GUIDELINES FOR USE
OF
UNDER GROUND CABLE SYSTEM
AND
OVERHEAD CONDUCTOR SYSTEM
ALONG WITH COST BENEFIT ANALYSIS

CENTRAL ELECTRICITY AUTHORITY
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1. **INTRODUCTION**

Distribution of electricity involves the transfer of electrical energy from one electric substation to another electrical substation (like from 220/33 KV S/S to 33/11 KV S/S and 33/11 KV S/S to 11/0.4 KV Distribution Transformer S/S etc) through sub-transmission and distribution lines. These lines may be Overhead lines or Underground cables. Each of the two types has its benefits as well as demerits. The choice of Overhead Network or Underground network depends on many factors like safety requirement, Right of way, cost ,aesthetic look and other factors. Despite being expensive, Underground cables have several advantages over OH lines. These are mostly used where safe clearances for Overhead Network is not available as well as in densely populated areas where Overhead Network cannot be used., whereas, Overhead Network is cheaper, easy to install/upgrade and easy to attend the fault etc.

a. OVERHEAD NETWORK

In overhead power lines, a structure based network is used to transmit electrical energy from one point to another. It consists of adequate size of conductors , commonly three conductor in 66 KV , 33 KV or 11 KV lines or four conductor in 11 KV lines or 5 conductor in LT lines (5^{th} conductor for street lighting) for three phase lines and two conductors for single phase lines etc suspended by towers or poles and generally comprising of the items- such as Poles, Conductors, Cross arms, pin insulators, Stay Wires, Stay Rod, Stay Anchor, Guy Insulator, earthing materials, Guard wire, Barbed wire and Danger plate etc

The Poles for the electrical network may be a Steel Poles (Tubular Poles, Rolled Steel Joists and Rails),Concrete Poles (RCCPoles,PCC poles and Pre-Stressed Concrete - PSC) Pole) of various heights of 9 meters to 13 meters (IS: 5613 (Part 1, 2, 3) depending on site location, minimum safety clearance and Voltage (230Volts, 415Volts, 11KV and 33KV etc) of the overhead network system. Along with these poles, Rail poles, which have more strength then other poles, are generally used in overhead network along and across the Road, Public Places, Residential areas, River crossing etc.

Sometimes, for supporting different voltages on the same poles and to maintain the adequate clearance between the different lines of different voltage levels, poles with higher heights are used, and in such cases, guard wires are also provided to prevent

accidental over charging of lines of lower voltage system due to conductor snapping etc.

The conductors for the overhead network can be a bare conductor or an insulated conductor (ABC) depending on the requirement. It is an important component of overhead electrical transmission and distribution systems. The choice of conductor depends on the power carrying capacity, cost, growth of the load, and reliability & efficiency. While selecting an ideal conductor, some of the following features such as -i) maximum electrical & thermal capacity and cost effectiveness etc are considered.

As per CEA(Technical Standards for construction of Electrical Plants and Electric Lines) regulations 2010, as amended upto date, adequate capacity AAC (All Aluminium Conductor), AAAC (All Aluminum Alloy Conductor), ACSR (Aluminum Conductor Steel Reinforced), ACAR (Aluminum Conductor, Aluminum Reinforce) or any new technology higher current carrying conductors (AL-59, HLTS etc) may be used in sub –transmission and Distribution system. Since, the insulations between the conductors is provided by air, overhead power lines are generally the lowest-cost method of power transmission for large quantities of electric energy from one point to another.

In addition to above types of bare conductors, Insulated conductors (Aerial Bunched cables) may also be used in Overhead network system. The use of Aerial Bunched Cables (ABC) is a good concept for overhead power LT distribution where the

electrical clearance is not available or where theft is there. When compared with the overhead distribution system with conventional bare conductors, ABC provides higher safety and reliability and system economy by reducing theft in the area of installation. . This system is ideal for rural distribution and especially attractive for installation in difficult terrains such as hilly areas, forest areas, coastal areas etc. Aerial Bunched Cables is also considered to be the best choice for power distribution in congested urban areas with narrow lanes and by-lanes.

Some other advantages of use of ABC are-

- ABC provide safety to human life when used in congested area and narrow lane areas.
- ABC provides flexibility to use multiple circuits of different voltages strung on the same set of poles without using separate poles.
- ABC provides better adaptability to run concurrently with other overhead system with bare conductor and also with communication lines without any interference.
- ABC provides insulation resistance to earth in all seasons and negligible leakage of currents and thereby, the low losses of leakage.
- ABC is unaffected by pollution in the atmosphere.
- ABC, at the same time also reduces the theft of energy as it can not be tapped i.e it prevents the use of illegal hooks etc on LT lines in the theft prone areas and helps to improve the AT&C losses of the system.

b. UNDERGROUND NETWORK

In Under Ground cable system, the power is transferred from one point to another through underground cables laid in the ground in place of overhead lines on poles/ towers. As these cables are not exposed to the air/ atmosphere, this makes the U/G cabling system less susceptible to outages due to various atmospheric conditions like high wind, storm, thunder storms, heavy snow or ice storms etc. As these cables are not visible on ground, these provide an aesthetic look to the area where these are laid as compare to OH lines. However, the U/G cables have to be laid in the proper tranches and also have more restoration time in case of any fault as compare to OH lines.

While selecting the rating of cables to be used, some of the parameters such as Current carrying capacity, Voltage drop and short circuit rating are important factors to select the economical and optimum size of cable.

The cable generally comprises of the conductor, insulation material, bedding, beading/ armoring, and outer sheath etc. Although, the armoring and outer sheath takes care of the physical safety of cable , adequate care has to be taken by cable manufactures during manufacturing of the cable.

Normally the lifespan of a cable is about 40 to 50 years. But over the time, the insulation of cable may get damaged or weakened due to ageing. Wrong handling of cabals, such as damages due to wrong handling/laying of cable also weakens the insulation of the cables. Normally, some of cable faults may be as-

1. a short circuit fault between two conductor due to failure of insulation between the two conductors
2. a earth fault, i.e., fault between conductor and ground due to failure of outer insulation sheath
3. an open circuit fault, caused due to disconnection of the conductor etc.

The choice of whether to use overhead line (OHL) or underground cable (UGC) must be made keeping in view the safety, reliability and operational constraints.The choice between OHL and UGC is driven by technical, environmental and economic considerations.

2. COMPARISON OF UG SYSTEM AND OH SYSTEM - FEASIBILITY ANALYSIS

Feasibility study of Overhead and Underground line on various points is classified below :

i. COST OF INSTALLATION

Underground network installation is more expensive than OH lines , since the cost of cables include cable charges along with road restoration charges which make the per unit coat of U/G cabling system several times greater than overhead system.

ii. FAULT LOCATION IDENTIFICATION & REPAIRING TIME

The identification of fault finding and repairing on overhead wire is easy as compare to UG cables as UG cables are buried in the ground and it require specialized techniques to find out the fault location as compare to OH lines. Some time, it may take several days or weeks to find and repair the fault in underground system.

iii. COST OF REPAIR A FAULT

In underground cables, when a fault occurs, the cost of finding its location, trenching, cable splicing, and re-embedment is sometimes five to 10 times more expensive than repairing a fault in an overhead line where the conductors are visible, readily accessible and easier to repair.

iv. LINE OUTAGE DURATIONS

As extended repair time is required in underground system, services to customers may be disrupted for a long time in UG system. However, the time duration of customer outages can be reduced by using additional feeders with Ring Main Units (RTUs) in UG system which involves much more cost as compare to OH system.

v. LINE MODIFICATIONS

Overhead power lines are easily tapped, rerouted or modified to serve customers; while underground lines are more difficult to modify after the cables have been laid. Such modifications to underground power lines are more expensive because of the inability to readily access lines or relocate sections of lines.

vi. EFFECT FROM WEATHER CONDITIONS

Overhead Lines are more prone to damage from severe weather conditions (mainly lightning, hurricanes/cyclones/typhoons, tornados, other winds, and freezing) than Underground Network.

vii. RANGE OF ELECTROMAGNETIC FIELDS (EMF) EMISSION

The electric current in the conductor produces a magnetic field around it but the closer grouping of underground power cables reduces the resultant external magnetic field and hence provide less magnetic effect as compare to OH line conductors. Further to reduce the magnetic effect in cables, a shielding is also provided over the cables which further reduces the magnetic effect in surrounding areas.

viii. SPACE REQUIREMENT

Underground cables do not need physical ground space as these are laid under the ground in the dedicated tranches whereas an overhead line requires a corridor on ground along with surrounding clearance strip permanently clear for safety, maintenance and repair.

ix. HAZARD TO WILDLIFE

Underground cables generally pose no hazard to wildlife as compared to overhead network.

x. ILLEGAL CONNECTION/THEFT OF POWER /PILFERAGE

In underground cabling system , it is generally impossible to have illegal connection by tapping the conductor for theft of power. These are also less susceptive for sabotage, and damage from armed conflict.

xi. AESTHETICS

As UG cables are not visible from outside, these provide a clean and aesthetic view of the city /town where UG cables are laid. The above space may be used for any other purposes like making of roads, providing green environment/trees on sidewalks etc having environmental benefits and increase of property values etc.

xii. FLEXIBILITY TO INCREASE LINE CAPACITY

Overhead lines can easily be upgraded/ augmented by modifying line clearances and power poles to carry more power while underground cables cannot be up-rated

and must be supplemented by laying another cables or to be replaced to increase the capacity.

xiii. LINE LIFE

Insulation deterioration takes place in underground cables much faster because of various loading cycles during their lifetimes as compare to OH conductor which do not have any insulation layering. As time passes, the cables insulation weakens, which increases the potential for a line fault.

xiv. SAFETY

As OH conductor are exposed in air, a minimum safety clearance is required for the overhead line from any surrounding like surrounding building /trees etc which may not be available in densely populated areas, while underground cables do not require such clearances . Also, the snapping of the overhead conductors in densely populated areas poses serious safety hazard. Hence, UG cables are preferred in the densely populated areas.

3. COST ANALYSIS

As discussed above, the estimated cost of the UG cabling system is about 3-4 times than the equivalent OH system (like the Est cost of 11 KV OH S/C line with Dog conductor is around Rs 5-6 Lakh/ km while the Est cost of 1 km of 3 x300 sq mm 11 KV cabling system would be around Rs 20 Lakh/km). The tentative unit costs of 11 KV OH lines and UG cabling system are given in Annex. These are only the suggestive figures and the actual costs may vary frm utility to utility based on there technical requirement / schedule rates etc. Following is the cost comparison for installation of one kilometer of underground and Overhead lines:

S No.	Voltage Level	Tentative Est Cost Per km (lacs)		
		OH	UG	ABC
1	LT	3.5	13	8
1	11 kV	5.0	20	13.5
3	33 kV	12.0	35	
5	66 kV	45.0	80	

The above cost may vary depending upon road restoration cost for installation of the underground cables/ overhead poles. The cost is much higher for installation of

underground cables depending on the nature of the road surface to be disturbed and area of installation (Metropolitan/Rural area etc).

4. RECOMMENDATION

It may be seen that both overhead & underground network have their own advantage and disadvantage over each other and also have virtually no cost comparison for cost benefit analysis. As a sub-transmission and distribution line cover the landscape and population structure within the city/town/village throughout its length, the choice between OH and U/G cabling system has be taken based on safety, esthetic look, clearance available, rules and regulations in force and other factors . The sub transmission and distribution lines may also be a mix of both as per actual site conditions. Underground power distribution system is an expensive choice but is mandatory to supply electricity in highly populated areas.

Annex

(NOTE: These are the typical examples of cost estimate of OH line/UG cables.The actual estimates of the Discoms may differ depending upon their schedules cost estimates as approved by their competent Authorities in Discoms)

TYPICAL COST ESTIMATE FOR 1KM 11 KV (SINGLE CIRCUIT) OVERHEAD HT LINE WITH DOG CONDUCTOR ON STEEL TUBULAR POLE					
S. No	**Particulars**	**Unit**	**Qty**	**Rate**	**Amount(Rs)**
1	ST Pole 9 Mtr.	No.	25	2904	72600
2	X-arm M.S. Angle 65x65x6mm V Type	No.	25	597	14925
3	Cross arms holding clamps	No.	25	57	1425
4	11 kV Pin insulators with GI Pins(320CD)	Nos	75	67	5025
5	45 kN disc insulators	Nos	6	533	3198
6	F-bracket for fitting top insulator	No.	25	228	5700
7	ACSR Dog conductor	Km	3.09	59579	184099
8	Jointing sleeve for ACSR DOG	No.	3	171	513
9	Danger Plate	Nos	25	155	3875
10	Barbed wire	Kg.	8	68	544
11	Stay Set Complete	No.	8	1140	9120
12	Sectional D/P on Steel Tubular Pole	No.	1	45593	45593
13	Concreting of supports ST Pole	No.	25	969	24225
14	Stone pad 300x300x75mm	No.	25	182	4550
15	Earthing complete	No.	6	570	3420
	Material Cost in Rs				**378812**
	Misc. Items (Like Nut & Bolts,Clamps,Binding Wire,Aluminium Tape etc) @ 0.5 % of the material cost			0.50%	1894
	Contingency @3% of Material Cost			3%	11365
	Total Material Cost (Part-I)				**392090**
	*Labour Cost for execution of the Scheme, Overhead charges including Transportation, Establishment & Supervision Charges for Erection, Testing & Commissioning **(Part-II)**			14%	54893
	Total Cost (Part-I+Part-II)				447082
	Say in Rs. Lakhs				4.47

TYPICAL COST ESTIMATE FOR 1 KM HT OVERHEAD LINE WITH 11KV ABC CABLE WITH SPAN 30 METERS					
Sl.No	**Particulars**	**Unit**	**Qty**	**Rate**	**Amount(Rs)**
1	PCC Poles 11 M	No.	35	5465	191275
2	ABC Cable 3CX150+150 mm2	Kms	1.02	760013	775213.26
3	Clamp Suspension LT ABC 3X120-150 SQMM	EA	35	244	8540
4	EYE HOOK ANCHOR/ SUSPENSION CLAMP 300MM	EA	35	118	4130
5	Anchor HT ABC 3CX120 TO 150 SQMM	EA	10	349	3490
6	EYE HOOK ANCHOR/ SUSPENSION CLAMP 300MM	EA	10	118	1180
7	Stay Set Complete	No	10	1140	11400
8	Stay Wire GI,7/8 SWG	kg	100	65	6500
9	Full clamp assembly (alongwith Nuts,Bolts and Washers) for stay	No	10	57	570
10	Egg insulators	No	10	13	130
11	Barbed wire	kg	35	68	2380
12	Pipe earth G.I. 40MMX2.5/3 M 'B' CLASS	EA	40	706	28240
13	PIPE HDPE SIZE 25 MM	EA	120	22	2640
14	WIRE STAY GI 7/10 SWG	KG	400	65	26000
15	LUG AL Crimping 70 SQMM XLPE SINGLE HOLE	EA	160	20	3200
16	GI Strip 25x6 mm , 9 meter for earthing	No	7	570	3990
17	Phase plate for each phase set of 3 (on each H-Pole & 4-Pole)	Set	35	57	1995
18	Danger Plate	No	35	155	5425
19	Number Plate	No	35	70	2450
20	JT. KIT O/D HT ABC 3CX150+1CX150 HS ONE	EA	12	1797	21564
21	COVER INSULATION REOPENABLE ON INSULATOR	EA	9	2251	20259
22	CHANNEL MS SIZE 75X40MM	KG	89	65	5785
23	ANGLE MS SIZE 50X50X6MM	KG	41	33	1353
24	FLAT GI SIZE 50X6MM	KG	15	123	1845
	Total Material Cost(Part-I)				**1129554**
	*Labour Cost for execution of the Scheme,Overhead charges including Transportation, Establishment & Supervision Charges for Erection, Testing & Commissioning @14% of Total Material Cost**(Part-II)**			14%	163651
	Total cost in Rs.(Part-I+Part-II)				1332688
	Say(Rs. In Lakhs)				13.33

TYPICAL COST ESTIMATE FOR 1 KM 11KV UNDERGROUND XLPE CABLE (3CX300 SQ.MM.)					
Sl. No.	**Particulars**	**Unit**	**Qty.**	**RATE**	**Amount**
1	HT 11 kV 3CX300 sq.mm XLPE cable	M	1000	1137	1137000
2	11kV outdoor Joint Kit 3X300 Sq. mm.	No.	2	2471	4942
3	11 kV Straigth Through Joint Kit 3X300 Sq.mm.	No.	3	5846	17538
4	RCC Hume Pipe,150MMX2M	Nos.	50	355	17750
5	Collar RCC Hume Pipe 150MM	Nos.	30	55	1650
6	Route and Joint indicating stone	No.	30	130	3900
7	RCC cable cover(2 feet long)	No.	1666	243	404838
8	Sand	No.	250	388	97000
9	Pipe earth G.I. 40MMX2.5/3 M 'B' Class	EA	2	706	1412
10	Pipe HDPE Size 25MM	M	6	22	132
11	LUG AL Crimping 70 SQMM XLPE Single HOLE	EA	8	20	160
12	FLAT GI Size 25x6 MM	KG	7	78	546
13	Cleat HDPE for Cable Support	KG	4	763	3052
14	Pipe G.I. 100MM DIA 'B' CLASS	M	6	716	4296
15	FLAT GI Size 50x6 MM	KG	10	123	1230
16	Channel MS Sixe 75x40MM	EA	60	65	3900
	Material Cost				**1699346**
	Misc Material like nuts & Bolts, Lugs etc. @ 0.5% of the material cost			0.50%	8495
	Contingency Charges @3%			3%	50972
	Total Material Cost (Part -I)				1758557.
	Labour cost for execution of the scheme, overhead charges including Transportation, Establishment & Supervision charges for erection, testing & commissioning Part (II)			14%	246198
	Total Cost (Part I +Part II) in Rs.				2004856
	Total Cost Rs. in Lacs				20.05

Standard cost estimation report mentioned above shows that installation cost of 11 kV Underground cable network is nearly 4 times the cost of installation of overhead network of same voltage rating.

1. CEA (Technical Standards for construction of Electrical Plants and Electric Lines) regulations 2010 as amended upto date

2. Main Indian standards (as amended up to date)

IS 5613 Code of practice for design, installation and maintenance of overhead power lines (Part 1/Sec 1) : 1985 Lines up to and including 11 kV. Section 1 Design (first revision)
(Part 2/Sec 1) : 1985 Lines above 11 kV and up to and including 220 kV, Section 1 design
(Part 2/Sec 2) : 1985 Lines above 11 kV and up to and including 220 kV, Section 2 installation and maintenance
IS 9708 : 1980 Specification for stock bridge vibration dampers for overhead power lines
IS 10162 : 1982 Specification for spacers and spacer dampers for twin horizontal bundle conductors
IS 12360 : 1988 Voltage bands for electrical Installations including preferred voltages and frequency
IS:1554- PVC power cables.
IS:7098- XLPE power cables
IS:9968- Rubber based power cables
IS 3043 : 1987 Code or practice for earthing (first revision)
IS 14255/1995 : ABC cables upto 1100 volts.
IS 8130/1984 : Conductors for insulated cables.
IS 398/Pt.IV/1994: Aluminium alloy conductor.
IS 10418/1982 : Drums for electric cables
IS 1778 - Reels and drums of bare conductor.

IS: 1678, Specification for pre stressed concrete poles for overhead power, traction and telecommunication lines
IS: 2905, Method of test for concrete poles for overhead power and telecommunications lines.
IS: 7321, Code of Practice for selection, handling and erection of concrete poles for overhead power and telecommunication lines