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High Sheath Current in EHV Underground Cable Circuit

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Abstract

Navi Mumbai International Airport (NMIA) is being developed through a Public-Private partnership (PPP) model by M/s City and Industrial Development Corporation (CIDCO). The airport is located off National Highway No. 4B near Panvel and is 35 km from Mumbai's existing airport. Tata Power's Overhead Line network was passing through the proposed plot. There were 4 EHV circuits used for transmitting power from Tata Power's Hydro Generating stations to Mumbai. To facilitate the construction of the NMIA project, CIDCO had requested Tata Power to divert all overhead lines passing through the NMIA site and suggested laying EHV underground cables along the periphery of the airport. The proposed cable route length is 8.5 km between Karnajade and Waghivali Village, with switching stations at Karanajde and Waghivali. The cable circuit design is divided into seven major sections and 21 minor sections with cross-bonding. After the commissioning of underground cable circuits, heavy sheath currents than permissible limits were observed at the termination of one of the circuits. To reduce the sheath currents within limits, a detailed investigation was carried out and the observed issues were addressed. This document gives the idea of areas to be focused on during the installation of EHV cable circuits.

Keywords: Components of EHV Cable Systems, Cross Bonded System, Extra High Voltage Cable Circuit Design, High Sheath Current

1. Introduction

The Navi Mumbai International Airport (NMIA) is being constructed by CIDCO to address the future growth of air traffic in the city of Mumbai.

The proposed Airport is located off National Highway No. 4B near Panvel in the geographical centre of Navi Mumbai. It is situated approximately 35 km from the Mumbai airport. The access to this Airport is by 4 4-lane highway running along the east side boundaries and Aamra highway on the west side of the Airport.

The Tata Power Co. Ltd. has four circuits of overhead transmission lines which are major trunk lines for evacuation of Power from Hydro generating stations as mentioned, which were crossing the proposed site for NMIA directly cutting across the runway of the Airport.

220 kV Bhira-Dharavi lines # 7 and 8 (two lines on one tower),

110 kV Khopoli – Mankhurd Line

110 kV Khopoli - Lodhivali- Chembur line.

For the construction of the NMIA project, CIDCO had requested Tata Power to reroute all overhead lines (04 circuits) crossing the proposed NMIA plot. Hence, as per the route offered by CIDCO, the laying of underground cables along the boundary of the airport was planned. Also, to maintain the reliability of the power supply new switching stations were constructed on either side of the underground section.

Figure 1 for Site location with markings of overhead and underground network.

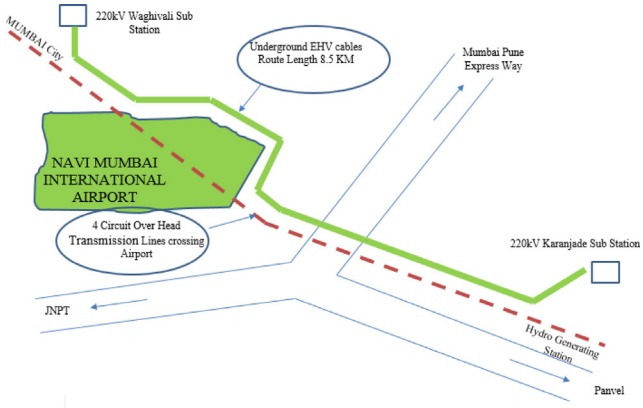


Figure 1. Site location with overhead and underground network.

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2. Proposed Scheme for Re-Routing of EHV Overhead-Lines

The proposed cable route offered by the Airport Development Authority was almost 8.5 Km between Karnajade and Waghivali Village wherein switching stations were proposed at Karanajde and Waghivali.

The cable circuit design comprised 7 major sections and 21 minor sections (from Karanajade GIS to Waghivali Gantry) with cross bonding (Refer to Figure 2).

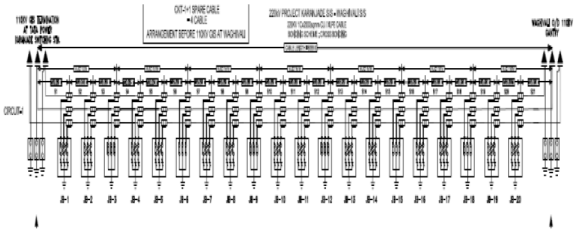


Figure 2. Extra High Voltage cable system design[1].

3. Brief about Cross-Bonded Cable System

(i) At the joint of every minor section, the sheath of one phase is connected to the other phase in cyclic order and grounded at the end of the major section. i.e. the sheaths are sectionalized and cross-connected at the end of every minor section. This helps in reducing the sheath circulating current in EHV cross-bonded circuits.

(ii) In a properly connected cross-bonded system, the induced voltage between the sheath and earth will not achieve significant current flow.

(iii) In cross-bonding, the cable section between two major sections is divided into three equal sections. The induced voltage in the sheath is transposed at 120° at every link box.

(iv) Each Minor section comprises one drum length (500 m approx) which is solidly earthed at major section joints.

(v) In cross bonded cable system, as the cable sheaths are transposed in the link boxes (at the joints of minor sections), the resultant induced voltages U(Rise) = 0. But practically, due to varied site conditions, cable length and laying conditions, there is always a small residual voltage and a negligible current. Due to negligible current flow, there are practically no losses in the sheath.

(vi) Due to cross bonding of sheaths, the total of the three induced voltages is zero, thus the ends of the three sections can be grounded (Figure 3).

(vii) Advantages

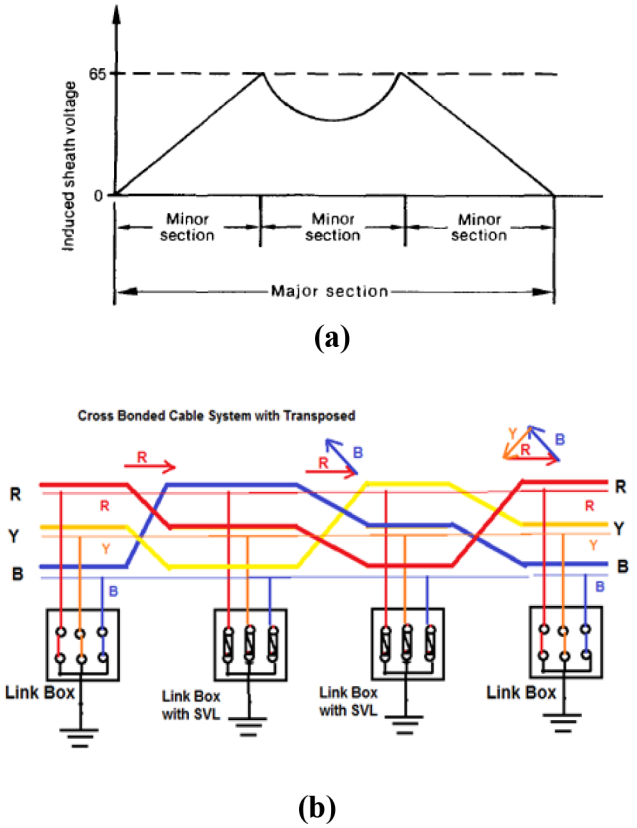


Figure 3. **(a)** Induced voltage profile in minor and Major sections, **(b)** Cross-bonded cable system.

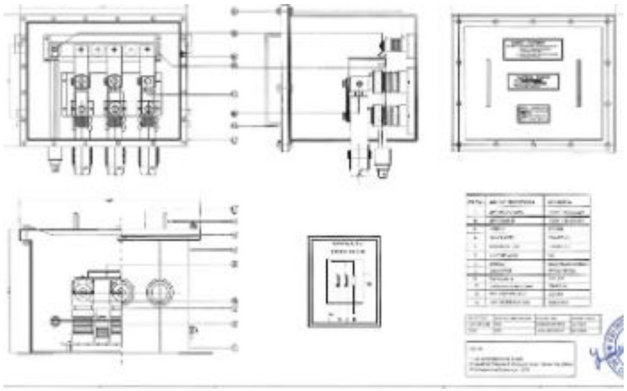
1. No need to lay Earth Continuity Cable (ECC).
2. Ideally no or zero current circulation in the screen or sheath.
3. Induced voltage in the screen is within limit.
4. Technically superior to other EHV cable bonding methods.
5. Long-distance cable circuits are possible.

4. Components of Cross Bonding EHV Cable System

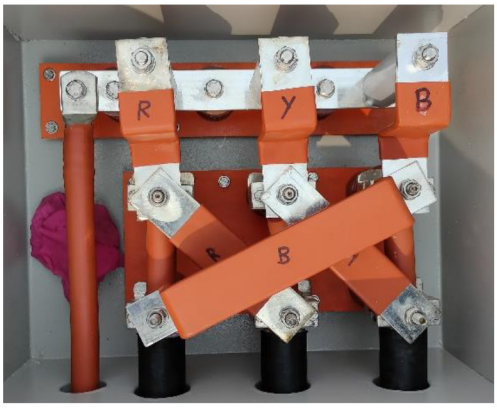
4.1 Link Box

The Link Box is electrically and mechanically one of the important accessories of the EHV underground cable system. It is installed at every joint and the end of the cable

sections. At the link boxes, cable sheaths are connected to the earth or transposed through bolted connections and hence cable sheaths can be accessed easily for testing purposes. Also, to limit voltage surges the link boxes at minor sections are provided with SVL – Sheath voltage limiters. Figures 4 (a, b) for the drawings of the link box.



(a)



(b)

Figure 4. **(a)** Link Box Drawing, **(b)** Three-phase link box with SVL.

4.2 Sheath Voltage Limiters (SVL) or (Surge Arrestors)

A sheath voltage limiter is installed to control the induced voltages in bonded cable circuits under fault conditions. It is installed between the earth and the sheath of the cables.

4.3 Coaxial Cable

It is a double conductor cable – two conductors are separated by a layer of XLPE insulation (rated 6.35 kV/11kV) (Figure 5) for the cross-section of the coaxial cable. The dual conductors in a single co-axial cable help in the transposition of cable sheaths at link boxes.

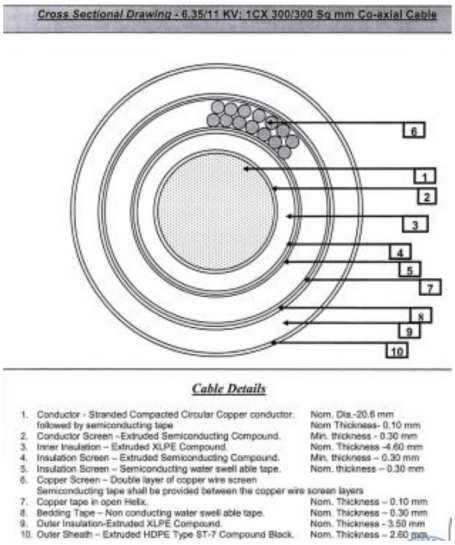


Figure 5. Cross section of coaxial cable.

4.4 Joint Bays

It is a location where the ends of EHV single-core cables are jointed. It is provided with a controlled environment like air conditioning and lighting for the cleanliness during jointing process. In general, for a single circuit, a joint bay is 10 m in length, 1.5 m wide and 2.5 m deep (Figure 6).



Figure 6. EHV cable joint bay.

5. Problem Statement

5.1 High Sheath Current on 110kV Waghivali # 2 FDR (Karanjade–Waghivali–Chembur)

In FY 20 Karanajde GIS with cable sections between Karanjade GIS to Waghivali Gantry had been commissioned. As per the Scheme, In FY 21, Waghivali GIS commissioned by Loop In Loop Out (LILO) of 220kV and 110kV cables- cable sections:

1. 220kV Karanjade – Dharavi 7 and 8
2. 110kV Karanajde – Chembur and Mankhurd

After LILO work of all 4 transmission lines section, sheath currents were measured and abnormality was noticed in one of the sections, *i.e.,* in the 110kV network of Karanajade–Waghivali-Chembur cable section.

The sheath current values observed are shown in Table 1.

Table 1. Sheath currents values.

Date	R A	Y A	B A	Load A	% rise w.r.t. to load
28.03.2021	55	61	17	142	42
27.03.2021	65	120	43	230	52
26.03.2021	63	125	48	256	48

The observed values of sheath currents were 42 to 52% more than the normal values (10% of load current TPCL Standards and O and M Practices)[2] and hence, it was required to take necessary actions to reduce it within the permissible limit.

5.2 Preparation of Action Plan

To identify the suspected location/sections, sheath current measurements were taken at Karanjade and Waghivali end (Table 2).

Table 2. Sheath current measurements at Karanjade and Waghivali

Phase GIS End	R A	Y A	B A	Load A
Karanjade	8	4.1	2.4	185
Waghivali	73	89	22	

Based on shown results and the joint discussion with OEM and TPCL officers, it was concluded with the following points.

(i) The problem is towards Waghivali's end.

(ii) To identify the section, it was decided to measure sheath currents at the grounded joint (Every major section) locations- refer SLD of 110kV Karnanjade to Waghivali section, *i.e.*, JB 18, 15, 12, 9, 6. (Refer to Figure 7).

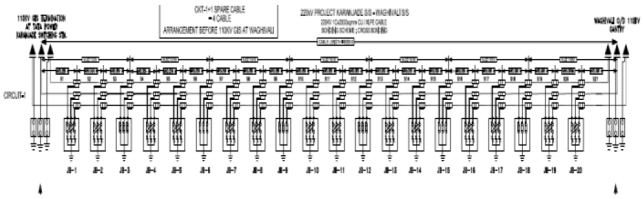


Figure 7. Extra High Voltage cable system design[1].

(iii) Results of Sheath currents at JB 18, 15, 12, 9, and 6 are shown in Table 3.

Table 3. Sheath currents at JB 18, 15, 12, 9 and 6

Joint Bay	Sheath Current (Amps)			
	R	Y	B	Earth
JB 18	113.4	75.2	193	5
JB 15	2.5	**6.1**	**3.3**	**1.9**
JB 12	**2.5**	**3.5**	**6.7**	**1.9**
JB 9	**0.5**	**13.7**	**3.5**	**5.3**
JB 6	**7.7**	**5.5**	**5.6**	**3.5**

(iv) Based on the said results it was concluded that the suspected problematic section is from JB 18 to Waghivali GIS.

(v) Probable causes of high sheath currents:

a. Sheath Fault
b. Loose connections in link boxes at joints
c. SVL short at joint link box
d. Sheath cross phasing
e. Moisture in link boxes

6. Findings and Observation

At Joint Bay 18



Figure 8. Link box filled with bitumen compound.

It was observed that R Phase coaxial cable came out from the clamp and hence no grounding of circulating currents, failing sheath cross bonding and a further increase in sheath currents at the Waghivali GIS end (Figure 8).

Probable Causes:

1. Poor Workmanship,
2. Lack of Supervision,
3. Application of External heavy load on that phase, like unloading of sand by dumper.

At Joint Bay 19

Y and B Phase, coaxial cables core and conductor were found short as shown in Figure 9.



Figure 9. Link box filled with bitumen compound.

Probable Causes:

1. Poor workmanship
2. Use improper-sized bolts and overtightening.
3. Lack of supervision.

Action Taken:

The defects mentioned at JB 18 and 19 were attended and the cable was taken into service.

The Sheath Currents at Waghivali GIS on a working day were recorded in Table 4.

Table 4. Sheath Currents at Waghivali GIS

	Location	Date	R A	Y A	B A	Load A	% of load current
Before	Waghivali	28.03.2021	55	61	17	142	45%
After	Waghivali	30.04.2021	7	12	18	160	10%

7. Recommendations

(i) Link box installation has to be done by an experienced cable jointer only.
(ii) Maintain uniformity in the direction of laying of coaxial cable from the joint body in all joint bays.
(iii) Before the commissioning of cables, phasing and continuity of sheath has to be checked.
(iv) After Commissioning sheath current is to be measured and recorded.
(v) Checklists to be modified with the said recommendations.

8. References

1. NMIA Concept Note
2. Tata Power operation and maintenance manuals.