REPORT OF THE COMMITTEE OF EXPERTS TO REVIEW THE INSULATION REQUIREMENT OF EHV TRANSMISSION LINES OF VARIOUS VOLTAGES

CENTRAL ELECTRICITY AUTHORITY
MINISTRY OF POWER
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1. INTRODUCTION

Frequent tripping of a number of 400kV transmission lines in the Northern Region, particularly in the winter season, due to pollutants in presence of fog, had drawn the attention of many power utilities. Keeping this in view the Central Electricity Authority (CEA) constituted, vide Order No. CEA/5-41(05)/Secy./2008/67, dated 06-05-2008, a Committee, comprising experts in the field of design, operation and maintenance of EHV transmission Lines, under Section-73 of the Electricity Act, 2003, to review the insulation requirement of EHV transmission lines of various voltages in the context of rapid industrialization and infrastructural development in the country in the last 60 years, and to suggest a solution for the entire country. The Committee comprised of experts from CEA, various power utilities, insulator manufacturers and research / academic institutes. The composition of the Committee is given at **Annexure – A**. The scope and terms of reference of the Committee were as follows:

- To review the insulation requirement of EHV transmission lines of various voltages keeping in view the rapid industrialization in the country resulting in increasing the pollution level.

- To suggest remedial measures for improving the performance and minimizing the outages of the existing EHV transmission lines of various voltages in light of the increased pollution level.

2. REVIEW OF PRACTICES

2.1 In the country transmission lines traverse areas having different environmental conditions and different pollution levels. Increase in pollution level has become a global phenomenon. Over the years the pollution level is increasing in India because of industrial and infrastructure development activity. Therefore, existing old transmission lines are under serious threat due to industrial pollution as well as other related activities like increase in number of brick kilns, cement industries and slaughter houses (which lead to deposit of acidic bird droppings over insulators), etc. The scenario is changing so fast that lines constructed today in a clean and pollution free environment may have to operate under severely polluted environment in future because of these activities. The situation has become unpredictable and is a cause of concern to power utilities. Moreover, because of irregular rains and short monsoon seasons, cleaning of insulators by natural process is not effective resulting in increase in deposit of pollutants over insulators.

2.2 Hot line washing of insulators or cleaning using helicopter, without taking shut down is a costly practice. In certain sections, shut down is also not permitted for regular off line periodic maintenance and washing.

2.3 Electrical stresses on insulation are of three types: continuous power frequency voltages, temporary over voltages, switching and lightning over voltages. Usually the insulators show a significant change in their natural operation when they are exposed to severe environmental condition. The electrical stress, which causes flashover, decreases by increasing the level of pollution over insulators. Pollution is one of the main causes of flashover in the insulator.

2.4 The major problem with porcelain insulators is pollution, which generally reduce the flashover voltage under the rated voltage. Contamination and wetting (due to fog, light rain, or dew) causes insulator flashover. Fog, dew, mist or light rain wets the pollution deposits and forms a conductive layer leading to increase in the surface leakage current, formation of dry band and flashover. Other problems related to pollution are: corrosion and erosion of insulator.

2.5 The cost of insulators in the construction of a transmission line represent usually less than 5% of the over all cost of the project. Despite the low cost impact of insulators in the total cost of a line, flashover phenomena on the high voltage outdoor ceramic insulators are a serious threat to safe and uninterrupted operation of the transmission system.

2.6 In general the type of pollution can be broadly classified as industrial, marine or desert pollution. Contaminated particle are driven by the wind and deposited on the outdoor insulator surface. Insulators near coastal areas are contaminated by wind driven salt and those inland by wind driven soil dust, fertilizer deposits, industrial emissions, generating station emissions (fly ash) and pollutants from construction activities, etc. The intensity of accumulation is dependent upon wind speed, line orientation, particle size, material and insulator shape.

2.7 The contamination severity on the insulator surface is generally expressed by equivalent salt deposit density (ESDD). The value of ESDD varies with the distance of the insulator from the source of contaminants. The values of ESDD tend to decrease with increasing distance from the source.

2.8 As per the recommendation of the Enquiry Committee on the grid incident in the Northern Region in January 2007, light, medium, heavy and very heavy pollution levels can be defined as follows in terms of ESDD values.

Pollution Level	**ESDD (mg / sq.cm)**
Light	0.03 ï 0.06
Medium	0.06 ï 0.20
Heavy	0.20 ï 0.60
Very Heavy	>0.60

2.9 The methods of pollution control are based mainly on following:

- Analyzing the severity of the pollution to establish ñzone of pollutionò
- Cleaning or maintenance of the insulators
- Comparing the behaviour of the different designs of insulators and /or of the materials of the insulator that are going to work under contaminated environments.

2.10 Under the present scenario there is a need to review the requirement of specific creepage distance or number of insulators or use of insulators of different profile (aerodynamic profile) or insulation level.

2.11 Insulators used in transmission lines are generally designed for light/normal pollution. It is found that the specific creepage distance of insulators used in old lines (being 292 mm per insulator) is lower than that of insulators used in new lines (320 to 350 mm). Insulators designed for light/normal pollution cannot be used for coastal areas or areas with high pollution level. For such locations, specific creepage distance or number of insulator discs are to be increased. In existing lines, increase in number of insulator discs would not be possible because of ground clearance problems. As a standard practice Antifog type insulators with high specific creepage distance or polymer insulators are being used in such critical locations and their performance is reported to be quite satisfactory and trouble free.

2.12 The present practice of various utilities for adoption of specific creepage distance is based on the following provisions of IS 731:

Highest system Voltage (kV)	**Minimum Creepage Distances (mm) requirement**	
	Moderately polluted atmosphere	**Heavily Polluted atmosphere**
72.5	1100	1700
123	1850	2800
145	2250	3400
245	3800	5600
420	6480	9660

3. PROCEEDINGS OF THE COMMITTEE OF EXPERTS

3.1 The Committee of Experts held three meetings at New Delhi and discussed in detail the existing practices and their limitations. Minutes of the three meetings are given at **Annexure – B.**

3.2 The discussion / deliberation during the meetings primarily centered around the application of outdoor porcelain type insulators(cap and pin type / long rod). However, utilities can also consider the application of polymeric composite insulators where the level of pollution is high.

3.3 The use of composite insulators for outdoor applications has rapidly increased during the last decades. Because of its excellent hydrophobicity property, polymer insulators are considered to have higher pollution withstand voltages compared to porcelain or glass insulators. For composite insulators, the main risk is the quality of interface between the fiberglass / resin rod and the housing. The damage to seal at end fittings can promote tracking, an irreversible deterioration, of rod which is not visible from outside. Polymeric insulators may suffer loss of hydrophilic surface condition as they age. The corona (cutting or aging induced by corona discharge) and arcing can seriously damage the insulator surface. Risk of brittle fracture, assessment of service life due to ageing, long term integrity of joints between end fittings and FRP and proper handling (during storage, transportation and installation) are the causes of concern.

3.4 Strict Quality Control measures during the manufacturing process are essential to overcome such problems. Manufacturers may analyze the failure data, improve prevalent design and adopt international quality control measures. Indigenous manufacturers may have to take extra precautions and adopt stringent Quality Control measures to improve upon the quality of product to match with international standard.

3.5 The Committee noted that as per IEC-60815 ñGuide for selection of Insulation for pollutionò, considerable increase in creepage distance is required to counter the increase in pollution levels from lower severity level to higher severity levels. As the pollution level experienced by certain stretches of lines had undergone change, the insulation provided for lower severity would not be adequate to offer trouble free service.

3.6 Unfortunately, some Indian Standards have not been revised in line with IEC. The Indian Standard (IS-731) on insulators defines only two levels of pollution (medium and heavy) unlike IEC 60815 wherein four levels of pollution have been defined (light, medium, heavy and very heavy) as follows in terms of specific creepage distance (mm/kV)**.**

Pollution Level	**Minimum Nominal Specific creepage distance (mm / kV of phase to phase value of highest system voltage)**
Light	16
Medium	20
Heavy	25
Very Heavy	31

3.7 In the present scenario, there is an urgent need for pollution mapping of the entire country to solve the problems arising due to

pollution in coastal areas and in industrial areas etc. In the process the pollution zones can be identified for the entire country. A power utility should measure the pollution levels in different areas served by it and come forward to assist in development of a pollution map for the entire country. Pollution mapping is not a one time job and needs to be reviewed at regular intervals as pollution levels will definitely change over a period of time.

3.8 To increase the specific creepage distance, the profile of an insulator is normally changed for which a different die and mould set has to be developed as it will be different for different creepage requirements of an insulator disk (e.g.315mm, 370mm) which requires additional investment and consequently increase in cost. The cost of insulator is expected to increase by about 20% for raising the specific creepage distance. However, the new profile of insulators, needs to be tested for the required pollution level before field application.

3.9 The development and type testing of open profile type insulators for heavy pollution areas (which have better performance as compared to under-rib type anti-fog AC insulators) with higher creepage distance was discussed with various manufacturers. The manufacturers emphasized that since the rejection rate is very high for production of open profile insulators, the development cost would be substantial and would not be economical unless there was some assurance from utilities for their use.

3.10 It was emphasized that the concerned pollution control board should develop a suitable regulatory framework so that new brick kilns / polluting industries do not come up near transmission lines.

4. RECOMMENDATIONS

After deliberations in the three meetings, the committee recommended the following (for EHV transmission lines upto 400kV level) :

1. Due to rising level of pollution, the lines upto 400 kV voltage level traversing through the country which are being designed at present for moderately (as per IS 731) / light (as per IEC 60815) pollution level be designed in future for medium pollution level (creepage of 20mm/kV as per IEC-60815)as per following table, keeping the same number of insulators / string lengths.

Highest system Voltage (kV)	**Minimum Creepage Distances (mm)**		
	Requirement as per IS 731 (Moderately polluted atmosphere)	**Actual creepage being provided as per existing Practice (for Moderately polluted atmosphere considering creepage of 320mm per disc insulator)**	**Recommended Value (20mm/kV)**
72.5	1100(15mm/kV)	1600	1450
123	1850(15mm/kV)	2560	2460
145	2250(15.5mm/kV)	2880	2900
245	3800(15.5mm/kV)	4480	4900
420	6480(15.4mm/kV)	7360	8400

For critical locations coming in areas with higher pollution level, utilities can specify antifog type insulators with higher creepage distance or polymer insulators depending on the level of pollution and as per the recommendations of the Regional Power Committee (RPC) Inquiry Committee constituted by CEA on the Grid Incident in the Northern Region in January 2007 [Ref: **Annexure C**].

2. Manufacturers have agreed to develop the required profile to meet above specific creepage requirement within the same string lengths as are being used at present and get it type tested by end of March 2009 so that utilities can ask for such profiles in their specification in the next financial year(2009-2010).

3. To tackle the problem of higher pollution levels encountered near existing lines, critical locations may be identified and replacement of insulators with higher creepage or with polymer insulator within the existing string length can be taken up in a phased manner by the concerned utilities. Frequency of cleaning of insulators of critical locations may also be increased as per site conditions.

4. Pollution mapping of the entire country must be taken up as a parallel activity and accordingly pollution zones can be identified. PowerGrid in association with Regional Power Committees may take lead to discuss the matter at appropriate forum with constituents of the committee for carrying out pollution mapping of all regions of the country. CPRI has to be involved and the methodology to be followed for collection of relevant data & samples and modality for training of concerned persons of the various utilities may be framed and finalized in consultation with CPRI. The modalities of sharing expenditure involved in carrying out such activities may be discussed with concerned utilities or concerned RPC may find out alternative arrangement for funding to expedite the work. Since pollution mapping is not a one time activity, necessary mechanism has to be developed by RPC/Power Grid to review at regular intervals for continuation of the work as a long term activity.

5. Manufacturers should consider development of open profile type insulators for heavy pollution zones meeting 25 mm/kV specific creepage distance requirement within the same string lengths and PGCIL would help out to place a few trial orders in coastal / industrial areas etc. for such insulators to assess the performance.

6. CPRI should take up development of facility for pollution tests on complete insulator strings using solid layer method.

7. Recommendations of the committee shall be forwarded to BIS. BIS would be requested to take early action for revising the relevant standards in line with IEC.

New Delhi
November 17, 2008

(T.P Singh)
Chief Engineer
and
Chairman of
Committee of
Experts

Annexure –C

RECOMMENDATIONS OF THE REGIONAL POWER COMMITTEE (RPC) INQUIRY COMMITTEE CONSTITUTED BY CEA ON THE GRID INCIDENT IN THE NORTHERN REGION IN JANUARY 2007

RECOMMENDATIONS OF REGIONAL POWER COMMITTEE (RPC) INQUIRY COMMITTEE CONSTITUTED BY CEA ON THE GRID INCIDENT IN THE NORTHERN REGION IN JANUARY 2007

(A) Arresting tripping of transmission lines during heavy fog conditions

1. The entire line length shall be classified as stretches of light, medium heavy and very heavy pollution as per the following ESDD values

Pollution level	ESDD (mg/sq. cm)
Light	0.03 - 0.06
Medium	0.06 - 0.2
Heavy	0.2 ï 0.6
Very Heavy	>0.6

For new lines such stretches shall be identified during survey. Medium, heavy and very heavy pollution stretches shall further be categorized to washable and non washable pollution. The pollution levels shall be reviewed periodically and reclassification done if required.

2. Till data are created by ESDD measurements, pollution levels/ stretches shall be determined as per the following:

Pollution level	Basis
Light	All line stretches not covered by medium heavy and very heavy pollution
Medium	Line stretches within 5 to 10 km radius from polluting sources like industrial pollution, brick kiln / sugar cane crushers/dying industry / bio mass power plant or similar installation having smoke emission and chimney height of 20-30 meters or salt laden barren land or kuchha road in agricultural land with heavy traffic or locations within a band of + 2 kms (as per distance to fault locator or visual inspection) where at least 3 flashovers has been observed in one single foggy day with normal creepage distance porcelain/ toughened glass discs.
Heavy	Line stretches within 2 to 5 km radius from polluting sources as defined for medium

	pollution and from coal /lignite based thermal power plants or dry ash disposal area or locations within a band of + 2 kms where at least 3 flashovers has been observed in one single foggy day with high creepage distance porcelain/ toughened discs.
Very Heavy	Line stretches near sea or within 2 km radius from polluting sources like of coal /lignite based thermal power plants or dry ash disposal area or locations within a band of + 2 kms where more than 3 flashovers has been observed in one single foggy day with high creepage distance porcelain/ toughened discs.

3. Present practice of using porcelain insulator string units of 292 to 350 mm creepage distance may be continued to be employed in light pollution areas. In areas exposed to heavy fog and medium pollution level antifog insulators discs of creepage distance of 430 mm or higher (corresponding to creepage distance of 22 mm /kV for 400kV lines with 23 discs) or Porcelain long rod insulators offering equal creepage distance may be employed with insulator profile as per IEC 60815. In areas exposed to heavy fog and heavy & very heavy pollution levels composite long rod (polymer) insulators with silicon impregnated (SIR) weather sheds having creepage distance of 25mm/kV & 31mm/kV respectively may be employed.

4. In respect of lines in operation, insulator strings shall be progressively replaced as per 3 above depending upon pollution levels. 36

5. Cleaning of insulators may be completed by 15th November every year for all affected stretches. For very heavy pollution stretches the cleaning may be completed by 15th Dec so that pollution deposits shall be minimum during foggy days.

6. Cleaning of insulators in the polluted areas with non washable contamination, shall be effected as per the procedures indicated in IEEE guidelines

7. For cleaning of insulators in polluted areas with washable contamination, the present practice of manual cleaning of insulators may be progressively replaced with high pressure water jet live line washing wherever approach of truck mounted or telescopic boom washers are feasible. Else the practice of replacing polluted insulator string with cleaned insulator string may be adopted. The polluted insulator string removed from the line shall be washed/ cleaned at ground level and reused for replacing polluted insulator strings at subsequent locations. Helicopter live line washing needs to be resorted to in the areas

where approach of truck mounted washers / telescopic boom washers is not feasible or where due to high pollution and its faster accumulation, speed of operation so demands. While practicing helicopter washing the safety considerations as per the IEEE guidelines (Refer Appendix)needs to be ensured. On an average , the helicopter needs to be utilized for approx. 5 hours per day or for effecting cleaning of approx. 10 circuit-km stretch of line.

8. High pressure water jet cleaning shall not be practiced on polymer insulators.

9. The state governments of Rajasthan, Uttar Pradesh, Utrakhund, and Delhi may also notify that no brick kiln or any industrial unit or biomass or diesel based power plant having chimney height up to 30 meters shall be set up with its chimney within 0.5 km of the 220 kV or higher voltage transmission line. Punjab , Haryana and Himachal Pradesh may also extend their notifications of brick kilns to any industrial unit or biomass or diesel based power plant with its chimney height up to 30 meters within 0.5 km of the 220 kV or higher voltage transmission line. The State governments may also take action so that such chimneys within 0.5 kms meters of lines are shifted. The notifications should also include that height of brick kilns shall be at least 5 m more than the height of tower in vicinity

10. The pollution standards in respect of smoke emission from chimneys of brick kiln or any industrial unit or biomass power plant with height up to 30 meters may be reviewed to have reduced level of emission of suspended particulate matter.

11. No detergent or soap water be used for cleaning of line insulators under energized conditions. If used for cleaning during un-energized conditions, this should be followed by a low-pressure flood rinse with clean water to remove any residue. Solvents may be used only after manufacturer approval, provided all cleaning residue are removed by the final clean water rinse. 37

(B) Improvements in Maintenance & Construction Practices of transmission lines

12. Bird guards shall be provided on all I and V insulator string supporting towers of new lines. For existing lines bird guards may be provided progressively. Bird guards shall be provided immediately on towers within 1.0 km on either side of locations experiencing bird droppings.

13. Synchronizing facility wherever provided need be kept in working conditions, and its working condition shall be confirmed to NRPC before 15th December every year.

14. In emergency / critical situation like the event of 27.01.2007 and in case line has not autoreclosed at a substation or autoreclose has locked out, but synchronization of system is not lost and line has autoreclosed from other end as evident from line end voltage, then it need be reclosed from the substation through syncronizing trolley without waiting for clearance from load dispatcher. RLDC / SLDC may be informed subsequently as soon as possible.

15. Detection of punctured insulators needs to be carried out using hotline puncture detectors and change of punctured insulators so identified shall be replaced during scheduled maintenance. For medium, heavy and very heavy heavily polluted stretches the replacement should be effected before onset of winters i.e October every year.

16. For change of insulator strings, as far as possible hot line techniques may be followed and necessary hotline tools & gadgets and trained manpower be employed.

17. The quality of insulator cleaning whether by wet cloth or by pressurized water jet is dependant on adoption of correct methodology by the operator and better supervision (more so where it is outsourced). . The operators /supervisors may be provided training in cleaning / replacement of insulator strings on de-energised line as well as live line working .

18. Agreement to in principle implementation of the remedial measures may be given by the constituents pending finalization of the tariff aspects. Since the matter concerns grid security, therefore the matter of finalization of tariff may be taken up on priority

19. The pollution measurements on transmission lines need be undertaken in the area having heavy fog which may be defined as no visibility at 20 meter distance (approximately corresponding to height of insulator string from ground level). Such measurements may be effected by suspending dummy insulator string in tower or by sampling from existing insulators at randomly selected location in area suspected to be having industrial pollution, brick kiln / sugar cane crushers/dying industry / bio mass power plant or similar installation having smoke emission and chimney height of 20-30 meters or salt / dust pollution. such measurements may be carried out at adequate number of locations every year and continued for 2-3 Years. ESDD in mg/sq.cms of insulator surface area may be determined every quarter as specified at **Annexure - IX[15].**

(C) Other relevant issues

20. The time synchronization of disturbance recorders and event loggers should be checked and wherever required their clock shall be reset.
21. PLCC equipments for direct tripping need be tested periodically to avert false tripping .Wherever the protection schemes have not operated from both ends, cause need to be investigated on each & every occurrence and protection scheme may be set right.

22. From the consideration of grid security, autoreclosing may also be resorted on critical 220kV lines. The Protection committee may identify all such lines. Where single pole autoreclosing is unsuccessful its autoreclose time be increased at the first instant.

ANNEXURE –A

COMPOSITION OF COMMITTEE
OF
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