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B2-OVERHEAD LINES: PS3/ ENVIRONMENTAL AND SAFETY ASPECTS FROM OHL/INNOVATIVE ENGINEERING SOLUTIONS/ DESIGN TO DEAL WITH ENVIRONMENTAL CHALLENGES

"POWERGRID Experience on Installation of Transmission Line Arresters in OVERHEAD HV Transmission Lines"

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SUMMARY

Power Grid Corporation of India Limited, India has over 172,000 circuit kms of Transmission Lines passing through various difficult terrains like hills, valleys, rivers, forests etc. spreading across length & breadth of the country. The operational performance of power transmission system of POWERGRID is at par with International standards, with system availability ≥99.75%.

In POWERGRID, the tripping of transmission lines is mainly due to lightning strikes, vegetation growth & insulator failures. Out of these, lightning strike is one of the major contributor of transmission line tripping. Further, in North Eastern part of India, tripping of transmission lines is primarily attributable to lightning strikes, considering high isokeraunic levels of the region. Moreover, in some locations tower footing impedance values are very high due to poor soil conditions/ rocky soil etc. leading to tripping of lines as a result of back flashover during lightning strikes.

In order to study & reduce the instants of tripping in Transmission Lines, POWERGRID followed a two-pronged approach, firstly, to reduce the tower footing impedance by chemical/ bentonite treatment and secondly, to provide Transmission Line Arresters (TLAs) in case tower footing impedance could not be improved due to very poor soil conditions.

This paper presents extensively covers POWERGRID strategy & experience of application of Transmission Line Arresters (TLAs) in 220kV and 132kV Transmission Lines.

KEYWORDS

Overhead Lines (OHL), Transmission Lines(TL), Transmission Line Arresters (TLAs), Externally Gapped Line Arrester (EGLA), High Voltage (HV), Tower Footing Resistance (TFR), North Eastern Region of India (NER).

1.0 Introduction

POWERGRID transmission network of over 172,000 circuit kilo meters is divided into eleven (11) distinct regions based on the respective geographical locations.

The North-East part of the country, classified as North Eastern Region Transmission System (NERTS) of POWERGRID, is affected by high Isokeraunic levels (over 50 days in a year). The heavy rainfall and thunderstorm in this part of the country causes a significant number of tripping in transmission lines due to severe lightning strikes.

In order to reduce the instants of tripping, POWERGRID followed a two-pronged approach, firstly, to reduce the tower footing impedance by chemical/ bentonite treatment and secondly, to provide Transmission Line Arresters (TLAs), in case tower footing impedance could not be improved due to very poor soil conditions.

Working Principle :

The working principle of Transmission Line Arresters (TLAs) have been discussed below:

- When a lightning flash directly strikes the tower, a part of lightning current flows through the grounding wire to the adjacent tower, while other part of lightning current flows into the earth through the tower.
- Grounding resistance of tower manifests transient resistance characteristic and it is generally characterized by the impulse grounding resistance.
- The electric potential of cross arm rapidly increases when lightning strikes the tower, its potential value is

$$V_i = iR_i + L\frac{di}{dt}$$

In the Inductor Equation (Refer book A.K. Theraja),

i= Lightning current (Ampere),
R_i=impulse grounding resistance (Ohm),
$L\frac{di}{dt}$= transient state componen (Henry).
Vi=Voltage

- In absence of TLAs, When the potential difference of cross arm potential (Vt) and line induced potential (V1) is more than 50% of discharge voltage of the insulator string (U50%) i.e. (Vt -V1) > U50%, flashover will take place from cross arm to the line and the entire surge voltage gets discharged into earth through the Tower counterpoise earthing and shield wire earthing. Moreover, it is very difficult to reduce grounding resistance in the mountains. When a lightning strike occurs on TL, the earth fault current travels through back-flashover caused across the insulators towards the switchyard and the relay detects earth fault which leads to operation of CB causing interruption of continuous power supply and thereby affecting availability. Further, unnecessary CB operation due to lightning strike may also hamper the life of the equipment.

- After the installation of TLA in parallel with insulator, when lightning strike occurs in peak of the tower, part of the lightning current flows through the grounding wire to adjacent tower, the other part of the lightning current flows into the earth through the tower. When lightning current exceeds the threshold value of the arrester, current will flow through the arrester. Incase tower footing impedance is high, the surge current flows through the arrester to the adjacent tower, thus ensuring continuous power supply.

Figure-1: TLA installtion in 132kV Line

Figure-2: TLA installtion in 132kV Line

Technical Parameters of TLAs

The technical parameters have been selected in such a way that Station line entry LAs are not stressed. The rated voltages as well as Lightning Impulse Protective levels have been selected after studying the technical parameters of line insulators. The details of technical parameters selected for TLAs are given below in Table-1.

Table 1: Technical Parameters of TLAs

Technical Parameters	**132kV**	**220kV**
Rated Voltage (Ur)	141kV	228kV
Line Discharge Class (IEC-60099)	Class-2	Class-2
Lightning Impulse Protective Level (LIPL) at 10kA	375kV	609kV
Rated Energy value	4.1kJ/kV	4.1kJ/kV

2.0 Case Study: Frequent Tripping of various Transmission Lines in POWERGRID

There have been frequent tripping in following transmission lines of POWERGRID as detailed in Table 2:

i) **Total Tripping (including due to lightning)**:

SN	Name of Lines	Line length (km)	No of Towers	No. of Tripping						
				2015-16	**2016-17**	**2017-18**	**2018-19**	**2019-20**	**2020-21**	**2021-22**
1	132kV Khandong Khliehriat I	42	136	34	29	16	13	15	12	11
2	132kV Khliehriat - Badarpur	76	219	27	27	29	12	10	11	9
3	132kV Aizawl-Kumarghat	130	377	42	28	33	17	13	11	10
4	132kV Khandong-Khliehriat II	41	132	14	12	13	11	1	0	0
5	132KV Salakati Gelephu	49	156	13	9	14	11	9	21	0
6	132KV RCNagar Kumarghat	104	349	13	12	11	10	11	9	2
7	220 kV D/C Alipurduar-Salakati	100	298	22	21	20	18	14	12	7

Table 2 : Total tripping

Note : 2015-16 is the Financial year (01.04.2015 to 31.03.2016) and so on. Tripping count is compared in financial year so financial year data taken for comparison.

Out of above, tripping only on account of lightning are shown in Table :6

On analysis of the data from Table 2 and Table 6, it has been observed that locations having high value of tower footing impedance have frequent incidents of lightning flash over. To improve the tower footing impedance of the tower locations, following measures have been taken:

- ✓ Additional counter poise earthing.
- ✓ Chemical treatment of counter poise earthing.

3.0 Improvement of Tower footing impedance by chemical treatment of counter poise earthing :

POWERGRID has used Bentonite compound for chemical treatment of the soil to improve the tower footing impedance. For the purpose of chemical treatment of counter poise earthing, 10.97 mm diameter galvanized earth wire (of minimum 15 meter in length for towers of 132kV and 30 meter for towers of 220kV) is connected with each leg of the tower. This counter poise earthing runs under the soil at a minimum depth of 1.0 meter & it is covered with bentonite compound. This has helped in achieving lower tower footing impedance. A comparison of tower footing impedance pre and post bentonite compound treatment is shown below:

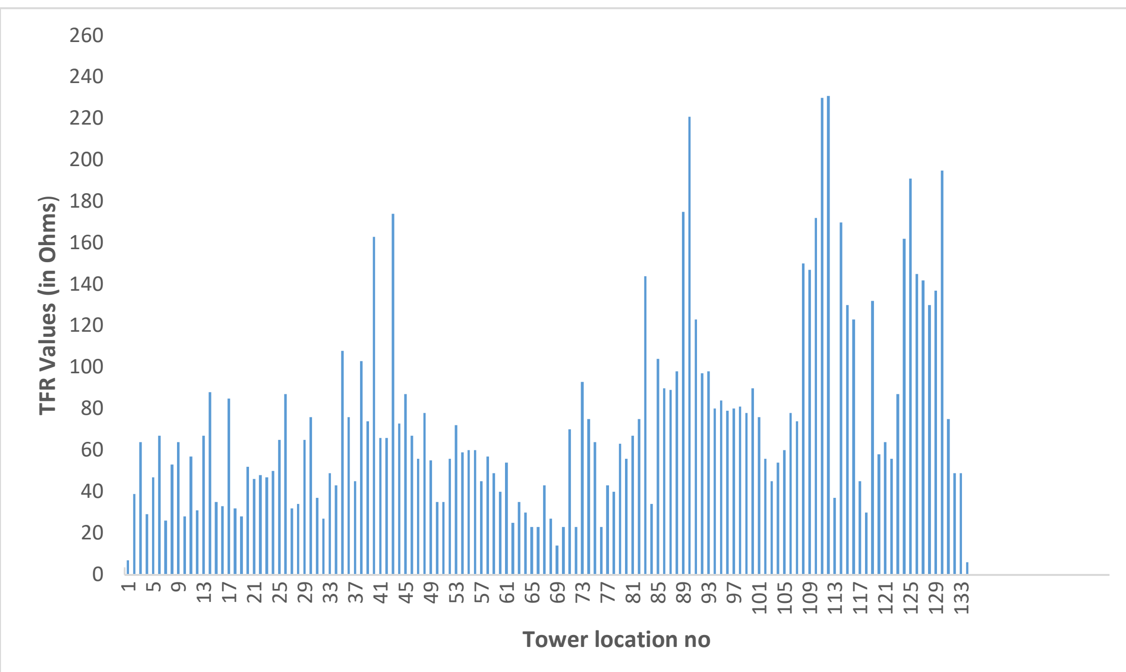

Figure:3 TFR Value before Chemical treatment of 132kV Khliehriat Khondong#2 TL

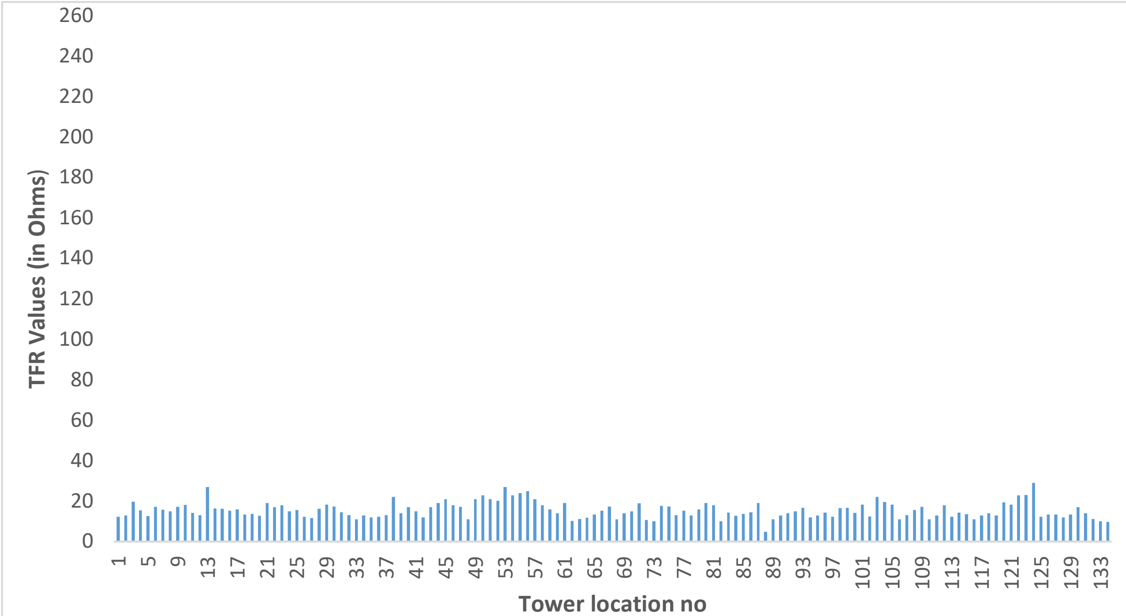

Figure:4 TFR Value after Chemical treatment of 132kV Khliehriat Khondong#2 TL

Figure 3 represents the TFR values before chemical treatment of 132kV Khliehriat Khondong#2 TL & Figure 4 represents post chemical treatment. From comparison of Figure 3 and Figure 4 carried out for 132kV Khliehriat Khondong#2 TL, that chemical treatment helped in improvement of tower footing impedence.

However, still in many tower locations TFR value measured to be more than 10 Ohms. Further it has also been observed that, the TFR value has deviated (increased) in dry season from that of rainy season. This indicates that chemical treatment (bentonite application) could only be able to provide temporary improvement of tower footing impedence and that too during wet season only.

4.0 Considerations for installations of TLAs in transmission lines:

From the above, it is seen that to reduce lightning related line tripping various activities like additional counter poise earthing, chemical earthing have been taken up. Inspite of these measures, tripping of the lines due to lightning had been continued. As such in order to eliminate lighning related tripping, the concept of installation of Transmission Line Arrestor (TLAs) was initiated with following considerations for selection of tower locations for installation of TLAs:

a) Tower Footing Impedance - Tower locations with higher tower footing impedance are chosen for installation of TLAs.
b) Historical data - Tower locations with history of frequent faults (on account of lightning) are chosen for installation of TLAs.
c) Elevation/ Geographical profile - Towers at relatively higher altitude are chosen for installation of TLAs.
d) Installation of TLAs in all the three phase (R, Y & B) in 132 kV & 220kv line.

e) For line with tower locations in Hilly Terrain: It has been observed that in hilly terrain the tower footing impedance is generally found to be in the higher side even after chemical treatment during dry seasons. Hence all tower locations of the line should be been considered for installation of TLAs.

f) For line with tower Locations in Plain Terrain: For deciding placement of TLAs on towers in plain area, studies were carried out as per guidelines given in IEEE-81-2012 which is based on tower footing impedance of transmission line towers. For effective performance, TLAs need to be installed on one more tower on each side of the Tower having high tower footing impedance (generally >10 ohms considered). In 132kV & 220kV line TLA has been installed in all the three phase (R, Y & B).

5.0 POWERGRID Experience: Installation of TLAs in Transmission Lines.

In POWERGRID, as on date, a total of 1941 nos of TLAs has been installed in HV transmission lines as stated under in Table 4 :

<table>
<tr><th>Sl. No.</th><th>Name of line</th><th>Tower Configuration</th><th>Month of Installation</th><th>No of towers in line</th><th>No of locations where TLAs are installed</th></tr>
<tr><td>1</td><td>132 kV Khandong–Khliehriat–I</td><td rowspan="6">Single circuit, Wind Zone-V, ACSR Panther conductor</td><td>Nov-16</td><td>136</td><td>17</td></tr>
<tr><td>2</td><td>132 kV Khliehriat – Badarpur</td><td>Mar-17</td><td>219</td><td>16</td></tr>
<tr><td>3</td><td>132kV Aizawl-Kumarghat</td><td>Dec-17</td><td>377</td><td>25</td></tr>
<tr><td>4</td><td>132 kV Khandong–Khliehriat–II</td><td>Jan-19</td><td>132</td><td>132</td></tr>
<tr><td>5</td><td>132kV Salakati Gelephu</td><td>Apr-21</td><td>155</td><td>155</td></tr>
<tr><td>6</td><td>132kV RCNagar Kumarghat</td><td>Apr-21</td><td>349</td><td>174</td></tr>
<tr><td>7</td><td>220 kV D/C Alipurduar -Salakati</td><td>Double circuit, Wind Zone-V, ACSR Zebra conductor</td><td>May' 19</td><td>298</td><td>93</td></tr>
</table>

Note : Shield wires are provided at Tension Towers at every 7 to 8 Kms distance in the above lines.

Table 4: TLAs installed in POWERGRID Lines

Voltage level wise installation of TLAs in POWERGRID as shown in Table 5 below:-

Sr. No.	**Voltage class of Transmission Lines**	**No of TLAs installed**
1	132kV	1383
2	220kV	558
Total TLAs installed		**1941**

Table: 5 Total TLAs installed in POWERGRID

Figure:5: TLAs installed in 132kV line

Since installation of TLAs in above mentioned lines, operational performance of transmission lines has been improved considerably. For e.g, In 132kV Khliehriat Khondong#2 TL, wherein majority of the line sections falls under hilly terrain, prior to installation of TLAs , every year, there were about 10-20 tripping. But after installation of TLAs in all locations, there is no tripping in this line in last three years. This proves effectiveness of TLAs in this line.

Similarly, in 220 kV D/C Alipurduar-Salakati Transmission Line, after installation of TLAs in identified locations based on IEEE-81-2012 guidelines in May-19, tripping in the line has reduced considerably by over 50%.

Table 6 below depicts operational performance of transmission lines subsequent to installation of TLAs.

SN	Line	Basis of TLAs installation	2015-16	2016-17	2017-18	2018-19	2019-20	2020-21	2021-22
1	132 kV Khandong–Khliehriat–I	IEEE-81-2012 guidelines	22	19	11	13	12	10	7
2	132 kV Khliehriat – Badarpur	IEEE-81-2012 guidelines	25	24	17	4	8	9	7
3	132kV Aizawl-Kumarghat	IEEE-81-2012 guidelines	26	21	29	11	10	7	4
4	132 kV Khandong–Khliehriat–II	Full Line	14	12	13	11	1	0	0
5	132kV Salakati Gelephu	Full Line	13	9	13	10	9	20	0
6	132kV RCNagar Kumarghat	IEEE-81-2012 guidelines	11	10	11	9	10	9	2
7	220 kV D/C Alipurduar -Salakati	IEEE-81-2012 guidelines	19	21	20	18	11	10	4

(Yellow:) No of Tripping after installtion of TLA.

Table: 6 Tripping after installation of TLA

7.0 Conclusion-

From the experience of installation of TLAs by POWERGRID in North East Region of India, affected by high Isokeraunic levels (Average Number of Thunderstorm Days/Year in the weather station near the above mentioned lines found to be around 75 to 80), significant reduction in the number of tripping in transmission lines of POWERGRID have been recorded. This establishes the fact that TLAs considerably improve the system availability and reliability by preventing the outage of transmission lines due to lightning.

Furthermore, in areas of high lightning and high ground resistivities, chemical treatment of tower earthing together with installation of TLAs can prove to be the most cost-effective option to achieve high availability of transmission lines.

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