1/2T)$$

S. No.	Description	Reliability Level 1	Reliability Level 2	Reliability Level 3
	Return period of design loads, in years, T	50	150	500
	Yearly Reliability, P_s	$1-10^{-2}$	$1-10^{-2.5}$	$1-10^{-3}$

Reliability level 1 is adopted for EHV transmission lines upto 400 kV class.
Reliability level 2 is adopted for EHV transmission lines above 400 kV class.
Reliability level 3 is adopted for tall river crossing towers and special towers.

(j) Temperature: Following temperature values are considered for sag & tension and other load calculations

(1) ACSR Conductor

Maximum: 85° C

Minimum: -25 ° C to 0 ° C (depends on location of trans. line, however 0 ° C widely used in the country)

- (2) Earth wire/ OPGW Maximum : 53⁰ C
- (3) Every day temp. 32⁰ C (for most part of the country)

Note: - For region with colder climates (-5⁰ C or lower), every day temperature to be considered as 15⁰ C or as specified by the power utilities.

(k) Sag Tension Calculation:

Sag tension calculations for Conductor and Ground Wire / OPGW are made in accordance with the relevant provisions of IS 5613 (Part 2 / Sec 1) for the following combinations:

- (i) 100% design wind pressure after accounting for drag coefficient and Gust response factor at every day temperature, and
- (ii) 75% design wind pressure after accounting for drag coefficient and Gust response factor at every day temperature, and
- (iii) 36% design wind pressure after accounting for drag coefficient and Gust response factor at minimum temperature.

(l) Basic Wind Speed, Wind zone, Terrain Category and Wind Pressure:

(i) Wind Speed:

The basic wind zone map has been published by Bureau of Indian Standards in IS: 875-part 3. This map represents basic wind speed based on peak gust velocity averaged over a short time interval of about 3 seconds and corresponds to 10 m height above mean ground level in terrain Category-2 for a 50-yr return period.

Based on the wind speed map, the entire Country has been divided into six wind zones. Basic wind speeds for the six wind zones are given in Table 1 / Figure 1

Wind Zone	Basic Wind Speed V _b (m/sec)
1	33
2	39
3	44
4	47
5	50
6	55

Note: In case the line traverses on the border of different wind zones, the higher wind speed may be considered.

(ii) Terrain Category:

Category 1 — Exposed open terrain with few or no obstruction and in which the average height of any object surrounding the structure is less than 1.5 m.

Category 2 — Open terrain with well scattered obstructions having height generally between 1.5 m and 10 m.

Category 3-Terrains with numerous closely spaced obstructions

(iii) Design Wind Pressure:

Design Wind Pressure on towers, conductors and insulators for the three reliability levels and three terrain categories pertaining to six wind zones (in N/m²) is tabulated below:

Sl. No.	Reliability Level	Terrain Category	Design Wind Pressure, P _d for wind zone					
			1	2	3	4	5	6
I)	1	1	403	563	717	818	925	1120
		2	346	483	614	701	793	960
		3	250	349	444	507	573	694
II)	2	1	470	681	883	1026	1 182	1455
		2	403	584	757	879	1 013	1248
		3	291	422	547	635	732	901
III)	3	1	552	838	1 120	1319	1 516	1892
		2	473	719	960	1131	1 300	1622
		3	342	519	694	817	39	1172

(iv) WIND LOAD:

Wind load on tower, wind load on conductor and ground wire/OPGW and wind load on insulator string can be calculated in accordance with IS: 802/Part-I (Sec-I) 2015.

(m) Loads on towers:

Transmission lines are subjected to various loads during their lifetime. These loads are classified into three distinct categories namely,

- a) Climatic loads -- related to the reliability requirements.
- b) Failure containment loads - related to security requirements.
- c) Construction and maintenance loads – related to safety requirements.

The various loads on tower under different loading combinations can be computed in accordance with IS: 802/Part-I (Sec-I) 2015.

(n) Tension Limits:

- (i) Conductor/Ground Wire/OPGW tension at everyday temperature and without external load, should not exceed the following percentage of the ultimate tensile strength of the conductor:

Initial unloaded tension	35 percent
Final unloaded tension	25 percent

Provided that the ultimate tension under everyday temperature and 100% design wind pressure or minimum temperature and 36% design wind pressure does not exceed 70 percent of the ultimate tensile strength of the Conductor/Ground Wire.

- (ii) For 400 kV and higher voltage lines, the final unloaded tension on conductors and groundwire / OPGW at everyday temperature shall not exceed 22 percent of the UTS of conductors and 20 percent of the UTS of groundwire / OPGW respectively.
- (iii) The Earthwire / OPGW Sag shall not be more than 90% of the corresponding sag of Power conductor under still air conditions for entire specified temperature range.
- (iv) For transmission line traversing through snow zone, the radial thickness of ice on conductor/ earthwire / OPGW at minimum temperature shall be taken into account while computing the loads.
- (v) For longer spans (above 600m), final unloaded tension of conductor/ earthwire / OPGW shall be computed/adopted suitably taking into consideration the effect of Aeolian vibrations of conductor/ earthwire / OPGW.

(o) Broken Wire Conditions: The following broken wire conditions are assumed in the design of towers:

Type of Tower	Broken Wire Conditions to be adopted
(a) Single Circuit towers	Any one phase or groundwire / OPGW broken, whichever is more stringent for a particular member.

(b) Double, triple Circuit and quadruple Circuit towers:	
(i) Suspension towers	Any one phase or groundwire / OPGW broken, whichever is more stringent for a particular member.
(ii) Small & Medium Angle Tower	Any two phases broken on the same side and same span or anyone phase and one groundwire / OPGW broken on the same side and same span whichever Combination is more stringent for a particular member.
(iii) Large Angle tension towers / Deadend towers	Any three phases broken on the same side and the same span or any two phases and one groundwire / OPGW broken on the same side and same span, whichever combination constitutes the most stringent condition for a particular member.

1.8 INSULATOR STRINGS DETAILS

Requisite type of suspension and tension insulator strings with disc insulators or long rod insulators offering equivalent performance are used. Number of insulators and creepage distance is selected based on electrical system parameters and requirements taking into account other factors and conditions viz. line attitude, expected environmental and pollution conditions etc. However, for critical locations with high pollution level, antifog type insulators or polymer insulators may be used for better performance. The preferred values of minimum specific creepage distances of insulators are 25 mm/kV line to line voltage or 31 mm/kV line to line voltage based on the pollution level site requirement in the area of installation.

The following type of insulator strings are generally used on transmission lines. Depending on actual insulation requirement and mechanical strength, other suitable insulators can also be used.

- **765 kV Insulators (for Double circuit with Hexa “Zebra” Conductor)**

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Double ‘I’ Suspension	Standard Tangent	2 x 35	160	320

		Type Tower			
2.	Single 'I' Suspension Pilot	Large angle Towers for restraining the jumper from coming closer to the tower body	1 x 35	160	160
3.	Single Tension	For Transposition Towers.	1 x 35	160	160
4.	Quadruple tension	All types of Angle Towers.	4 x 35	210	840

- **765 kV Insulators (for Single circuit with Quad "Bersimis" Conductor)**

Sl. No.	Type of String	Tower Type		No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Double 'I' Suspension	Horz.	For Tangent Type Tower, A&B in Outer Phase	2 x 40	120	240
		Delta	For Tangent Type Tower, A, in Outer Phase			
2.	Single 'I' Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body,		1 x 40	120	120
		Horz.	Outer Phase of Tower type D&E			
		Delta	Outer Phase of Tower type C&D			

3.	Single 'V' Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body,		2 x 40	120	120
		Horz.	Middle Phase of Tower type D&E			
		Delta	Middle Phase of Tower type C & D			
4.	Single 'V' Suspension	Horz.	Middle Phase of Tower Type A	2 x 35	210	210
		Delta	Middle Phase of Tower Type A			
5.	Double 'V' Suspension	Horz.	Middle Phase of Tower Type B	2x2 x 35	210	420
		Delta	All phases of Tower Type B			
6.	Quadruple tension	Horz.	All phases of Tower Type D&E	4x 35	210	840
		Delta	All phases of Tower Type C&D			

- **400kV Insulators (for Double circuit with Quad "Moose" Conductor)**

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Double 'I' Suspension	Standard Tangent Type Tower (DA)	2x23	120	240
2.	Quadruple tension	All types of Angle Towers (DB, DC & DD)	4 x 23	160	640

3.	Single 'I' Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body. (DD)	1 x 23	120	120
4.	Single Tension	For Transposition Towers.	1 x 24	120	120

• **400 kV Insulators (for Double circuit with Twin “Moose” Conductor)**

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single 'I' Suspension	Standard Tangent Type Tower (DA)	1 x 23	120	120
2.	Single 'I' Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body (DD)	1 x 23	120	120
3.	Single Tension	For Transposition Towers	1 x 24	120	120
4.	Double Tension	All types of Angle Towers (DB, DC & DD)	2 x 23	160	320

• **400 kV Insulators (for Double circuit with Triple “Snowbird” Conductor)**

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
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1.	Double 'I' Suspension	Standard Tangent Type Tower (DA)	2x23	120	240
2.	Single 'I' Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body. (DD)	1 x 23	120	120
3.	Single Tension	For Transposition Towers.	1 x 24	120	120
4.	Double Tension	All types of Angle Towers.	2 x 23	210	420

• **400 kV Insulators (for Single circuit with Twin “Moose” Conductor)**

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single 'I' Suspension	Standard Tangent Type Tower (DA)	1 x 23	120	120
2.	Single 'I' Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body (DD)	1 x 23	120	120
3.	Single Tension	For Transposition Towers.	1 x 24	120	120
4.	Double Tension	All types of Angle Towers (DB, DC & DD)	2 x 23	160	320

- 220 kV Insulators (With Single “Zebra” Conductor)

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single ‘I’ Suspension	Standard Tangent Type Tower (DA)	1 x 14	70	70
2.	Single ‘I’ Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body (DD)	1 x 14	70	70
3.	Single Tension	All types of Angle Towers (DB,DC& DD)	1 x 15	120	120

- 132 kV Insulators (With Single “Panther” Conductor)

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single ‘I’ Suspension	Standard Tangent Type Tower (DA)	1 x 9	70	70
2.	Single ‘I’ Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body (DD)	1 x 9	70	70
3.	Single Tension	All types of Angle Towers (DB,DC& DD)	1 x 10	90	90

- 66 kV Insulators (With Single “Dog” Conductor)

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single ‘I’ Suspension	Standard Tangent Type Tower (DA)	1 x 6	70	70
2.	Single ‘I’ Suspension Pilot	Large deviation angle Towers for restraining the jumper from coming closer to the tower body (DD)	1 x 6	70	70
3.	Single Tension	All types of Angle Towers.	1 x 6	90	90

- ± 800 kV (DC) Insulators (With ACSR “lapwing” Conductor)

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single ‘Y’ Suspension	Standard Tangent Type Tower	2 x 45 (V-portion) & 2 x 22 (II portion)	420	420 (along one limb of V-portion mechanical strength of complete string is dependent on angle of Y string)
2.	Triple Tension	All types of Angle Towers.	3 x 64	420	1260

• **± 500 kV (DC) Insulators (With ACSR “lapwing” Conductor)**

Sl. No.	Type of String	Tower Type	No. of standard discs	Electro Mechanical Strength of Insulator Disc (kN)	Mechanical Strength of Complete String (kN)
1.	Single ‘V’ suspension	Standard Tangent Type Tower (A)	2 x 41	210	210 (along one limb of V-portion mechanical strength of complete string is dependent on angle of V string)
2.	Quadruple Tension	All types of Angle Towers (B, C & D)	4 x 41	210	840

1.9 DESIGN OF TOWER MEMBERS

(a) Tower Steel Sections

Steel sections in conformity to IS:808 are used in towers, extensions and stub-setting-templates and are of tested quality conforming to IS:2062. Use of high tensile steel as per IS:2062 (2011) is also permitted for fabrication of towers.

For designing of towers, only rationalized steel sections are used. During execution of the project, if any particular section is not available, the same can be substituted by higher section.

(b) Thickness of Members / Stub Section

The minimum thickness of galvanized angle section used in the design of towers, unless otherwise specified, is kept not less than the following values:

- | | | |
|----|--|------|
| a) | Main corner leg members including the Ground Wire peak and lower members of cross arm in compression | 5 mm |
| b) | For all other members | 4 mm |

Above thickness is increased by 1 mm for painted angle section.

Strengthening cleat is provided in stub to take care of unbraced portion during tower testing, the same is kept in supply though the portion is covered by concrete during line construction.

(c) Allowable Stress

Design stresses are computed as per IS 802 part 1, section 2: 2016.

The redundant members are checked individually for 2.5 percent of axial load carried by the member to which it supports.

(d) Strength factors related to Quality

The design of tower is carried out in accordance with the provisions covered in IS:802 (Part-1/Section 2):2016. However, to account for the reduction in strength due to dimensional tolerance of the structural sections, yield strength of steel used, the following strength factors are considered:

- i) If steel with minimum guaranteed yield strength is used for fabrication of tower, the estimated loads are increased by a factor of 1.02, to account for dimensional tolerances.
- ii) If steel of minimum guaranteed yield strength is not used for fabrication of tower, the estimated loads are increased by a factor of 1.07.

(e) Slenderness Ratio

Slenderness ratios of compression and redundant members is computed in accordance with clause 6 of IS:802 (Part1/ section 2) -2016. Provisions are reproduced below for reference.

	Type of Members	Value of KL/r
a)	Compression Members	
i)	Leg sections or joint members bolted in both faces at connections for $0 < L/r < 120$	L/r
ii)	Members with concentric loading at both ends of the unsupported panel for $0 < L/r < 120$	L/r
iii)	Member with concentric loading at one end and normal framing eccentricity at the other end of the unsupported panel for $0 < L/r < 120$	$30+0.75 L/r$



iv)	Member with normal framing eccentricities at both ends of the un-supported panel for $0 < L/r < 120$	$60+0.50 L/r$
v)	Member unrestrained against rotation at both ends of the unsupported panel for $120 < L/r < 200$	L/r
vi)	Member partially restrained against rotation at one end of the unsupported panel for $120 < L/r < 225$	$28.6+0.762 L/r$
vii)	Member partially restrained against rotation at both ends of the unsupported panel for $120 < L/r < 250$	$46.2+0.615 L/r$
b)	Redundant Members	
i)	For $0 < L/r < 250$	L/r

Note: The values of KL/r corresponding to (a) (vi) and (a) (vii), the following evaluation is suggested:

- I. The restrained member must be connected to the restraining member with at least two bolts.
- II. The restraining member must have a stiffness factor I/L in the stress plane (I =Moment of inertia and L =Length) that equals or exceeds the sum of the stiffness factors in the stress plane of the restrained members that are connected to it.
- III. Angle members connected by one leg should have the holes located as close to the outstanding leg as feasible. Normal framing eccentricities at load transfer connection imply that connection holes are located between the heel of the angle and the centre line of the framing leg.

The following is the maximum limit of the effective slenderness ratio i.e. the ratio of unsupported length of the section in any plane to the appropriate radius of gyration shall not exceed value specified here under.

a)	Leg members, Ground Wire peak member and lower members of the cross-arms in compression	150
b)	Other members carrying computed stresses	150
c)	Redundant members and those carrying	250

normal stresses

- d) For members carrying axial tension only 400

(f) Fasteners: Bolts, Nuts and Washers

Bolts and nuts used in the tower body conform to IS: 6639 and IS 12427. All bolts and nuts are galvanized and have hexagonal head and hexagonal nut. The heads being forged out of the solid truly concentric, and square with the shank, which must be perfectly straight.

Diameter of bolts should not be less than 12 mm. Preferred sizes are 12, 16, 20 and 24 mm. Fully threaded bolts are not used. The length of bolts is maintained such that the threaded portion does not extend into the plane of contact of the member.

All bolts are threaded to take the full depth of the nut and threaded for enough to permit firm gripping of the members, but not further. It is ensured that the threaded portion of each bolt protrudes not less than 3mm and not more than 8mm when fully tightened. All nuts shall fit and tight to the point where the shank of the bolt connect to the thread.

(g) Stresses in bolts:

The estimated stresses in bolts should not exceed the values given in Table (1) of IS:802-Part-1/ Section 2 - 2016.

1.10 ELECTRICAL CLEARANCES

Electrical performance of a transmission line is affected by electrical stresses, air gap clearances, insulation co-ordination etc. The electrical clearances are required to be maintained to prevent disruptive discharge between live parts and any earthed object which may or may not be part of transmission line or between live phases of transmission line under the influence of power frequency steady state voltage or temporary overvoltage, lightning and switching impulse overvoltage and to maintain electrostatic & electromagnetic interference, radio interference voltage, audible noise etc. within acceptable limits. For electrical clearances requirement of CEA (Measures relating to Safety and Electric Supply) Regulations 2010 (as amended from time to time) and other relevant authorities such as railways, highways etc. are need to be followed. Some of the clearance practiced by most of the utilities in India are given below and for other clearances respective Regulations/Rules may be referred.

(a) Ground Clearance:

Minimum ground clearance for conductor shall be maintained as per requirement of CEA (Measures relating to Safety and Electric Supply) Regulations 2010 (as amended from time to time). However, requirement

of maintaining electrostatic & electromagnetic interference, radio interference voltage, audible noise etc. within acceptable limits becomes ruling condition specifically for transmission lines of above 400 kV voltage class. Accordingly, minimum ground clearance being adopted by the utilities in India is as follows: -

Voltage (kV)	Minimum Clearance above Ground (m)
66 kV AC	5.5 m (6.1m for line erected across street)
110 / 132 kV AC	6.1 m
220 kV AC	7.015 m
400 kV AC	8.84 m
765 kV AC	15.0 m
500 kV DC	12.5 m
800 kV DC	18.0 m

Note: -

- The minimum clearances given above are Normative as these are dependent upon conductor configuration, phase to phase distances, other mitigation measures etc. For river crossing, railway crossing, power line crossing, State and National highways crossing etc. additional clearances might be required.
- The above values are considered to be suitable for elevations upto 1000m above the mean sea level (MSL). For heights over 1000 m and upto 3000 m above MSL, it is recommended that the values should be increased by 1.25% for every 100 m height or part thereof.

(b) Phase to Ground Metal Clearances:

The swing angles and corresponding Phase to Ground Metal Clearances being followed at present in the Country for Single 'I' suspension string and for jumper (with and without pilot string) are given below.

Swing Angles and Electrical Clearances for "I" Suspension Strings

Voltage level (Nominal)	Clearance in meters	Swing angle in degrees
66 kV	0.610	60



	0.610	45					
	0.760	30					
	0.915	15					
	0.915	0					
110 kV & 132 kV	1.07	60					
	1.22	45					
	1.37	30					
	1.53	15					
	1.53	0					
220 kV	1.675	45					
	1.83	30					
	1.98	15					
	2.13	0					
		WZ-1	WZ-2	WZ-3	WZ-4	WZ-5	WZ-6
400 kV	1.2	36.5	46.2	53	56.7	60.2	65
	3.05	12.2	16.6	20.55	23	25.6	29.9
	3.05	0					
765 kV	1.3	55					
	4.4	25					
	5.6 (S/C) 6.1 (D/C)	0					
±500 kV DC Twin Lapwing (V insulator string)	3750	0					
±800 kV DC Hexa Lapwing (Y insulator string)		WZ-1	WZ-2	WZ-3	WZ-4	WZ-5	WZ-6
	2.0	34	44	51	54	58	62
	6.5	10	14	17	20	22	26
	7.7	5	9	9	10	12	14

	7.7	0
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- **Swing Angles and Electrical Clearances for Jumper**

Voltage level (Nominal)	Clearance in metres	Swing angle in degrees	
		Jumper without pilot string	Jumper with pilot string
66 kV	0.610	30	-
	0.610	20	-
	0.915	10	-
	0.915	0	-
110 kV & 132 kV	1.07	30	-
	1.22	20	-
	1.53	10	-
	1.53	0	-
220 kV	1.675	20	-
	2.13	10	15
	2.13	0	0
400 kV	3.05	25	15
	3.05	0	0
765 kV	1.3	55	#
	4.4	25	
	5.6 (S/C) 6.1 (D/C)	0	
±500 kV DC Twin Lapwing (V insulator string)	1.15	57	#
	3.15	15	
	3.75	0	
±800 kV DC Hexa Lapwing (Y insulator string)	2.0	72	#
	6.5	25	
	7.7	0	

There are various means of limiting jumper swing by making use of (i) custom made jumpers (Rigid, ladder type etc), (ii) appropriate configuration of

Pilot Insulator string (I, V, Y, Strut), (iii) suitably designing the cross arm & (iv) suitably positioning the pilot string attachment point. For 765kV & above voltage lines these alternatives can provide overall techno- economics and therefore need serious consideration during design Clearance depends on type of pilot sting and position of pilot string and construction of jumper.

Note: - The above values are considered to be suitable for elevations upto 1000m above the mean sea level (MSL). For heights over 1000 m and upto 3000 m above MSL, it is recommended that the values should be increased by 1.25% for every 100 m height or part thereof.

(c) Phase to Phase clearance:

For AC lines the minimum clearance generally adopted between conductors of different phases under stationary condition is based upon empirical formulae as given below:

$$\text{Vertical clearance} = (0.75 \times \text{sqrt of } (f_{\max} + l_k)) + V/150$$

$$\text{Horizontal clearance} = (0.62 \times \text{sqrt of } (f_{\max} + l_k)) + V/150$$

Where:

$f_{\max}$ = Conductor Sag in meters at maximum continuous operating temperature of the conductor of the transmission line considered in design. (maximum continuous operating temperature is 85 deg C for ACSR conductor and 95 deg C for AAAC conductor)

l_k = length of insulator string in meters

V = Line Voltage in kV.

The following values are representative of minimum spacing adopted currently.

Line kV	No. of circuits	Minimum electrical clearance between conductors (in Meters)	
		Vertical	Horizontal
66	1 or 2	2.0	3.5
110	1 or 2	3.2	5.5
132	1 or 2	3.9	6.8
220	1 (Horizontal formation)	-	6.0
220	1 or 2	4.9	8.4
400	1 (Horizontal	-	11.3

	formation)		
400	1 or 2	8.0	13 to 16 (Approx)
800	1 or 2	14.0	25.0

Note: The required phase to phase spacing and horizontal spacing for 400kV & above transmission lines shall be governed by the tower design /geometrical configuration as well as minimum live metal clearances required under different insulator swing angles.

(d) Clearance between Conductor & Ground/Shield wire/OPGW:

Shield Angle: The height and location of ground wires shall be such that line joining the groundwire to the outermost conductor shall make an angle with the vertical plane passing through groundwire equal to desired shield angle. The angle of shield adopted for various voltage transmission lines in India is given as under:

Voltage (Nominal)	Angle of Shield of Ground wire (θ°)
66 kV	30
110 kV & 132 kV	30
220 kV	30
400 kV	20
765 kV	20 (10 for Double ckt)
± 500 kV DC	10
± 800 kV DC	10

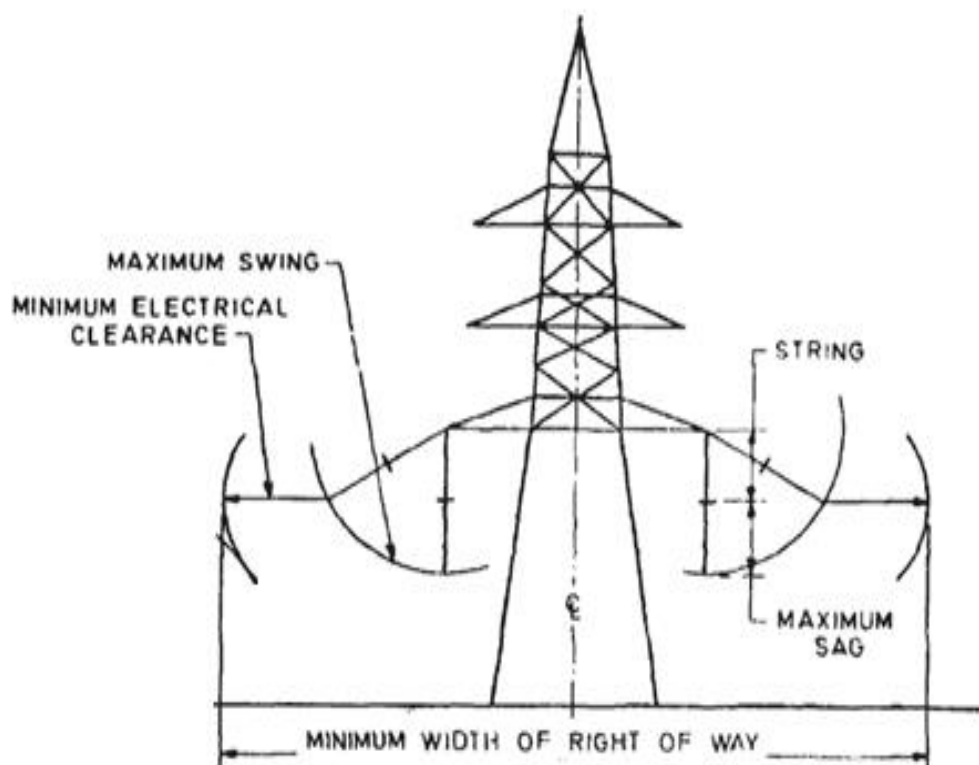
Mid Span Clearance: The minimum vertical mid span clearance means the vertical clearance between Ground Wire and the nearest conductor under all temperatures conditions and still air in the normal ruling span. The Ground Wire sag is not kept not more than 90 per cent of the corresponding sag of Power Conductor under still air conditions for the entire specified temperature range. The minimum vertical midspan clearance between Ground Wire and the nearest Power Conductor is not kept less than the value specified as under:

AC Voltage (Nominal)	Minimum mid span clearance (in meters)
66 kV	3.0 m
110 kV	4.5 m
132 kV	6.1 m

220 kV	8.5 m
400 kV	9.0 m
765 kV	9.0 m

1.11 RIGHT OF WAY:

Before commencing any work on chosen route for laying of transmission line, it is necessary to ascertain availability of Right of Way. Obtaining required right of way is major hurdle in today's time in timely construction of the lines. Issues of land compensation, forest clearances and wild life clearances are also major problems. Figure given below, which is self-explanatory, explains the way to calculate Right of way.



Right of way corridor required for different voltage class transmission lines is given below.

Voltage level	Corridor Requirement (Meters)
66 kV	18 m
110 kV	22 m
132 kV	27 m

220 kV	35 m
400 kV Single Ckt. (Horizontal Configuration)	52 m
400 kV Double Ckt./400 kV S/C (Vertical Configuration)	46 m
765 kV Single Ckt. (Horizontal Configuration)	85 m
765 kV Single Ckt. (Delta / Vertical Configuration)	64 m
765 kV Double Ckt.	67 m
1200 kV	89 m
± 500 kV HVDC	52 m
± 800 kV HVDC	69 m

1.12 GALVANISING

All tower members and stubs shall be fully galvanised. Galvanising of the member of the towers, stubs and fasteners should conform to IS:2629, IS: 4759 and IS:5358 respectively. All galvanised members should withstand tests as per IS:2633-1992. The Galvanising is done after all fabrication work is completed, except that the nuts may be tapped or re-run after galvanising. Threads of bolts and nuts should have a neat fit and be such that they can be turned with finger throughout the length of the threads of bolts and they are capable of developing full strength of the bolts. Spring washers are electro-galvanised as per Grade 4 of IS :1573.

The finished materials are dipped into the solution of dichromate after galvanising or treated with approved inhibitor (for protection against white rust formation during sea transportation).

Galvanization Thickness:

(A) Normal Environment:			
S. No.	Description of Item:	Minimum value or average mass of Zinc coating (g/m ²)	Thickness (microns)
1.	Fabricated tower parts and stubs:		
	(a) 5 mm thick and over	610	86
	(b) Under 5 mm., but not less than 2 mm	460	65

2.	Hardware fittings, bolts, nuts and tower Accessories	300	43
(B) Marine Environment:			
1.	Fabricated tower parts and stubs:	900	127
	(a) 5 mm thick and over	610	87
	(b) Under 5 mm, but not less than 2 mm		

1.13 SPACING OF BOLTS AND EDGE DISTANCE

The minimum spacing of bolts and edge distances are as given below:

Bolt diameter (mm)	Hole diameter (mm)	Bolt spacing (mm)	Edge Distance (mm)	
			Hole center to rolled or sawn edge	Hole center to sheared or flame cut edge
12	13.5	32	16	20
16	17.5	40	20	23
20	21.5	48	25	28
24	26.0	60	33	38

1.14 TESTING OF TOWERS

- All standard tests, including quality control tests are carried out in accordance with relevant Indian Standards
- Tower of each type (Normally towers are tested with 9m extension. However, in case of very broad towers like 1200 kV/ 800 kV or very high towers like multi-circuit or 765 kV D/C due to limitations of test bed owner

may decide to test the tower with standard height) is subjected to design and destruction tests by first applying test loads equivalent to the specified ultimate tower loadings and applied in a manner approved by the purchaser. The tower shall withstand these tests without showing any sign of failure or permanent distortion in any part. Thereafter the tower is subjected to destruction by increasing the loads further in an approved manner till it fails. The tower is tested for all the conditions considered for the design of tower.

- (c) In case of premature failure, the tower is retested and steel already used in the earlier test is not used again. However, in case of minor failures, replacement of members may be done with higher section and testing may be carried out.
- (d) In case of any premature failure even during waiting period, the tower is retested with rectified members.
- (e) No part of any tower subject to test is allowed to be used on the line.
- (f) Each type of tower to be tested is a full scale prototype black tower and is erected vertically on rigid foundation and the stub protruding above ground level as provided in the design drawing between ground level and concrete level. This portion of the stub is kept unbraced while testing.
- (g) All the measuring instruments are calibrated in systematic approved manner with the help of standard weight/device. Calibration is done before commencing the test of each tower upto 20% above maximum anticipated loads to be applied during testing with the help of standard weights. The test loads are corrected with the help of calibration curves.
- (h) The tensile test, bend test etc. as per relevant IS may be carried out on few members of the test tower after completion of the test.

(i) TESTS

The procedure for conducting the tower test are as specified in IS: 802 (Part - III) (latest edition).

(i) BOLT SLIP TEST:

The test loads are gradually applied upto the design loads according to rigging diagram, kept constant for two (2) minutes at the design loads and then released gradually. The initial and final readings on the scales before application and after the release of loads

respectively are taken with the help of theodolite and the bolt slip are determined from the readings so obtained.

(ii) **NORMAL LOAD / BROKEN WIRE LOAD TESTS:**

All the loads are applied gradually upto the ultimate design loads in the following steps and shall be released in a similar manner:

- 25 percent
- 50 percent
- 75 percent
- 90 percent
- 95 percent
- 100 percent

Under normal and broken wire load tests, the tower is kept under observation for any sign of failure for two minutes (excluding the time for adjustment of loads) for all intermediate steps of loading upto and including 95% of ultimate design loads.

For normal as well as broken-wire tests, the tower is kept under observation for five minutes with 100% ultimate design load applied to it.

While the loading operations are in progress, the tower is constantly watched and if it shows any tendency of failure anywhere, the loading is immediately stopped, released and then the entire tower is inspected. The re-loading is started only after corrective measures are taken.

The deflection of the tower is recorded at each intermediate and final stage of normal load/ broken - wire load test by means of a theodolite and graduated scales fitted on the tower. The structures are considered to be satisfactory if it is able to support the specific ultimate load for five (5) minutes with no visible deformation after unloading (such as bowing, buckling) and no breakage of elements or constituent parts. Ovalisation of holes and permanent deformation of bolts are considered as failure.

- (iii) **Destruction Tests:** If desired, all types of towers are tested to destruction. The test is carried out under normal condition. However, the loads are increased in steps of 5% after the ultimate design loads have been reached.
- (iv) **Material Test:** In case of failure of towers after retest, coupons are cut from test tower members and tested in a laboratory to ascertain conformity of the material to the governing standard.



(j) RETEST

In the event of premature failure of tower, the part that has failed may be replaced by another with a greater mechanical strength. The modified structure is required to pass the test for the specified ultimate load values (100% step)

CHAPTER – 2
DESIGN OF EHV TRANSMISSION
LINE TOWER FOUNDATION



SAMBA-AMARGARH LINE



SAMBA-AMARGARH LINE

CHAPTER - 2

DESIGN OF EHV TRANSMISSION LINE TOWER FOUNDATION

2.1 Introduction

2.1.1 Transmission line towers foundations are subjected to heavier loads and as such requiring bigger and heavier foundations. A large number of foundations are normally required in any transmission line project, therefore the total cost of foundations in a transmission line project becomes quite substantial. Apart from the financial aspects, past records show that failure of tower foundations has also been responsible for collapse of towers. These failures have usually been associated with certain deficiencies either in the design or classification or construction of foundations. Many times, foundations cast are over safe because of inappropriate classification, resulting in wastage of resources. From engineering point of view, the task of design and selection of most suitable type of tower foundation is challenging because of the variety of soil conditions encountered enroute the transmission line and remoteness of construction sites. The foundations in various types of soils have to be designed to suit the soil conditions of particular type.

In addition to foundations of normal towers, there are situations where one has to decide the most suitable type of foundation system considering techno-economical aspects for special towers required for river crossing which may be located either on the bank of the river or in the mid-stream or both. This is generally decided based on the actual river crossing requirements; and the choice of type of foundation and its design would be based on actual soil exploration data, high flood level, velocity of water, scour depth etc.

2.2 TYPES OF FOUNDATIONS

Based on the ground water table, type of soil and structural arrangement foundations for EHV transmission line towers may be classified as follows:

- a) Based on the ground water table and type of soil and rock
- b) Based on the structural arrangement

2.2.1 Based on the Ground Water table and Type of Soil and Rock

As uplift resistance of foundation is a critical design factor which is greatly affected by the location of water table and the soil surrounding the foundation, therefore for economizing the cost of foundations, the foundations are classified in different categories as given below:

- (a) *Normal Dry Soil Foundations*

These foundations are used when water table is below foundation level and when soil is cohesive and homogeneous up to the full depth having a minimum clay content of 10-15%.

(b) *Wet Soil Foundations*

When water table is above foundation level and up to 1.5 m below ground level, the foundation is classified as the wet soil foundation. The foundations in the soils which have standing surface water for a long period with water penetration not exceeding 1.0 m below ground level (e.g. paddy fields) are also classified as wet foundations, however, some organizations are designing separate foundation for this type named as WET Cultivated soil foundation.

(c) *Partially Submerged Foundations*

The foundation may be termed as the partially submerged foundation when water table is at a depth between 0.75 m & 1.5 m below ground level and the soil is normal and cohesive.

(d) *Fully Submerged Foundations*

When water table is within 0.75 m below ground and the soil is normal and cohesive, the foundation to be used is called fully submerged foundation.

(e) *Black Cotton Soil Foundations*

These foundations are used when the soil is cohesive having inorganic clay content exceeding 15% and characterized by high shrinkage and swelling property (need not be always black in colour).

(f) *Partial Black Cotton Foundations*

These type of foundations are used when the top layer of soil up to 1.5 m is Black Cotton and thereafter it is normal dry cohesive soil.

(g) *Soft Rock / Fissured Rock Foundations*

The foundation may be termed as the soft rock/fissured foundation when decomposed or fissured rock, hard gravel, kankar or any other soil of similar nature is met which can be excavated without blasting. Under cut foundation is to be used at these locations.

(h) *Hard Rock Foundations*

Where chiseling, drilling and blasting is required for excavation, foundation to be used is classified as hard rock foundation.

(i) *Sandy Soil Foundations*

These foundations are used when the soil possesses negligible cohesion or low

clay content (0-10%).

2.2.2 Based on the Structural Arrangement

Based on the shape of foundation and type of construction material/method various types of structural arrangement of foundations are as described below:

(a) *P.C.C. Type*

It consists of a plain concrete footing pad with reinforced chimney in which the stub angle is taken inside and effectively anchored to the bottom pad by cleat angles and/or keying roads, and the chimney with reinforcement & stub angle inside works as a composite member. The pad may be either pyramidal in shape or stepped. Stepped footings will require less shuttering materials but need more attention during construction to avoid cold-joints between the steps. The pyramidal footings, on the other hand, will require somewhat costlier form work.

(b) *R.C.C. Spread Type*

This is the most common type of foundation used in India. It consists of a R.C.C. base slab or mat with chimney. The chimney and pad are generally square in shape. The base slab provided for the footing shall be either in single step or multiple steps. These steps may be sometimes chamfered also. These type of footings can be suitably designed for variety of soil conditions.

(c) *Block Type*

It consists of a chimney and block of concrete. In this type of foundation, concrete is poured in direct contact with the inner surfaces of the excavated rock so that concrete develops bond with rock. The uplift resistance in this type of footing is provided by the bond between concrete and rock. The thickness and size of the block is decided based on uplift capacity of foundation and bearing area required. This type of foundation is usually provided where soft rock and hard rock strata are encountered at the tower location. The minimum depth of this type of foundation is generally kept 1.5 m below ground level.

(d) *Under-Cut Type*

These types of foundation are constructed by making under-cut in soil/rock at foundation level. The size of under-cut shall not be less than 150 mm. A footing with an under-cut generally develops higher uplift resistance as compared to that of an identical footing without under-cut. This is due to the anchorage in undisturbed virgin soil. This type of foundation is very useful in normal dry cohesive soil, hard murrum, fissured/soft rock, soils mixed with kankar, where soil is not collapsible type i.e., it can stand by itself.

(e) *Grouted Rock and Rock Anchor Type*

Grouted Rock and Rock Anchor type of foundations are used in the conditions where the hard rock is encountered. In these type of foundations chimney and a block of shallow depth is used. For uplift resistance the block is anchored to the rock strata with help of anchor bars embedded in the Grouted Holes. The top part of the bar is embedded in the concrete of the shallow block. The depth of embedment, diameter and number of anchor bars will depend upon the uplift force on the footing. The effective anchoring strength should preferably be determined by testing.

(f) *Augur Type*

The primary benefit of using this type of foundation is its speedy construction thus resulting in saving in time and man-power. For construction of these types of foundations holes are drilled with the help of augur or drilling machine. Then the reinforcement cage is lowered into the holes and concreting is carried out. In case, the soil is weak, the bentonite slurry or steel casing may be used to support the sides of the holes. For increasing the uplift resistance, the bottom of the shaft of foundation may be belled.

(g) *Under-Reamed Pile Type*

These foundations are more or less similar to augured foundations except that they have under-reaming at different levels. The bore is drilled vertically or at a batter with having an arrangement of cutting flanges (edges) to be opened by the lever. This arrangement makes it possible to make under-reams at various levels of bores. The load carrying capacity of these footings, both for downward and uplift forces should be established by tests. These types of foundation are useful in case of expansive soils or black cotton soils.

(h) *Steel Grillage Type*

The Steel Grillage type of foundation consisting of structural steel sections are generally used in case of firm soils and for locations where concreting is not possible and head loading is difficult. Steel grillages can be of various designs. Generally, it consists of a layer of steel beams as pad for the bearing area. The footing reaction is transmitted to the pad by means of heavier joists or channels resting cross-ways on the bearing beams. These foundations are very helpful in restoring the collapsed transmission lines because of quicker construction.

(i) *Steel Plated Type*

These Foundations are more or less similar to Steel Grillage type of foundations except that the base grillage is replaced by a pressed steel plate. This type of foundation is usually adopted for locations where concreting work is difficult due to head loading. The advantage of this type of foundation is its simplicity. However, the disadvantage of this type of foundation is possibility of corrosion of steel.

(j) *Pile Type*

This type of foundation is usually adopted when soil is very weak and has very

poor bearing capacity or foundation has to be located in filled-up soil or sea mud to a large depth or where tower location falls within river bed and creek bed which are likely to get scoured during floods. Pile foundation usually costs more and may be adopted only after detailed examination of the site condition and soil data.

The downward vertical load on the foundation is carried by the piles through skin friction or by end bearing or both; while the uplift is resisted by the skin friction only. For resisting large lateral loads, battered piles may be used. Different types of piles may be used such as driven pre-cast piles, cast-in-situ bored piles. Mostly, cast-in-situ concrete bored piles are preferred over driven pre-cast piles. Load carrying capacity of different types of piles should normally be established by load tests.

(k) *Well Type*

This type of foundation is generally used in case of river crossing tower. The cast-in-situ wells of R.C.C. or brick masonry are sunk by continuous excavation from within the wells.

The well has to be taken below the estimated scour level to a sufficient depth for obtaining desired load carrying capacity of the well. Kent ledge may have to be used during sinking of the well for penetrating the hard strata and also to prevent its tilting during sinking operation. The top of the wells is normally kept above the high flood level. After the well has been sunk to its design depth, the well is filled up with sand and suitable well cap is constructed on the top of the well to accommodate the tower. The well is filled up well with sand or some suitable material to increase its weight and stability.

(l) *Raft Foundation*

In this type of foundation, all the four legs of tower are supported on a single concrete footing instead of having individual footing under each leg. This type of foundation can be provided where bearing capacity of soil is poor or individual concrete footing overlap each other.

2.3 Selection of Type of Foundation for Different Types of Tower

Generally, for normal and special towers, PCC type, RCC type, Block type, Under-Cut type, Augur type, Under-Reamed pile type, Steel grillage or Steel plated type foundation may be used depending upon the soil conditions of the site where tower has to be installed.

While for river crossing towers, Pile type, well type or Raft type of foundation may be used depending upon the site conditions.

2.4 DESIGN PROCEDURE FOR FOUNDATION

The design of any foundation consists of following two parts:

2.4.1 Stability Analysis of foundation

Stability analysis aims at removing the possibility of failure of foundation by tilting, Overturning, uprooting and sliding due to load intensity imposed on soil by the foundation being in excess of the ultimate capacity of the soil.

The most important aspect of the foundation design is the necessary check for the stability of foundation under various loads imposed on it by the tower which it supports. The foundation should remain stable under all the possible combinations of loadings; to which it is likely to be subjected under the most stringent conditions. The stability of foundation should be checked for the following aspects;

(a) *Check for Bearing Capacity*

The total downward load at the base of footing consists of compression per leg derived from the tower design, buoyant weight of concrete below ground level (*i.e.* difference in the weight of concrete and soil) and weight of concrete above ground level.

While calculating over weight of concrete to check bearing capacity of soil, the position of water table should be considered at critical location *i.e.* which would give maximum over weight of concrete. In case of foundation with chimney battered along the slope of leg, the centre line of chimney may not coincide with the C.G. of the base slabs/pyramid/block, under such situation axial load in the chimney can be resolved into vertical and horizontal components at the top of base slab/pyramid/block.

The additional moments due to the above horizontal loads should be considered while checking the bearing capacity of soil.

Further, even in cases where full horizontal shear is balanced by the passive pressure of soil, the horizontal shears would cause moment at the base of footing as the line of action of side thrusts (horizontal shears) and resultant of passive pressure of soil are not in the same line. It may be noted that passive pressure of soil is reactive force from the soil for balancing the external horizontal forces and as such mobilized passive pressure in soil adjoining the footing cannot be more than the external horizontal shear.

Thus, the maximum soil pressure below the base of the foundation (Toe pressure) will depend upon the vertical thrust (compression load) on the footing and the moments at the base level due to the horizontal shears and other eccentric loadings. Under the action of down thrust and moments, the soil pressure below the footing will not be uniform and the maximum toe pressure 'P' on the soil can be determined from the equation:

$$P = \frac{W}{B \times B} + \frac{MT}{ZT} + \frac{ML}{ZL}$$

Where,

W is the total vertical down thrust including over weight of the footing

B' is dimension of the footing base

MT & ML are, moments at the base of footing about transverse and longitudinal axes of footing; and ZT & ZL are the section modulus of footing which are equal to $(1/6) B^3$ for a square footing.

The above equation is not valid when minimum pressure under the footing becomes negative. The maximum pressure on the soil so obtained should not exceed the limit bearing capacity of the soil.

(b) *Check for Uplift Resistance*

In the case of spread foundations, the resistance to uplift is considered to be provided by the buoyant weight of the foundation and the weight of the soil volume contained in the inverted frustum of cone on the base of the footing with sides making an angle equal to the angle of earth frustum applicable for a particular type of the soil.

$$UP = W_s + W_f$$

Where

'W_s' is the weight of soil in frustum of cone

'W_f' is the buoyant weight/overload of the foundation

Depending upon the type of foundation i.e. whether dry or wet or partially submerged or fully submerged, the weights 'W_s' and 'W_f' should be calculated taking into account the location of ground water table.

Under-cut type of foundation offers greater resistance to uplift than an identical footing without undercut. This is for the simple reason that the angle of earth frustum originates from the toe of the undercut and there is perfect bond between concrete and the soil surrounding it and there is no need to depend on the behavior of backfilled earth. Substantial additional uplift resistance is developed due to use of under-cut type of foundation. In case of under-cut type of foundation, the additional uplift resistance is taken into account by increasing the density of soil as given in Annexure-I.

In cases where frustum of earth pyramid of two adjoining legs superimpose each other, the earth frustum is assumed truncated by a vertical plane passing through the centre line of the tower base.

(c) *Check for Over-Turning*

Stability of the foundation against overturning under the combined action of uplift and horizontal shears may be checked by the following criteria.

- (i) The foundation over-turns at the toe.
- (ii) The weight of the footing acts at the centre of the base; and
- (iii) Mainly that part of the earth cone which stands over the heel causes the stabilizing moment. However, for design purpose, this may be taken equal to half the weight of the cone of earth and it is assumed to act through the tip of the heel.
- (iv) For stability of foundation against overturning, stabilizing moment should be more than overturning moment.

(d) *Check for Sliding*

In the foundations of transmission towers, the horizontal shear is comparatively small and possibility of sliding is generally negligible. However, resistance to sliding is evaluated assuming that passive earth pressure conditions are developed on a vertical projection above the toe of foundation. The friction between bottom of the footing and soil also resist the sliding of footing and can be considered in the stability of foundation against sliding. The coefficient of friction between concrete and soil can be considered between 0.2 to 0.3. However, the frictional force is directly proportional to vertical downward load and as such may not exist under uplift condition. For cohesive soil the following formula can be applied for calculating the passive pressure to resist sliding:

$$P = 2 C \tan \theta + Y h \tan^2 \theta$$

C = Cohesion ($2t/m^2$ min.)
 $\theta = 45^\circ + 1/2$ of angle of earth frustum
h = Height of foundation
Y = Unit Wt. of soil

(e) *Check for uprooting of stub*

Appropriate size of cleat angle should be provided to prevent uprooting of stub. The Cleat angle should be connected with stub with adequate number of bolts. The suitable bolted connection should be designed as per the relevant Indian Standard which must be safe in tension and shear.

2.4.2 STRUCTURAL DESIGN OF FOUNDATION

Structural design of concrete foundation comprises the design of chimney and the design of base slab/pyramid/block. The structural design of different elements of concrete foundation is discussed in the following paragraphs.

(a) Structural Design of Chimney

The chimney is required to be designed for combined action of axial force, tension or compression, and maximum bending moments due to longitudinal and transverse side thrust. The design of chimney for combined action of axial force and bending moment is very important for the structural safety of foundation.

The requirement longitudinal reinforcement in the chimney is usually governed under the combined action of tensile force/uplift and bending moments due to side thrust. When stub angle is embedded in the chimney to its full depth and anchored into the base slab, the chimney can be treated as a composite member with the stub angle inside the chimney action as a rigid reinforcement. In case, the size of sub provided and anchored in base slab is not adequate for combined stresses due to direct tension/compression and bending, reinforcement needs to be provided in the chimney for its structural safety and integrity.

If stub is embedded in the chimney for the required development length alone and same is not taken up to the bottom of foundation or leg of the tower is fixed at the top of the chimney/pedestal by anchor bolts, chimney is required to be designed for combined stresses due to direct pull (tension)/down thrust (compression) and bending moment due to side thrust.

The structural design of chimney for above cases should comply with the procedure as given in IS: 456 and SP: 16. The procedure for structural design of chimney for three cases is described below:

Case-I: Stub alone is provided in the chimney and anchored in bottom pad/pyramid:

When stub alone is provided in the chimney and the same is anchored in base slab/pyramid and no reinforcement is provided in the chimney, stub would act as reinforcement placed at the center of chimney. For this case, no charts or graphs exist in SP: 16 for calculating the moment capacity of the chimney section.

The equations for this case are as follows:

$$\begin{aligned}
 P_u &= 0.36 f_{ck} B_3 X_u + A_{ss} (f_{ss} - f_{cc}) \\
 P_u / f_{ck} B_3^2 &= 0.36k + (p_u/100) [(f_{ss} - f_{cs}) / f_{ck}] \quad \dots\dots\dots (1) \\
 M_u / f_{ck} B_3^3 &= 0.36k (0.5 - 0.416k) \quad \dots\dots\dots (2)
 \end{aligned}$$

Where:-

A_{ss}	=	Cross-sectional Area of Stub;
ρ_u	=	$100 A_{ss}/B_3^2$
f_{ck}	=	Characteristic Strength of Concrete;
f_{cs}	=	Stress in Concrete at Stub Level;
f_{ss}	=	Stress in Stub, Compression being positive and Tension being Negative;
P_u	=	Limiting Axial Force in the Chimney, compression being positive and tension being negative;
M_u	=	Moment capacity of the chimney section;
k	=	(Depth of Neutral Axis / B_3) = X_u / B_3
B_3	=	Size of chimney

Case-II: When stub provided and anchored in bottom pad/pyramid is not adequate for combined stresses due to Axial Forces and Bending Moment and Reinforcement Steel is required to be provided:

When the stub provided and anchored in base slab/pyramid is not adequate for combined stresses due to direct axial force and bending moment, reinforcement needs be provided in the chimney for structural safety. In this case also, stub would act as reinforcement placed at the centre of chimney. However, the necessary reinforcement steel shall be provided on the sides of the chimney at the periphery. For this case also, which is normally encountered in practice, no charts or graphs exist in SP-16 for calculating the moment capacity of the chimney section.

The equations for this case are as follows:

$$P_u/f_{ck}B_3^2 = 0.36k + \sum_{i=1} (p_i/100) [(f_{si} - f_{ci})/f_{ck}] + (p_s/100) [(f_{ss} - f_{cs})/f_{ck}] \quad \text{.....(3)}$$

$$M_u/f_{ck}B_3^3 = 0.36k (0.5 - 0.416k) + \sum_{i=1} (p_i/100) [(f_{si} - f_{ci})/f_{ck}] (y_i / D) \quad \text{.....(4)}$$

Where:

A_{si}	=	Cross-sectional Area of Reinforcement in i^{th} Row;
p_i	=	$100 A_{si}/B_3^2$
f_{ci}	=	Stress in Concrete at the level of i^{th} Row of reinforcement;
f_{si}	=	Stress in the i^{th} Row of Reinforcement, Compression being positive Tension being negative;
y_i	=	Distance from the Centroid of the Section to the i^{th} Row of Reinforcement, positive towards the highly compressed edge and negative towards the least compressed edge;
n	=	Number of rows of Reinforcement

Case-III: When Stub is provided in Chimney only for its Development Length:

When stub is provided in chimney only for its development length chimney has to be designed for and full reinforcement provided in the chimney for combined stresses due to direct pull (tension)/Thrust (compression) and bending moments. In this case, stub would not be available as reinforcement at the center of chimney. In this case, the requirement of longitudinal reinforcement in the chimney can be calculated using appropriate charts given in SP: 16.

The equations for this case are as follows:

$$P_u/f_{ck}B_3^2 = 0.36k + \sum (\pi/100) [(f_{si} - f_{ci})/f_{ck}] \dots\dots (5)$$

$$M_u/f_{ck}B_3^3 = 0.36k (0.5 - 0.416k) + \sum (\pi/100) [(f_{si} - f_{ci})/f_{ck}] (y_i/D) \dots\dots (6)$$

In each of the above three cases, for a given axial force (compressive or tensile) and for given area of stub and area of reinforcement, the depth of neutral axis $X_u = KB_3$ can be calculated from equation (1), (3) or (5) using stress strain relationship for concrete and steel is given in IS: 456. After finding out the depth of Neutral Axis, the moment capacity of the chimney section can be find out using equation (2), (4) or (6) depending on the case. The moment capacity of the chimney section should be more than the moment on chimney caused by side thrust.

In case, chimney is subjected to bi-axial moment i.e. both longitudinal and transverse moment, the structural adequacy of chimney is required to be checked as per the following equation:

$$(M_T/M_{UT})^n + (M_L/M_{UL})^n \leq 1.0$$

Where: -

M_T and M_L are the moment about transverse and longitudinal axis of the chimney;

M_{UT} and M_{UL} are the maximum uniaxial moment capacities of the chimney section about transverse and longitudinal axis of chimney with an axial load of P_u .

'n' is an exponent whose value would be 1.0 when axial forces is tensile and depends on the value of P_u/P_{uz} when axial forces is compressive where,

$$P_{uz} = 0.45f_{ck} A_c + 0.75f_y A_s + 0.75 f_{ys} A_{ss}$$

In the above equation,

A_c is the area of concrete;
 A_s is the area of reinforcement steel;
 A_{ss} is the cross-sectional area of stub;
 f_y is the yield stress of reinforcement steel; and

f_{ys} is the yield stress of stub steel.

P_u / P_{uz}	n
0.2	1.0
0.8	2.0

The solution of equation (5) & (6) for case-3 is given in SP-16 in the form of graphs for various grades of concrete and steel and these can be readily used. However, equations (1) & (2) in case-1 and equations (3) & (4) in case-2 have to be solved on computer by developing appropriate program for finding out the moment capacity of the chimney section.

IMPORTANT CODAL STIPULATIONS FOR STRUCTURAL DETAILING OF CHIMNEY

While designing the chimney, the important codal provisions as given below should be followed:

- In any chimney that has a larger cross-sectional area than that required to support the load, the minimum percentage of steel shall be based on the area of concrete required to resist the direct stress and not on the actual area.
- The minimum number of longitudinal bars provided in a column shall be four in square chimney and six in a circular chimney.
- The bars shall not be less than 12 mm in diameter.
- In case of a chimney in which the longitudinal reinforcement is not required in strength calculations, nominal longitudinal reinforcement not less than 0.15% of the cross sectional area shall be provided.
- The spacing of stirrups/lateral ties shall be not more than the least of the following distances:
 - (a) The least lateral dimension of the chimney
 - (b) Sixteen times the smallest diameter of the longitudinal reinforcement bar to be tied
 - (c) 300mm
- The diameter of the polygonal links or lateral ties shall be not less than one-fourth of the diameter of the largest longitudinal bar, and in no case less than 6 mm.

(b) Structural Design of Base Slab

The base slab in R.C.C. Spread foundations could be single stepped or multi stepped. The critical section for bending moment for single stepped footing, is at the face of chimney and for double stepped footing, the critical section for bending is at the face of chimney and at all other vertical planes where abrupt change of section occurs i.e. junction of steps.

A through vertical section has to be considered for calculating the moment and shear in the bottom pad as per provision of IS: 456. The effect of only the higher moment on bearing pressure needs to be considered for the structural design of the bottom pad. The procedure of calculating the moment of resistance of section and reinforcement for stepped footing both under down thrust and uplift loading condition is given below based on Limit State Method of Design in IS: 456.

Design of Bottom Pad under Down Thrust:

Tension under the down thrust occurs at the bottom face of footing pad.

Design of Bottom Pad at Face of Chimney

From the equilibrium of internal and external forces on the pad section and using stress and strains of concrete and steel as per IS:456, the following equations as given in SP: 16 can be obtained:

$$0.36f_{ck}B_2X_u = 0.87A_{s1}f_y \quad \text{which can be written as}$$

$$X_u / d_1 = (p_1 / 100) \times (0.87 f_y) / (0.36 f_{ck}) \quad \dots\dots\dots (7)$$

Where:-

$$p_1 = (100A_{s1})/B_2d_1$$

Moment of resistance of Pad Section at the face of Chimney:

$$M_u = 0.87f_y (p_1/100) \times (1-0.416 X_u / d_1) B_2d_1^2 \quad \dots\dots\dots (8)$$

Design of Bottom Pad at the Junction of Steps:

From the equilibrium of internal and external forces on the pad section and using stress and strains of concrete and steel as per IS:456, the following equations as given in SP:16 can be obtained:

$$X_u/d_2 = (p_2 / 100) \times (0.87 f_y) / 0.36 f_{ck} \quad \dots\dots\dots (9)$$

Where:-

$$p_2 = (100A_{s1})/B_1d_2$$

$$M_u = 0.87f_y (p_2/100) \times (1- 0.416X_u /d_2) B_1d_2^2 \quad \dots\dots\dots (10)$$

The reinforcement provided at the face of chimney at the bottom face of the base slab is normally continued up to edge of the footing without any curtailment and only the depth of footing is reduced by providing step as moment reduces away from the face of the chimney. Thus, the location of step is required to be chosen in such a manner that reduced depth provided at the junction of the steps is structurally adequate in bending and shear for the reinforcement provided at the

face of chimney.

Design of Bottom Pad under Uplift Load:

In this case, tension in footing pad occurs at the top face.

Design of Pad at the Junction of Step:

From the equilibrium of internal and external forces on the pad section and using stress and strains of concrete and steel as per IS: 456, the following equations can be obtained.

$$X_u/d_2 = (p_3/100) \times (0.87 f_y)/0.36 f_{ck} \dots\dots\dots (11)$$

Where: -

$$p_3 = (100 A_{s3})/Bd_2$$

Moment of resistance of section:

$$M_u = 0.87f_y \times (p_3/100) [(1 - (0.416 X_u/d_2))] Bd_2^2 \dots\dots\dots (12)$$

Design at the Face of Chimney:

It may be noted that reinforcement provided at the junction of the step for uplift falls in tension zone and thus would also contribute in moment capacity of section at the face of chimney. This is because under uplift, compression occurs at the bottom face of the base slab having more width (more area of compression flange) and section behaves as a highly under reinforced section. From the equilibrium of internal and external forces on the Pad section and using stress and strains of concrete and steel as per IS: 456 the following equation can be obtained:

$$X_u/d_1 = (p_3/100) \times (d_2/d_1) \times (0.87 f_y/0.36 f_{ck}) + (p_4/100) \times (0.87 f_y/0.36 f_{ck}) \dots\dots(13)$$

Where:-

$$p_3 = (100 A_{s3}/Bd_2)$$

$$p_4 = (100 A_{s4}/Bd_1)$$

Moment of Resistance of Pad Section at the Face of Chimney:

$$M_u = [0.87f_y \times (p_3/100) \times (d_2/d_1) \times (d_2/d_1 - 0.416 X_u/d_1) + (0.87f_y) \times (p_4/100) \times (1 - 0.416 X_u/d_1)] \times Bd_1^2 \dots\dots\dots (14)$$

Since, reinforcement percentage `p3` at the junction of steps is already known, the problem reduces to finding out the requirement of reinforcement of `p4` to be provided at depth `d1` in addition to reinforcement `p3` already provided at depth `d2`. This can be calculated by solving the equation (13) & (14).

In other cases, for a given moment, % of reinforcement can be calculated by solving the equations (7) & (8), (9) & (10) and (11) & (12) and reinforcement so calculated should be provided uniformly at tension face of the footing.

IMPORTANT CODAL STIPULATIONS FOR R.C.C. FOUNDATIONS

The important provisions applicable for concrete foundations which are necessary and should be considered in the design are explained below.

- (a) Footings shall be designed to sustain the applied loads, moments and forces and the induced reactions and to ensure that any settlement which may occur shall be as nearly uniform as possible, and the bearing capacity of the soil is not exceeded.
- (b) Thickness of the edge of footing in reinforced concrete footings shall be not less than 15 cm (5 cm lean concrete plus 10 cm structural concrete). In case of plain concrete footing, thickness at the edge shall not be less than 5 cm).
- (c) *Bending Moment*
 - (i) The bending moment at any section shall be determined by passing through the section of a vertical plane which extends completely across the footing, and computing the moment of the forces acting over the entire area of the footing on the side of the said plane.
 - (ii) The greatest bending moment to be used in the design of an isolated concrete footing which supports a column/pedestal shall be the moment computed in the manner prescribed in c(i) above at sections located as follows:
 - At the face of the chimney.
 - At sections where width/thickness of the footing changes.
- (d) *Shear and Bond*

The shear strength of footing is governed by the more severe of the following two conditions:

- (i) The footing acting essentially as a wide beam, with a potential diagonal crack extending in a plane across the entire width; the critical section for this condition shall be assumed as a vertical section located from the face of the chimney at a distance equal to the effective depth of the footing in case of footings on soils;
 - (ii) Two-way action of the footing, with potential diagonal cracking along the surface of truncated cone or pyramid around the concentrated load;
- (e) *Critical Section for development length*

The critical section for checking the development length in a footing shall be assumed at the same planes as those described for bending moment in para (c)

above and also at all other vertical planes where abrupt changes of section occur.

2.5 CONCRETE TECHNOLOGY FOR TOWER FOUNDATION DESIGNS

While designing the various types of concrete footings, it is better to know about certain aspects of concrete technology which are given below.

(a) *Properties of Concrete*

The grade of the structural concrete used for tower foundations should not be leaner than M-20 (1:1.5:3) having a 28-day cube strength of not less than 20 N/mm² and concrete shall conform to IS: 456. For special foundations like pile foundations, richer concrete of grade of M 25 (design mix) having a 28-day cube strength of not less than 25 N/mm² should be used. M-20 grade concrete shall have the nominal strength of not less than 20 N/mm² at the end of 28 days as ascertained from the cube test. Such strength at the end of 7 days shall not be less than 14 N/mm².

The density of the concrete will be 2300 kg/m³ for plain concrete and 2400 kg/m³ for R.C.C. Other properties of concrete are given in IS: 456.

(b) *Properties of Steel*

The high yield stress cold deformed reinforcement bars used in the R.C.C. shall conform to IS: 1786-1979 and shall have yield stress of not less than 415 N/mm². When mild steel reinforcement bars are used in R.C.C, they shall conform to IS: 432 (Part-I) and shall have yield stress of not less 26 N/mm² for bars of size up to 20 mm diameter and 24 N/mm² for bars above 20 mm diameter.

Annexure - I

Soil Properties to be considered in Foundation Designs for various types of Soil

Sl. No.	Type of Soil	Angle of earth frustum (degrees)	Unit weight of soil (kg/cum)	Limit Bearing Capacity (kg/sqm)
1.	Normal Dry Soil	30	1440	27,350 25,000
2.	Wet soil due to presence of sub soil water /surface water	15	940	12,500
3.	Black Cotton Soil			
	(a) In Dry portion	0	1440	12,500
	(b) In wet portion	0	940	
4.	Sandy Soil	20	1440	27,350
5(A).	Fissured Rock/Soft Rock (With undercut)			
	(a) In Dry Portion	20	1700	62,500
	(b) In Wet Portion	10	940	62,500
5(B).	Fissured Rock/Soft Rock (Without undercut)			
	(a) In Dry Portion	0	1440	62500
	(b) In Wet Portion	0	940	62500
6.	Hard Rock	--	--	1,25,000

Note:

- Above values are general in nature and may vary from state to state. In case of any variance location specific soil properties are chosen based on actual soil data. Soil research institutes will be approached to furnish the limit bearing capacities of soil, if and when such data are available the above values can be reviewed.
- Where clay content is more than 10% but less than 15%, the soil will be classified



as Normal Dry Soil

3. Angle of Earth shall be taken with respect to vertical.

LIST OF SOIL TESTS

A. To find out the soil properties, the following laboratory tests shall be carried out:

- (1) Grain size distribution/sieve analysis to identify the type of soil
- (2) Atterburg limits (liquid and plastic limits only)
- (3) Specific gravity, bulk unit weight, moisture content
- (4) Triaxial shear test for cohesion (c) and angle of internal friction (ϕ)
- (5) Consolidation test
- (6) Standard penetration test
- (7) Chemical test on soil and water (only at special locations such as marshy soils, chemically active soils etc.) to determine the carbonates, sulphates, nitrates, organic matters and any other chemicals harmful to the concrete foundations.

B. The above tests shall be useful in determining the types of soil, density, limit bearing capacity etc. For determining the angle of earth friction ϕ 2/3rd value of angle of internal friction (ϕ) or the values given in Annexure-I whichever is smaller shall be taken.

C. Standard penetration tests shall be conducted at depths as follows:

Location	Depth (m)
(i) Normal Locations	1.5, 3.0, 4.5, 7.00
(ii) River crossing & special Locations thereafter at the rate of 3 M intervals up to 40 M.	1.5, 3.0, 4.5, 7.00, 10.00 &

Bore hole logs shall be prepared for the locations where above tests have been conducted.

D. During execution, trial pits up to a minimum depth of 3.0 m (except rocky locations) shall be excavated at each and every tower location (at all four legs) to obtain following details in order to classify the type of foundation to be adopted:

- 1) Type of soil encountered
- 2) Ground Water table.

Annexure - III

Guidelines for classification of Foundations in different Soils

S.No.	Name of soil encountered	Types of Foundation be adopted
1.	In good soil (silty sand mixed with clay)	Normal Dry
2.	Where top layer of Black Cotton soil extends up to 50% of the depth with good soil there after	Partial Black Cotton
3.	Where top layer of black cotton soil exceeds 50% and extends up to full depth, or is followed by good soil	Black Cotton
4.	Where top layer is good soil up to 50% of the depth but the lower layer is a black cotton soil	Black Cotton
5.	Where subsoil water is met at 1.5 m or more below the ground level in good soil	Wet
6.	Good soil locations which are in surface water for long period with water penetration not exceeding 1.0 m below ground level (e.g., paddy fields)	Wet or Wet Cultivated
7.	In good soil where subsoil water is encountered between 0.75 m and 1.5 m depth from ground level	Partially submerged
8.	In good soil where subsoil water is encountered within 0.75 m depth from ground level	Fully Submerged
9.	Where top layer of normal dry soil extends up to 85% of the depth followed by fissured rock without presence of water	Dry Fissured Rock
10.	Where top layer is fissured rock followed by good soil/sandy soil with/without presence of water	Special foundation
11.	Where normal soil/fissured rock extends up to 85% of the depth followed by hard rock	Dry fissured Rock with under cut in Fissured Rock combined with anchor bar for hard



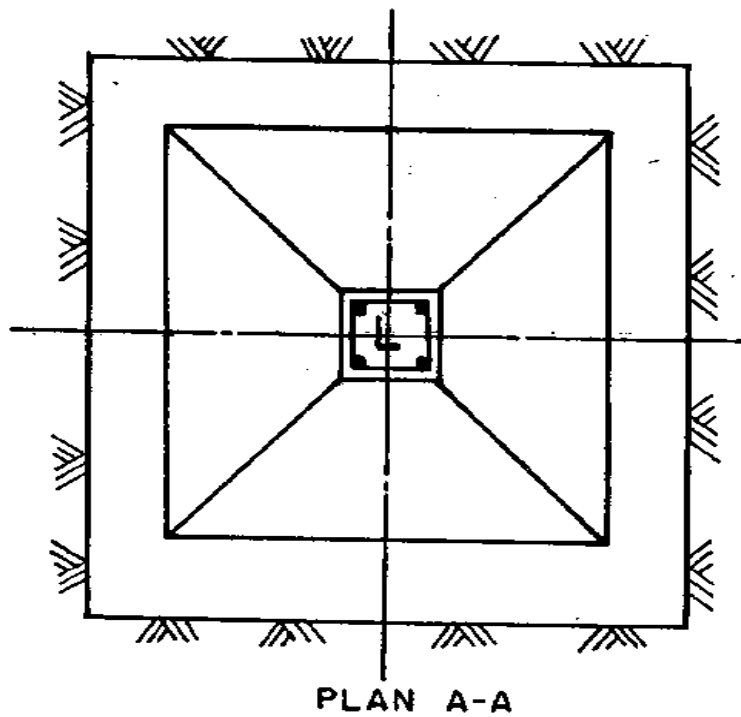
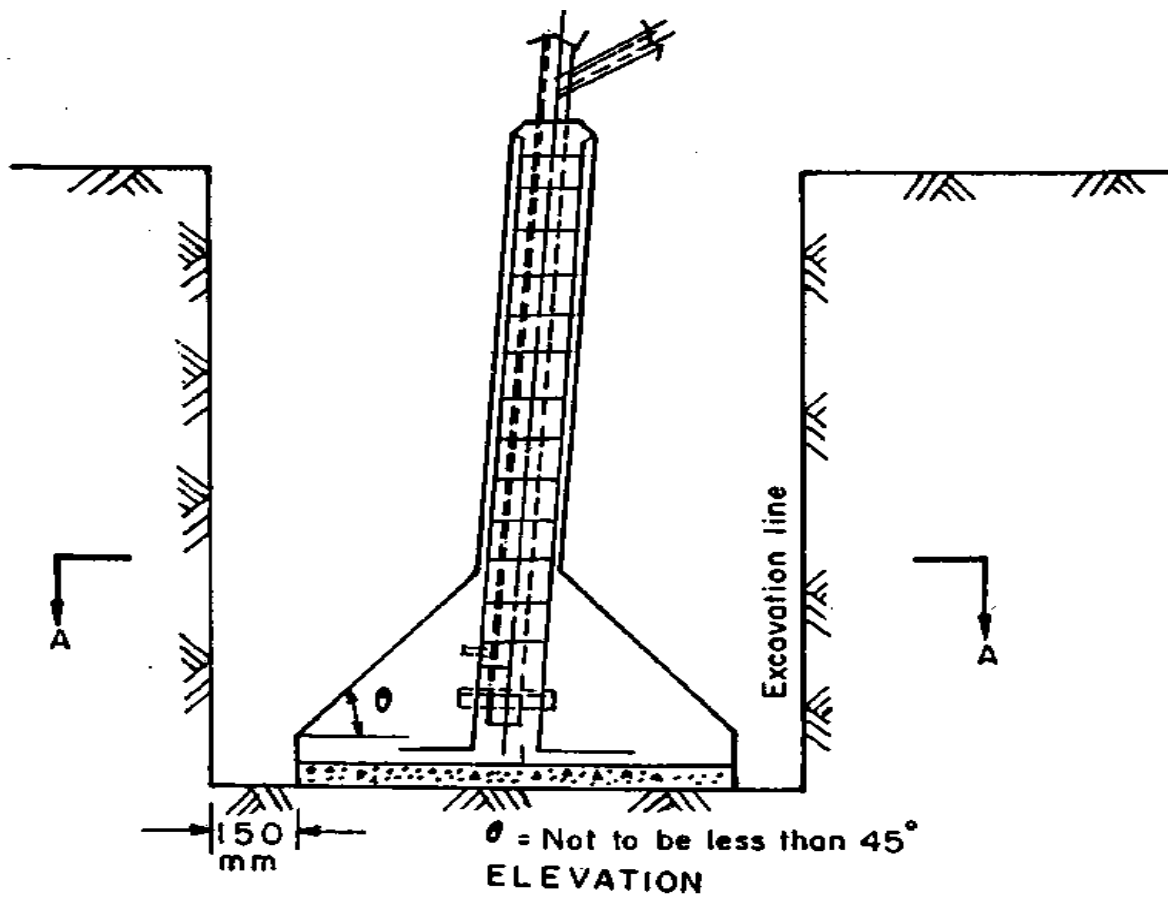
		rock design
12.	Where fissure rock is encountered with subsoil water within 0.75 m or below 0.75 m from G.L. (Top layer may be either a good soil or black cotton soil)	Submerged Fissured Rock
13.	Where Hard Rock is encountered at 1.5 m or less below ground level	Hard Rock
14.	Where Hard Rock is from 1.5 m to 2.5 m encountered below G.L. (Top layer being good soil)	Hard Rock Foundation with chimney for Normal Soil
15.	Where hard rock is encountered from 1.5 m to 2.5 m below G.L. (Top layer either in Black cotton) soil or fissured Rock	Hard Rock Foundation design with chimneys designed for wet black cotton soil
16.	Where fissured rock is encountered at the bottom of pit (with black cotton soil at top)	Composite Foundation
17.	Where hard rock is encountered at bottom with water and black cotton soil at top and hard rock layer depth is less than 1.5 m	Hard Rock
18.	Sandy soil with clay content not exceeding 10%	Dry Sandy soil foundation
19.	Sandy soil with water table in the pits	Wet sandy soil design to be developed considering the depth of water
20.	Where top layer up to 1.5 m below G.L. is normal dry soil and thereafter hard soil/murum	Normal dry with undercut
21.	Where bottom layer is marshy soil with top layer of good soil/fissured rock/black cotton	Soil investigation is to be carried out and



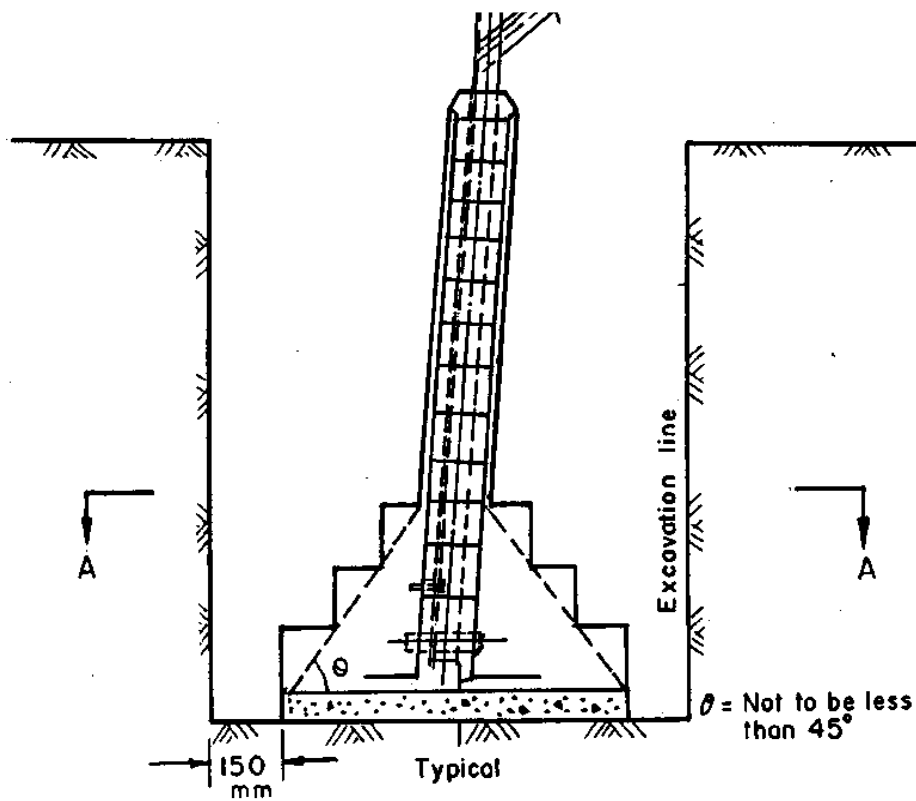
		special foundation design to be developed
22.	Where the top layers are a combination of clinker mixed with firm soil, gravel and stone chips up to 60% of foundation depth from ground level followed by hard murrum	Normal dry with undercut
23.	Where top layers are combination of hard murrum, soft rock etc. followed by yellow/black clayey soil	Special foundation design is to be developed after carrying out soil investigation

Any other combination of soil not covered above shall require development of special foundation design.

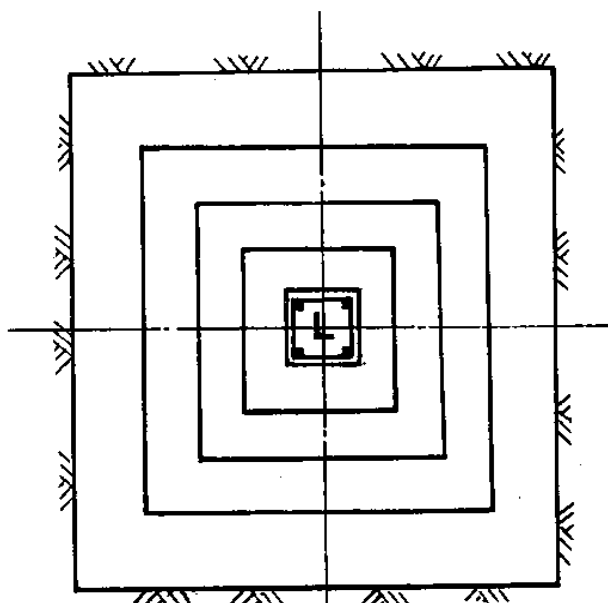
Figures of different types of foundations: As shown below



PLAN A-A
PCC Type Pyramidal Foundation



ELEVATION



PLAN 'A-A'

Figure I (b): P.C.C. Type Stepped Foundation

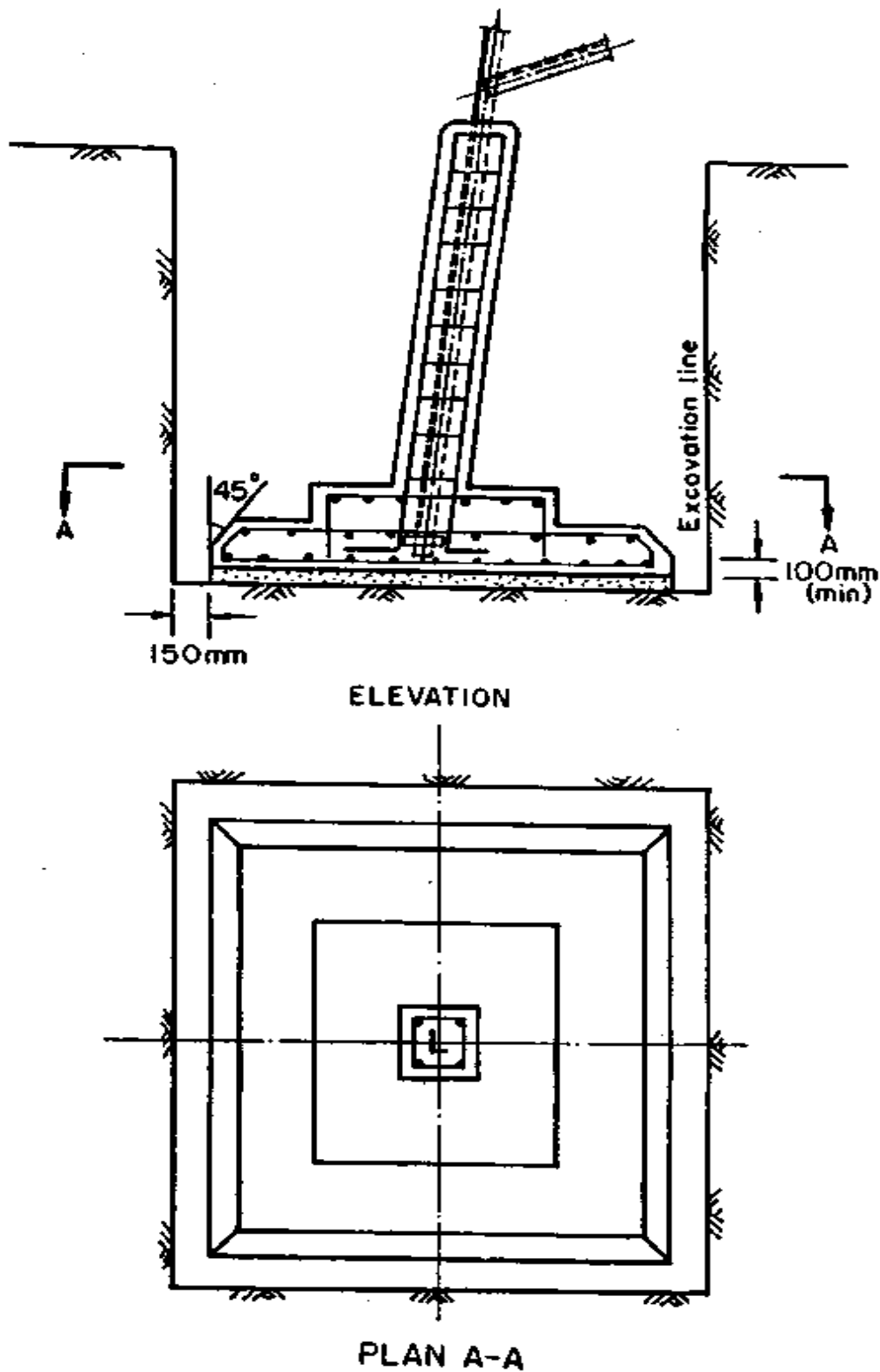


Figure 2(a): R.C.C. Spread Type Foundation (Chamfered Type)

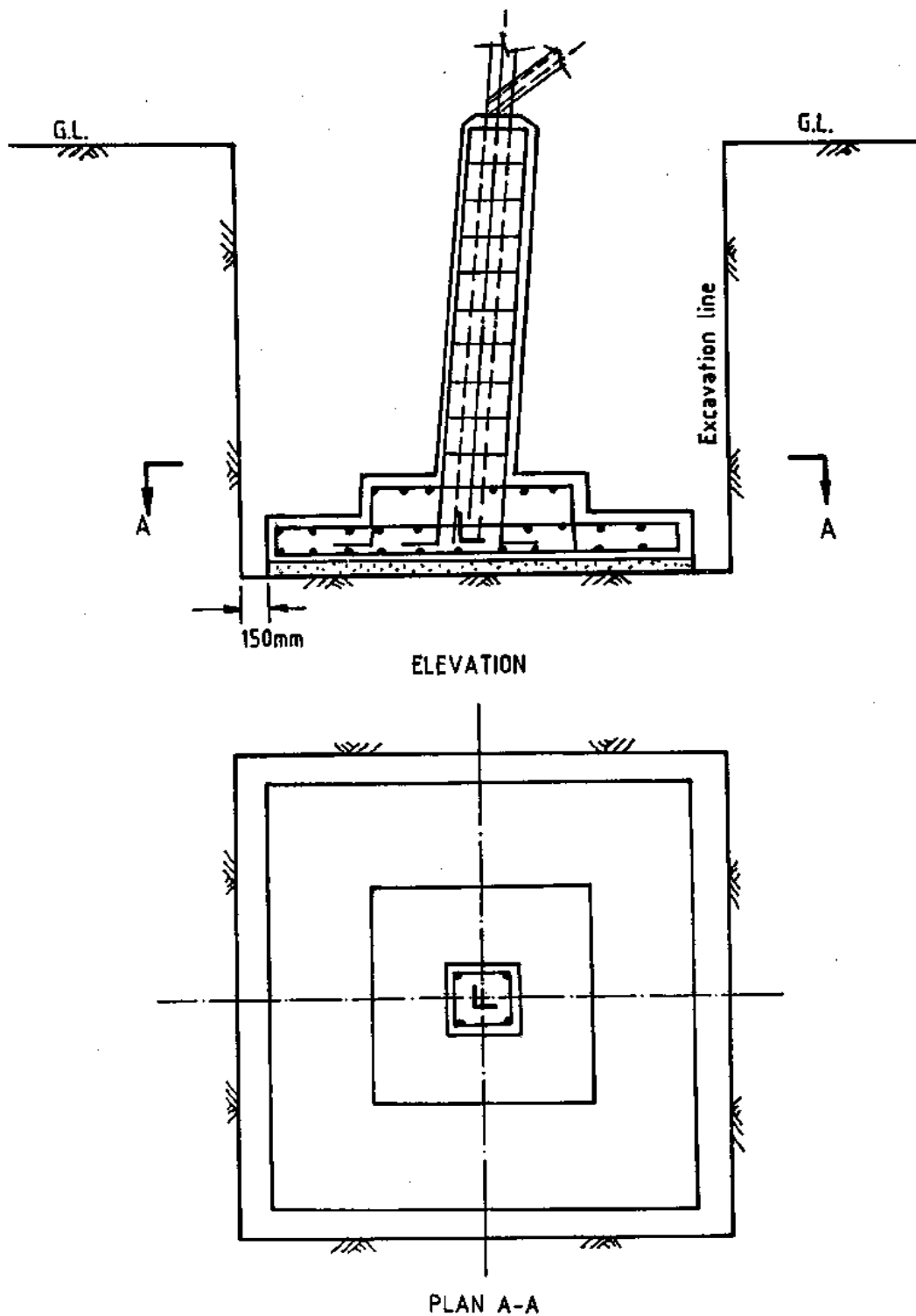


Figure 2(b): R.C.C. Spread Type Foundation (Step) with 150mm Working Clearance

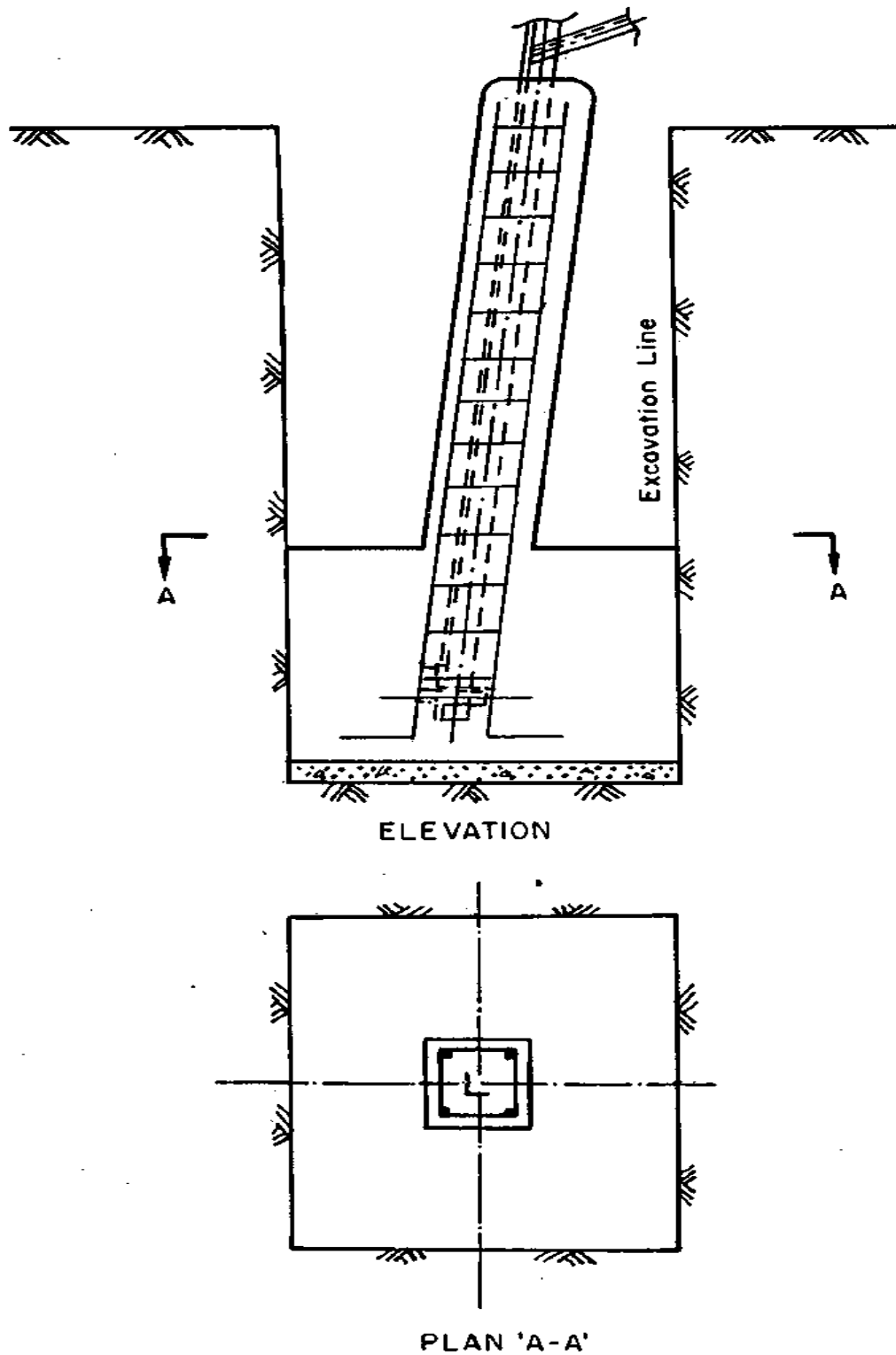


Figure 3 : Block Foundation(Friction Type)

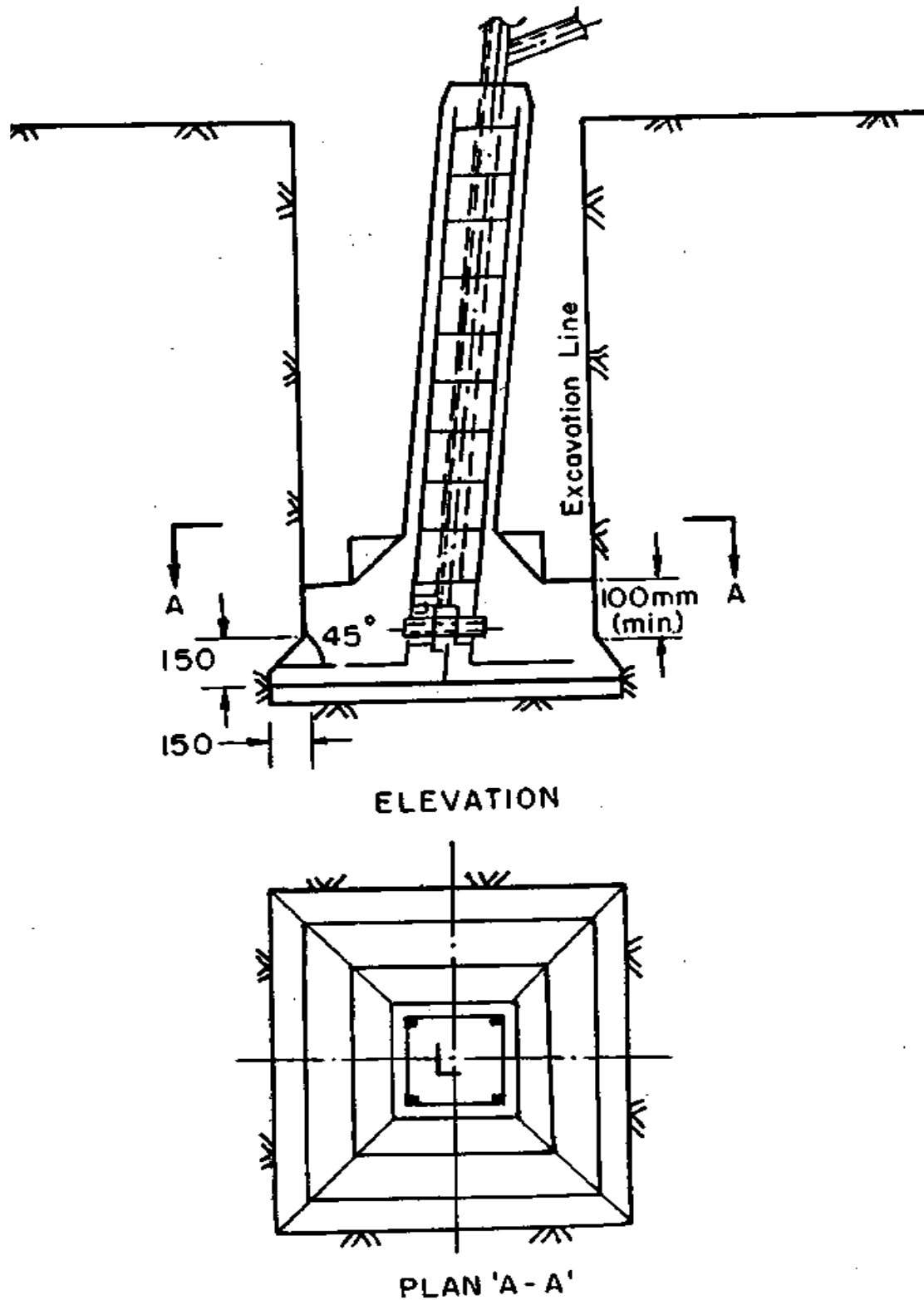


Figure-4 Pyramid Type with Undercut

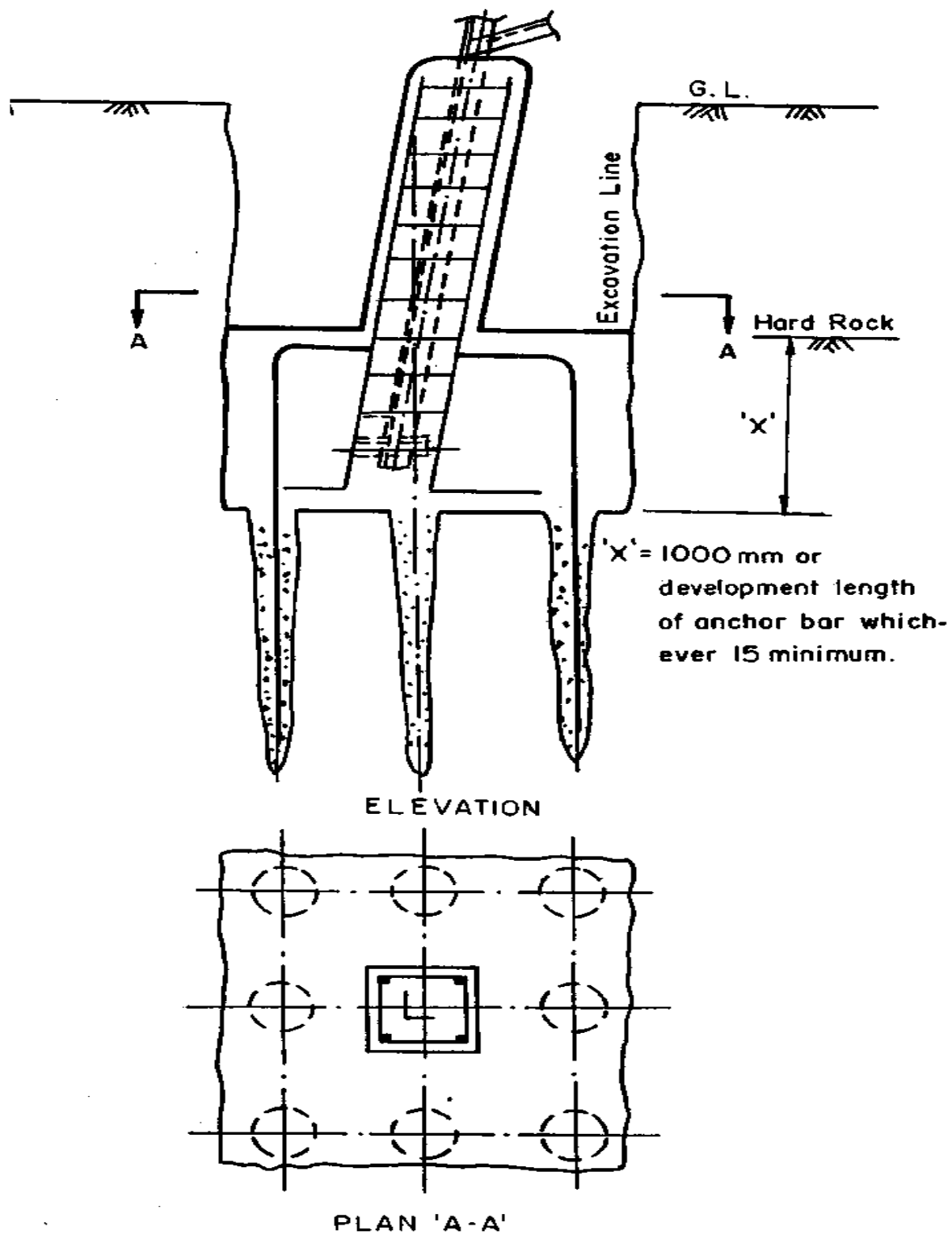


Figure-5 Rock Anchor Type Foundation

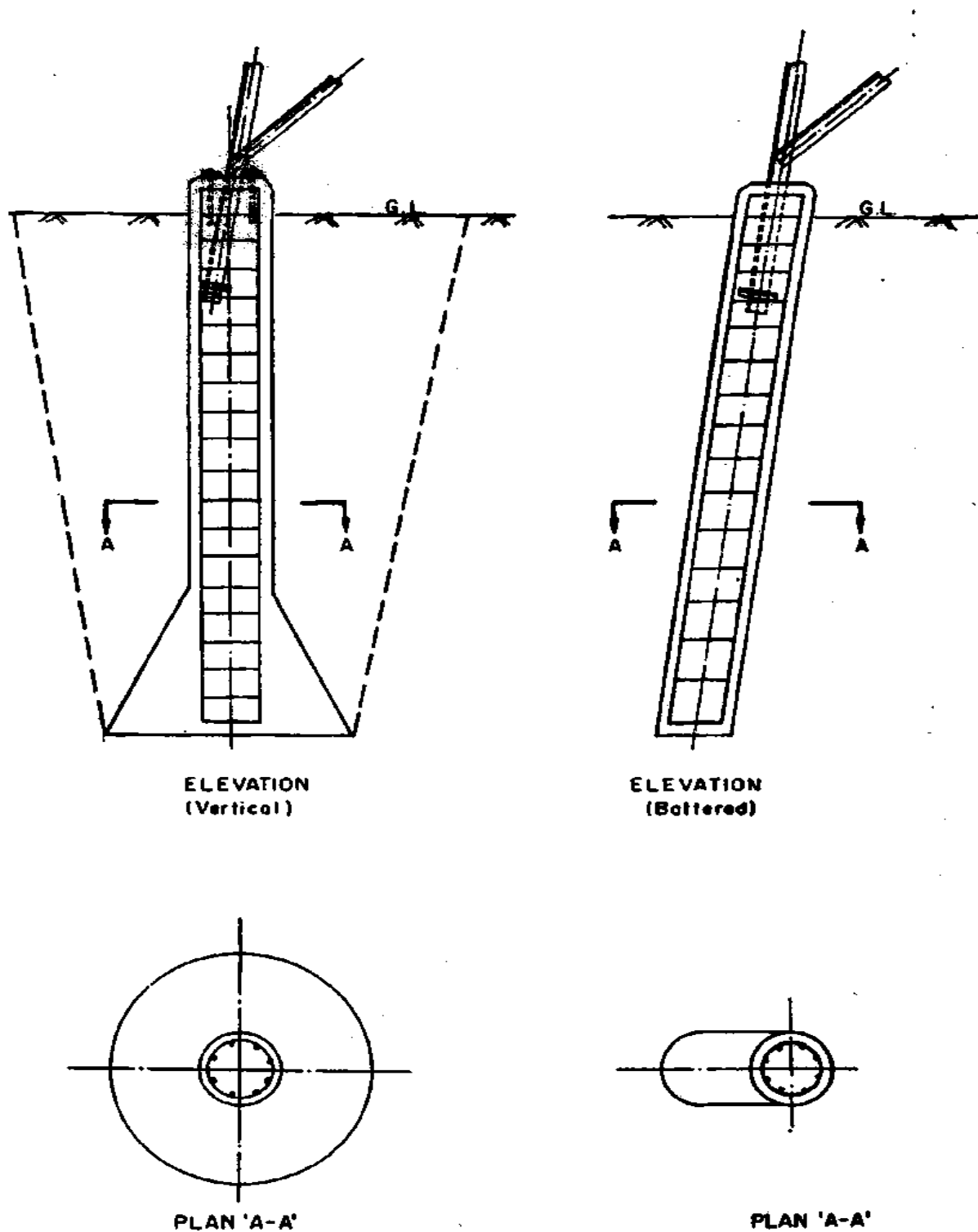


Figure-6. Augur Type

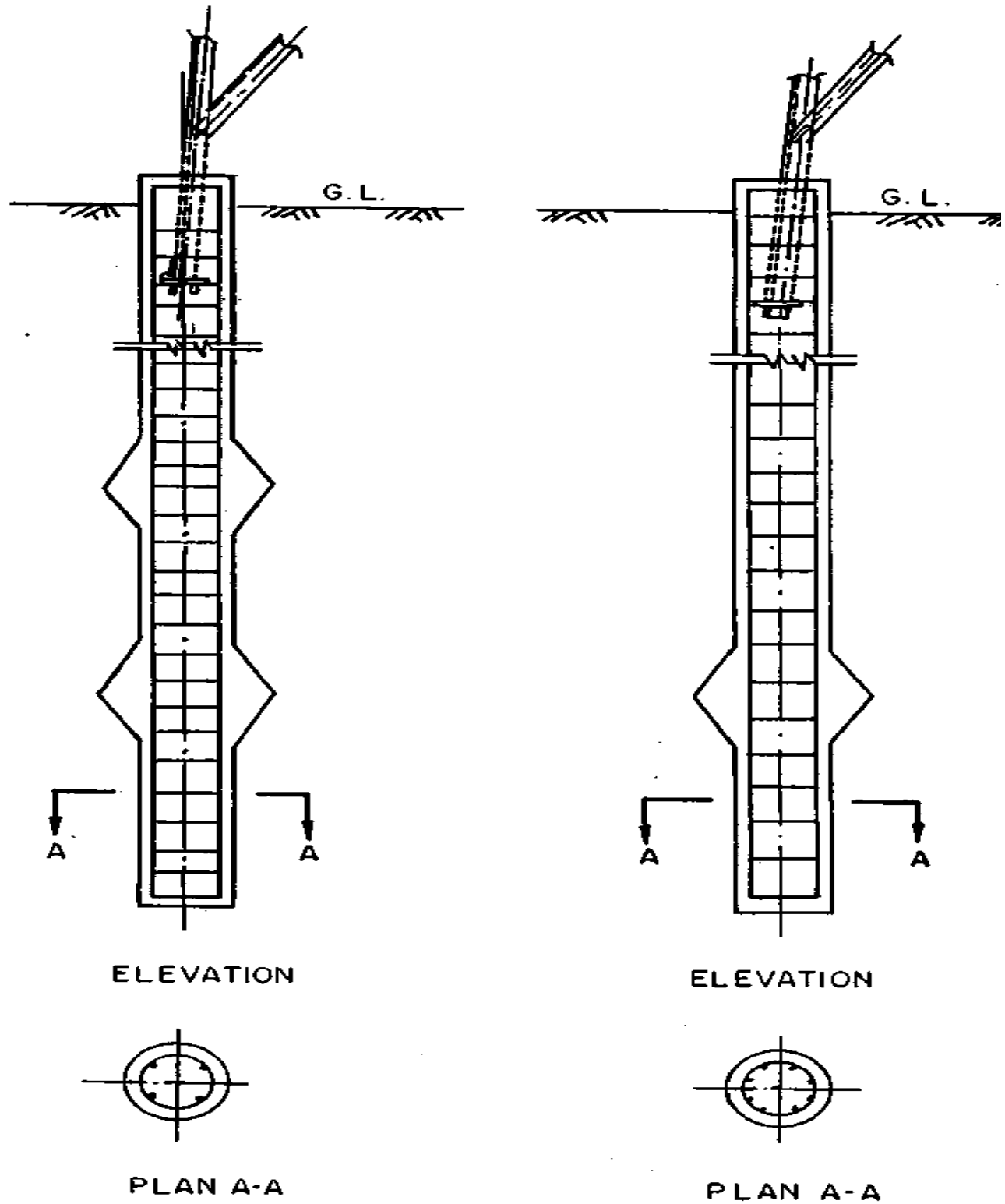


Figure-7 Under-Reamed Pile Type

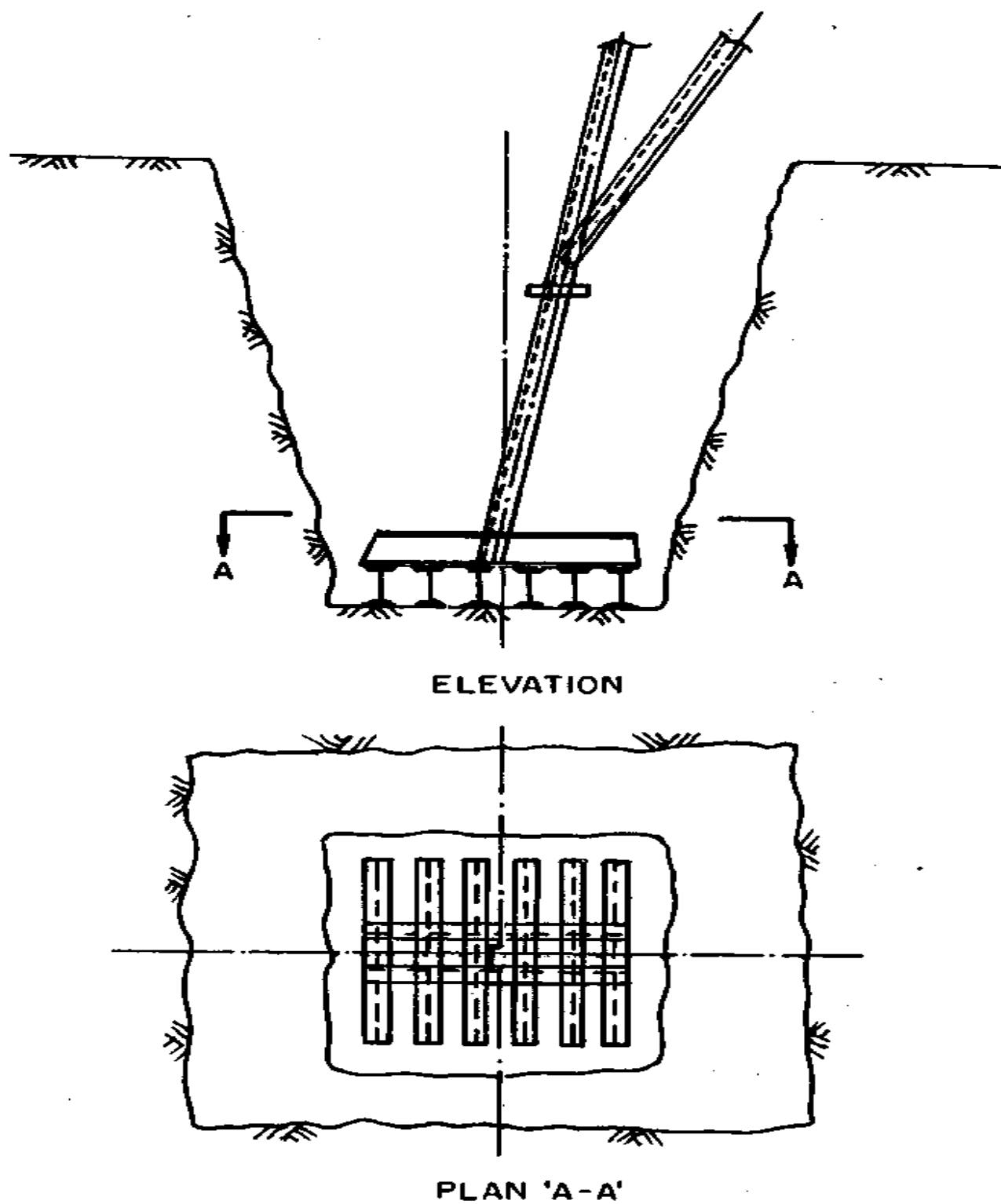


Figure-8. Steel Grillage Type

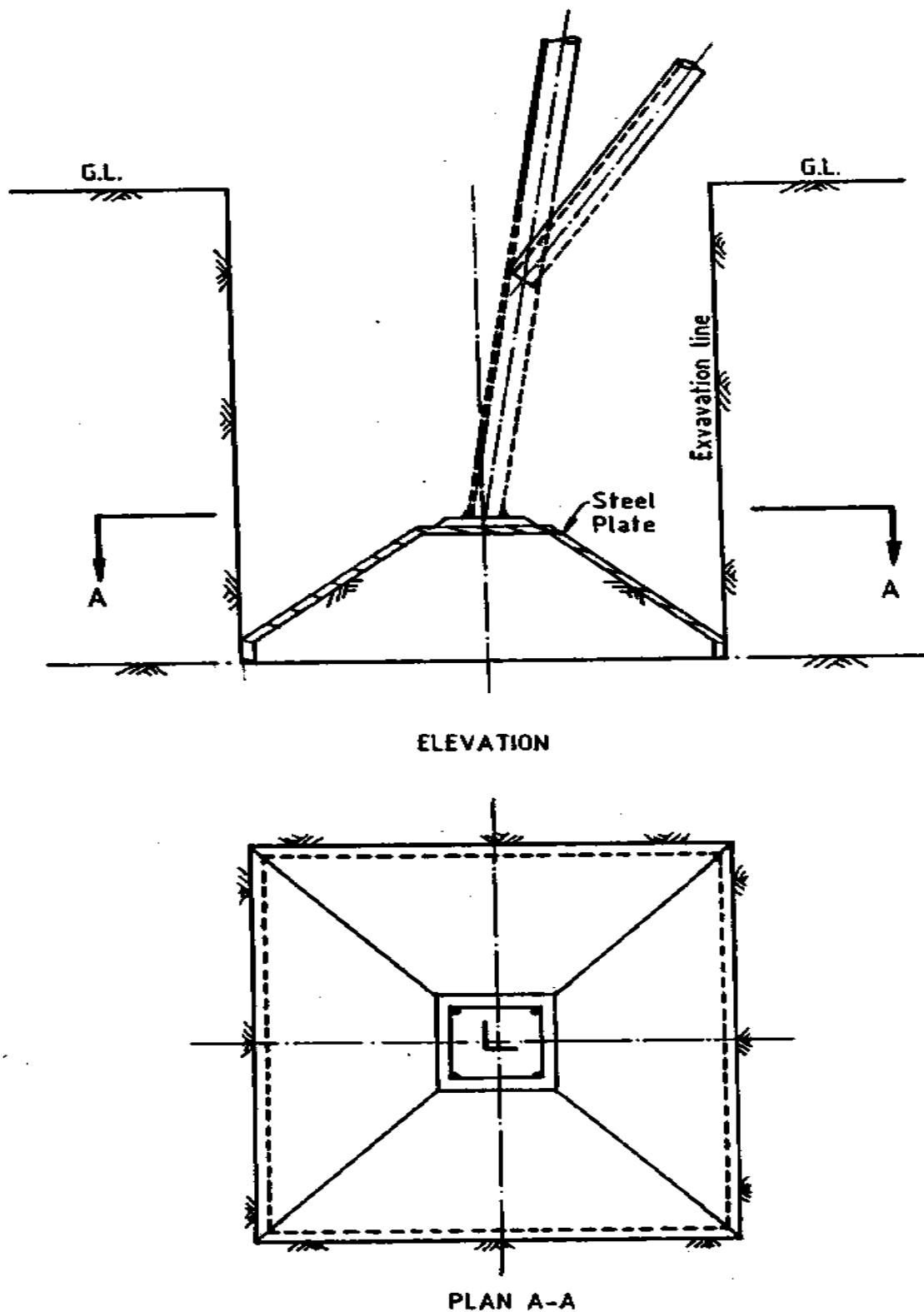


Figure-9. Steel Plated Type

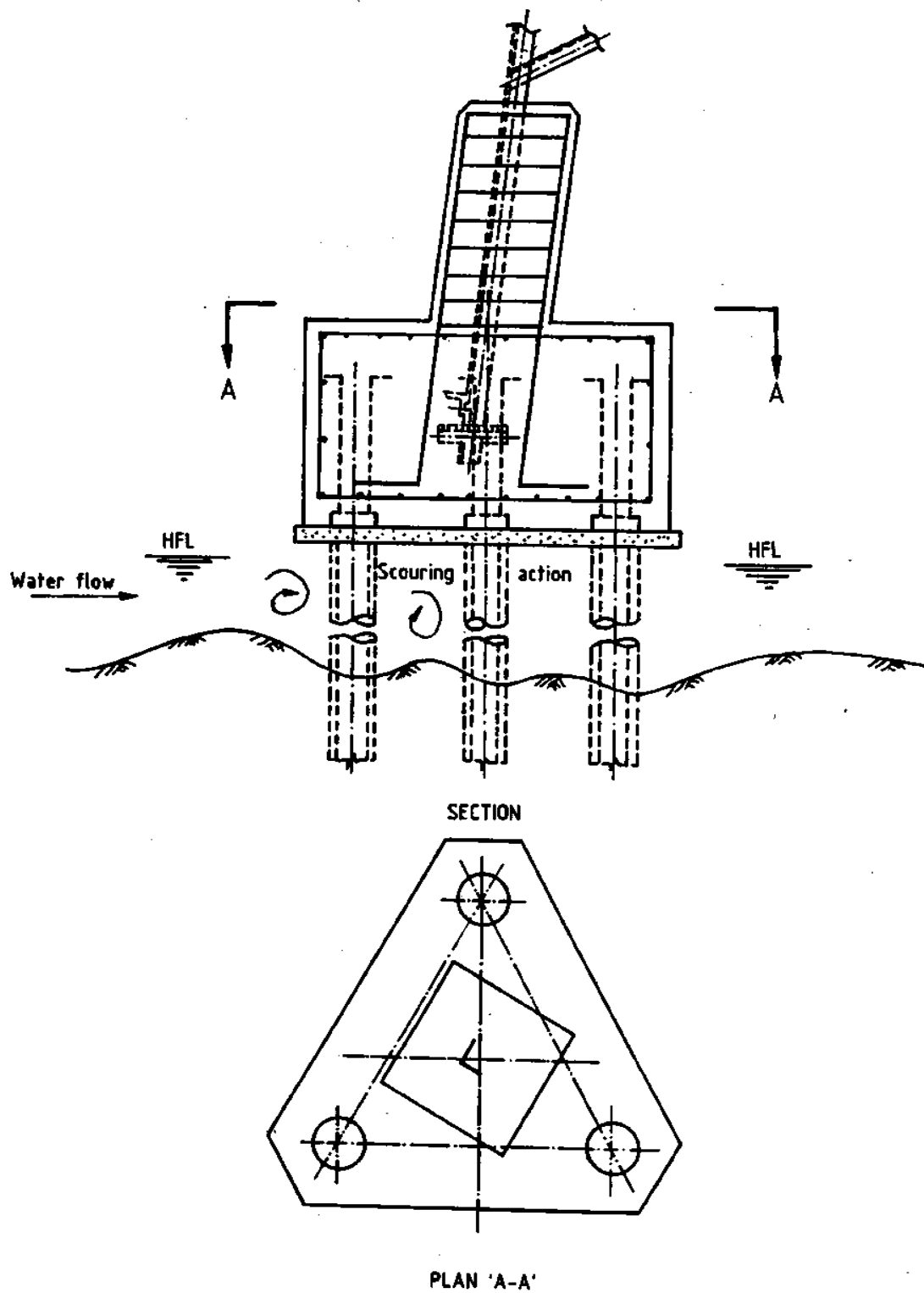


Figure-10. Pile Type

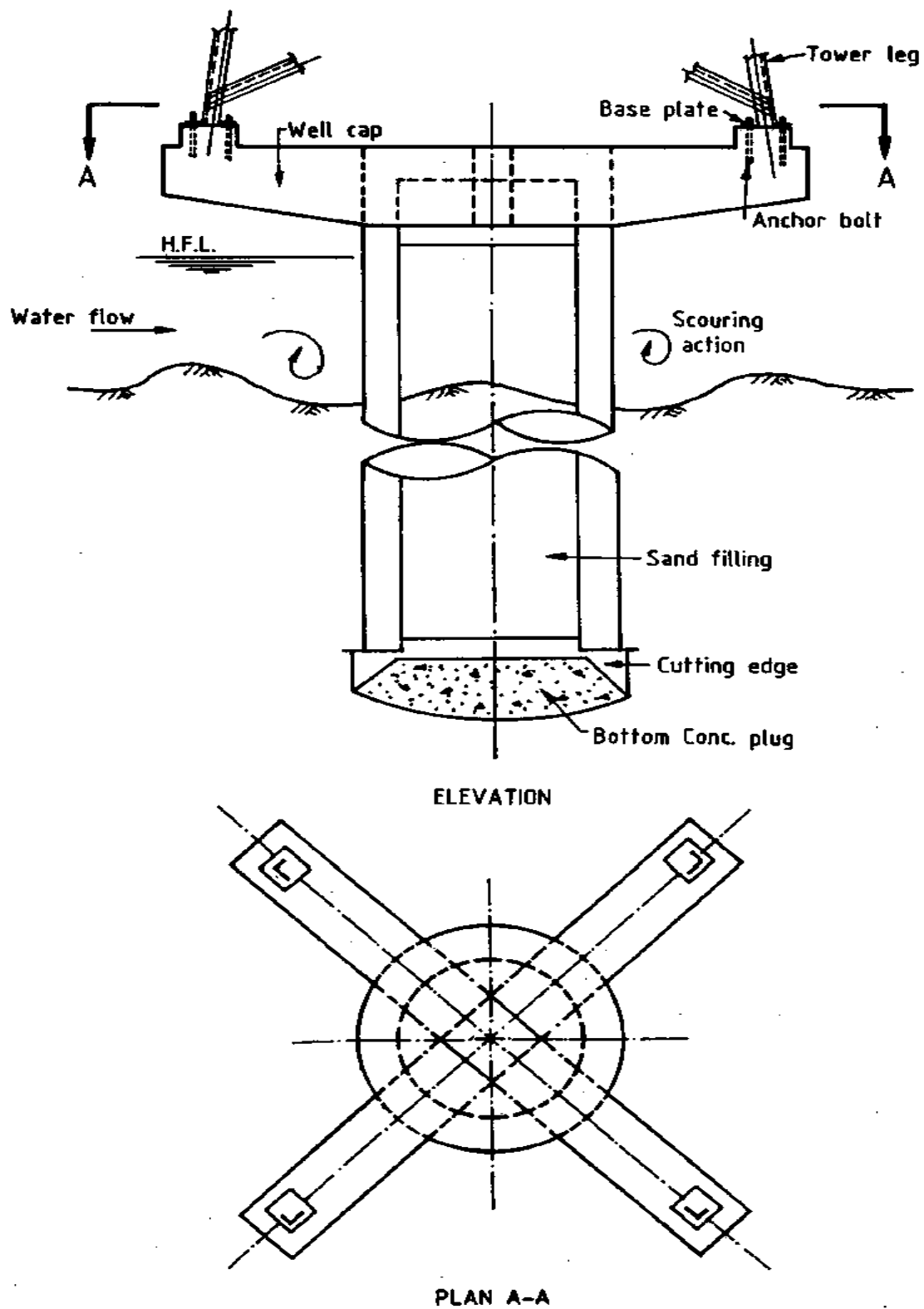


Figure-11. Well Type Foundation

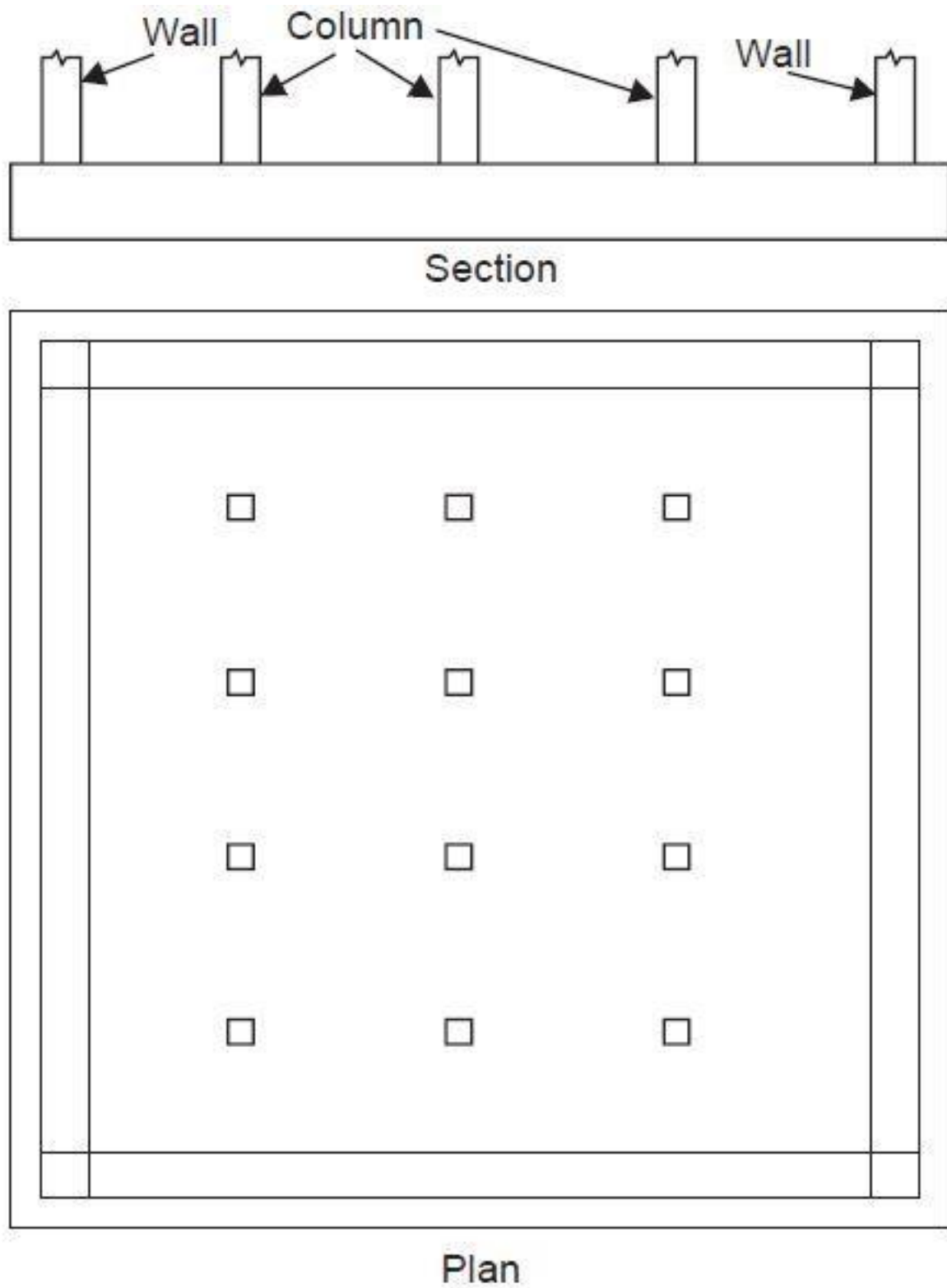


Figure-12. Raft Foundation

CHAPTER – 3
TYPE TESTED EHV TRANSMISSION LINE
TOWER DESIGNS
(AS PER IS 802:2015)

BINA – GWALIOR LINE



TALA-SILIGURI LINE

CHAPTER - 3

TYPE TESTED EHV TRANSMISSION LINE TOWER DESIGNS (AS PER IS 802:2015)

3.1 220 kV, Double circuit, DB type, Vertical configuration, Wind zone: 4

1. Tower structure : Self-supported Lattice

2. Voltage Class : 220kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: B type tower (deviation angle 0-15Deg)

5. Extension of Tower: -4.5 m / -3.0 m / -1.5 m / 0 m / +1.5 m / +3.0 m / +4.5 m / +6.0 m / +7.5 m / +9.0m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	MOOSE
2.	No. of conductor / Phase	TWIN
3.	Stranding & Wire diameter	54/3.53 mm Al+7/3.53 mm Steel
4.	Total sectional area	5.970 cm ²
5.	Overall diameter	3.177 cm
6.	Approx. Weight	2.004 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.05552 Ohm/km
8.	Approximate calculated breaking load	16428 kgs
9.	Modulus of elasticity	703400 kg/cm ²
10.	Co-efficient of linear Expansion	0.0000193/deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.223
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW		
1.	Type & Name	ZTT 11.2
2.	Stranding/Wire diameter	6.40 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	70.60 mm ²
4.	Overall diameter	1.12 cm
5.	Approx. Weight	0.414kg/m
6.	Calculated D.C resistance at 20 deg. C	0.836 Ohm/Km



7.	Min. UTS	7471.96 kgs
8.	Modulus of elasticity	11641.182 kg/mm ²
9.	Co-efficient of linear expansion	14.3X10 ⁻⁶ /deg C
10.	Temperature: • Max. temperature • Everyday temperature • Minimum temperature	53 deg.C 32 deg.C -5 deg.C
11.	Gust Response Factor	2.324
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- **Normal Span:**

Normal condition	Broken Wire Condition
350 m	210 m

- **Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	3614.16 kgs	877 kgs
Everyday Temperature Full Wind	7700.52 kgs	2557 kgs
0-degree Temperature 36% Wind	5269.88 kgs	1525 kgs

13. Height:

- Height of tower (Earth wire attachment point): 40.308 m
- Height of conductor attachment point(s): 30.285 m

14. Right of Way: 35 m

15. Insulator Strings Details:

- Size: 0.28m Dia
- No. of Discs: 17 (per Insulator String)
- Diameter: 0.28m
- Length: 3.44m
- Weight of Insulator: 150kg (per Insulator String)

- Electromechanical strength of strings: 320kN(Combined Strength for two strings)
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.390
- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 7.47 m
- Vertical spacing (Phase to Phase): 4.9 m
- Horizontal spacing (Phase to Phase): 8.40m
- Mid Span clearance: 8.50 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	2.663
10°	2.663
20°	2.094

- Shield angle: <30 deg

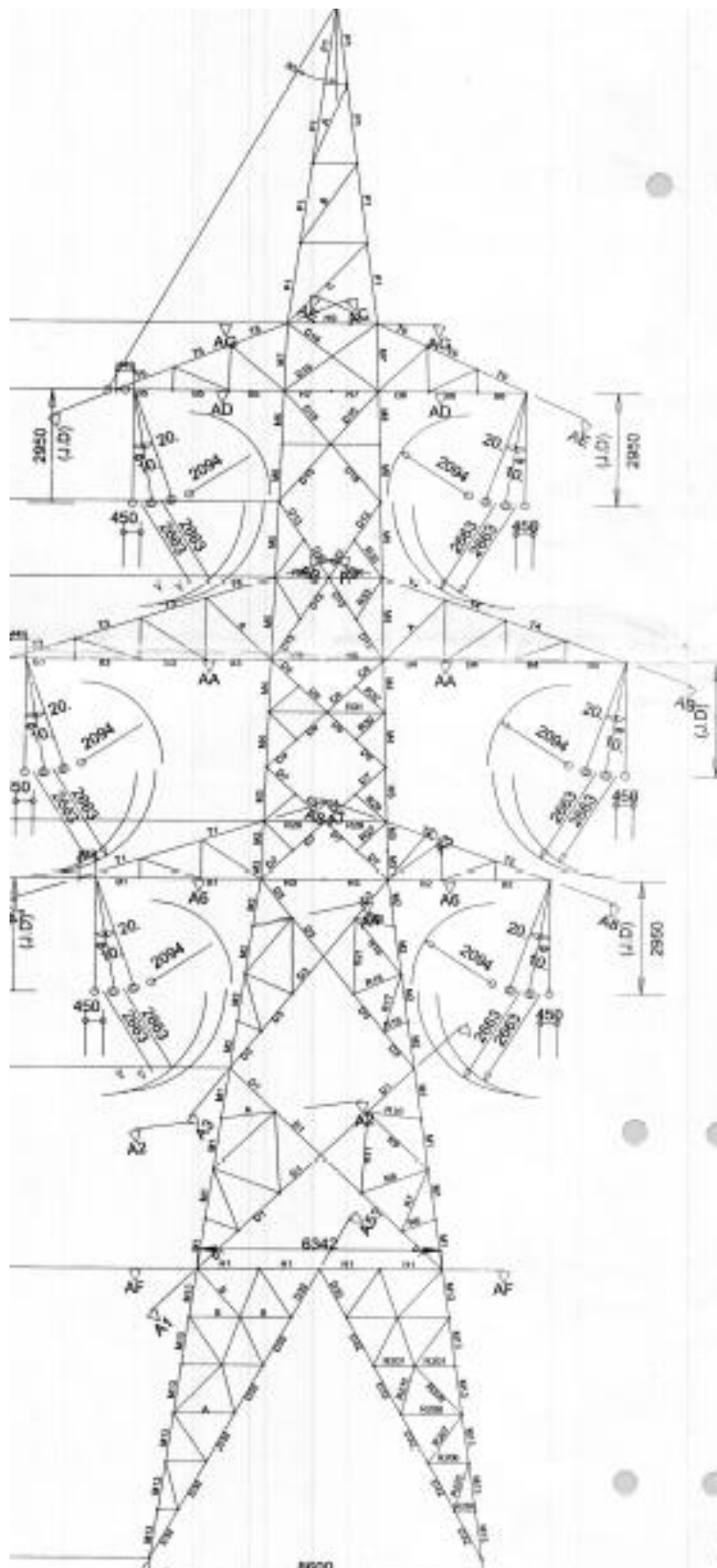
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



220KV D/C WZ 4 T.T. 'DB'

3.2 220 kV, Double circuit, DC type, Vertical configuration, Wind zone: 4

1. Tower structure : Self-supported Lattice

2. Voltage Class : 220kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: C type tower (deviation angle 0-30 Deg)

5. Extension of Tower: -4.5 m /-3.0 m /-1.5 m/ 0 m /+1.5 m /+3.0 m /+4.5 m / +6.0 m/
+7.5 m /+9.0 m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	MOOSE
2.	No. of conductor / Phase	TWIN
3.	Stranding & Wire diameter	54/3.53 mm Al+7/3.53 mm Steel
4.	Total sectional area	5.970 cm ²
5.	Overall diameter	3.177 cm

6.	Approx. Weight	2.004 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.05552 Ohm/km
8.	Approximate calculated breaking load	16428 kgs
9.	Modulus of elasticity	703400 kg/cm ²
10.	Co-efficient of linear Expansion	0.0000193/deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.223
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	ZTT 11.2
2.	Stranding/Wire diameter	6.40 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	70.60 mm ²
4.	Overall diameter	1.12 cm
5.	Approx. Weight	0.414kg/m
6.	Calculated D.C resistance at 20 deg. C	0.836 Ohm/Km
7.	Min. UTS	7471.96 kgs
8.	Modulus of elasticity	11641.182 kg/mm ²
9.	Co-efficient of linear expansion	14.3X10 ⁻⁶ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C



11.	Gust Response Factor	2.324
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
350 m	210 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	3614.16 kgs	877 kgs
Everyday Temperature Full Wind	7700.52 kgs	2557 kgs
0-degree Temperature 36% Wind	5269.88 kgs	1525 kgs

13. Height:

- Height of tower (Earth wire attachment point): 41.238 m
- Height of conductor attachment point(s): 30.285 m

14. Right of Way: 35 m**15. Insulator Strings Details:**

- Size: 0.28m Dia
- No. of Discs: 17 (per Insulator string)
- Diameter: 0.28m
- Length: 3.44m
- Weight of Insulator: 150kg (per Insulator string)
- Electromechanical strength of strings: 320kN(Combined Strength for two strings)



- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.390
- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 7.47 m
- Vertical spacing (Phase to Phase): 4.9 m
- Horizontal spacing (Phase to Phase): 8.40m
- Mid Span clearance: 8.50 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	2.663
10°	2.663
20°	2.094

- Shield angle: <30 deg

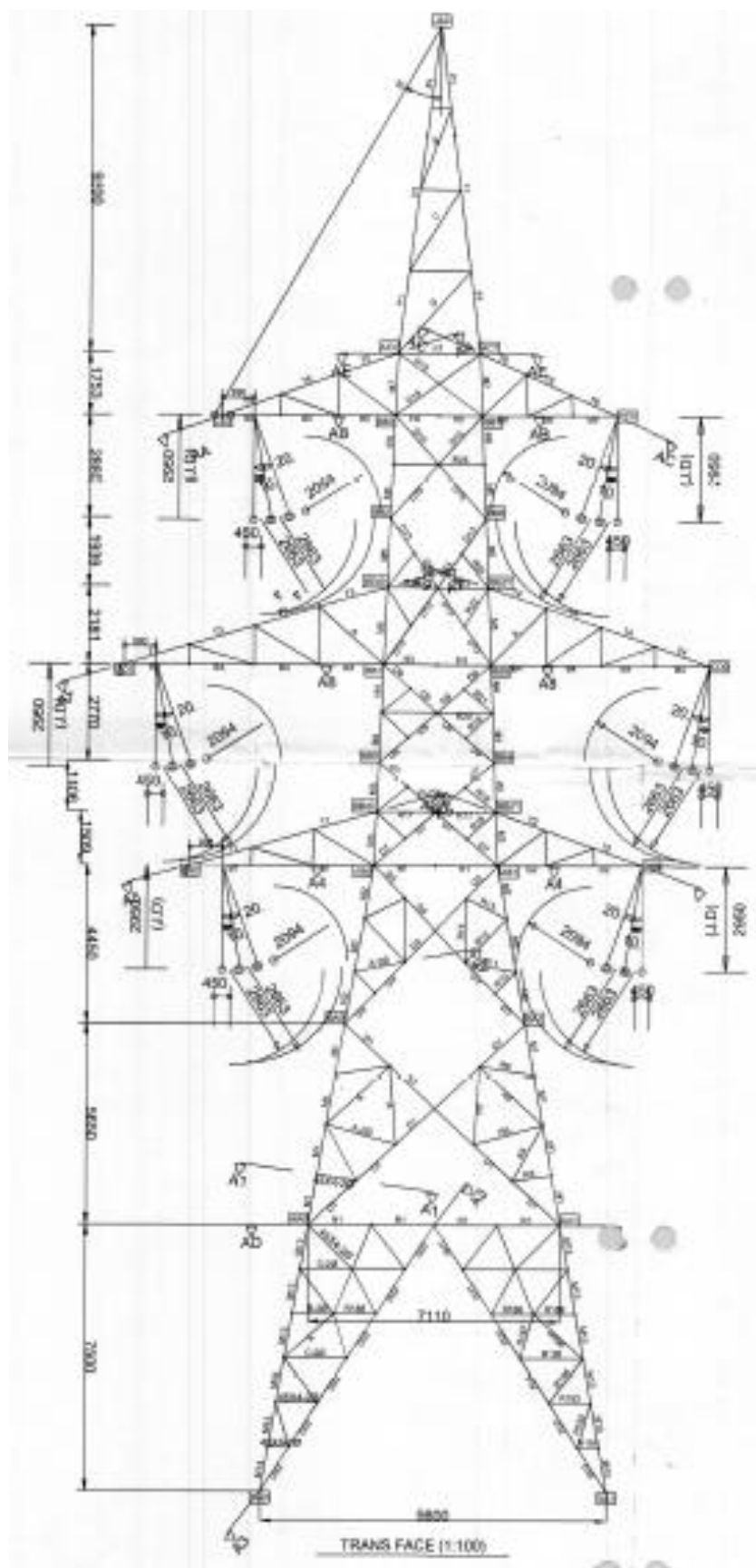
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



220KV D/C WZ 4 T.T. 'DC'

3.3 220 kV, Double circuit, DD type, Vertical configuration, Wind zone: 4

1. Tower structure : Self-supported Lattice

2. Voltage Class : 220kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: D type tower (deviation angle 30-60 Deg)

5. Extension of Tower: -4.5 m /-3.0 m /-1.5 m /0 m /+1.5 m /+3.0 m /+4.5 m /+6.0 m /+7.5 m /+9.0 m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	MOOSE
2.	No. of conductor / Phase	TWIN
3.	Stranding & Wire diameter	54/3.53 mm Al+7/3.53 mm Steel
4.	Total sectional area	5.970 cm ²
5.	Overall diameter	3.177 cm

6.	Approx. Weight	2.004 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.05552 Ohm/km
8.	Approximate calculated breaking load	16428 kgs
9.	Modulus of elasticity	703400 kg/cm ²
10.	Co-efficient of linear Expansion	0.0000193/deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.223
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	ZTT 11.2
2.	Stranding/Wire diameter	6.40 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	70.60 mm ²
4.	Overall diameter	1.12 cm
5.	Approx. Weight	0.414kg/m
6.	Calculated D.C resistance at 20 deg. C	0.836 Ohm/Km
7.	Min. UTS	7471.96 kgs
8.	Modulus of elasticity	11641.182 kg/mm ²
9.	Co-efficient of linear expansion	14.3X10 ⁻⁶ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C



11.	Gust Response Factor	2.324
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- **Normal Span:**

Normal condition	Broken Wire Condition
350 m	210 m

- **Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1500	900
Minimum	-1500	-900

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	3614.16 kgs	877 kgs
Everyday Temperature Full Wind	7700.52 kgs	2557 kgs
0-degree Temperature 36% Wind	5269.88 kgs	1525 kgs

13. Height:

- Height of tower (Earth wire attachment point): 42.881 m
- Height of conductor attachment point(s): 31.290 m

14. Right of Way: 35 m**15. Insulator Strings Details:**

- Size: 0.28m Dia
- No. of Discs: 17(per Insulator string)
- Diameter: 0.28m
- Length: 3.44m
- Weight of Insulator: 150kg (per Insulator string)
- Electromechanical strength of strings: 320kN (Combined Strength for two strings)
- Drag Coefficient: 1.2



- Gust Response Factor (GRF): 2.390
- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 7.47 m
- Vertical spacing (Phase to Phase): 4.9 m
- Horizontal spacing (Phase to Phase): 8.40m
- Mid Span clearance: 8.50 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	2.663
10°	2.663
20°	2.094

- Shield angle: <30 deg

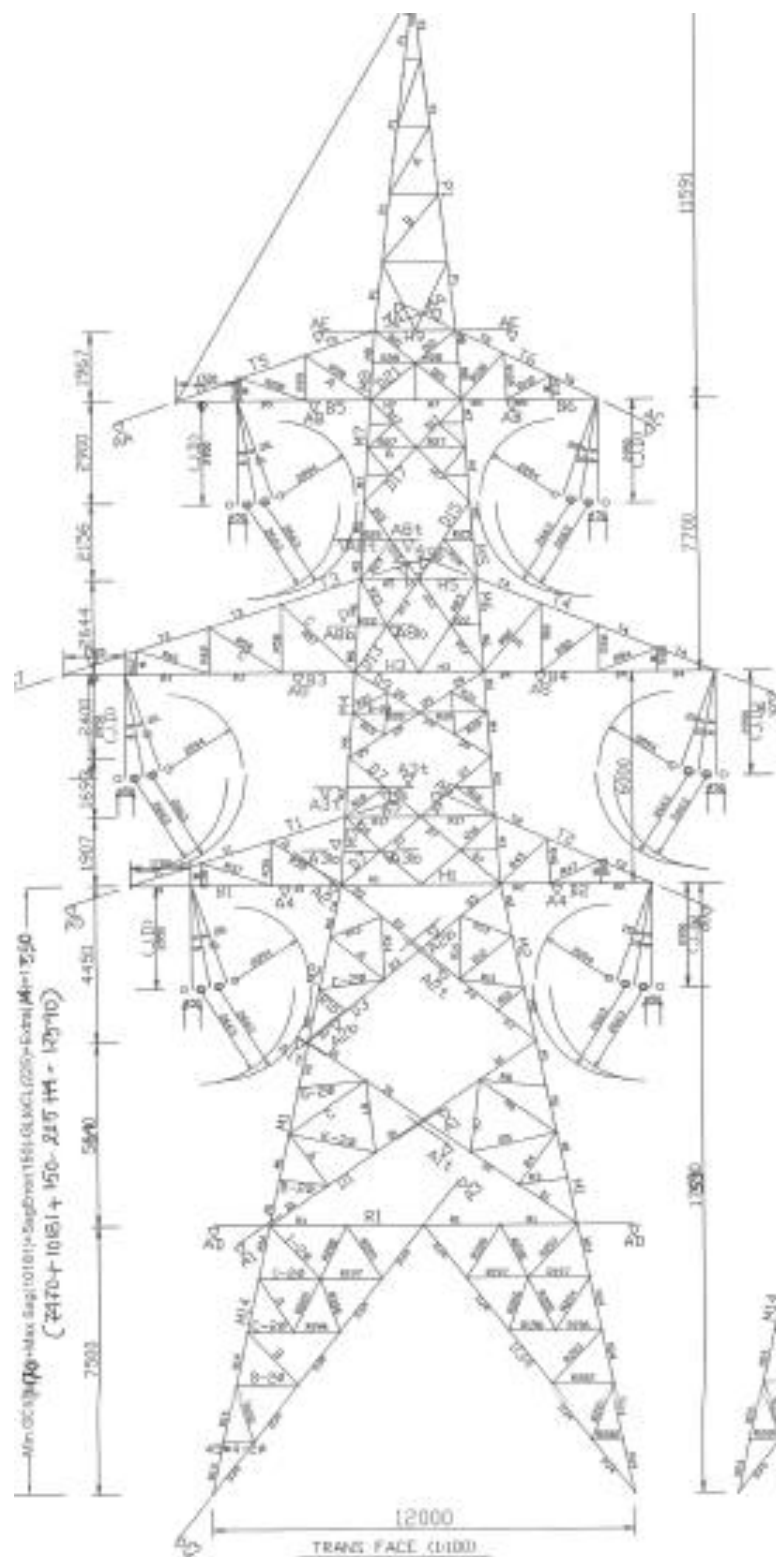
17. Type Test Result:

Type Tested Successfully

18. Installation experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



3.4 220 kV, Double circuit, DB type, Vertical configuration, Wind zone: 5

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 220kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: B type tower (deviation angle 0-15Deg)

5. **Extension of Tower**: -3.0 m / -1.5 m / 0 m / +1.5 m / +3.0 m / +4.5 m / +6.0 m / +7.5 m / +9.0 m

6. **Type of Configuration**: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 5(50 m/s)
- Design wind pressure: 80.88 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 2000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	ZEBRA
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	54/3.18 mm Al+7/3.18 mm Steel
4.	Total sectional area	4.8800 cm ²
5.	Overall diameter	2.8710 cm

6.	Approx. Weight	1.3450 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.06868 Ohm/km
8.	Approximate calculated breaking load	13154 kgs
9.	Modulus of elasticity	550000 kg/cm ²
10.	Co-efficient of linear Expansion	0.2300x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.2130
14.	Full Wind Pressure	80.88 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium cladded SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
11.	Gust Response Factor	2.233



12.	Full Wind Pressure	80.88 kg/m ²
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11. Spans

- Normal Span:**

Normal condition	Broken Wire Condition
350 m	210 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2894.17 kgs	1016.17 kgs
Everyday Temperature Full Wind	7263.03 kgs	2970.14 kgs
0-degree Temperature 36% Wind	4898.08 kgs	1811.33 kgs

13. Height:

- Height of tower (Earth wire attachment point): 37.115 m
- Height of conductor attachment point(s): 29.170 m

14. Right of Way: 35 m**15. Insulator Strings Details:**

- Size: 0.28m Dia
- No. of Discs: 16
- Diameter: 0.28m
- Length: 2.879m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 120kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.40



- Shape factor of Insulator: 0.5
- Full wind pressure: 80.88 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 7.25 m
- Vertical spacing (Phase to Phase): 4.9 m
- Horizontal spacing (Phase to Phase): 8.40m
- Mid Span clearance: 8.50 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	2.396
10°	2.396
20°	1.884

- Shield angle: <30 deg

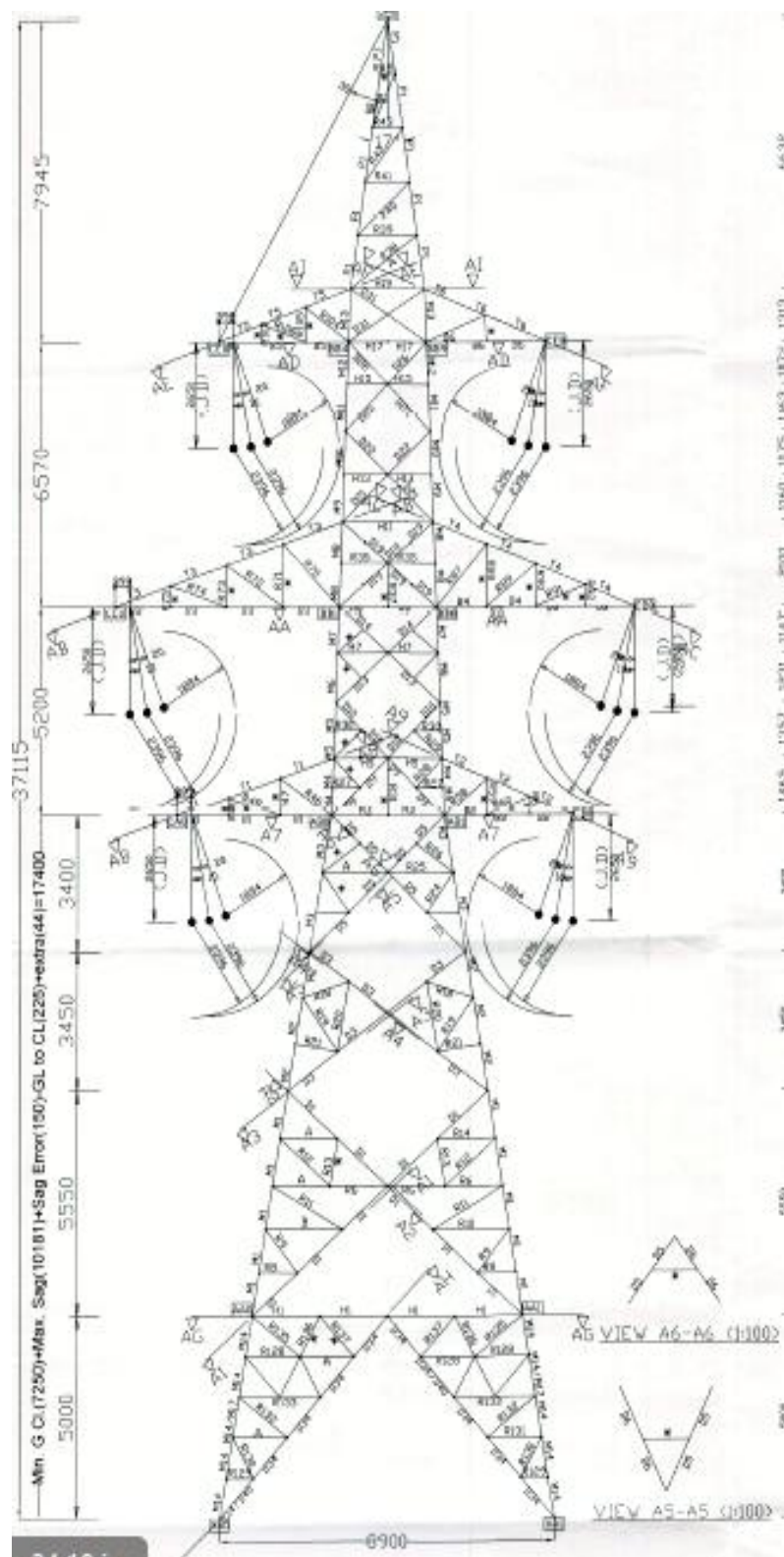
17. Type Test Result:

Type Tested Successfully

18. Installation experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



220KV D/C WZ 5 T.T. 'DB'

3.5 220 kV, Double circuit, DC type, Vertical configuration, Wind zone: 5

1. Tower structure : Self-supported Lattice

2. Voltage Class : 220kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: C type tower (deviation angle 0-30Deg)

5. Extension of Tower: 3.0 m /-1.5 m/ 0 m / +1.5 m/ +3.0 m /+4.5 m /+6.0 m/+7.5 m /+9.0 m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 5(50 m/s)
- Design wind pressure: 80.88 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 2000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	ZEBRA
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	54/3.18 mm Al+7/3.18 mm Steel
4.	Total sectional area	4.8800 cm ²



5.	Overall diameter	2.8710 cm
6.	Approx. Weight	1.3450 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.06868 Ohm/km
8.	Approximate calculated breaking load	13154 kgs
9.	Modulus of elasticity	550000 kg/cm ²
10.	Co-efficient of linear Expansion	0.2300x10 ⁻⁴ /deg.C
11.	Temperature: • Max. temperature • Everyday temperature • Minimum temperature	75 deg.C 32 deg.C 0 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.2130
14.	Full Wind Pressure	80.88 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium cladded SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: • Max. temperature • Everyday temperature • Minimum temperature	75 deg.C 32 deg.C 0 deg.C



11.	Gust Response Factor	2.233
12.	Full Wind Pressure	80.88 kg/m ²

11. Spans

- **Normal Span:**

Normal condition	Broken Wire Condition
350 m	210 m

- **Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2894.17 kgs	1016.17 kgs
Everyday Temperature Full Wind	7263.03 kgs	2970.14 kgs
0-degree Temperature 36% Wind	4898.08 kgs	1811.33 kgs

13. Height:

- Height of tower (Earth wire attachment point): 38.02 m
- Height of conductor attachment point(s): 29.170 m

14. Right of Way: 35 m**15. Insulator Strings Details:**

- Size: 0. 28m Dia
- No. of Discs: 16
- Diameter: 0.28m
- Length: 2.879m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 120kN



- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.40
- Shape factor of Insulator: 0.5
- Full wind pressure: 80.88 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 7.25 m
- Vertical spacing (Phase to Phase): 4.9 m
- Horizontal spacing (Phase to Phase): 8.40m
- Mid Span clearance: 8.50 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	2.396
10°	2.396
20°	1.884

- Shield angle: <30 deg

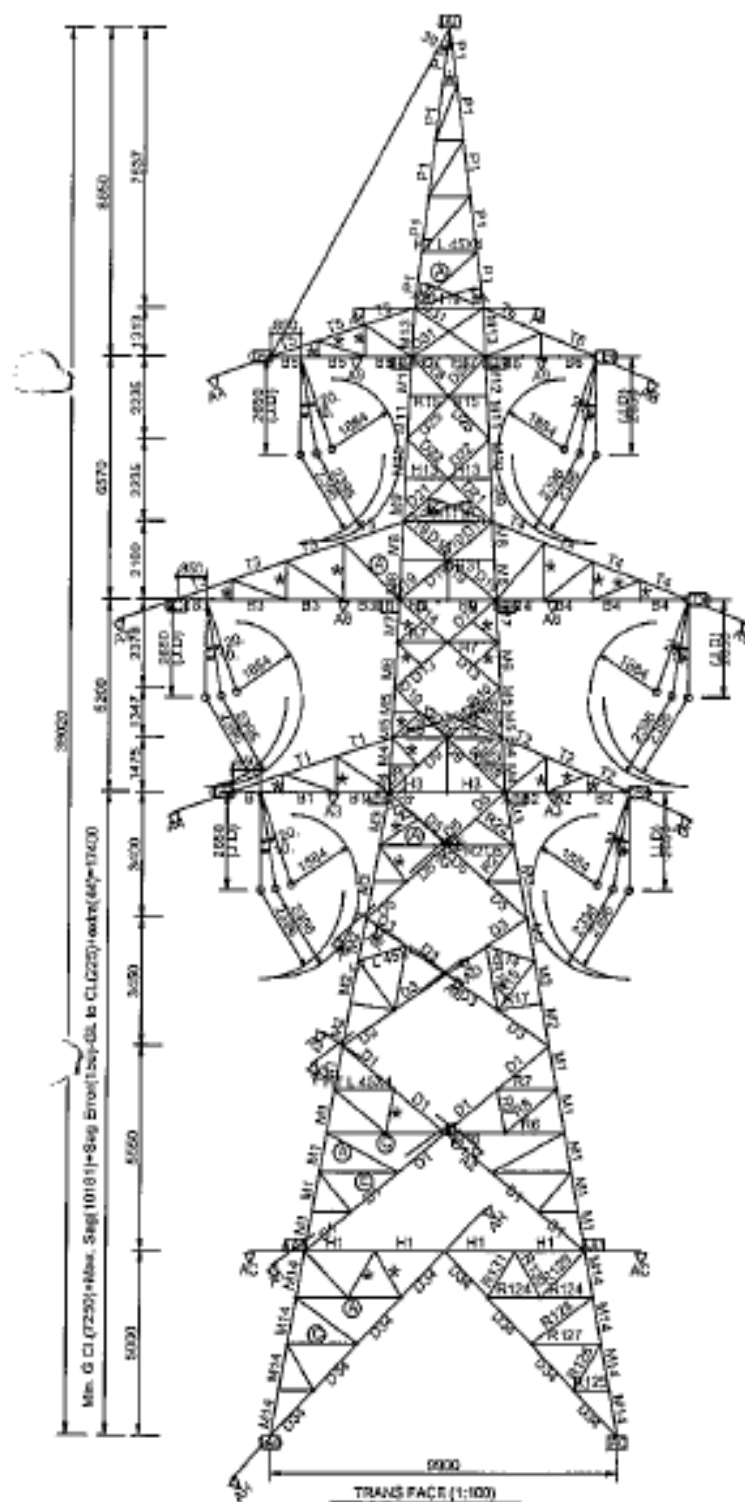
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



220KV D/C WZ 5 T.T. 'DC'

3.6 220 kV, Double circuit, DD type, Vertical configuration, Wind zone: 5

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 220kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: D type tower (deviation angle 0-60Deg)

5. **Extension of Tower**: -3.0 m /-1.5 m / 0 m/+1.5 m/+3.0 m/+4.5 m/+6.0 m /+7.5 m /+9.0 m

6. **Type of Configuration**: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 5(50 m/s)
- Design wind pressure: 80.88 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 2000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	ZEBRA
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	54/3.18 mm Al+7/3.18 mm Steel
4.	Total sectional area	4.8800 cm ²
5.	Overall diameter	2.8710 cm

6.	Approx. Weight	1.3450 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.06868 Ohm/km
8.	Approximate calculated breaking load	13154 kgs
9.	Modulus of elasticity	550000 kg/cm ²
10.	Co-efficient of linear Expansion	0.2300x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.2130
14.	Full Wind Pressure	80.88 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium cladded SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
11.	Gust Response Factor	2.233



12.	Full Wind Pressure	80.88 kg/m ²
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11. Spans

- Normal Span:**

Normal condition	Broken Wire Condition
350 m	210 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1500	900
Minimum	-1500	-900

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2894.17 kgs	1016.17 kgs
Everyday Temperature Full Wind	7263.03 kgs	2970.14 kgs
0-degree Temperature 36% Wind	4898.08 kgs	1811.33 kgs

13. Height:

- Height of tower (Earth wire attachment point): 40.120 m
- Height of conductor attachment point(s): 29.470 m

14. Right of Way: 35 m**15. Insulator Strings Details:**

- Size: 0.28m Dia
- No. of Discs: 16
- Diameter: 0.28m
- Length: 2.879m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 120kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.40



- Shape factor of Insulator: 0.5
- Full wind pressure: 80.88 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 7.25 m
- Vertical spacing (Phase to Phase): 4.9 m
- Horizontal spacing (Phase to Phase): 8.40m
- Mid Span clearance: 8.50 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	2.396
10°	2.396
20°	1.884

- Shield angle: <30 deg

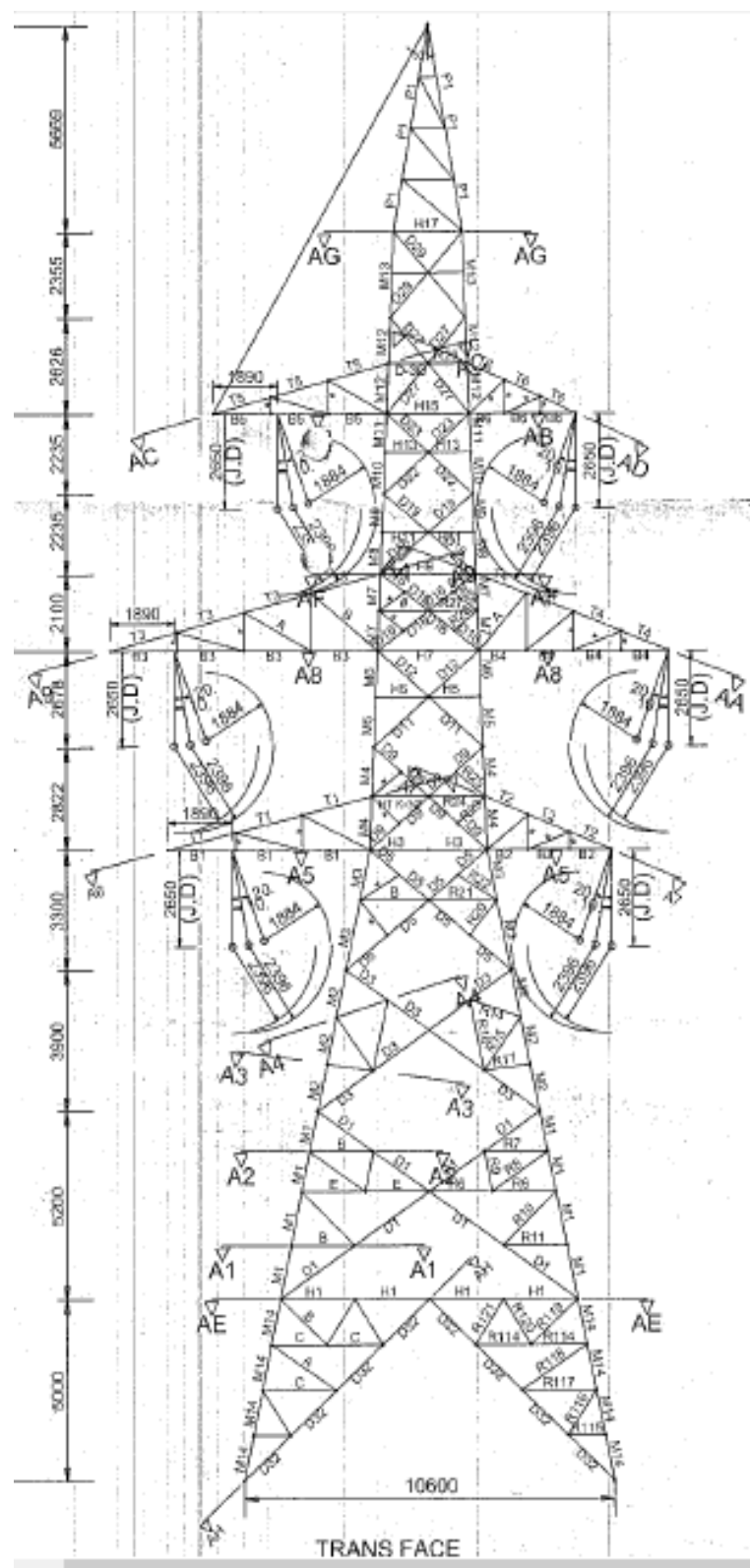
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



220KV D/C WZ 5 T.T. 'DD'

3.7 132 kV, Double circuit, Tower type DB, Vertical configuration Wind zone:4

1. **Tower structure** : Self-supported Lattice
2. **Voltage Class** : 132kV
3. **Utility / Firm** : PGCIL
4. **Classification/Type of Tower**: DB type tower (deviation angle 0-15Deg)
5. **Extension of Tower**: -3.0 m /-1.5 m /0 m /+1.5 m /+3.0 m/+4.5 m/ +6.0 m/+7.5 m / +9.0 m
6. **Type of Configuration**: Double Circuit (D/C)
 - Configuration of Conductors: Vertical
 - Configuration of Insulators: Tension
 - Configuration of Earth wire : Single peak
7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).
8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:
 - Wind Zone and Basic Wind Speed: 4(47 m/s)
 - Design wind pressure: 71.46 kg/m²
 - Terrain Category: 2
 - Reliability Level: 1
 - Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	PANTHER
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	30/3.00 mm Al+7/3.00 mm Steel
4.	Total sectional area	2.6150 cm ²
5.	Overall diameter	2.10 cm

6.	Approx. Weight	0.9740 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.14 Ohm/km
8.	Approximate calculated breaking load	9144 kgs
9.	Modulus of elasticity	815800 kg/cm ²
10.	Co-efficient of linear Expansion	0.178x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1630
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: 1. Max. temperature 2. Everyday temperature 3. Minimum temperature	53 deg.C 32 deg.C -5 deg.C



11.	Gust response factor	2.238
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
320 m	192 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2286 kgs	1095 kgs
Everyday Temperature Full Wind	4931.29 kgs	2664.44 kgs
0-degree Temperature 36% Wind	3534.53 kgs	1739.18 kgs

13. Height:

- Height of tower (Earth wire attachment point): 29.305 m
- Height of conductor attachment point(s): 23.035 m

14. Right of Way: 27 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 12
- Diameter: 0.255m
- Length: 2.098m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 90kN



- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.32
- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m^2

16. Electrical Clearances:

- Minimum Ground Clearance: 6.33 m
- Vertical spacing (Phase to Phase): 4.6 m
- Horizontal spacing (Phase to Phase): 7.06m
- Mid Span clearance: 6.33 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.913
10°	1.913
20°	1.338
30°	1.338

- Shield angle: <30 deg

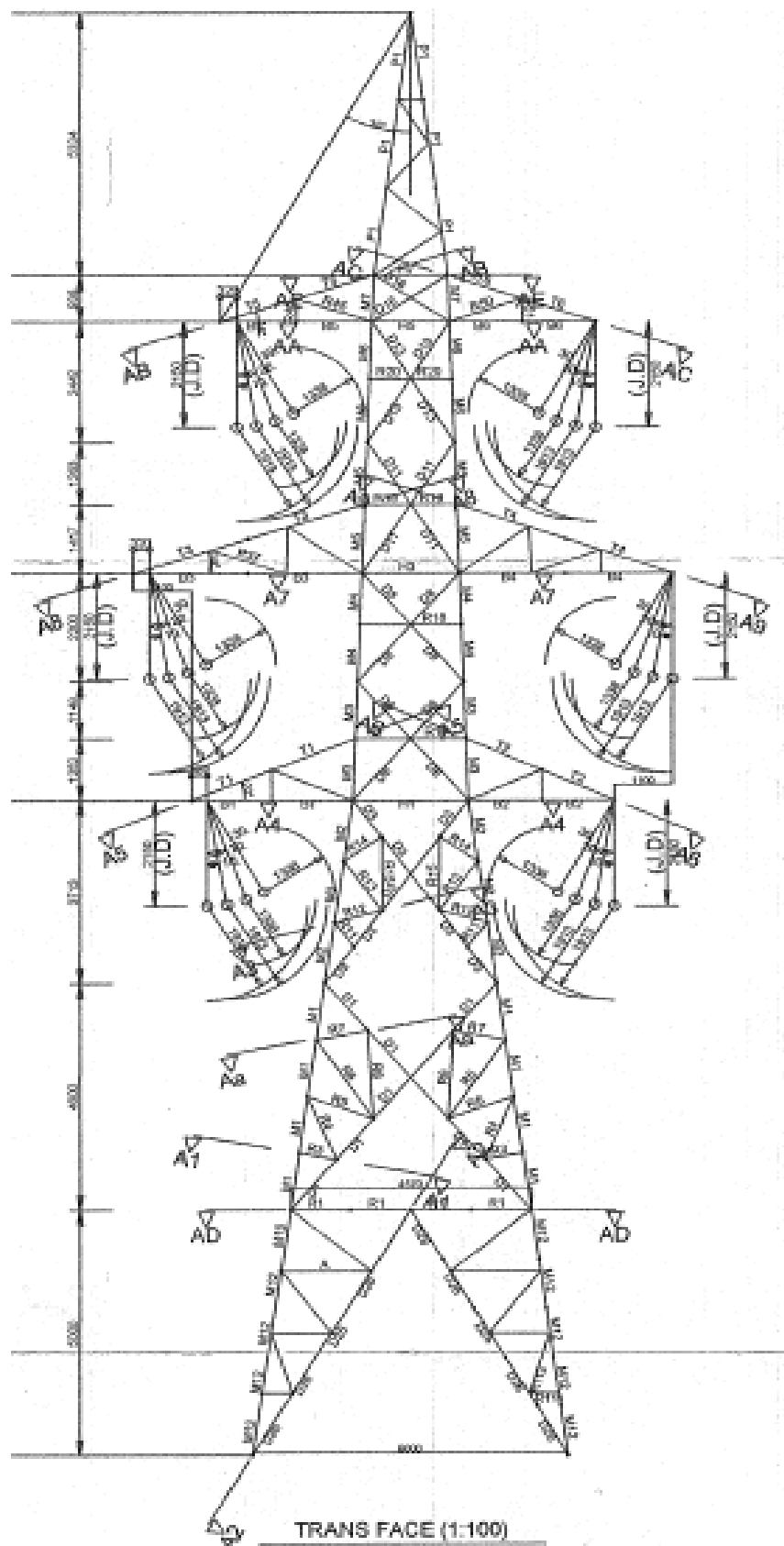
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



132KV D/C WZ 4 T.T. 'DB'

3.8 132 kV, Double circuit, Tower type DC, Vertical configuration, Wind zone: 4

1. Tower structure : Self-supported Lattice

2. Voltage Class : 132kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: C type tower (deviation angle 15-30 Deg)

5. Extension of Tower: -3.0 m/-1.5 m/ 0 m / +1.5 m/ +3.0 m/ +4.5 m/+6.0 m/+7.5 m /+9.0 m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	PANTHER
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	30/3.00 mm Al+7/3.00 mm Steel
4.	Total sectional area	2.6150 cm ²
5.	Overall diameter	2.10 cm

6.	Approx. Weight	0.9740 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.14 Ohm/km
8.	Approximate calculated breaking load	9144 kgs
9.	Modulus of elasticity	815800 kg/cm ²
10.	Co-efficient of linear Expansion	0.178x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1630
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C



11.	Gust response factor	2.238
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
320 m	192 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2286 kgs	1095 kgs
Everyday Temperature Full Wind	4931.29 kgs	2664.44 kgs
0-degree Temperature 36% Wind	3534.53 kgs	1739.18 kgs

13. Height:

- Height of tower (Earth wire attachment point): 30.187 m
- Height of conductor attachment point(s): 23.061 m

14. Right of Way: 27 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 12
- Diameter: 0.255m
- Length: 2.098m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 90kN
- Drag Coefficient: 1.2



- Gust Response Factor (GRF): 2.32
- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 6.33 m
- Vertical spacing (Phase to Phase): 4.6 m
- Horizontal spacing (Phase to Phase): 7.06m
- Mid Span clearance: 6.33 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.913
10°	1.913
20°	1.338
30°	1.338

- Shield angle: <30 deg

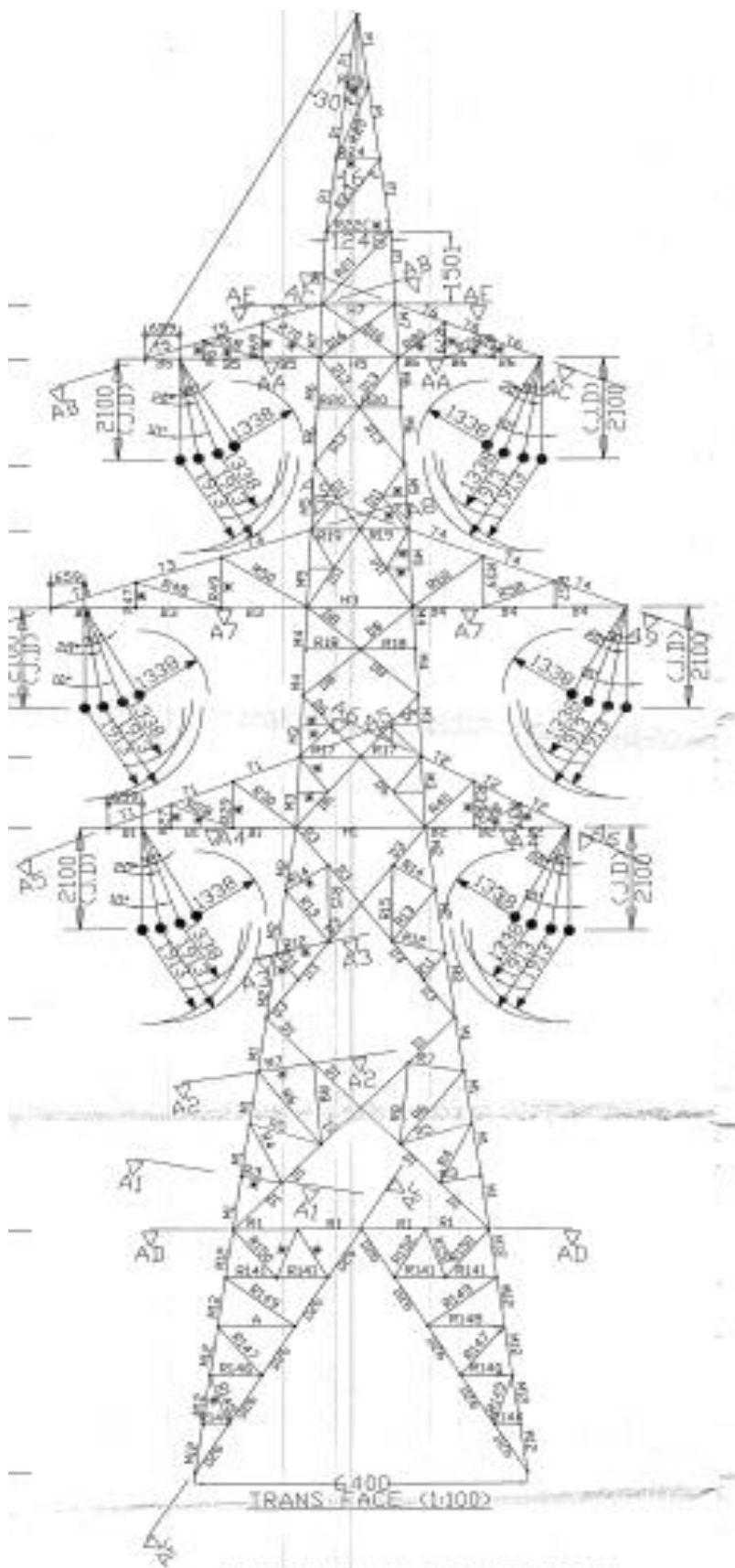
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



132KV D/C WZ 4 T.T. 'DC'

3.9 132 kV, Double circuit, Tower type DD, Vertical configuration, Wind zone: 4

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 132kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: D type tower (deviation angle 0-60 Deg)

5. **Extension of Tower**: -3.0 m /-1.5 m/ 0 m /+1.5 m /+3.0 m/+4.5 m/+6.0 m /+7.5 m /+9.0 m

6. **Type of Configuration**: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	PANTHER
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	30/3.00 mm Al+7/3.00 mm Steel
4.	Total sectional area	2.6150 cm ²
5.	Overall diameter	2.10 cm
6.	Approx. Weight	0.9740 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.14 Ohm/km
8.	Approximate calculated breaking load	9144 kgs
9.	Modulus of elasticity	815800 kg/cm ²
10.	Co-efficient of linear Expansion	0.178x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1630
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: 1. Max. temperature 2. Everyday temperature 3. Minimum temperature	53 deg.C 32 deg.C -5 deg.C
11.	Gust response factor	2.238



12.	Full Wind Pressure	71.46 kg/m ²
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11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
320 m	192 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1500	900
Minimum	-1500	-900

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2286 kgs	1095 kgs
Everyday Temperature Full Wind	4931.29 kgs	2664.44 kgs
0-degree Temperature 36% Wind	3534.53 kgs	1739.18 kgs

13. Height:

- Height of tower (Earth wire attachment point): 31.162 m
- Height of conductor attachment point(s): 23.077 m

14. Right of Way: 27 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 12
- Diameter: 0.255m
- Length: 2.098m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 90kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.32



- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 6.33 m
- Vertical spacing (Phase to Phase): 4.6 m
- Horizontal spacing (Phase to Phase): 7.06m
- Mid Span clearance: 6.33 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.913
10°	1.913
20°	1.338
30°	1.338

- Shield angle: <30 deg

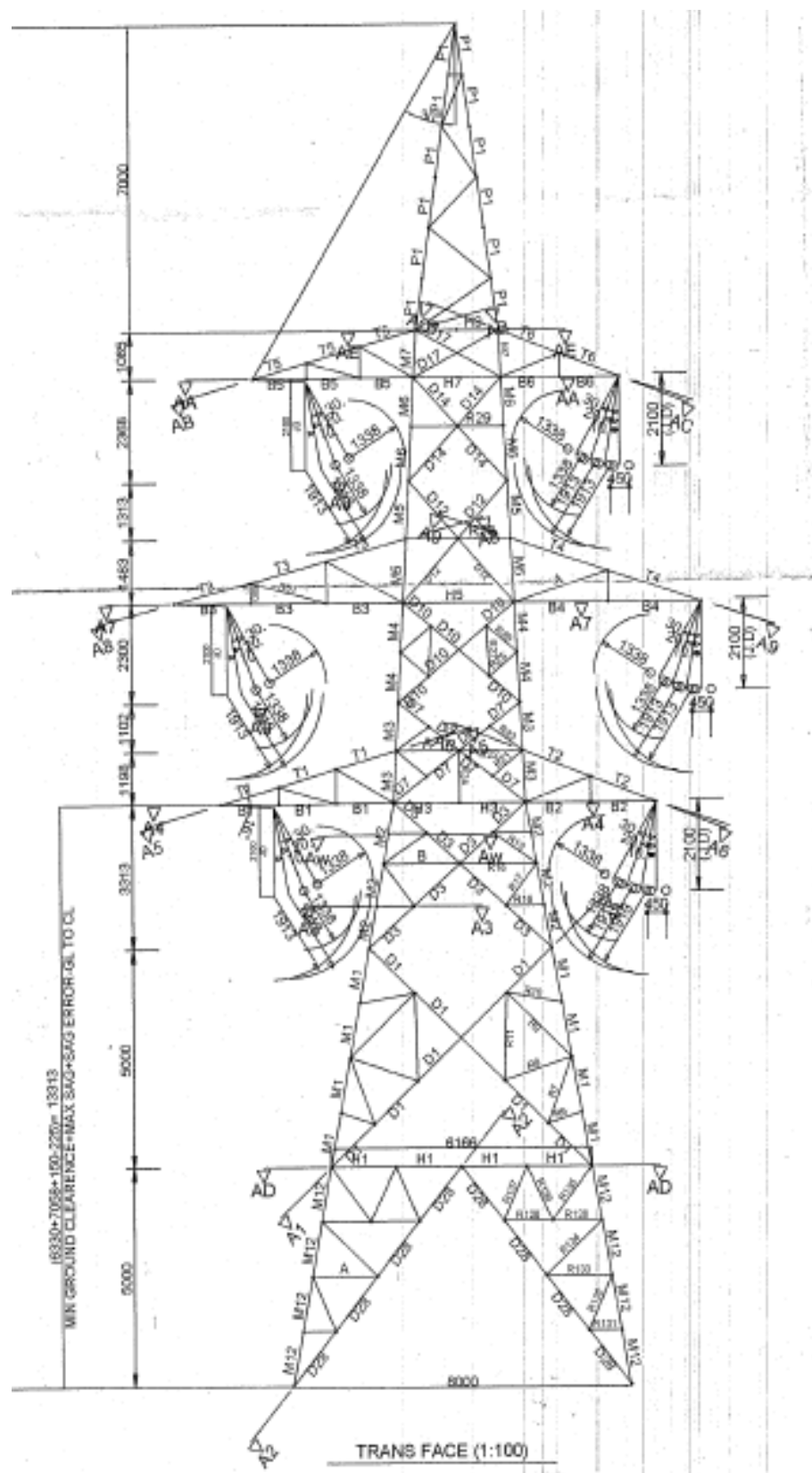
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



3.10 132 kV, Double circuit, DB type, Vertical configuration, Wind zone: 6

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 132kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: DB type tower (deviation angle 0-15Deg)

5. **Extension of Tower**: -3.0 m /-1.5 m /0 m /+1.5 m/+3.0 m/+4.5 m /+6.0 m/+7.5 m /+9.0 m

6. **Type of Configuration**: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 6(55 m/s)
- Design wind pressure: 97.89 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 2000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	PANTHER
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	30/3.00 mm Al+7/3.00 mm Steel
4.	Total sectional area	2.6150 cm ²
5.	Overall diameter	2.10 cm
6.	Approx. Weight	0.9740 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.14 Ohm/km
8.	Approximate calculated breaking load	9144 kgs
9.	Modulus of elasticity	815800 kg/cm ²
10.	Co-efficient of linear Expansion	0.178x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1630
14.	Full Wind Pressure	97.89 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C 0 deg.C
11.	Gust Response Factor	2.233



12.	Full Wind Pressure	97.89 kg/m ²
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11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
320 m	192 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2286 kgs	1080 kgs
Everyday Temperature Full Wind	5953.85 kgs	3185.12 kgs
0-degree Temperature 36% Wind	3924.11 kgs	1955.26 kgs

13. Height:

- Height of tower (Earth wire attachment point): 28.681 m
- Height of conductor attachment point(s): 22.515 m

14. Right of Way: 27 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 11
- Diameter: 0.255m
- Length: 1.939m
- Weight of Insulator: 145kg
- Electromechanical strength of strings: 120kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.32



- Shape factor of Insulator: 0.5
- Full wind pressure: 97.89 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 6.33 m
- Vertical spacing (Phase to Phase): 4.6 m
- Horizontal spacing (Phase to Phase): 7.06m
- Mid Span clearance: 6.33 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.722
10°	1.722
20°	1.204
30°	1.204

- Shield angle: <30 deg

17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



3.11 132 kV, Double circuit, DC type, Vertical configuration, Wind zone: 6

1. Tower structure : Self-supported Lattice

2. Voltage Class : 132kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: C type tower (deviation angle 15-30Deg)

5. Extension of Tower: -3.0 m /-1.5 m /0 m/+1.5 m/ +3.0 m /+4.5 m/+6.0 m /+7.5 m /+9.0 m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 6(55 m/s)
- Design wind pressure: 97.89 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 2000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	PANTHER
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	30/3.00 mm Al+7/3.00 mm Steel
4.	Total sectional area	2.6150 CM ²
5.	Overall diameter	2.10 cm
6.	Approx. Weight	0.9740 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.14 Ohm/km
8.	Approximate calculated breaking load	9144 kgs
9.	Modulus of elasticity	815800 kg/cm ²
10.	Co-efficient of linear Expansion	0.178x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1630
14.	Full Wind Pressure	97.89 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C 0 deg.C
11.	Gust Response Factor	2.233



12.	Full Wind Pressure	97.89 kg/m ²
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11. Spans

- Normal Span:**

Normal condition	Broken Wire Condition
320 m	192 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2286 kgs	1080 kgs
Everyday Temperature Full Wind	5953.85 kgs	3185.12 kgs
0-degree Temperature 36% Wind	3924.11 kgs	1955.26 kgs

13. Height:

- Height of tower (Earth wire attachment point): 29.252 m
- Height of conductor attachment point(s): 22.515 m

14. Right of Way: 27 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 11
- Diameter: 0.255m
- Length: 1.939m
- Weight of Insulator: 145kg
- Electromechanical strength of strings: 120kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.32



- Shape factor of Insulator: 0.5
- Full wind pressure: 97.89 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 6.33 m
- Vertical spacing (Phase to Phase): 4.6 m
- Horizontal spacing (Phase to Phase): 7.06m
- Mid Span clearance: 6.33 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.722
10°	1.722
20°	1.204
30°	1.204

- Shield angle: <30 deg

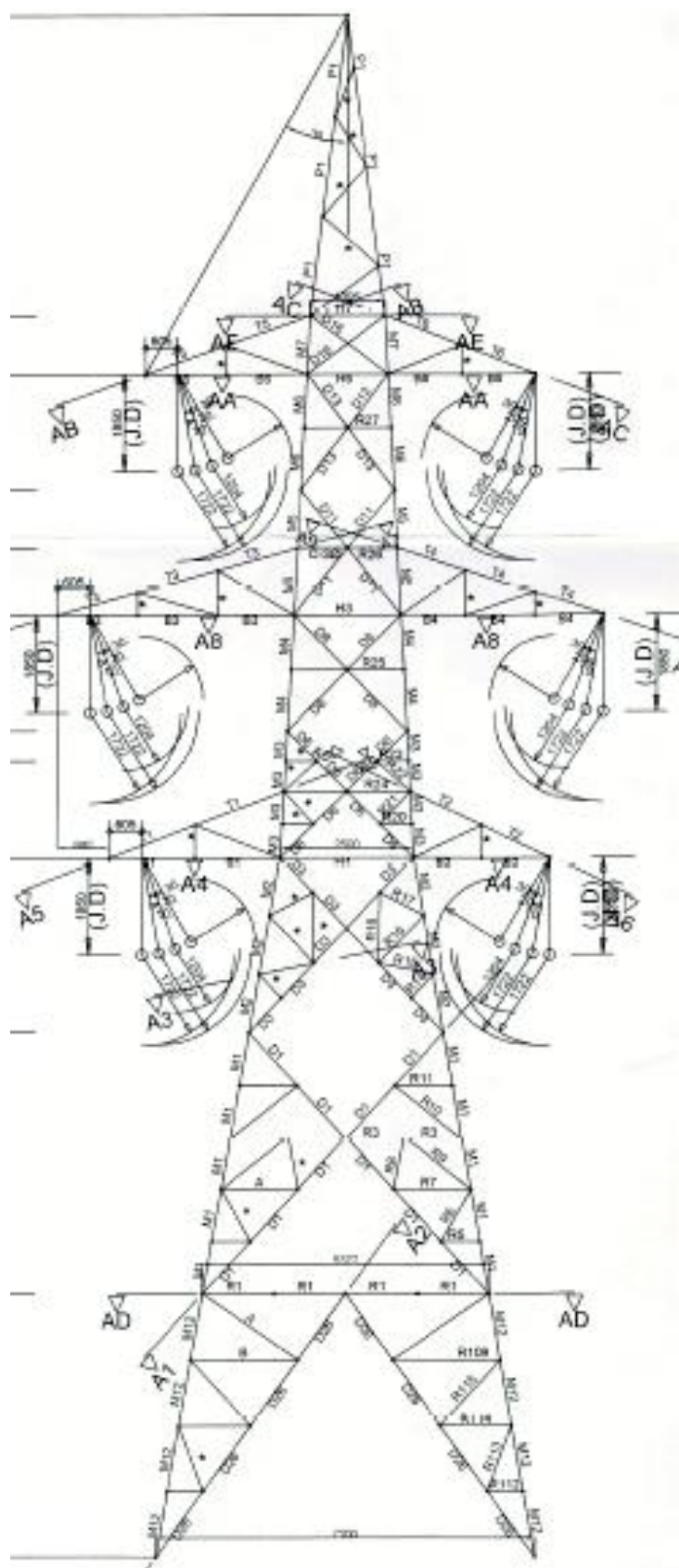
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



132KV D/C WZ 6 T.T. 'DC'

3.12 132 kV, Double circuit, DD type, Vertical configuration, Wind zone: 6

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 132kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: D type tower (deviation angle 0-60 Deg)

5. **Extension of Tower**: -3.0 m/-1.5 m /0 m/+1.5 m /+3.0 m /+4.5 m /+6.0 m /+7.5 m /+9.0m

6. **Type of Configuration**: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 6(55 m/s)
- Design wind pressure: 97.89 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 2000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	PANTHER
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	30/3.00 mm Al+7/3.00 mm Steel
4.	Total sectional area	2.6150 cm ²
5.	Overall diameter	2.10 cm
6.	Approx. Weight	0.9740 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.14 Ohm/km
8.	Approximate calculated breaking load	9144 kgs
9.	Modulus of elasticity	815800 kg/cm ²
10.	Co-efficient of linear Expansion	0.178x10 ⁻⁴ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C 0 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1630
14.	Full Wind Pressure	97.89 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C 0 deg.C
11.	Gust Response Factor	2.233



12.	Full Wind Pressure	97.89 kg/m ²
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11. Spans

- Normal Span:**

Normal condition	Broken Wire Condition
320 m	192 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1500	900
Minimum	-1500	-900

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	2286 kgs	1080 kgs
Everyday Temperature Full Wind	5953.85 kgs	3185.12 kgs
0-degree Temperature 36% Wind	3924.11 kgs	1955.26 kgs

13. Height:

- Height of tower (Earth wire attachment point): 31.913 m
- Height of conductor attachment point(s): 23.013 m

14. Right of Way: 27 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 11
- Diameter: 0.255m
- Length: 1.939m
- Weight of Insulator: 145kg
- Electromechanical strength of strings: 120kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.32



- Shape factor of Insulator: 0.5
- Full wind pressure: 97.89 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 6.33 m
- Vertical spacing (Phase to Phase): 4.6 m
- Horizontal spacing (Phase to Phase): 7.06m
- Mid Span clearance: 6.33 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.722
10°	1.722
20°	1.204
30°	1.204

- Shield angle: <30 deg

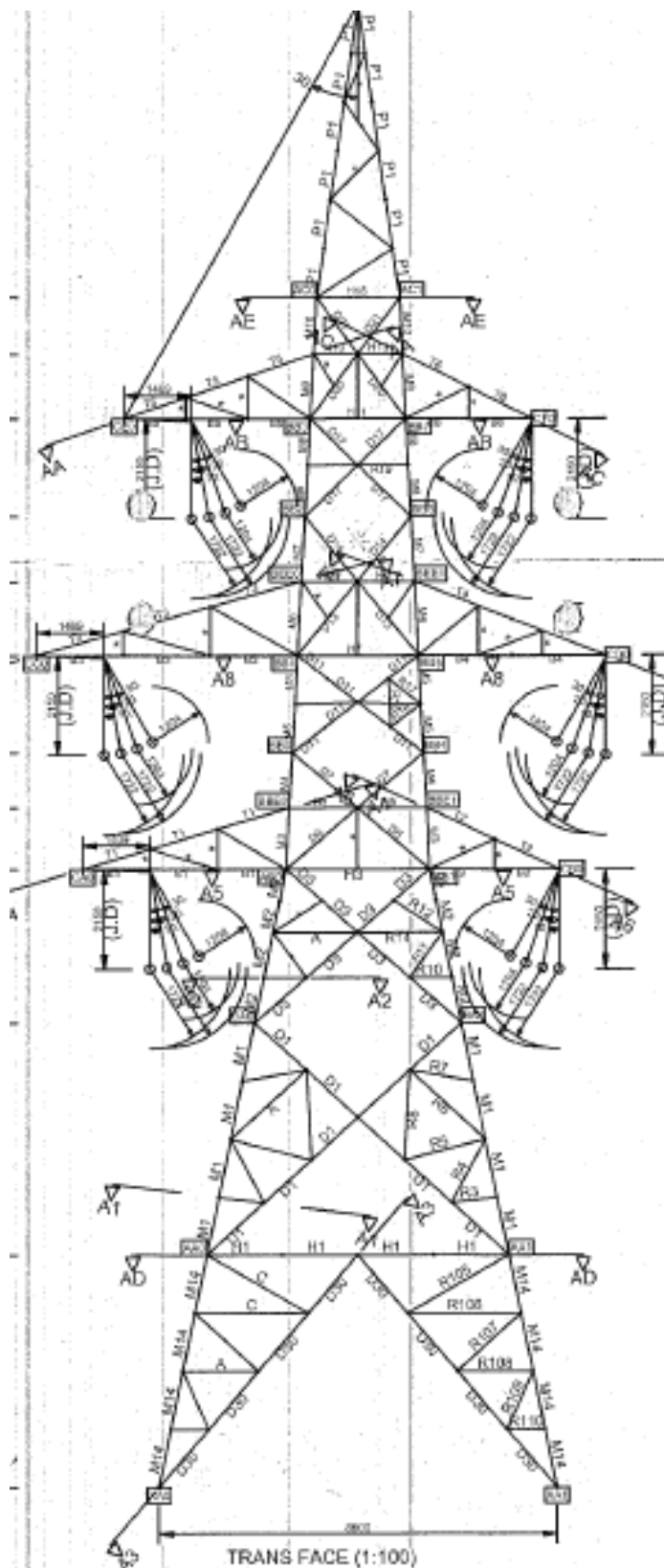
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



132KV D/C WZ 6 T.T. 'DD'

3.13 66 kV, Single circuit, B type, Vertical configuration, Wind zone: 4

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 66kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: B type tower (deviation angle 0-15Deg)

5. **Extension of Tower**: -1.5 m /0 m/+1.5 m/+3.0 m/+4.5 m/+6.0 m/+7.5 m/+9.0 m

6. **Type of Configuration**: Single Circuit (S/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details**: Towers were designed as per provisions of IS 802 (Part I /Sec 1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	DOG
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	6/4.72 mm Al+7/1.57mm Steel
4.	Total sectional area	1.1850 cm ²
5.	Overall diameter	1.415 cm
6.	Approx. Weight	0.3940 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km
8.	Approximate calculated breaking load	32.41kN
9.	Modulus of elasticity	7747 kg/mm ²
10.	Co-efficient of linear Expansion	19.80x10 ⁻⁶ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.0900
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C
11.	Gust Response Factor	2.15



12.	Full Wind Pressure	71.46 kg/m ²
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11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
275 m	165 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	679.14 kgs	983.55 kgs
Everyday Temperature Full Wind	2311.97 kgs	2375.39 kgs
0-degree Temperature 36% Wind	1384.89 kgs	1559.23 kgs

13. Height:

- Height of tower (Earth wire attachment point): 19.45 m
- Height of conductor attachment point(s): 15.550 m

14. Right of Way: 18 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 8
- Diameter: 0.255m
- Length: 1.518m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 45kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.250

- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 5.58 m
- Vertical spacing (Phase to Phase): 2.0 m
- Horizontal spacing (Phase to Phase): 3.5m
- Mid Span clearance: 3.0 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.144
10°	1.144
20°	0.763
30°	0.763

- Shield angle: <30 deg

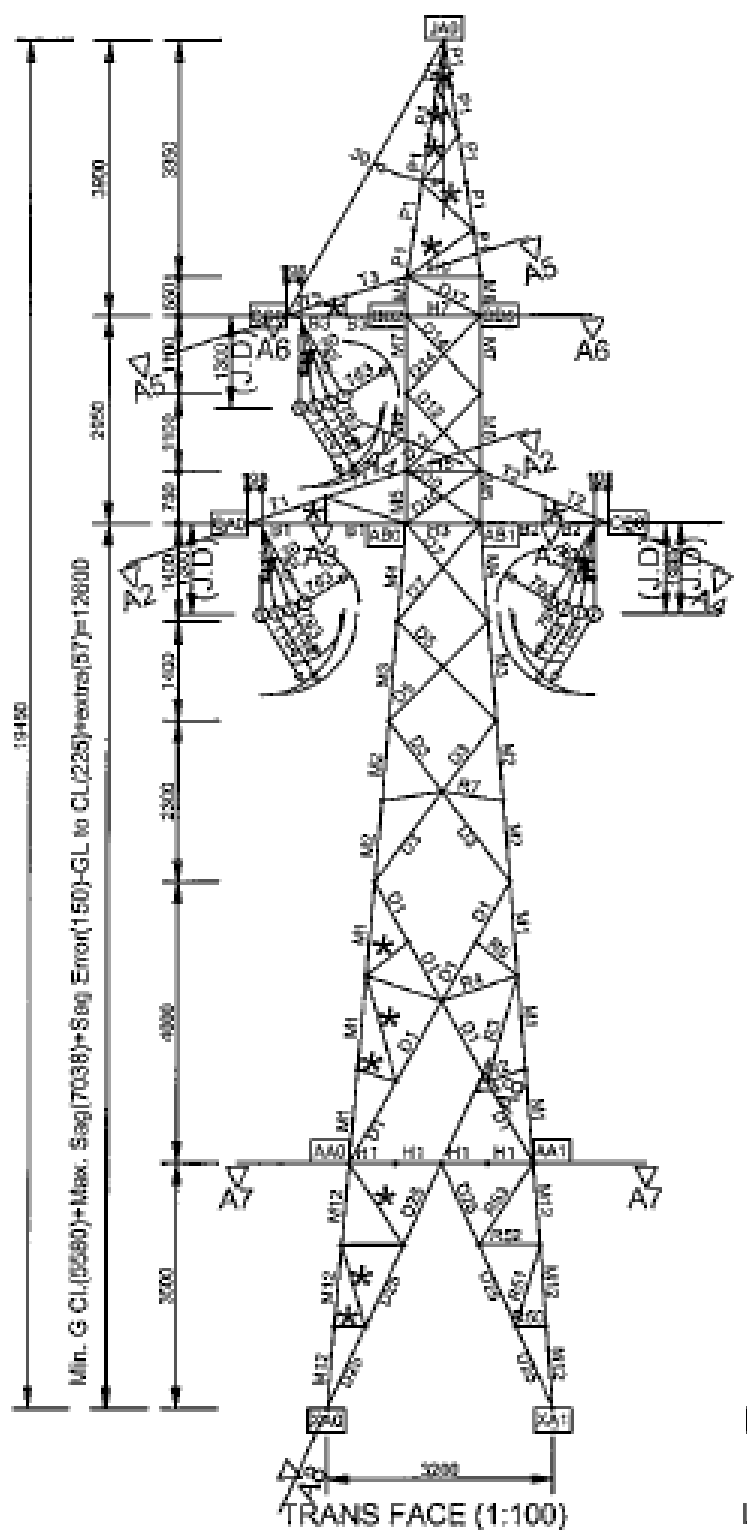
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



66 kV S/C WZ 4 T.T. 'B'

3.14 66 kV, Single circuit, C type, Vertical configuration, Wind zone: 4

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 66kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: C type tower (deviation angle 15-30Deg)

5. **Extension of Tower**: -1.5 m/0 m/+1.5 m/+3.0 m/+4.5 m/+6.0 m/+7.5 m/+9.0 m

6. **Type of Configuration**: Single Circuit (S/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	DOG
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	6/4.72 mm Al+7/1.57mm Steel
4.	Total sectional area	1.1850 cm ²
5.	Overall diameter	1.415 cm
6.	Approx. Weight	0.3940 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km
8.	Approximate calculated breaking load	32.41kN
9.	Modulus of elasticity	7747 kg/mm ²
10.	Co-efficient of linear Expansion	19.80x10 ⁻⁶ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.0900
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C
11.	Gust Response Factor	2.15



12.	Full Wind Pressure	71.46 kg/m ²
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11. Spans

- Normal Span:**

Normal condition	Broken Wire Condition
275 m	165 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	679.14 kgs	983.55 kgs
Everyday Temperature Full Wind	2311.97 kgs	2375.39 kgs
0-degree Temperature 36% Wind	1384.89 kgs	1559.23 kgs

13. Height:

- Height of tower (Earth wire attachment point): 19.90 m
- Height of conductor attachment point(s): 15.60 m

14. Right of Way: 18 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 8
- Diameter: 0.255m
- Length: 1.518m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 45kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.250



- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 5.58 m
- Vertical spacing (Phase to Phase): 2.0 m
- Horizontal spacing (Phase to Phase): 3.5m
- Mid Span clearance: 3.0 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.144
10°	1.144
20°	0.763
30°	0.763

- Shield angle: <30 deg

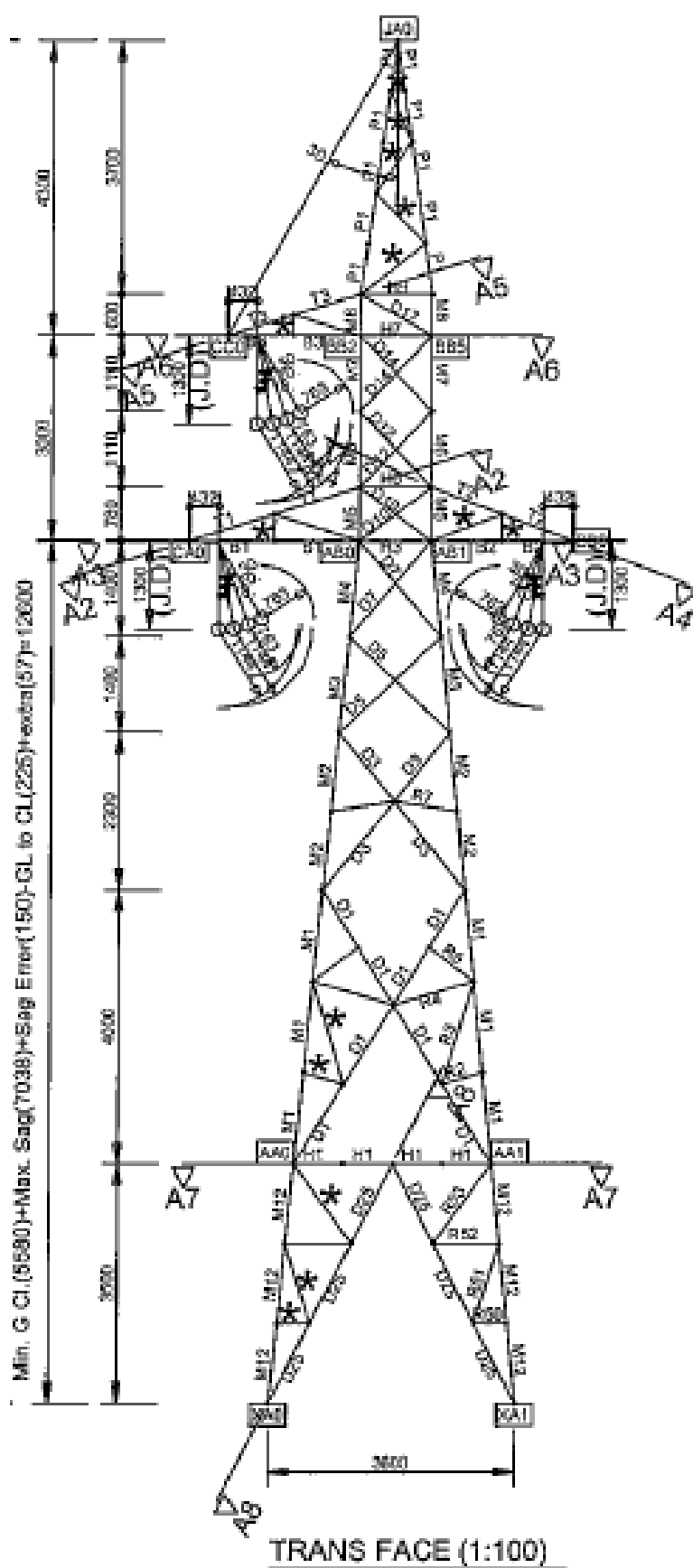
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



3.15 66 kV, Single circuit, D type, Vertical configuration, Wind zone: 4

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 66kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: D type tower (deviation angle 0-60Deg)

5. **Extension of Tower**: -1.5 m/0 m/+1.5 m/+3.0 m/+4.5 m/+6.0 m/+7.5 m/+9.0 m

6. **Type of Configuration**: Single Circuit (S/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	DOG
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	6/4.72 mm Al+7/1.57mm Steel
4.	Total sectional area	1.1850 cm ²
5.	Overall diameter	1.415 cm
6.	Approx. Weight	0.3940 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km
8.	Approximate calculated breaking load	32.41kN
9.	Modulus of elasticity	7747 kg/mm ²
10.	Co-efficient of linear Expansion	19.80x10 ⁻⁶ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.0900
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C
11.	Gust Response Factor	2.15



12.	Full Wind Pressure	71.46 kg/m ²
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11. Spans

- Normal Span:**

Normal condition	Broken Wire Condition
275 m	165 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12. Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	679.14 kgs	983.55 kgs
Everyday Temperature Full Wind	2311.97 kgs	2375.39 kgs
0-degree Temperature 36% Wind	1384.89 kgs	1559.23 kgs

13. Height:

- Height of tower (Earth wire attachment point): 21.10 m
- Height of conductor attachment point(s): 15.70 m

14. Right of Way: 18 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 8
- Diameter: 0.255m
- Length: 1.518m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 45kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.250



- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 5.58 m
- Vertical spacing (Phase to Phase): 2.0 m
- Horizontal spacing (Phase to Phase): 3.5m
- Mid Span clearance: 3.0 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.144
10°	1.144
20°	0.763
30°	0.763

- Shield angle: <30 deg

17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



3.16 66 kV, Double circuit, Tower type DB, Vertical configuration, Wind zone: 4

1. **Tower structure** : Self-supported Lattice

2. **Voltage Class** : 66kV

3. **Utility / Firm** : PGCIL

4. **Classification/Type of Tower**: B type tower (deviation angle 0-15Deg)

5. **Extension of Tower**: -1.5 m/0 m/+1.5 m/+3.0 m/+4.5 m/+6.0 m/+7.5 m/+9.0 m

6. **Type of Configuration**: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. **Design Details** : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category**:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. **Conductor**:

- Parameters:

1.	Code Name of Conductor	DOG
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	6/4.72 mm Al+7/1.57mm Steel
4.	Total sectional area	1.1850 cm ²
5.	Overall diameter	1.415 cm

6.	Approx. Weight	0.3940 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km
8.	Approximate calculated breaking load	32.41kN
9.	Modulus of elasticity	7747 kg/mm ²
10.	Co-efficient of linear Expansion	19.80x10 ⁻⁶ /deg.C
11.	Temperature: • Max. temperature • Everyday temperature • Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1300
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: • Max. temperature • Everyday temperature • Minimum temperature	53 deg.C 32 deg.C -5 deg.C



11.	Gust Response Factor	2.21
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
275 m	165 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	656.09 kgs	938.89 kgs
Everyday Temperature Full Wind	2312.10 kgs	2382.34 kgs
0-degree Temperature 36% Wind	1362.96 kgs	1534.21 kgs

13. Height:

- Height of tower (Earth wire attachment point): 23.55 m
- Height of conductor attachment point(s): 18.55 m

14. Right of Way: 18 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 8
- Diameter: 0.255m
- Length: 1.518m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 45kN



- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.300
- Shape factor of Insulator: 0.5
- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 5.58 m
- Vertical spacing (Phase to Phase): 2.0 m
- Horizontal spacing (Phase to Phase): 3.5m
- Mid Span clearance: 3.0 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.144
10°	1.144
20°	0.763
30°	0.763

- Shield angle: <30 deg

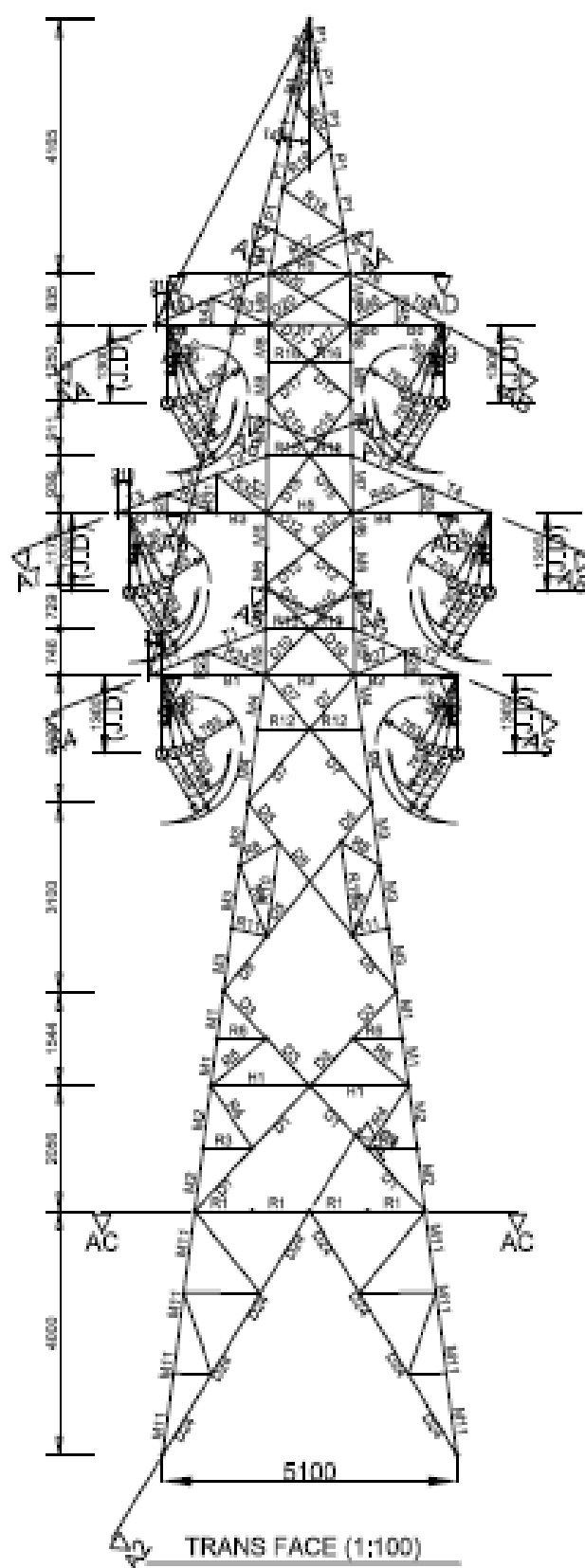
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



66 kV D/C WZ 4 T.T. 'DB'

3.17 66 kV, Double circuit, Tower type DC, Vertical configuration, Wind zone: 4

1. **Tower structure** : Self-supported Lattice
2. **Voltage Class** : 66kV
3. **Utility / Firm** : PGCIL
4. **Classification/Type of Tower:** C type tower (deviation angle 15-30 Deg)
5. **Extension of Tower:** -1.5 m /0 m /+1.5 m /+3.0 m /+4.5 m /+6.0 m / +7.5 m /+9.0 m
6. **Type of Configuration:** Double Circuit (D/C)
 - Configuration of Conductors: Vertical
 - Configuration of Insulators: Tension
 - Configuration of Earth wire : Single peak
7. **Design Details:** Towers were designed as per provisions of IS 802 (Part I/Sec 1 2015).
8. **Wind Pressure, Wind zone, Reliability Level and Terrain Category:**
 - a. Wind Zone and Basic Wind Speed: 4(47 m/s)
 - b. Design wind pressure: 71.46 kg/m²
 - c. Terrain Category: 2
 - d. Reliability Level: 1
 - e. Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	DOG
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	6/4.72 mm Al+7/1.57mm Steel
4.	Total sectional area	1.1850 cm ²
5.	Overall diameter	1.415 cm



6.	Approx. Weight	0.3940 kg/m
7.	Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km
8.	Approximate calculated breaking load	32.41kN
9.	Modulus of elasticity	7747 kg/mm ²
10.	Co-efficient of linear Expansion	19.80x10 ⁻⁶ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1300
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- No. of Earth wires in the tower: One
- OPGW: Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C



11.	Gust Response Factor	2.21
12.	Full Wind Pressure	71.46 kg/m ²

11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
275 m	165 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	656.09 kgs	938.89 kgs
Everyday Temperature Full Wind	2312.10 kgs	2382.34 kgs
0-degree Temperature 36% Wind	1362.96 kgs	1534.21 kgs

13. Height:

- Height of tower (Earth wire attachment point): 23.55 m
- Height of conductor attachment point(s): 18.55 m

14. Right of Way: 18 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 8
- Diameter: 0.255m
- Length: 1.518m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 45kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.300



- i. Shape factor of Insulator: 0.5
- j. Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- a. Minimum Ground Clearance: 5.58 m
- b. Vertical spacing (Phase to Phase): 2.0 m
- c. Horizontal spacing (Phase to Phase): 3.5m
- d. Mid Span clearance: 3.0 m
- e. Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.144
10°	1.144
20°	0.763
30°	0.763

- f. Shield angle: <30 deg

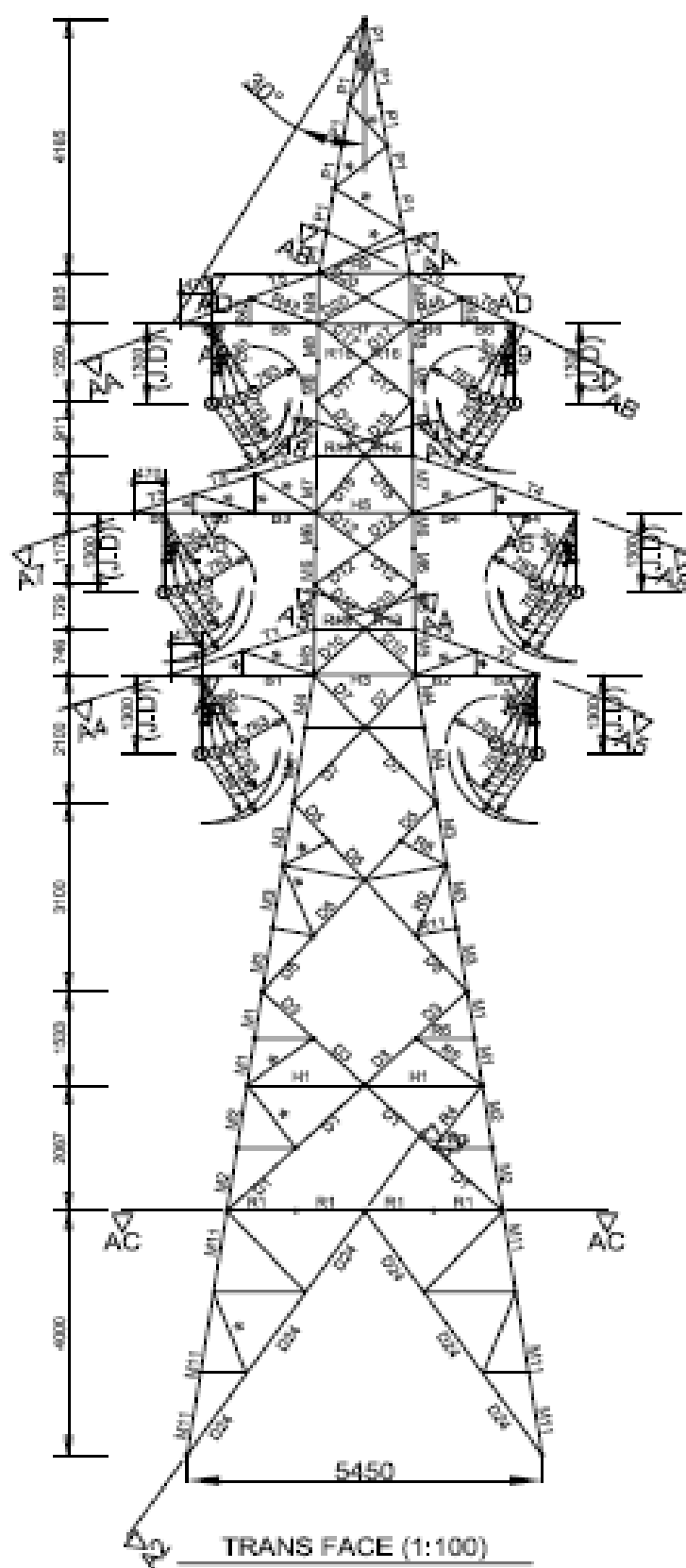
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



66 kV D/C WZ 4 T.T. 'DC'

3.18 66 kV, Double circuit, Tower type DD, Vertical configuration, Wind zone: 4

1. Tower structure : Self-supported Lattice

2. Voltage Class : 66kV

3. Utility / Firm : PGCIL

4. Classification/Type of Tower: D type tower (deviation angle 30-60 Deg)

5. Extension of Tower: -1.5 m/0 m/+1.5 m/+3.0 m/+4.5 m/+6.0 m/+7.5 m/+9.0 m

6. Type of Configuration: Double Circuit (D/C)

- Configuration of Conductors: Vertical
- Configuration of Insulators: Tension
- Configuration of Earth wire : Single peak

7. Design Details : Towers were designed as per provisions of IS 802 (Part I/Sec1 2015).

8. Wind Pressure, Wind zone, Reliability Level and Terrain Category:

- Wind Zone and Basic Wind Speed: 4(47 m/s)
- Design wind pressure: 71.46 kg/m²
- Terrain Category: 2
- Reliability Level: 1
- Elevation level: 3000 m

9. Conductor:

- Parameters:

1.	Code Name of Conductor	DOG
2.	No. of conductor / Phase	SINGLE
3.	Stranding & Wire diameter	6/4.72 mm Al+7/1.57mm Steel
4.	Total sectional area	1.1850 cm ²
5.	Overall diameter	1.415 cm
6.	Approx. Weight	0.3940 kg/m

7.	Calculated D.C. resistance at 20 deg. C	0.281 Ohm/km
8.	Approximate calculated breaking load	32.41kN
9.	Modulus of elasticity	7747 kg/mm ²
10.	Co-efficient of linear Expansion	19.80x10 ⁻⁶ /deg.C
11.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	75 deg.C 32 deg.C -5 deg.C
12.	Shape factor:	1.0
13.	Gust Response factor (GRF)	2.1300
14.	Full Wind Pressure	71.46 kg/m ²

10. Earthwire & OPGW:

- **No. of Earth wires in the tower:** One
- **OPGW:** Yes

Details of OPGW:		
1.	Type & Name	OPGW2
2.	Stranding/Wire diameter	6.0 mm Nominal Diameter for Aluminium clad SS tube
3.	Total sectional Area	0.5401 cm ²
4.	Overall diameter	1.20 cm
5.	Approx. Weight	0.3850 kg/m
6.	Calculated D.C resistance at 20 deg. C	0.96 Ohm/Km
7.	Min. UTS	6612.2450 kgs
8.	Modulus of elasticity	1057143 kg/cm ²
9.	Co-efficient of linear expansion	0.1490x10 ⁻⁴ /deg C
10.	Temperature: - Max. temperature - Everyday temperature - Minimum temperature	53 deg.C 32 deg.C -5 deg.C
11.	Gust Response Factor	2.21



12.	Full Wind Pressure	71.46 kg/m ²
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11.Spans

- Normal Span:**

Normal condition	Broken Wire Condition
275 m	165 m

- Weight Span:**

	Normal Condition	Broken Wire Condition
Maximum	1000	600
Minimum	-1000	-600

12.Tension Limits:

	Conductor	Earth wire
Everyday Temperature Nil Wind	656.09 kgs	938.89 kgs
Everyday Temperature Full Wind	2312.10 kgs	2382.34 kgs
0-degree Temperature 36% Wind	1362.96 kgs	1534.21 kgs

13. Height:

- Height of tower (Earth wire attachment point): 24.29 m
- Height of conductor attachment point(s): 18.655 m

14. Right of Way: 18 m**15. Insulator Strings Details:**

- Size: 0.255m Dia
- No. of Discs: 8
- Diameter: 0.255m
- Length: 1.518m
- Weight of Insulator: 150kg
- Electromechanical strength of strings: 45kN
- Drag Coefficient: 1.2
- Gust Response Factor (GRF): 2.300
- Shape factor of Insulator: 0.5



- Full wind pressure: 71.46 kg/m²

16. Electrical Clearances:

- Minimum Ground Clearance: 5.58 m
- Vertical spacing (Phase to Phase): 2.0 m
- Horizontal spacing (Phase to Phase): 3.5 m
- Mid Span clearance: 3.0 m
- Live metal clearance:

<i>Swing Angle</i>	<i>Clearance (m)</i>
0°	1.144
10°	1.144
20°	0.763
30°	0.763

- Shield angle: <30 deg

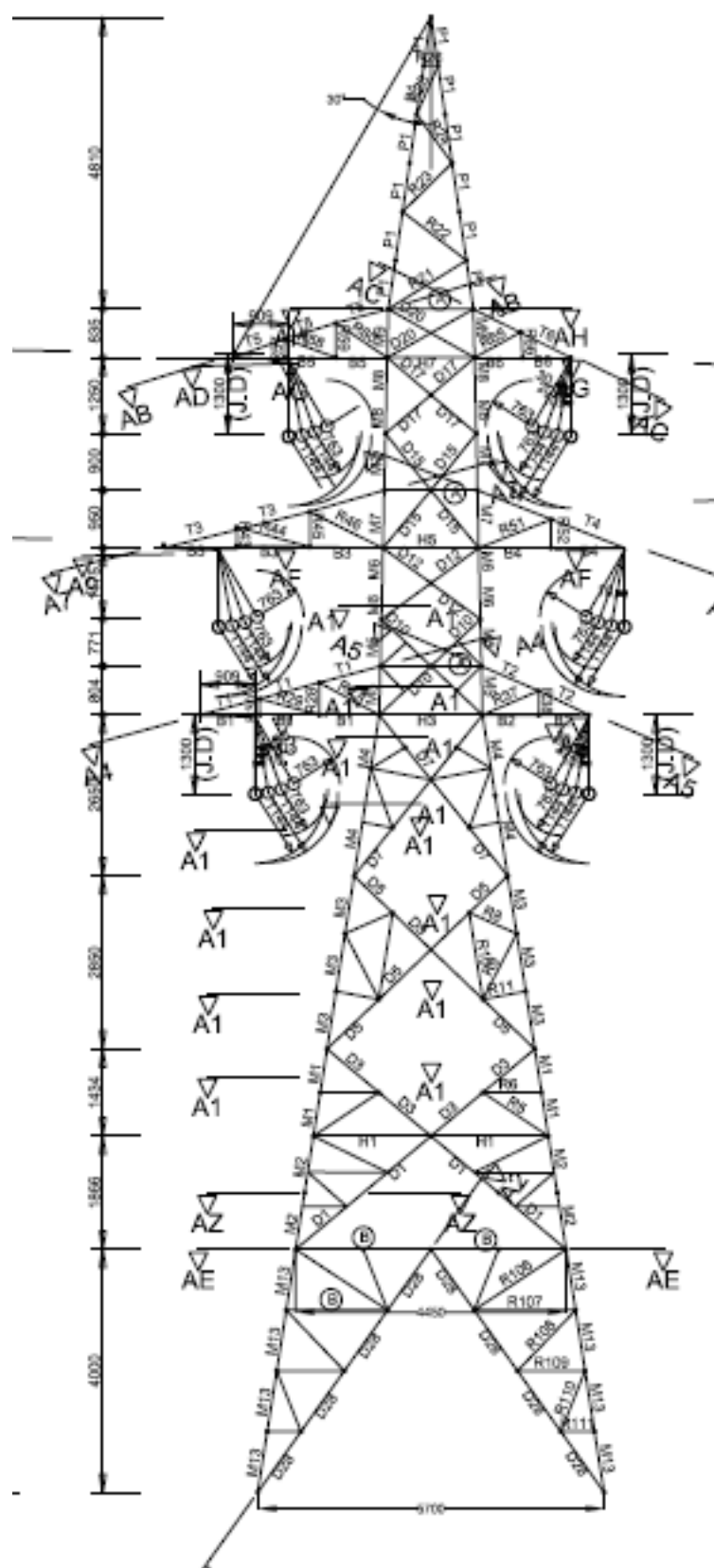
17. Type Test Result:

Type Tested Successfully

18. Installation Experience:

(e.g. Number of towers in use, typical field photographs etc.):

Not available yet



66 kV D/C WZ 4 T.T. 'DD'

An aerial photograph of a large, lattice-structured transmission tower standing in a rural landscape. The tower is surrounded by green fields and some trees. In the background, other similar towers are visible, and a small cluster of buildings can be seen. The sky is clear and blue.

CHAPTER – 4
TYPE TESTED EHV TRANSMISSION LINE
TOWER DESIGNS
(AS PER IS: 802 – 1995)

HVDC CHAMPA – KURUKSHETRA LINE



HVDC CHAMPA – KURUKSHETRA LINE

CHAPTER - 4

TYPE TESTED EHV TRANSMISSION LINE TOWER DESIGNS (AS PER IS: 802 - 1995)

4.1 TECHNICAL PARAMETERS AND INDICATIVE SKETCHES OF TOWERS

1200 kV Transmission Tower

4.1.1 1200 kV S/C WZ 2 Octa MOOSE Transmission Line (PGCIL)

Line Parameters

a) Voltage Level:	1200 kV
b) Configuration:	Single Circuit (S/C)
c) Conductor:	ACSR OCTA MOOSE
d) Earth wire:	19/3.00:2No.
e) Shield Angle:	<10 Deg.
f) Ground Clearance:	24.0m
g) Mid Span Clearance:	18.0m
h) Max Conductor Temp:	70 Deg C
i) Line Altitude:	Upto 1000m

Tower Design Parameters

a) IS:	802:1995
b) Wind zone:	2
c) Reliability Level:	2
d) Terrain Category:	2
e) Wind Span:	400m

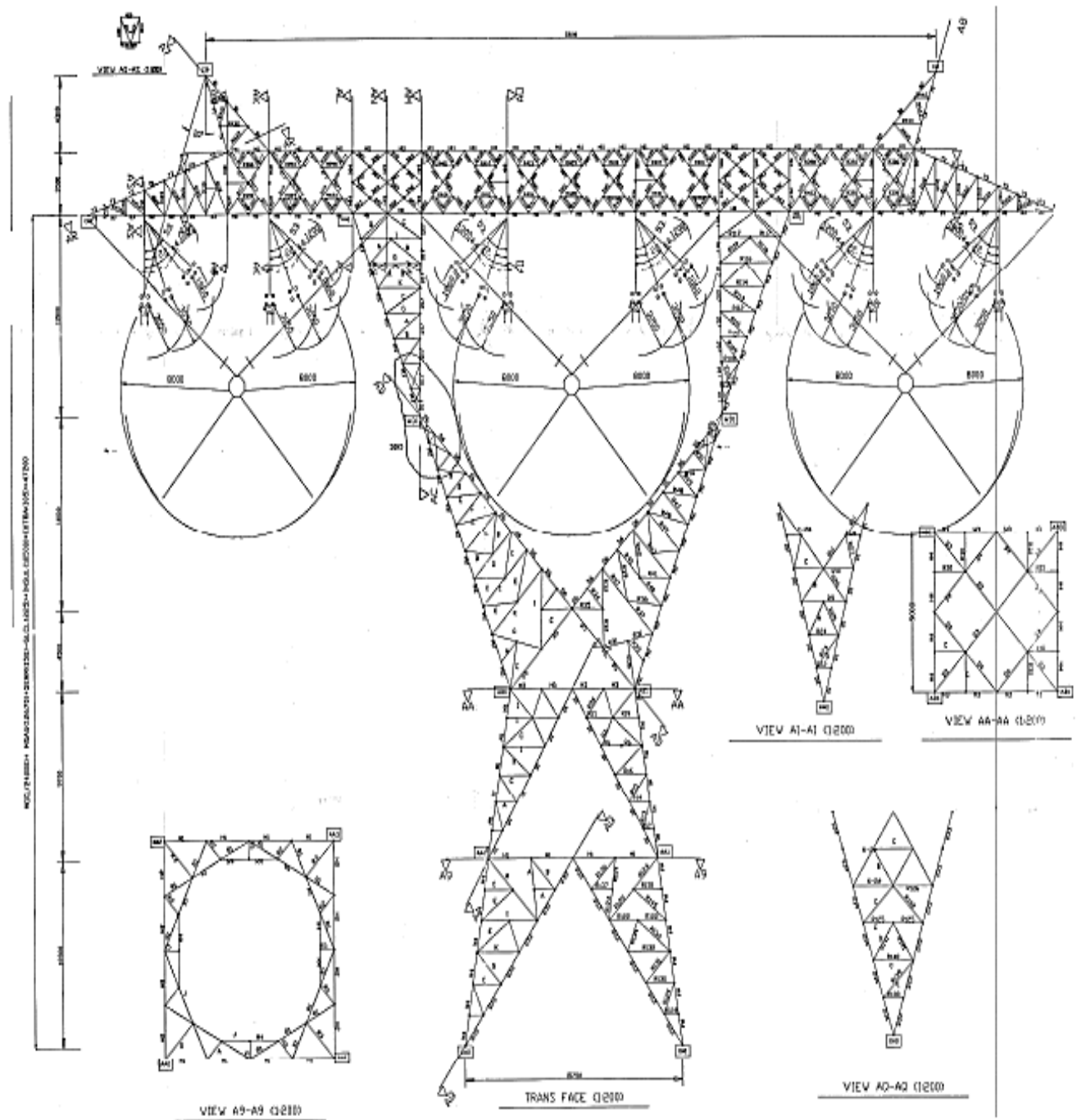


Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	15.75 X 15.75
2	AS	1000/-200	600/-200	14.65 X 14.65
3	B	1000 /-200	600/-200	16.00 X 16.00
4	C	1000 /-200	600/-200	17.50 X 17.50
5	D	1000/-300	600/-300	18.00 X 18.00
6	E	1000/-300	600/-300	18.00 X 18.00

Remarks: In house Tested Towers

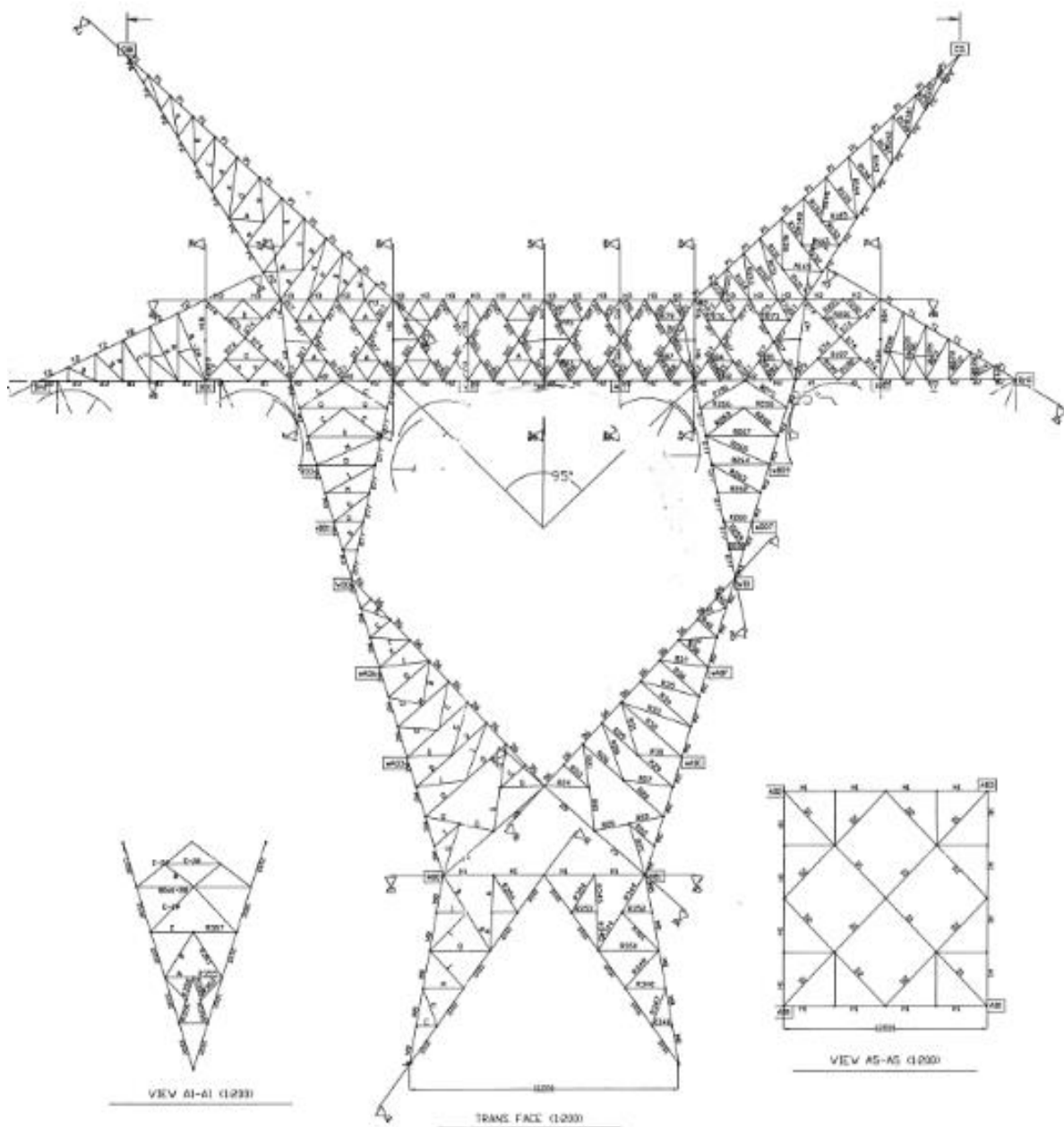
Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-1
2	AS	0-7
3	B	0-15
4	C	0-30
5	D	30-45
6	E	45-60

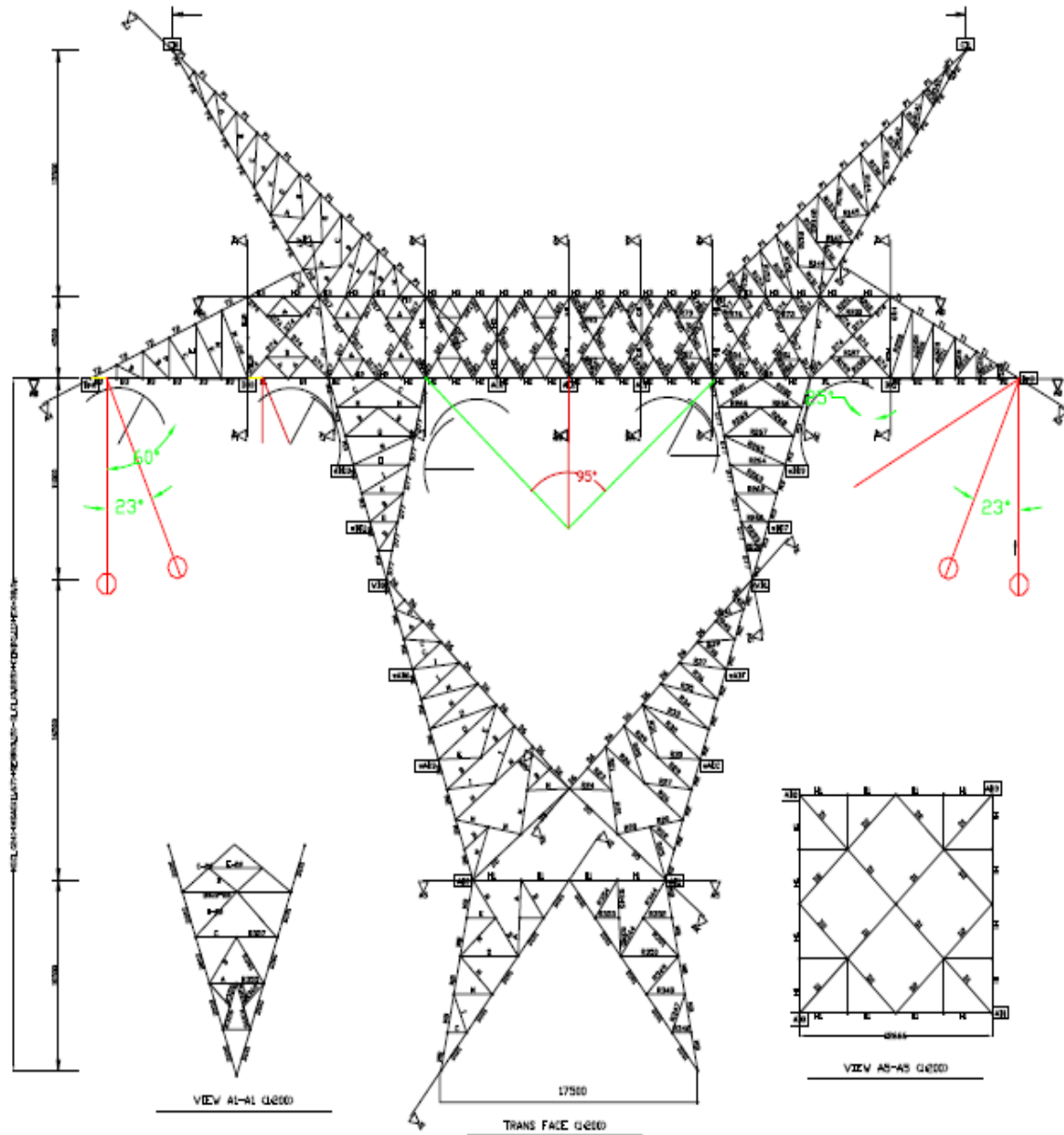


1200 kV S/C WZ 2 OCTA MOOSE T.T. 'A'

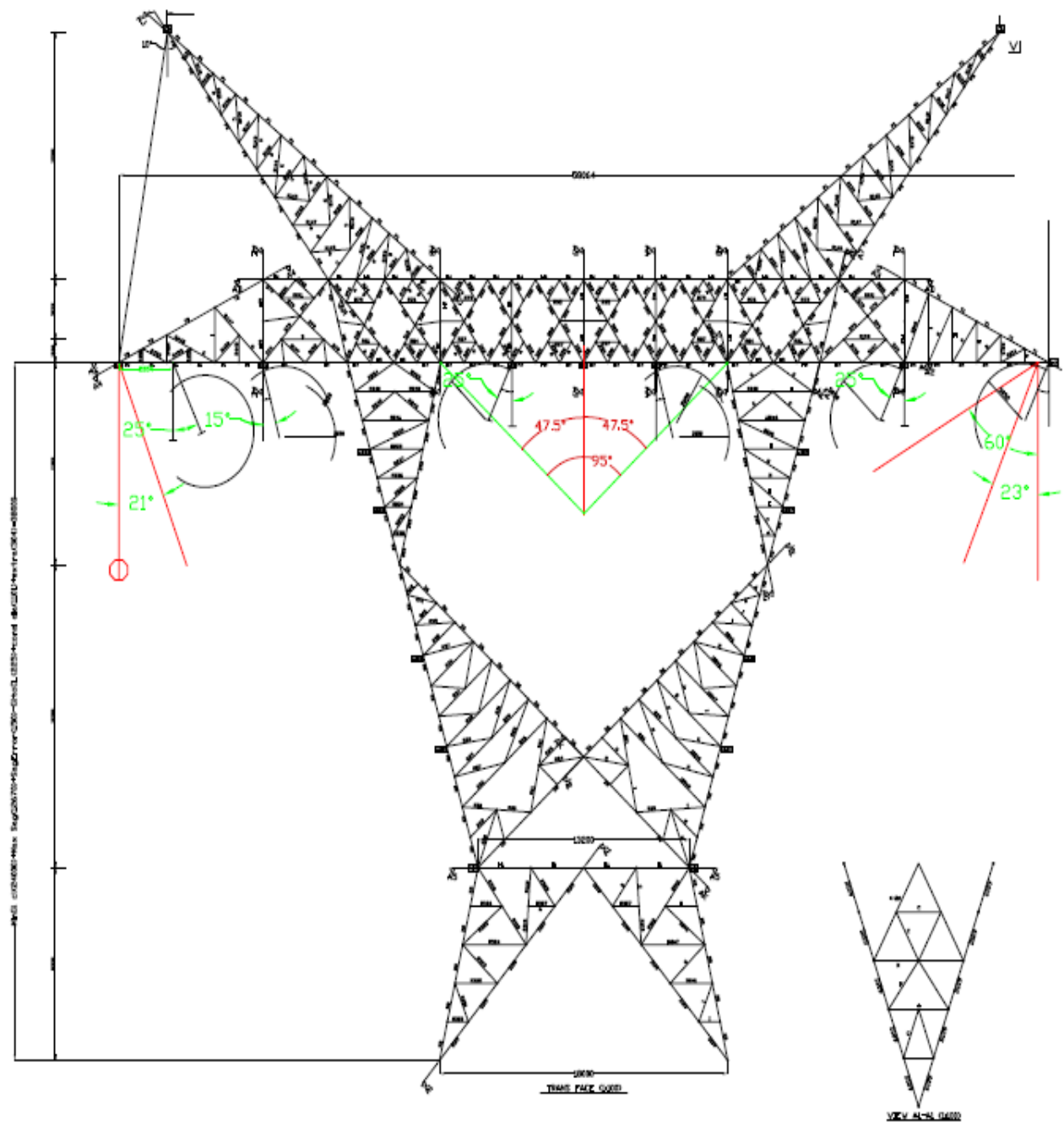




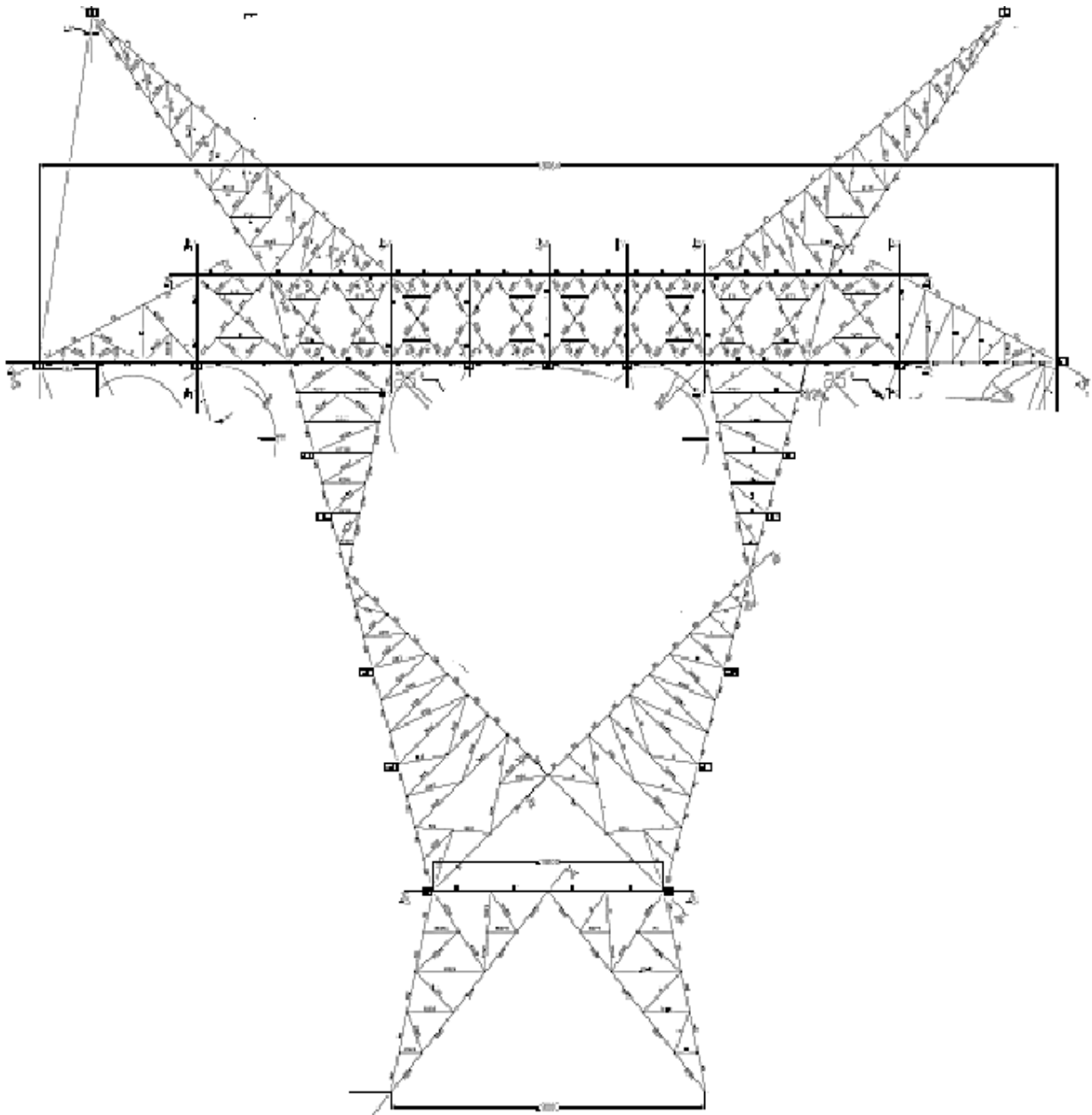
1200 kV S/C WZ 2 OCTA MOOSE T.T. 'B'



1200 kV S/C WZ 2 OCTA MOOSE T.T. 'C'



1200 kV S/C WZ 2 OCTA MOOSE T.T. 'D'



1200 kV S/C WZ 2 OCTA MOOSE T.T. 'E'

4.2 TECHNICAL PARAMETERS AND INDICATIVE SKETCHES OF TOWERS

±800 kV Transmission Towers

4.2.1 ±800 kV HVDC WZ 5 Hex Lapwing Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: ±800 kV
b) Configuration: HVDC
c) Conductor: ACSR HEXA
LAPWING
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 18.0m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Design Parameters

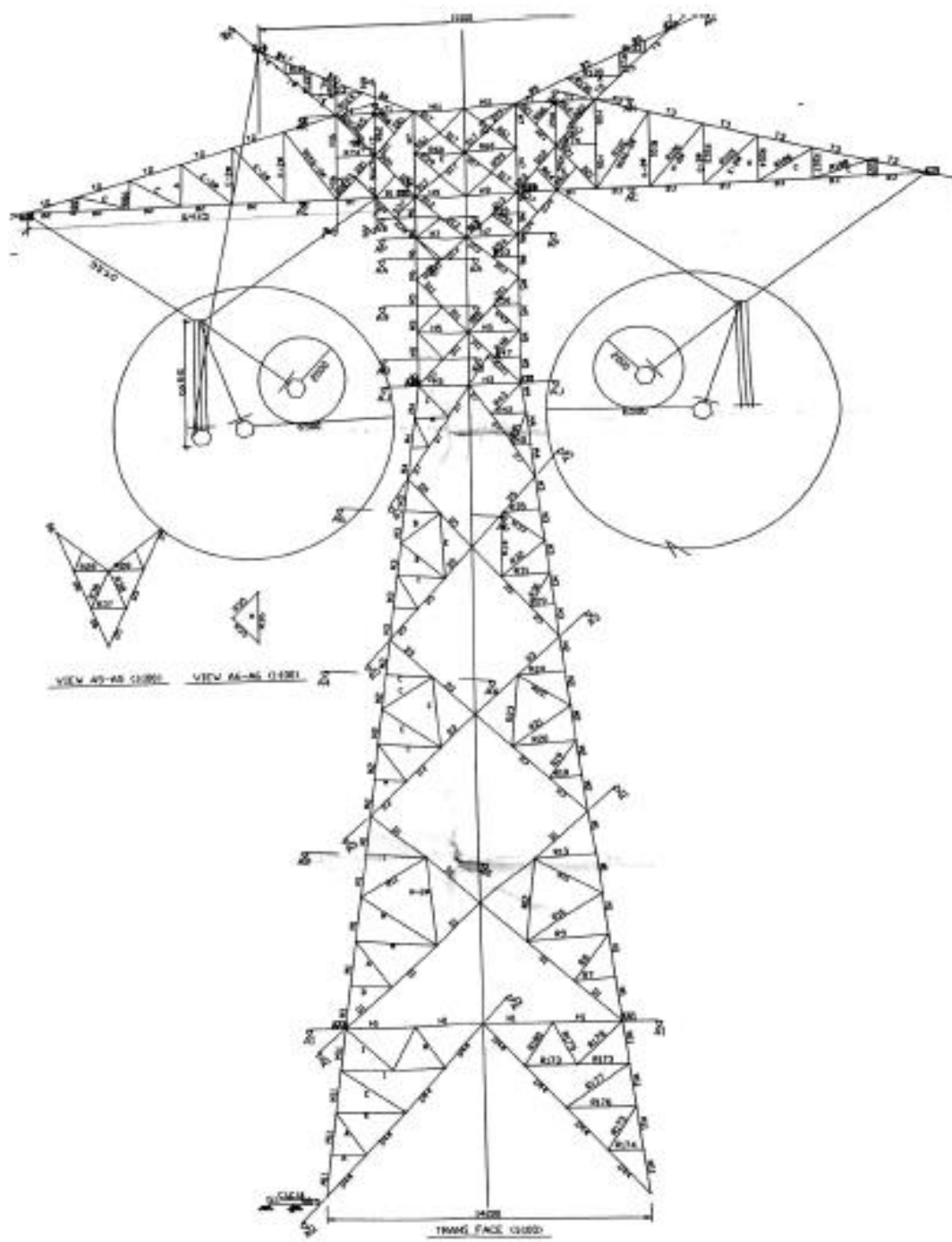
- a) IS: 802:1995
b) Wind zone: 5/4
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m (for WZ 5)
450m (for WZ 4)

Tower Types

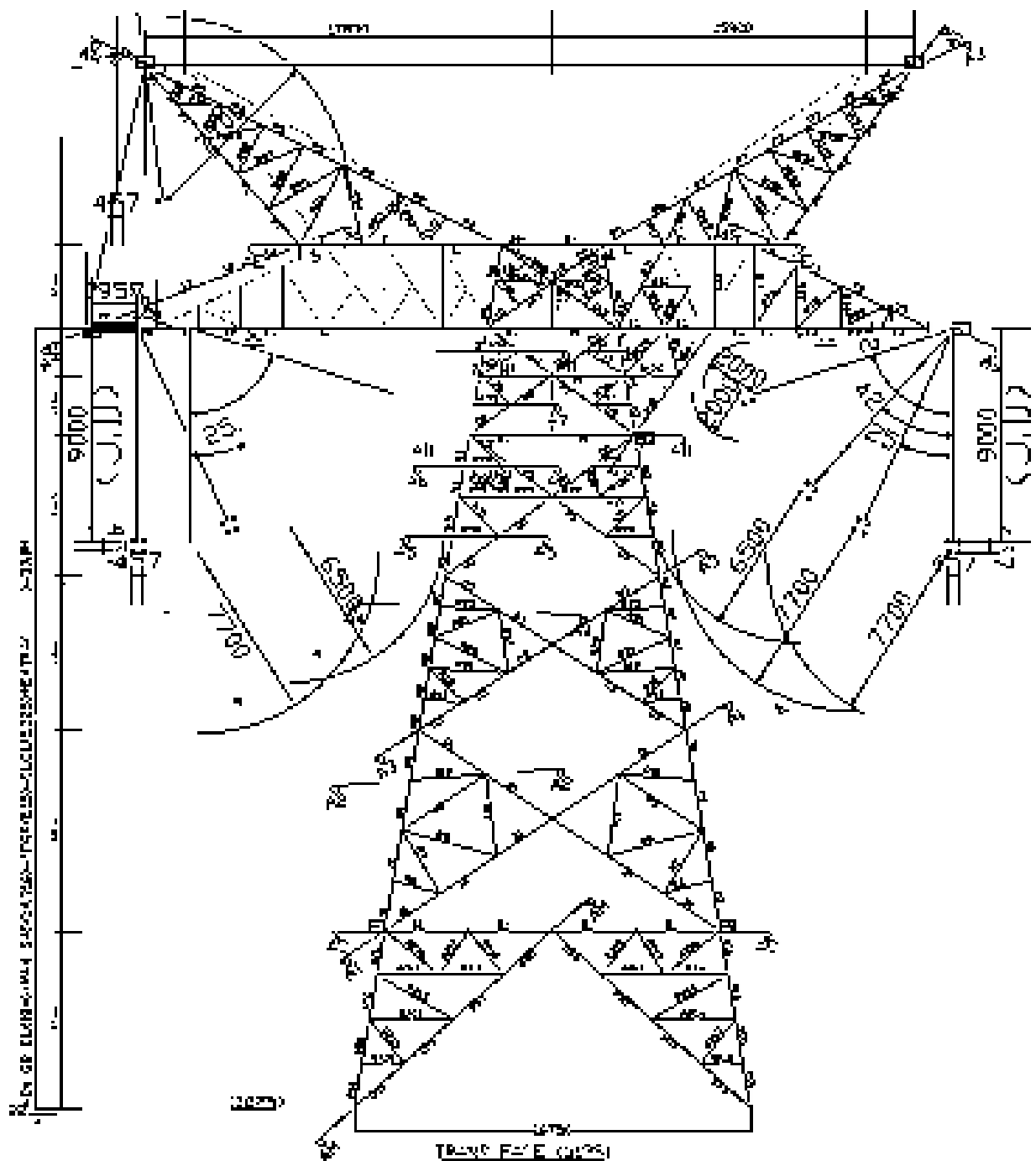
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A (Y String)	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A (Y String)	550/200	330/100	14.20 X 14.20
2	B	675/0	405/-200	16.75 X 16.75
3	C	675/0	405/-200	18.40 X 18.40
4	D	675/0	405/-300	22.00 X 22.00

Remarks: In house Tested Towers

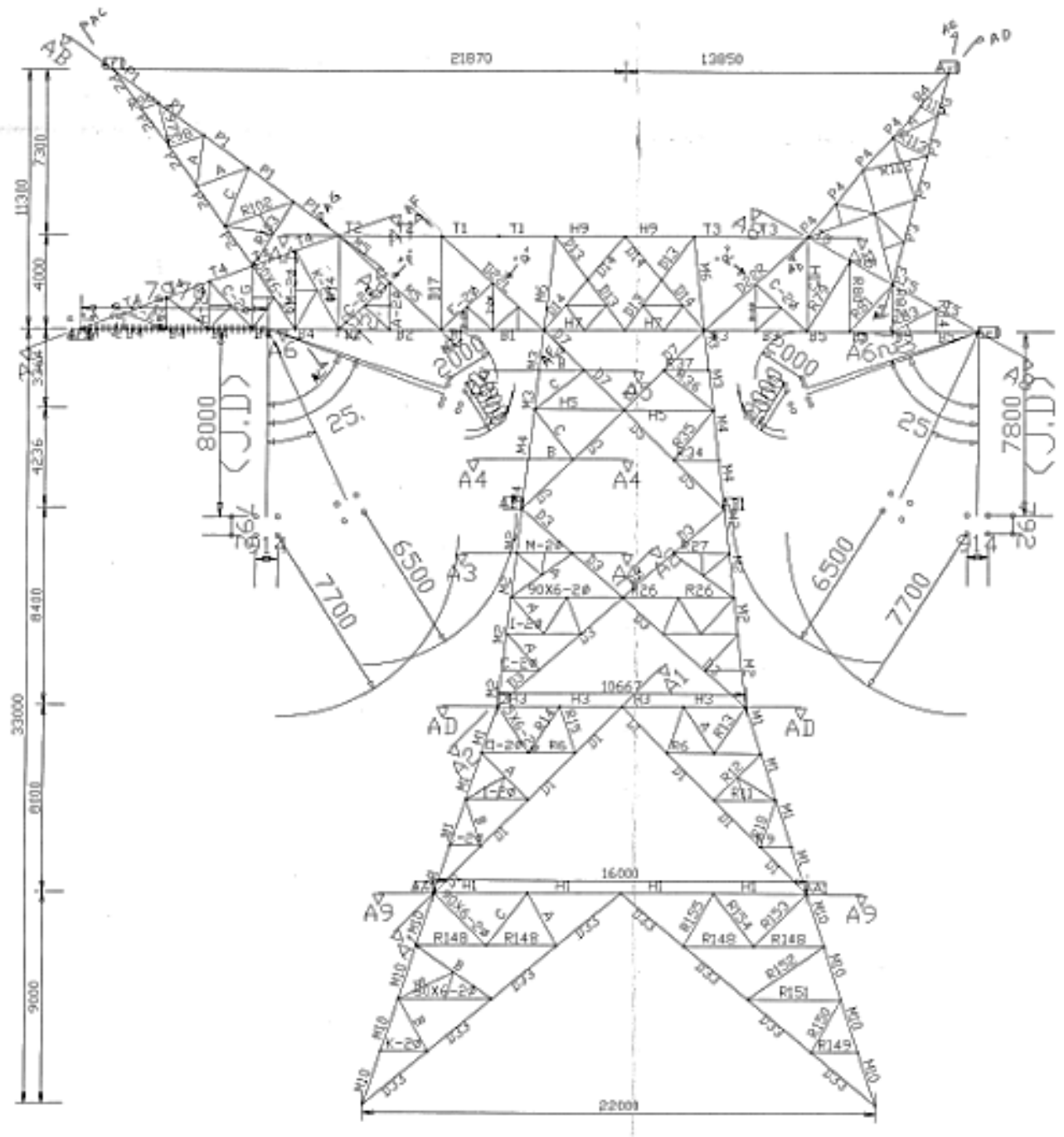


+ 800 kV HVDC WZ 5/4 Hex Lapwing T.T 'A' Y String



+ 800 kV HVDC WZ 5/4 Hex Lapwing T.T. 'B'





+ 800 kV HVDC WZ 5/4 Hex Lapwing T.T.'D'

4.2.2 $\pm$ 800 kV HVDC with DMR WZ 4 Hex Lapwing Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: $\pm$ 800 kV
 b) Configuration: HVDC
 c) Conductor: ACSR HEXA
 LAPWING
 d) Earth wire: 7/4.5: 2No.
 e) Shield Angle: <10 Deg.
 f) Ground Clearance: 18.0m
 g) Mid Span Clearance: 12.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 2
 d) Terrain Category: 2
 e) Wind Span: 400m

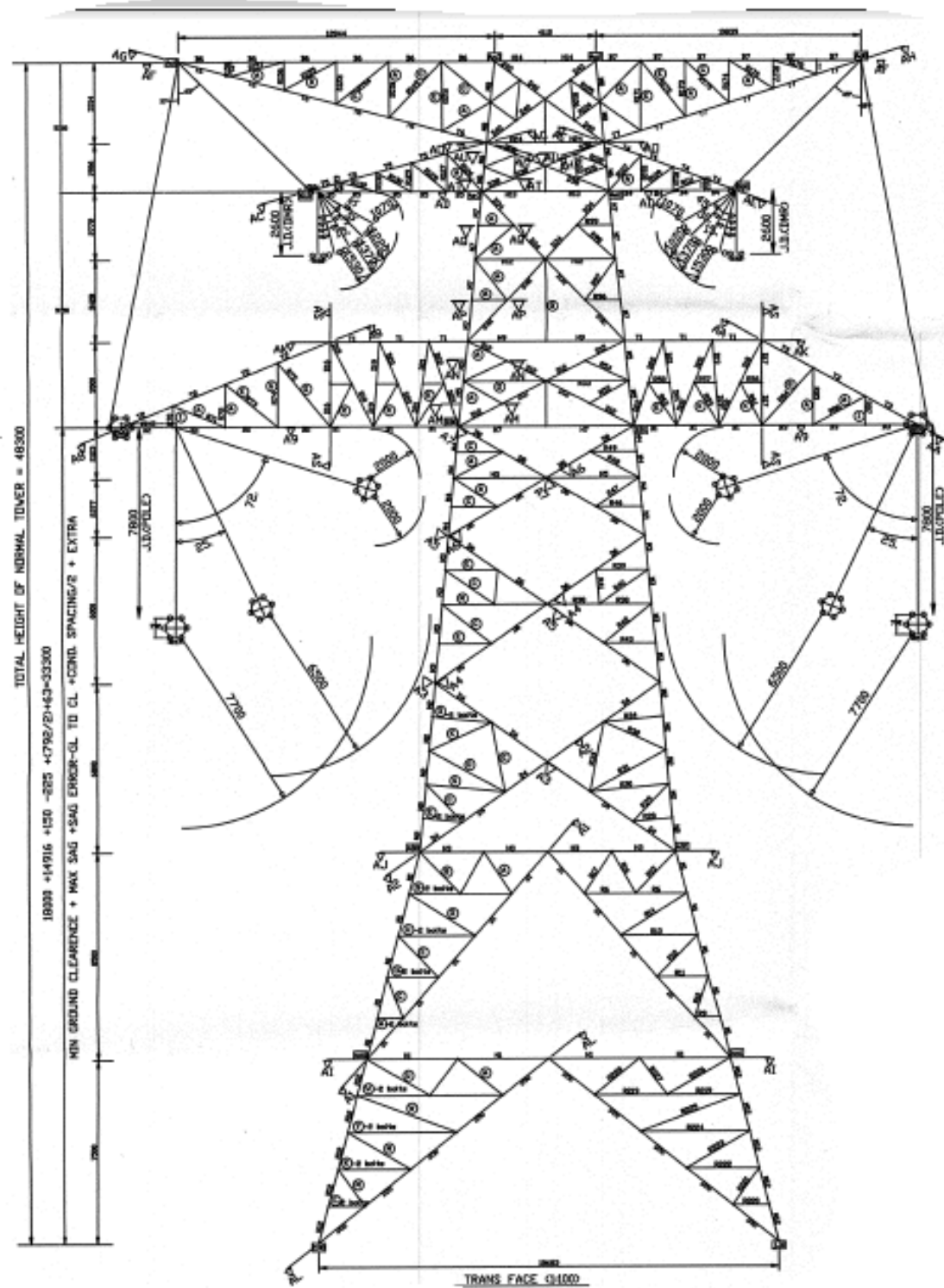
Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

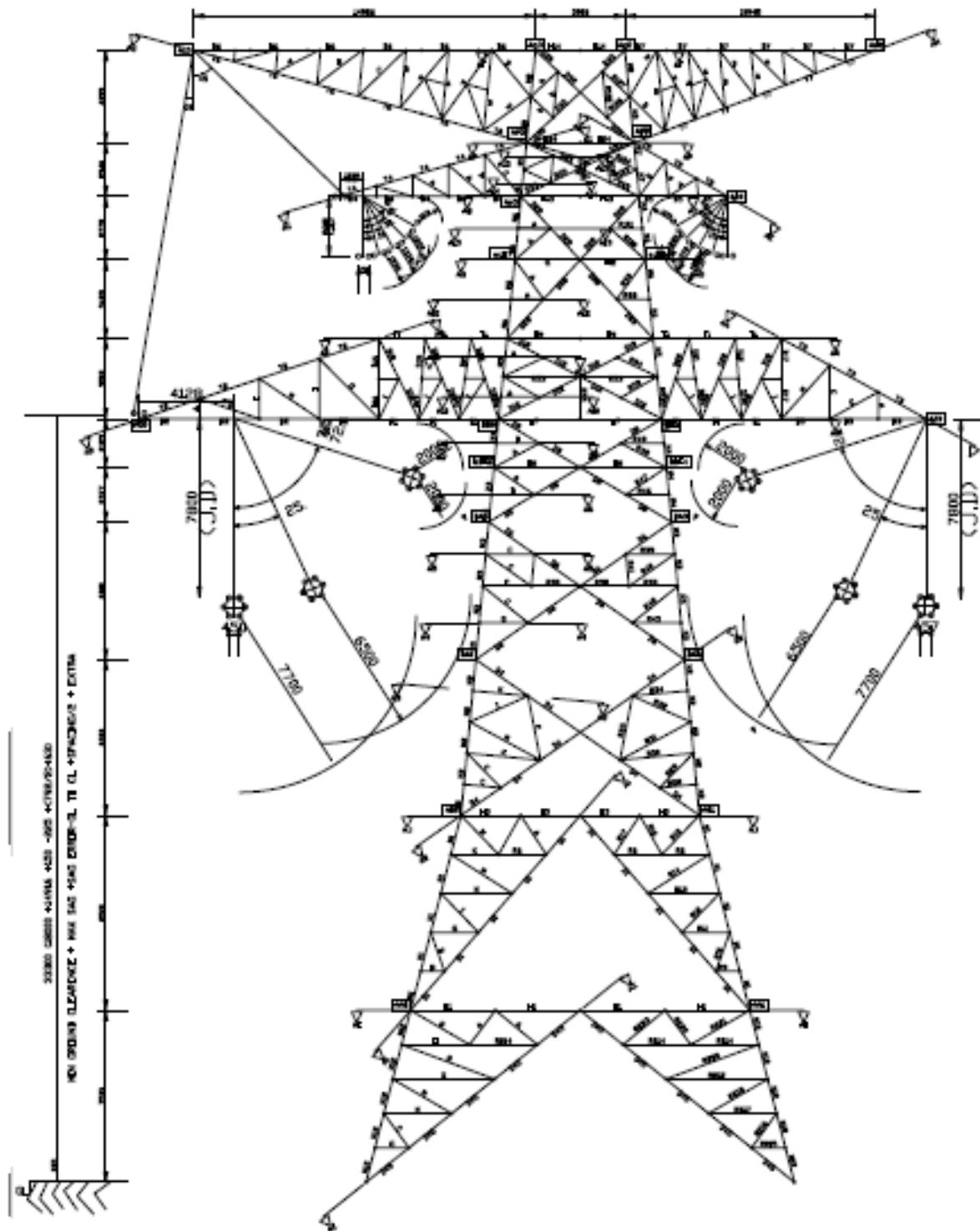
Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	14.300 X 14.300
2	B	600/0	360/-200	18.683 X 18.683
3	C	600/0	360/-200	18.683 X 18.683
4	D	600/0	360/-300	20.622 X 20.622

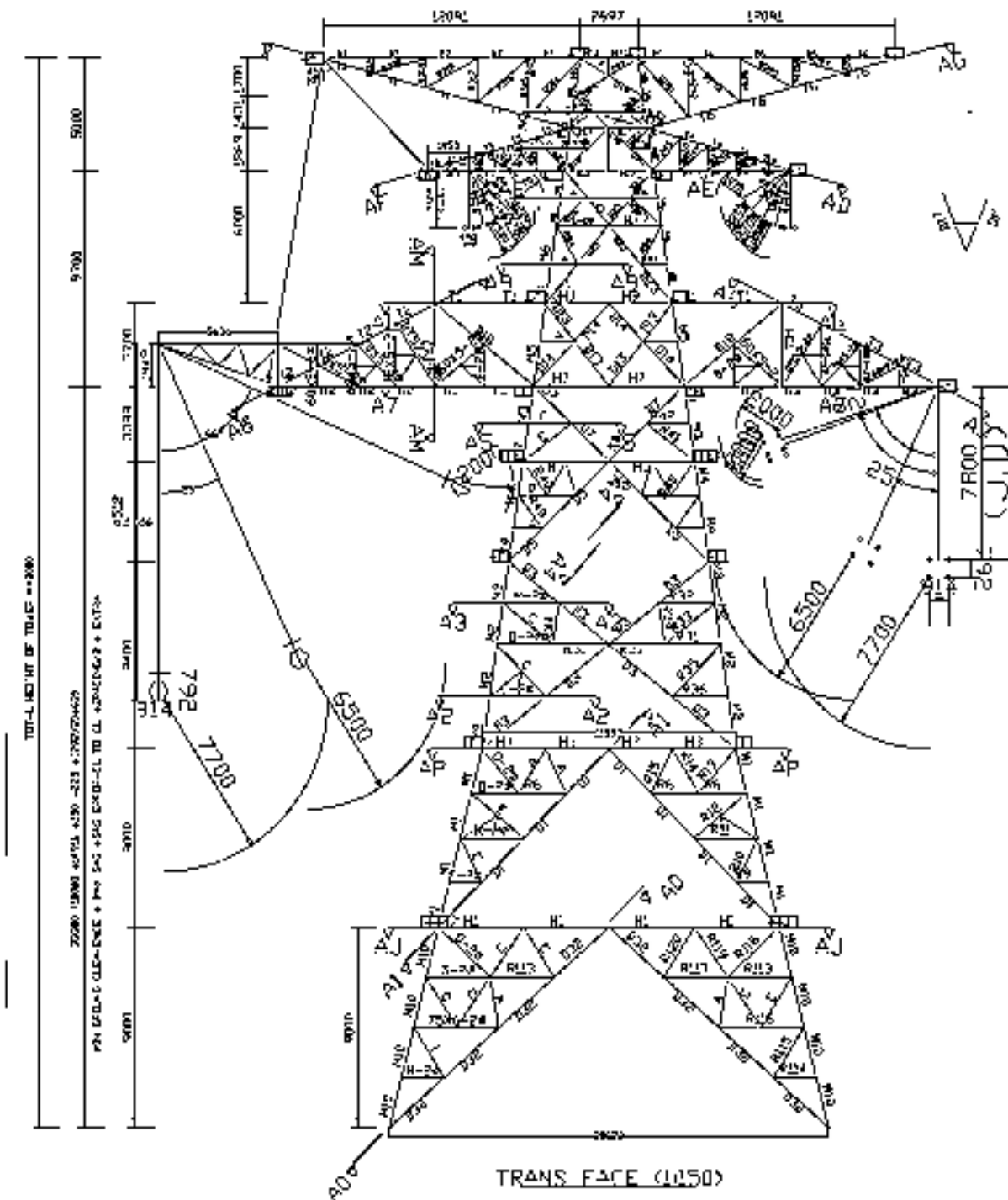
Remarks: In house Tested Towers





± 800 kV HVDC WITH DMR WZ 4 Hex Lapwing T.T. 'B'





+ 800 kV HVDC WITH DMR WZ 4 Hex Lapwing T.T.'D'

4.2.3 ± 800 kV HVDC with DMR WZ 3 Hex Lapwing Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: ± 800 kV
b) Configuration: HVDC
c) Conductor: ACSR HEXA
LAPWING
d) Earth wire: 7/4.5: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 18.0m
g) Mid Span Clearance: 12.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

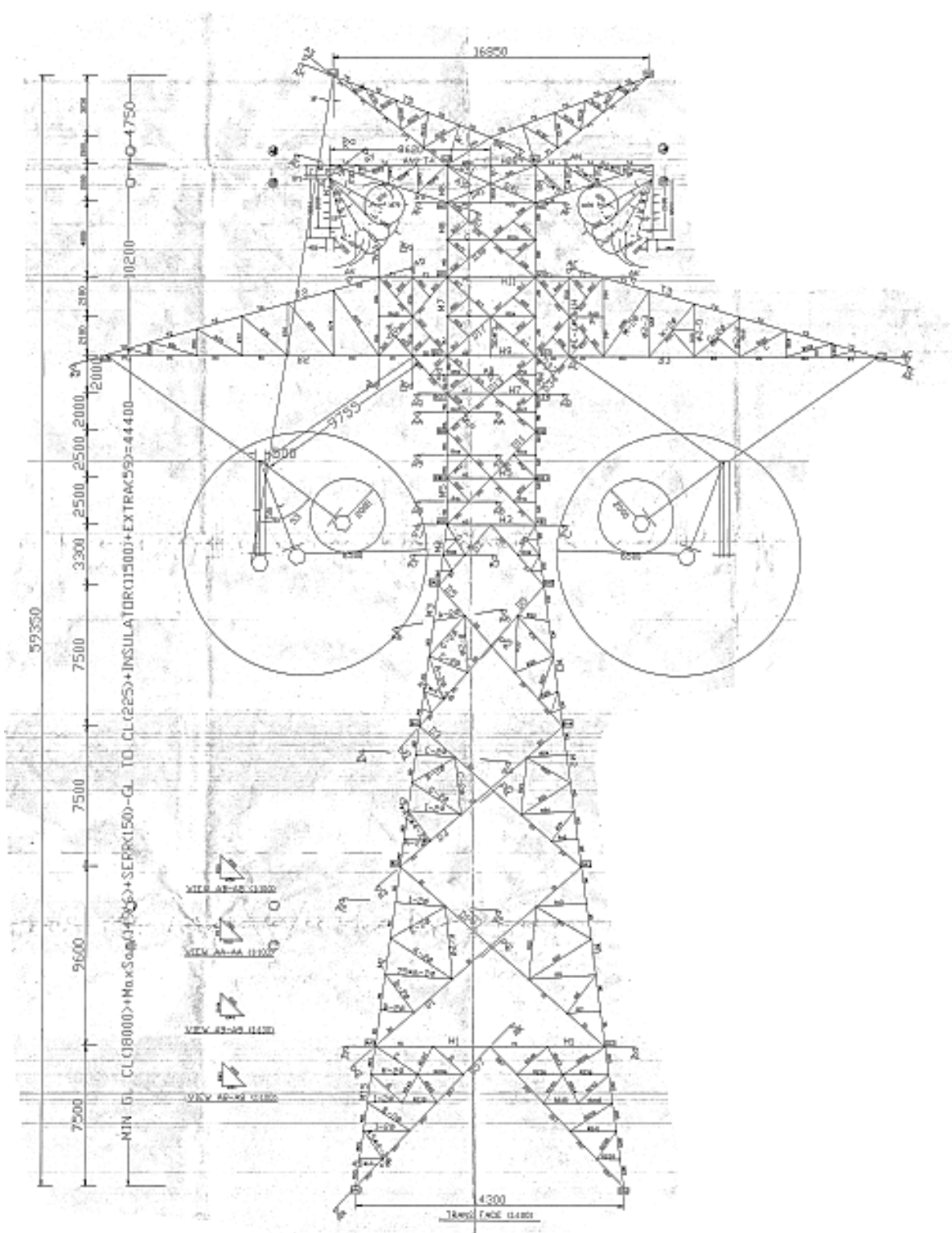
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Tower Design Parameters

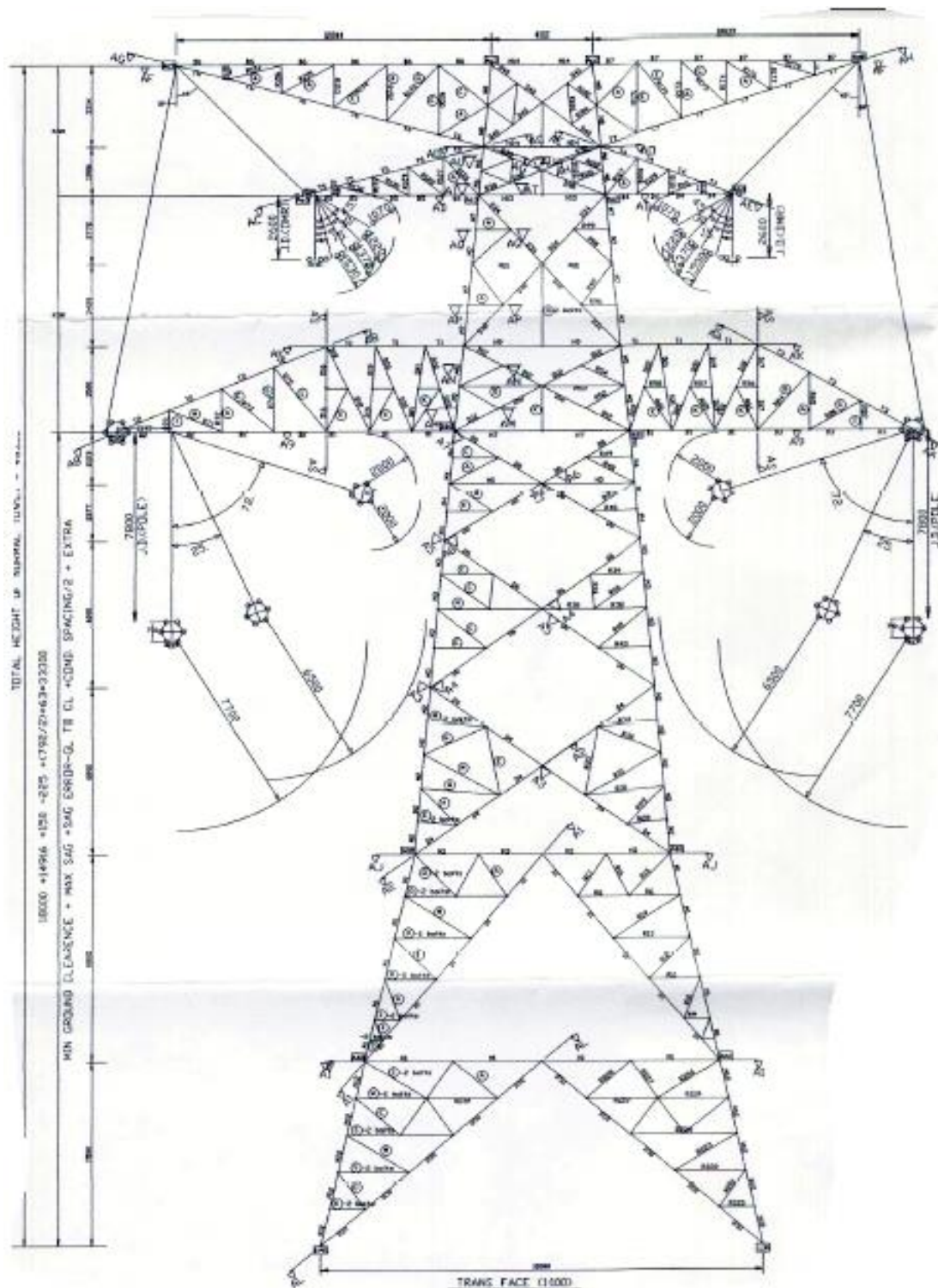
- a) IS: 802:1995
b) Wind zone: 3
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	14.30 X 14.30
2	B	600/0	360/-200	18.00 X 18.00
3	C	600/0	360/-200	19.00 X 19.00
3	D	600/0	360/-300	19.00 X 19.00

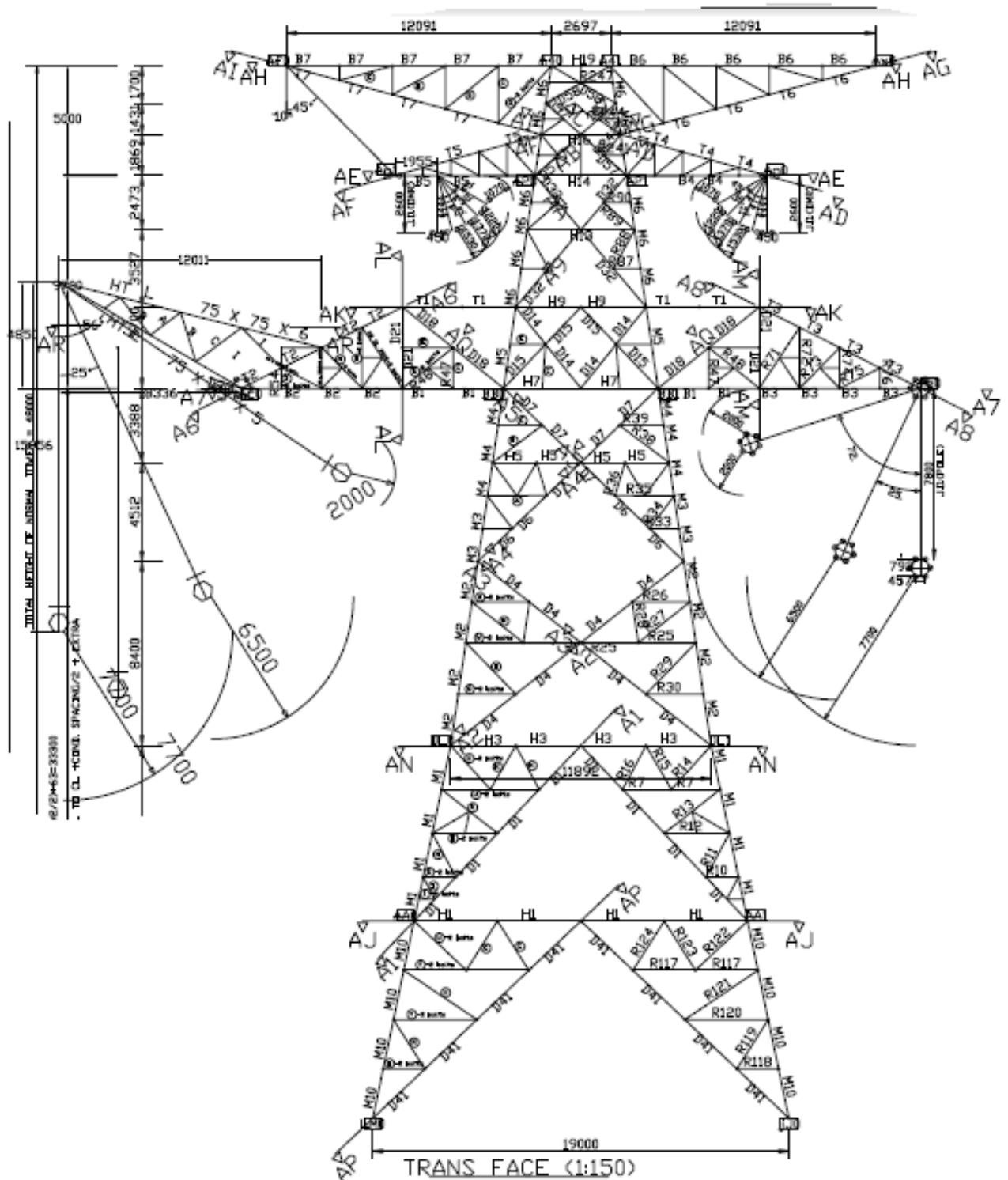
Remarks: In house Tested Towers



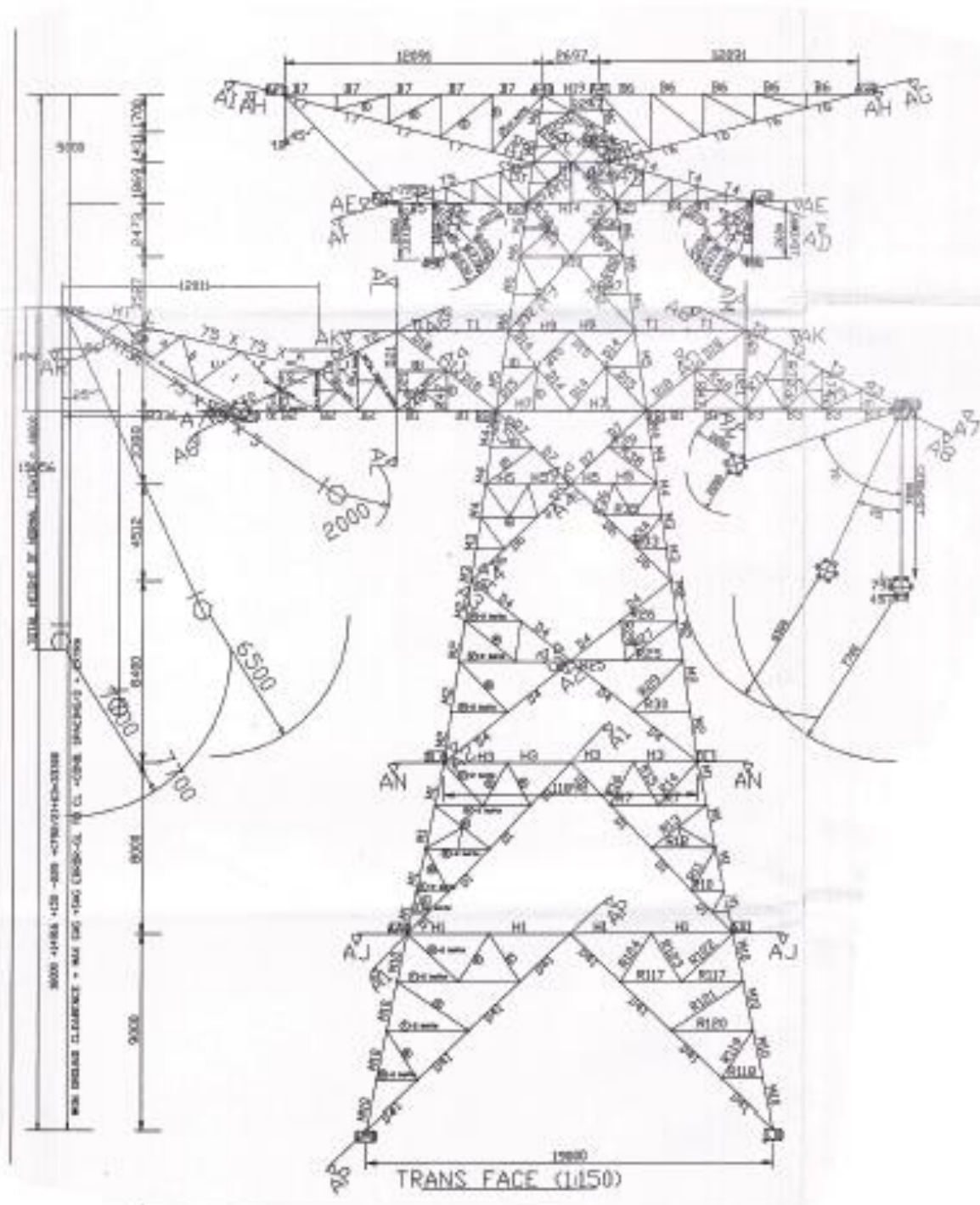
+ 800 kV HVDC WITH DMR WZ 3 Hex Lapwing T.T.'A'



+ 800 kV HVDC WITH DMR WZ 3 Hex Lapwing T.T.'B'



+ 800 kV HVDC WITH DMR WZ 3 Hex Lapwing T.T.'C'



+ 800 kV HVDC WITH DMR WZ 3 Hex Lapwing T.T.'D'

4.2.4 $\pm$ 800 kV HVDC with DMR WZ 2 Hex Lapwing Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: $\pm$ 800 kV
b) Configuration: HVDC
c) Conductor: ACSR HEXA
LAPWING
d) Earth wire: 7/4.5: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 18.0m
g) Mid Span Clearance: 12.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

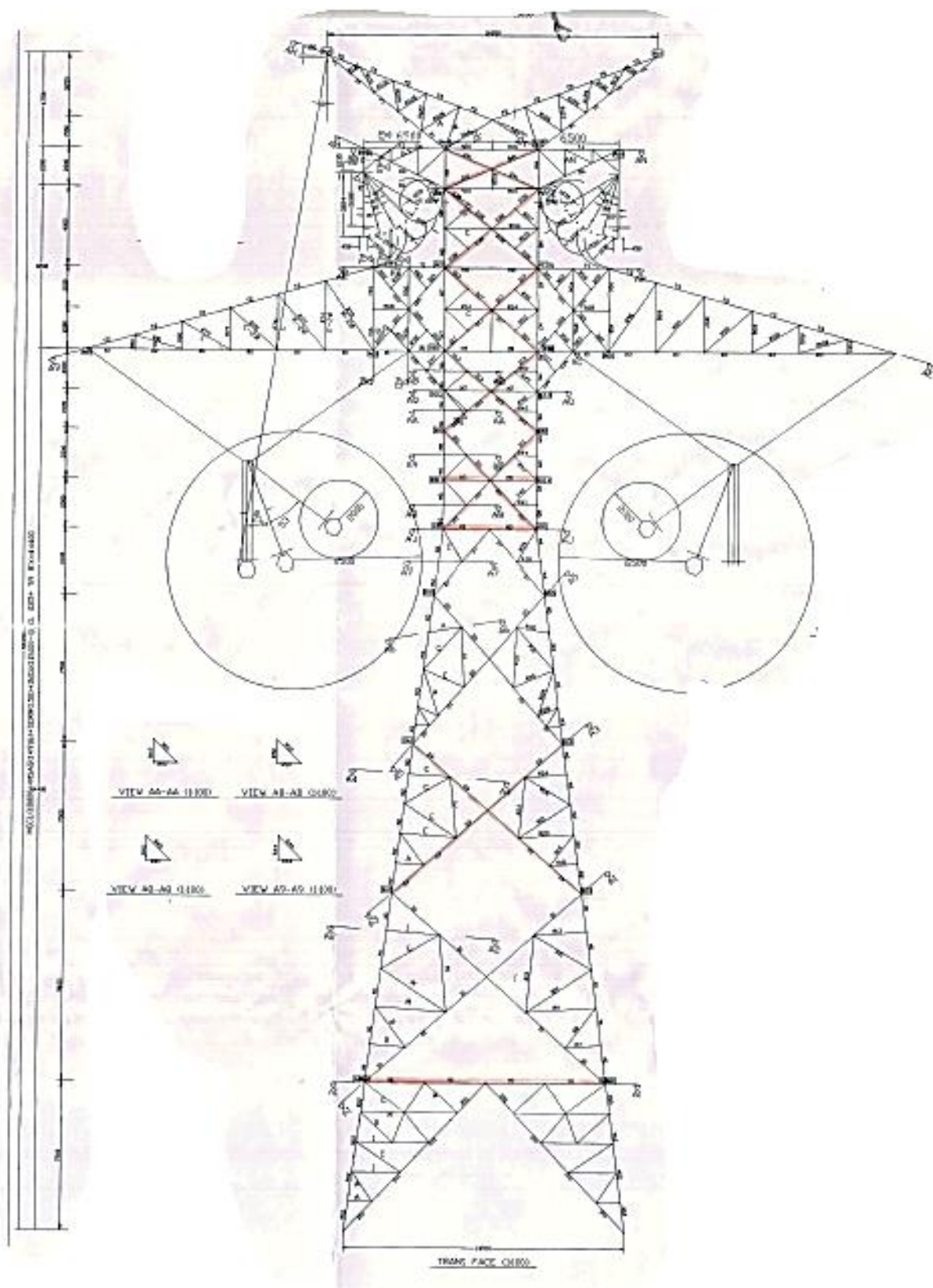
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	D	30-60

Tower Design Parameters

- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	13.591 X 13.591
2	D	600/0	360/-300	19.000 X 19.000

Remarks: In house Tested Towers



+ 800 kV HVDC WITH DMR WZ 2 Hex Lapwing T.T. 'A'





4.3 TECHNICAL PARAMETERS AND INDICATIVE SKETCHES OF TOWERS AT 765 kV

4.3.1 765 kV S/C (Horizontal) WZ 4 Quad Bersimis Transmission line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
- b) Configuration: SINGLE CIRCUIT (Horizontal)
- c) Conductor: ACSR QUAD BERSIMIS
- d) Earth wire: 7/3.66: 2No.
- e) Shield Angle: <20 Deg.
- f) Ground Clearance: 15.0m
- g) Mid Span Clearance: 9.0m
- h) Max Conductor Temp: 85 Deg C
- i) Line Altitude: Upto 1000m

Tower Types

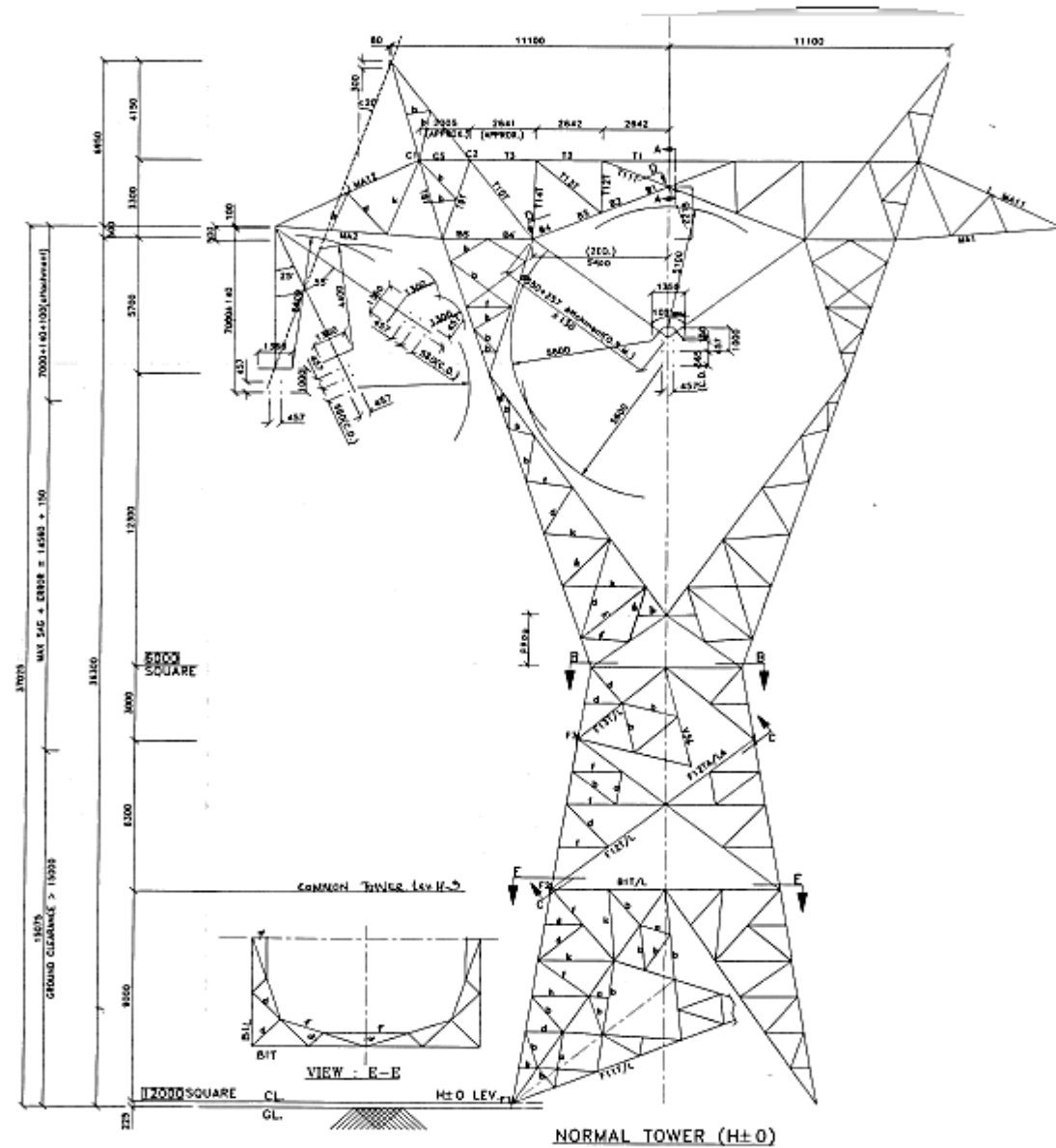
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0
2	B	0-5
3	D	0-30
4	E	30-60

Tower Design Parameters

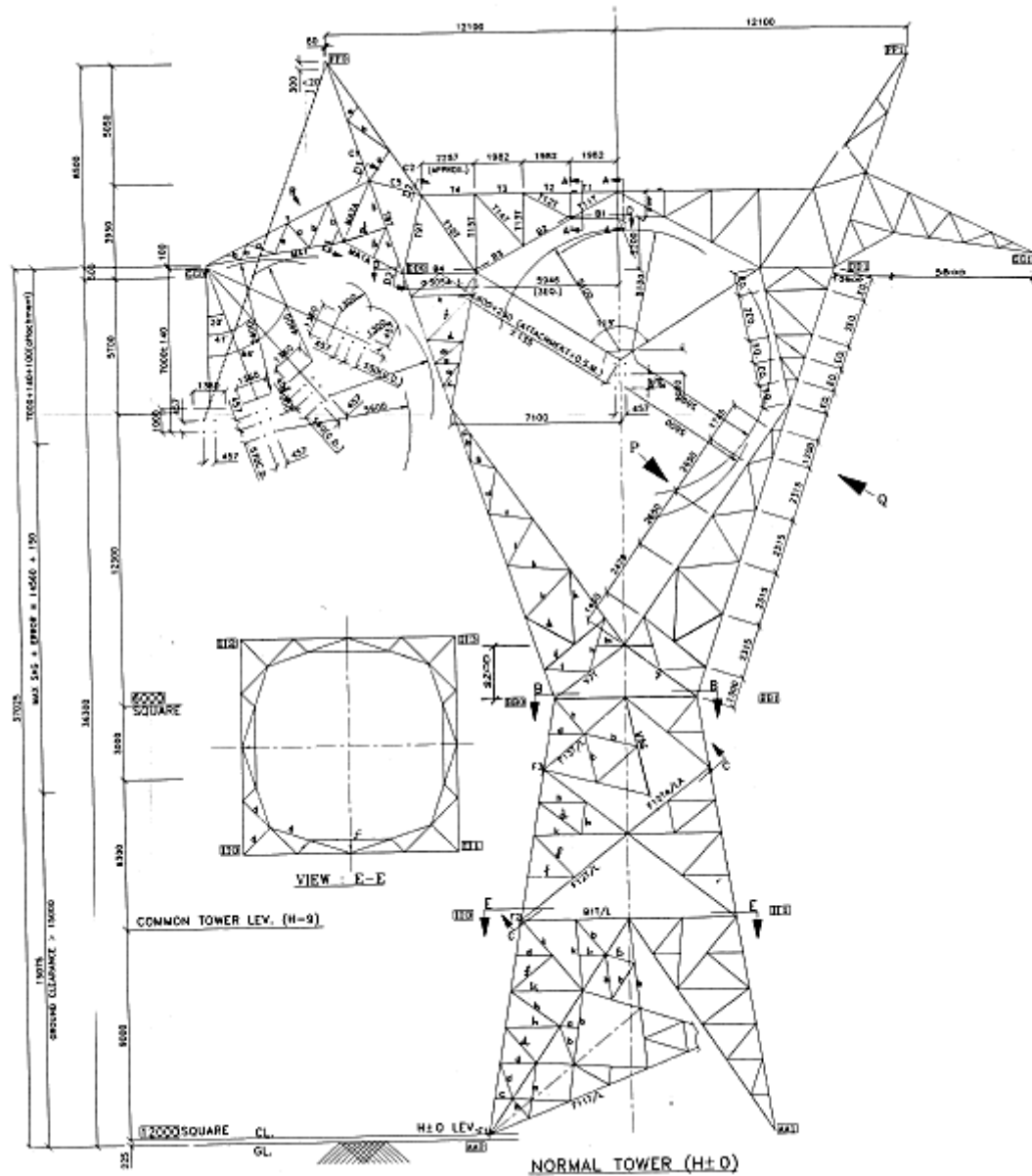
- a) IS: 802:1995
- b) Wind zone: 4
- c) Reliability Level: 2
- d) Terrain Category: 2
- e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/250	360/100	12.00 X 12.00
2	B	600/250	360/100	12.00 X 12.00
3	D	850/-350	700/-350	15.00 X 15.00
4	E	850/-350	700/-350	15.00 X 15.00

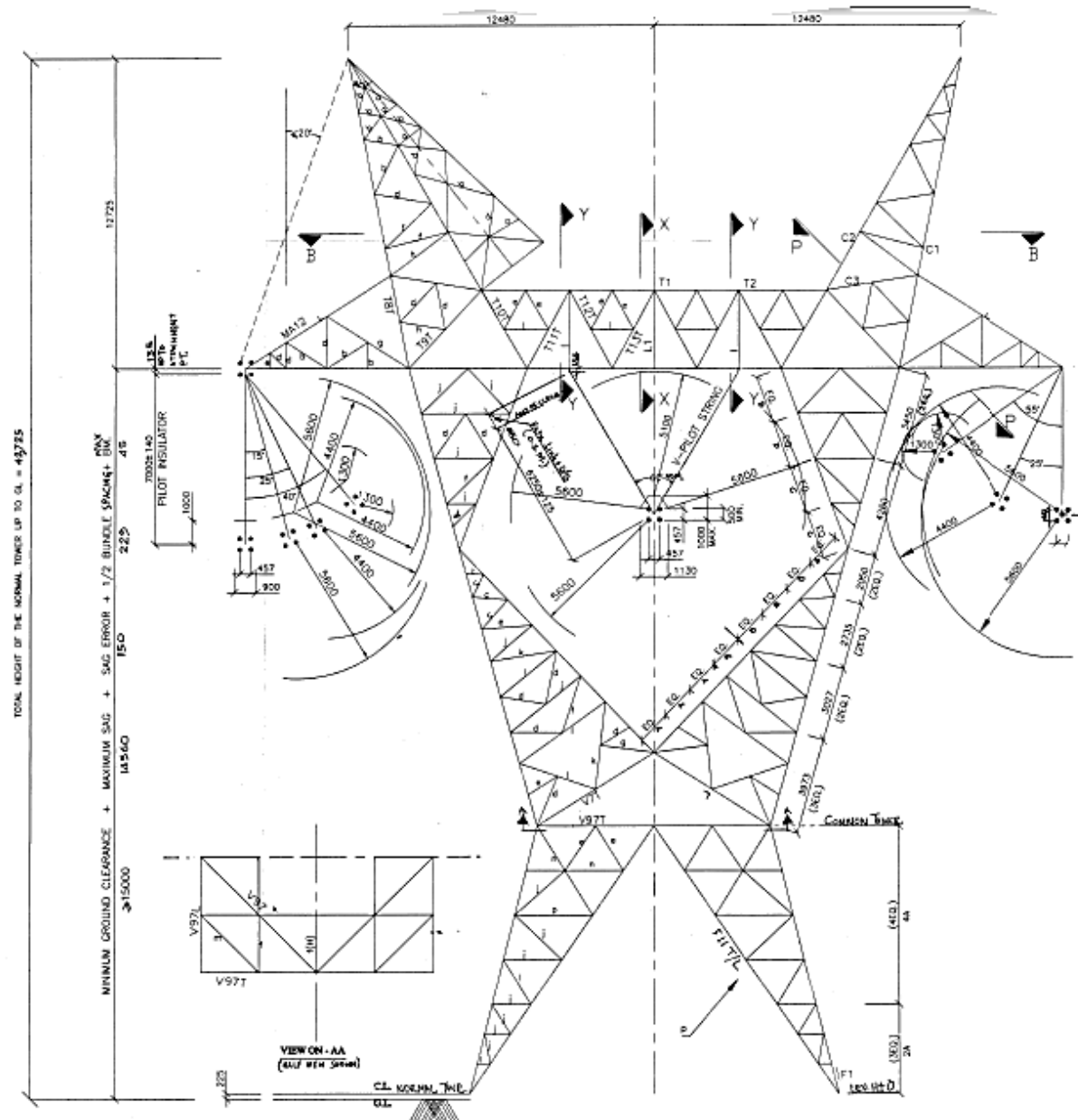
Remarks: Contractor Designed and Tested Towers



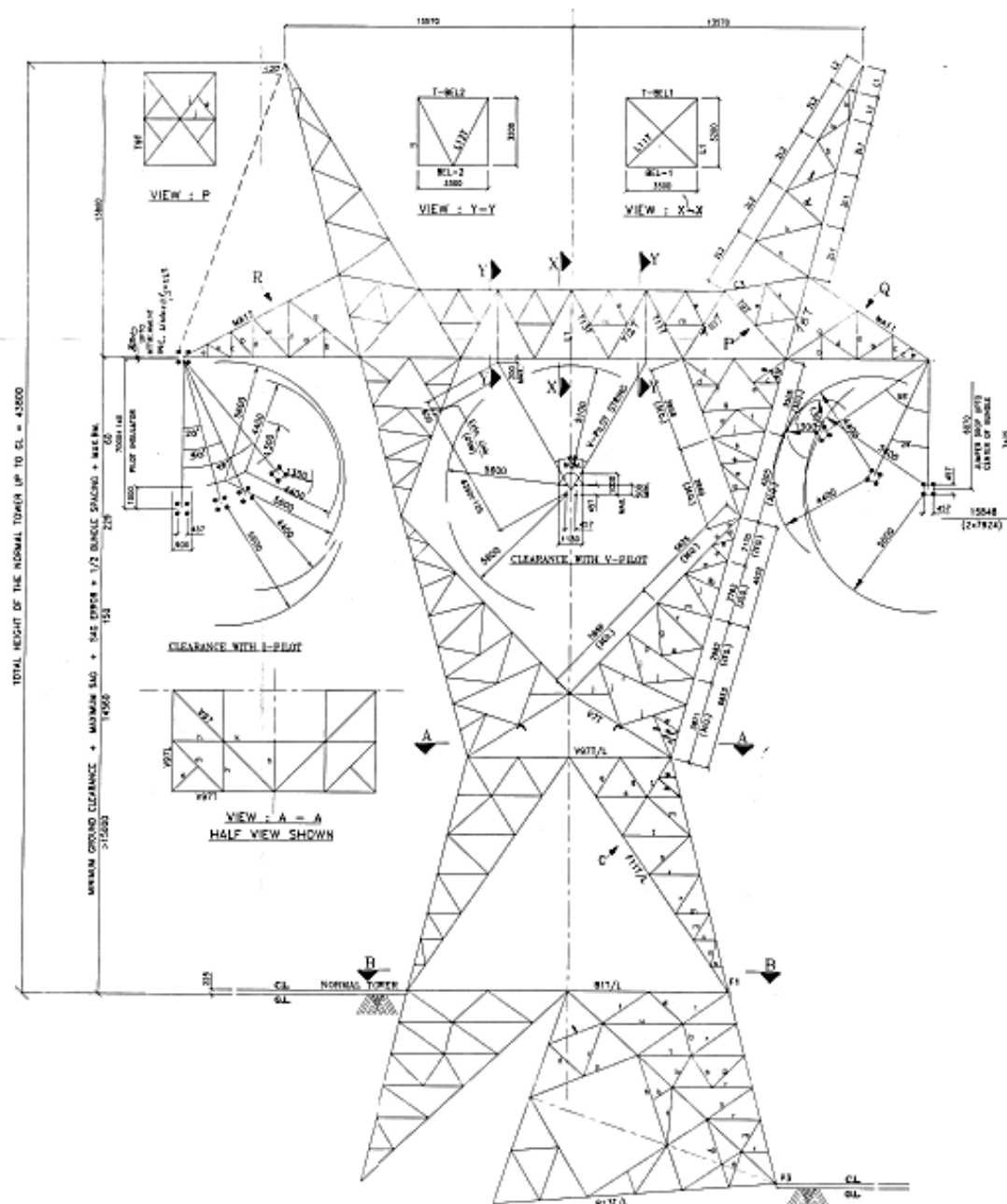
765 kV S/C (Horizontal) WZ 4 Quad Bersimis T.T. 'A'



765 kV S/C (Horizontal) WZ 4 Quad Bersimis T.T. 'B'



765 kV S/C (Horizontal) WZ 4 Quad Bersimis T.T. 'D'



765 kV S/C (Horizontal) WZ 4 Quad Bersimis T.T. 'E'

4.3.2 765 kV S/C (Delta) WZ 4 Quad Bersimis Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
b) Configuration: SINGLE CIRCUIT (Delta)
c) Conductor: ACSR QUAD BERSIMIS
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 15.0m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

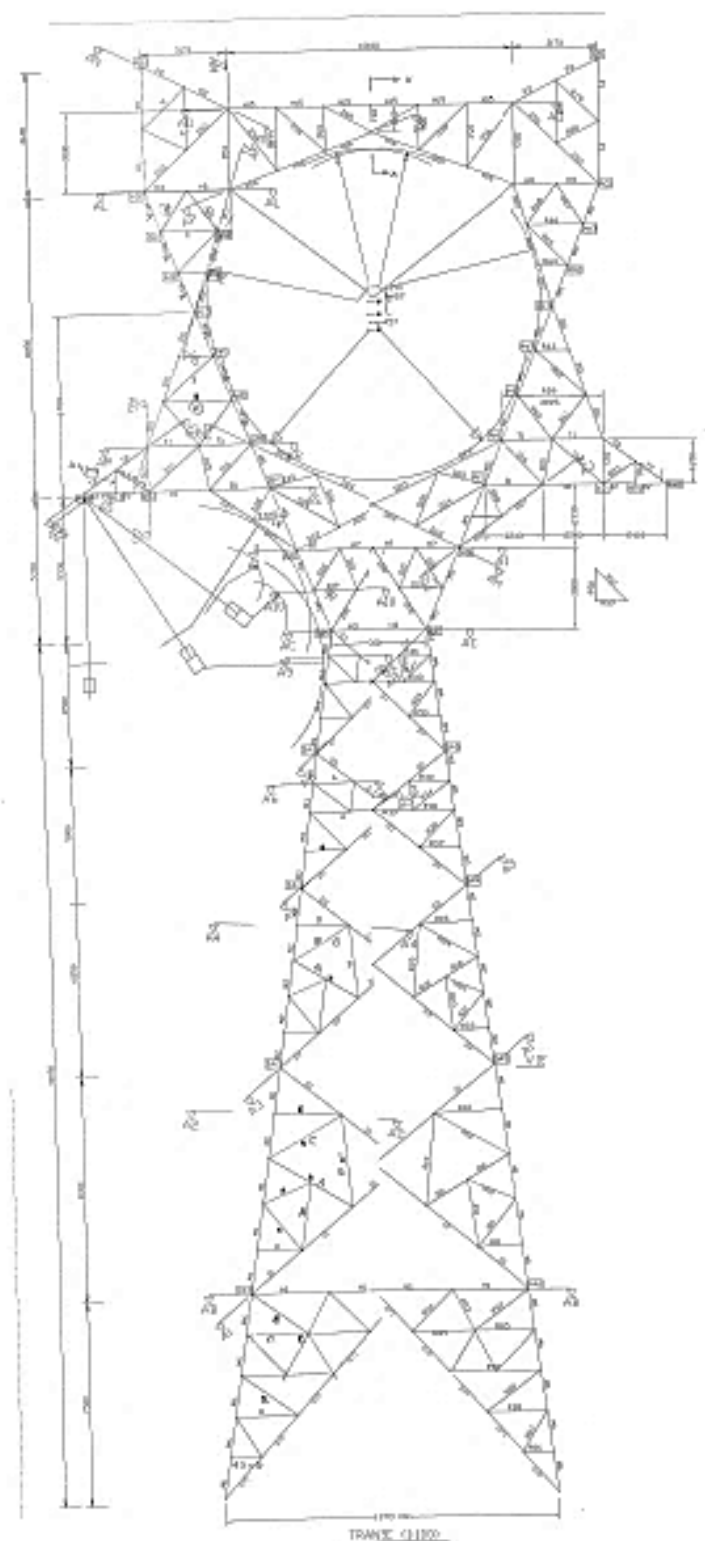
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Tower Design Parameters

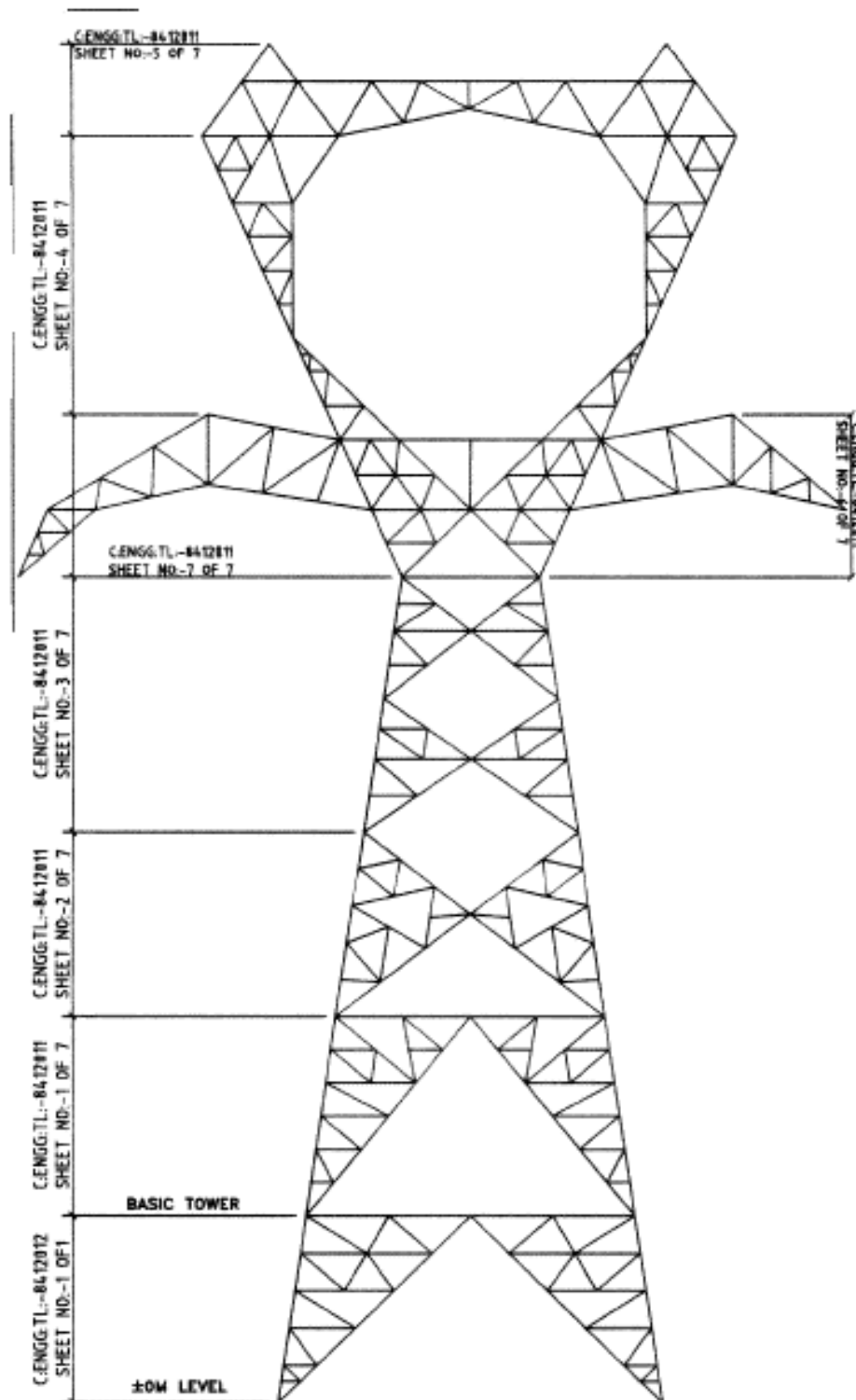
- a) IS: 802: 1995
b) Wind zone: 4
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/(Min)	BWC (Max)/(Min)	
1	A	600/200	360/100	13.75 X 13.75
2	B	600/200	360/100	16.30 X 16.30
3	C	600/0	360/-300	18.30 X 18.30
4	D	600/0	360/-300	19.20 X 19.20

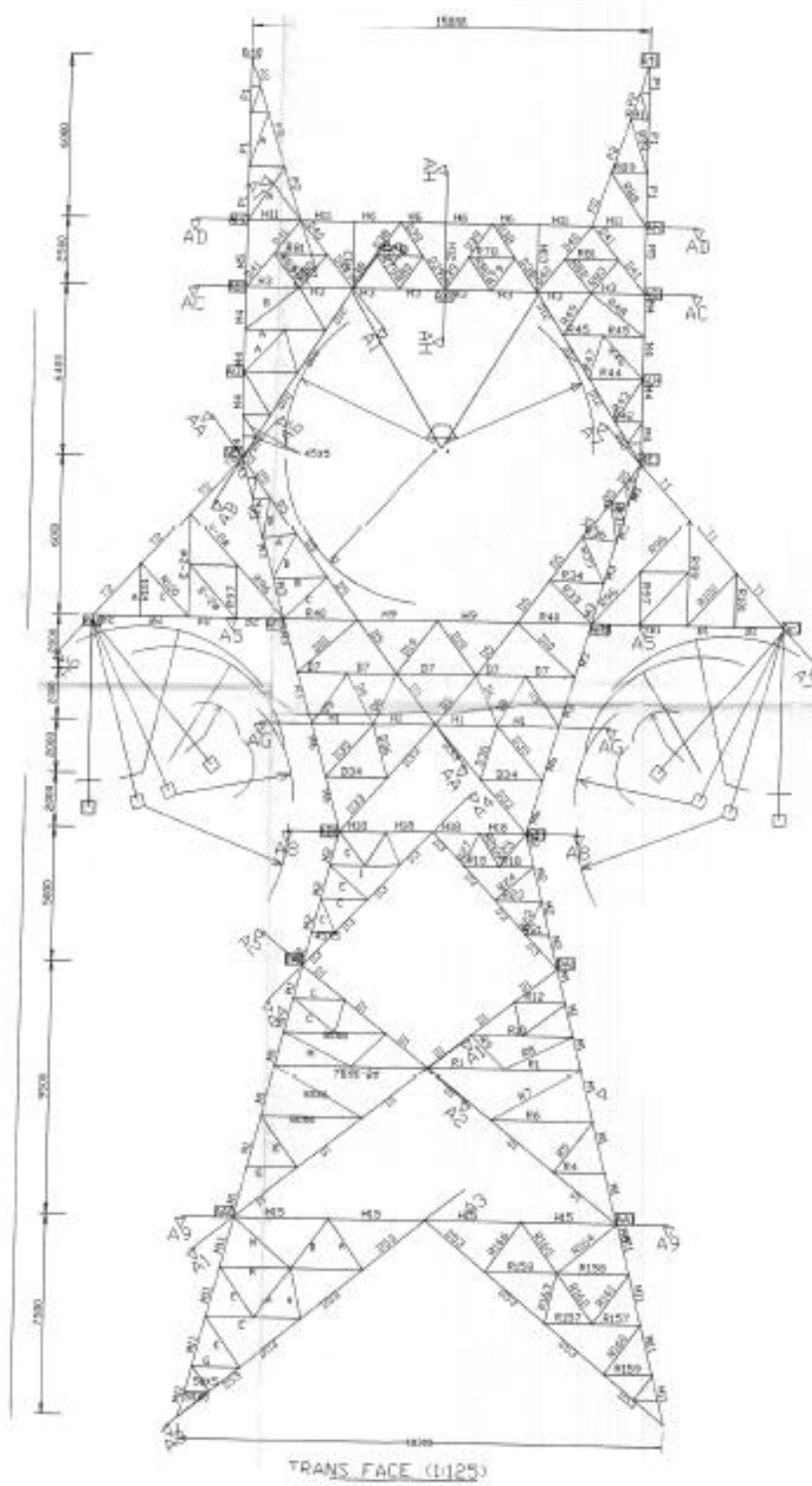
Remarks: In house Tested Towers



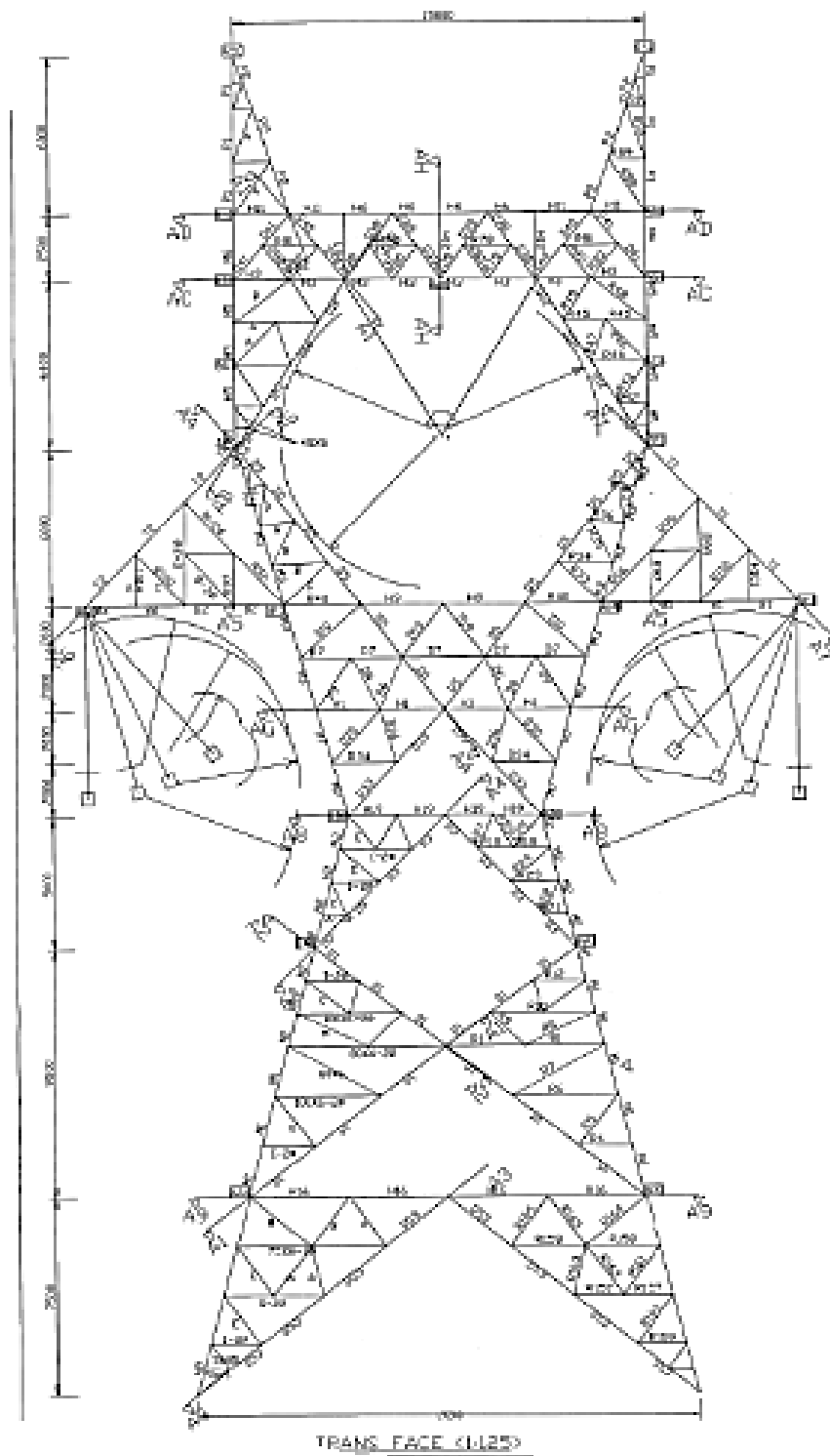
765 kV S/C (Delta) WZ 4 Quad Bersimis T.T. 'A'



765 kV S/C (Delta) WZ 4 Quad Bersimis T.T. 'B'



765 kV S/C (Delta) WZ 4 Quad Bersimis T.T.'C



765 kV S/C (Delta) WZ 4 Quad Bersimis T.T.'



4.3.3 765 kV S/C (VERTICAL DELTA) WZ 2 Quad Bersimis Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
b) Configuration: SINGLE CIRCUIT (VERTICAL DELTA)
c) Conductor: ACSR QUAD BERSIMIS
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 15.0m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

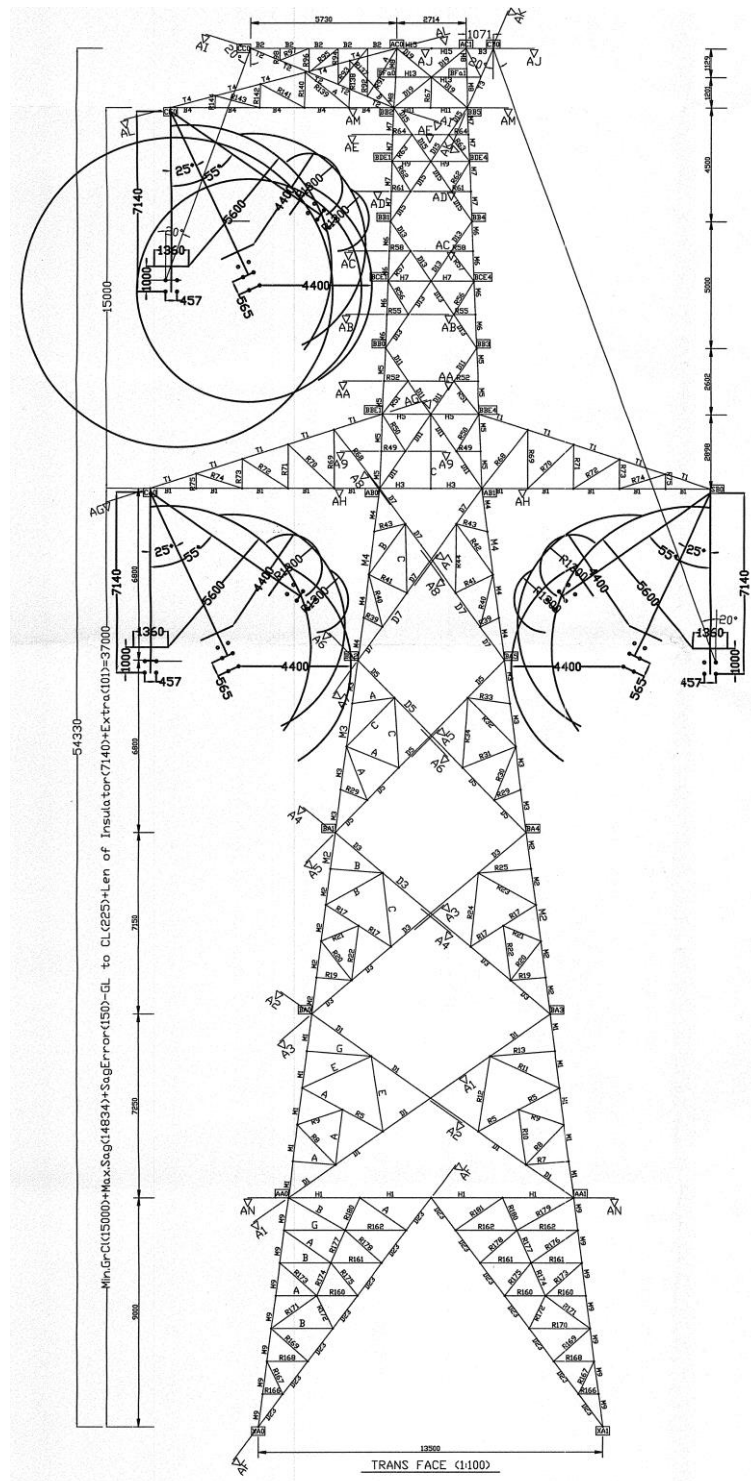
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Tower Design Parameters

- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

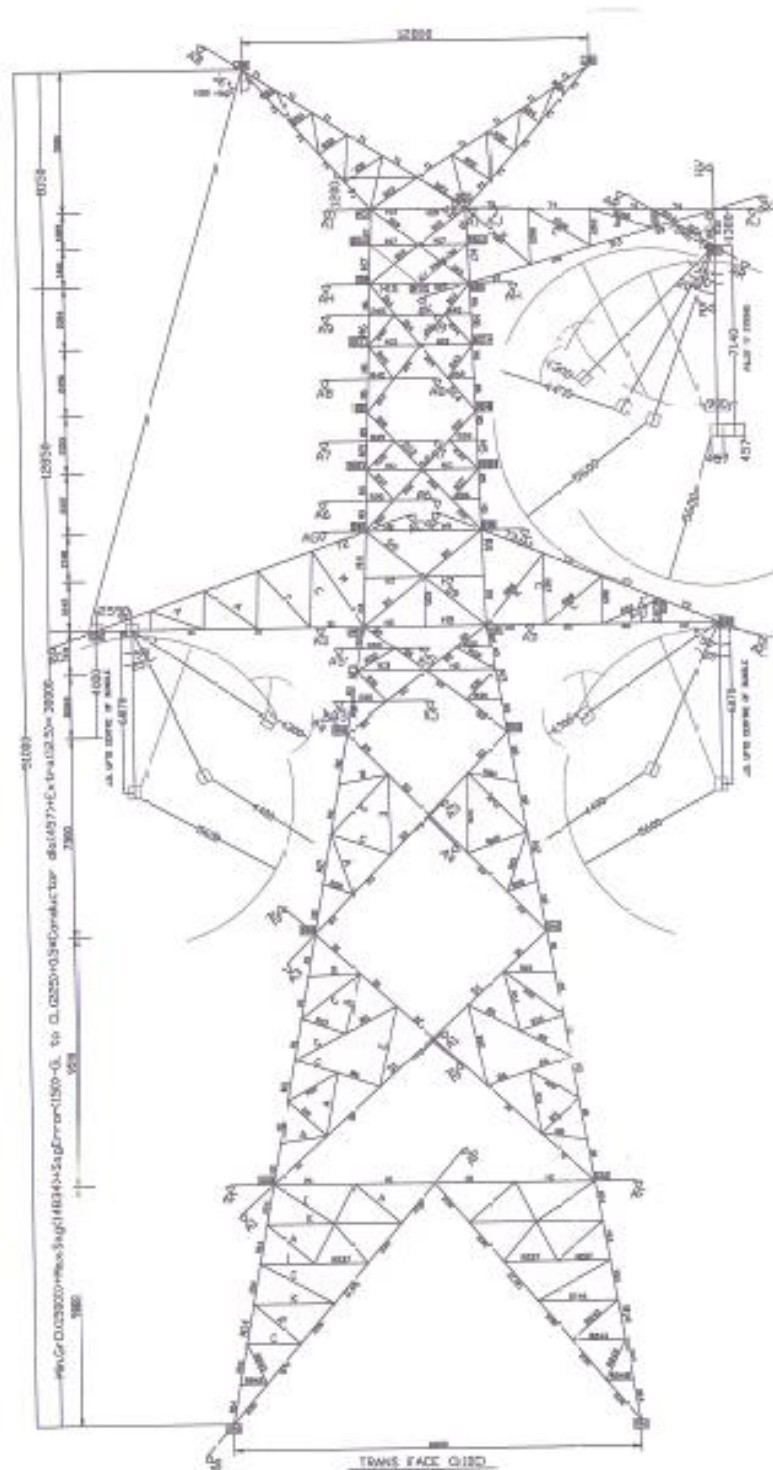
Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	13.50 X 13.50
2	B	600/0	360/-200	15.00 X 15.00
3	C	600/0	360/-200	16.10 X 16.10
4	D	600/0	360/-300	17.00 X 17.00

Remarks: In house Tested Towers

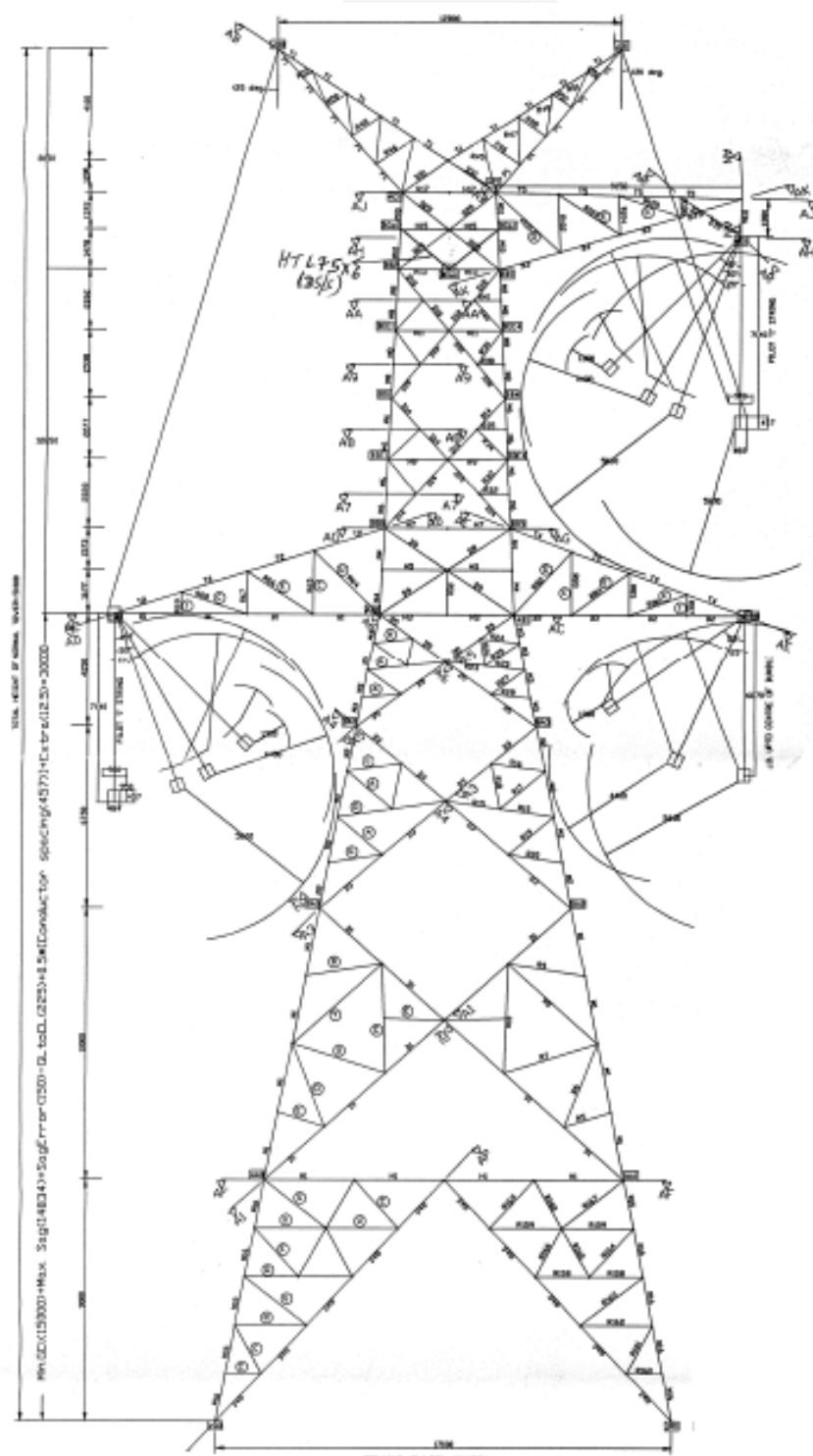


765 kV S/C (VERTICAL DELTA) WZ 2 Quad Bersimis T.T. 'A'





765 kV S/C (VERTICAL DELTA) WZ 2 Quad Bersimis T.T. 'C'



765 kV S/C (VERTICAL DELTA) WZ 2 Quad Bersimis T.T. 'D'

4.3.4 765 kV S/C (DELTA)WZ 2 Quad Bersimis Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
b) Configuration: SINGLE CIRCUIT (DELTA)
c) Conductor: ACSR QUAD BERSIMIS
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 15.0m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Tower Design Parameters

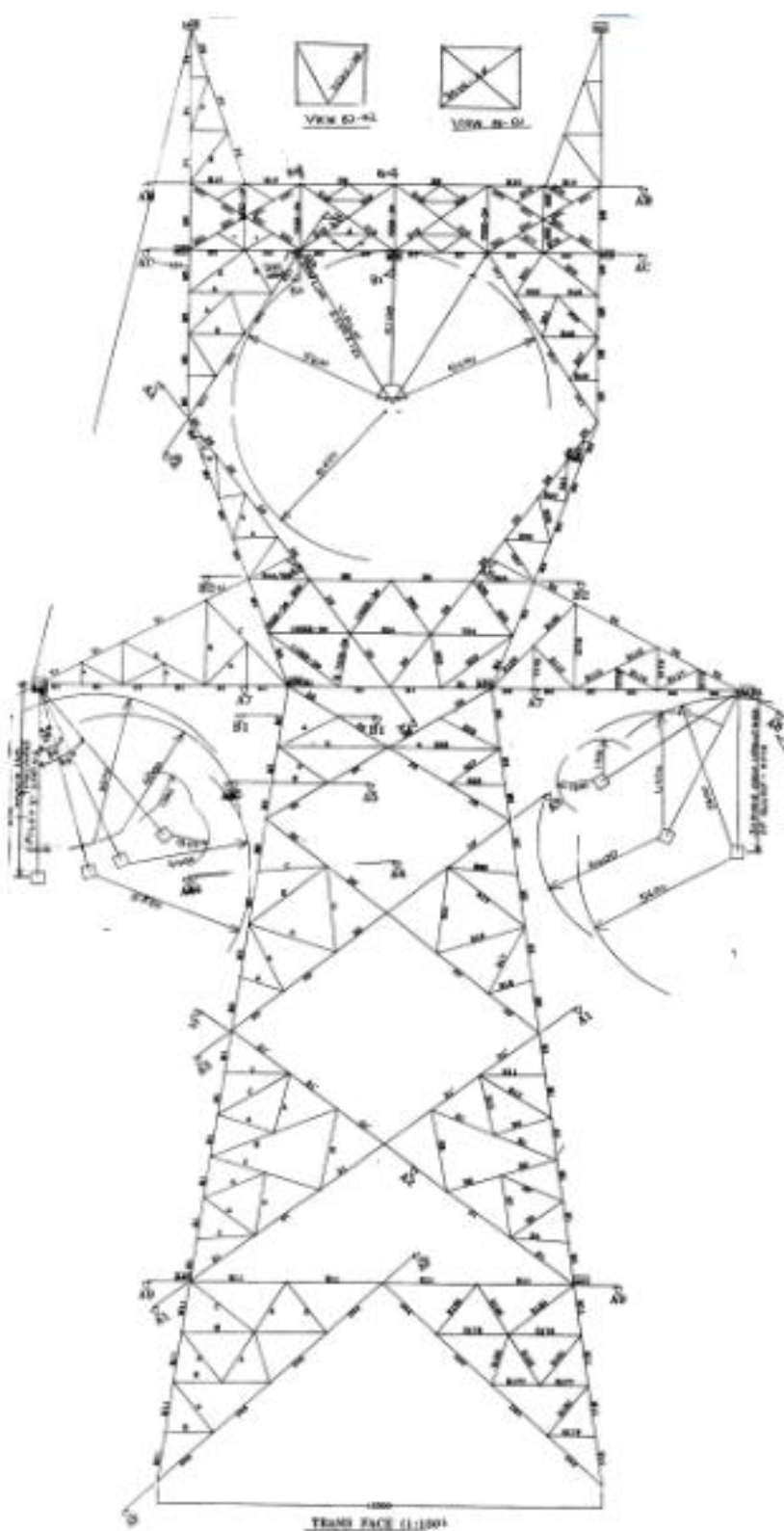
- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	12.50 X 12.50
2	B	600/200	360/100	15.30 X 15.30
3	C	600/0	360/-200	16.30 X 16.30
4	D	600/0	360/-300	17.00 X 17.00

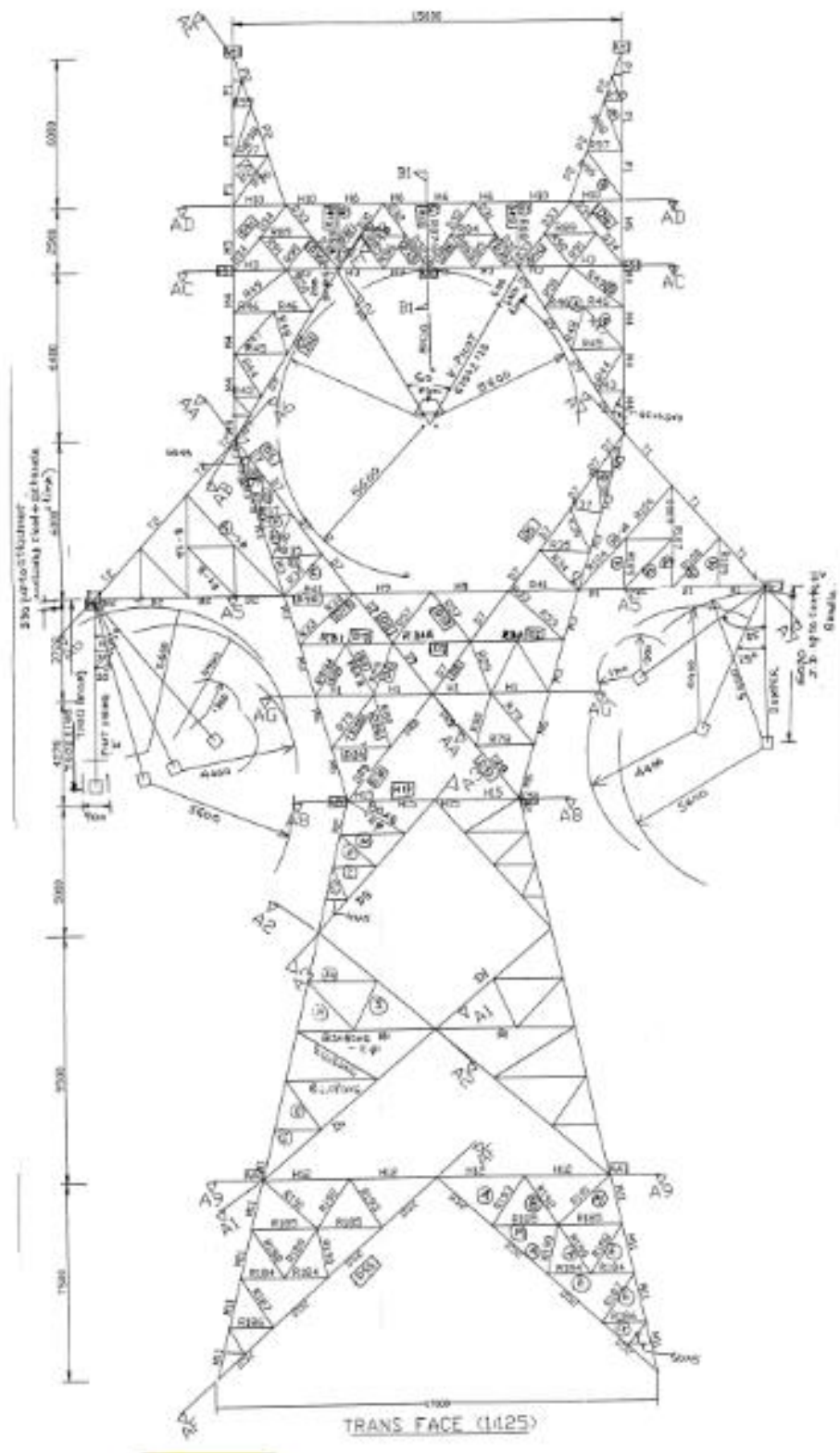
Remarks: In house Tested Towers







765 kV S/C (DELTA) WZ 2 Quad Bersimis T.T 'C'



765 kV S/C (DELTA) WZ 2 Quad Bersimis T.T 'D'



4.3.5 765 kV S/C (HORIZONTAL) WZ 1 Quad Bersimis Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
b) Configuration: SINGLE CIRCUIT (HORIZONTAL)
c) Conductor: ACSR QUAD BERSIMIS
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 15.0m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

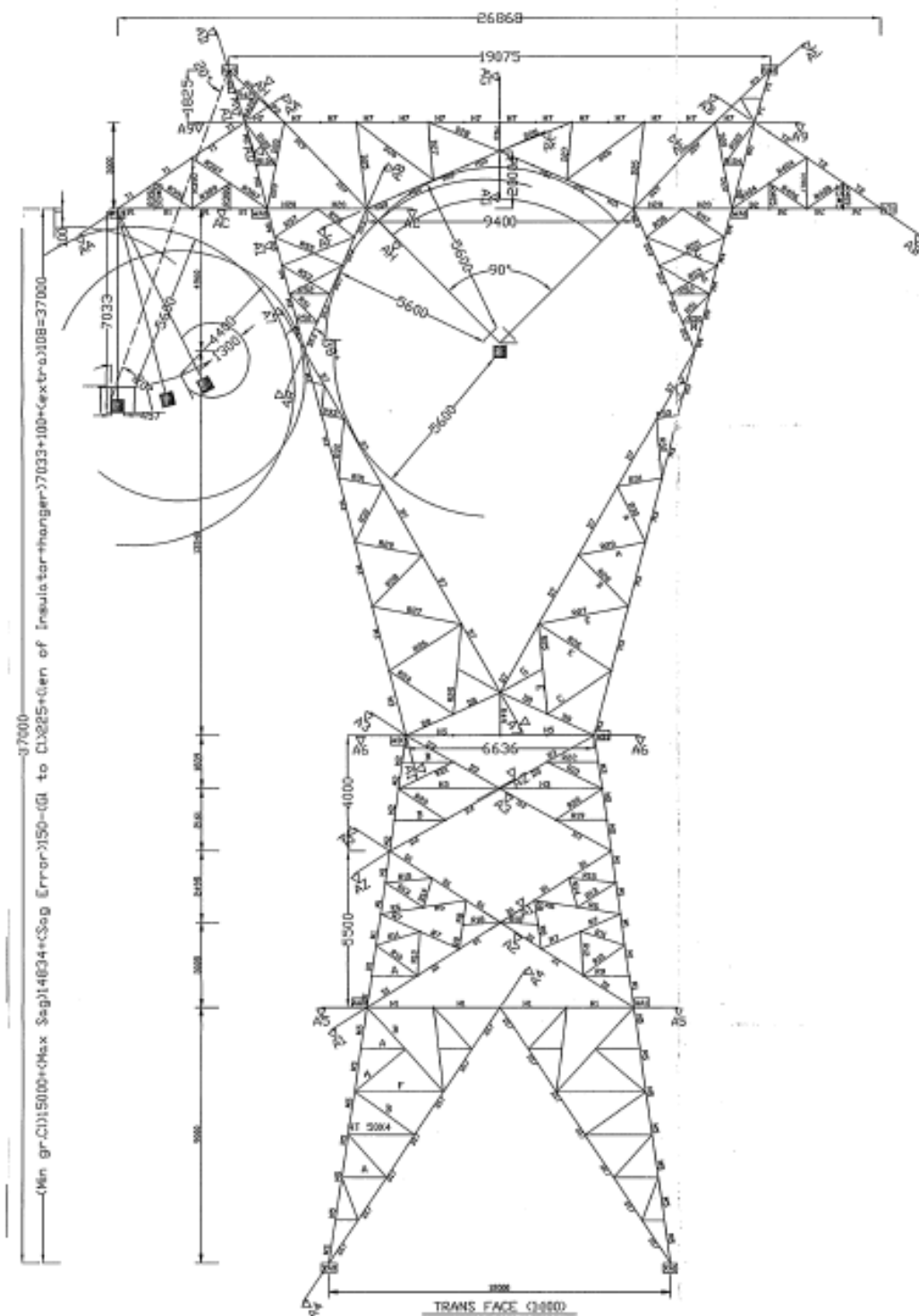
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2

Tower Design Parameters

- a) IS : 802:1995
b) Wind zone: 1
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	12.00 X 12.00

Remarks: In house Tested Towers



765 kV S/C (HORIZONTAL) WZ 1 Quad Bersimis T.T. 'A'

4.3.6 765 kV S/C (VERTICAL DELTA) WZ 1 Quad Bersimis Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
b) Configuration: SINGLE CIRCUIT (VERTICAL DELTA)
c) Conductor: ACSR QUAD BERSIMIS
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 15.0m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

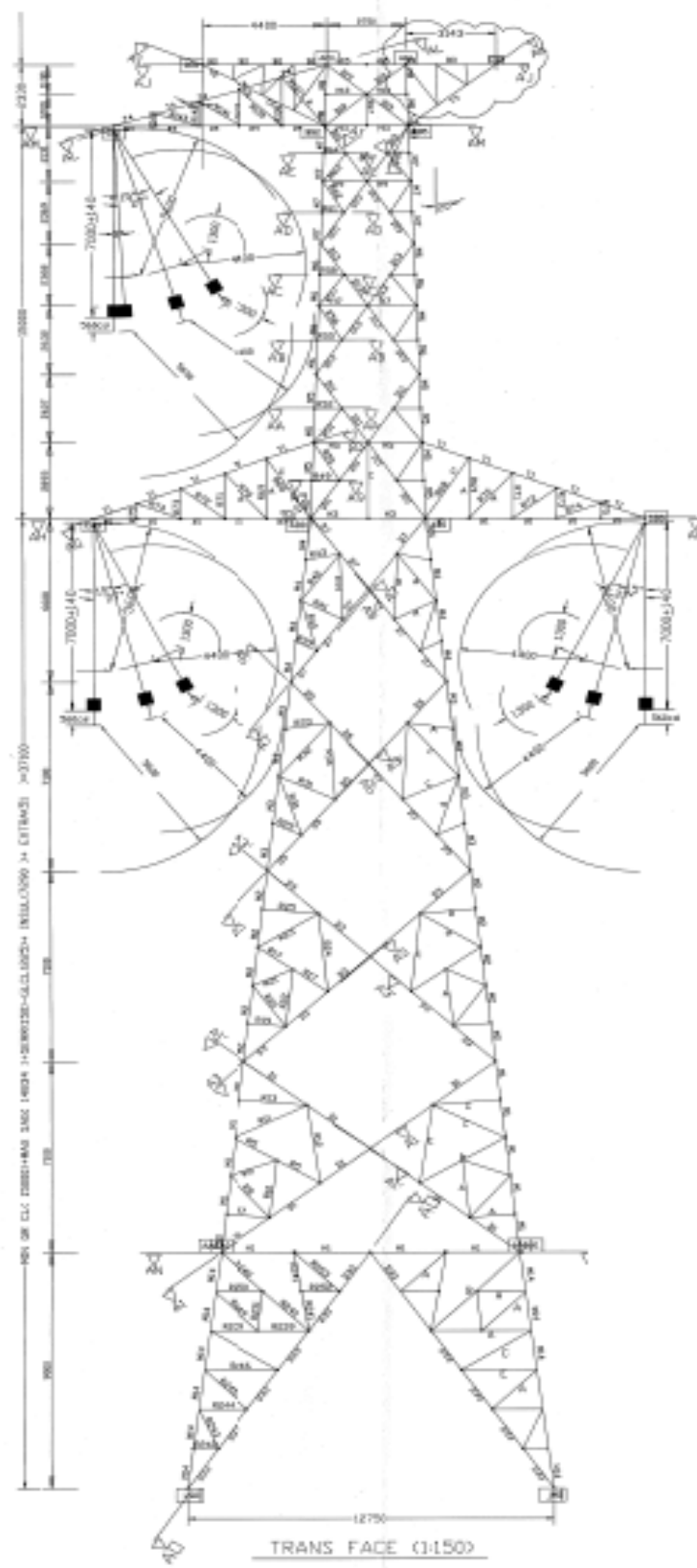
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Tower Design Parameters

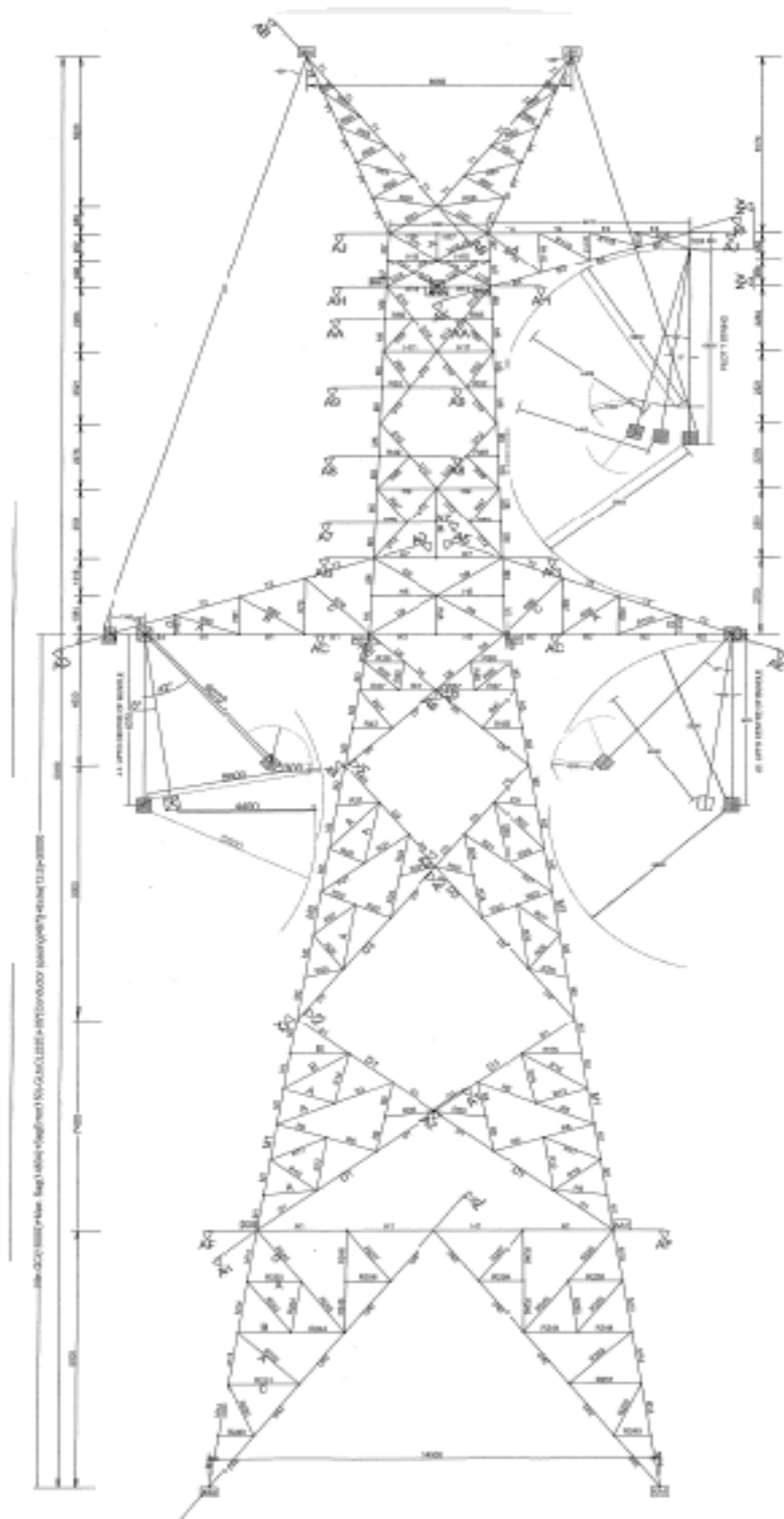
- a) IS : 802:1995
b) Wind zone: 1
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	12.750 X 12.750
2	B	600/0	360/-200	14.500 x 14.500
3	C	600/0	360/-300	14.828 x 14.828
4	D	600/0	360/-300	15.500 x 15.500

Remarks: In house Tested Towers

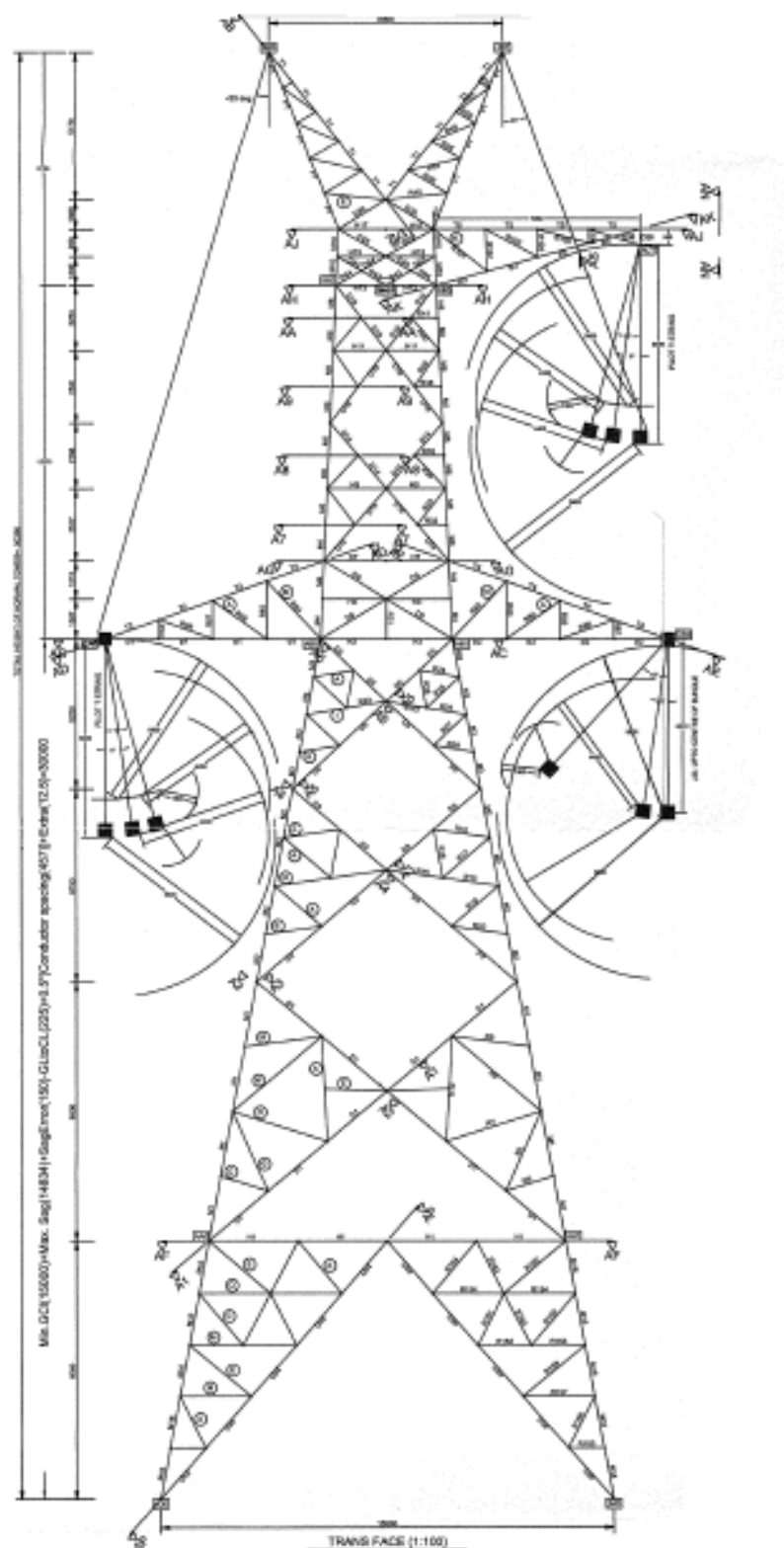


765 kV S/C (VERTICAL DELTA) WZ 1 Quad Bersimis T.T 'A'



765 kV S/C (VERTICAL DELTA) WZ 1 Quad Bersimis T.T 'B'





765 kV S/C (VERTICAL DELTA) WZ 1 Quad Bersimis T.T 'D'

4.3.7 765 kV D/C WZ 5 Hex Zebra Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level:** 765 kV
b) Configuration: DOUBLE CIRCUIT
c) Conductor: ACSR HEXA ZEBRA
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 15.0m (for DA)
15.5m (for DB, DC, DD)
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

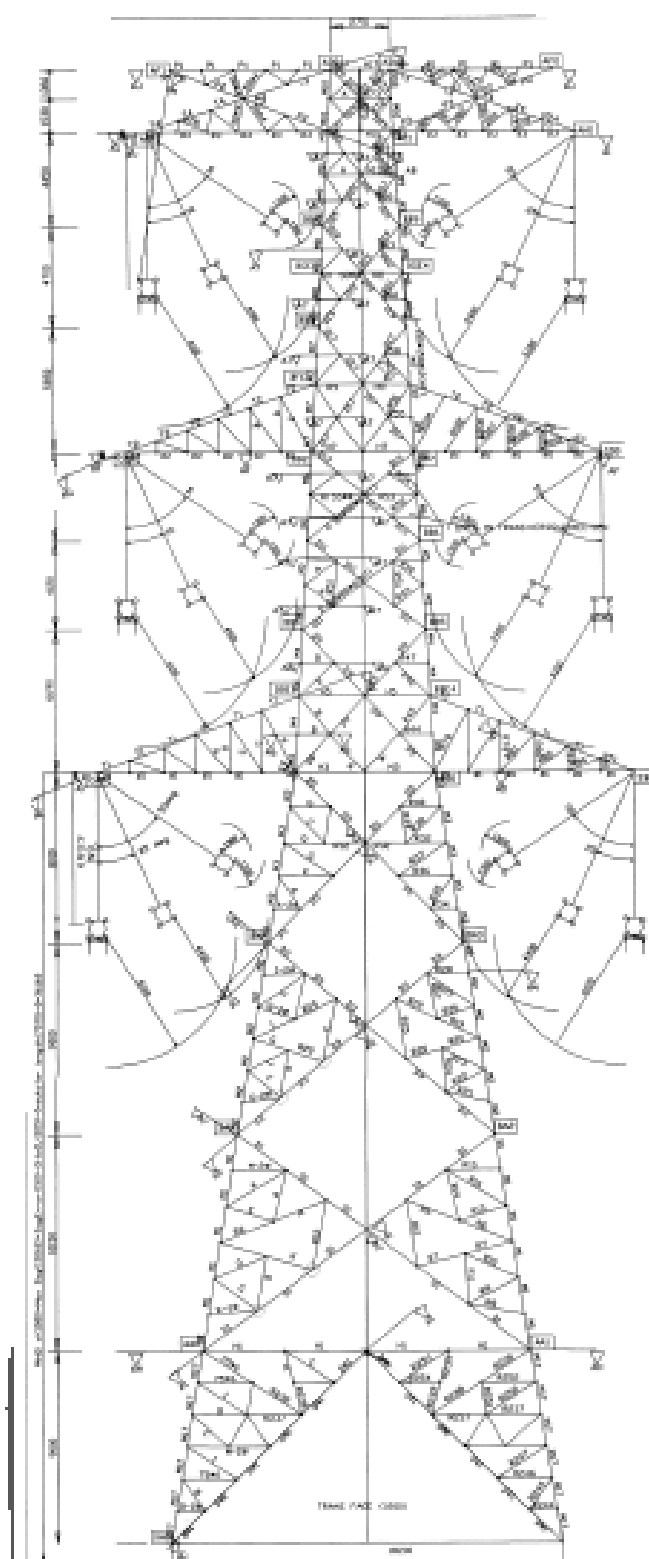
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

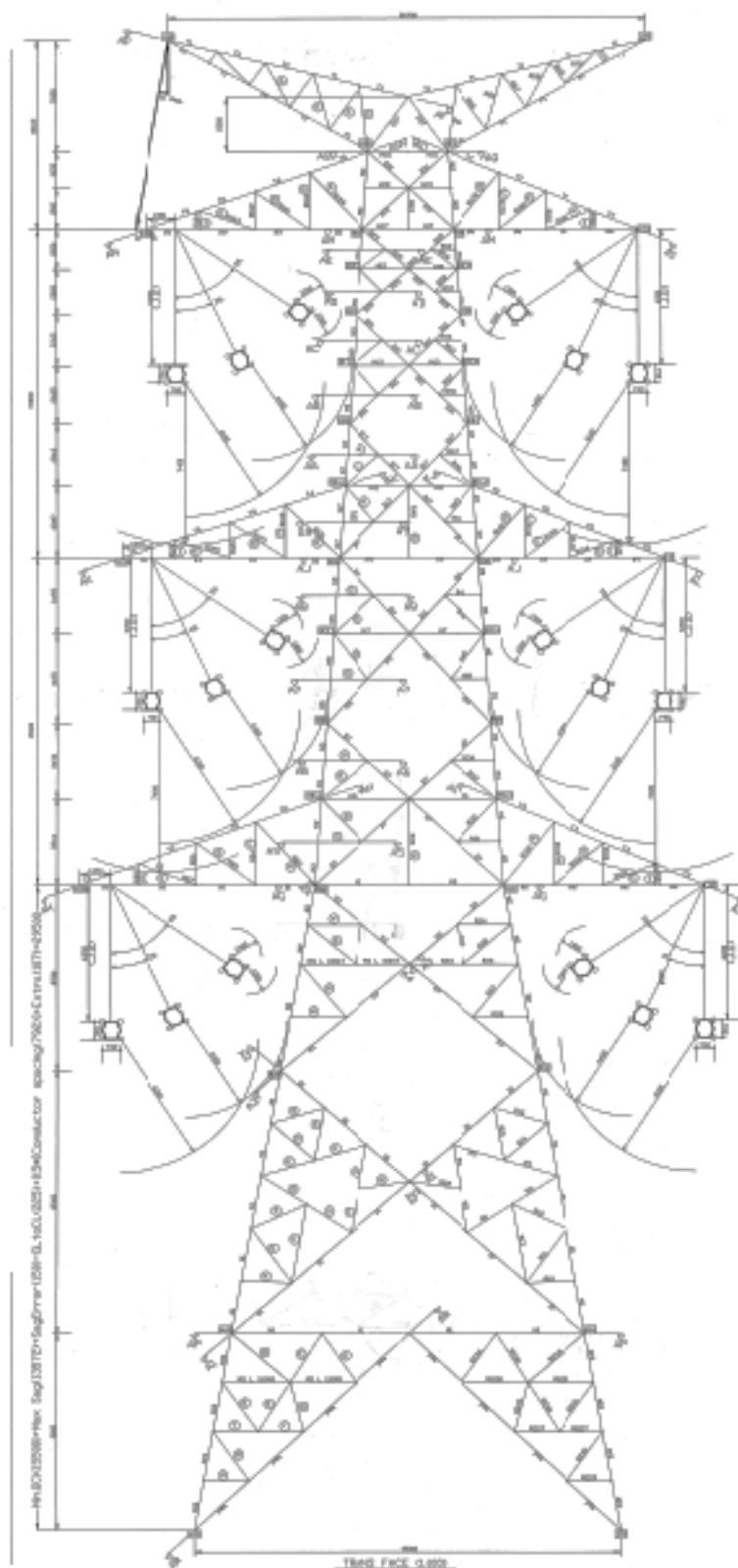
- a) IS :** 802:1995
b) Wind zone: 5
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	18.200 X 18.200
2	DB	600/0	360/-200	19.000 x 19.000
3	DC	600/0	360/-200	20.000 x 20.000
4	DD	675/0	405/-300	23.000 x 23.000

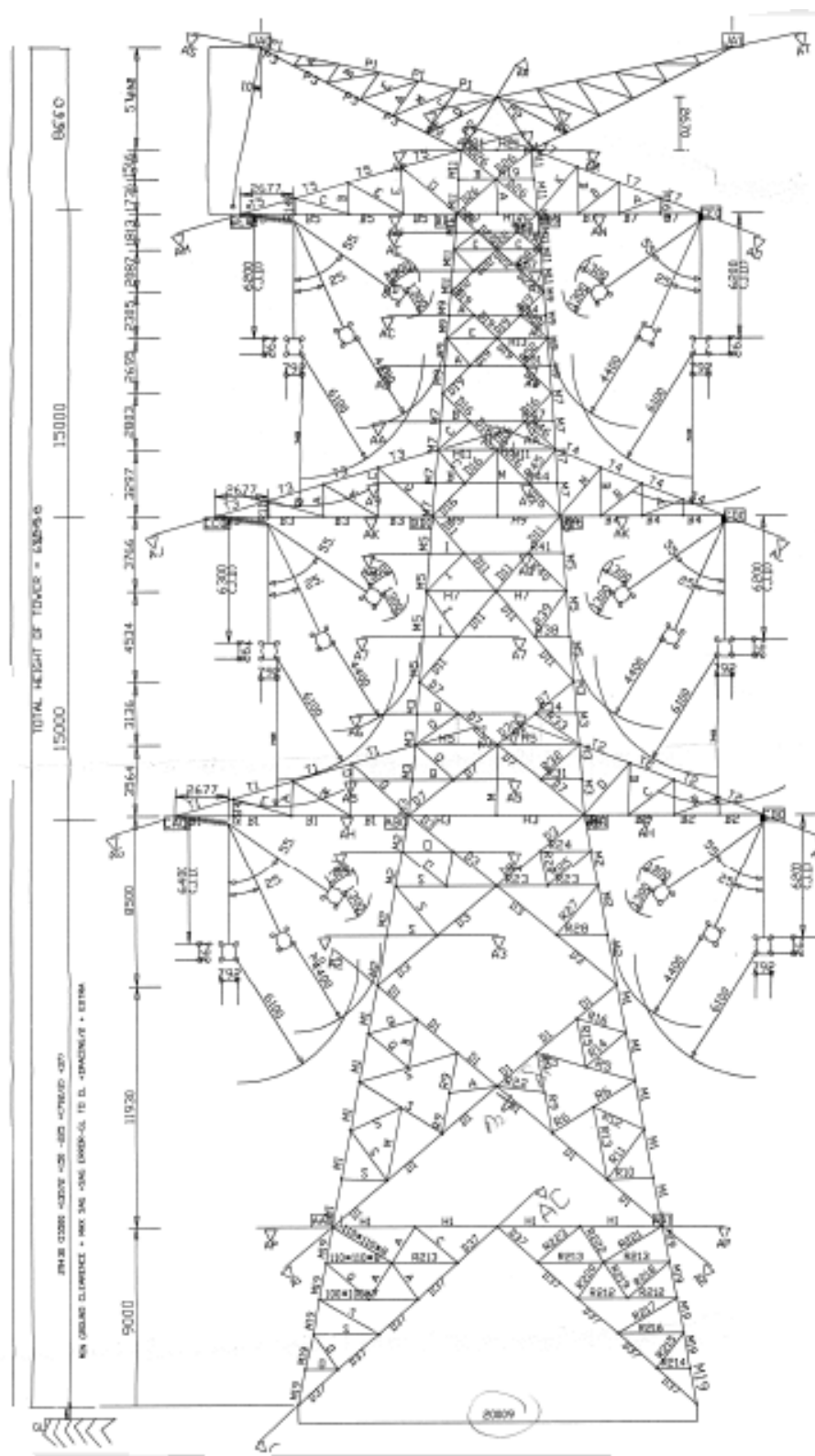
Remarks: In house Tested Towers



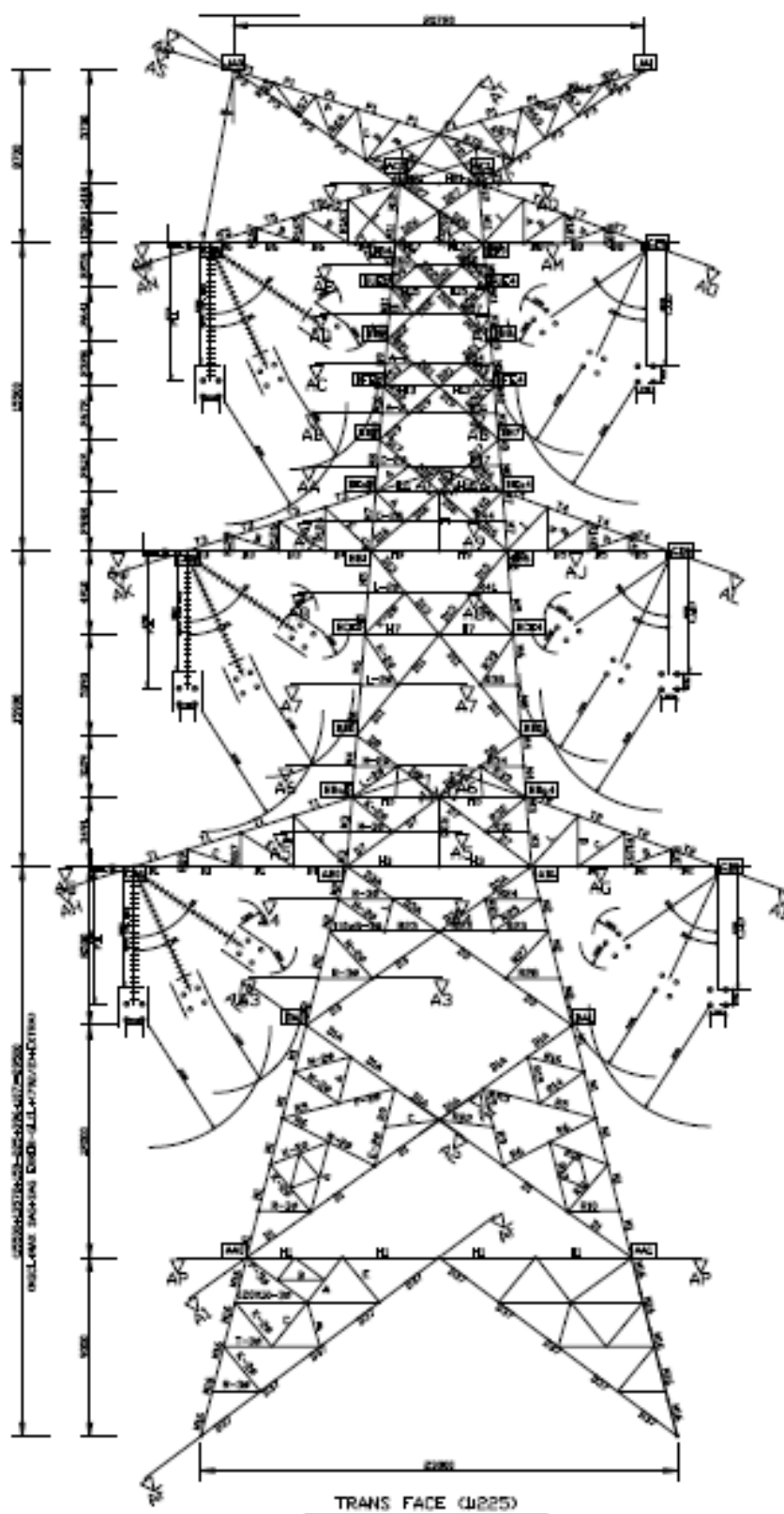
765 kV D/C WZ 5 Hex Zebra T.T. 'DA'



765 kV D/C WZ 5 Hex Zebra T.T. 'DB'



765 kV D/C WZ 5 Hex Zebra T.T. 'DC'



765 kV D/C WZ 5 Hex Zebra T.T. 'DD'

4.3.8 765 kV D/C WZ 4 Hex Zebra Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 765 kV
b) Configuration: DOUBLE
CIRCUIT
c) Conductor: ACSR HEXA
ZEBRA
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 15.5m (for DD)
15.0m (for DA,
DB, DC)
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

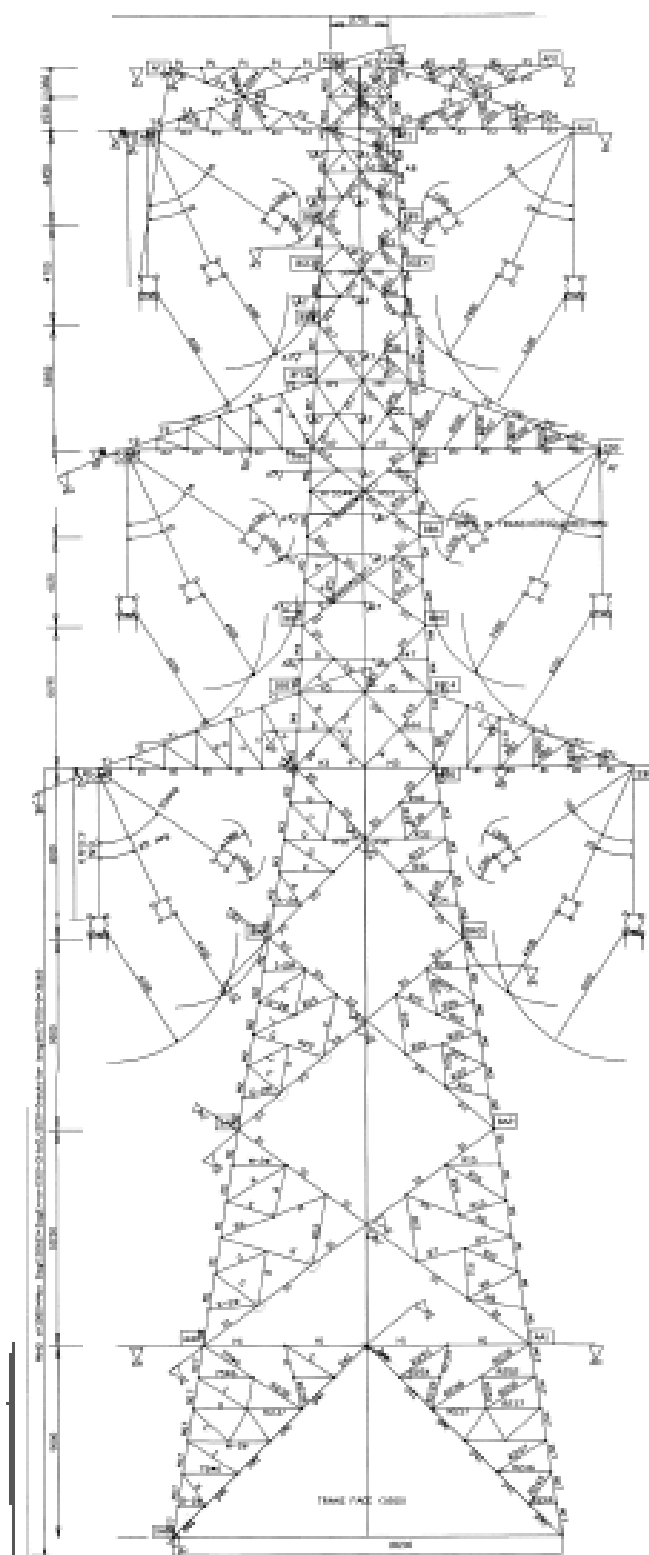
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

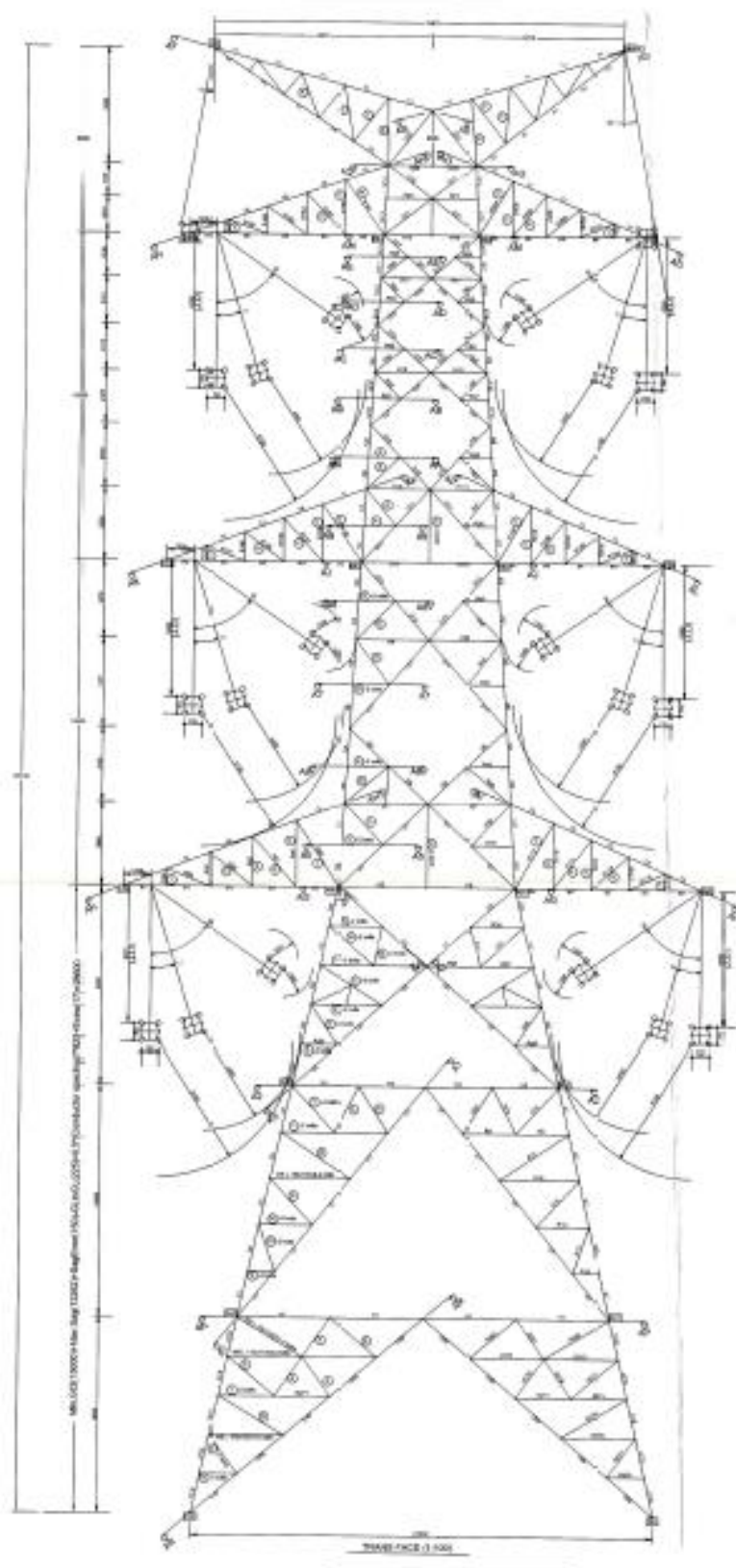
- a) IS: 802:1995
b) Wind zone: 4
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	18.20 X 18.20
2	DB	600/0	360/-200	21.00 x 21.00
3	DC	600/0	360/-200	21.00 x 21.00
4	DD	675/0	405/-300	24.26 x 24.26

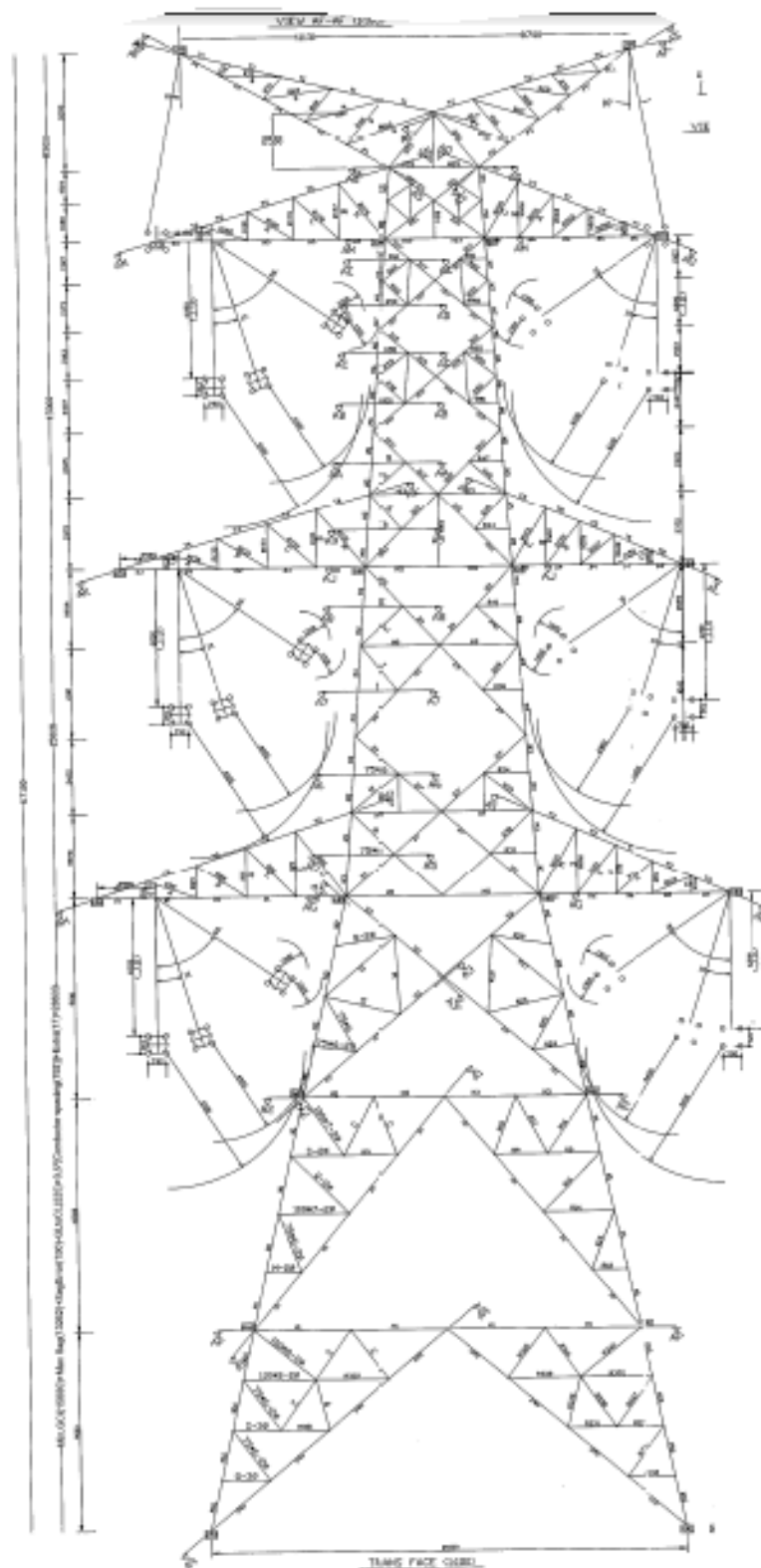
Remarks: In house Tested Towers



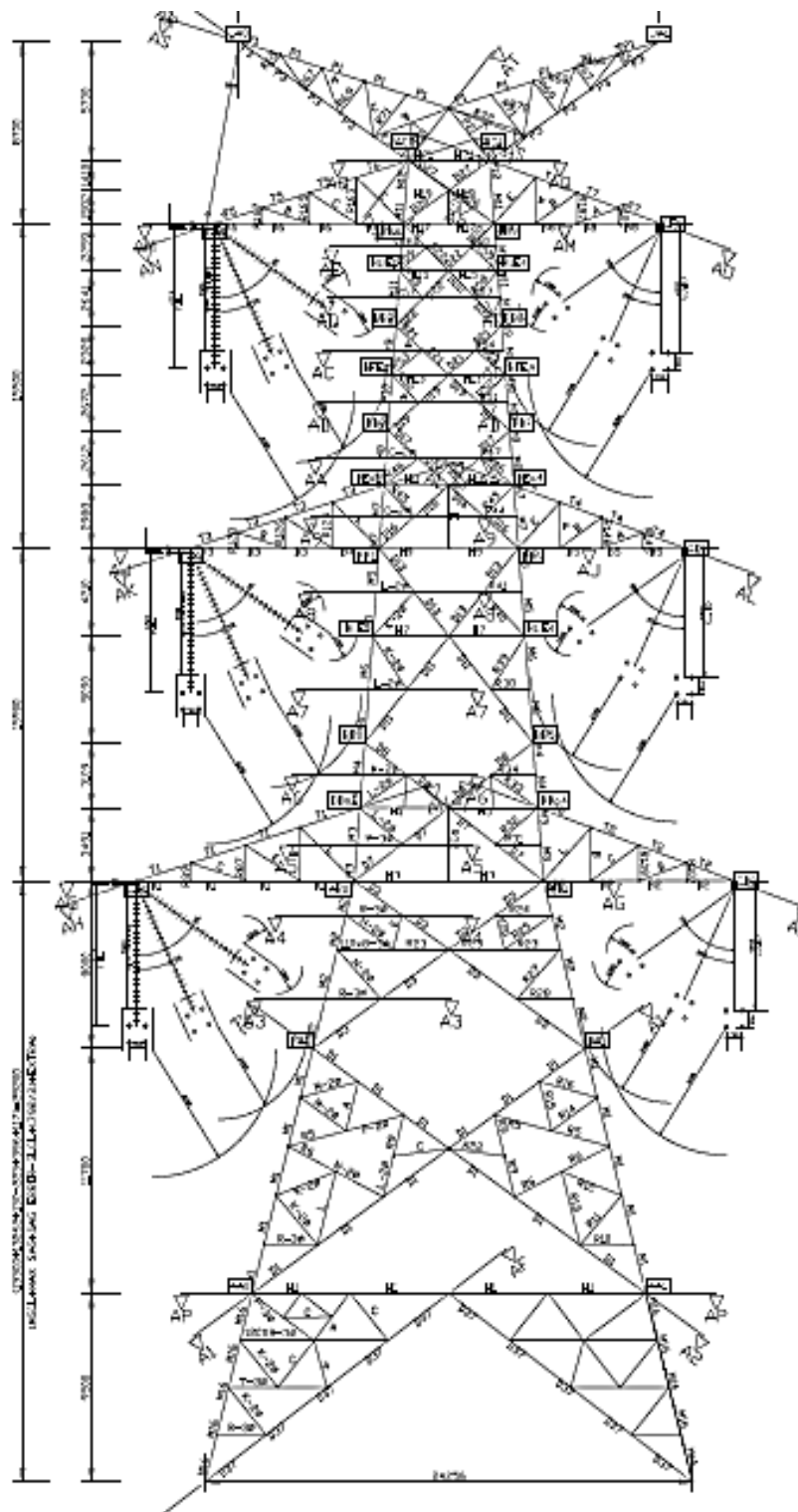
765 kV D/C WZ 4 Hex Zebra T.T. 'DA'



765 kV D/C WZ 4 Hex Zebra T.T. 'DB'



765 kV D/C WZ 4 Hex Zebra T.T. 'DC'



765 kV D/C WZ 4 Hex Zebra T.T. 'DD'

4.3.9 765 kV D/C WZ 3 Hex Zebra Transmission Line (PGCIL)

Line Parameters

- a) **Voltage Level:** 765 kV
b) **Configuration:** DOUBLE CIRCUIT
c) **Conductor:** ACSR HEXA ZEBRA
d) **Earth wire:** 7/3.66: 2No.
e) **Shield Angle:** zero deg (for DA)
<10 Deg (for DB, DC, DD)
f) **Ground Clearance:** 15.5m (for DA)
15.0m (for DB, DC, DD)
g) **Mid Span Clearance:** 12.0m (for DA)
9.0m (for DB, DC, DD)
h) **Max Conductor Temp:** 85 Deg C
i) **Line Altitude:** Upto 1000m

Tower Types

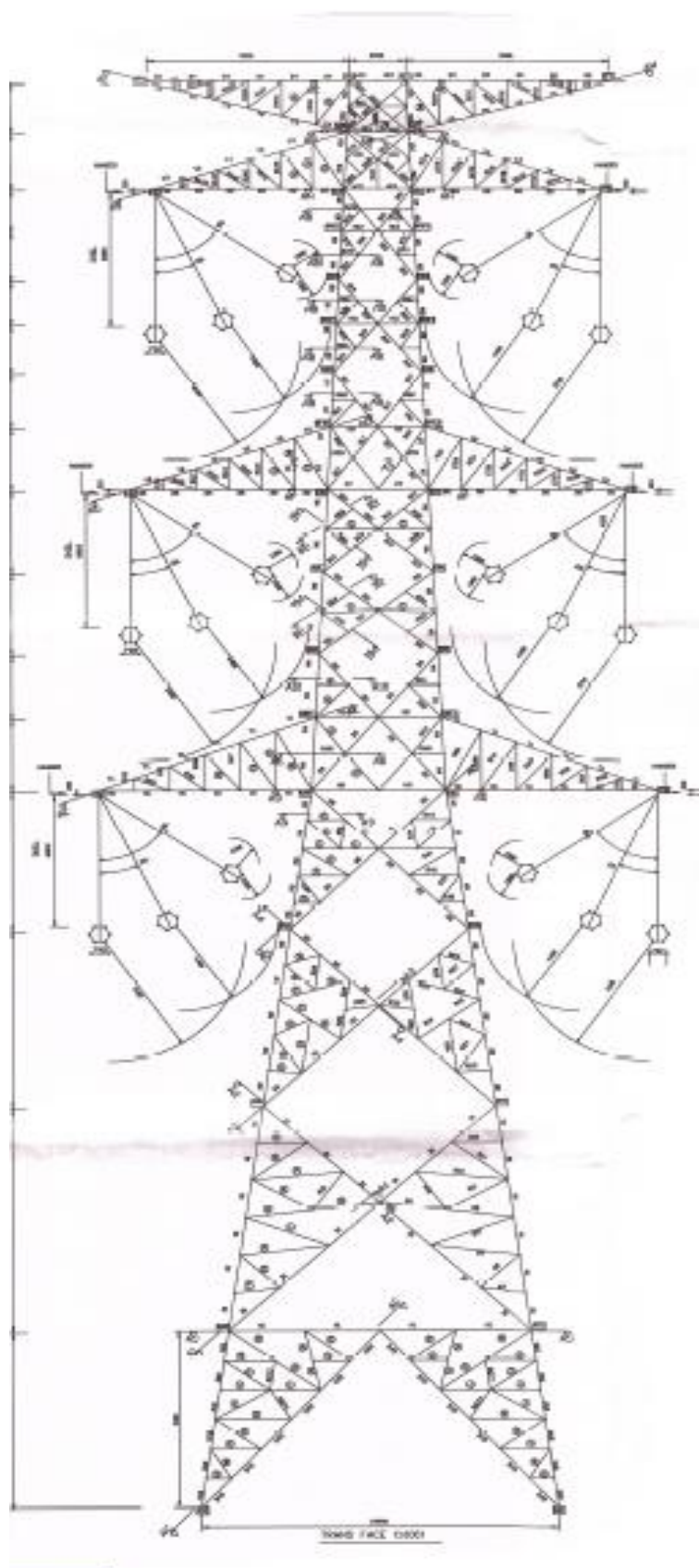
Sr No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

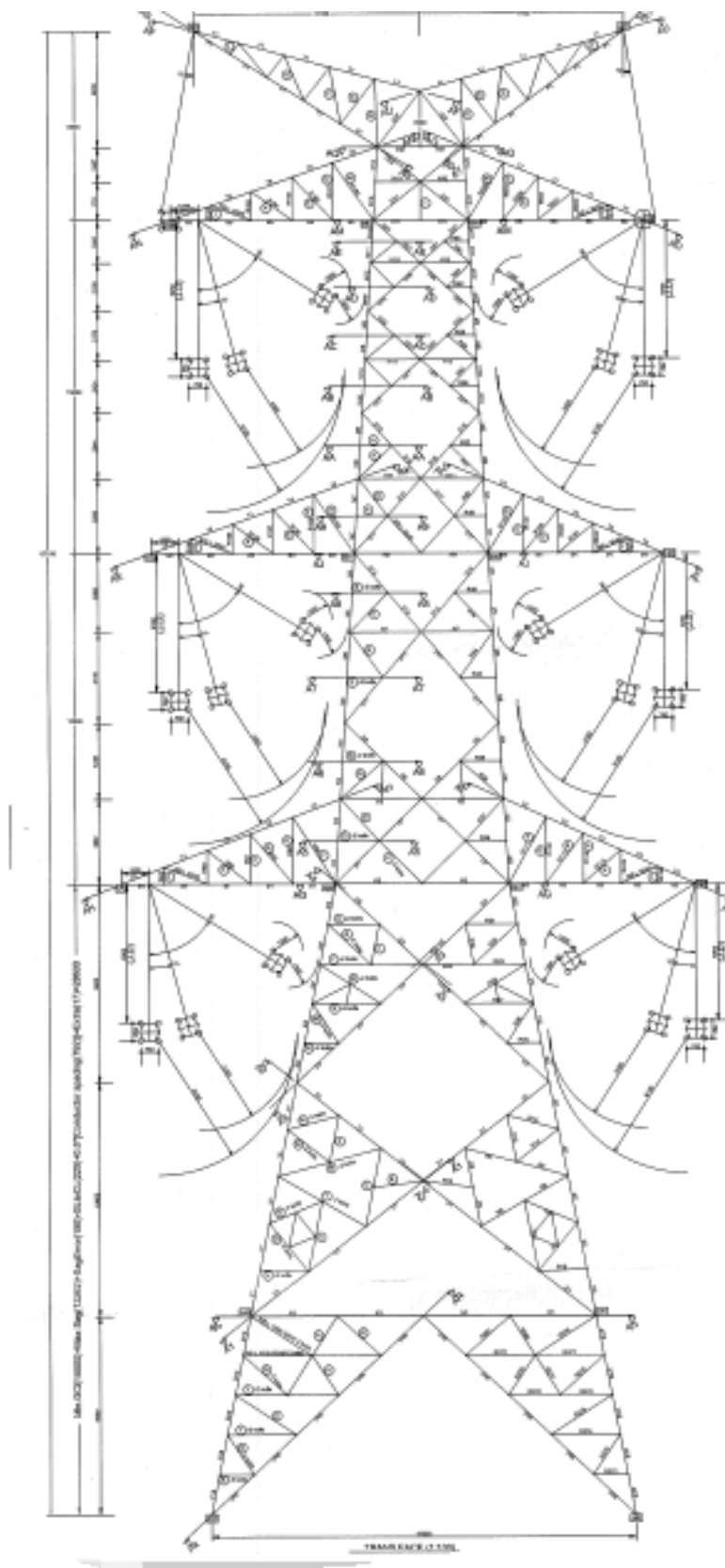
- a) **IS:** 802:1995
b) **Wind zone:** 3
c) **Reliability Level:** 2
d) **Terrain Category:** 2
e) **Wind Span:** 400m

Sr No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	675/200	405/100	15.99 X 15.99
2	DB	675/0	405/-200	19.00 x 19.00
3	DC	675/0	405/-200	19.50 x 19.50
4	DD	675/0	405/-300	23.50 x 23.50

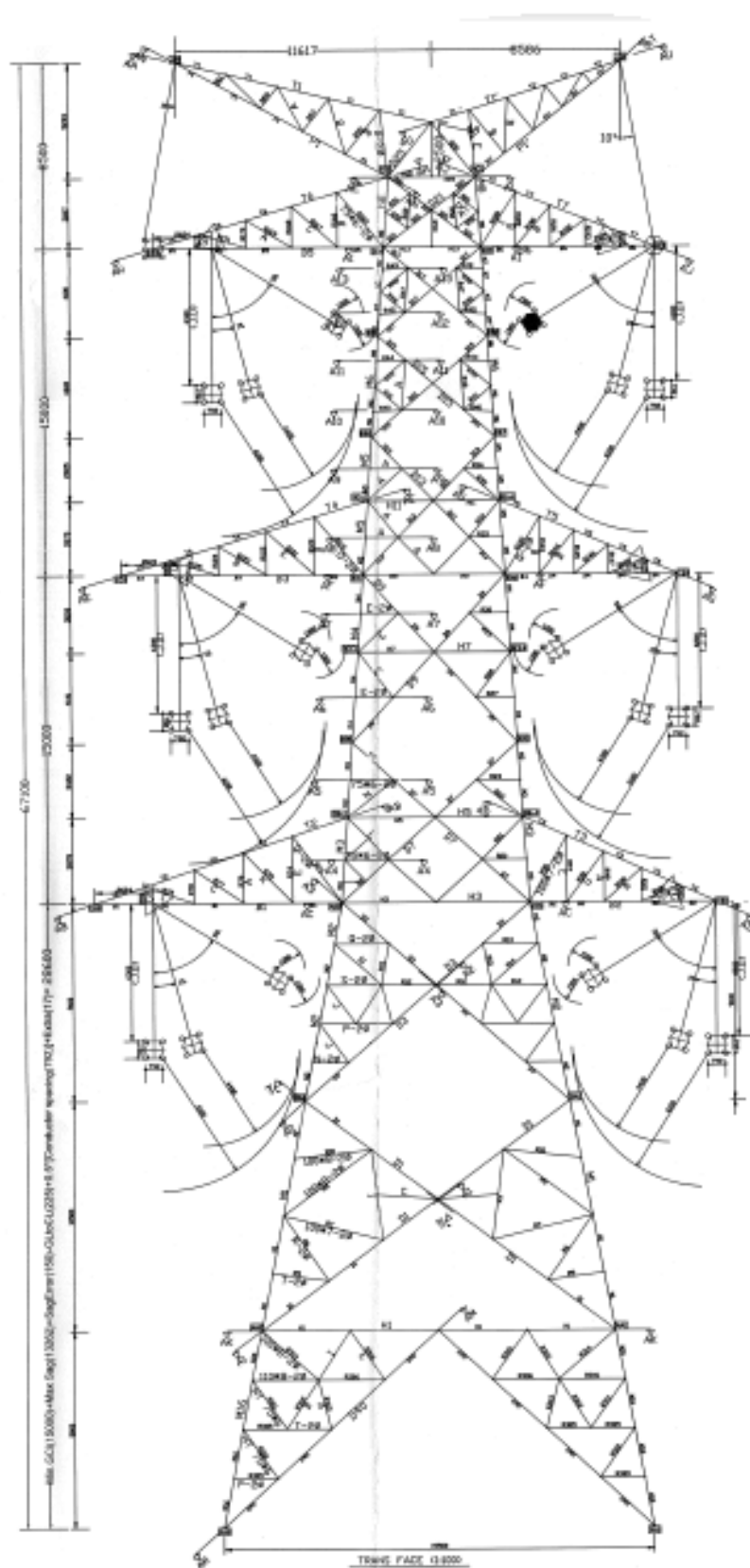
Remarks: In house Tested Towers



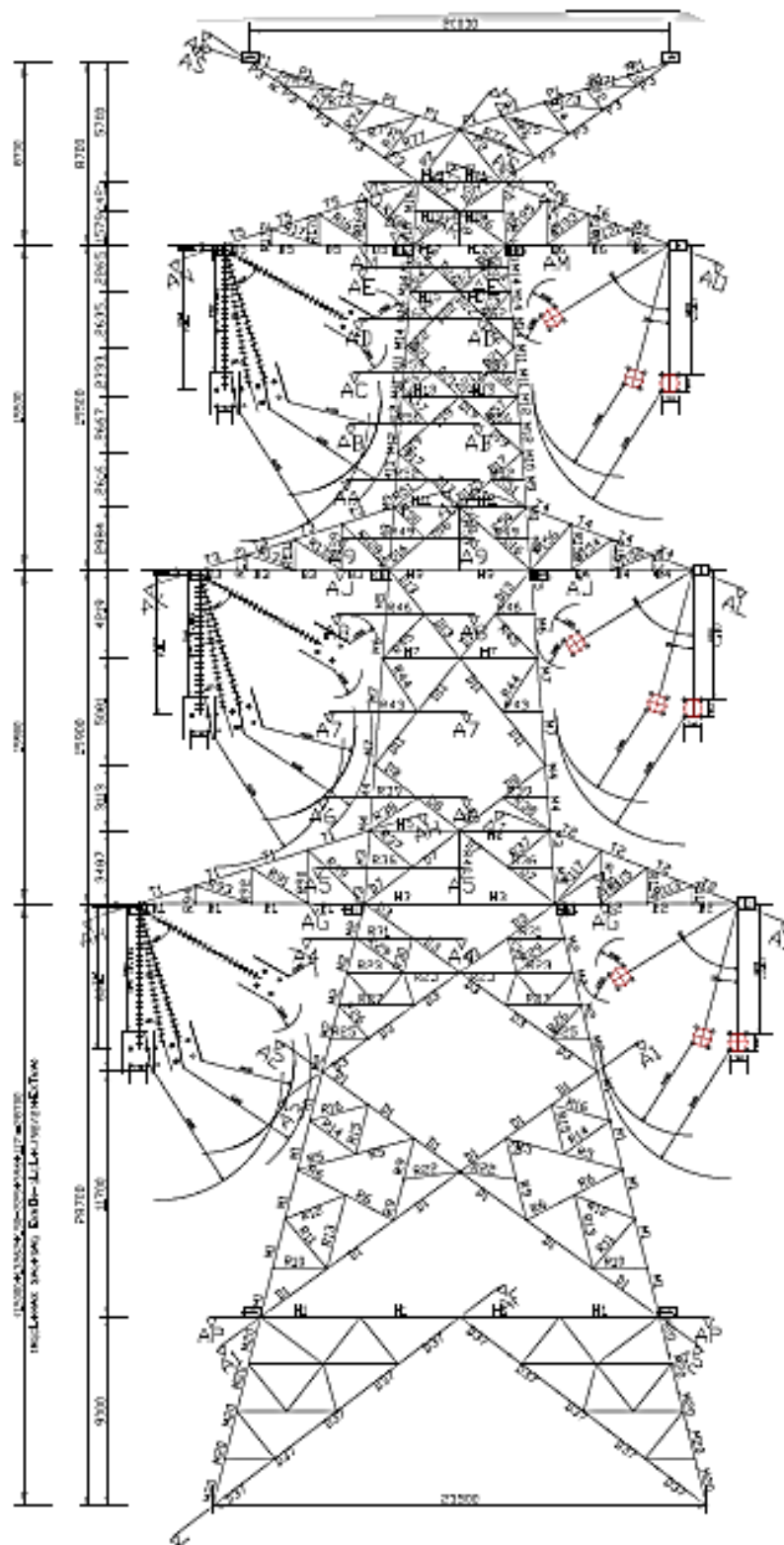
765 kV D/C WZ 3 Hex Zebra T.T. 'DA'



765 kV D/C WZ 3 Hex Zebra T.T. 'DB'



765 kV D/C WZ 3 Hex Zebra T.T. 'DC'



4.3.10 765 kV D/C WZ 2 Hex Zebra Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level:** 765 kV
b) Configuration: DOUBLE CIRCUIT
c) Conductor: ACSR HEXA ZEBRA
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: Zero Deg (for DA)
<10 Deg. (for DB,DC,DD)
f) Ground Clearance: 15.5m (forDA,DB)
15.0m (for DC, DD)
g) Mid Span Clearance: 12.0m (for DA)
9.0m (for DB, DC, DD)
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

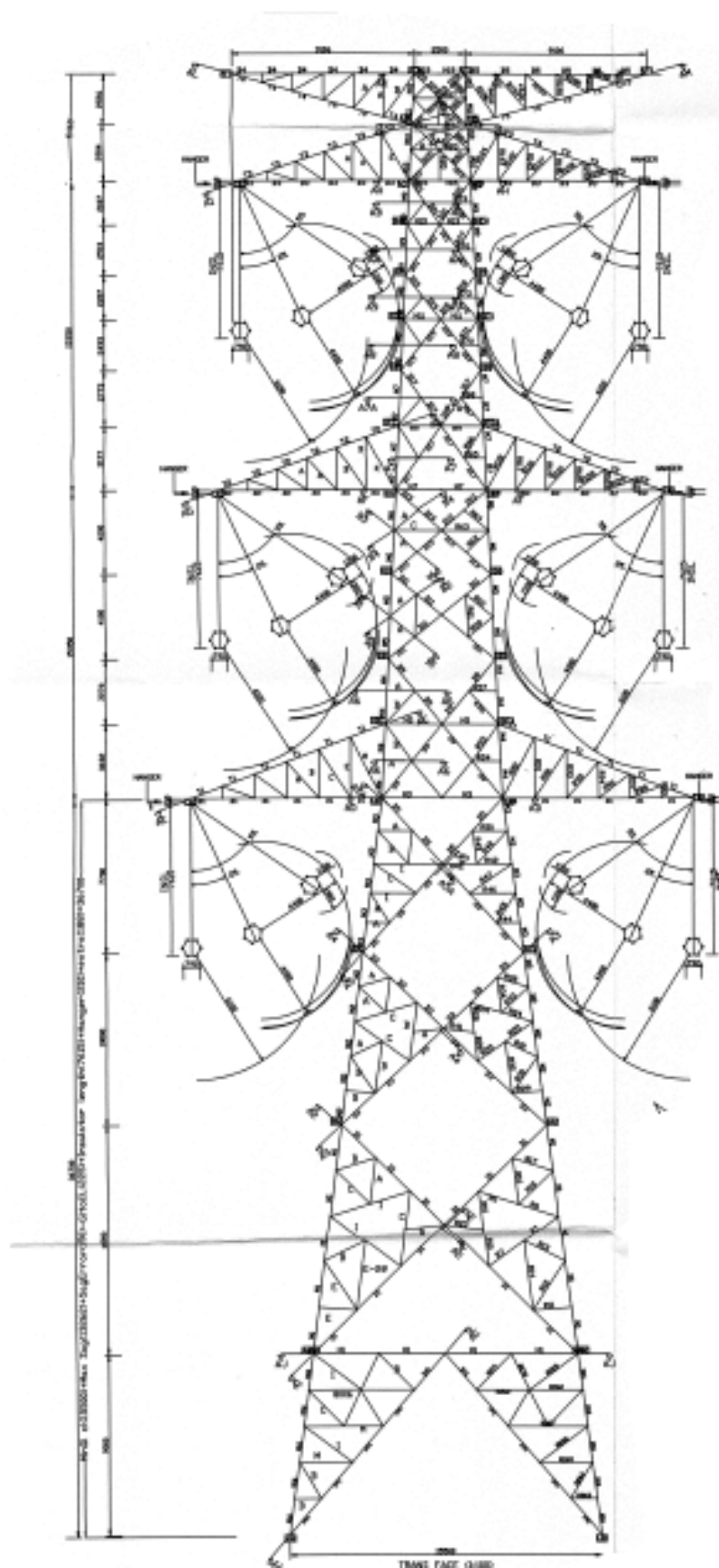
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

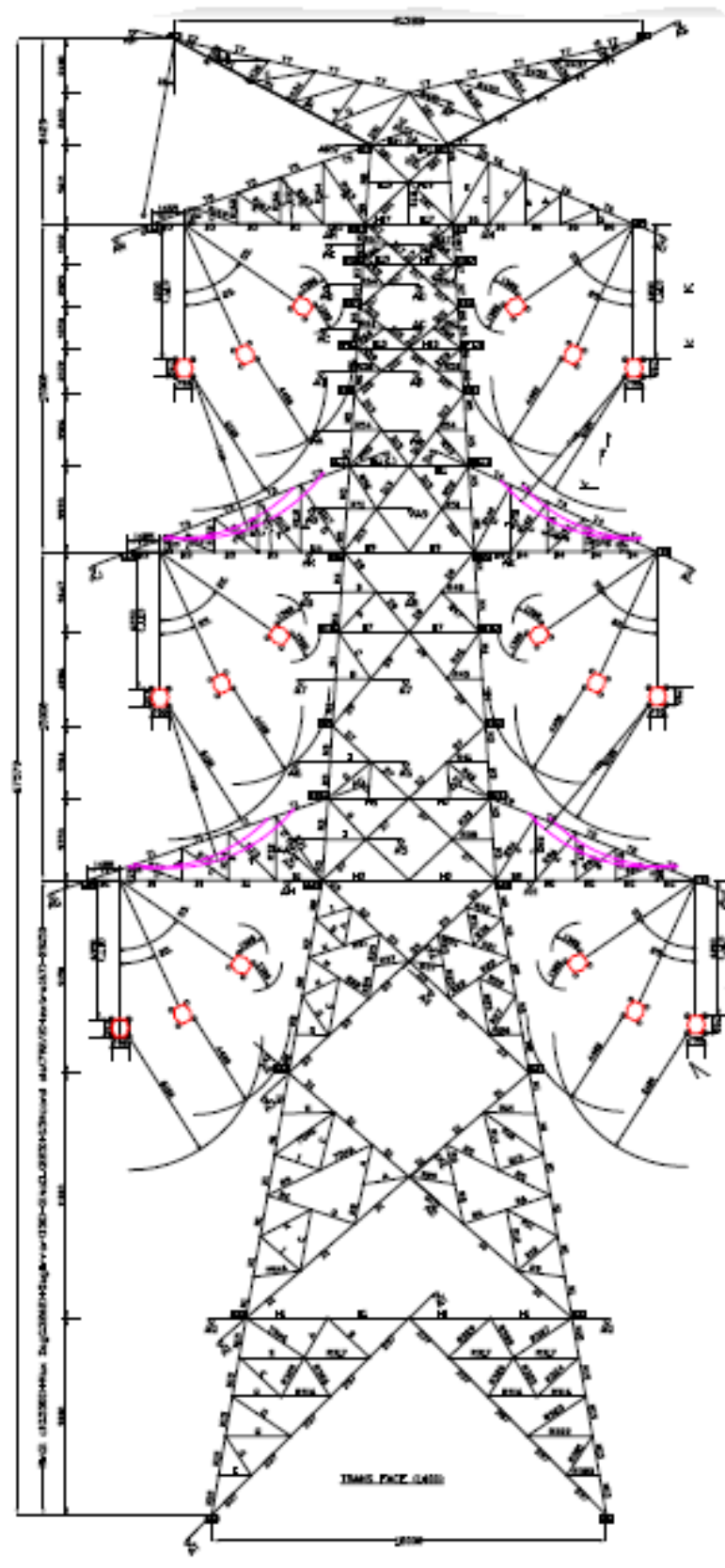
- a) IS:** 802:1995
b) Wind zone: 2
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	675/200	405/100	15.50 X 15.50
2	DB	600/0	360/-200	18.00 x 18.00
3	DC	675/0	405/-200	19.50 x 19.50
4	DD	600/0	360/-300	23.50 x 23.50

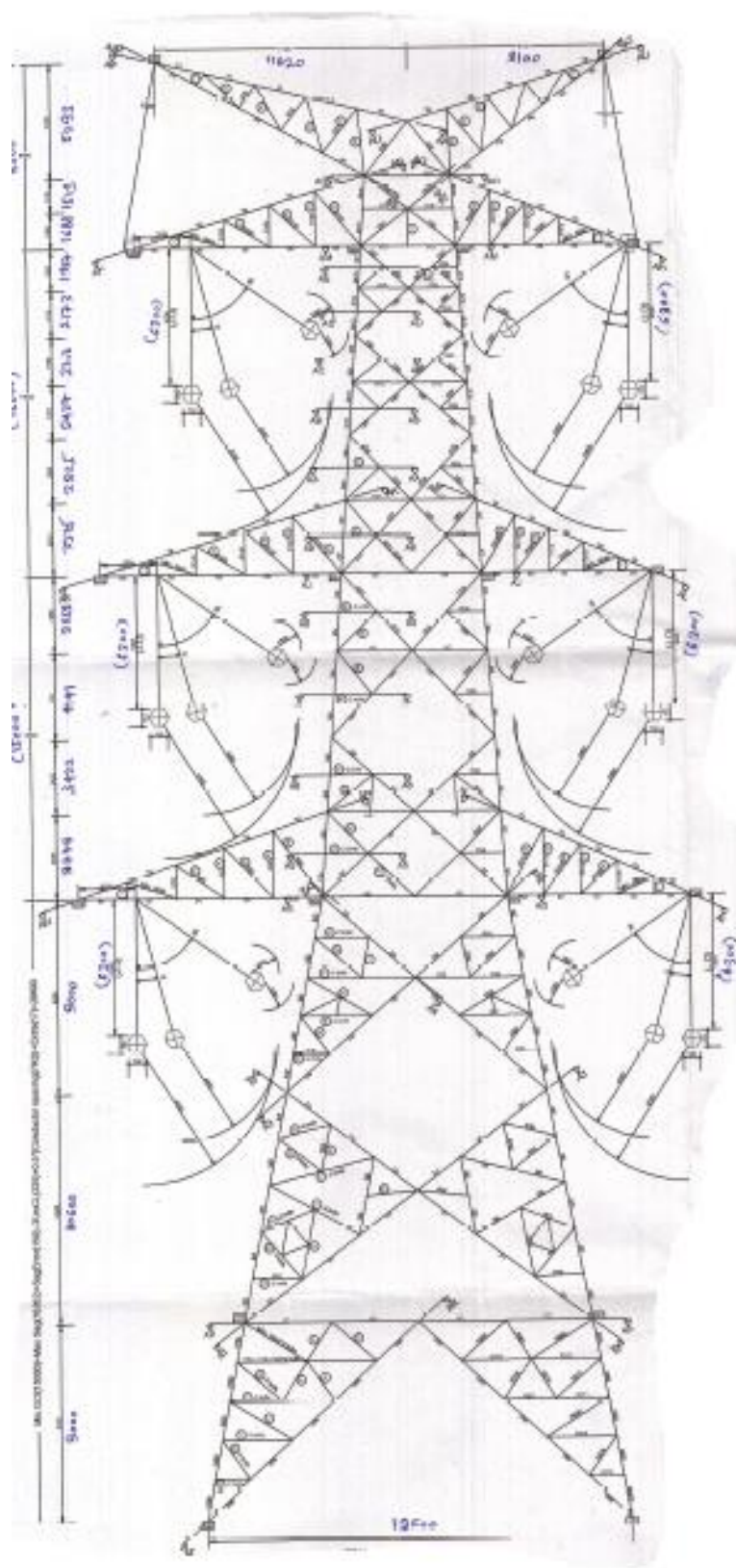
Remarks: In house Tested Towers



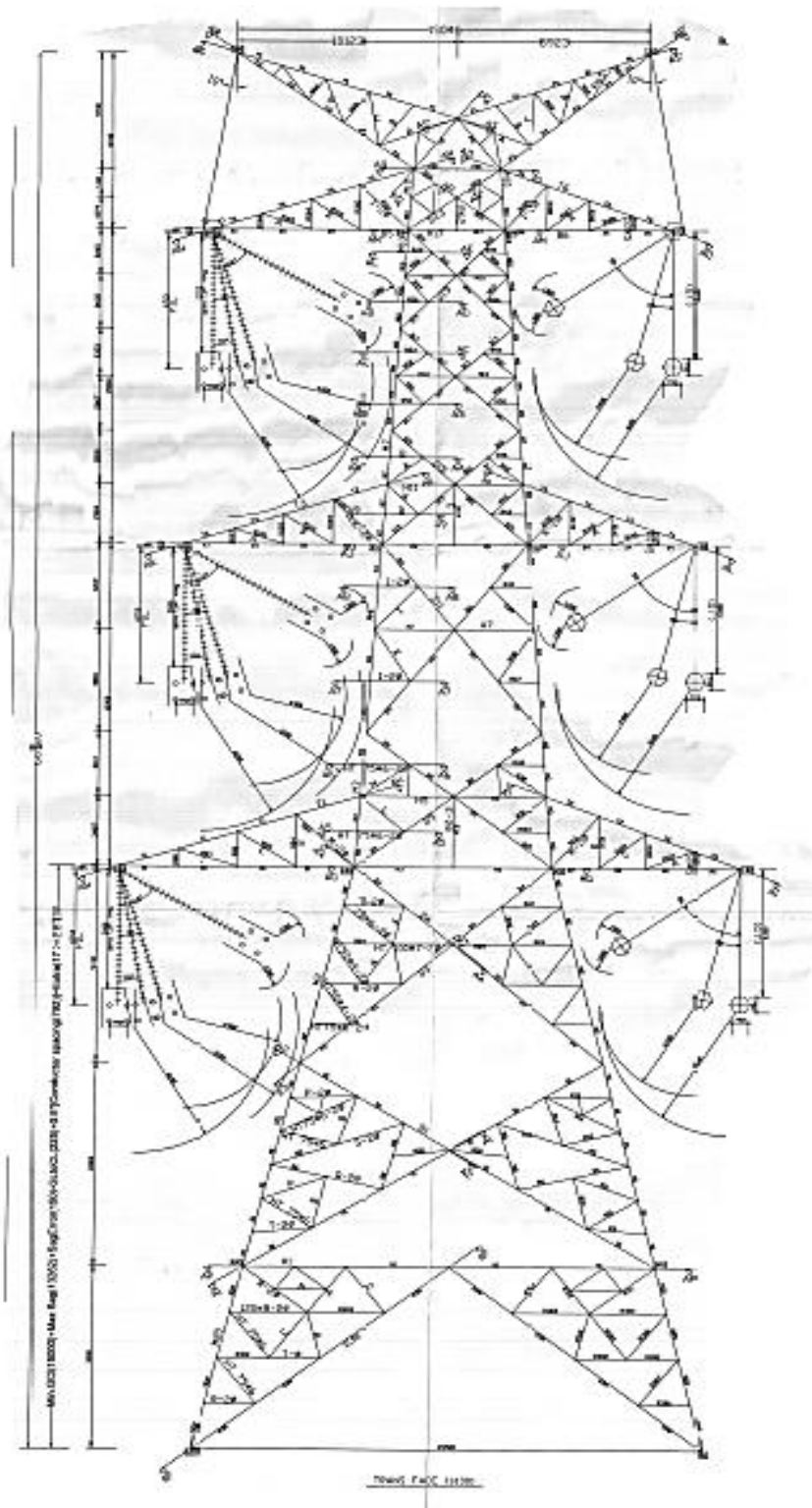
765 kV D/C WZ 2 Hex Zebra T.T. 'DA'



765 kV D/C WZ 2 Hex Zebra T.T. 'DB'



765 kV D/C WZ 2 Hex Zebra T.T. 'DC'



765 kV D/C WZ 2 Hex Zebra T.T. 'DD'

4.4 TECHNICAL PARAMETERS AND INDICATIVE SKETCHES OF TOWERS AT ± 500 kV

4.4.1 ± 500 kV HVDC WZ 5 QUAD BERSIMIS Transmission line (PGCIL)

Line Parameters

- a) Voltage Level: ± 500 kV
b) Configuration: HVDC
c) Conductor: ACSR QUAD BERSIMIS
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 12.5m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 75 Deg C
i) Line Altitude: Upto 1000m

Tower Design Parameters

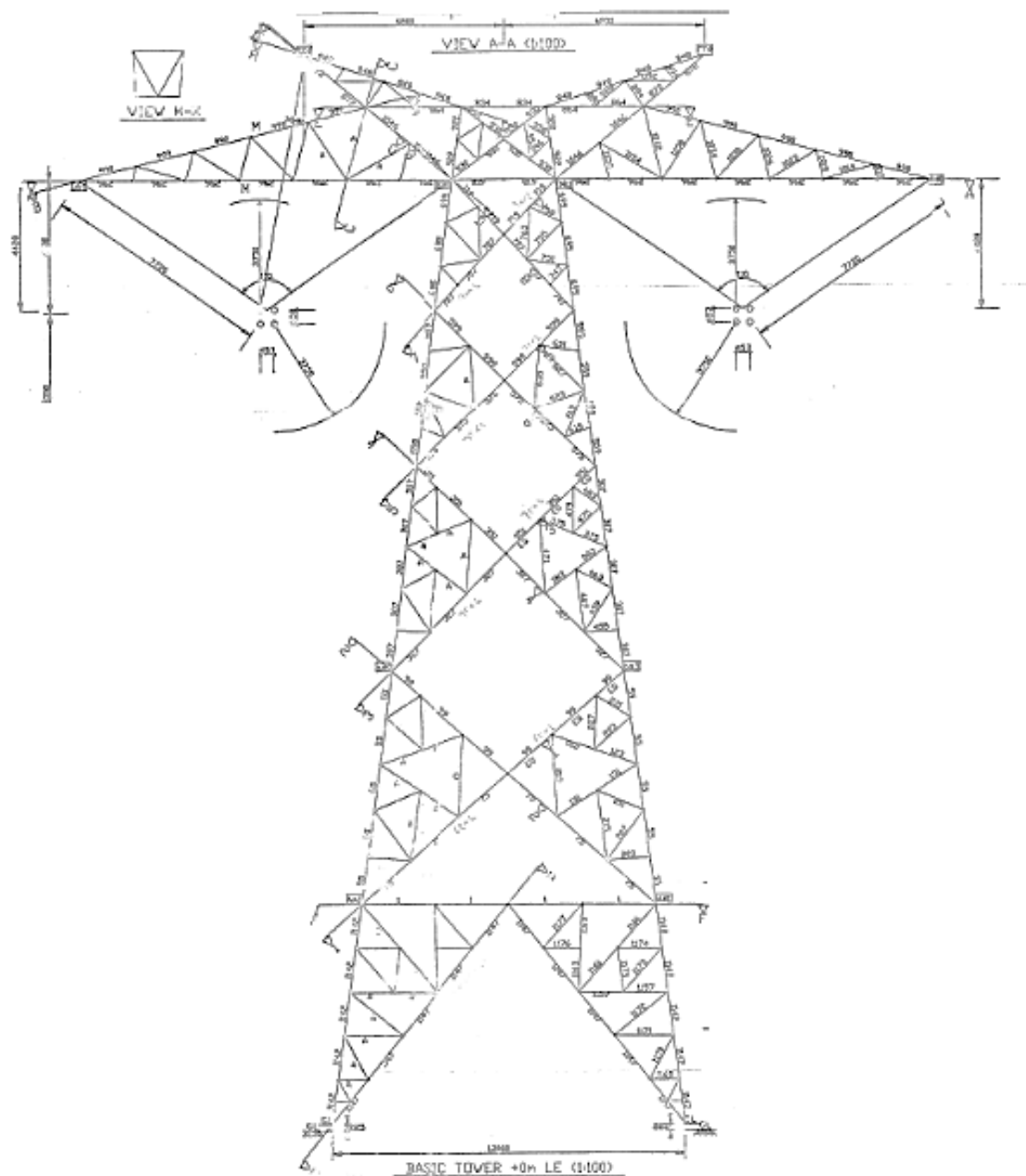
- a) IS: 802:1995
b) Wind zone: 5
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Tower Types

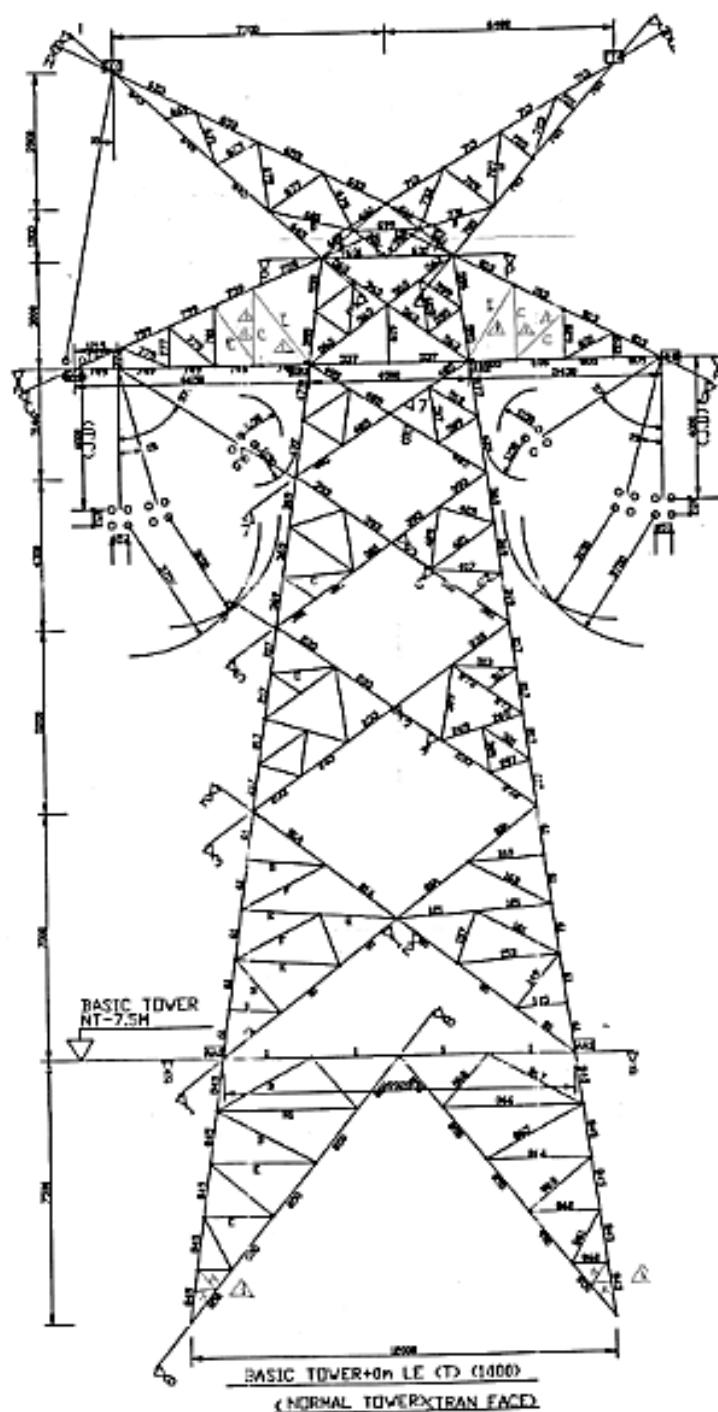
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	12.00 X 12.00
2	B	600/-250	360/-200	12.00 x 12.00
3	C	600/-250	360/-200	14.30 x 14.30
4	D	600/-400	360/-300	16.00 x 16.00

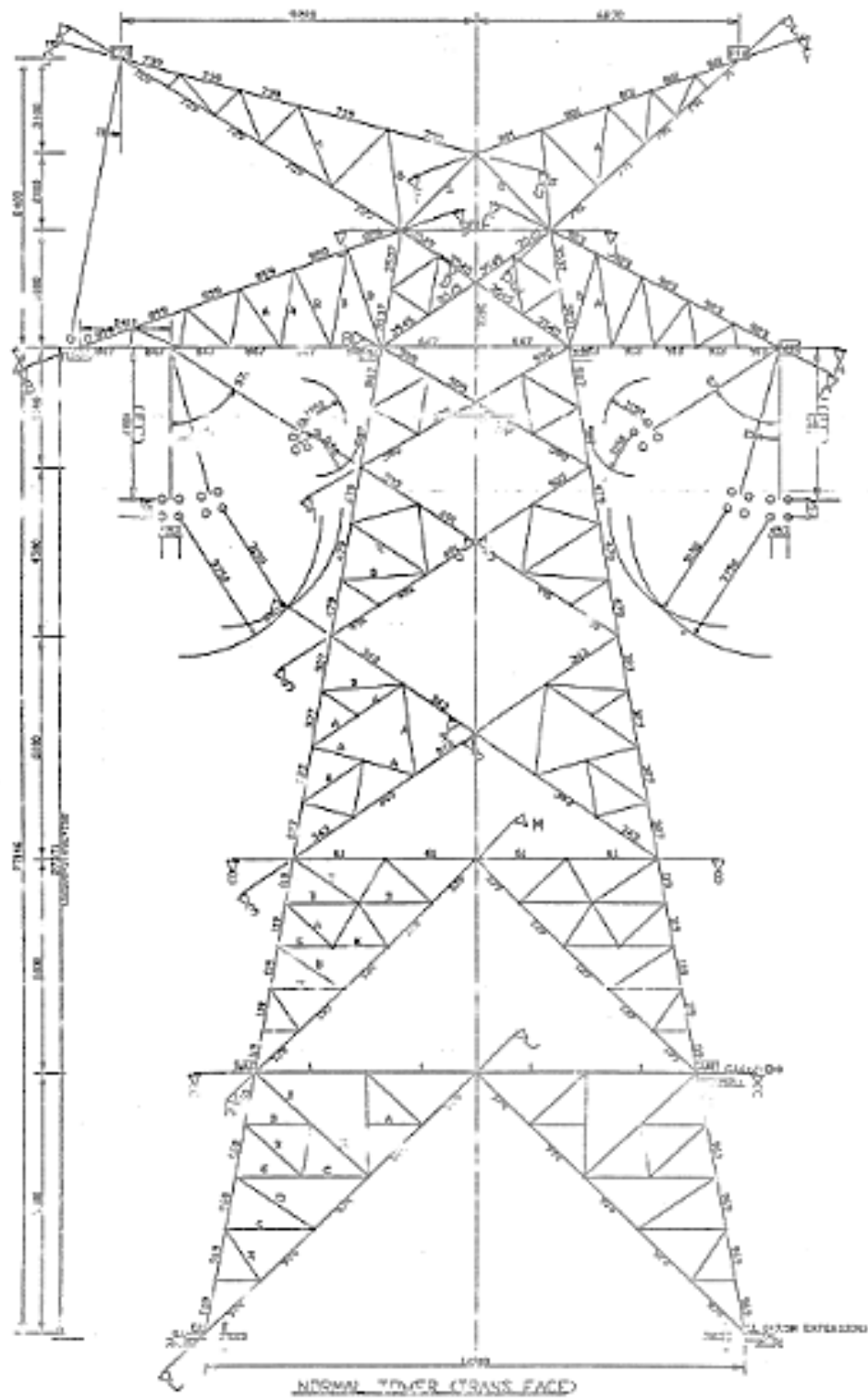
Remarks: In house Tested Towers



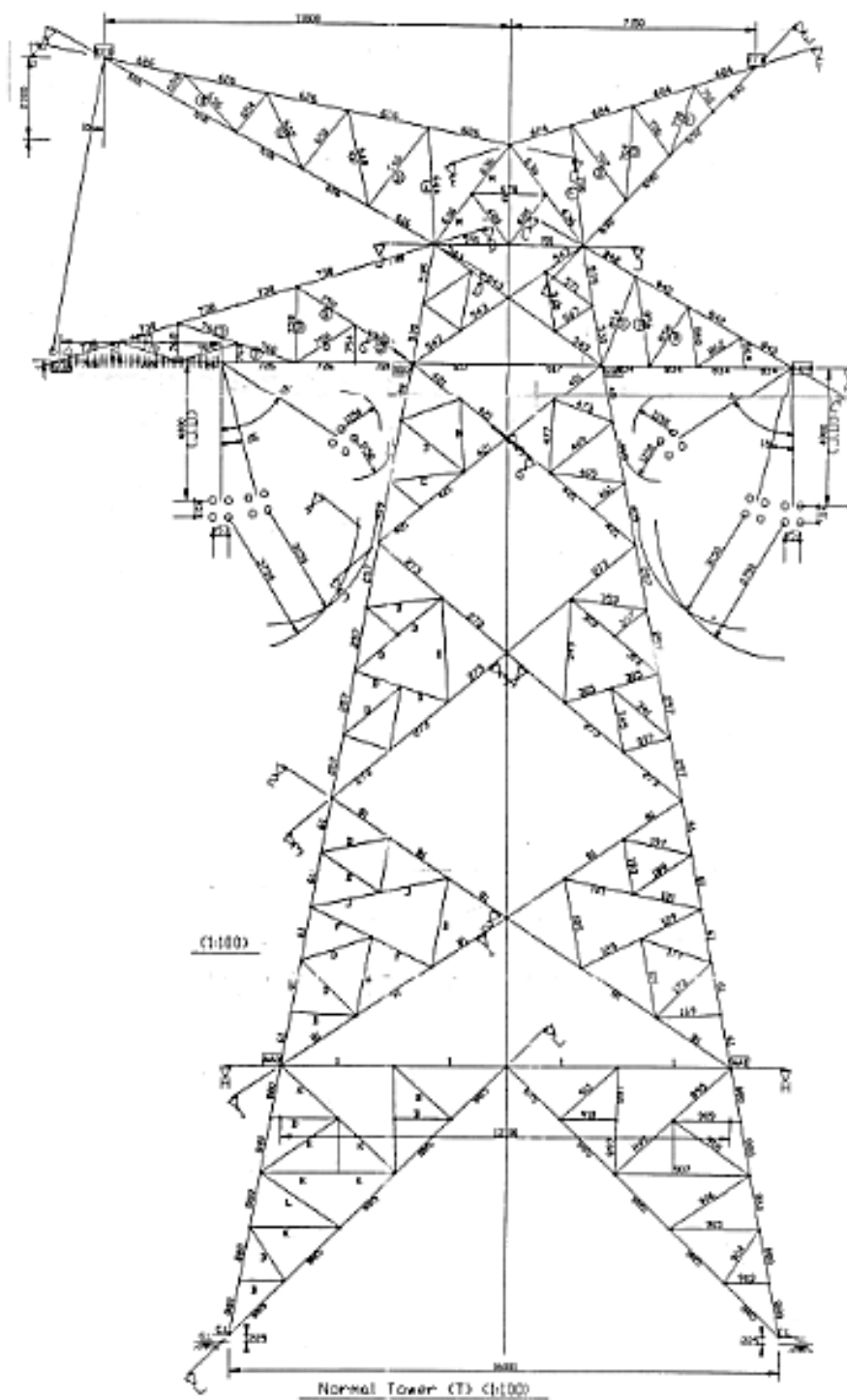
± 500 kV HVDC WZ 5 Quad Bersimis T.T. 'A'



± 500 kV HVDC WZ 5 Quad Bersimis T.T. 'B'



+ 500 kV HVDC WZ 5 Quad Bersimis T.T. 'C'



± 500 kV HVDC WZ 5 Quad Bersimis T.T. 'D'



4.4.2 $\pm$ 500 kV HVDC WZ 4 QUAD LAPWING Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: $\pm$ 500 kV
- b) Configuration: HVDC
- c) Conductor: ACSR QUAD LAPWING
- d) Earth wire: 7/3.66: 2No.
- e) Shield Angle: <10 Deg.
- f) Ground Clearance: 12.5m
- g) Mid Span Clearance: 9.0m
- h) Max Conductor Temp: 85 Deg C
- i) Line Altitude: Upto 1000m

Tower Types

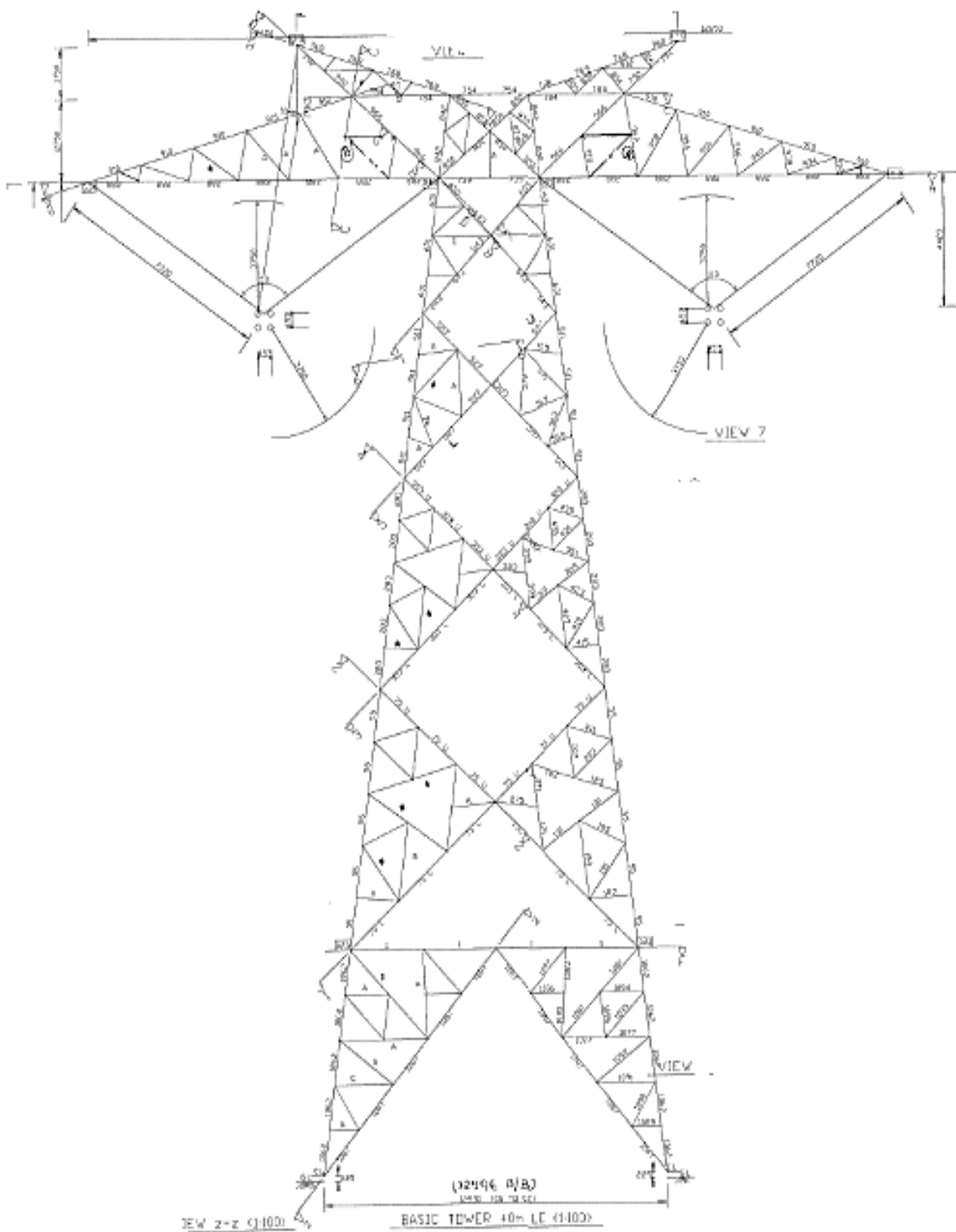
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2

Tower Design Parameters

- a) IS: 802:1995
- b) Wind zone: 4
- c) Reliability Level: 2
- d) Terrain Category: 2
- e) Wind Span: 400m

Sr No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	12.530 X 12.530

Remarks: In house Tested Towers



+ 500 kV HVDC WZ 4 Quad Lapwing T.T. 'A'



4.4.3 $\pm$ 500 kV HVDC WZ 2 QUAD BERSIMIS Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: $\pm$ 500 kV
- b) Configuration: HVDC
- c) Conductor: ACSR QUAD BERSIMIS
- d) Earth wire: 7/3.66: 2No.
- e) Shield Angle: <10 Deg.
- f) Ground Clearance: 12.5m
- g) Mid Span Clearance: 9.0m
- h) Max Conductor Temp: 75 Deg C
- i) Line Altitude: Upto 1000m

Tower Types

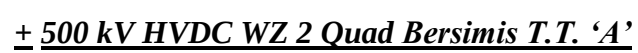
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2

Tower Design Parameters

- a) IS: 802:1995
- b) Wind zone: 2
- c) Reliability Level: 2
- d) Terrain Category: 2
- e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	10.515 X 10.515

Remarks: In house Tested Towers



4.5 TECHNICAL PARAMETERS AND INDICATIVE SKETCHES OF TOWERS AT 400 kV

4.5.1 400 kV S/C WZ 4+25 mm ICE TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: SINGLE CIRCUIT
(HORIZONTAL)
c) Conductor: ACSR TWIN MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 8.84m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 65 Deg C
i) Radial ice thickness: 25mm
j) Line Altitude: Upto 3000m

Tower Design Parameters

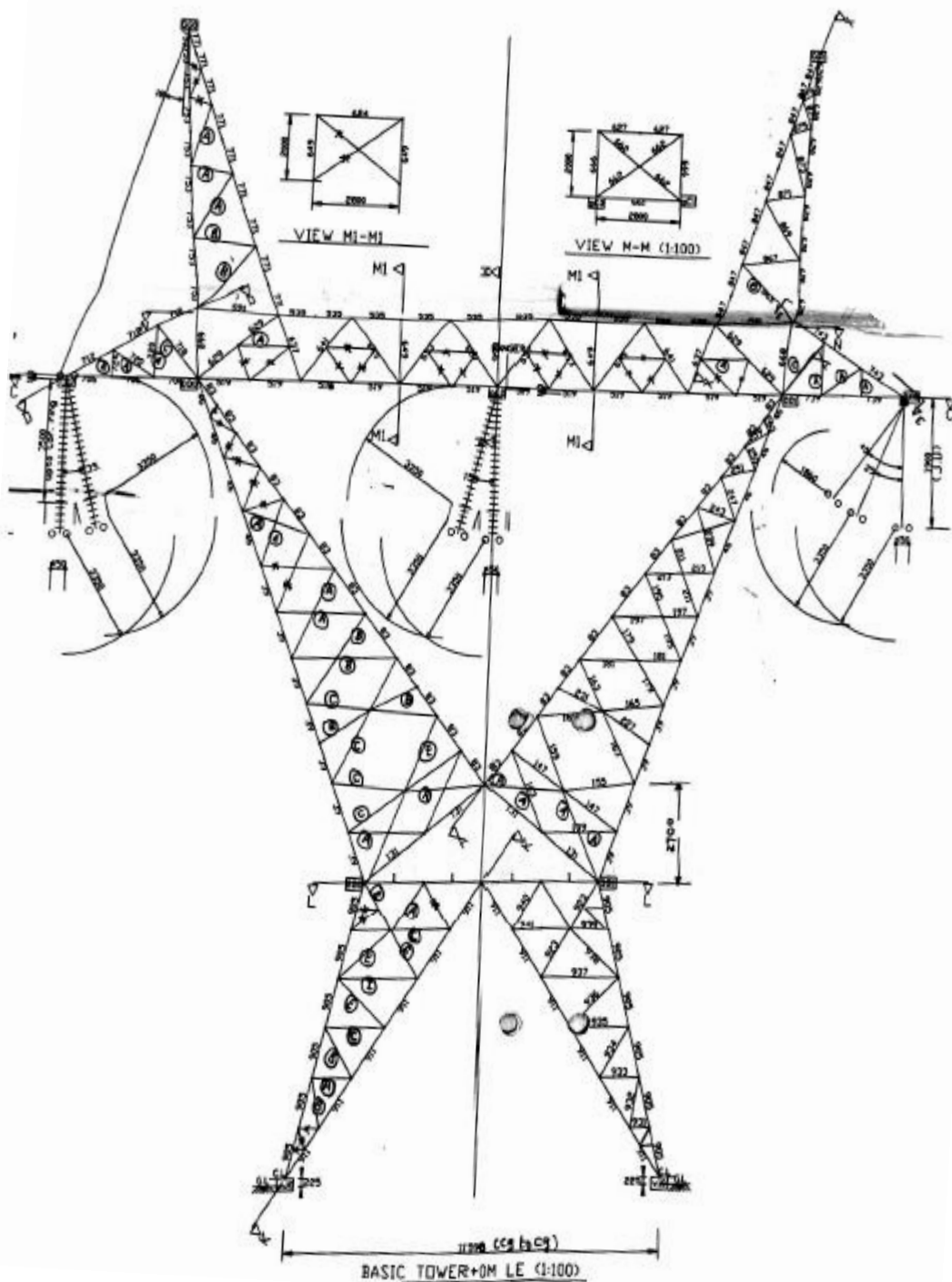
- a) IS: 802:1995
b) Wind zone: 4
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	D	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	D	1500/-1500	900/-900	11.590 X 11.590

Remarks: In house Tested Towers



400 kV S/C WZ 4+25mm (HORIZONTAL) ICE TWIN MOOSE T.T 'D'

4.5.2 400 kV S/C WZ 2+15 mm ICE QUAD MOOSE (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: SINGLE CIRCUIT
(VERTICAL DELTA)
c) Conductor: ACSR QUAD MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 9.5m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Radial ice thickness: 15mm.
j) Line Altitude: Upto 2500m

Tower Types

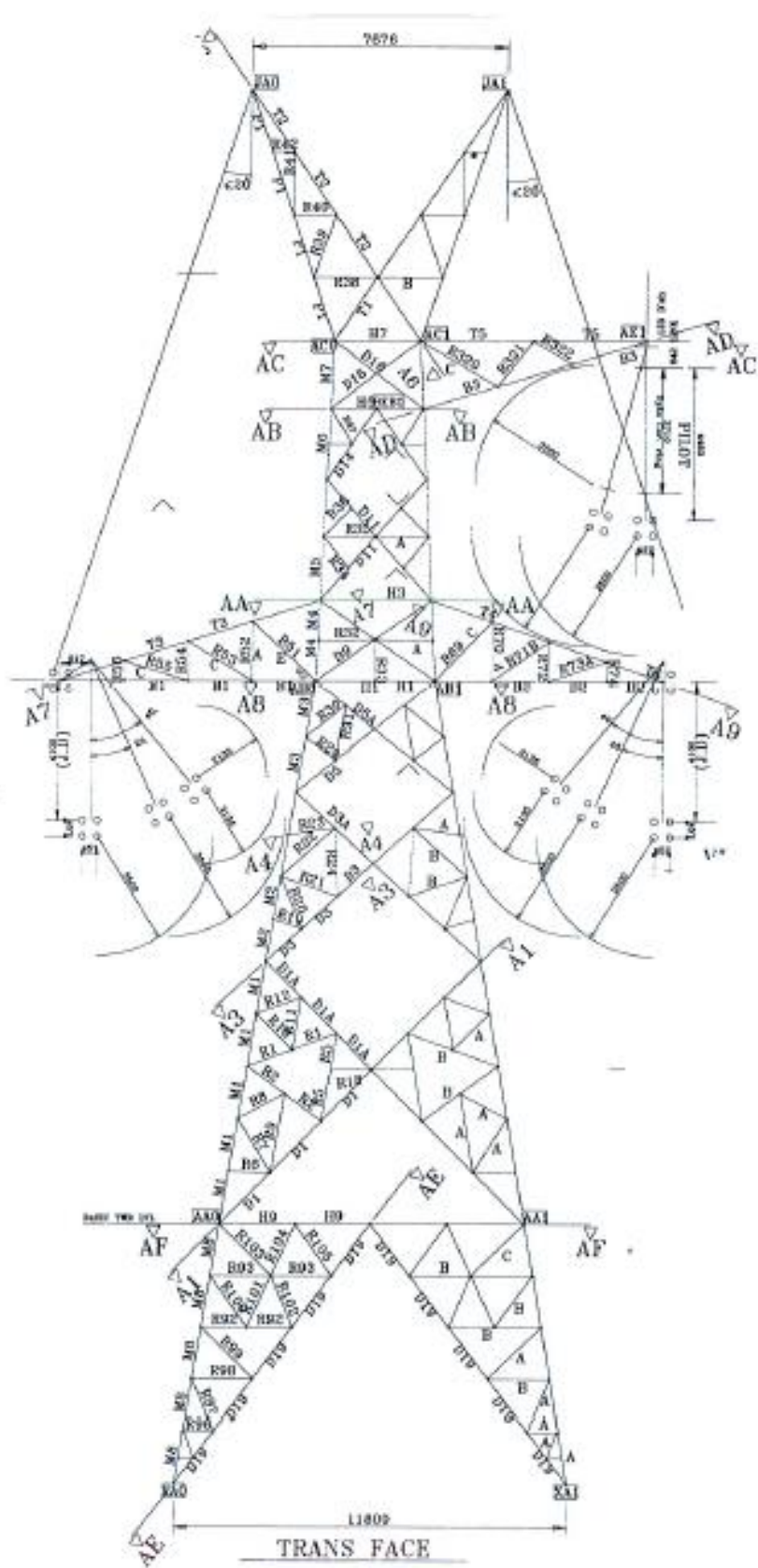
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	B	0-15
2	C	15-30
3	D	30-60

Tower Design Parameters

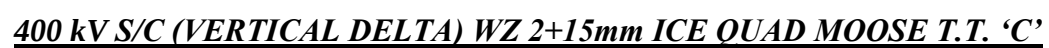
- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

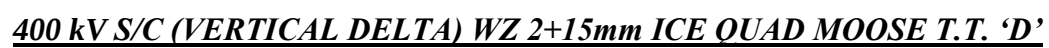
Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	B	1500/-1000	1200/-1000	11.80 X 11.80
2	C	1500/-1000	1200/-1000	11.80 X 11.80
3	D	1500/-1000	1200/-1000	12.00 X 12.00

Remarks: In house Tested Towers



400 kV S/C (VERTICAL DELTA) WZ 2+15mm ICE QUAD MOOSE T.T. 'B'





4.5.3 400 kV S/C (HORIZONTAL) WZ 2+10mm ICE TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: SINGLE CIRCUIT (HORIZONTAL)
c) Conductor: ACSR TWIN MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 8.84m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 75 Deg C
i) Radial ice thickness: 10mm
j) Line Altitude: Upto 2800m

Tower Types

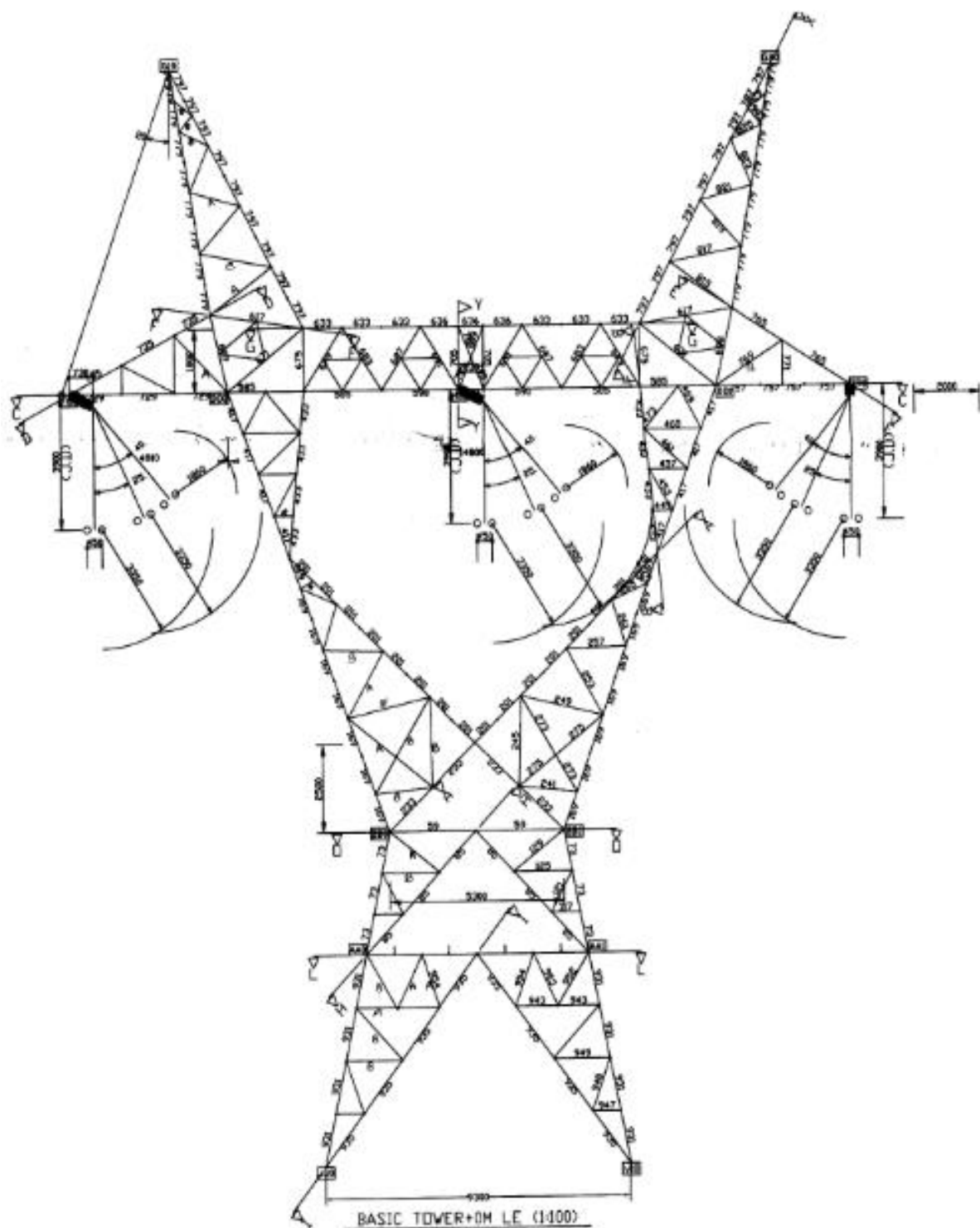
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	B	0-15
2	C	15-30
3	D	30-60

Tower Design Parameters

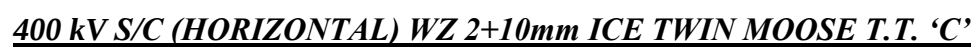
- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

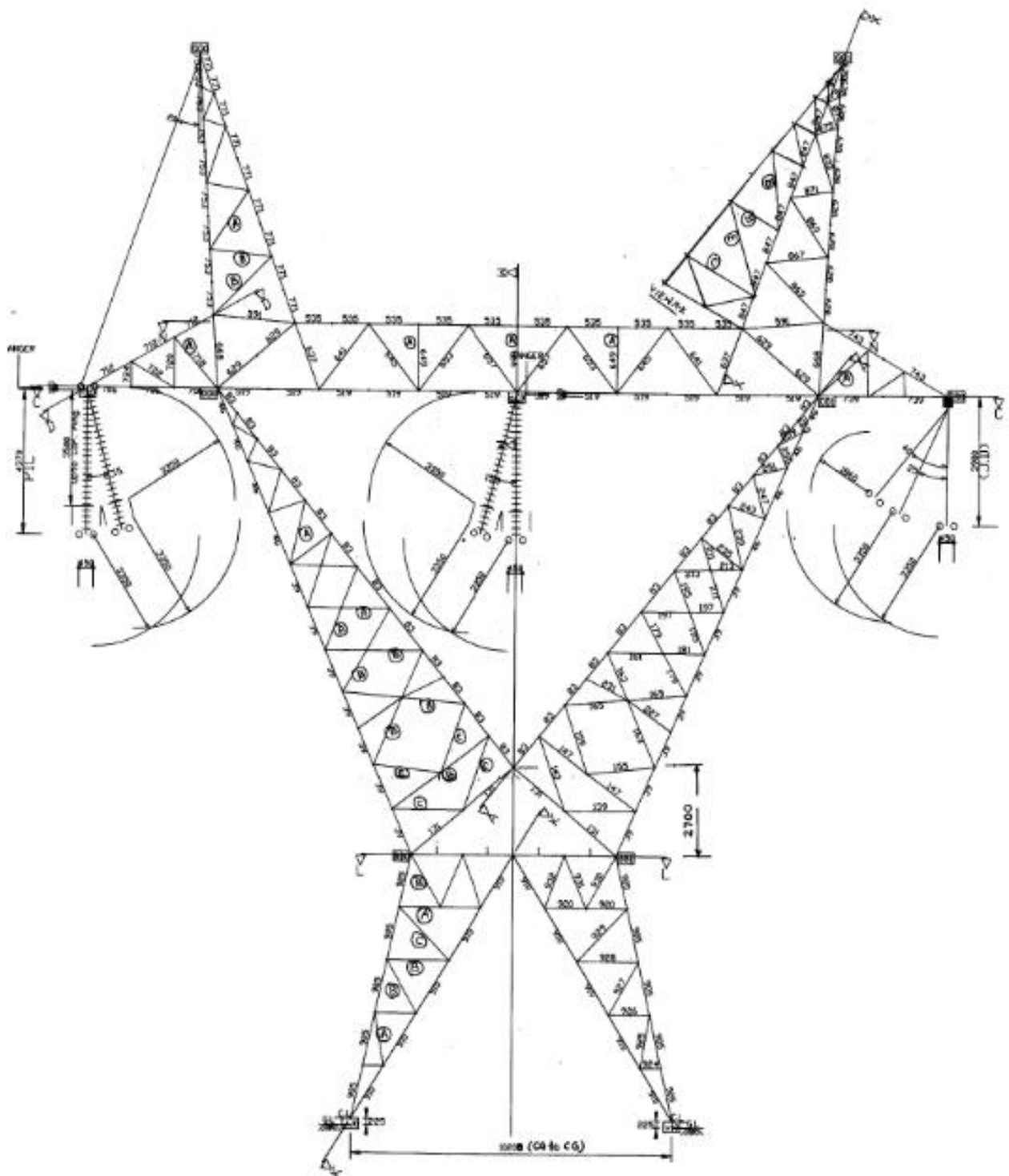
Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	B	1200/-1200	720/-720	9.30 X 9.30
2	C	1200/-1200	720/-720	9.65 X 9.65
3	D	1200/-1200	720/-720	10.20 X 10.2

Remarks: In house Tested Towers



400 kV S/C (HORIZONTAL) WZ 2+10mm ICE TWIN MOOSE T.T. 'B'





400 kV S/C (HORIZONTAL) WZ 2+10mm ICE TWIN MOOSE T.T. 'D'

4.5.4 400 kV S/C WZ 4 (HORIZONTAL)TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: SINGLE CIRCUIT (HORIZONTAL)
c) Conductor: ACSR TWIN MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 8.84m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

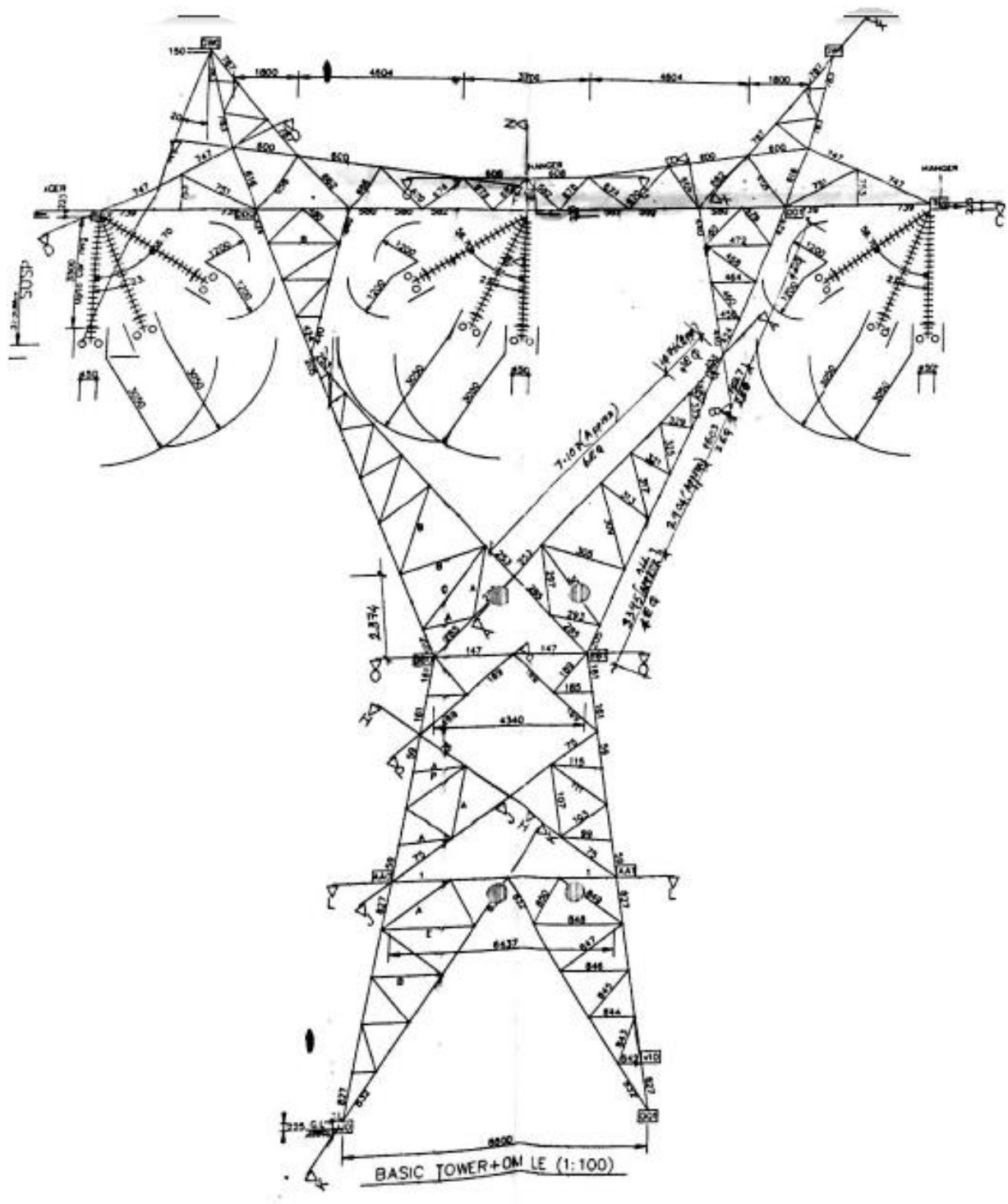
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2

Tower Design Parameters

- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	8.60 X 8.60

Remarks: In house Tested Towers



400 kV S/C WZ 4 (HORIZONTAL) TWIN MOOSE T.T. 'A'



4.5 400 kV S/C (HORIZONTAL)WZ 3 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
- b) Configuration: SINGLE CIRCUIT
(HORIZONTAL)
- c) Conductor: ACSR TWIN MOOSE
- d) Earth wire: 7/3.66: 2No.
- e) Shield Angle: <20 Deg.
- f) Ground Clearance: 8.84m
- g) Mid Span Clearance: 9.0m
- h) Max Conductor Temp: 75 Deg C
- i) Line Altitude: Upto 1000m

Tower Design Parameters

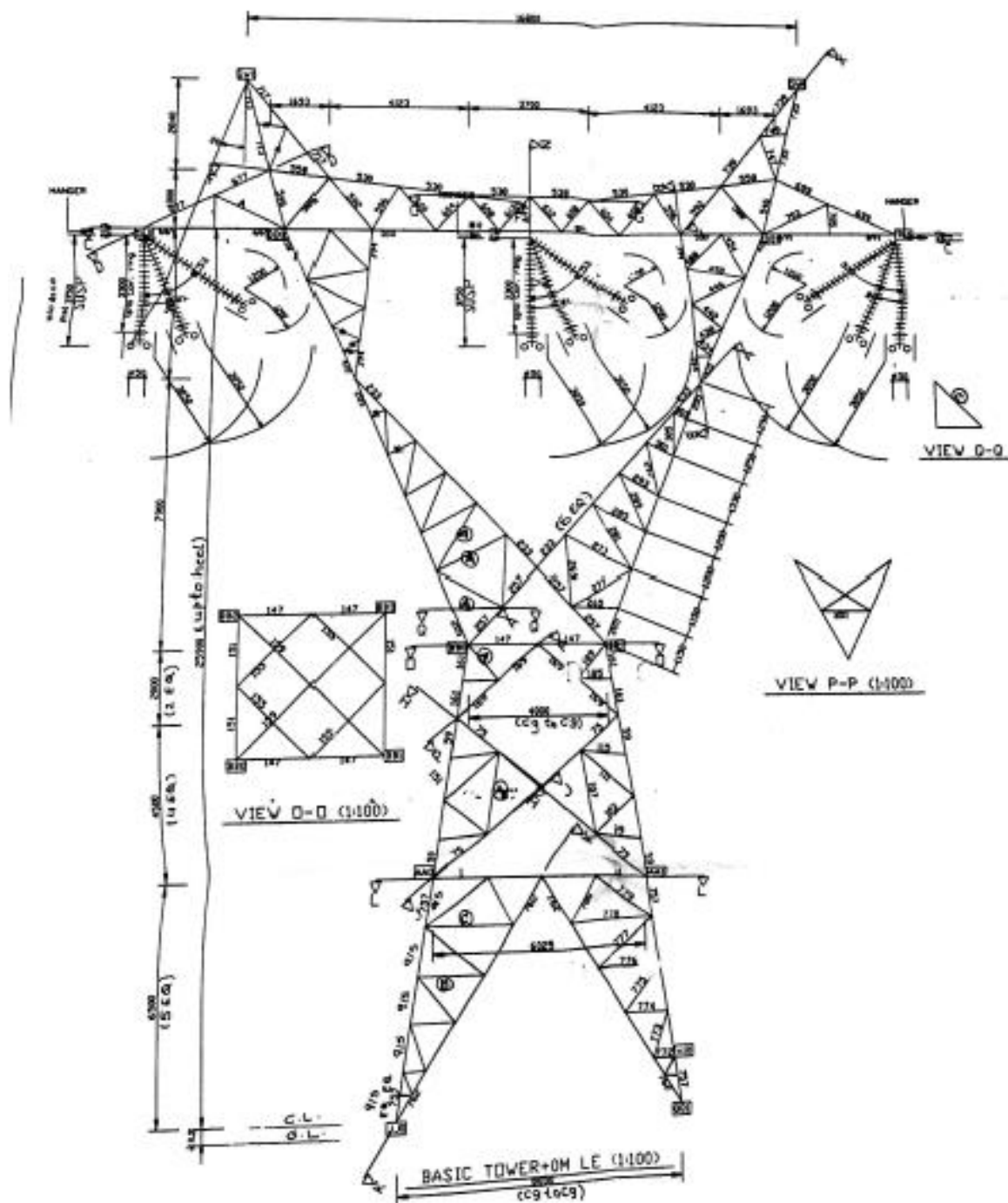
- a) IS : 802:1995
- b) Wind zone: 3
- c) Reliability Level: 1
- d) Terrain Category: 2
- e) Wind Span: 400m

Tower Types

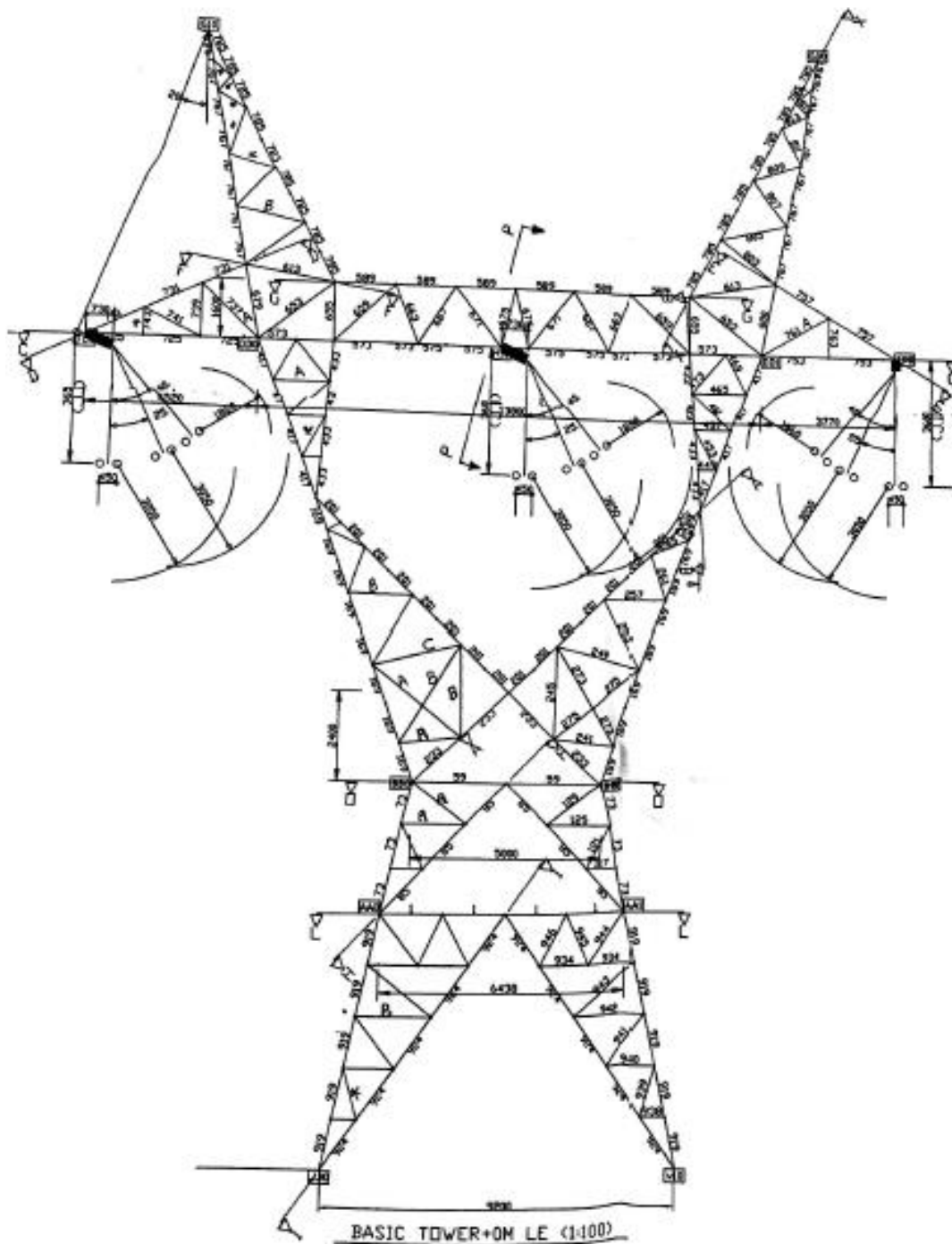
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	8.05 X 8.05
2	B	600/0	360/-200	9.20 X 9.20
3	C	600/0	360/-200	9.50 X 9.50
4	D	600/0	360/-300	11.00 X 11.00

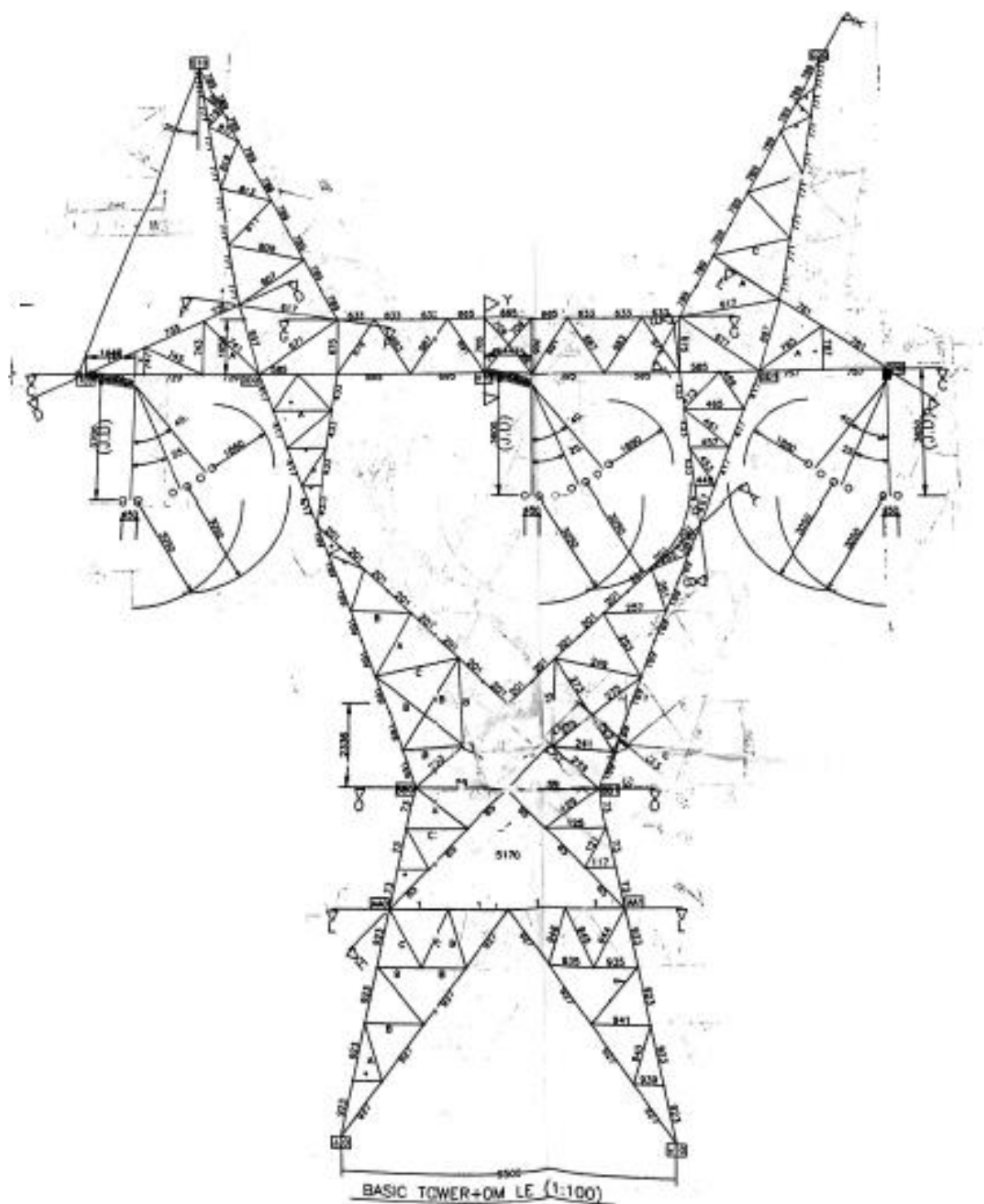
Remarks: In house Tested Towers



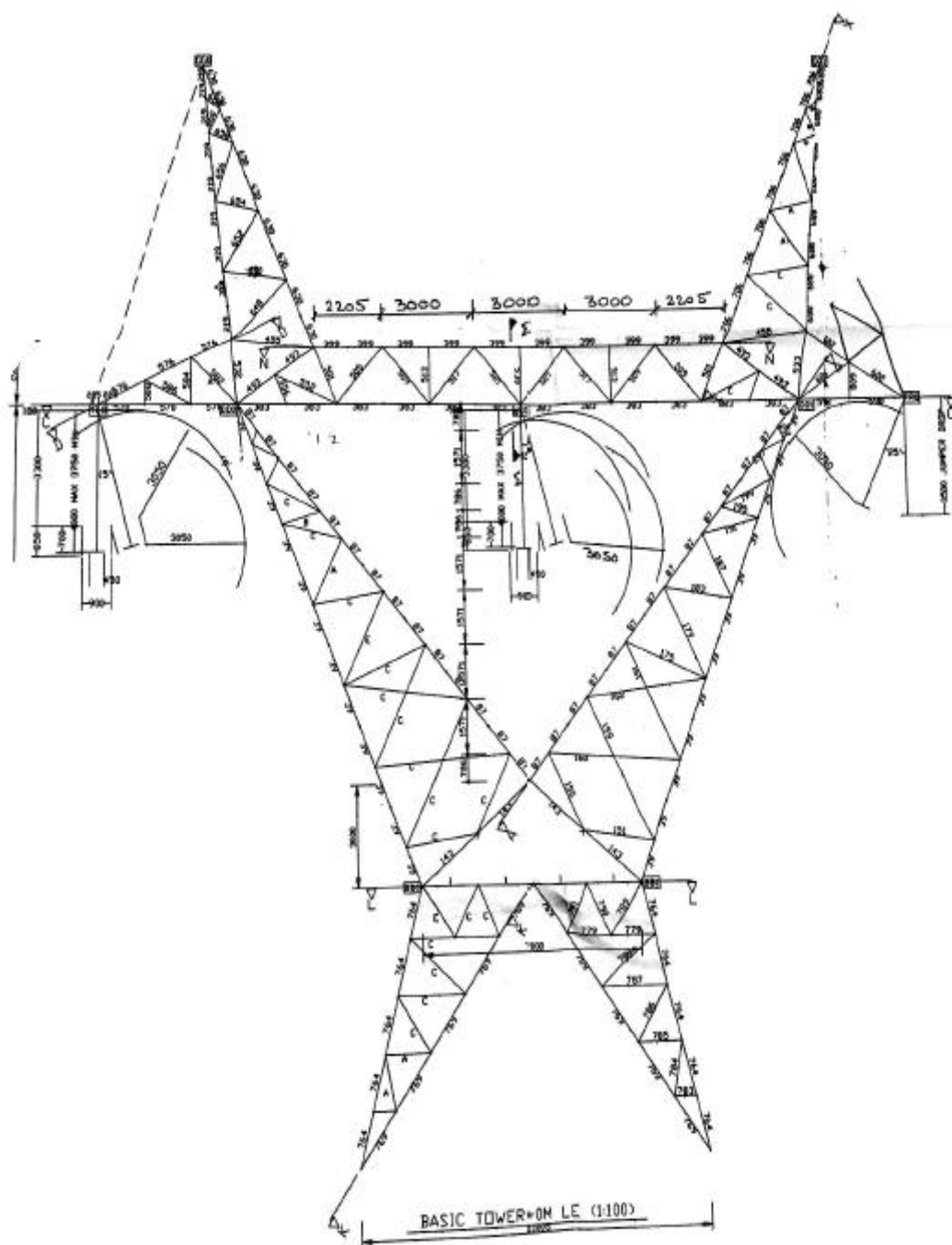
400 kV S/C (HORIZONTAL) WZ 3 TWIN MOOSE T.T 'A'



400 kV S/C (HORIZONTAL) WZ 3 TWIN MOOSE T.T 'B'



400 kV S/C (HORIZONTAL) WZ 3 TWIN MOOSE T.T 'C'



400 kV S/C (HORIZONTAL) WZ 3 TWIN MOOSE T.T 'D'

4.5.6 400 kV S/C (HORIZONTAL)WZ 2 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: SINGLE CIRCUIT (HORIZONTAL)
c) Conductor: ACSR TWIN MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 8.84m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 75 Deg C
i) Line Altitude: Upto 1000m

Tower Types

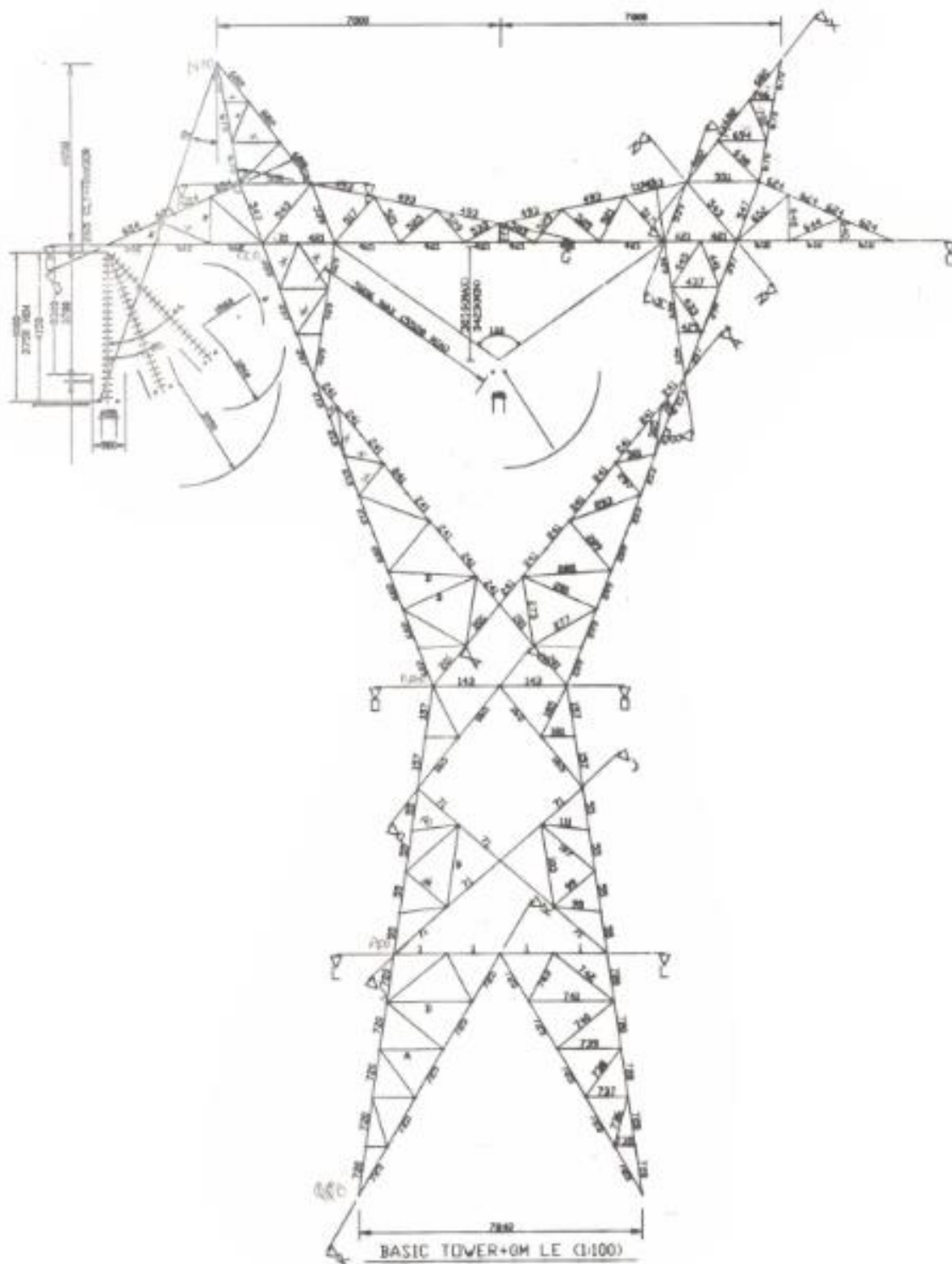
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	A	0-2
2	B	0-15
3	C	15-30
4	D	30-60

Tower Design Parameters

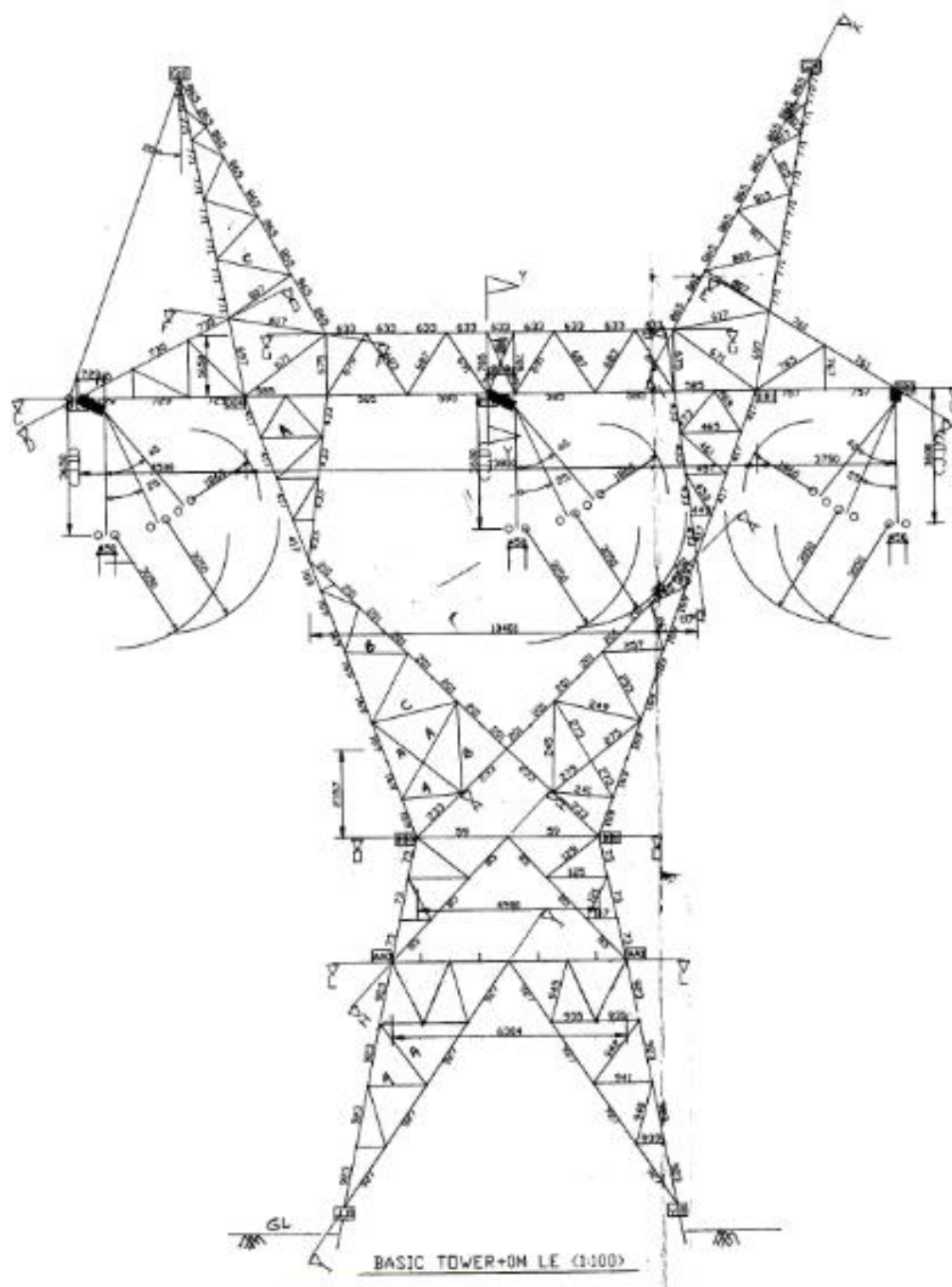
- a) IS: 802:1995
b) Wind zone: 2
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	7.80 x 7.80
2	B	600/0	360/-200	9.00 X 9.00
3	C	600/0	360/-200	9.00 X 9.00
4	D	600/0	360/-300	11.00. X 11.00

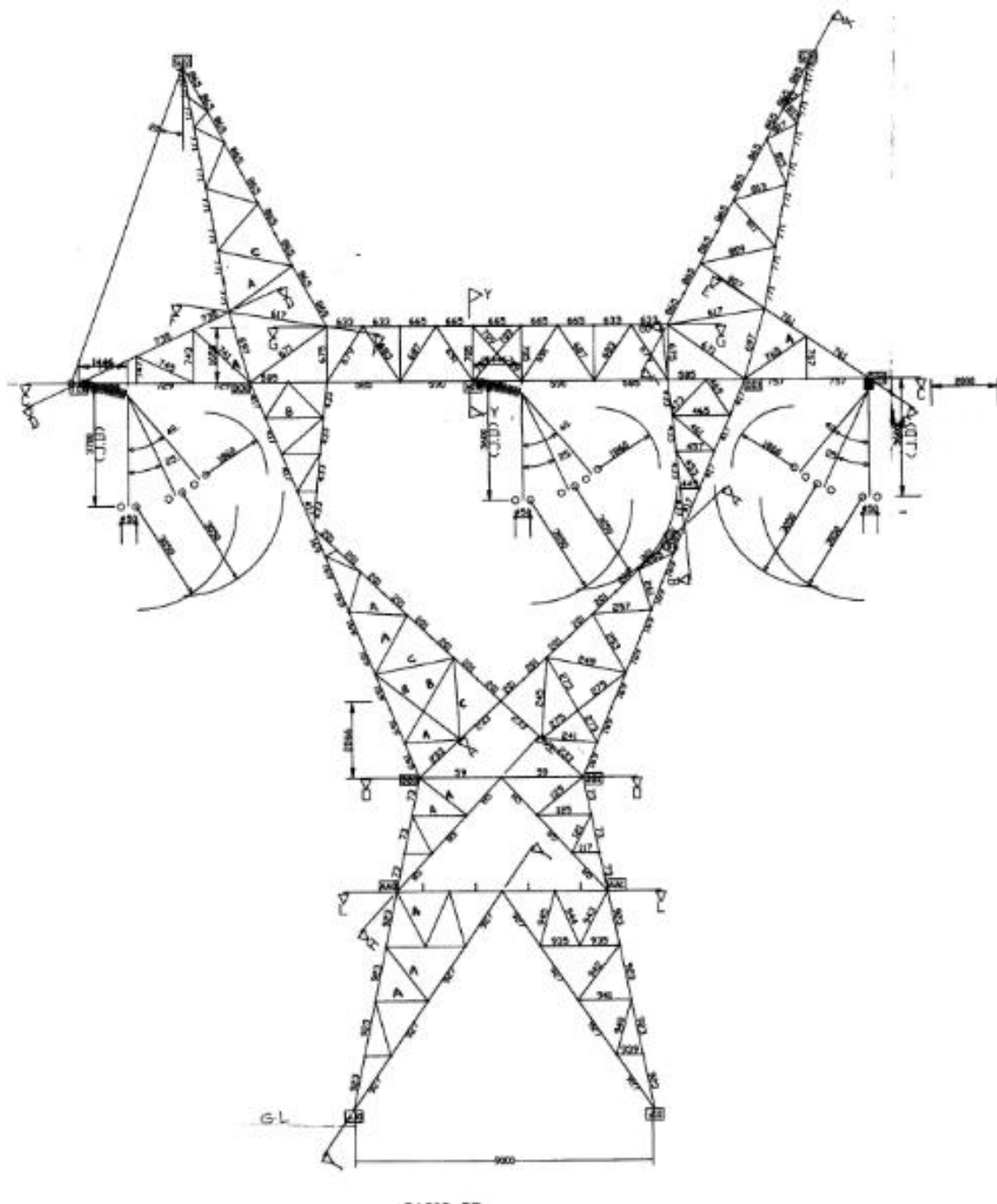
Remarks: In house Tested Towers



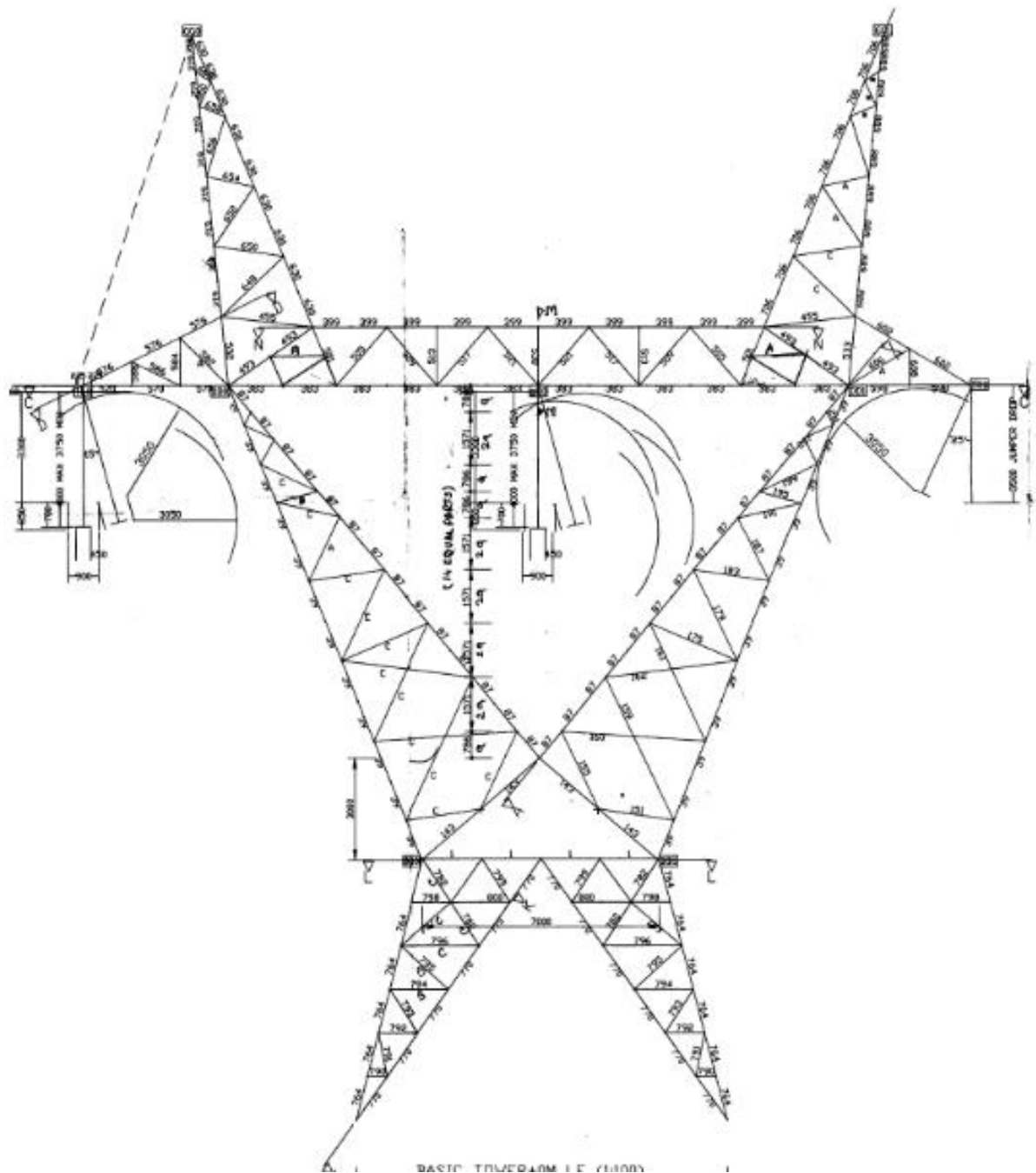
400 kV S/C WZ 2 (HORIZONTAL) TWIN MOOSE T.T. 'A'



400 kV S/C WZ 2 (HORIZONTAL) TWIN MOOSE T.T.'B'



400 kV S/C WZ 2 (HORIZONTAL) TWIN MOOSE T.T.'C'



400 kV S/C WZ 2 (HORIZONTAL) TWIN MOOSE T.T.'D'



4.5.7 400 kV M/C WZ 4 TWIN MOOSE (NARROW BASE) Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
- b) Configuration: MULTI CIRCUIT (NARROW BASE)
- c) Conductor: ACSR TWIN MOOSE
- d) Earth wire: 7/3.66: 2No.
- e) Shield Angle: <20 Deg.
- f) Ground Clearance: 8.84m
- g) Mid Span Clearance: 9.0m
- h) Max Conductor Temp: 85 Deg C
- i) Line Altitude: Upto 1000m

Tower Design Parameters

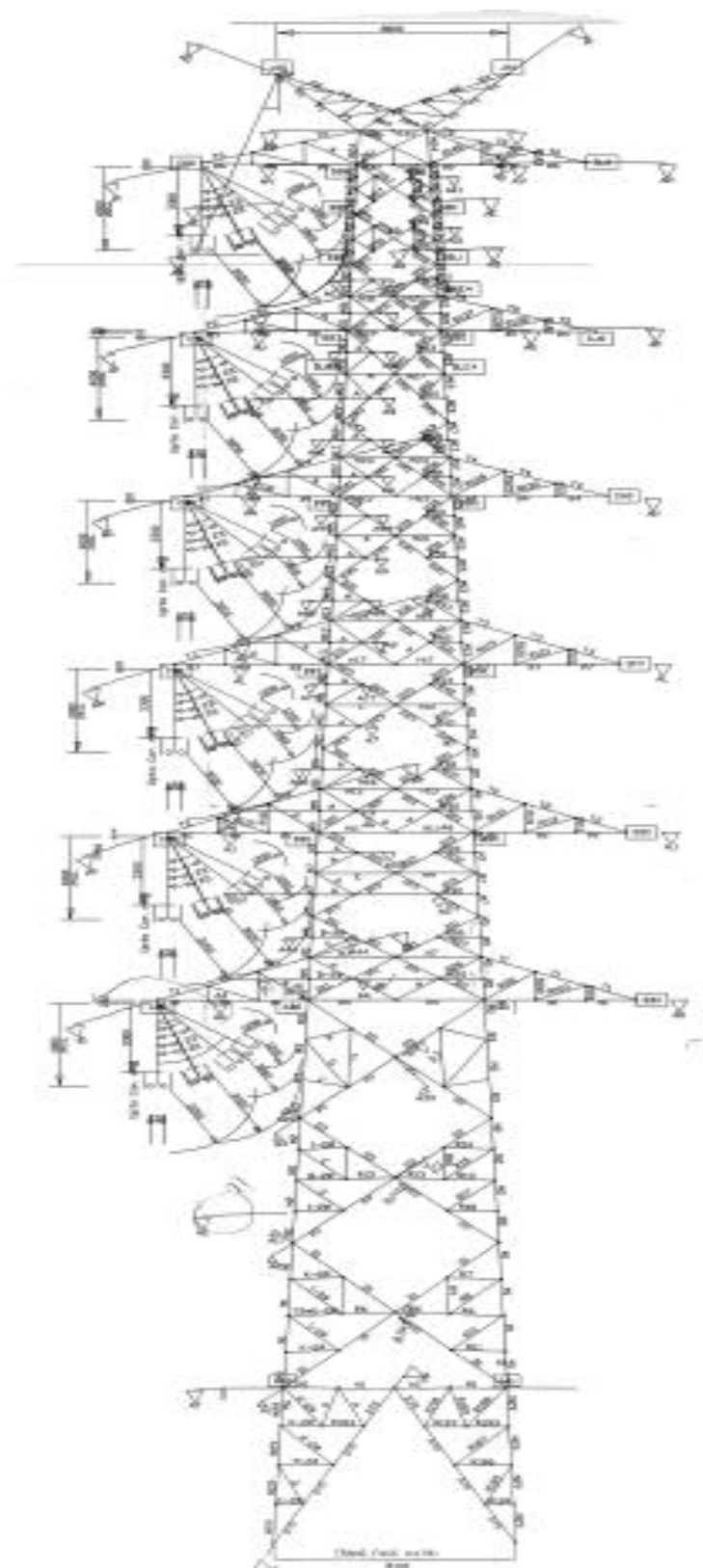
- a) IS: 802:1995
- b) Wind zone: 4
- c) Reliability Level: 2
- d) Terrain Category: 2
- e) Wind Span: 400m

Tower Types

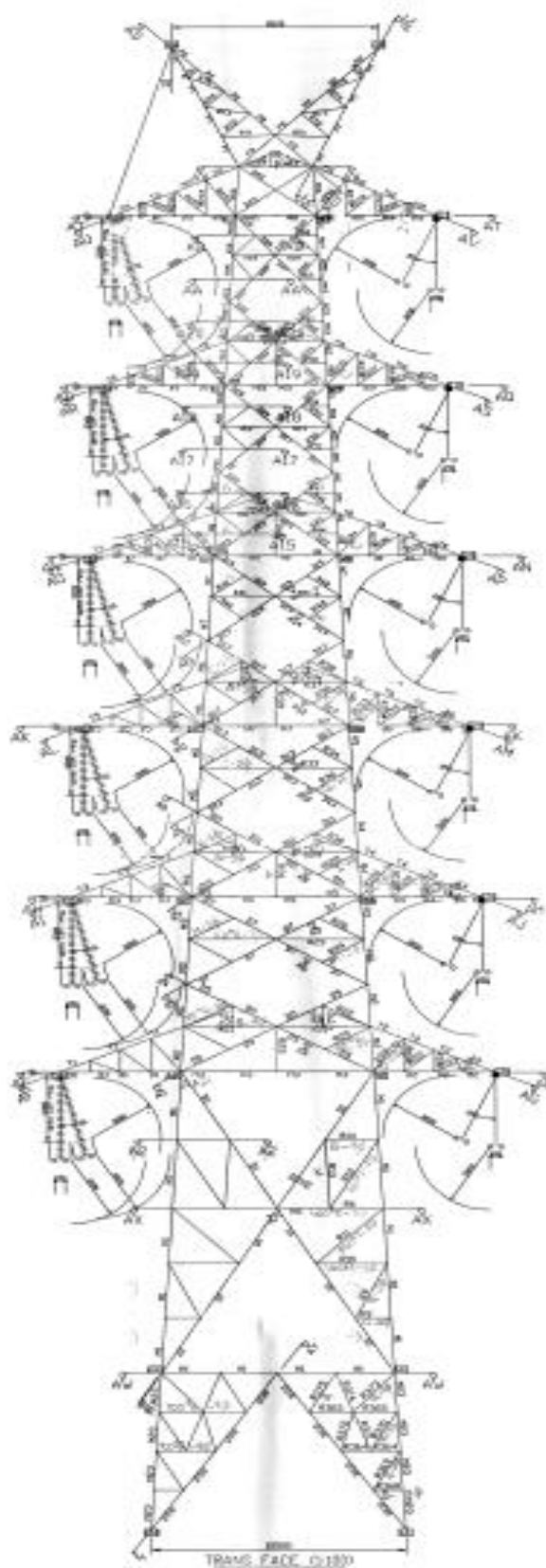
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	QA	0-2
2	QD	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	QA	600/200	360/100	8.40 x 8.40
2	QD	600/0	360/-300	10.50. X 10.50

Remarks: In house Tested Towers



400 kV M/C WZ 4 TWIN MOOSE T.T 'QA'



400 kV M/C WZ 4 TWIN MOOSE T.T 'OD'

4.5.8 400 kV M/C WZ 4 QUAD MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: MULTI CIRCUIT
 c) Conductor: ACSR QUAD MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg. (for QD)
 0 Deg. (for QA)
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Design Parameters

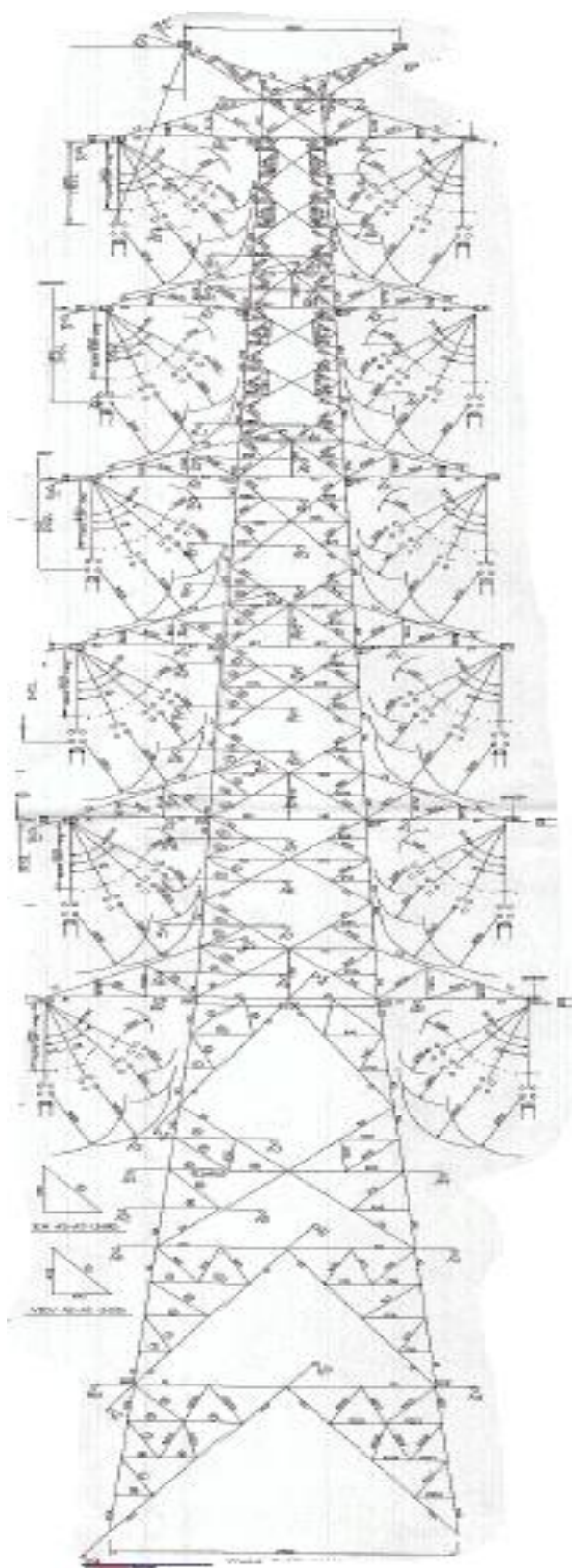
- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 2
 d) Terrain Category: 2
 e) Wind Span: 400m

Tower Types

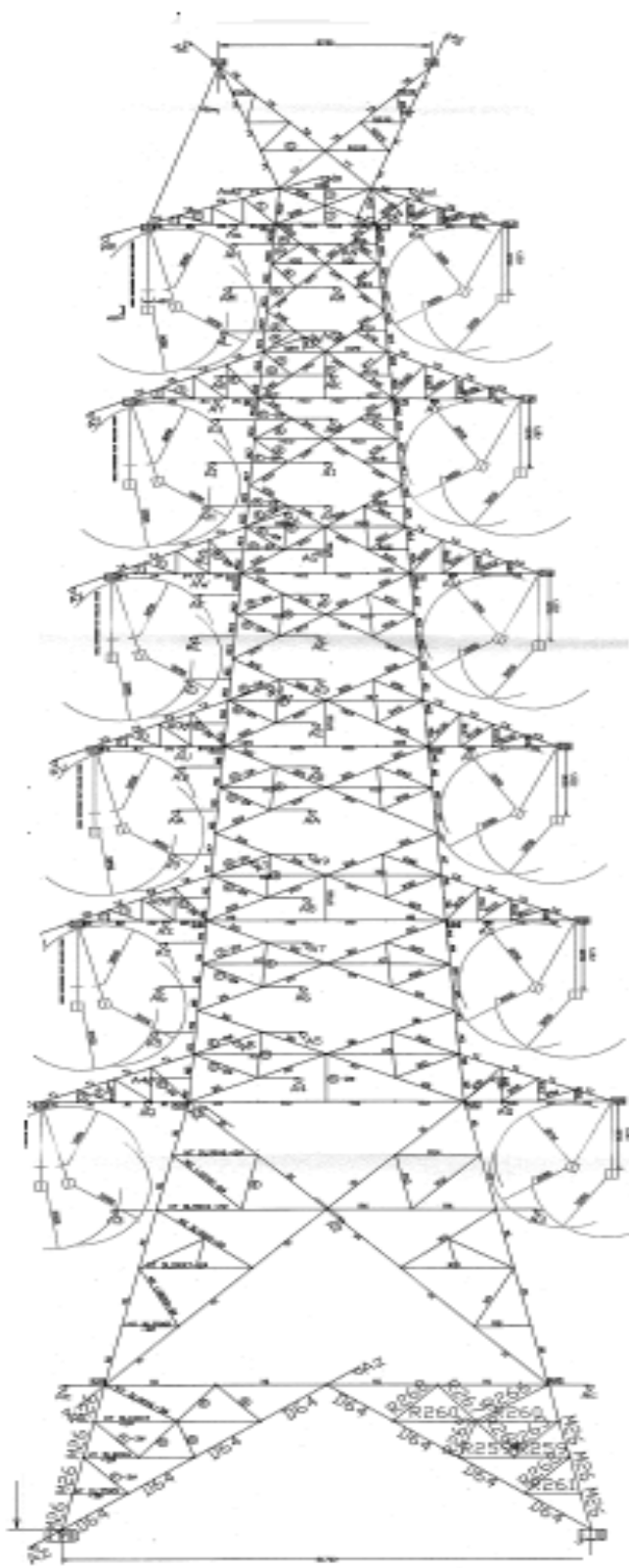
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	QA	0-2
2	QD	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	QA	600/200	360/100	14.00 x 14.00
2	QD	600/0	360/-300	21.70. X 21.70

Remarks: In house Tested Towers



400 kV M/C WZ 4 QUAD MOOSE T.T 'QA'



400 kV M/C WZ 4 QUAD MOOSE T.T 'OD'

4.5.9 400 kV M/C WZ 4 ALL CIRCUITS TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: MULTI CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

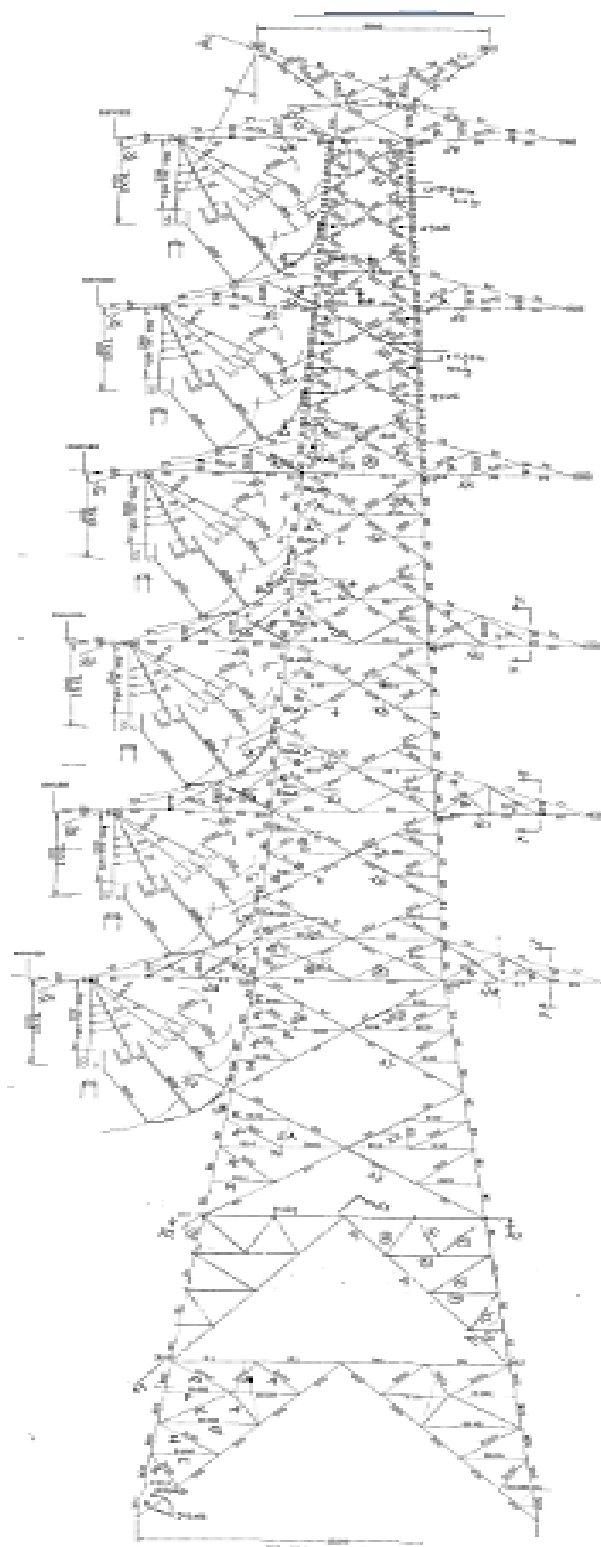
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	QA	0-2
2	QB	0-15
3	QC	15-30
4	QD	30-60

Tower Design Parameters

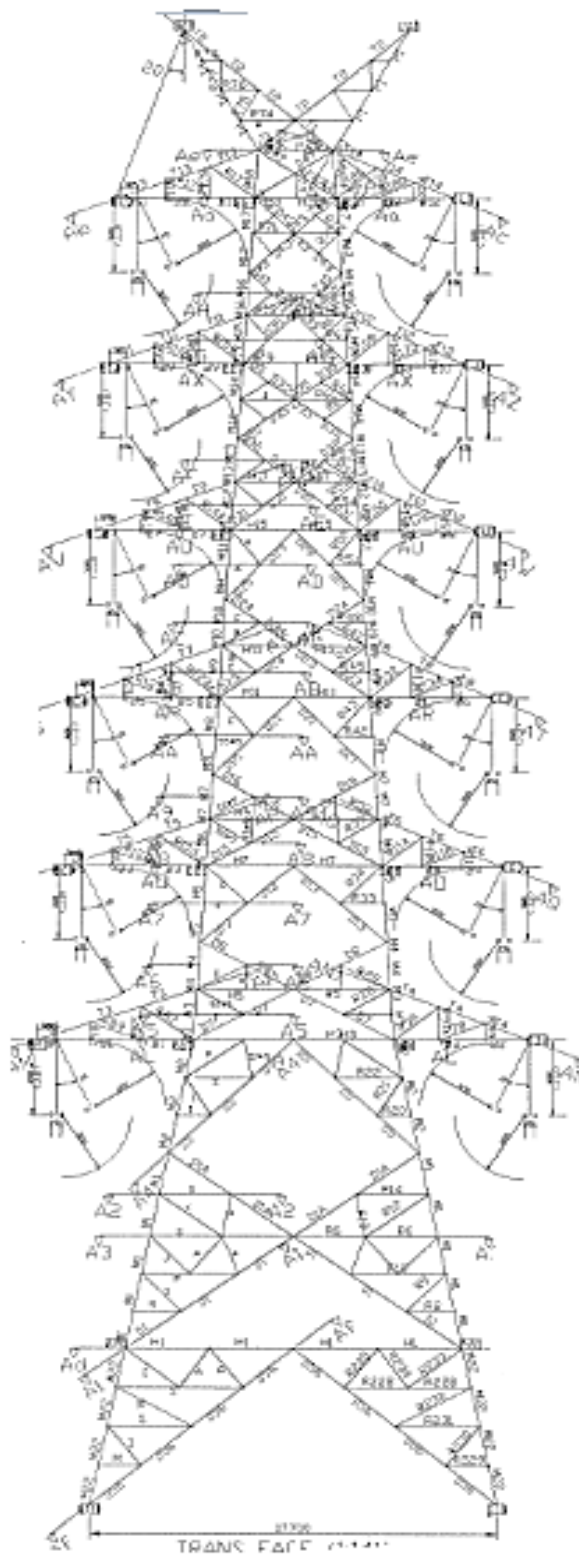
- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 2
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	QA	600/200	360/100	15.50 x 15.50
2	QB	600/0	360/-200	17.70 X 17.70
3	QC	600/0	360/-200	17.70 X 17.70
4	QD	600/0	360/-300	20.00 X 20.00

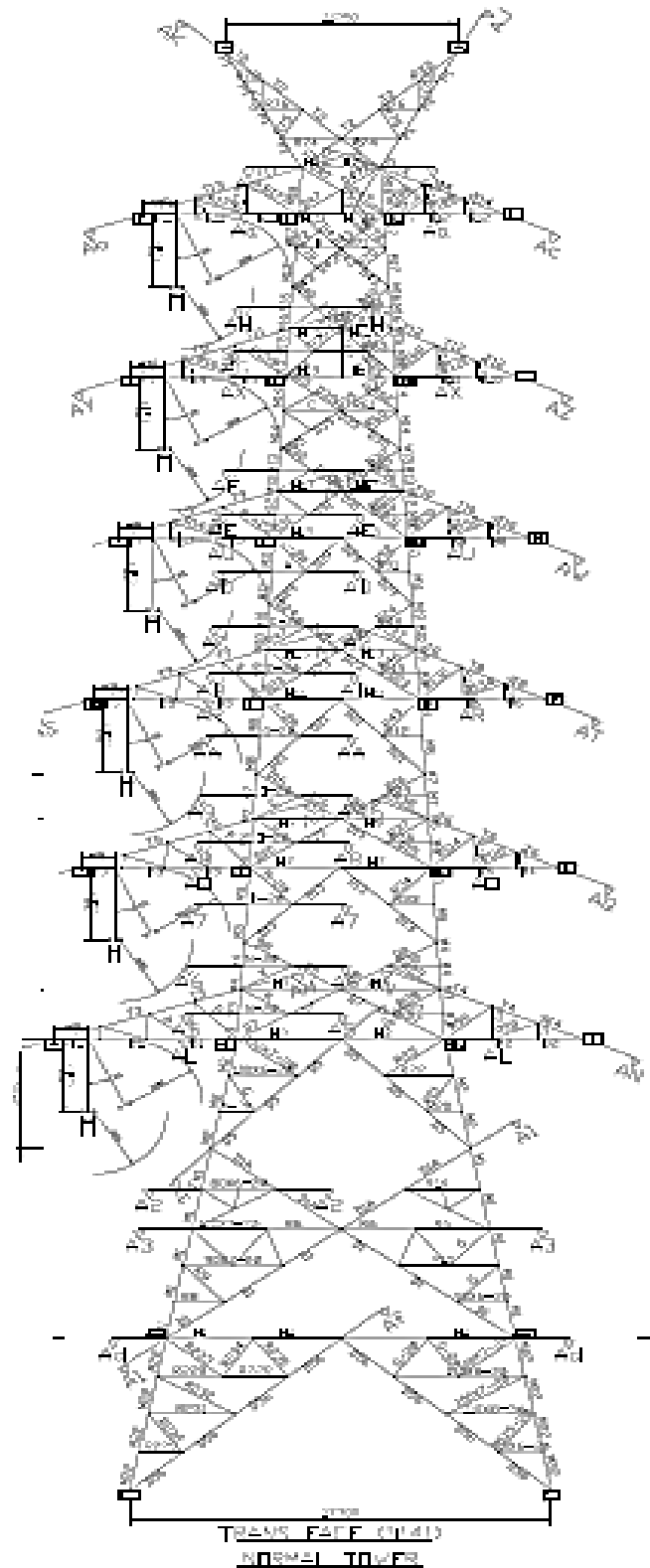
Remarks: In house Tested Towers



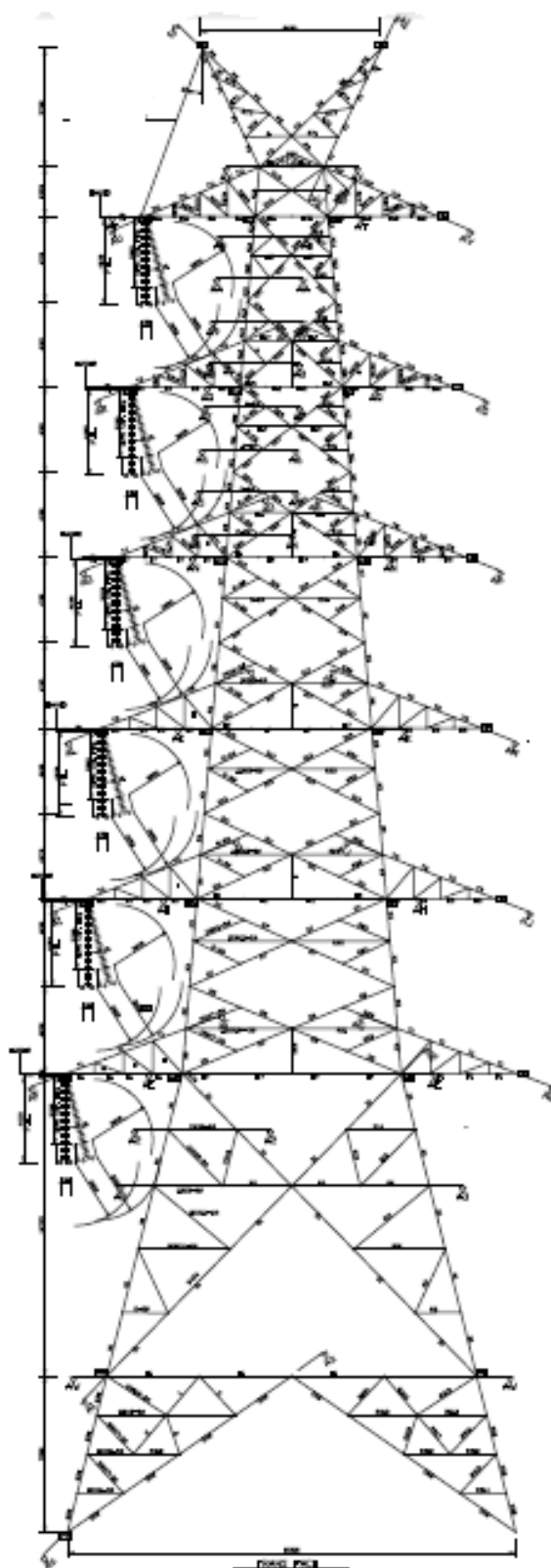
400 kV M/C WZ 4 ALL CIRCUITS TWIN MOOSE T.T. 'QA'



400 kV M/C WZ 4 ALL CIRCUITS TWIN MOOSE T.T. 'QB'



400 kV M/C WZ 4 ALL CIRCUITS TWIN MOOSE T.T. 'QC'



400 kV M/C WZ 4 ALL CIRCUITS TWIN MOOSE T.T. 'OD'



**4.5.10 400 kV M/C WZ 2 TOP CIRCUITS TWIN/ BOTTOM CIRCUITS QUAD
MOOSE Transmission Line (PGCIL)**

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: MULTI CIRCUIT
c) Conductor: TOP CIRCUITS TWIN/ BOTTOM CIRCUITS ACSR
QUAD MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 8.84m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 1000m

Tower Types

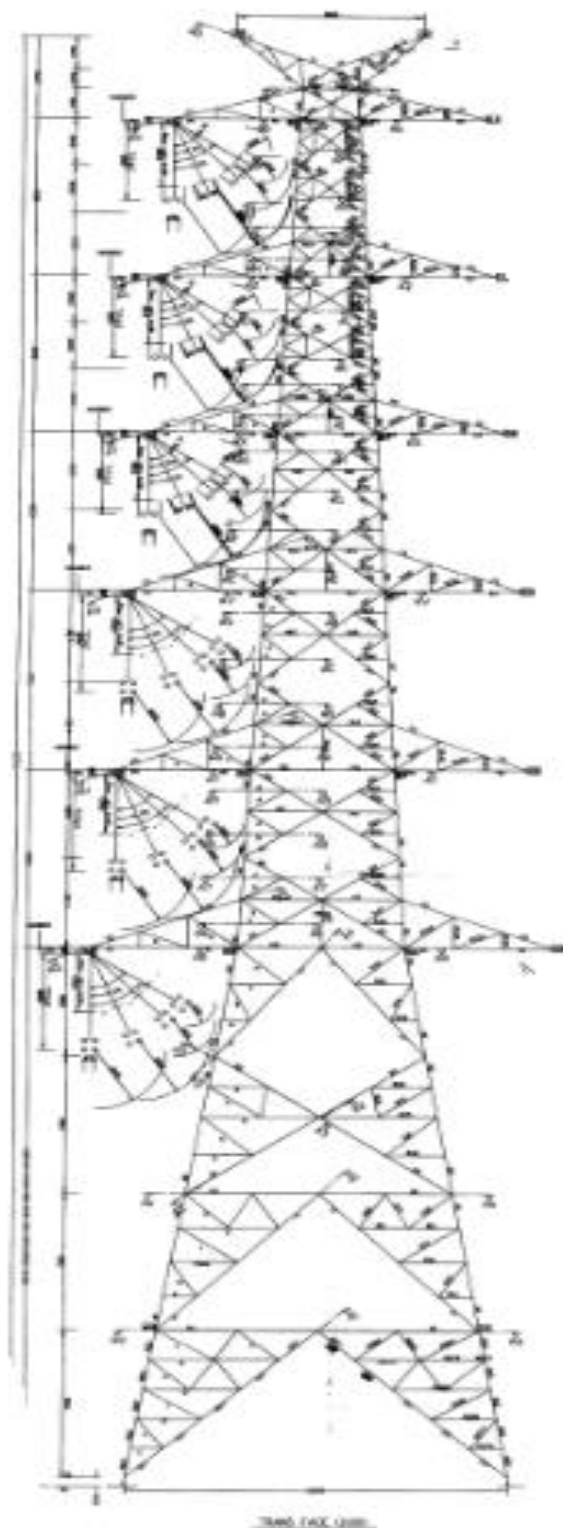
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	QA	0-2
2	QB	0-15
3	QC	15-30
4	QD	30-60

Tower Design Parameters

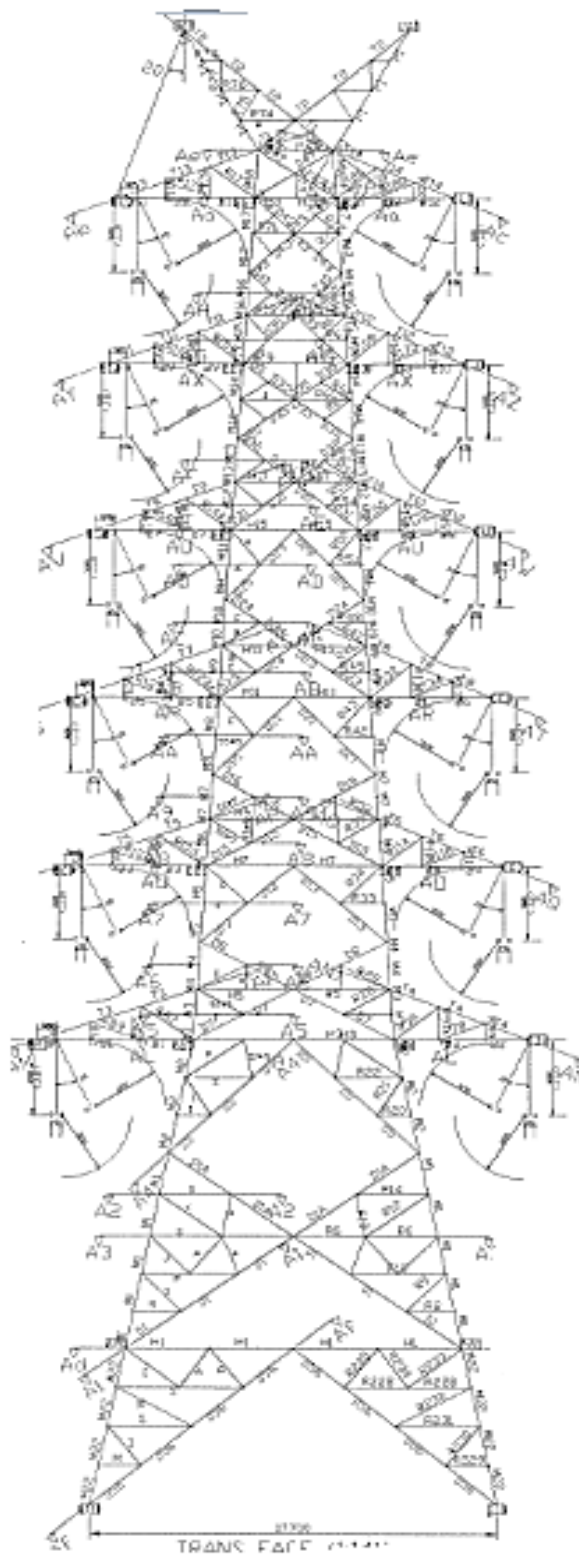
- a) IS: 802:1995
b) Wind zone: 4
c) Reliability Level: 2
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	QA	600/200	360/100	16.50 x 16.50
2	QB	600/0	360/-200	17.70 X 17.70
3	QC	600/0	360/-200	17.70 X 17.70
4	QD	600/0	360/-300	20.00 X 20.00

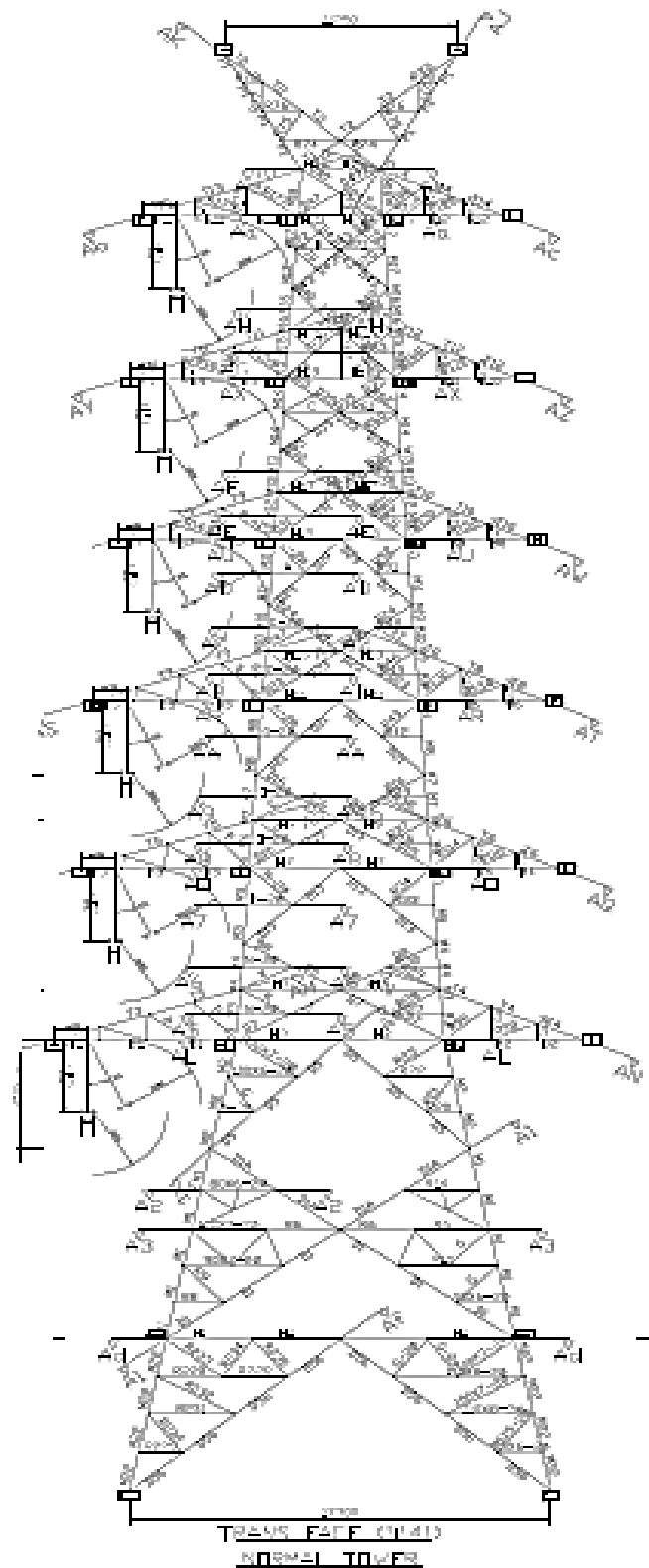
Remarks: In house Tested Towers



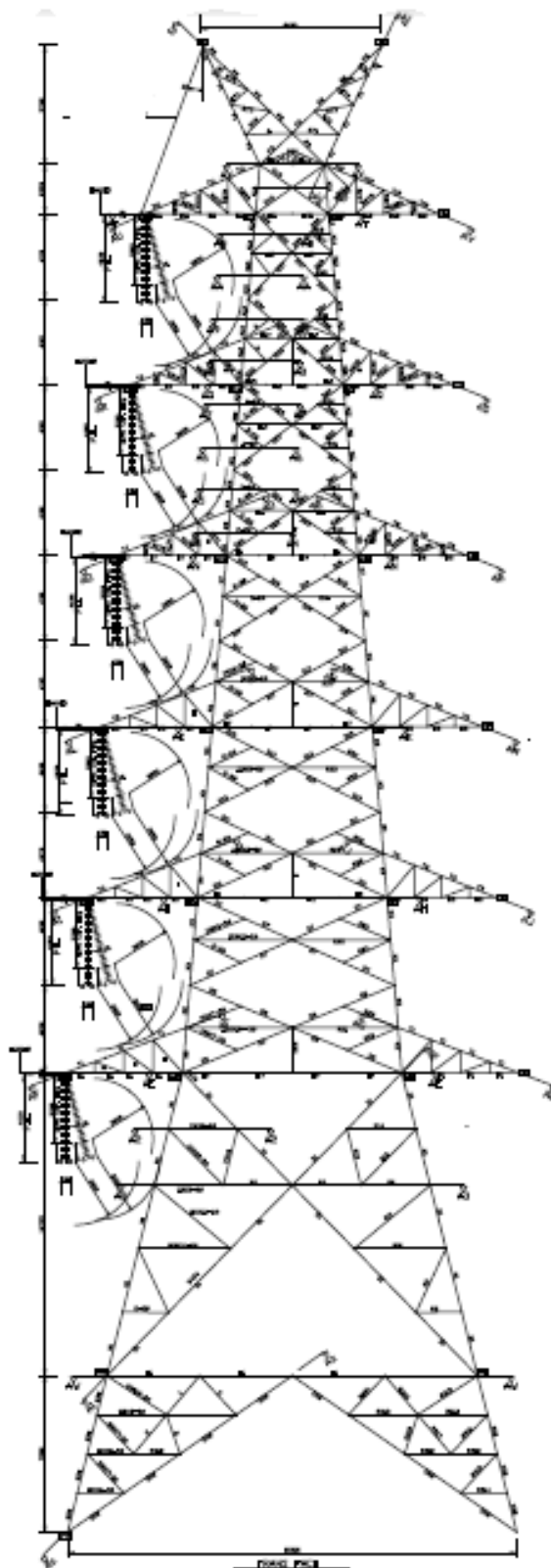
400 kV M/C WZ 2 TOP CIRCUITS TWIN/ BOTTOM CIRCUITS QUAD MOOSE T.T 'QA'



400 kV M/C WZ 2 TOP CIRCUITS TWIN/ BOTTOM CIRCUITS QUAD MOOSE T.T 'QB'



400 kV M/C WZ 2 TOP CIRCUITS TWIN/ BOTTOM CIRCUITS QUAD MOOSE T.T 'QC'



400 kV M/C WZ 2 TOP CIRCUITS TWIN/ BOTTOM CIRCUITS QUAD MOOSE T.T 'OD'



4.5.11 400 kV D/C WZ 2+15mm ICE QUAD MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR QUAD MOOSE
 d) Earth wire: 7/3.15: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 9.5m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Radial ice thickness: 15mm
 j) Line Altitude: Upto 2500m

Tower Types

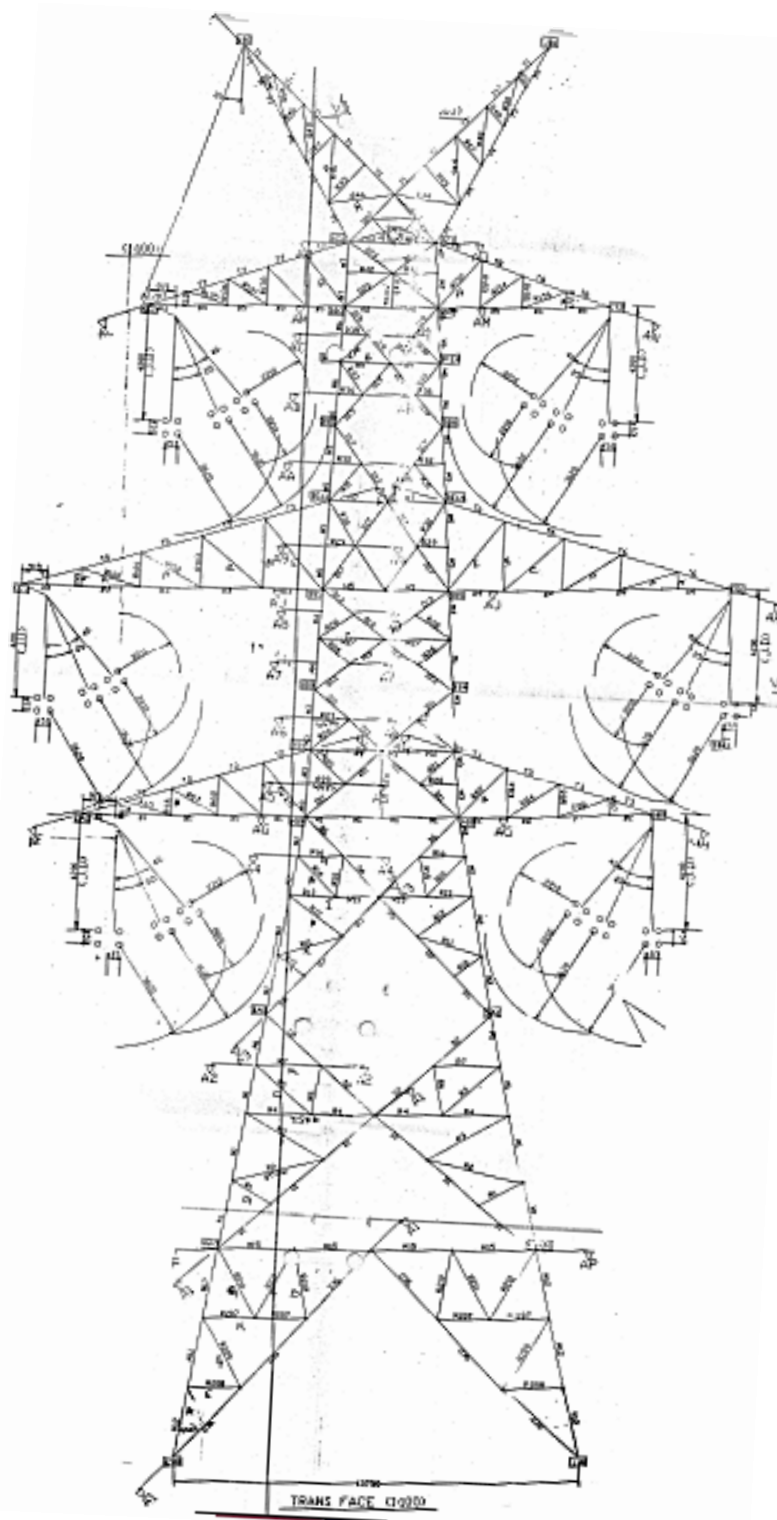
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DB	0-15
2	DC	15-30
3	DD	30-60

Tower Design Parameters

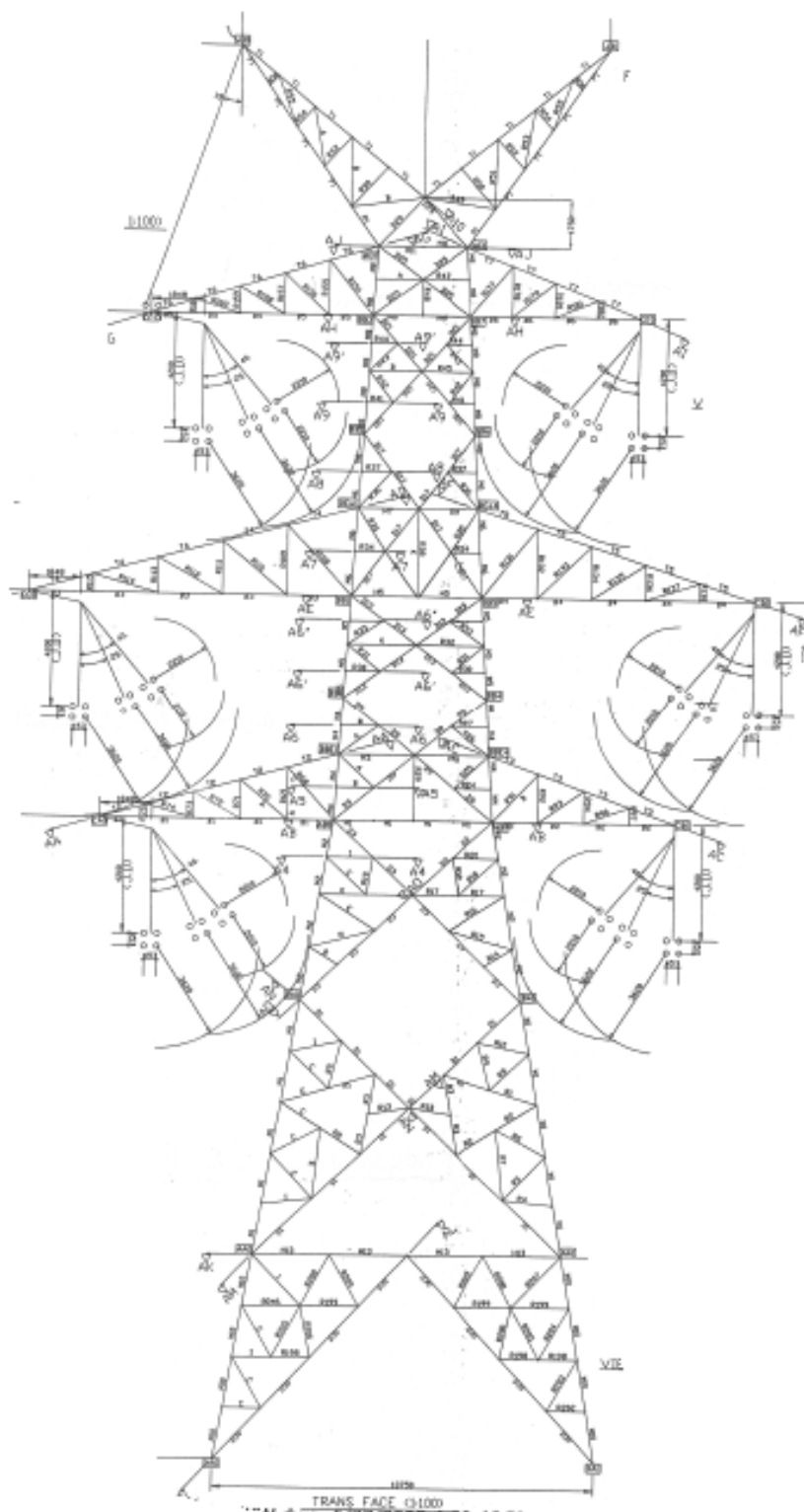
- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DB	1200/-1200	720/-720	13.75 X 13.75
2	DC	1200/-1200	720/-720	13.75 X 13.75
3	DD	1500/-1500	900/-900	15.00 X 15.00

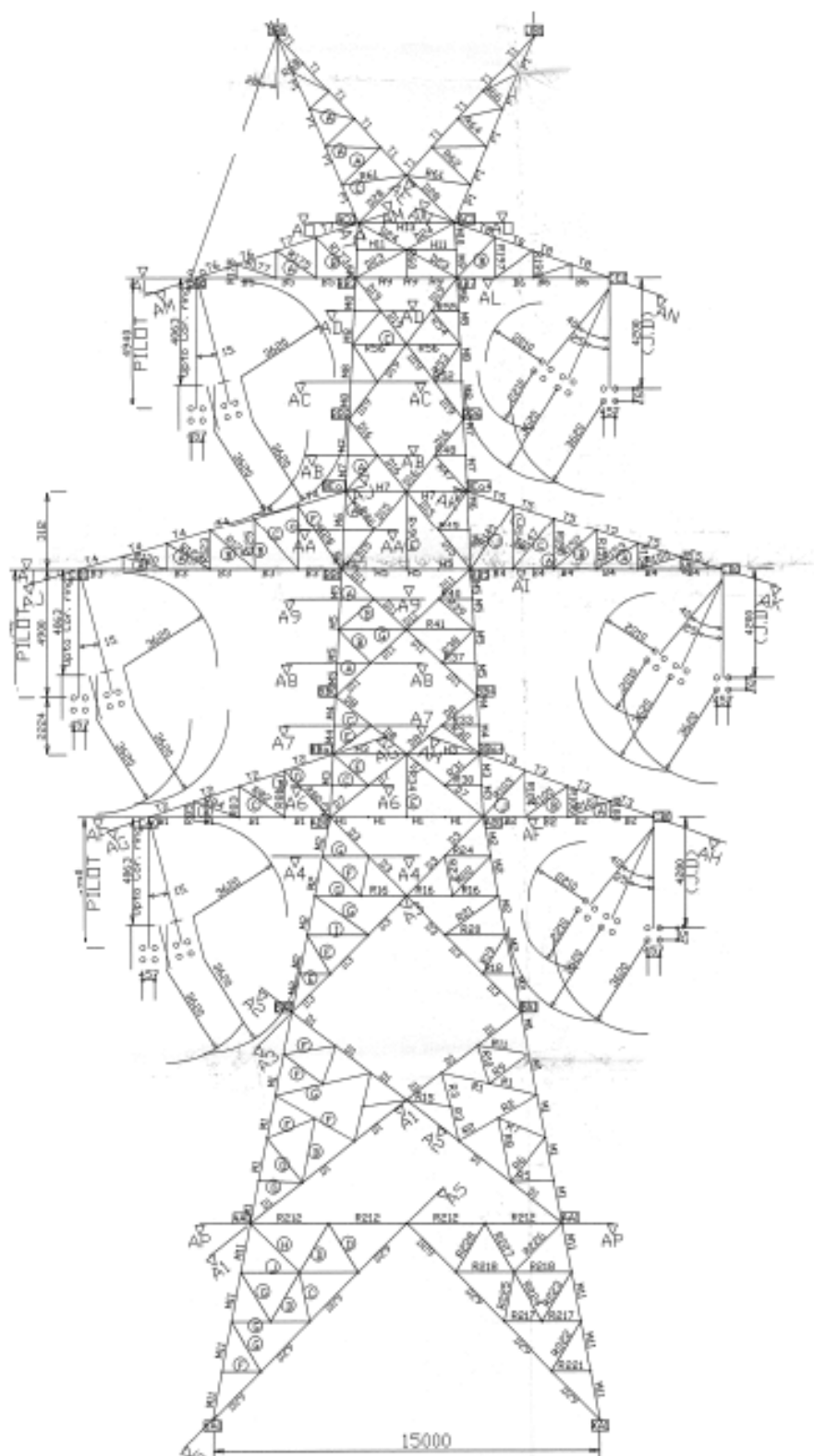
Remarks: In house Tested Towers



400 kV D/C WZ 2+15mm ICE QUAD MOOSE T.T. 'DB'



400 kV D/C WZ 2+15mm ICE QUAD MOOSE T.T. 'DC'



400 kV D/C WZ 2+15mm ICE QUAD MOOSE T.T. 'DD'

4.5.12 400 kV D/C WZ 6 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Design Parameters

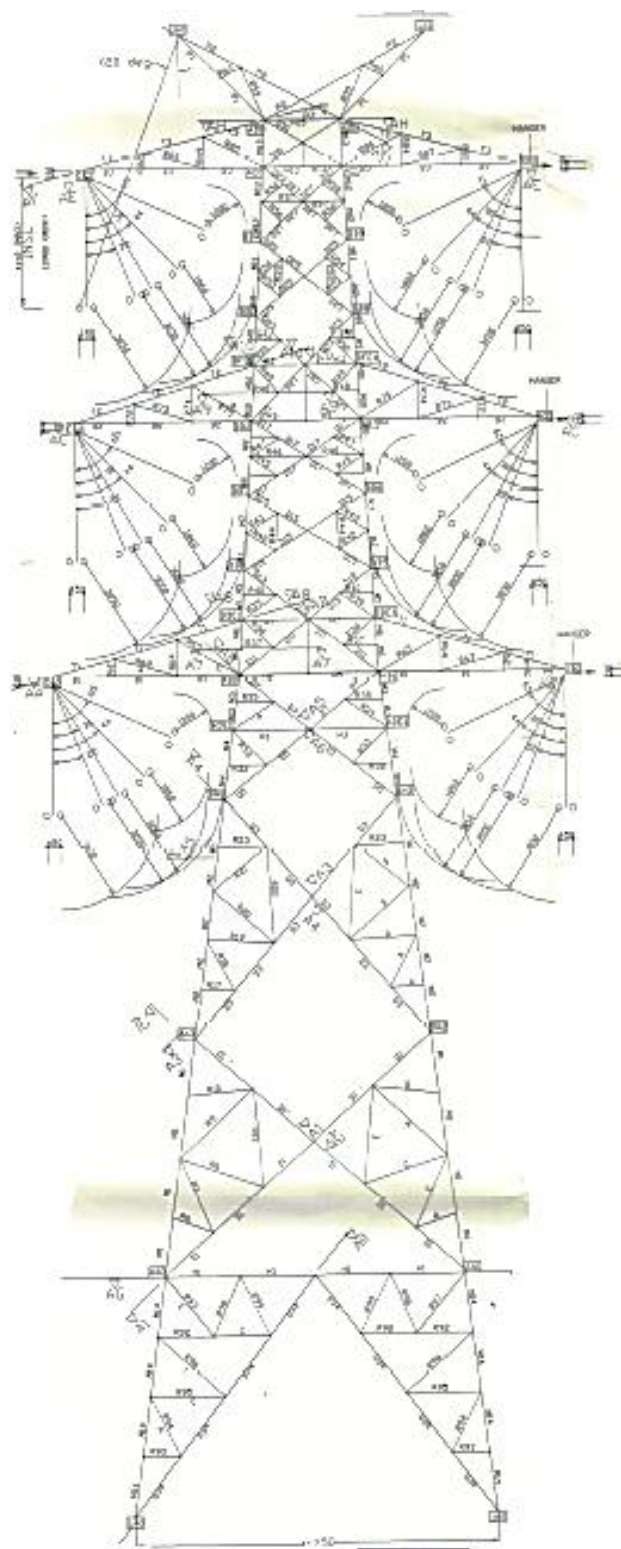
- a) IS: 802:1995
 b) Wind zone: 6
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Tower Types

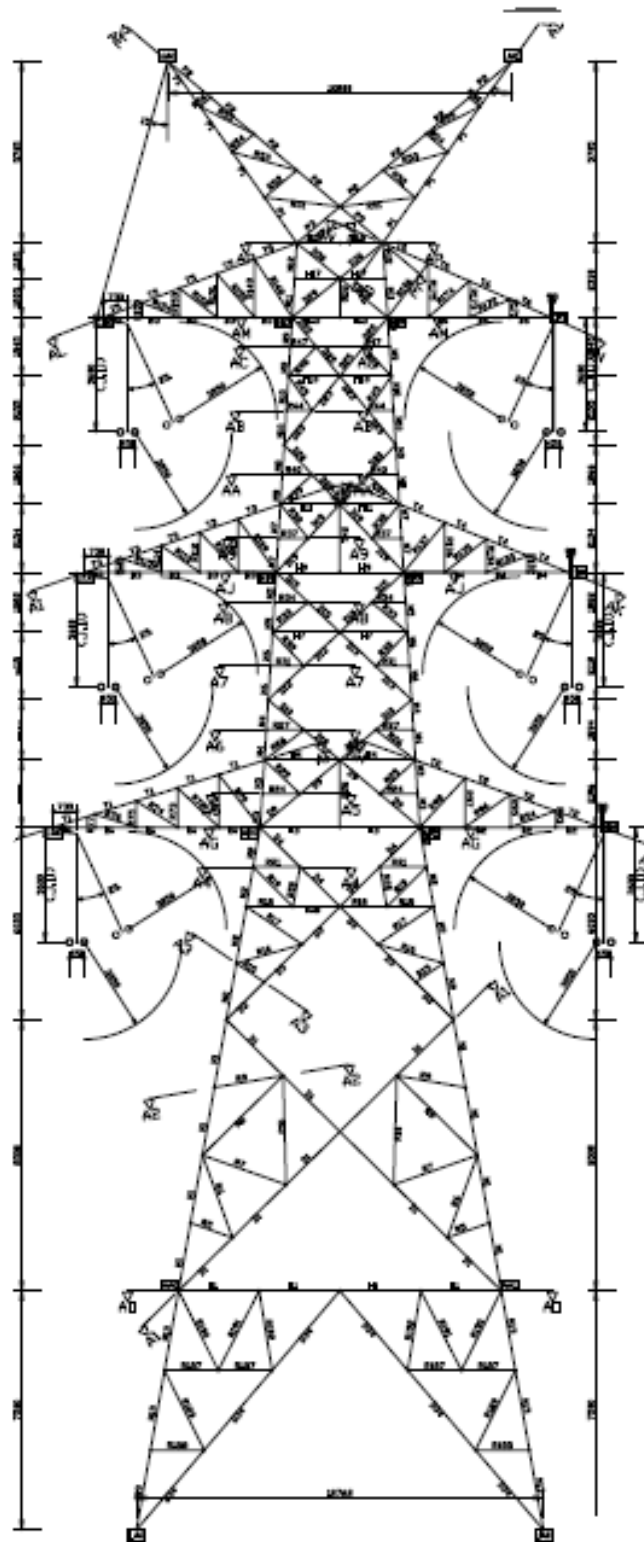
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/(Min)	BWC (Max)/(Min)	
1	DA	600/200	360/100	11.75 X 11.75
2	DB	1000/-1000	600/-600	12.75 X 12.75
3	DC	1000/-1000	600/-600	12.75 X 12.75
4	DD	1500/-1000	900/-850	15.00 X 15.00

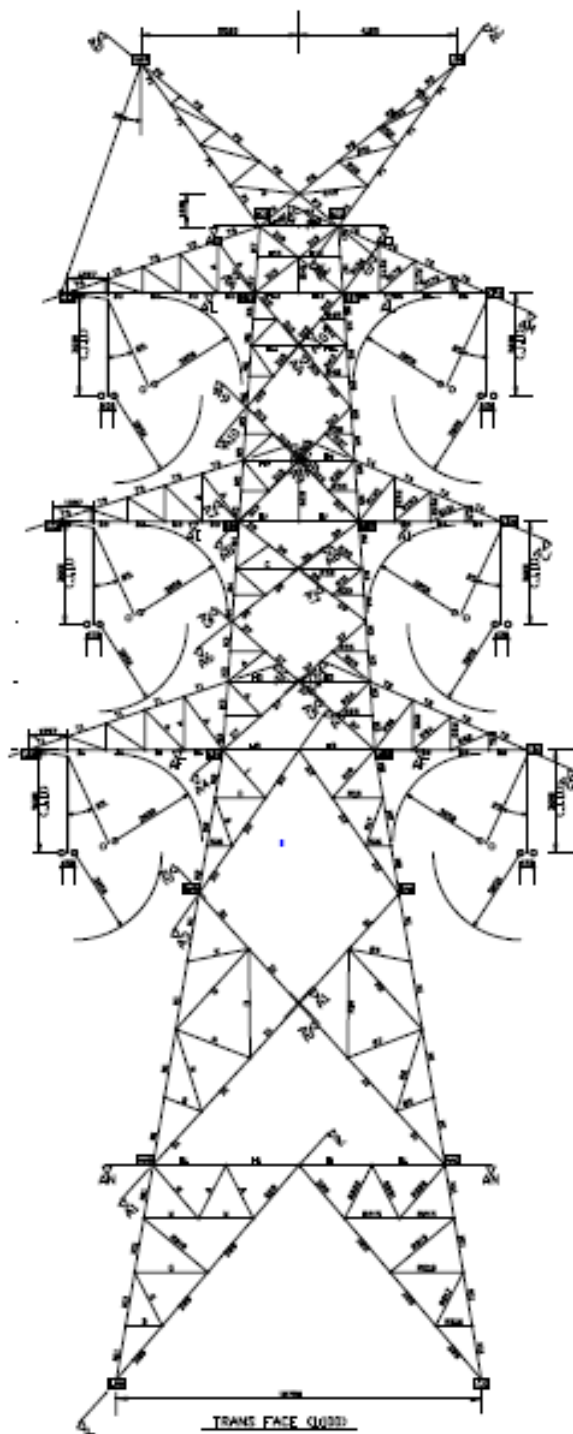
Remarks: In house Tested Towers



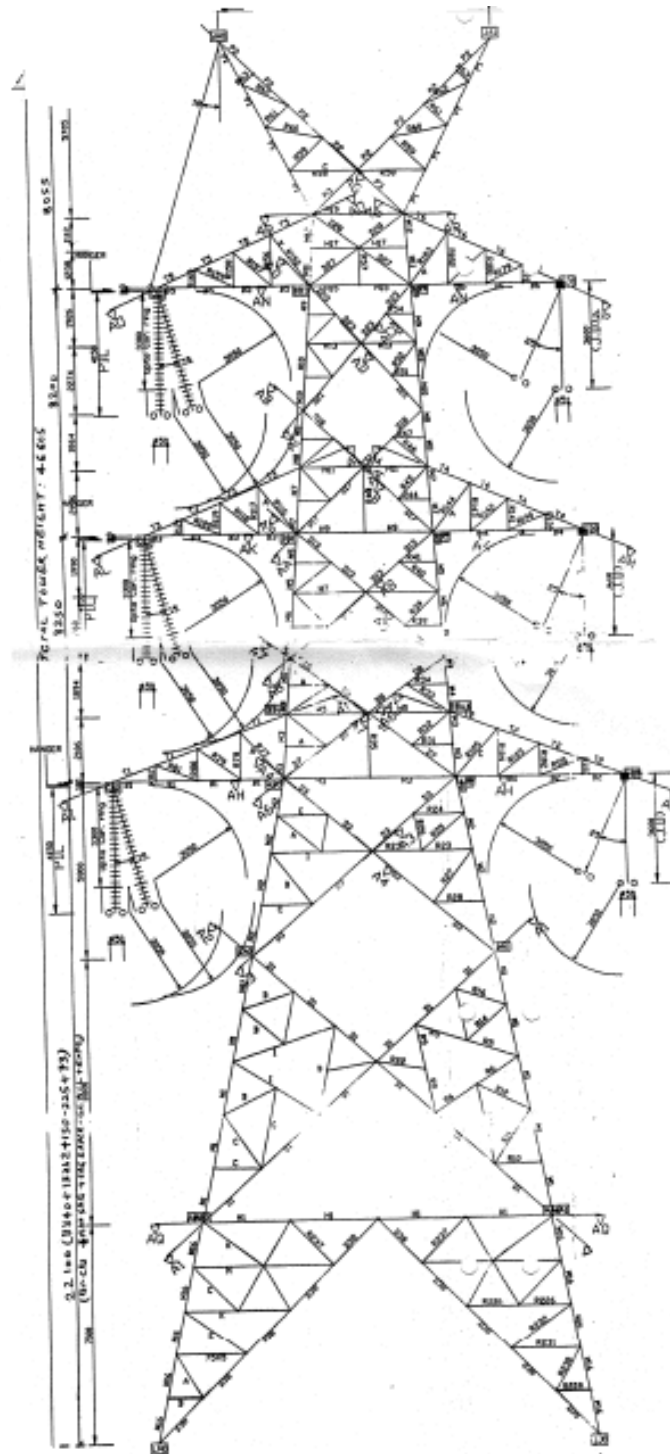
400 kV D/C WZ 6 TWIN MOOSE T.T 'DA'



400 kV D/C WZ 6 TWIN MOOSE T.T 'DB'



400 kV D/C WZ 6 TWIN MOOSE T.T 'DC'



400 kV D/C WZ 6 TWIN MOOSE T.T 'DD'

4.5.13 400 kV D/C WZ 5 TRIPLE SNOWBIRD Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TRIPLE SNOWBIRD
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2

Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 5
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	11.50 X 11.50

Remarks: In house Tested Towers



**4.5.14 400 kV D/C WZ 5 QUAD MOOSE Transmission Line (PGCIL)****Line Parameters**

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR QUAD MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

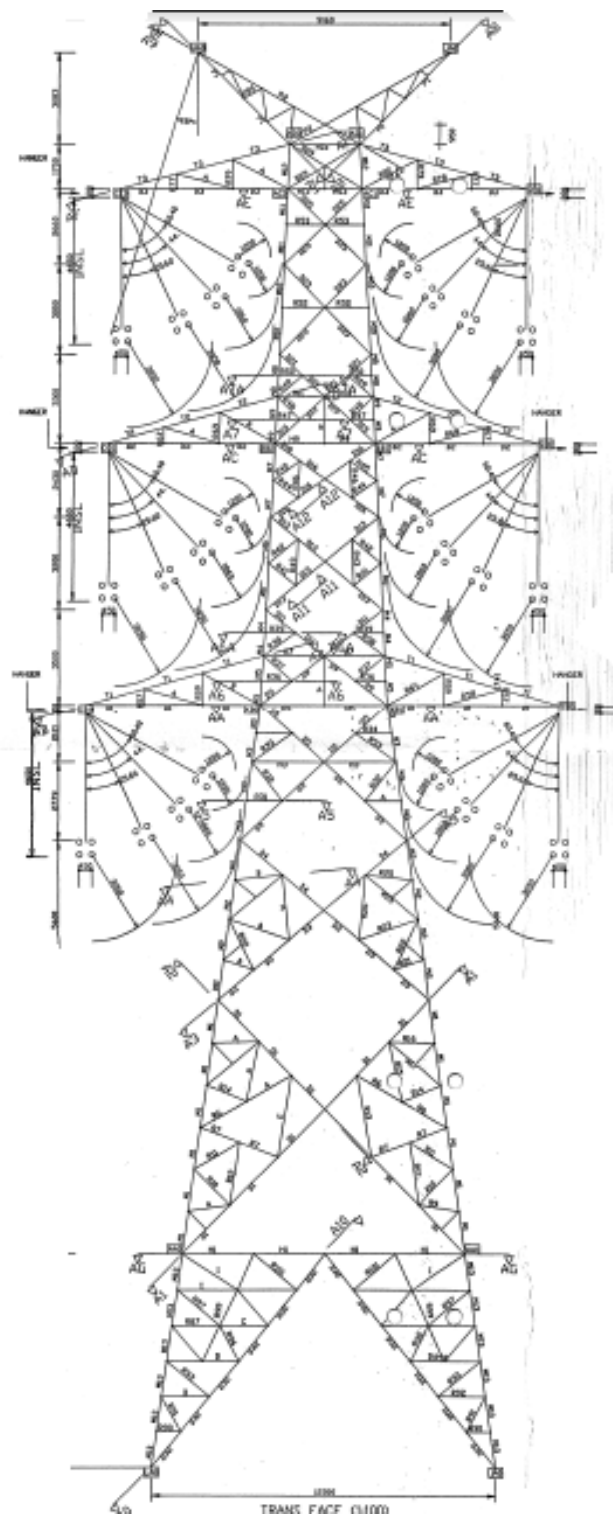
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2

Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 5
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 380m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	A	600/200	360/100	12.50 X 12.50

Remarks: In house Tested Towers



400 kV D/C WZ 5 QUAD MOOSE T.T 'DA'

4.5.15 400 kV D/C WZ 5 TWIN LAPWING Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN
 LAPWING
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <10 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

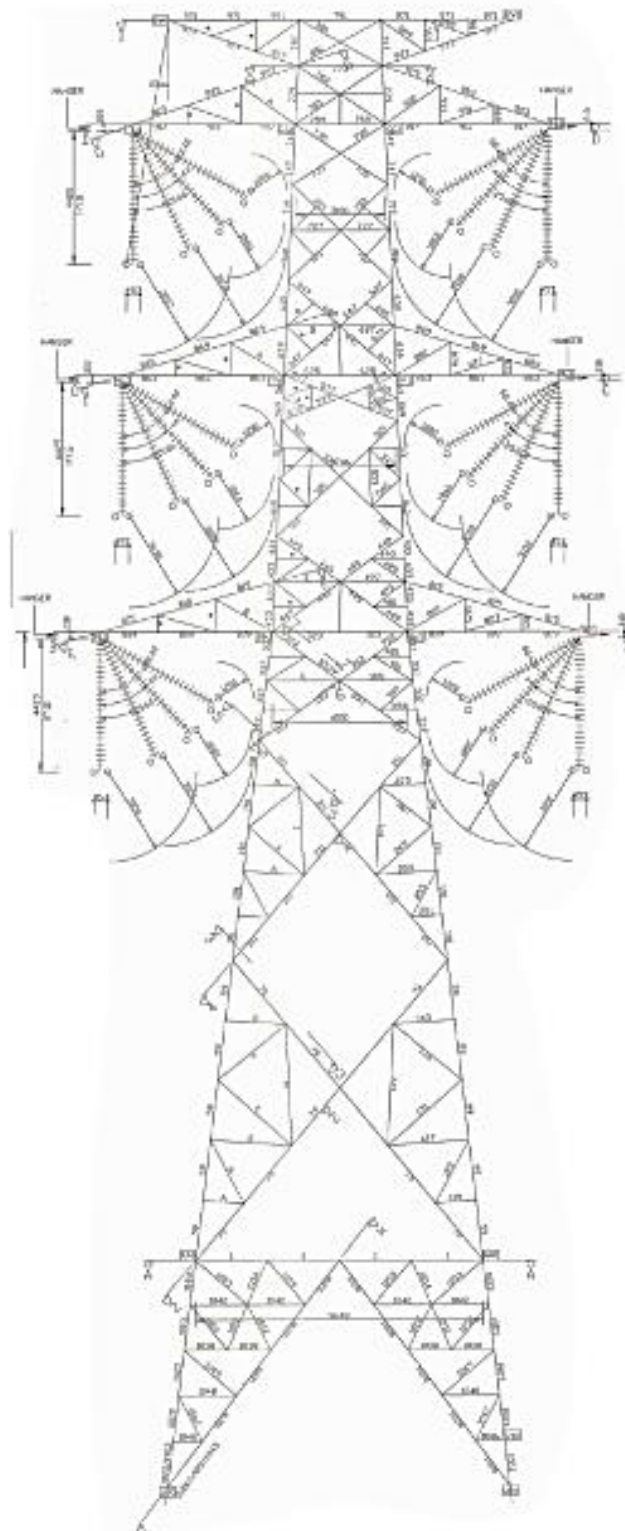
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

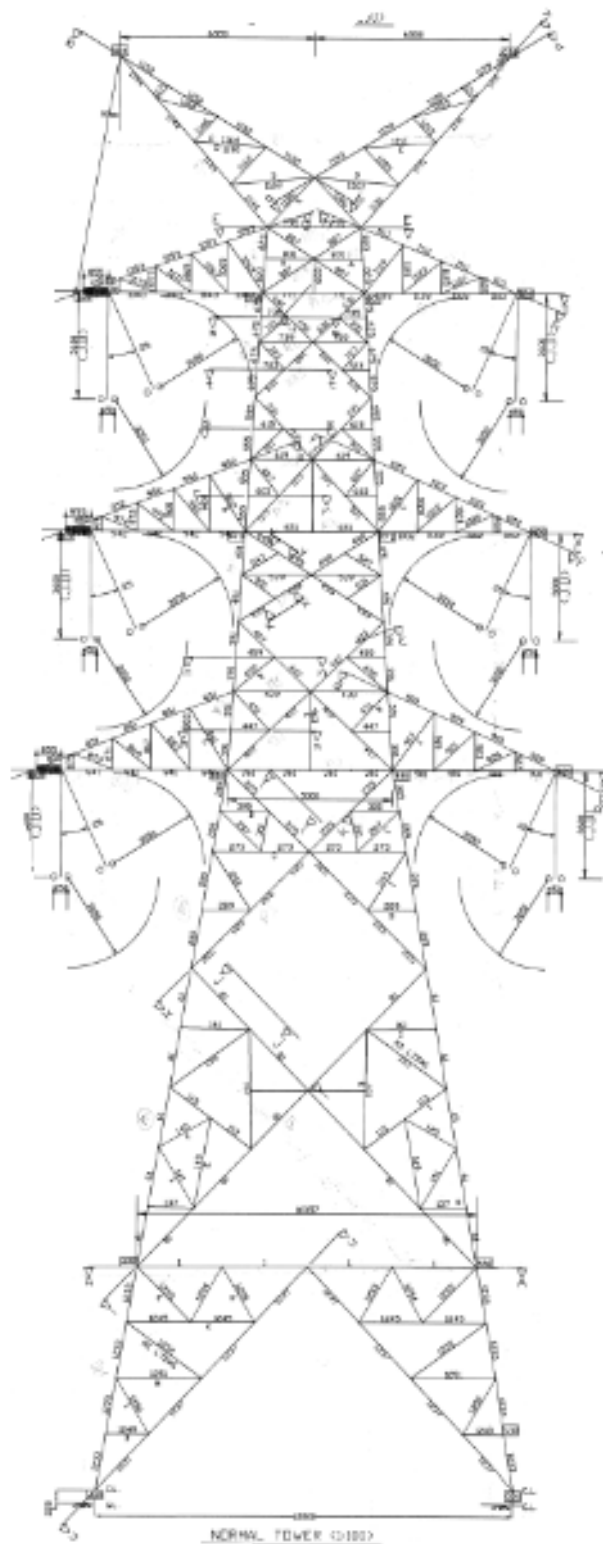
- a) IS: 802:1995
 b) Wind zone: 5
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	11.50 X 11.50
2	DB	1000/-1000	600/-600	12.80 x 12.80
3	DC	1000/-1000	600/-600	12.80 x 12.80
4	DD	1500/-1000	900/-850	13.472 x 13.472

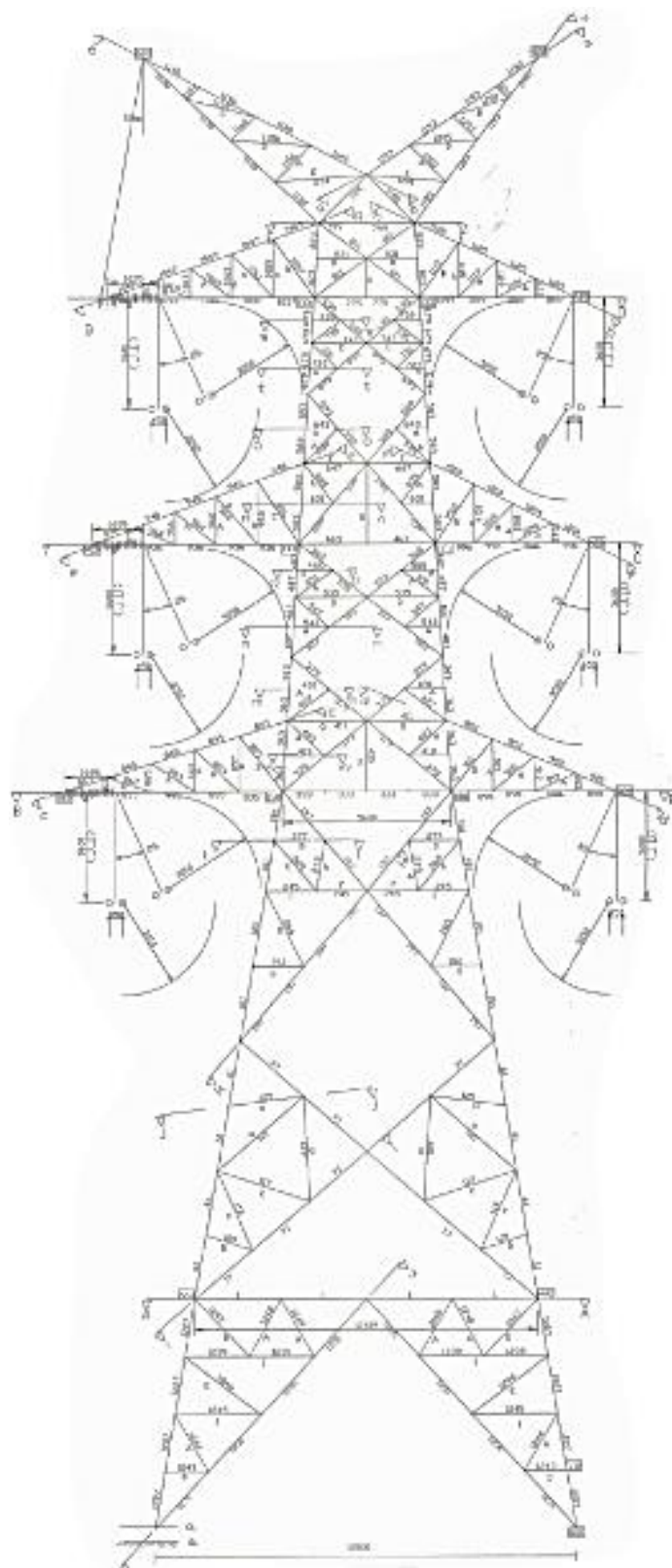
Remarks: In house Tested Towers



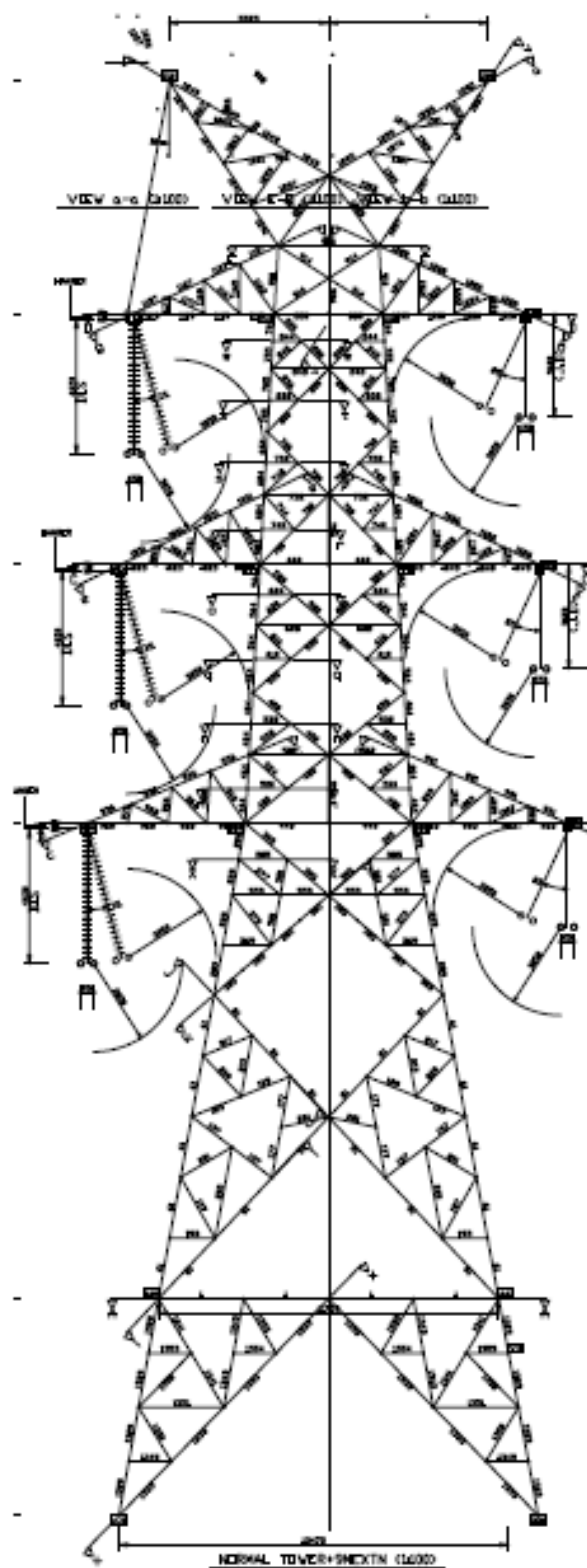
400 kV D/C WZ 5 TWIN LAPWING T.T.'DA'



400 kV D/C WZ 5 TWIN LAPWING T.T.'DB'



400 kV D/C WZ 5 TWIN LAPWING T.T. 'DC'



400 kV D/C WZ 5 TWIN LAPWING T.T.'DD'

**4.5.16 400 kV D/C WZ 5 TWIN MOOSE Transmission Line (PGCIL)****Line Parameters**

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

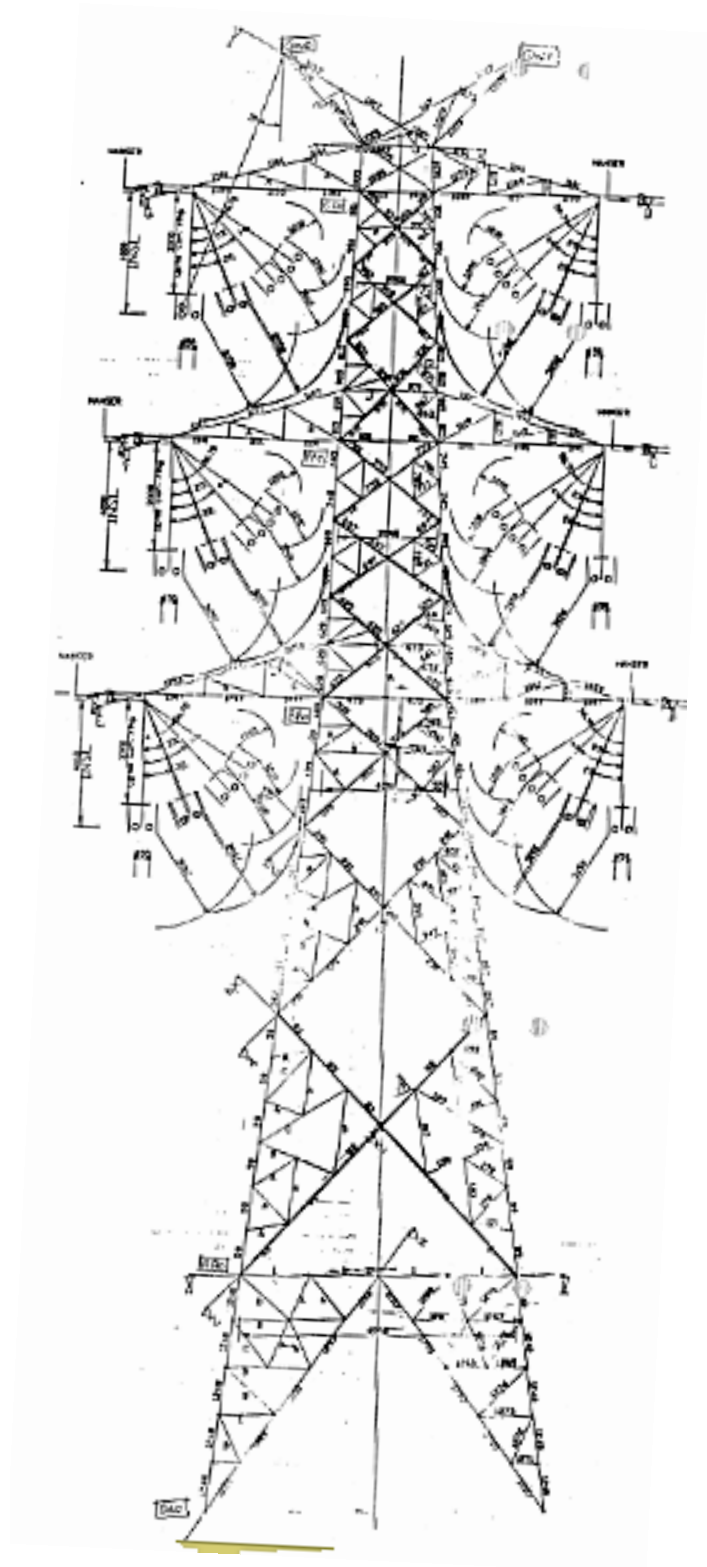
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

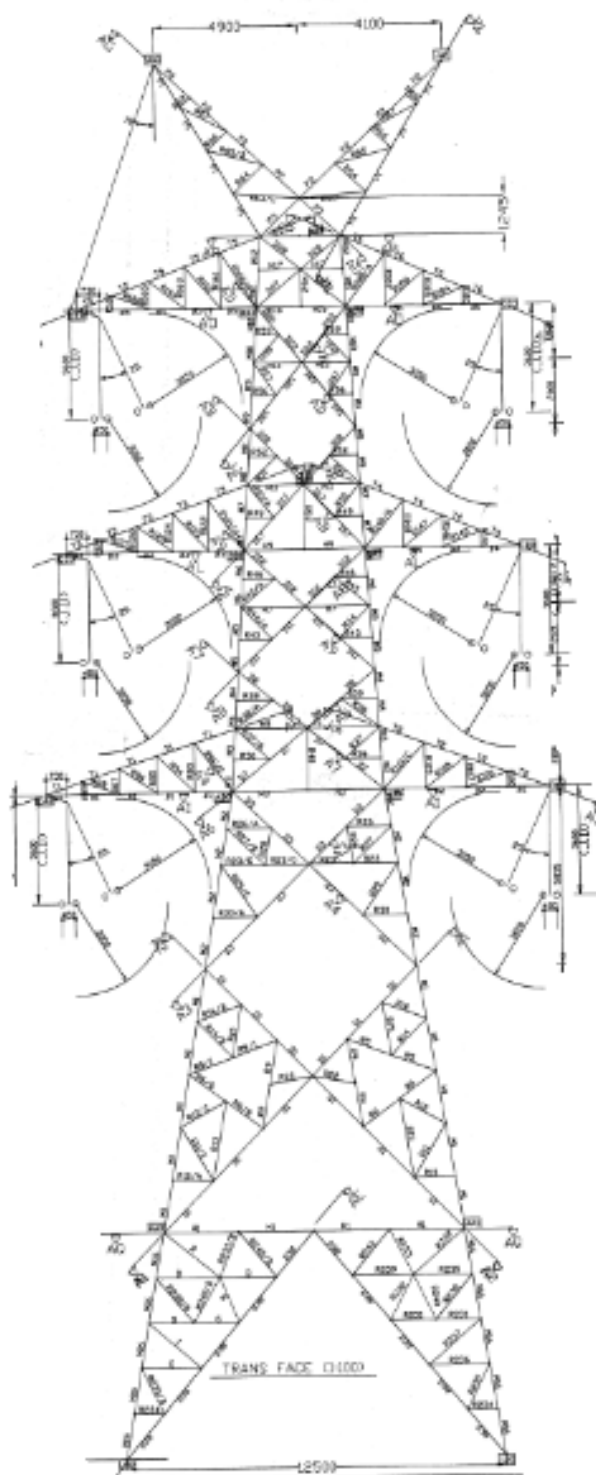
- a) IS: 802:1995
 b) Wind zone: 5
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	11.00 X 11.00
2	DB	1000/-1000	600/-600	12.50 x 12.50
3	DC	1000/-1000	600/-600	12.80 x 12.80
4	DD	1500/-1000	900/-850	14.60 x 14.60

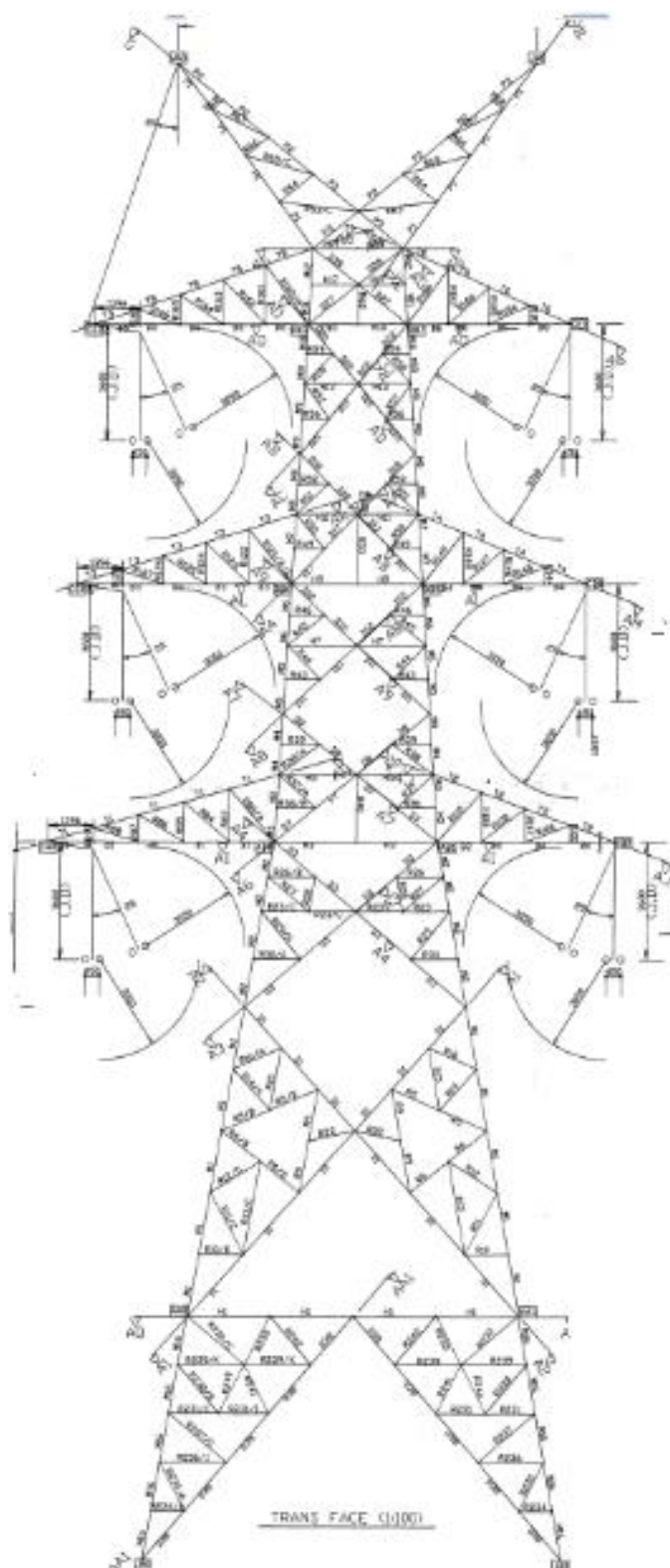
Remarks: In house Tested Towers



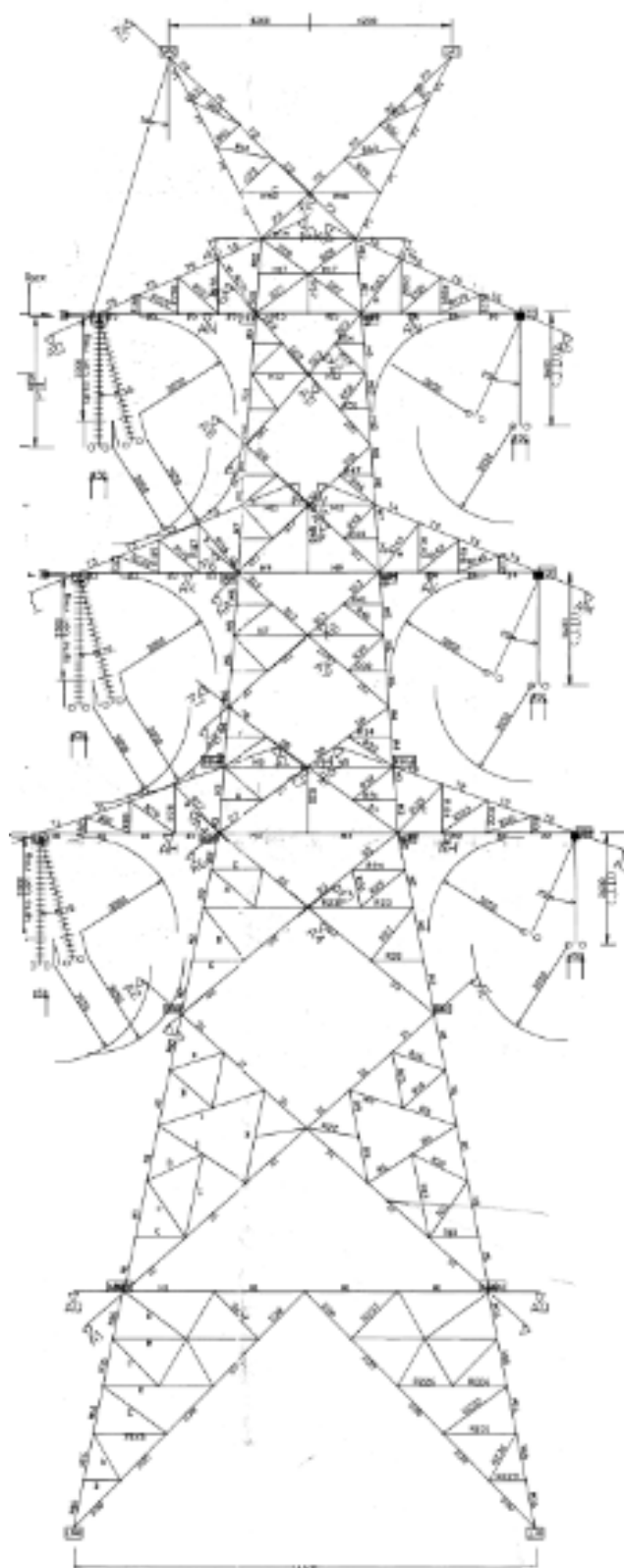
400 kV D/C WZ 5 TWIN MOOSE T.T 'DA'



400 kV D/C WZ 5 TWIN MOOSE T.T 'DB'



400 kV D/C WZ 5 TWIN MOOSE T.T 'DC'



400 kV D/C WZ 5 TWIN MOOSE T.T 'DD'

4.5.17 400 kV D/C (POLE) WZ 4 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

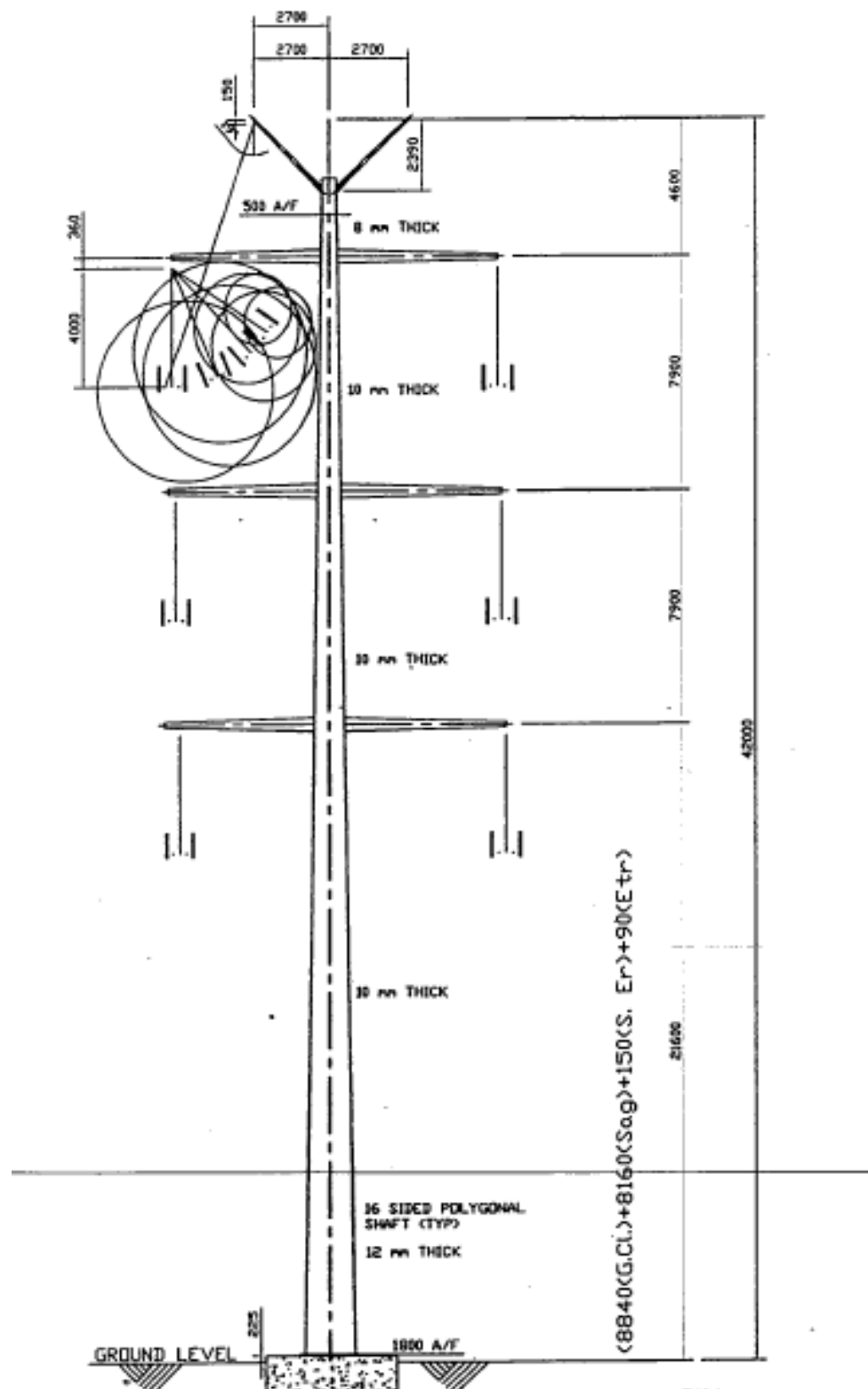
Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 300m

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	PA (POLE)	0-2

Sr. No.	Tower Type	Weight Span (m)		Diameter at the bottom Level (m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	PA (POLE)	450/150	270/75	1.8

Remarks: Contractor Designed and Tested Pole



400 kV D/C (POLE) WZ 4 TWIN MOOSE 'PA' (POLE)

4.5.18 400 kV D/C WZ 4 QUAD MOOSE (HILLY) Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: DOUBLE CIRCUIT
c) Conductor: ACSR QUAD MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <20 Deg.
f) Ground Clearance: 9.35m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 2500m

Tower Types

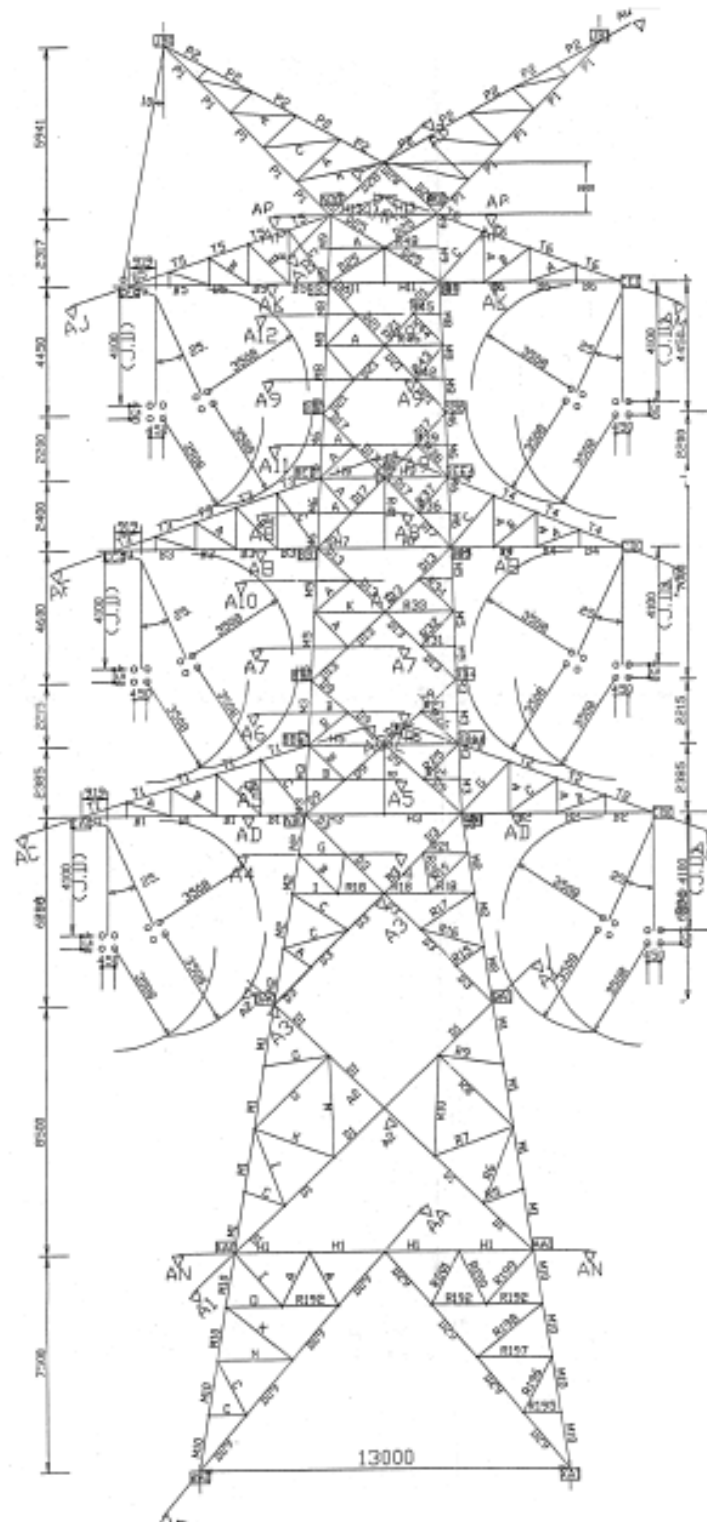
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DB	0-15
2	DC	15-30
3	DD	30-60

Tower Design Parameters

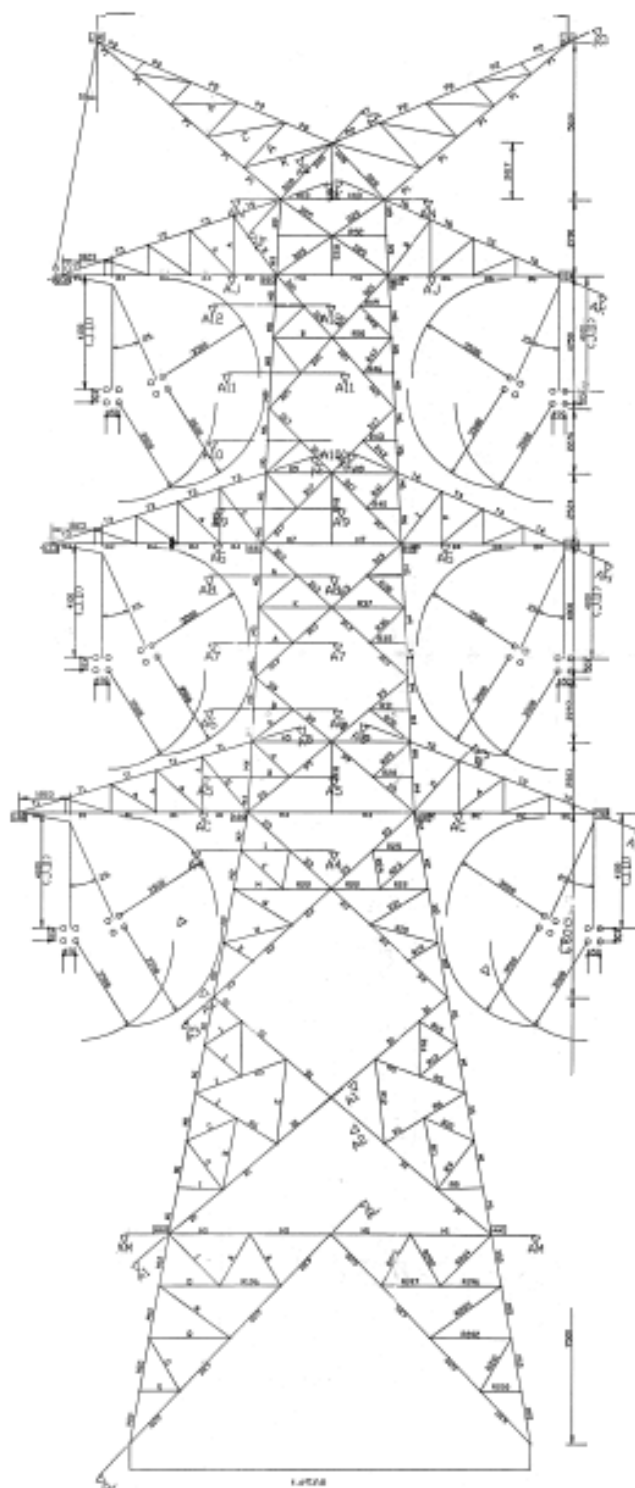
- a) IS: 802:1995
b) Wind zone: 4
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DB	1200/-1200	720/-720	13.00 x 13.00
2	DC	1200/-1200	720/-720	14.50 x 14.50
3	DD	1600/-1500	960/-900	15.50 x 15.50

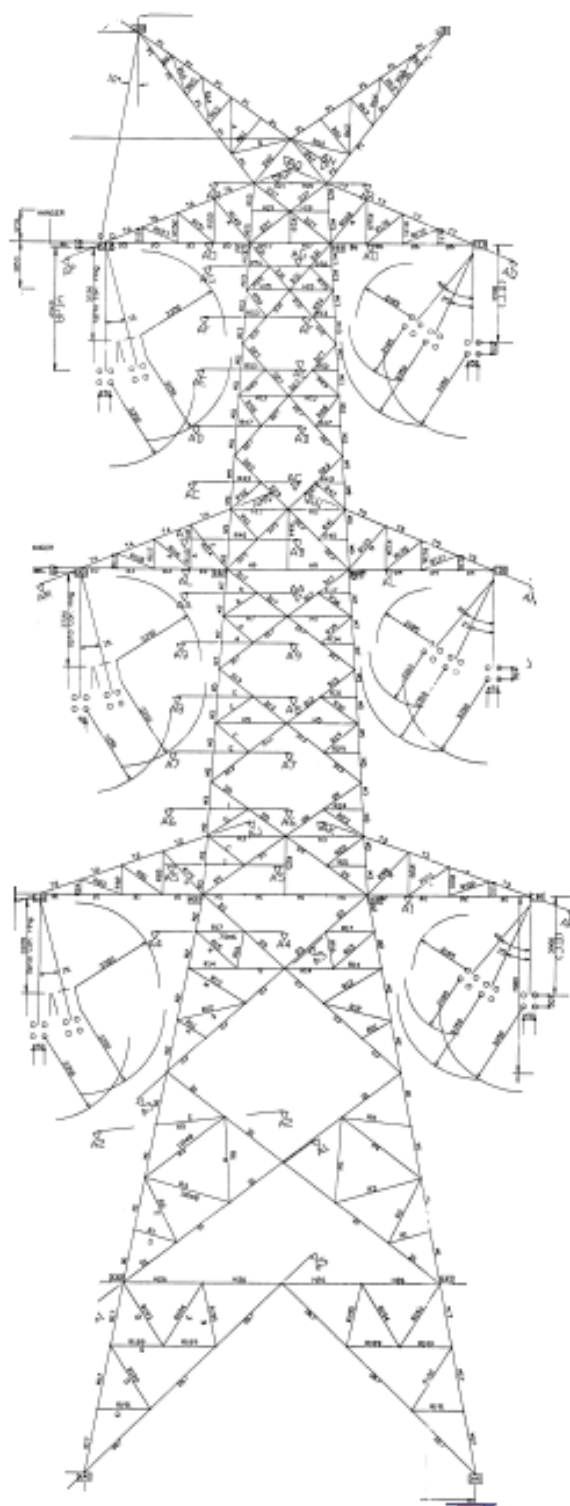
Remarks: In house Tested Towers



400 kV D/C WZ 4 QUAD MOOSE (HILLY) T.T 'DB'



400 kV D/C WZ 4 QUAD MOOSE (HILLY) T.T 'DC'



400 kV D/C WZ 4 QUAD MOOSE (HILLY) T.T 'DD'

4.5.19 400 kV D/C WZ 4 TWIN MOOSE (HILLY) Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
b) Configuration: DOUBLE CIRCUIT
c) Conductor: ACSR TWIN MOOSE
d) Earth wire: 7/3.66: 2No.
e) Shield Angle: <10 Deg.
f) Ground Clearance: 9.35m
g) Mid Span Clearance: 9.0m
h) Max Conductor Temp: 85 Deg C
i) Line Altitude: Upto 2400m

Tower Types

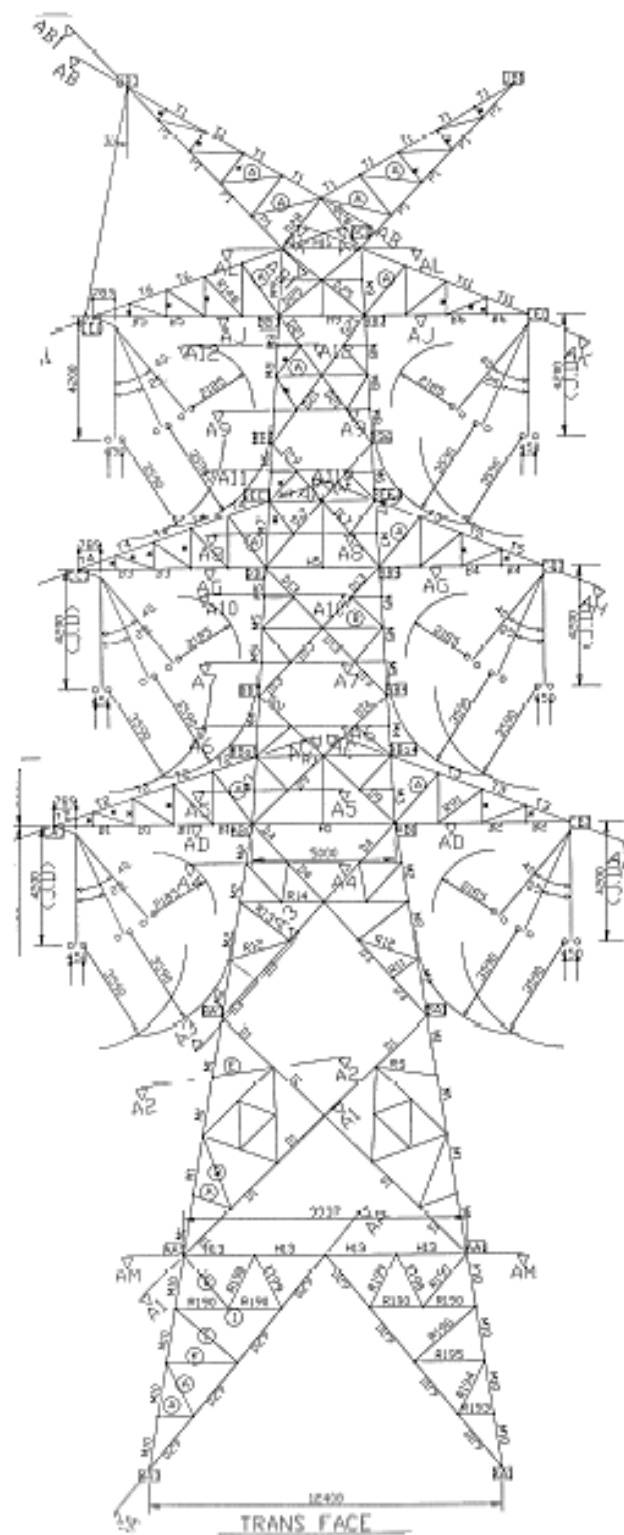
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DB	0-15
2	DC	15-30
3	DD	30-60

Tower Design Parameters

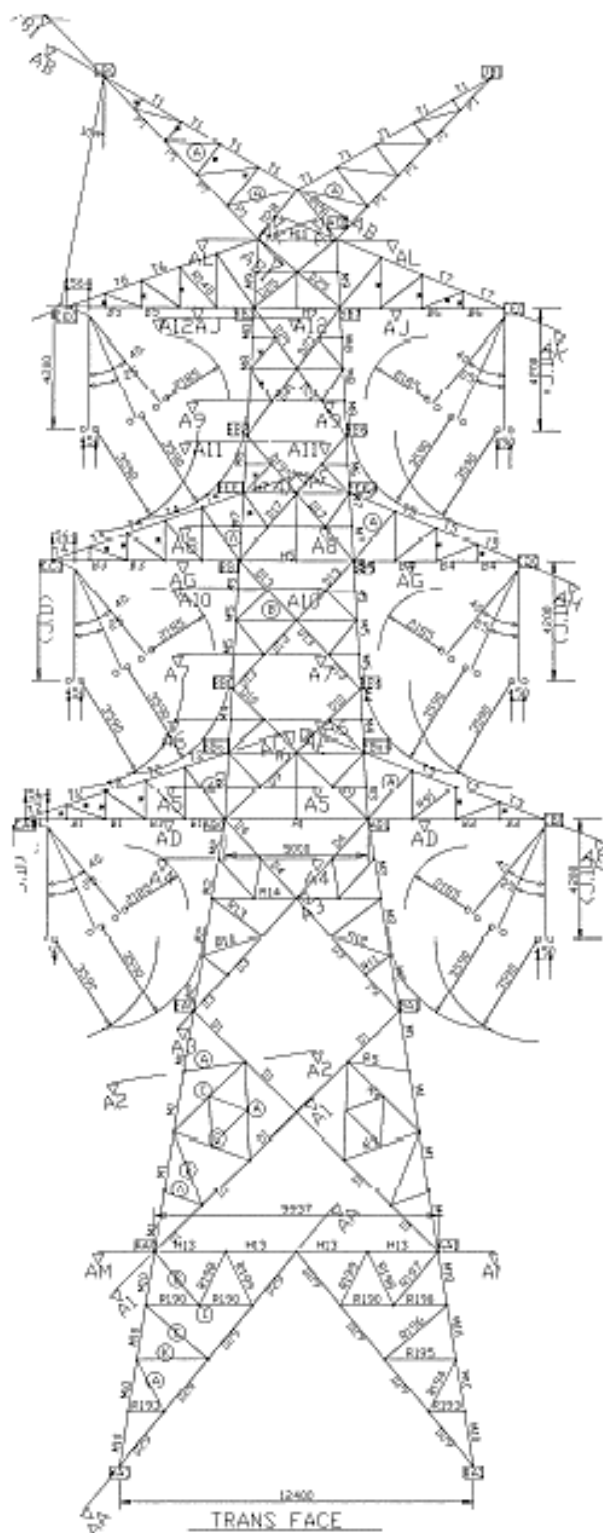
- a) IS: 802:1995
b) Wind zone: 4
c) Reliability Level: 1
d) Terrain Category: 2
e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/(Min)	BWC (Max)/(Min)	
1	DB	1000/-1000	600/-600	12.40 x 12.40
2	DC	1000/-1000	600/-600	12.40 x 12.40
3	DD	1600/-1500	960/-900	14.00 x 14.00

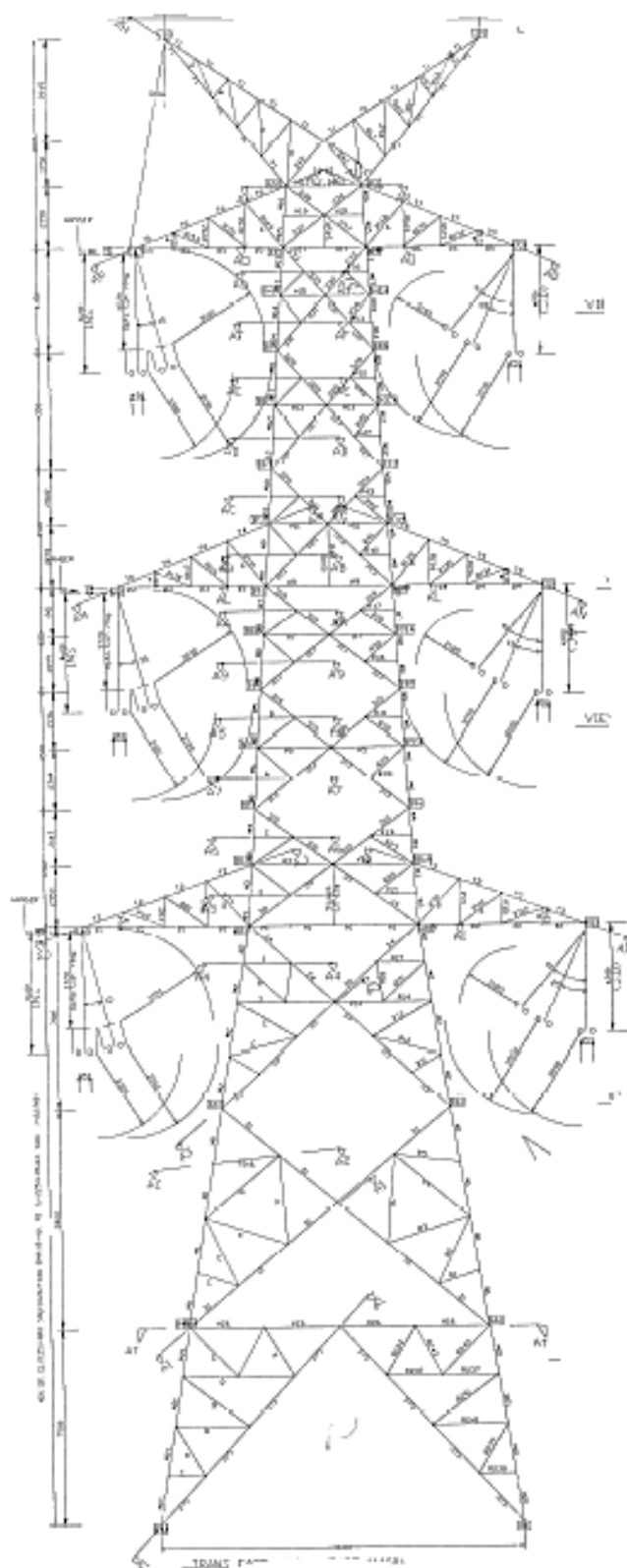
Remarks: In house Tested Towers.



400 kV D/C WZ 4 TWIN MOOSE (HILLY) T.T 'DB'



400 kV D/C WZ 4 TWIN MOOSE (HILLY) T.T 'DC'



400 kV D/C WZ 4 TWIN MOOSE (HILLY) T.T 'DD'

4.5.20 400 kV D/C WZ 4 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 75 Deg C
 i) Line Altitude: Upto 1000m

Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

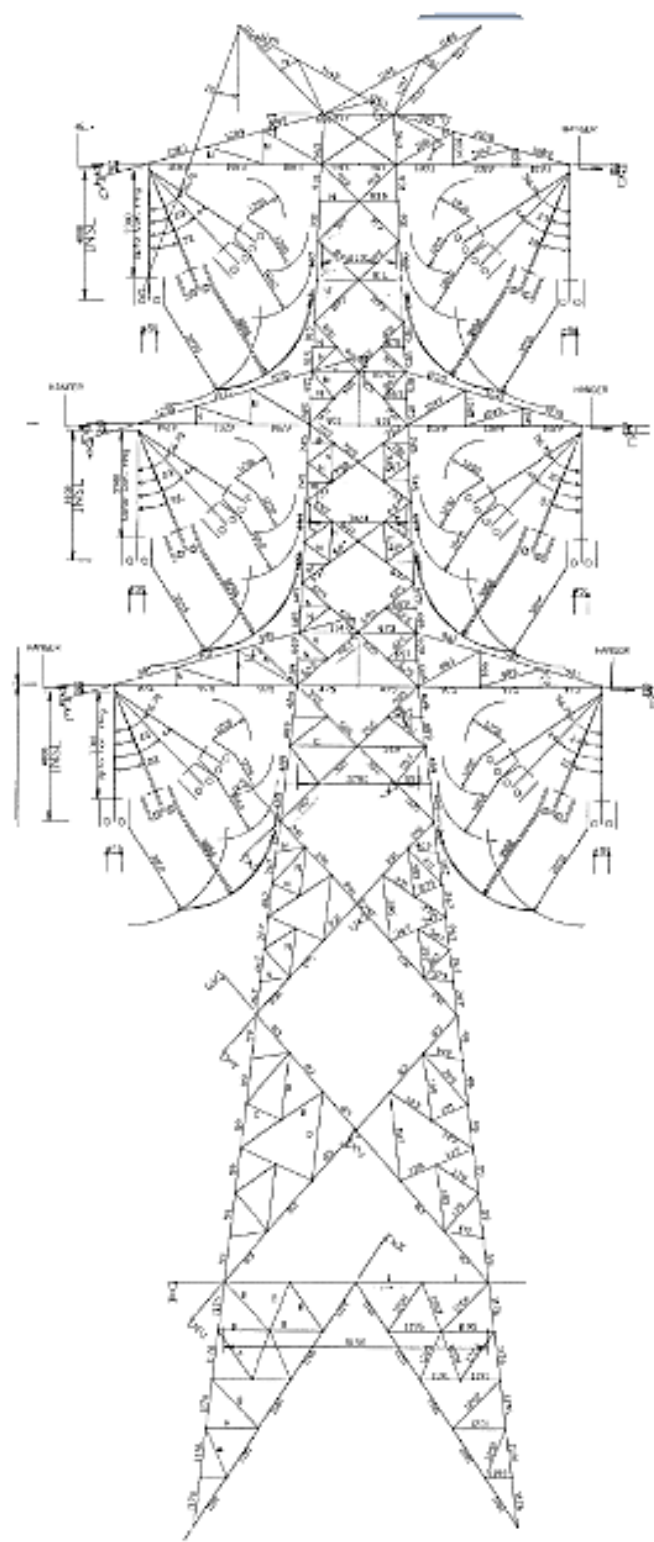
Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

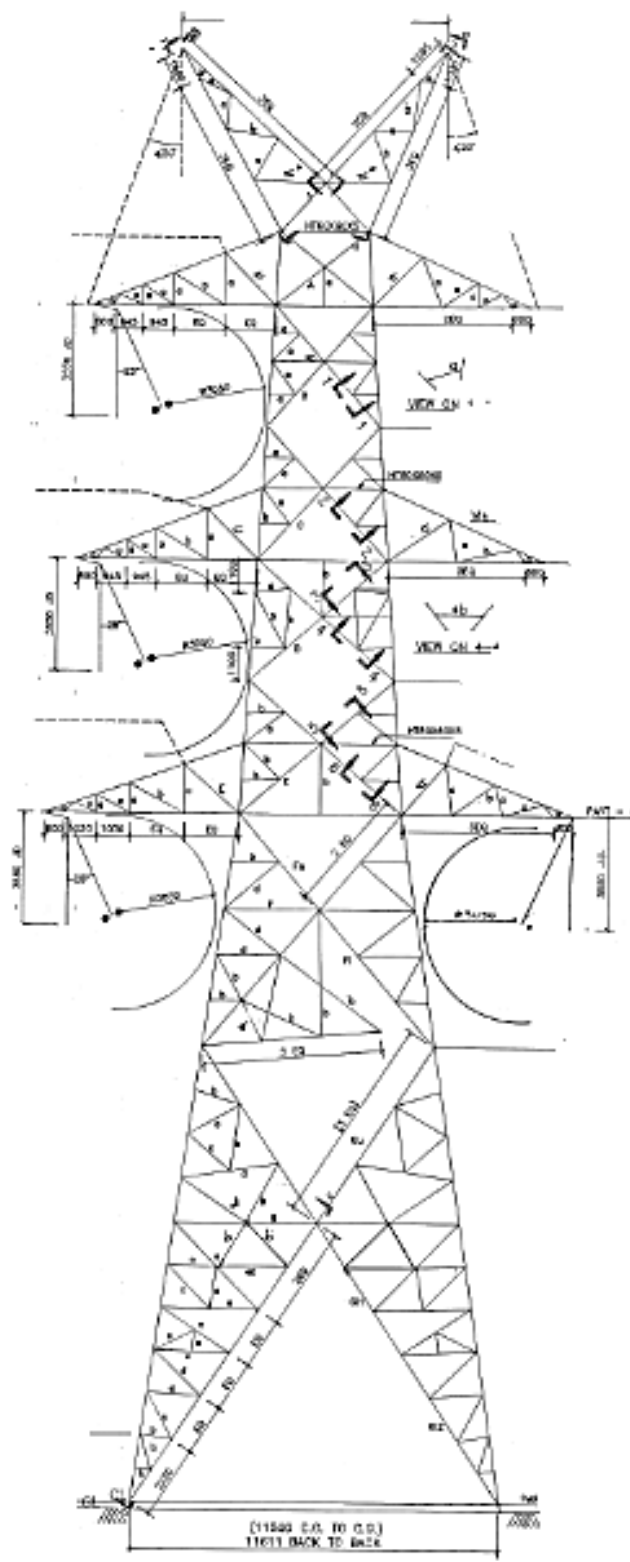
Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	#DA	600/200	360/100	10.00 x 10.00
2	*DB	600/0	360/-200	11.50 x 11.50
3	*DC	600/0	360/-200	11.50 x 11.50
4	*DD	600/0	360/-300	13.00 x 13.00

Remarks: # In house Tested Towers

* Contractor Designed and Tested Towers

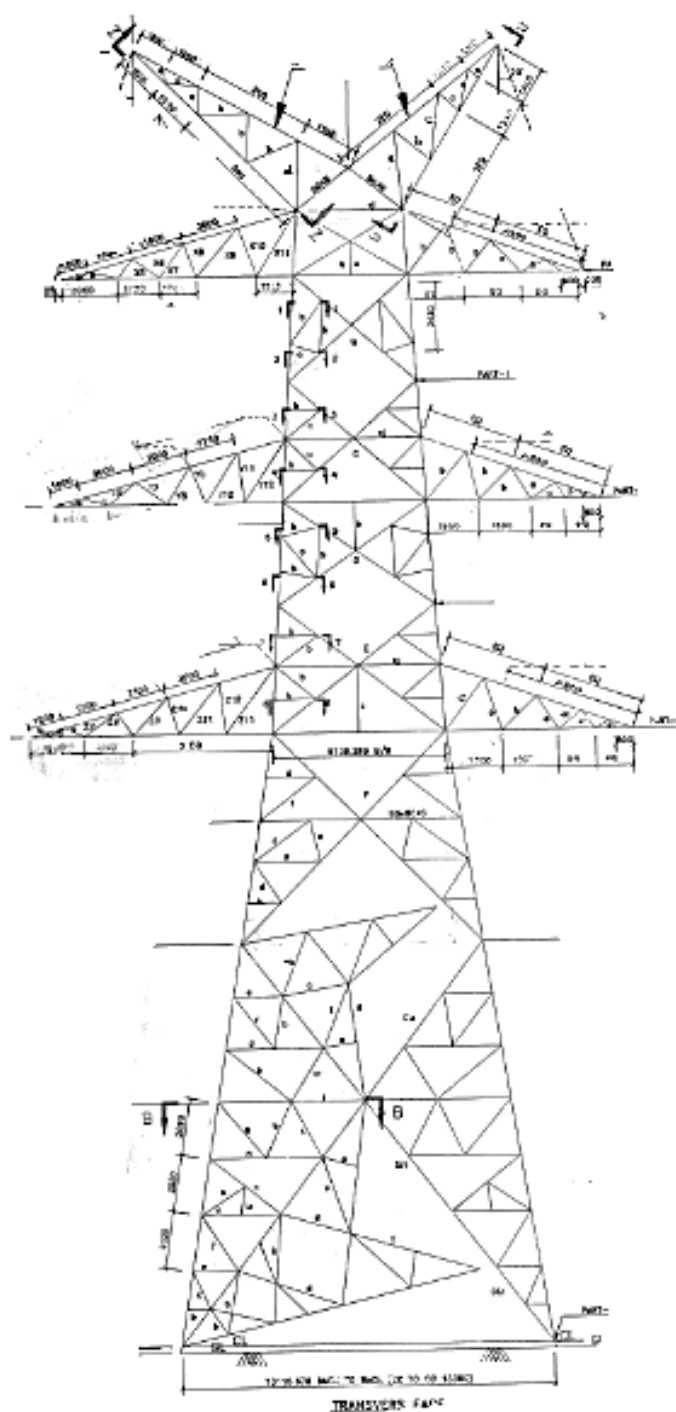


400 kV D/C WZ 4 TWIN MOOSE T.T. 'DA'



400 kV D/C WZ 4 TWIN MOOSE T.T. 'DB'





400 kV D/C WZ 4 TWIN MOOSE T.T. 'DD'

4.5.21 400 kV D/C WZ 4 QUAD MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR QUAD MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Design Parameters

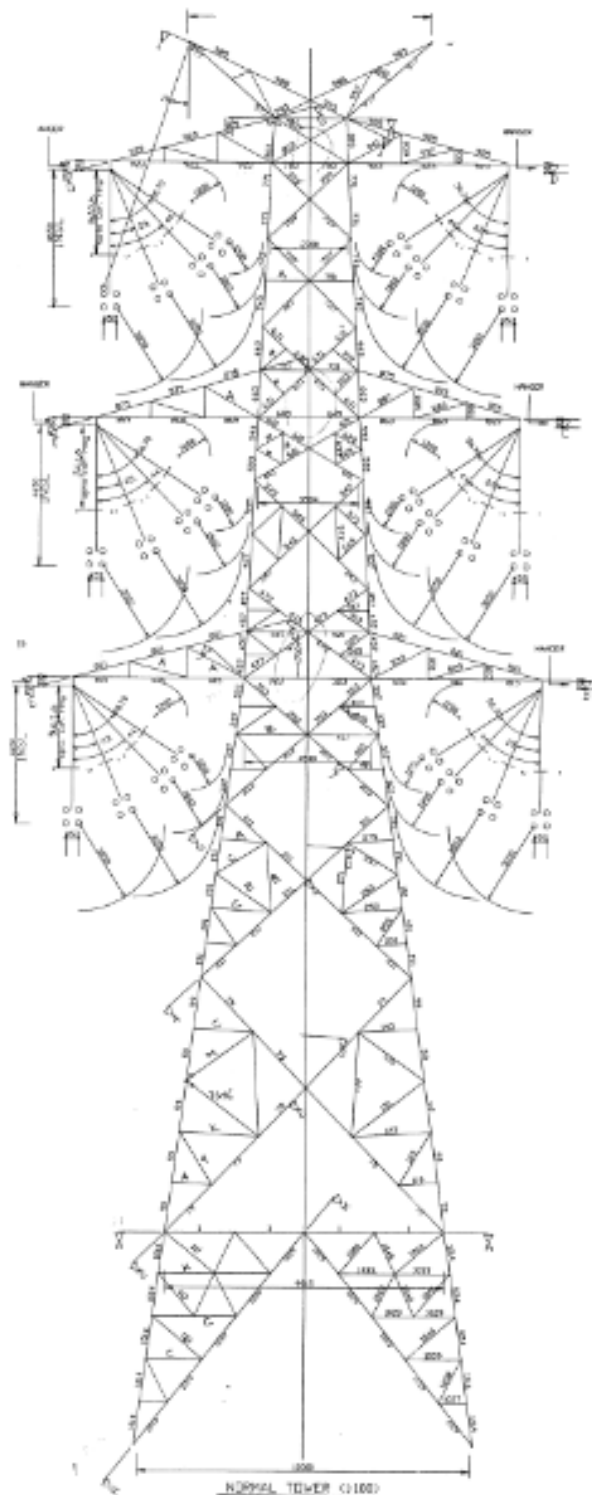
- a) IS: 802:1995
 b) Wind zone: 4
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Tower Types

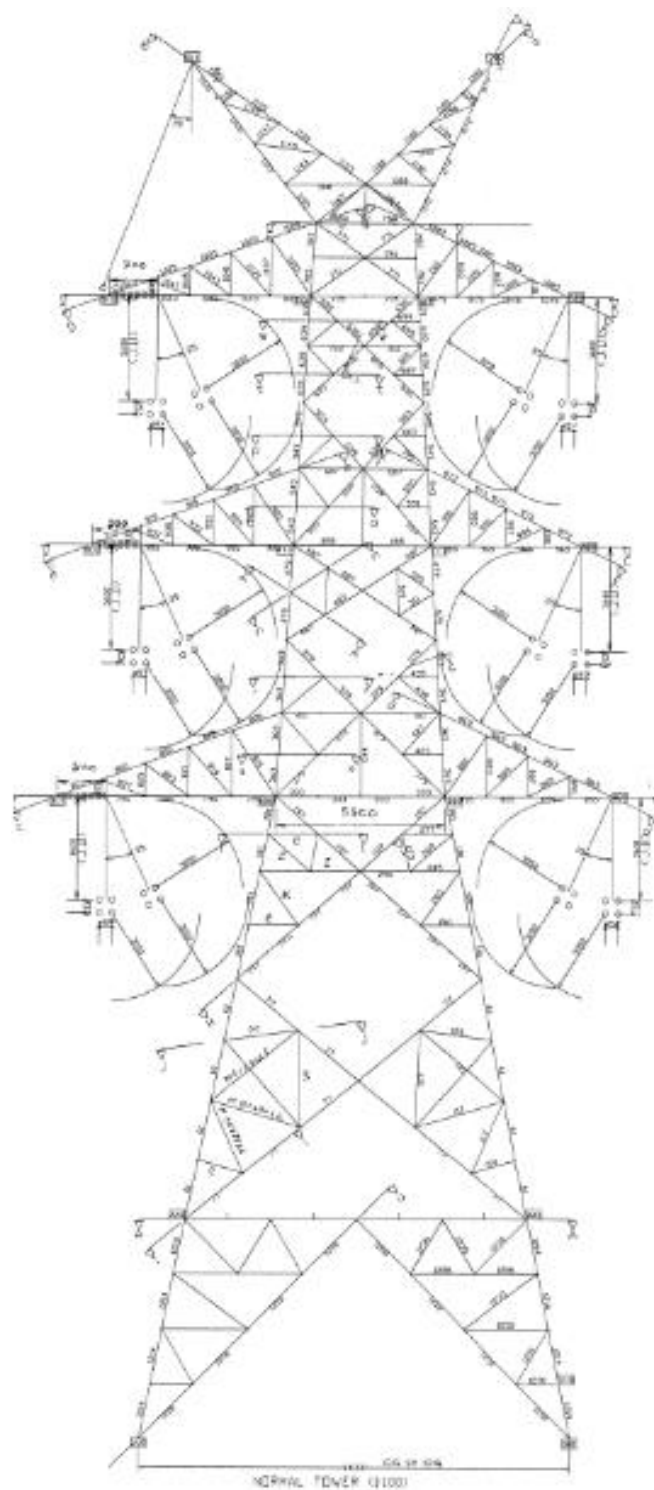
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	12.00 x 12.00
2	DB	600/0	360/-200	14.00 x 14.00
3	DC	600/0	360/-200	15.10 x 15.10
4	DD	600/0	360/-300	17.50 x 17.50

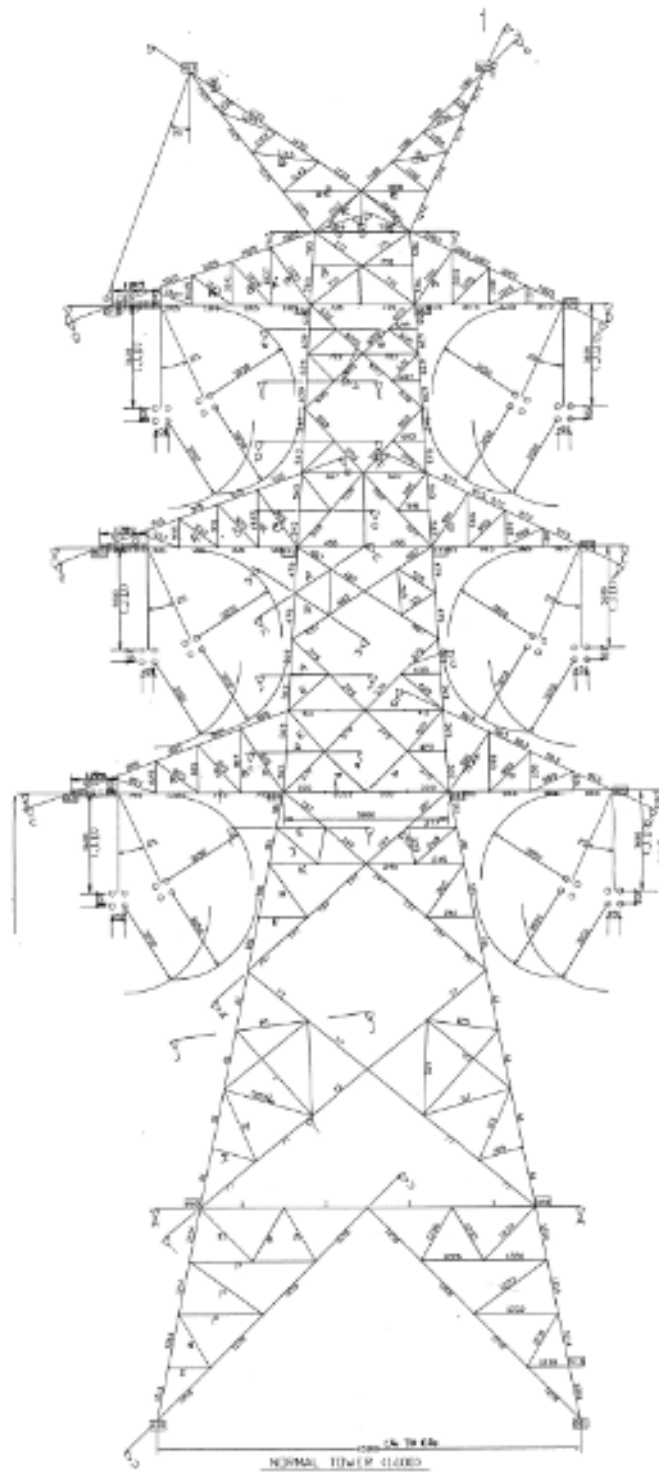
Remarks: In house Tested Towers



400 kV D/C WZ 4 QUAD MOOSE T.T 'DA'



400 kV D/C WZ 4 QUAD MOOSE T.T 'DB'



400 kV D/C WZ 4 QUAD MOOSE T.T 'DC'



4.5.22 400 kV D/C WZ 3 QUAD MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
- b) Configuration: DOUBLE CIRCUIT
- c) Conductor: ACSR QUAD MOOSE
- d) Earth wire: 7/3.66: 2No.
- e) Shield Angle: <20 Deg.
- f) Ground Clearance: 8.84m
- g) Mid Span Clearance: 9.0m
- h) Max Conductor Temp: 85 Deg C
- i) Line Altitude: Upto 1000m

Tower Design Parameters

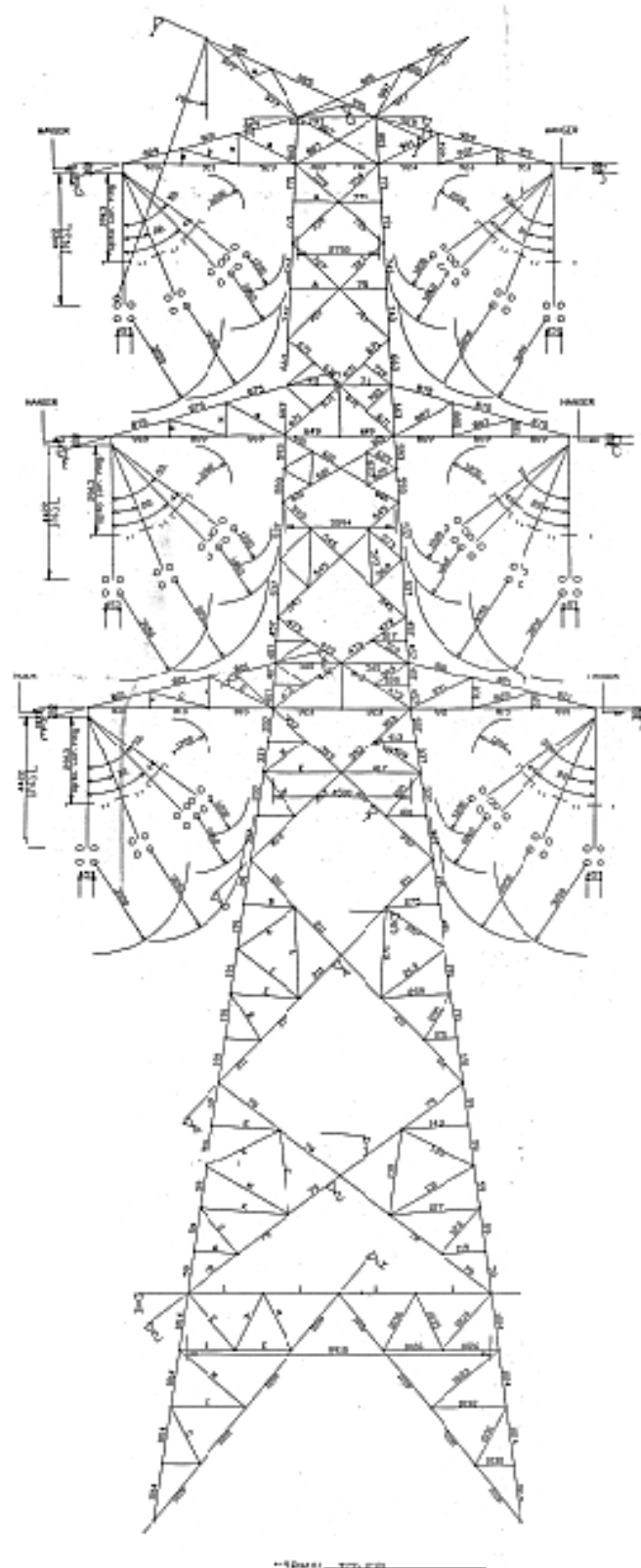
- a) IS 802:1995
- b) Wind zone: 3
- c) Reliability Level: 1
- d) Terrain Category: 2
- e) Wind Span: 400m

Tower Types

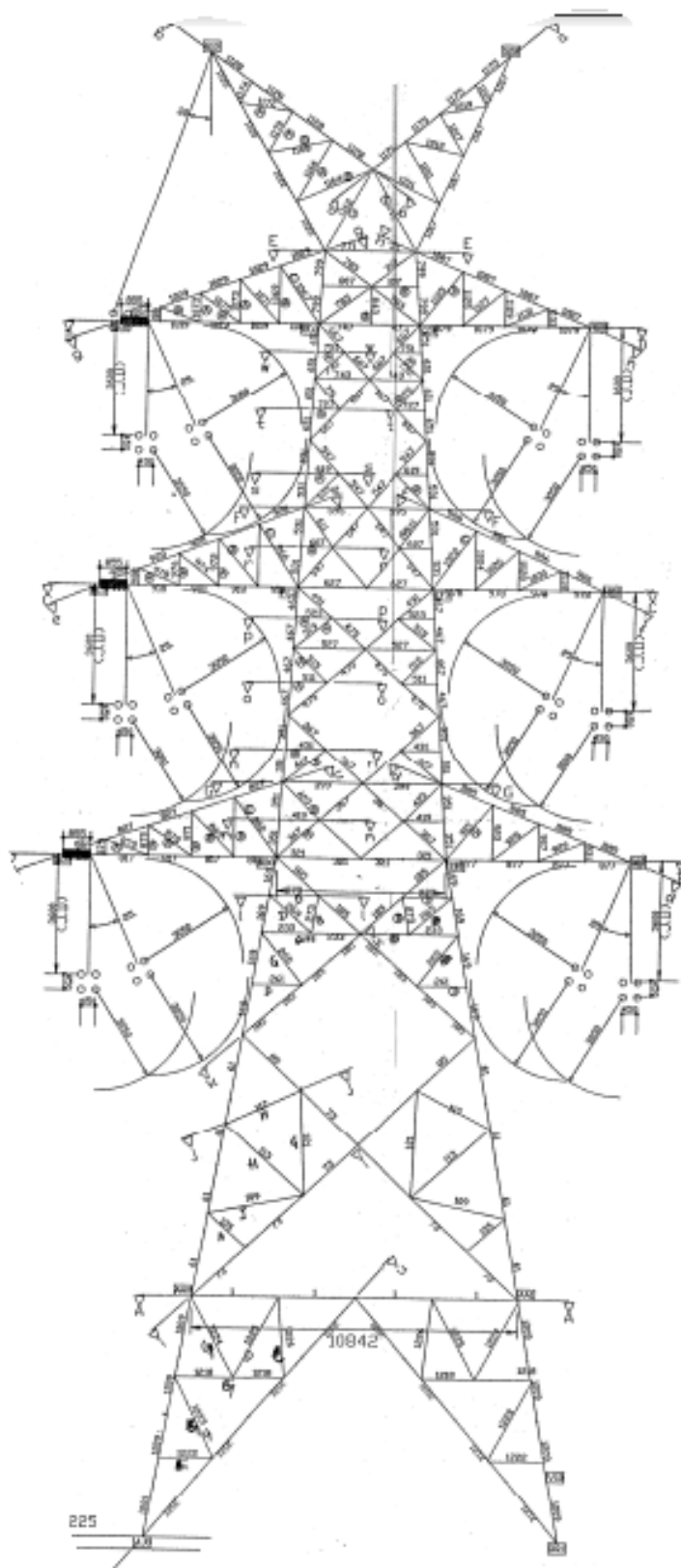
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	12.00 x 12.00
2	DB	600/0	360/-200	13.60 x 13.60
3	DC	600/0	360/-200	14.00 x 14.00
4	DD	600/0	360/-300	17.00 x 17.00

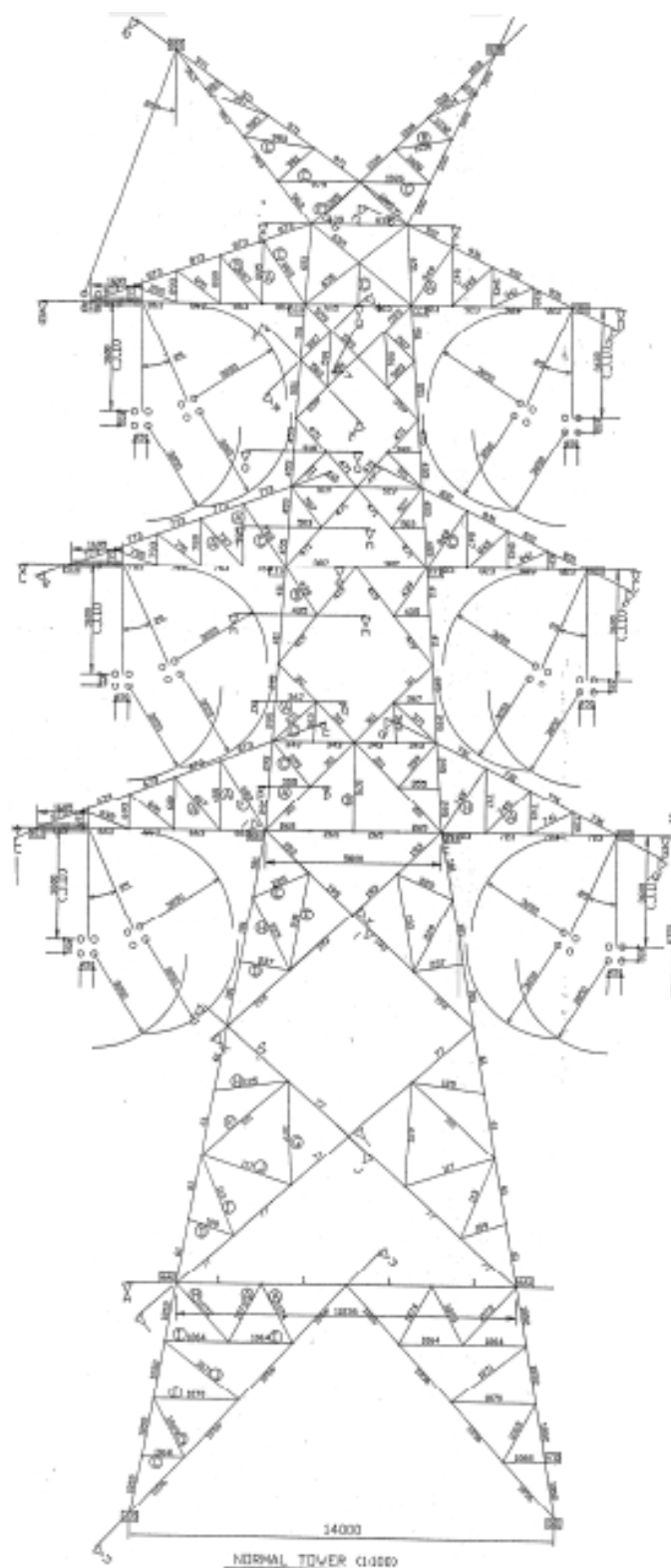
Remarks: In house Tested Towers



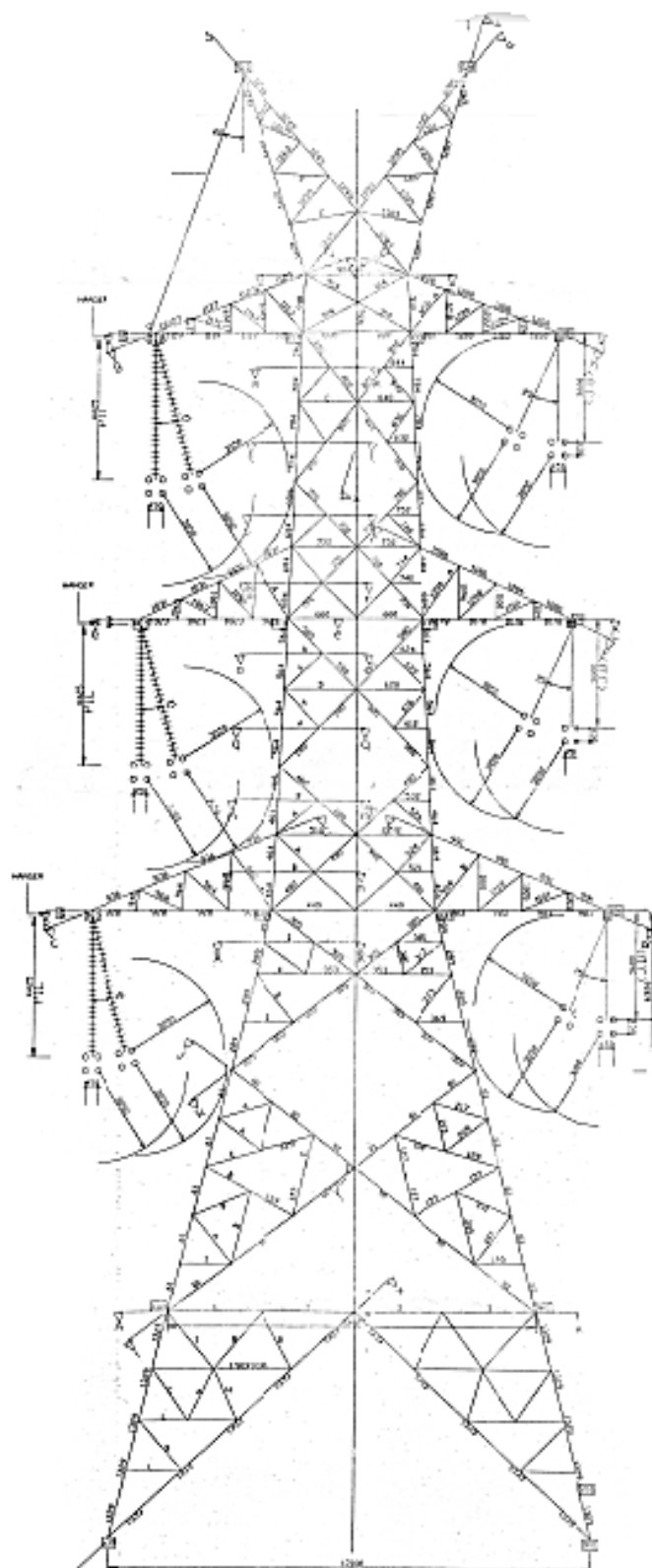
400 kV D/C WZ 3 QUAD MOOSE T.T 'DA'



400 kV D/C WZ 3 QUAD MOOSE T.T 'DB'



400 kV D/C WZ 3 QUAD MOOSE T.T 'DC'



400 kV D/C WZ 3 QUAD MOOSE T.T 'DD'

4.5.23 400 kV D/C WZ 3 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 75 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

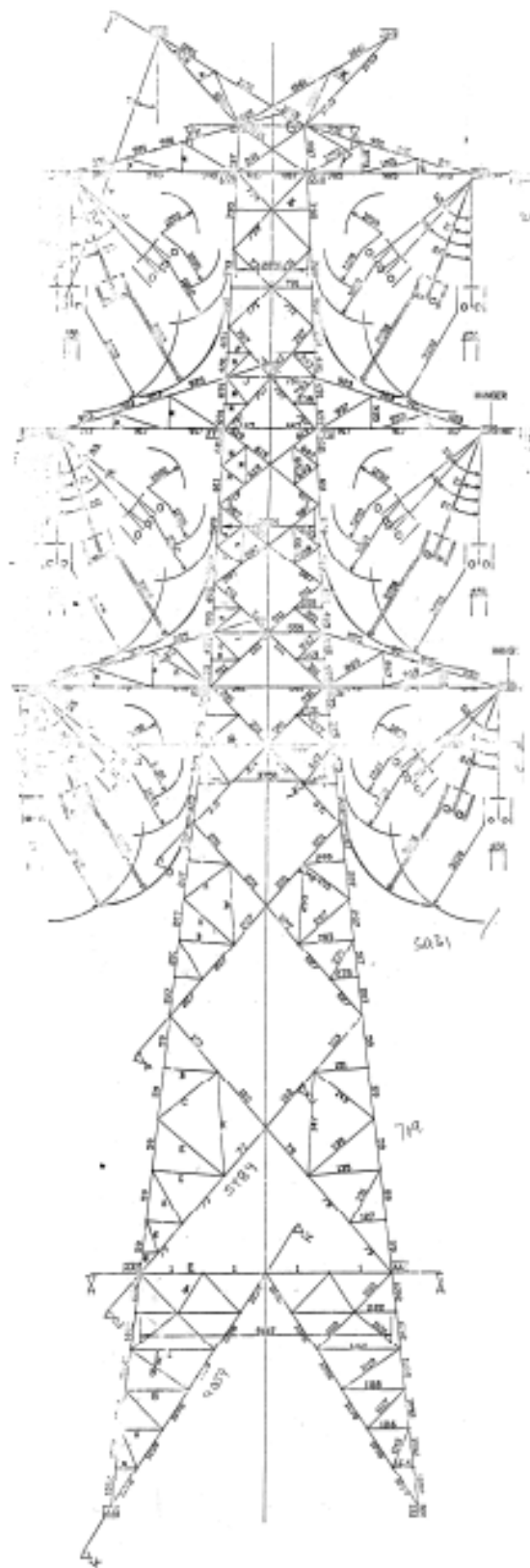
Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 3
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

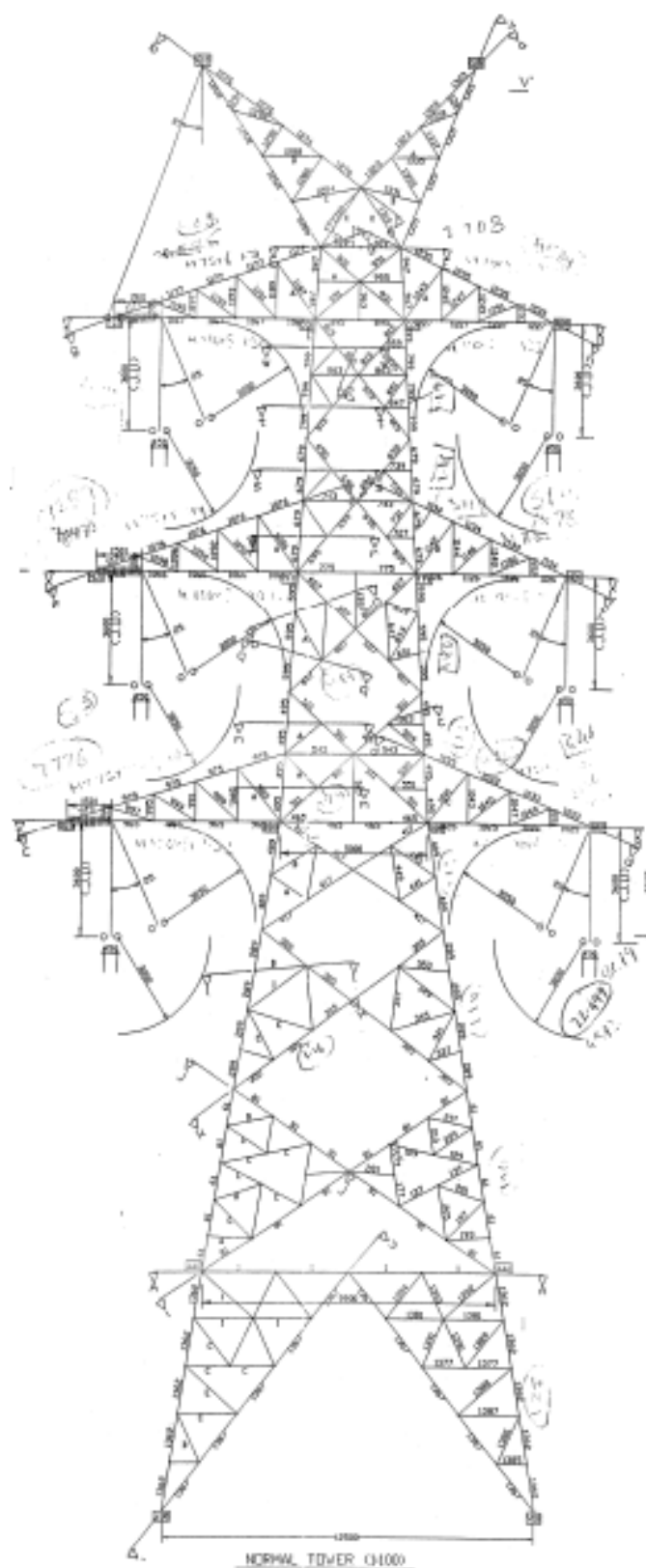
Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	10.00 x 10.00
2	DB	600/0	360/-200	12.00 x 12.00
3	DC	600/0	360/-200	12.50 x 12.50
4	DD	600/0	360/-300	13.20 x 13.20

Remarks: In house Tested Towers

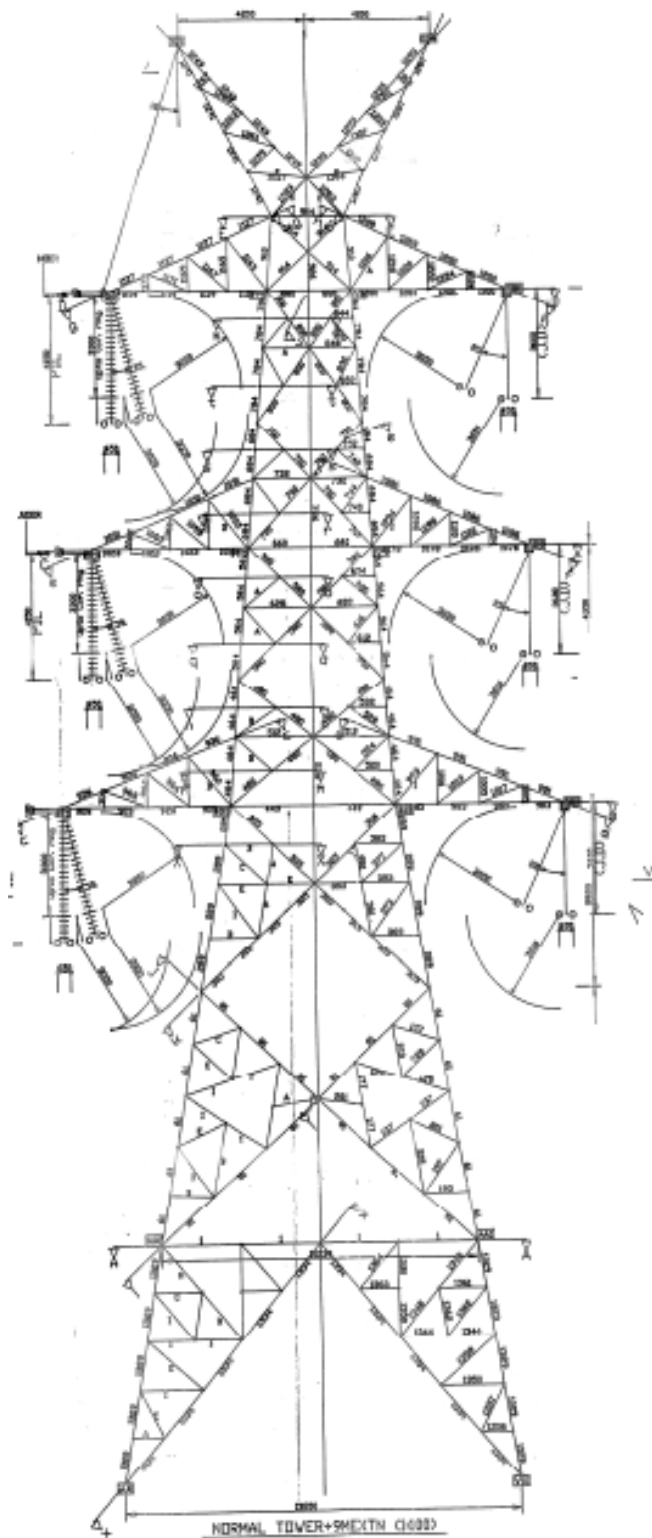


400 kV D/C WZ 3 TWIN MOOSE T.T 'DA'





400 kV D/C WZ 3 TWIN MOOSE T.T 'DC'



400 kV D/C WZ 3 TWIN MOOSE T.T 'DD'

4.5.24 400 kV D/C WZ 2 TWIN MOOSE (HILLY) Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 9.178m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 2500m

Tower Design Parameters

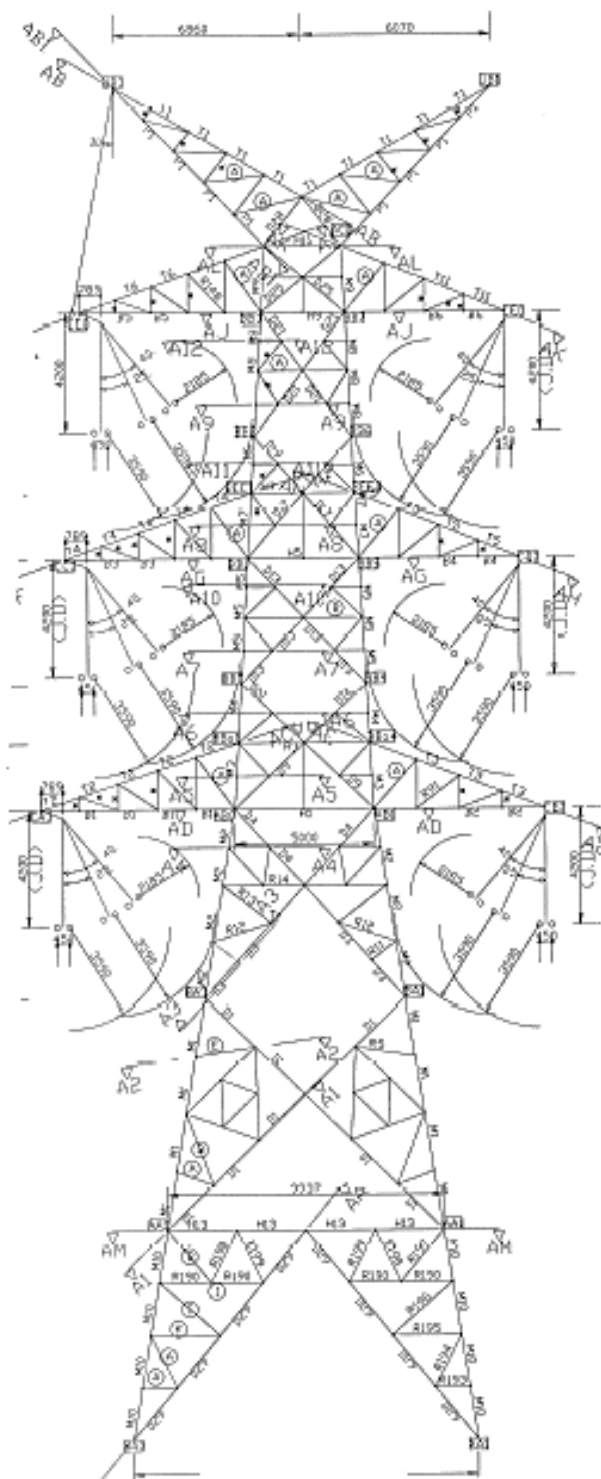
- a) IS: 802:1995
 b) Wind zone: 2
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Tower Types

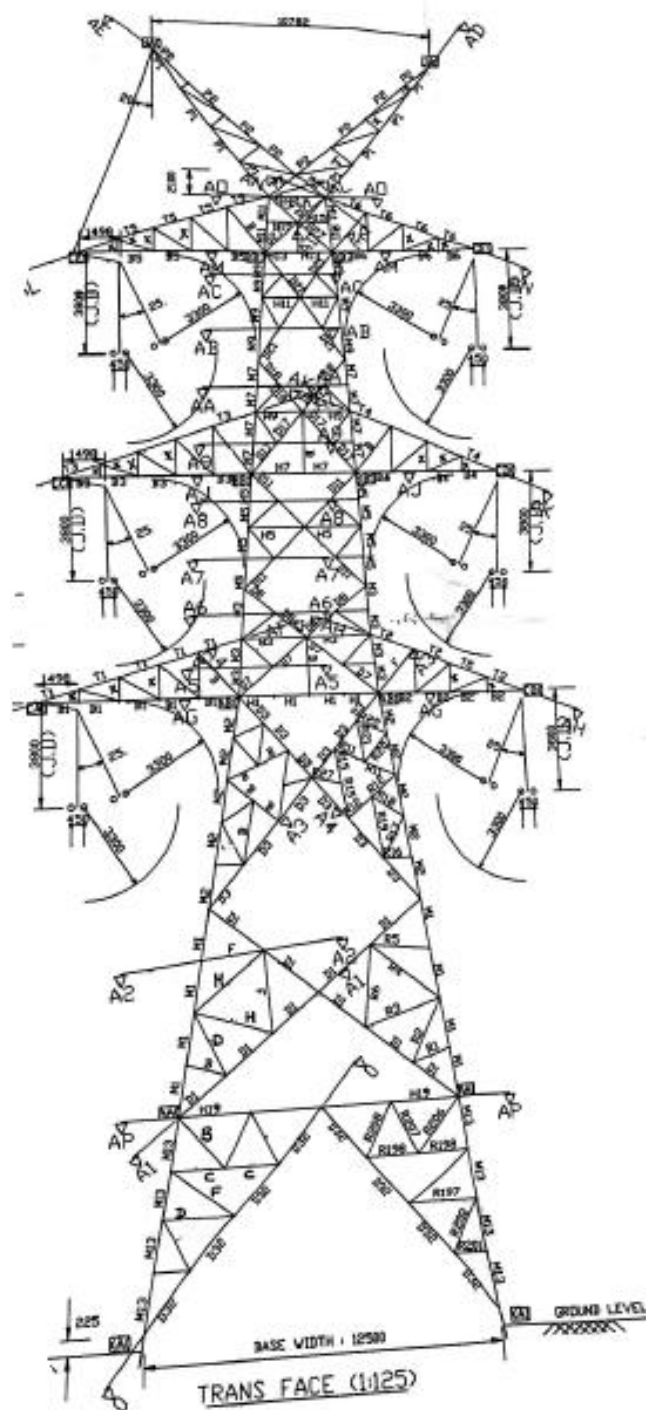
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DB	0-15
2	DC	15-30

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DB	1000/-1000	600/-600	12.00 x 12.00
2	DC	1000/-1000	600/-600	12.50 x 12.50

Remarks: In house Tested Towers



400 kV D/C WZ 2 TWIN MOOSE (HILLY) T.T 'DB'



400 kV D/C WZ 2 TWIN MOOSE (HILLY) T.T 'DC'

4.5.25 400 kV D/C WZ 2 QUAD MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR QUAD MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 85 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

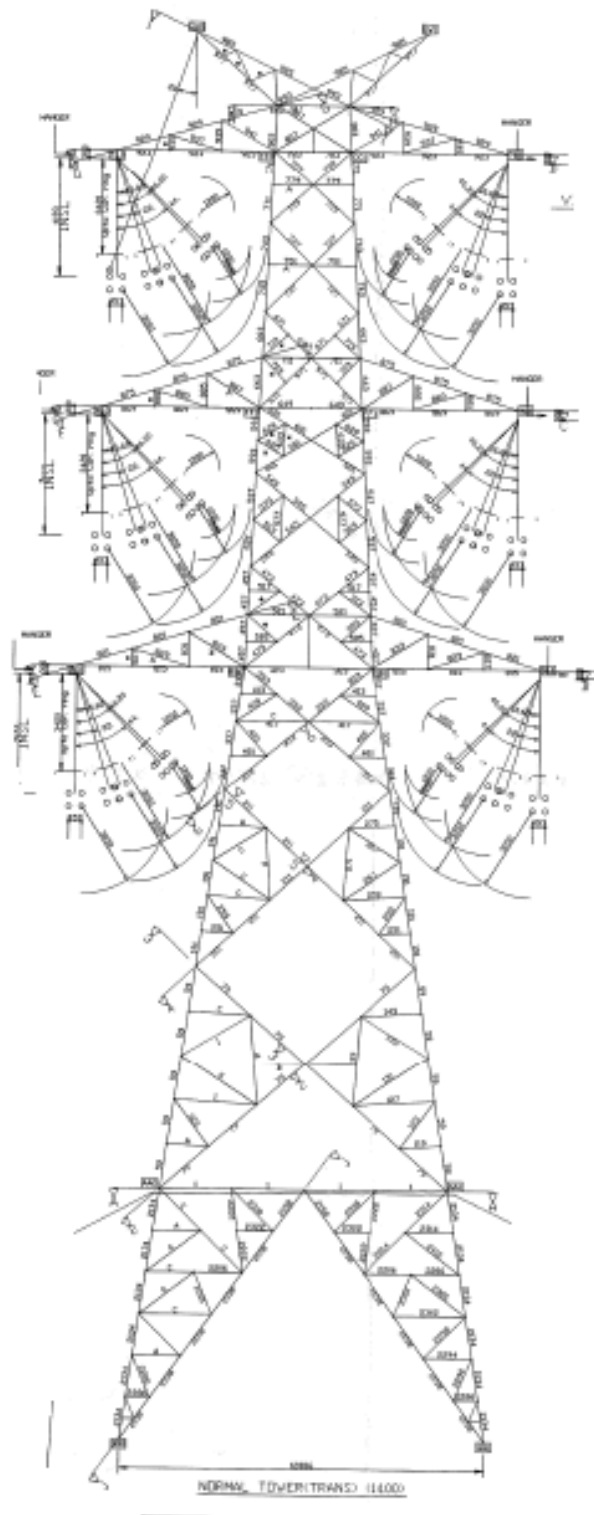
Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

Tower Design Parameters

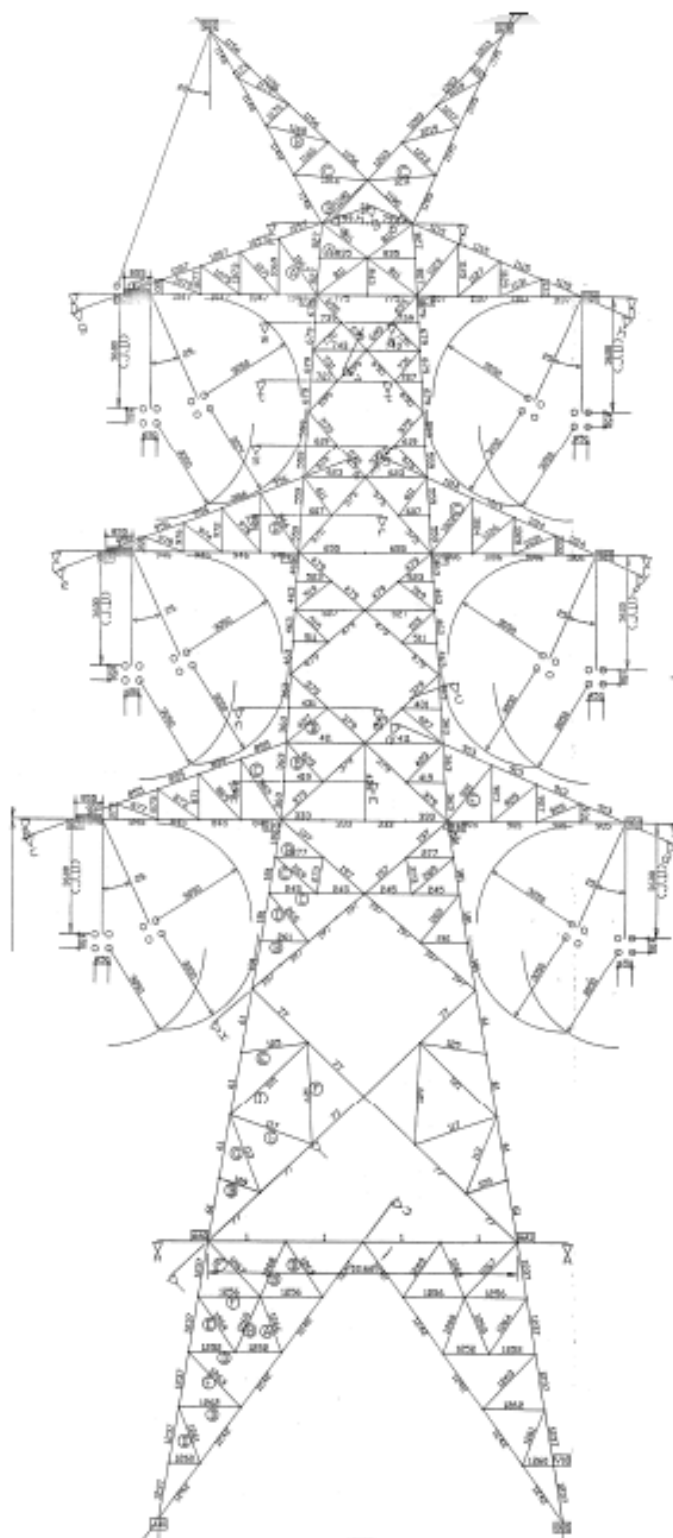
- a) IS: 802:1995
 b) Wind zone: 2
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	12.886 x 12.886
2	DB	600/0	360/-200	13.355 x 13.355
3	DC	600/0	360/-200	14.232 x 14.232
4	DD	600/0	360/-300	17.254 x 17.254

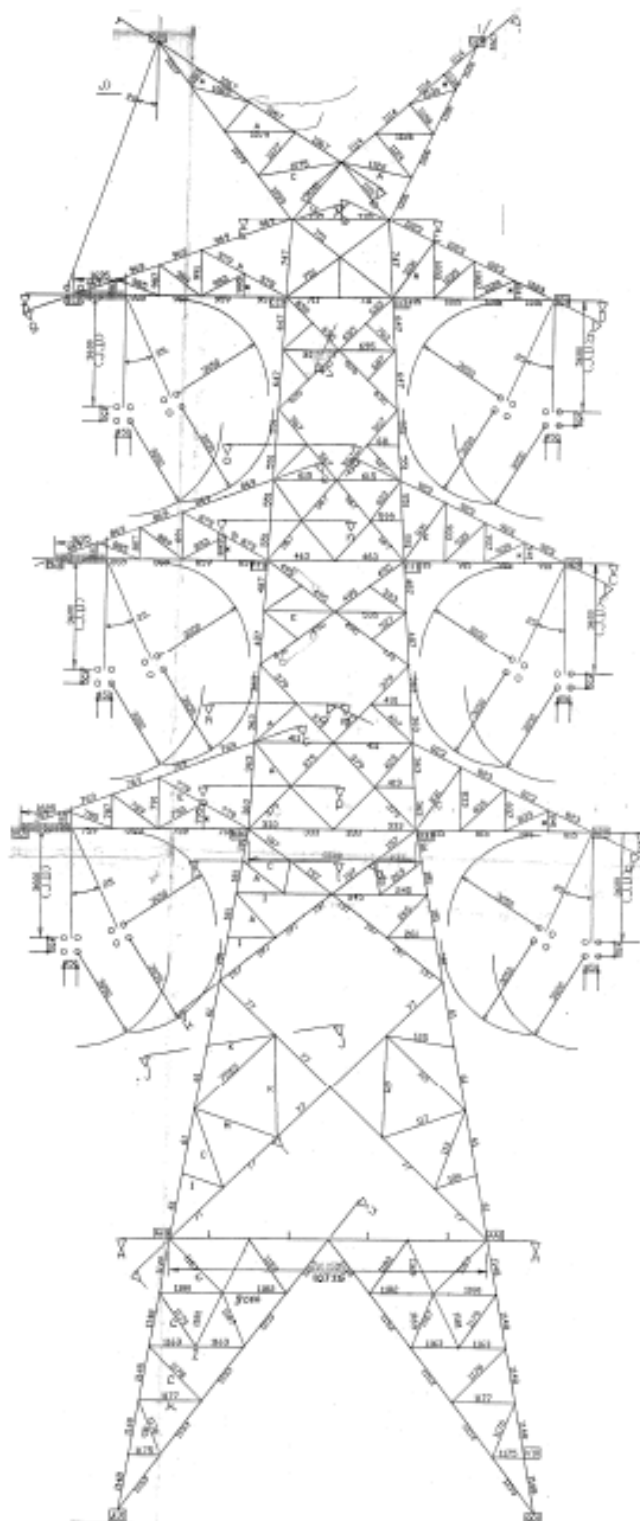
Remarks: In house Tested Towers



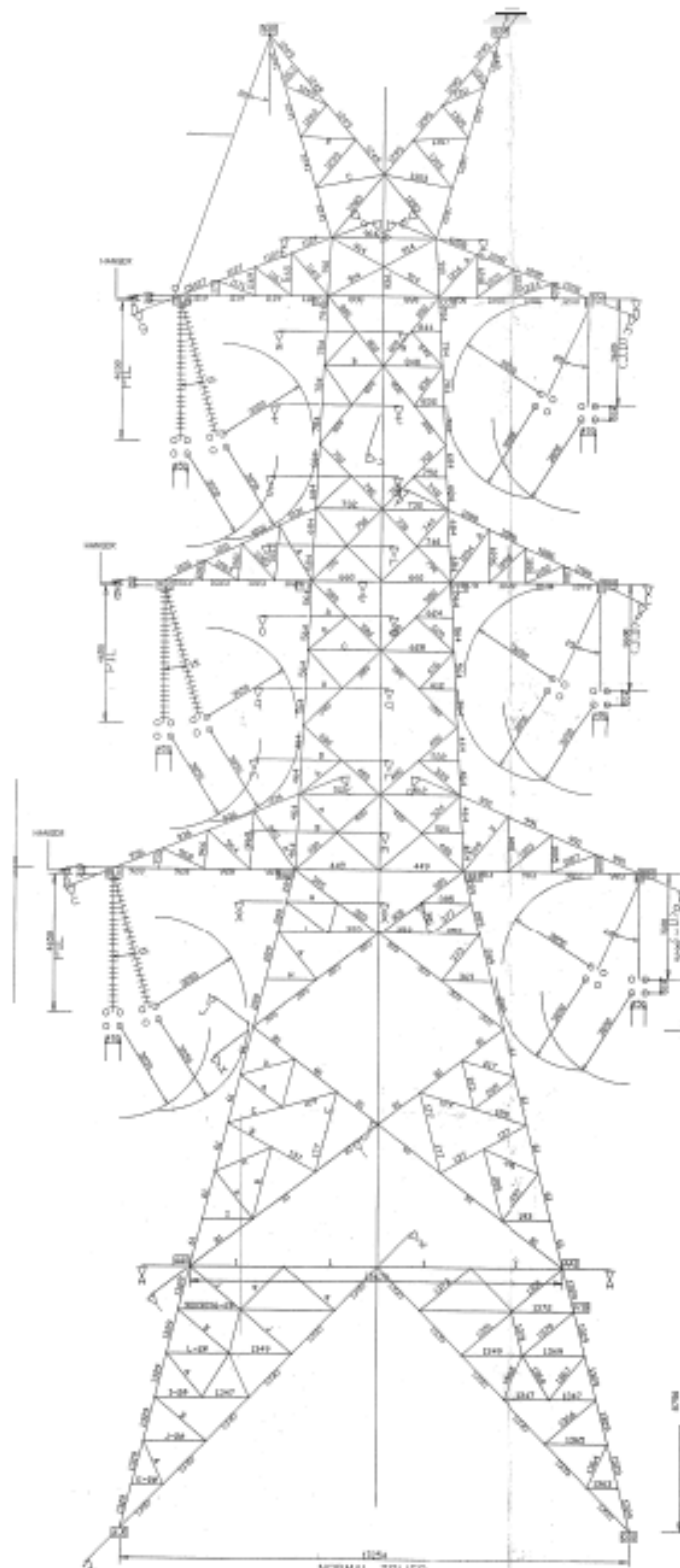
400 kV D/C WZ 2 QUAD MOOSE T.T 'DA'



400 kV D/C WZ 2 QUAD MOOSE T.T 'DB'



400 kV D/C WZ 2 QUAD MOOSE T.T 'DC'



400 kV D/C WZ 2 QUAD MOOSE T.T 'DD'

4.5.26 400 kV D/C WZ 2 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 75 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2
2	DB	0-15
3	DC	15-30
4	DD	30-60

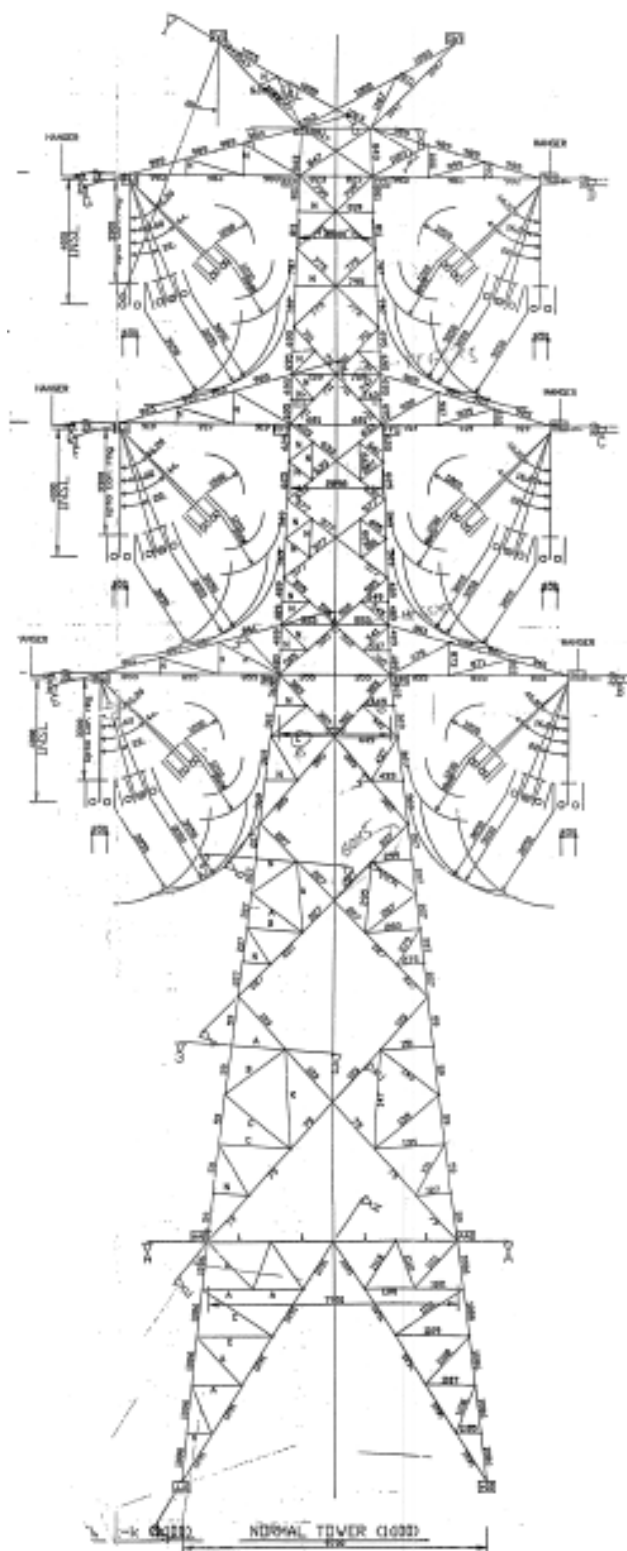
Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 2
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	#DA	600/200	360/100	9.70 x 9.70
2	*DB	600/0	360/-200	14.60 x 14.60
3	*DC	600/0	360/-200	14.60 x 14.60
4	*DD	600/0	360/-300	13.70 x 13.70

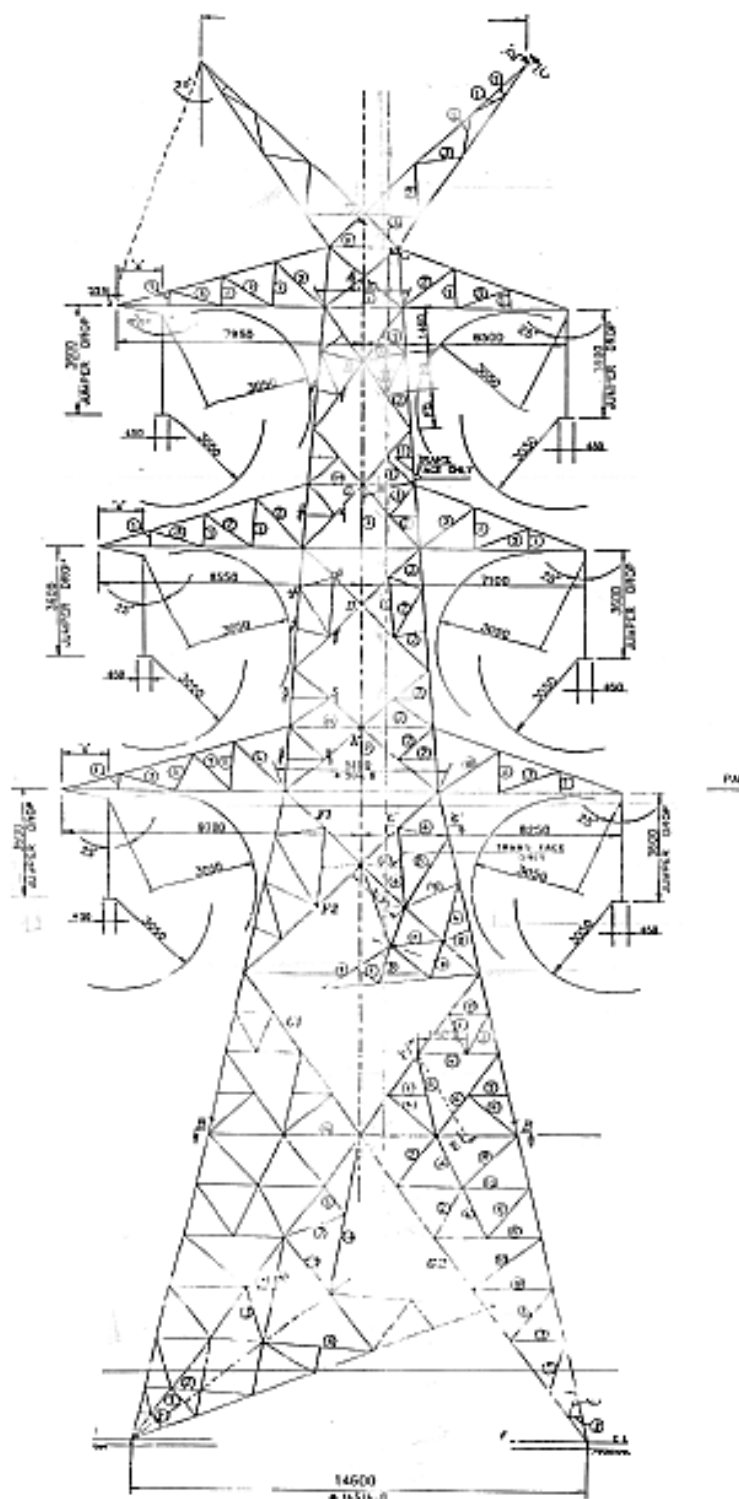
Remarks: # In house Tested Towers

* Contractor Designed and Tested Towers



400 kV D/C WZ 2 TWIN MOOSE T.T 'DA'





400 kV D/C WZ 2 TWIN MOOSE T.T 'DC'



4.5.27 400 kV D/C WZ 1 TWIN MOOSE Transmission Line (PGCIL)

Line Parameters

- a) Voltage Level: 400 kV
 b) Configuration: DOUBLE CIRCUIT
 c) Conductor: ACSR TWIN MOOSE
 d) Earth wire: 7/3.66: 2No.
 e) Shield Angle: <20 Deg.
 f) Ground Clearance: 8.84m
 g) Mid Span Clearance: 9.0m
 h) Max Conductor Temp: 75 Deg C
 i) Line Altitude: Upto 1000m

Tower Types

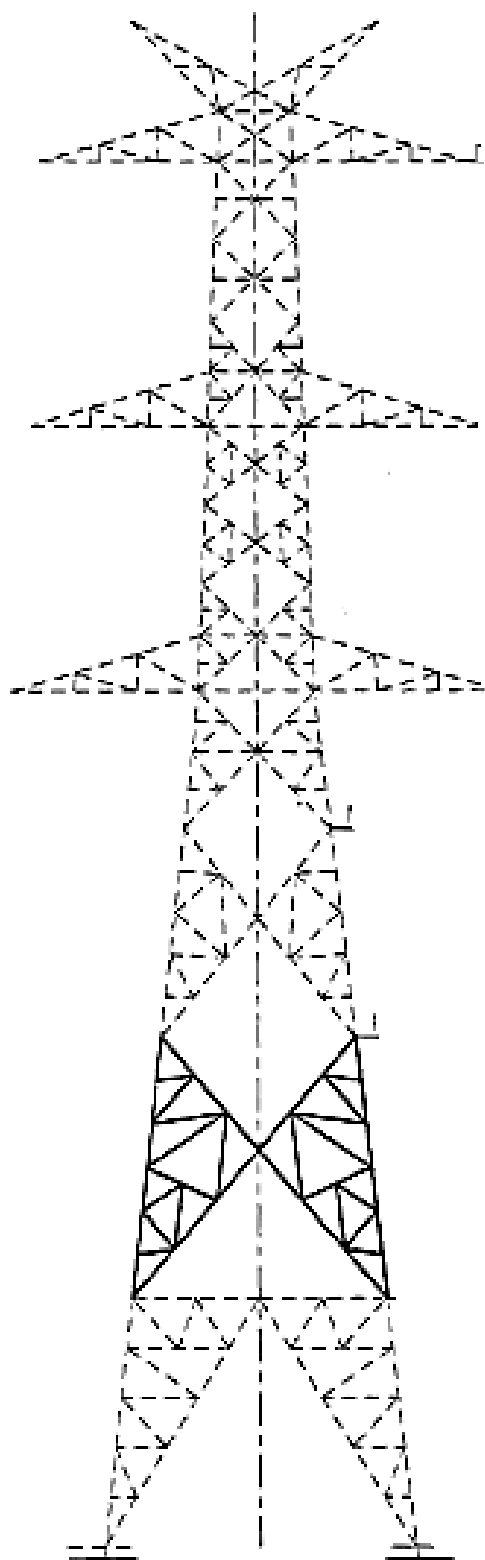
Tower Design Parameters

- a) IS: 802:1995
 b) Wind zone: 1
 c) Reliability Level: 1
 d) Terrain Category: 2
 e) Wind Span: 400m

Sr. No.	Tower Type	Range of Angle of Deviation (deg.)
1	DA	0-2

Sr. No.	Tower Type	Weight Span (m)		Base Width at Normal Tower Level(m)
		NC (Max)/ (Min)	BWC (Max)/ (Min)	
1	DA	600/200	360/100	9.40 x 9.40

Remarks: In house Tested Towers



400 kV D/C WZ 1 TWIN MOOSE T.T. 'DA'



220 kV SRINAGAR LEH TRANSMISSION LINE



Central Electricity Authority

Central Electricity Authority (CEA) is a statutory organization, originally constituted under Section 3 (1) of the replaced Electricity (Supply) Act, 1948, since substituted by section 70 of the Electricity Act, 2003. It was established as a part-time body in 1951 and made a full-time body in 1975. The functions and duties of CEA are delineated under Section 73 of the Electricity Act, 2003. The 'Office of CEA' is an Attached Office of the Ministry of Power. CEA is an apex technical body facilitating overall development of the power sector in the country with the vision to provide quality Power for all at an affordable price. CEA advises Central Government on the matters related to National Electricity Policy, formulates short-term and perspective plans for development of electricity systems, specify various technical standards for construction of the electric plans & electric lines, grid connectivity, safety requirement for construction and O &M of electrical plants & electric lines, installation & operation of electricity meters, promotes & assists in timely completion of schemes & projects, promotes measure for upgrading skills of human resource in the power sector, collects & utilization of industry, promotes research in matters affecting power sector, and advise the central Government, State Governments, Electricity Regulatory Commissions & licensees on all such matter of power Sector on which its advise is sought.

CENTRAL ELECTRICITY AUTHORITY

Ministry of Power, Government of India

Power System Engineering & Technology Development Division

Sewa Bhawan, R. K. Puram, New Delhi - 110 066