I N D E X

Sl. No.	Description		Page No.
1.	Introduction	----------	1
2.	Over view of Northern Regional Grid	----------	2
3.	Description of Incident	----------	3
4.	Restoration	----------	6
5.	Site visit & Discussion with site staff	----------	7
6.	Analysis of Tripping & Remedial Measures	----------	13
7.	Insulation Creepage Distance	----------	23
8.	Maintenance and Design Practices	----------	31
9.	Other Related Issues	----------	33
10.	Recommendations	----------	35
11.	Acknowledgement	----------	39
	References:	----------	40

EXHIBIT

Exhibit - I : A power map of the region showing major generating stations and transmission lines at 400 kV and above.

ANNEXURES

Annexure - I: Copy of CEA's Office Order No. CEA/BC/Delhi/1/2007 dated 27.1.2007.

Annexure - II: The breakup of the installed capacity as on 26.01.2007.

Annexure - III: Power flow on important 400 kV lines

Annexure – IV: Details of Corridors in the Northern Region

Annexure - V: Number of tripping of transmission lines on 27.1.2007.

Annexure - VI-A & VI-B :	Graphs indicating number of trippings & restoration versus time
Annexure -VII - A & VII - B:	Details of tripping of lines on 28.1.2007 & 29.1.2007
Annexure - VIII - A ; VIII - B & VIII - C	Copy of notification issued by Government of Punjab, Haryana and Himachal Pradesh on operation of brick kiln near transmission lines.
Annexure - IX:	Method of Measuring of Equivalent Salt Deposit Density (ESDD)
Annexure - X	Copy of Extract from IEEE Std 957-1995- IEEE Guide for Cleaning of line insulators

REPORT OF THE INQUIRY COMMITTEE ON GRID INCIDENT IN NORTHERN REGION ON 27th JANUARY, 2007.

1.0 INTRODUCTION

1.1 A grid incident occurred in Northern Region in early morning hours on 27.1.2007, due to heavy fog in the region, resulting in 201 trippings on the 400 kV and 220 kV system as recorded at NRLDC (including single pole autoreclosures). These trippings resulted in a situation where at 0812 hours, 53 lines (400 kV and 220 kV) were out, resulting in backing down / load shedding.

1.2 Four incidents of loss of a 400 kV or 220 kV bus also occurred during this incident at 400 kV NTPC Dadri, 220 kV Bawana, 220 kV Auraiya and 220 kV Panipat (BBMB). The latter two caused a loss of generation to the extent of 500 MW.

1.3 Central Electricity Authority vide its order No. CEA/BC/Delhi/1/2007 dated 27.1.2007 (**Annexure - I**) constituted a Committee comprising the following members to inquire into the incident and recommend remedial measures to avert recurrence of such incidents:

Sh. Shanti Prasad, Former Chairman R.E.R.C.	-	Chairman
Sh. Santosh Kumar, Member (GO&D), C.E.A.	-	Member
Sh. P. K. Kukde, Former Director, M.S.E.B.	-	Member
Sh. A. K. Tripathi, Director General, C.P.R.I.	-	Member
Sh. R. N. Nayak, Executive Director, P.G.C.I.L.	-	Member
Sh. Ashok Kumar, Chief Engineer, U.P.Transco	-	Member
Sh. P. P. Wahi, Director, C.B.I.P.	-	Member
Sh. S.P. Singh, Member Secretary, N.R.P.C.	-	Member Secretary

1.4 The terms of reference of the Committee are as under:

i) To analyse the tripping of the transmission lines and go into the genesis of the problem of tripping of lines under foggy condition.
ii) To look into the existing O&M practice of transmission system and suggest improvement thereof.
iii) To look into new technology options to avert such tripping in future.
iv) Any other relevant issue related to tripping of the lines and security of the grid under such conditions.

1.5 The Committee held its first meeting on 22nd February, 2007 (Thursday) at Conference hall of NRPC Secretariat and during the discussion and following course were identified to proceed further:-

i) Members of the Committee may visit 400 kV Ballabhgarh & Dadri S/S of POWERGRID, 400 kV Panipat S/S of BBMB and 400 kV Muradnagar S/S of UPPCL and have discussion with field engineer about their maintenance practices.

ii) Scrutiny of data pertaining to other grid incidents occurred in the month of December-2006 and January / February 2007 may serve the purpose of analyzing the causes of tripping of line and suggest measures to avert the same.

iii) All constituents members may instruct field engineers of their organizations to attempt to identify the physical locations of frequent flash over of line insulator string on the basis of readings of fault locators or inspection of line and identify source of pollution in the field causing tripping of the lines.

iv) Shri P. K. Kukde, Former Director MSEB didn't participate in the meetings.

2.0 OVER VIEW OF NORTHERN REGIONAL GRID

2.1 The Northern Region (NR) comprises the states of Punjab, Haryana, Rajasthan, Himachal Pradesh, Uttar Pradesh, Uttarakhand, Delhi, Jammu & Kashmir and the Union Territory of Chandigarh. Apart from the generating stations of SEBs, the region has Central Sector Generating Stations of Thermal and gas power stations of NTPC at Rihand, Singrauli, Unchahar, Dadri, Tanda, Faridabad, Anta, Auraiya and Badarpur and hydro power stations of NHPC at Bairasiul, Salal, Tanakpur, Chamera, Uri, Dauliganga, Dulhasti, hydro power station of Tehri Hydro Development Corporation, Satluj Jal Vidyut Nigam Limited and Bhakra Beas Management Board and Nuclear Power Stations of NPC at NAPS and RAPS and Baspa & Malana hydro Power Station in private sector. The Northern Regional Grid, which is predominantly thermal, is having thermal hydro mix of the order of 65:35. The total installed capacity of Northern Regional grid in the month of January'2007 (as on 26.1.2007) was 35225.65 MW. The breakup of the installed capacity as on 26.01.2007 is given in **Annexure-II**.

2.2 The maximum & minimum registered demand met during the month of January' 2007 (Upto 26.1.2007) was 25062 MW on 12.1.2007 and 20443 MW on 04.01.2007 respectively.

2.3 Major generating stations including Super Thermal Power Stations of NTPC at Rihand and Singrauli are located in the eastern part of the grid. Due to such concentration of generation in the eastern part of the grid and major load centers in the central and western part of the grid there is bulk active power transmission from eastern to western part over long distances.

2.4 Northern Regional transmission system consists of more than 14000 Circuit Kms of AC transmission lines and 815 Km long $\pm$ 500 kV HVDC Rihand - Dadri bipole line. The NR grid is connected to Western Region (WR) grid through 500 MW capacity HVDC back-to-back system at Vindhyachal. Northern Regional Grid is also connected to Eastern Regional Grid through 500 MW HVDC back to back at Sasaram. With the commissioning of 400 kV Muzzafarpur (ER) – Gorakhpur (NR) D/C line in August, 2006, Northern grid got synchronized with the Western Region (WR), Eastern Region (ER) & North Eastern Region (NER).

Since then NR, WR, ER and NER grids (i.e. Central Grid) are operating in synchronous mode.

2.5 A power map of the region showing major generating stations and transmission lines at 400 kV and above is given at **Exhibit - I**.

3.0 DESCRIPTION OF INCIDENT

3.1 Antecedent conditions at 02:55 HRS on 27.01.2007

A. System Frequency : 50 Hz

B. Power Flow in MW

NR - Load	**20556**
Inter Regional Power Flow on HVDC back to back and AC line (Import)	**1877**
East - West - Flowgate (Total)*	**6172**
Generation - Central Sector	**9651**

* East West flow gate consists of the 400 kV lines namely Allahabad - Mainpuri, Unnao Bareili, Lucknow - Moradabad, Unnao - Agra, Panki - Muradnagar, Rihand - Dadri, Panki - Auriaya, Kanour - Ballabgarh, Kanpur - Agra, Kanpur - Auriaya and 220 kV lines namely Kanpur - Mainpuri, Panki - Mainpuri, Sitapur - Sahazanpur.

i. **Generation, Schedule, Drawls and Demand**

(All figures in MW)

STATES / UT	SCHEDULE	DRAWL	GENERATION	DEMAND
PUNJAB	670	848	2144	2815
HARYANA	817	1081	1608	2571
RAJASTHAN	2113	2081	2405	4558
DELHI	257	-140	1184	957
H. P.	395	452	61	476
J&K	704	952	66	1019
U.P.	2910	3628	2951	6460
UTTARAKHAND	432	526	114	660
CHANDIGARH	87	72	0	72
TOTAL	**8385**	**9500**	**10533**	**19588**

D. **VOLATAGE PROFILE**

Name of Station (400 kV)	
Abdullapur	402
Agra(PG)	412
Allahabad	408
Ballabgarh	404
Bassi	403
Bawana	404
Bhiwani	402
Dadri	403
Hissar	397

Jhakri	400
Jullundar	410
Kanpur	403
Moga	398
Moradabad	404
Muradnagar	389
Nalagarh	412
Panipat	398
Rihand	410
Singrauli	414
Unnao	407
Uri	359
Varanasi	412
GORAKHPUR	419
Name of Station (220 kV)	
ANTA	232
BHILWARA	222
BTPS	218
CHITTORGARH	229
DEBARI	213
Ganguwal	230
IP	217
Jullundar	233
Kishenpur	225
Kota	220
Narela	227
Pampore	208
Panipat BBMB	222
Patparganj	222
RAPP A	225
RAPP B	227
Ropar	227
Salal	220
Suratgarh	227

E. Power flow on important 400 kV lines (MW) are given at **ANNEXURE - III**

3.2 **The Incident: Line tripping on 27.1.07**: A grid incident occurred on 27.1.07 in early hours due to heavy fog in the region.

BBMB reported tripping of 220 kV Ganguwal - Jamalpur (Luidhiana) at 0034 hrs subsequently another nine tripping were reported by BBMB at 0300 hrs. Thereafter, POWERGRID reported tripping of large number of lines. Tripping, envisaged to be due to heavy fog, commenced from 0319 hrs accompanied by auto re-closing with most critical period being from 0745 hours to 1130 hrs. Load at 0255 hrs was 20566 MW which increased to 22800 MW at about 0 630 hrs and at about 1000 hrs it was around 19800 MW. System frequency ranged from 49.23 Hz to 49.98 Hz. (average being 49.58) during the incident. There was no islanding / system separation. Severity of incident can be gauged from the fact that :

- 201 trippings of 400 kV and 220 kV lines occurred in the region. This includes 82 numbers of auto re-closing took place.
- Flow in East – West corridor of Northern Region was brought down from 6000MW to 3000 MW at 0800 hours by reducing generation on eastern side as well as import to Northern Region
- From operational considerations of Northern grid, Northern Regional Load Despatch Centre (NRLDC) considers power flows on 37 corridors (**Annexure-IV**), out of which 17 numbers of corridors (viz sr. no. 3, 6, 7, 8, 9, 10, 14, 16, 22, 23, 24, 27, 30, 35, 36, 37 of Annexure - III) were affected. 32 numbers of lines out of 81 in these corridors were affected.
- Four incidents of bus bar outages occurred viz at 400kV Dadri, 220 kV Bawana, 220 kV Auraiya and 220 kV Panipat. This caused loss of generation to the extent of 500 MW at Auraiya & Panipat.
- NRLDC had to take several control actions by way of curtailing Short Term Open Access (STOA) transactions, shedding load in Punjab, Haryana, J&K, Rajasthan and Delhi and backing down generation in Singrauli / Rihand complex. Compared with average load curve of winter season in the Northern Region close to a maximum of 3500 MW of load was shed in this incident.
- 8 nos. of 400 kV and 16 no. of 220 kV lines were declared under breakdown conditions.
- These trippings resulted in severest situation at 0812 hours when 53 transmission lines of 400kV and 220 kV were out.
- Number of trippings on 400kV and 220 kV AC lines are at **Annexure-V.**

3.2.1 Grid remained intact, partly because system was not heavily loaded and curtailment of STOA by 850 MW and partly because of number of successful auto re-closings. However, loss of energy based on average load curve of the season during 08 hrs from 0300 hrs on 27.1.2007 assessed out as 17 MU. Revenue loss of utility and indirect loss of consumers cannot be quantified.

3.2.2 Graphs at **Annexure – VI** indicate number of trippings & restoration versus time as a consequence of trippings and re-closing.

3.2.3 It is observed that HVDC Rihand-Dadri line had 25 restarts on 27.01.2007. As per operational guidelines, after 3 auto-restarts within 10 minutes, the line is manually shifted to reduced voltage operation (RVO) mode. Looking at repetitive auto-restarts, Pole-I & Pole – II were manually taken in RVO mode at 0336 hours & 0432 hours respectively. Both poles of $\pm$ 500 KV HVDC Rihand - Dadri line remained in operation at reduced voltage mode.

3.2.4 Fog related line trippings occurred on 28.01.07 also when about 10 lines of 400 kV and 15 lines of 220 kV had tripped. Similarly on 29.01.07, there were about 15 lines of 400 kV and 3 lines of 220 kV which had tripped as a result of which western UP system became critical. Though there was no backing down of generation but curtailment of short term open access (STOA) to the extent of 550 MW was done to save the system. Details of tripping are given in **Annexure - VII.**

4.0 RESTORATION

4.1 The restoration of the following important lines were as given below:

Sl. No.	Time of tripping	Line	Time of restoration
1	00.34 hrs	220 kV Ganguwal-Jamalpur-I	17.33 hrs
2	00.34 hrs	220 kV Ganguwal-Jamalpur-II	17.33 hrs
3	00.41 hrs	220 kV Bhakra-Jamalpur-I	18.06 hrs
4	01.38 hrs	220 kV Bhakra-Jamalpur-II	19.21 hrs
5	05.34 hrs	400 kV Bawana-Hissar	13.37 hrs
6	05.45 hrs	400kV Bhiwani- Bhadurgarh	09.24 hrs
7	06.02 hrs	400 kV Dadri-Panipat-II	08.10 hrs
8	06.02 hrs	400 kV Bawana-Bamnauli-I	08.56 hrs
9	06.11 hrs	400 kV Bawana-Bamnauli-II	08.57 hrs
10	06.16 hrs	220 kV BTPS-Alwar	21.20 hrs
11	06.26 hrs	220 kV Meerut-Simbholi	19.34 hrs
12	06.27 hrs	400 kV Meerut-Mandola-I	10.42 hrs
13	06.49 hrs	400 kV Mandola-Bawana -I	06.53 hrs
14	06.55 hrs	400 kV Mandaula- Bawana -II	06.59 hrs
15	06.57 hrs	400 kV Dadri-Panipat-I	10.41 hrs
16	07.12 hrs	400 kV Mandola-Bareily-II	09.19 hrs
17	07.12 hrs	400 kV Meerut-Mandola-II	13.11 hrs
18	07.14 hrs	220 kV Samaypur-Palawal-II	08.26 hrs
19	07.16 hrs	220 kV Bawana- Narela -I	07.19 hrs
20	07.18 hrs	220 kV Bawana- Narela-II	07.20 hrs

21	07.23 hrs	400 kV Dadri-Muradnagar	11.16 hrs
22	07.24 hrs	400 kV Bawana- Abdullapur-II	07 .38 hrs
23	07.39 hrs	220 kV Samaypur-Palawal-I	08.25 hrs
24	07.43 hrs	220 kV Panipat-Narela-III.	16.49 hrs
25	07.44 hrs	220 kV Bawana-Shalimarbagh-I	08.28 hrs
26	07.48 hrs	220 kV Bawana-Shalimarbagh-II	08.27 hrs
27	07.48 hrs	400/220 kV,315 MVA ICT-1, ICT-2 & ICT-3 at Bawana	08.35 hrs
28	07.50 hrs	400 kVBawana -Mandola-II	08.15 hrs
29	07.50 hrs	400 kV Bawana- Abdullapur-I	10.48 hrs
30	07.50 hrs	400 kV Agra-Ballabgarh	17.44 hrs
31	07.55 hrs	400 kV Bawana -Mandola-I	08.01 hrs
32	07.55 hrs	400 kV Bawana- Abdullapur-II	08.10 hrs
33	08.09 hrs	400 kV Dadri-Malerkotla	10.11 hrs
34	08.27 hrs	400 kV Dehar-Bhiwani	10.45 hrs
35	08.44 hrs	220 kV Auraiya-Agra-II	10.20 hrs
36	08.52 hrs	220 kV Bawana- Narela-I	13.16 hrs
37	08.53 hrs	220 kV Bawana- Narela-II	09.07 hrs
38	09.00 hrs	All the feeders and ICT's at 220kV Panipat	20.38 hrs
39	10.48 hrs	400 kV Bawana- Abdullapur-I	16.22 hrs

5.0 SITE VISIT & DISCUSSION WITH SITE STAFF

5.1 The committee visited Ballabhgarh and Dadri on 02.03.07 for discussions with POWERGRID engineers, Panipat on 03.03.07 for discussions with BBMB engineers and Murad Nagar on 23.03.07 for discussions with UPPCL's engineers. It had discussions with Delhi Transco's engineers on 23.03.07 at NRPC office.

O&M practices in vogue in these organizations and feed backs from their engineers are as under:

5.2.0 Power Grid Corporation of India (POWERGRID)

5.2.1 POWERGRID system is divided into NR-1 & NR-2. Former extending from Singrauli (UP) to Panipat (Haryana) and rest of the region is identified as NR-II. POWERGRID has categorized line sections into three parts viz. normal plain area, vulnerable (i.e. forest and pollution ladden area) and highly vulnerable area (prone to high theft of tower members and flash floods). Pollution affected areas are mainly industrial belt and those in the vicinity of brick kilns and stone crushers. It resorts to manual cleaning of insulator strings using wet cloth. Such cleaning is carried out during 15th Sept. to 15th Dec. based on areas identified from readings of fault locators during flashovers, historical information and feed back of ground patrolling. In NR-1 though there is no standing crop during this period but each location can not be approached by trucks. Replacement of strings is effected only at the locations where insulator strings have shattered or where inspection from tower top reveals discolorations on surface of insulator discs or marks of power arc on insulator caps. It takes about 45 minutes to replace a string on un-energized line. Entire work of cleaning / replacement of insulator strings is outsourced. They have observed same extent of breakage / shattering of insulator both in normal and vulnerable area. The locations of fault in 400kV Bhiwadi-Bassi & Ballabhgarh – Mainpuri lines have been close to brick kilns. They have observed no trippings (during fog) in eastern part of Northern Region as that area does not have dense fog as observed in western part. POWERGRID effects ground patrolling and tree cuttings once every six months.

5.2.2 At Dadri HVDC terminal substation adjacent to National Capital Thermal Power Station (NCTPS) porcelain insulators have been used, 1 mm thick silicon grease is applied on outdoor insulators and equipment bushings during maintenance outage. It attracts pollution (mainly of suspended carbon and fly ash dust from Coal Thermal Power plant) and within few days becomes black but no flashover is observed thereon. The grease forms a hardened layer and has to be scrubbed for removal and reapplying every year during maintenance.

5.2.3 At Katra PLCC repeater station (about 120 Kms from Allahabad near Allahabad - Rewa High Way) on $\pm$ 500 kV HVDC Rihand - Dadri bipole line, vehicular movement and dust on the village kutchcha road results in accumulation of pollution. To counter flashovers in foggy season, Silicon grease is applied every year on outdoor equipments viz Coupling capacitors, bus post insulators etc. by POWERGRID. No flashovers are observed at Katra.

5.2.4 As informed by POWERGRID at 220 KV switchyard associated with Dadri NCTPS, due to high occurrence of flash over, polymer insulator

strings have been used in the strung bus and hot line washing is being carried out on all outdoor switch yard equipments. In entire 400 KV Dadri NCTPS sub-station however hotline washing is being carried out 4 times in a year. With these no flashovers are observed during winter season in 220 KV & 400 KV switchyard.

5.2.5 POWERGRID has also carried out the pollution measurement recently using dummy disc insulator strings on approximately one tower every 75 km. These measurements have indicated equivalent salt deposit density of 0.1 mg/sq. cms and 0.184 mg/sq.cms at location no. 108 and 84 respectively on 400 KV S/C Ballabhgarh - Bhiwadi line. Measured value on 400 KV S/C Ballabhgarh -Agra line in Bullandsahar district was 0.068 mg/sq. cms. These values are much above the design level 0.03 mg / sq. cms.

5.2.6 On Rihand – Dadri HVDC line, polymer insulators were installed in the year 1997 on experimental basis (at location nos. 1847, 2007, 2024, 2093 in Pole – I and at location nos. 1843, 1891, 1961, 2093, 2099, 2121, 2124 & 2135 in Pole – II) in suspected polluted stretches.

5.2.7 During the discussions held at Panipat, POWERGRID reported that polymer insulators have also been used on 400kV Ramagundam – Hyderabad line on account of industrial pollution and 400kV Jeypore-Vishakhapatanam line due to sea-salt pollution. On Jeypore-Vishakhapatanam line long rod polymer insulators have been used since commissioning of line since 1999 for 1.395 km of length. On Ramagundam – Hyderabad - II circuit, these were provided since 1997 for 7.946 km length. All the polymer insulators used at above mentioned locations are in continuous operation successfully since their installation.

5.2.8 400 k V Dadri – Panipat line employs toughened glass insulators. The pollution flashover are reported on this line also. However, even though flashover sometimes causes shattering of the insulator, insulator string is not broken and transmission line does not fall to ground.

5.2.9 No tripping was observed in Tehri-Meerut line during foggy conditions. This line passes through sugar cane belt and does not have brick kilns. This line is of 765kV insulation, charged on 400kV and has creepage distance of 40mm/kV for vertical strings and 35 mm/kV for V strings (calculated with reference to system voltage of 400kV).

5.2.10 Fog related flashovers have occurred in certain stretches of 400 KV S/C Ballabhgarh - Agra line where it passes through barren land with salt deposit (locally called ‘rai’). On the same line fog related flashovers have also occurred in agricultural areas.

5.2.11 It was stated that tripping on 400 k V Agra – Ballabhgarh line has reduced considerably after iron bird guards were provided. POWERGRID

informed that they are providing bird guards for all future lines as well as at selected locations in existing lines.

5.2.12 Looking at wide spread flash over taking place on EHV lines during foggy season and also massive programme of expansion of transmission network in Northern Region. POWERGRID had proposed procurement of helicopters for insulator string washing and other transmission line maintenance activities.

5.2.13 Few Insulator which had strings failed on 27.01.07 were inspected by the Committee. Pollution deposit was visible on the surface in the form of black dust underneath the insulator petticoats. There were number of marks of heavy power arc on cap of a number of units of the strings and crack of insulator cap and the complete breakage of insulator disc were observed in one of them.

5.2.14 Rihand _Dadri HVDC have insulator strings with a creepage distance of 41 mm per kV. There has been number of autorestart. It was stated that insulators strings on pole-1 were cleaned in Oct 06 and pole-2 had been under outage for long duration (middle of Aug. 06 to Dec 06) due to transformer failures and this time was utilized for insulator cleaning. Fault locations are close to sugar cane crushers (which burns molasses for steam generation) and industrial areas. Sugar cane crushing season is from October to March every year.

5.3.0 Bhakra Beas Management Board (BBMB)

5.3.1 BBMB operates two 400 kV lines (viz. Dehar –Panipat and Dehar – Bhiwani) and number of 220 kV lines. They had one tripping on Dehar – Bhiwani line at tower location no. 761 about 1.5 kM from brick kiln. Other tripping were on 220 kV Bhakra – Jamalpur line 1 & 2 due to breaking of earthwire. There are dying units in neighbourhood which burns rice husks. BBMB has not carried out any pollution measurement but in the areas, where frequent flashovers are observed, BBMB has replaced normal 315 mm creepage distance insulator discs by 432 mm creepage distance anti fog insulator discs. Such replacements have been effected on 30 towers of Dehar – Panipat line passing through polluted industrial area near Panipat, Bilaspur(HP) and Derra-Bassi (near Chandigarh). BBMB carries out O&M departmentally through 5 subdivisions. During 20.9.06 to 01.12.06 they have cleaned manually the insulator strings using wet cloth, and thereafter during next 15 days it has cleaned insulator strings of susceptible area. BBMB engineers feel that insulator string can not be cleaned thoroughly (specially underneath the petticoat part) at cross arm level and their practice is to lower down the insulator string and replace it by thoroughly cleaned insulator string during maintenance outage during the year. Insulator strings so lowered down is thoroughly cleaned at ground level and utilized at other location. Their attempt is to effect such replacement of all the strings in a span of 5 years. As per their experience a gang of 2 persons affects cleaning of

insulator strings by wet cloth for 3 towers in a day except in hilly areas. Lowering of insulator string requires a gang of 15. Statistics indicate increasing number of strings have been cleaned by them on account of rising pollution. This year they have effected cleaning of 50% of the strings on Dehar –Bhiwani line and 25% of the strings of Dehar – Panipat line.

5.3.2 Survey of line using thermo-vision camera is effected by them once in 2 years to locate hot spots on line (i.e. clamps / joints) and to take remedial measures during shut down.

5.3.3 They had carried out live line maintenance by live line maintenance crew trained at Hot Line Training Centre (HLTC), Bangalore and it effected replacement of insulator strings of 2 towers in a day. It was stated that this was on account of permitted exposure of live line crew to high voltage level only for 2 hours in a day.

5.3.4 Insulator strings failed in BBMB on 27.1.07 were also inspected by the committee and it was observed that insulator strings were practically clean and had only 1-2 power arc marks on caps. They bore no sign of pollution on insulator string.

5.3.5 ***BBMB engineers also brought out that Punjab, Haryana and Himachal Pradesh Governments have notified that no brick kiln can be operated within 500 meters of H.V. lines. Copy of these notifications are at Annexure -VIII - A, B & C.***

5.4.0 Delhi Transmission Company Limited (DTL)

5.4.1 Infra red scanning of the lines is carried out especially on the tension towers to evaluate the condition of clamps.

5.4.2 Insulators of selected locations where the faults have taken place earlier or where during the patrolling blackening of insulators is noticed, the cleaning is carried out by jute and there after washing of insulators is carried out using normal water filled in tubes of the car tyres and carried on to the tower top by the workers.

5.4.3 Pollution level in Delhi has increased over a period of time. Geographical location of Delhi is being such that traffic from East, West, South and North passes through Delhi on NH-1, NH-2, NH-8, NH-10 and NH-24 etc. Heavily loaded trucks have been passing through Delhi, these trucks are high speed diesel driven and emit lot of un-burnt carbon particles causing blackening of insulators at some selected locations of 220 kV and 400 kV lines. Pollution level show detrimental effect on transmission line and during the period when the night temperature falls below 10^0 C, heavy fog engulfs the whole area. The lines are patrolled regularly and condition of insulators is monitored through high power binoculars.

5.4.4 On Bawana -Bamnauli line, insulator tracking / flashovers are observed near fishery ponds which results not only in foggy conditions but due to bird droppings. Further near Gajipur which is the chicken Mandi for sale of chickens, large number of vultures sit on tower cross arms. There are high trippings due to bird droppings. Providing of bird guards on all towers have been dispensed with following the earlier POWERGRID practice and these are now provided only at selected locations. Attempts were made to provide bird guard of plastic with proper adhesive, on the pattern of Delhi Metro Rail Corporation, but not found to be successful. Now it is proposed to provide bird guard made up of steel with proper clamping, on the pattern followed by POWERGRID on Agra - Ballabgarh line. They are proposing to providing bird guard on all new lines.

5.4.5 Some of the 400kV lines, which pass through the territories of Haryana and U.P (i.e. on the section Bamnauli - Ballabgarh and Mandola-Bawana), there are incidences of flashover where either due to stone blasting or burning of bagasse, pollution has shown increased trend causing deposition of carbon particles on the insulators which give way during foggy conditions in winter months.

5.4.6 Due to kite flying by metal powder coated thread, trippings have taken place during the summer months when the kite flying is prevalent. Action is being taken to ban the kite flying on 15th August, Janamashtmi, Raksha Bandhan and Basant Panchmi etc. There is provision in the law that empowers DCP of the area banning the kite flying under special circumstances.

5.4.7 Almost all their 220kV lines are passing through the areas where right of way have already been encroached upon by unauthorized construction and they apprehend that probably the helicopter washing may cause resentment from the residents occupying such dwelling units. They expressed that since the pollution is mostly caused by the vehicular traffic, which is more or less constant on daily basis, frequent washing of insulators would in any case be necessary.

5.4.8 They stated that their lines have been designed at a particular pollution level and the creepage distance of insulators corresponding to 20 mm per kV, but in 400kV grid stations, the creepage distance adopted is 25 mm per kV.

5.5.0 Uttar Pradesh Power Corporation Limited (UPPCL)

5.5.1 UPPCL stated that they have washed disc insulators on 60 Nos. towers during the season. Washing is carried out by using Nirma detergent powder and pouring full bucket of water. Such washing is done on selected locations based on past experience. Washing is done by outsourced person under supervision of AE/JE. Heavy fog in the vicinity

of Upper Ganges canal & Hindon river had caused failure of disc. Insulator. At such locations anti fog insulators have been provided based on studies got carried out at IIT Kanpur.

5.5.2 Insulator flashover and breakage was observed on 3 Nos tower of 400 kV Muradnagar- Agra line near industrial area of Sikandrabad. This area is having smoke prone atmosphere. Anti fog insulators have been provided on selected location on these lines. On Panki- Muradnagar line 13 numbers of towers normal insulators have been changed by anti fog type. It has improved line performance during foggy condition. They stated that a normal disc costs about Rs. 600-700 where as anti fog type cost Rs. 800-900.

5.5.3 Besides pollution flash over, cementing failure near pin of insulators was observed in eastern area of U.P. On 400 kV Unnao-Agra-Muradnagar line disc insulator has been increased in V string. Bird guards have also been provided at selected locations. 103 km of MuradNagar – Agra line have been provided with bird guards.

5.5.4 On 27.01.07 autoreclose lockout occurred on 400 kV Muradnagar- Dadri line at 0724 Hrs. It could be restored back after about 4 hours at 1116 Hrs after clearance from Central Load Despatch Station (CLDS) Lucknow. In the meanwhile line has been autoreclosed from Dadri 5 times at 0724, 0752, 0754, 0755 & 0811 Hrs before locking out at Dadri. It was stated that with recurring transient fault on line, closing from Muradnagar would have been of no help and system stability was thus not adversely affected, even after auto reclose lockout.

5.5.5 Protection system is checked annually.

6.0 ANALYSIS OF TRIPPING AND REMEDIAL MEASURES

6.1 It is observed that highest trippings and net loss of load was at 0812 hours. A vertical line at 0812 hrs on both graph of Annexure – VI indicate that the gap between tripping and restoration in 220 kV line is larger than 400 kV lines. Higher gap between tripping and restoration on 220 kV has been on account of the fact that unlike all 400 kV lines which are equipped with auto-re-closing, number of 220 kV lines do not have auto re-closing facility.

6.2 Pole I & II of HVDC Dadri - Rihand line were taken in RVO mode as per operational guidelines at 0336 hrs & 0432 hrs respectively. After that there was no auto-restart on pole – II, however Pole -1 experienced 18 auto-restarts showing heavy contamination on this circuit. Fault locaters have indicated location of flashovers at 4.9, 5.0, 8.4, 10.9, 11.0, 17.9, 18.1, 18.3, 21.2, 21.6, 21.7, 25.7, 27.3, 29.0, 29.1, 29.2, 29.3, 32.8, 122.1, 132.1 kms from Dadri. Considering a band of about 2 km on either side of fault as occurred on 27.1.07, the region of heavy pollution appears to be 3-13, 16-35 , 120-124 and 130-134 kms i.e a span of 37 km in line length of 815 km.

6.3 In the Northern Region winter rains are preceded by heavy foggy conditions usually in December – January. During heavy fog conditions, there has been trippings of transmission lines in Northern region in earlier occasions also i.e. previous winter seasons, notable were on 02.01.2001, 23.12.2002, 23.12.2005 and 16.2.2006. During this winter season transmission line trippings have been observed on 12, 23, 27, and 31.12.2006, 27, 28, 29.1.2007, 01.02.2007, 08.02.2007 and 09.02.2007. It was also noted that winter rains, whether before or after the onset of foggy season, reduced the number of trippings in subsequent foggy days.

6.4 Pollution related flashovers of insulator strings can be considered as the prime reason for such trippings in the winter seasons. The reduction in number of trippings in subsequent foggy weather after experiencing the rains in the region also establishes the fact that pollution deposits present on insulator surface could be the reason for flashovers during fog conditions and its frequency got reduced after rains possibly due to washing out of some pollutants from the insulator surface by the rain water.

6.5 **Pollution Flashover Mechanism[1,2]** : Wind drives airborne contaminant particles onto the outdoor insulator surfaces. Insulators near coastal areas are contaminated by wind driven salt and those inland, by wind driven soil dust, fertilizer deposits, industrial emissions, fly ash and construction activities, etc. Depending on proximity to highways and traffic, the wear of car tyres produces a slick, tar-like carbon deposit on the insulator's surface. It is inland pollution which is relevant to flashovers of line insulators in northern region and consequent the trippings of number of EHV lines.

6.6.1 The pollution level in some of the stretches of any transmission line can increase during its service life due to other progressive developments taking place in the vicinity of the transmission lines. The increase in levels is predominant in areas where:

(i) Industrial development has taken place after line construction (Fig-1)

Fig-1: Pollution Deposits On Insulator Strings Due To Industrial Emissions

(ii) A surge in agricultural activities using chemical fertilizers have taken place

(iii) Burning of agricultural waste is carried out after harvesting (Fig-2.)

Fig-2: Burning of Agricultural Waste

(iv) Brick kilns are in operation near to transmission lines (Fig-3a&b.)

Fig-3a: Smoke from Brick Kilns polluting Transmission Line

Fig-3b: Smoke from Brick Kilns polluting Transmission Line

(v) The normal soil itself has soluble conductive ingredients and there are dust storms and fewer showers (Fig-4.).

Fig-4: Dust Accumulation On Insulators

(vi) There is change in climatic pattern with less magnitude and frequency of rain

(vii) Birds are nesting on the transmission towers and its excreta falling and accumulating on insulator strings(Fig-5.)

Fig-5: Deposits On Insulator Surface Due To Bird Droppings

(viii) Increased vehicular traffic is observed with consequent vehicular emissions

(ix) Conductive fog conditions prevails due to increase in atmospheric pollution

6.6.2 In the Northern Region, all round developments are taking place in all sectors viz., industrial, agricultural, automobile and infrastructure sectors like road, rail etc. All these progressive developments and related construction activities gradually increase the risk of more and more stretches of transmission lines getting exposed to higher and higher pollution over the years during the course of its service life. The type of pollution experienced by Northern Region lines as reported by the Utilities are pollution on account of smoke from brick kilns, refineries, sugar mills, burning of agriculture waste, fertilizer, dust, salty soils, automobile emissions.

6.6.3 The flashover process develops in the phases as under:

i) Insulators operating in polluted atmosphere collect pollutants on insulator surfaces. Deposition of pollutants on insulator surface depends on many factors e.g. shape of insulator, nature of voltage (i.e. AC or DC), location, angle of inclination of insulator, wind, rain etc. The continuous depositing and cleaning by rain and wind produces a seasonal variation of the pollution on the insulator surfaces. The performance of the insulator itself is not altered significantly by the presence of dry contaminant because the electrical strength of a dry polluted insulator is close to that of a c1ean insulator. The pollutant particles are of both soluble and non soluble nature and contaminates the insulator surfaces.

ii) Porcelain and glass are easily wetable. Moisture in the form of fog, mist, drizzle, light rain or dew impinging on the insulator surface wets the pollution layer, dissolving the salts and soluble electrolytes produce a thin conducting layer on the insulator surface.

iii) Wetting of the contamination layer and consequent formation of a conductive layer on the insulator surface causes flow of leakage current through the surface when the insulator is under energized state. The leakage current flow generates heat due to I^2R losses and it heats the conductive layer. Surface deposit and wetting of deposit is not uniform. In the area of higher current (density around pin) the heat dissipated would be greater and therefore moisture dries more rapidly at these locations leading to the formation of dry bands. These dry bands have higher resistance than of other areas which are still moist. Due to the high resistance, the voltage drop across the dry band also would be more and sometimes become sufficient enough to create an electric arc across the most stressed dry band. Arc short circuit the dry band and heat generated keeps the bands dry and contributes to the overall drying process. Due to short circuiting by the arc the resistance of the dry band is quite low and therefore the leakage current increases further and leading to formation of other dry bands. Arc propagates along the insulator surface. In many cases arc extinguishes while in some cases flashover of insulator unit (unit 6) take place and the line trips.

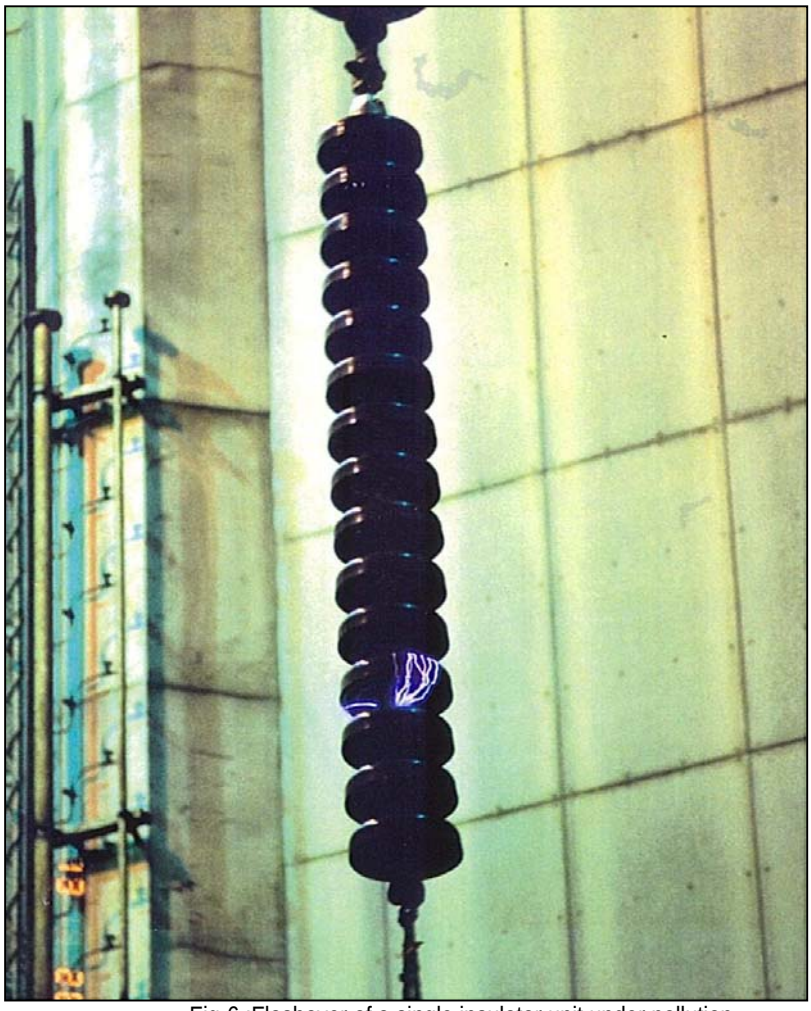

Fig-6 :Flashover of a single insulator unit under pollution

v) When one insulator unit has flashed over, as explained above, the leakage current flow along other insulator units in the string increases and the dry band arcing gets accelerates and progresses to other insulator units leading to arc cascading on the complete insulator string resulting in insulator string flashover (figure 7) and line tripping.

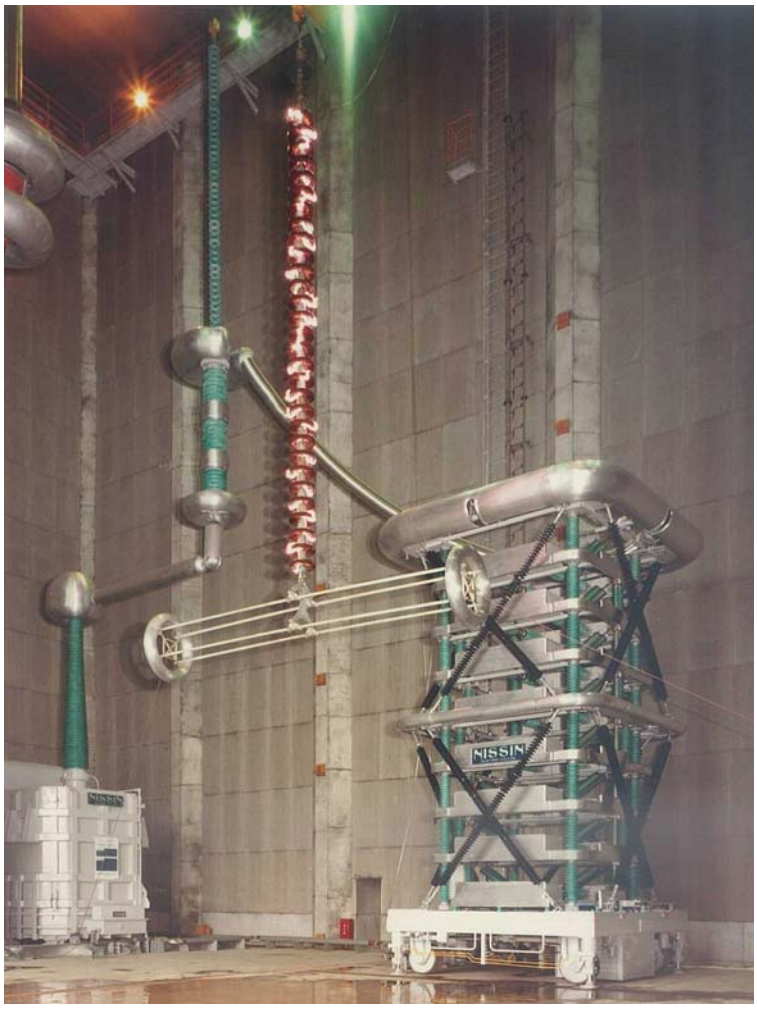

Fig -7 : Complete Flashover of an Insulator String under Pollution

6.7 It has been observed that DC flashover voltages are lower than the AC under the same operating conditions. More pollutants are attracted to an insulator under DC voltage than AC and it is higher on positive polarity. Also, due to absence of current zero in DC, the propagation of arc is easier than in AC and its arc quenching is more difficult.

6.8 Once a pollution flashover takes place on a string, it can repeat. As such wherever pollution flashover is observed at any location in a day of heavy fog that location be considered as of concern.

6.9 The severity (degree) of the pollution is characterized by the equivalent salt deposit density (ESDD). It is measured by periodically washing down the pollution from selected insulators with distilled water and measuring the conductivity of the collected water by determining and equivalent amount of salt in mg., which produces the same conductivity. This value is divided by the surface area of the insulator from where the pollution was washed to determine the applicable ESDD level.

6.9.1 Typical ranges for pollution severity in terms of ESDD (in mg/cm2 of insulated surface) for inland pollution and salinity (in kg/cum) as provided in IEC 60815 "Guide For the Selection of Insulators in Polluted Conditions" is as under.

Table - Pollution levels and creepage distances

Pollution level			Minimum nominal specific creepage distance
Category	Equivalent salt deposite density	Salt fog method	
	(mg/sq. cms)	(kg/cub.meters)	(mm/kV)
Light	≤ 0.06	≤ 14	16
Medium	> 0.06 & ≤ 0.20	> 14& ≤ 40	20
Heavy	> 0.20 & ≤ 0.60	> 40 &≤ 160	25
Very heavy	>0.60	> 160	31

Notes:

1. This table is based on table II & III of IEC – 60815 with appropriate changes made by the committee.
2. For actual creepage distance manufacturing tolerances, as permissible under IEC-273, 305,433 or 730, is applicable.
2. Specific creepage distance in mm/kV is ratio of creepage distance measured between phase to earth and r.m.s. phase to phase value of highest voltage for the equipment / line.
3. In case of exceptionally high pollution level, a specific nominal creepage distance higher than 31 kV/mm may be adopted based on service experience and /or on laboratory test results however before that practicability of washing or greasing may be considered.
4. Specific creepage distance less than 16 mm/kV is not recommended by the Committee.

6.10 Shri Vasudev of CPRI made a presentation on 2.3.07 showing pollution flashover of insulator string in salt-fog chamber in laboratory. He stated that laboratory testing has established that silicon polymer insulator have hydrophobicity and on account of this, salt fog pollution does not affect its flashover. Silicon insulators do not require high pressure washing. They are light in weight and one man can carry them to tower height. However no leg to be placed on these insulators while carrying out maintenance of line.

6.11 It is the inland pollution which has resulted in fog related flashovers in Northern Region. Remedial measures to eliminate / contain fog related flashover emerges out of the flashover mechanism described above and the fact as observed by NRLDC, POWERGRID, BBMB, UPPCL and DTL that once winter rains sets and washes the contaminates on insulators no fog - flashovers take place even under heavy fog. This leads to conclusion that **increasing the leakage path (i.e. creepage distance) to reduce leakage current, cleaning/washing of insulator strings (to make it pollution free or less polluted), making the insulator surface hydrophobic (to avoid wetting and dry band formation) or making**

the insulator surface semiconductive to contain voltage across dry band and avoid its flashover, will reduce flashovers under fog. These remedial measures have been adopted in one or other form internationally as under.

6.11.1 Providing Higher Insulation

i. Using anti-fog disc insulators with longer creepage distance .This results in reduced leakage current due to longer path. Antifog disc insulators are in use in moderately polluted environments in India and under these conditions the performance has been generally satisfactory.

ii. Using Porcelain long rod insulators with alternating sheds and higher creepage distance. Porcelain Long Rod Insulators have open shed profiles and hence facilitate better cleaning under natural rains as well as reduced accumulation/pollutants. Further, these insulators are puncture proof and hence insulation reduction due to puncture is not expected and would demand only less maintenance when compared with disc insulators.

iii. Using of semi conducting glaze disc insulators. A conductive layer is formed by the glaze and this conductive layer below dry band will reduce electric stress across dry band thereby reducing probability of its flashovers. However, the continuous conductive path through the glaze results in additional electric losses. Moreover, such insulators are manufactured only by limited number of manufacturers.

iv. Use of composite long rod (polymer) insulators with Silicone impregnated (SIR) weather sheds. Composite (Polymer) insulators having silicone/silicone based weather sheds have been recognized for their superior performance in pollution environments. The migration of low molecular weight silicone molecules from the weather sheds onto the contaminant layer accumulated on insulator surface making it hydrophobic (figure 8), reduces the effective soluble contaminant density and therefore reduces the leakage current flow as compared to ceramic insulators. This minimizes the dry-band arcing on the insulator surface. As long as the surface is hydrophobic this behavior is retained and flashover probability under pollution conditions shall be less than that of its porcelain or toughened glass counterpart under identical environments.

Fig-8 :Hydrophobic Surface of Composite long rod insulator

In the Report of Cigre on "World wide Experience With HV Composite Insulators" published in Electra No.191, August 2000 Working Group has stated that (i) in general the main reason to use composite insulators is because of their good performance under pollution and (ii) composite insulators are now a well accepted substitute for conventional porcelain or glass insulators.

6.11.2 Application of Silicone Grease on Insulator Surface

Application of silicone grease on porcelain / glass insulators to make them hydrophobic and there by avoiding conductive layer formation / dry band arcing etc have been practiced by some utilities.. Alternatively spray of silicone paint too has been reportedly tried. Requirement of scrubbing the existing silicon grease before application of fresh layer, poses practical problems in case of line insulators. This methodology is more appropriate for substation insulation.

6.11.3 Cleaning / Washing of Insulators

Cleaning/ washing of insulators have been adopted by Utilities to remove pollutant deposits from insulator surface. The methods generally practiced are:

i. Cleaning the insulator surface manually including scrubbing of firmly deposited insoluble pollutants like that from the cement industry.

ii. Washing the line insulators using high pressure water jet. This can be accomplished either from ground level or from cross arm level of transmission line tower or using truck mounted / telescopic boom with high pressure water spraying equipments or by high pressure water spraying using helicopter. Both hot line and off line washing are in practice.

7.0 INSULATION CREEPAGE DISTANCE

7.1 For transmission lines up to 400kV level

7.1.1 EHV standardization committee (vide Annexure IV of its report) has classified pollution levels and recommended phase to ground creepage distances as under:

Pollution level	Type of test		Recommended creepage distance phase to earth mm
	Salt-fog Kg/m2	Layer conductivity Micro siemens (i.e. micro mhos)	
Light pollution	10-20	10-20	7800
Heavy pollution	40-80	20-40	10500
Very heavy pollution	>=160	>50	14580

Table1. Classification of Pollution levels depending on severity (Ref :Report of EHV std. committee)

7.1.2 Based on these recommendations, creepage distance of 10500 mm has been adopted for substation equipments which correspond to heavy pollution level. It has been observed that insulators in the substations in the region did not generally experience pollution flashovers as in the case of transmission lines. As far as transmission lines are concerned, light pollution level along the line routes had been assumed in general (i.e. 16mm/kV creepage distance) where specific data on pollution levels were not available. Accordingly 23 nos disc insulators with 315 -330 mm creepage distance per disc insulators are provided in the 400 kV insulator strings. Insulator strings with 23 disc insulators as mentioned above provided in 400 kV Transmission line were found to be adequate for light pollution level having ESDD level of 0.03-0.06 mg/ sq.cm on the insulators and the transmission lines designed with these considerations have been functioning satisfactorily in lightly polluted areas.

7.2 500 kV HVDC Bipole Rihand to Dadri

For the HVDC Bipole designed during the late eighties, the expected pollution levels had been extrapolated from the level considered for AC lines in that region which was light pollution at that time and about 50 % extra for DC effect had been incorporated. The pollution level for HVDC Rihand- Dadri line thus considered during design was 0.045 mg/sq.cm ESDD and creepage distance of 41.4 mm/kV. On this basis, 38 nos. of 540 mm creepage distance (approx) antifog HVDC disc insulators were provided in suspension (V string configuration) and tension insulator strings. The design was also successfully verified through pollution tests in the laboratory. Moreover, with increase in pollution level, flashover have taken place even at reduced voltage level.

7.3 The above-mentioned insulation design concepts for AC and HVDC lines have been working satisfactorily where pollution levels are not more than the design limits. The performance has been however affected where pollution level had increased as discussed.

7.4 **Consequence of Pollution levels Exceeding Design Limits**

The environment in which an insulator is installed has significant impact on the insulator performance. In polluted environments as explained above, both soluble and non-soluble deposits get accumulated on insulator surface, which influence insulator performance. A.C. and HVDC line insulator strings designed for polluted conditions as explained above have been observed to be in adequate with increasing pollution and flashover on HVDC are observed even under reduced voltage (80 % operation mode). The various sources of pollution that were found to affect those insulators are Industrial affluent, burning of agricultural waste, large scale use of fertilizers in cultivated fields, exhaust from brick kilns, bird excreta, dust containing soluble salts etc. It has been noticed that vehicular and industrial emission, brick kilns, nesting of birds, soil having conductive ingredients etc are the major causes of insulator pollution in the region and are experienced in some stretches of the lines.

7.5 When there is pollution accumulation on insulator strings, it becomes the deciding factor for insulator string performance even under normal operating voltage conditions in situations of dense fog, mild rain etc and the insulation should be capable of withstanding the operating voltage under these conditions.

7.6 As per IEC-60815 “Guide for Selection of Insulation for Pollution”, considerable increase in creepage distance are required to counter increase in pollution levels from lower severity level to higher severity levels. As the pollution level experienced by certain stretches of the lines had undergone change, the insulation provided for a lower severity would not be adequate to offer trouble free service under dense fog conditions.

7.7 From the above it can be inferred that the reasons for frequent trippings of transmission lines of Northern Region in the days of dense fog are mainly:

(i) Increase in pollution levels on account of various pollution causing developments/ activities taking place in the region viz., industrial& agricultural activities, brick kilns etc.
(ii) Change in climatic pattern with less number of winter showers prior to foggy days and more number of foggy days.
(iii) The conventional maintenance practice not offering desired level of productivity and efficiency to the Utilities
(iv) As a consequence of the above, insulation for light pollution level as provided at the time of construction of lines becoming inadequate and therefore experiencing pollution flashovers under dense fog conditions

7.8 The above details also reveals that a multi prong strategy for mitigation of pollution related flashovers would be essential so that power system security in Northern Region is not adversely affected. In regard to selection of insulators, the IEC- 60815 'Guide for the Selection of Insulators in respect of Polluted Conditions" indicates that, "In exceptional cases, pollution problems cannot be solved economically by good choice of the insulator. For instance, in areas having very severe contamination or low annual rainfall, insulator maintenance may be required. This can also occur when the environment of an already built substation (or line) changes due to new polluting industries".

7.9 Cleaning and Washing of Insulator

7.9.1 The practice adopted by various utilities in the northern region vary from wet cloth cleaning (BBMB) & POWERGRID) to washing of insulator (UPPCL & DTL). It also varies from cleaning of all insulator strings at sites or replacing the insulator string to effect in such cleaning in some selected spans. High pressure water washing has not been employed. Information gathered by the Committee by internet surfing reveals that Southern California Edision[3] are using truck mounted live line insulator washing system. Their truck can carry 1200 to 6000 gallons of water and are equipped with 75 to 100 feet hydraulic actuated boom with nozzle and water pump are capable of discharging 60 gallons per minute at 700Psi. Insulator is washed in about 15 seconds. National Electric Power Company[4], Amman (NEPCO) after training their personnel and using two mobile skid mounted insulator washing units carried out live line washing of 808 towers of 400 kV transmission line from Aquaba to Amman in 90 days. This line in Jordan was initially energized on 132 kV for 12 Years and have major breakdown when energized on 400kV. It has ESDD of 0.2 mg/sq. cms. After live line washing there was no pollution flashover. NEPCO also has one telescopic boom insulator washer with about 50 meter high nozzle for use on flat agricultural terrain. Live line truck mounted insulator washing systems up to 400 kV and 1000 psi water pressure are also supplied by M/s Wiltron[5] and EGI[6]. Figure-9 illustrate telescope boom insulator washers.

Fig 9 : Telescope Boom Insulator Washer

7.9.2 Regarding helicopter based live line washing, a number of companies viz Aeropower[7], Heliwing[8], Haverfield[9], USA airmobile[10], Mt. Hutt helicopter corporation[11], are providing helicopter borne live line washing, indicating that this helicopter borne system is quite in use. M/s Aeropower and Mt. Hutt helicopters uses MD500 helicopter. MD500 helicopter[12] can have useful pay load of 1450 lbs (658 kg) for fuel personnel and cargo. Standard fuel load is 400 lbs.(60 gallons, 1 gallon=3.7854 liters) and fuel burn rate of 180 lbs. thus it can fly for 2.2 hours before refueling. It can hover and land virtually anywhere (even on landing platform on truck) figure 10 &11. With above fuel load, weight of pilot and one technician, it may require refilling of water in about 10-15 minutes. US patent 4477289 claims washing of 300 strings of 220 kV line in 10 mile (i.e. 16 km) span in 5 hours.operation[13]. Aero power claims productivity of up to 10 times over the ground based methods by using air borne washing techniques. In absence of experience of helicopter based line washing in the country, mobility and speed achievable in India need to be ascertained

Figure –10: Truck mounted Helipad

Figure –11: Washing of V- string using Helicopter.

7.9.3 A committee was constituted during the meeting of the utilities of Northern Region on 6th Jan 2006, taken by CMD, POWERGRID to look into the feasibility of use of helicopter for washing of the insulators of POWERGRID's transmission lines to avoid reoccurrence of such incidence. The recommendations of the committee was discussed in 6th and 7th meeting of operation coordination committee (OCC) held respectively on 8.9.06 & 09.10.2006. Constituents of NR expressed that acquiring of helicopter may be costly and hot line washing may not be a cost effective alternative, Therefore, it was decided that a pilot project

might be taken up by outsourcing the work of cleaning of insulators and if found successful issue of acquiring of helicopter may be considered again. This issue was then discussed in 2nd TCC meeting & 3rd NRPC meeting held respectively on 9th and 10th Nov. 2006. wherein it was stated that using helicopter on outsource basis as compared to outright purchase, would be desirable as the effectiveness of this technique was yet to be established.

7.9.4 The committee observed that in areas with light pollution (e.g. most of the BBMB or eastern UP or Rajasthan's system, normal creepage distance insulators with manual wet cloth cleaning of insulators has not resulted in flashover during fog. However with medium pollution like that in some part of BBMB's system higher creepage distance insulators with manual wet cloth cleaning has performed satisfactory. Polymer insulator string or silicone greasing has been effective in heavy polluted conditions. Latter though suitable at substation may not be so for transmission line as scrubbing of grease from the insulators will be cumbersome and time consuming. However for polymer insulators cleaning / washing is to be avoided. The creepage distance and pollution are the main parameters affecting fog flashovers. **The committee therefore proposes that pollution measurements on transmission lines need be undertaken in the regions 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 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 one location selected for a 50 km distance 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]**

7.9.5 The committee observes that pollution is local phenomena and its disbursement and deposition on insulator strings is dependant on wind direction , wind speed, rain washing etc. Therefore practice to be adopted will vary along the length of the line as per pollution levels measurements (ESDD). The Committee suggests that entire line length shall be classified as stretches of light, medium, heavy and very heavy pollution. Medium, heavy and very heavy pollution stretches shall further be categorized to washable and non washable pollution. Non washable pollution shall consists of pollution near cement plant, fly ash disposal / transportation, fertilizer plant, lime stone / rock phosphate quarries or chemical plant which firmly adheres to insulator surface and can be removed only by scrubbing. For new lines such stretches shall be identified during survey. Light, medium heavy and very heavy pollution will correspond to ESDD of less than 0.06, less than 0.20 and exceeding 0.2 mg/sq.cms as mentioned in the IEC 60815.

7.9.6 Pollution level measurements will take 2 – 3 years. Till the data are created by ESDD measurements, pollution level may be considered as under for inland pollution.

1. Light pollution	All line stretches not covered by medium heavy and very heavy pollution
2. Medium pollution.	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 $\pm$ 2 kms (as per distance to fault locator or visual inspection) where atleast 3 flashovers has been observed in one single foggy day with normal creepage distance porcelain / glass discs.
3. Heavy pollution.	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 $\pm$ 2 kms where atleast 3 flashovers has been observed in one single foggy day with high creepage distance porcelain / glass discs.
4. Very Heavy pollution	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 $\pm$ 2 kms where more than 3 flashovers has been observed in one single foggy day with high creepage distance porcelain / glass discs.

7.9.7 Present practice of using porcelain insulator string units of 300 – 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 disc insulators of creepage distance of 440 mm or higher (corresponding to creepage distance of 22 mm /kV for 400 kV lines of the 23 disc) or Porecelain longrod insulators offering equal creepage distance may be employed with insulator profiles 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 distance of 25 mm/kV and 31 mm / k V respectively as per table at para 6.7.1 may be employed.

7.9.8 In respect of lines in operation ,whether existing or new ones, insulator strings with normal creepage distance shall be replaced by that with antifog type insulator strings or silicone rubber insulator strings depending upon pollution levels as above.

7.9.9 Prevalent schedule of cleaning of insulators from 15th Oct to 15th Dec every year has been found satisfactory in light / medium pollution areas and may be continued. However in the region of higher pollutions earlier cleaning may result in further pollution deposits in the intervening period and may render the cleaning ineffective so far as fog pollution flashovers are concerned. As such cleaning in such areas be effected, if possible, in Dec. or that effected earlier may be repeated after 15th Dec. as may be necessary

7.9.10 Cleaning of insulators in the areas of medium or heavy pollution with non washable contamination, shall be effected by hand scrubbing or compressed air with abrasive substance like ground corn cob mixed with ground walnut or pecan shells[14].

7.9.11 Cleaning of insulators in the areas of medium and heavy pollution cum washable contamination, manual cleaning of insulators may be progressively replaced by high pressure water jet live line washing wherever approach of truck mounted or telescopic boom washers is feasible. Else the practice of replacing polluted string with string thoroughly washed at ground level may be effected. Helicopter washing to be resorted in the areas where approach of truck mounted washers / telescopic boom washers is not feasible or where due to high pollution, higher frequency of pollution accumulation and speed of operation so demands. Cleaning of insulators shall be carried out as per IEEE 957 (abstract placed at annexure –X) However feasibility of helicopter washing need be first examined as per IEC 957 2005

7.9.12 The committee also state that where distance between spray nozzle and conductor during live line washing using ground operated equipment can be minimum 6.10 meters for 400kV line (4.57 meters for 220 kV line), water of resistively 3000 ohm – cms (1300 ohm-cms) or higher can be used. [14] . Where it is not feasible, Demineralised water of resistivity of the order of 50000 ohm-cms shall be used. Leakage current through nozzle shall be continuously monitored and with nozzle earthed it shall not exceed 2 mA[14]. For helicopter washing water of resistivity of minimum 2600 ohm-cms (for 400 kV)shall be used to avoid flashover of insulator while washing[14].

7.9.13 It may not always be feasible to have shut down to effect string replacement as above. Live line replacement by outsourcing or creating live line maintenance facility in the organization and training the personnel for live line maintenance at HLTC.

7.9.14 The committee recommends that state governments of Rajasthan, UttarPradesh, Uttrakhand, and Delhi may also notify that no brick kiln or any industrial unit or biomass or diesel based power plant having chimney height upto 30 meters shall be set up with its chimney within 0.5 km of the 220 kV or higher voltage transmission line. Government of 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 upto 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 500 meters of lines are shifted.

7.9.15 The committee also recommends that 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.

7.9.16 No detergent or soap water be used for cleaning of line insulators under energized conditions. If used for cleaning during un-energised conditions, this should be followed by a low-pressure flood rinse with clean water to remove any residue. Solvents are not recommended. Solvents may be used only after manufacturer approval, provided all cleaning residue are removed by the final clean water rinse.

7.9.17 Syncronising facility wherever provided need be kept in working conditions, specially before onset of fog. 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.This will aid to stability of system.

8.0 MAINTENANCE AND DESIGN PRACTICES

8.1 The review carried out by the committee regarding maintenance practices for which the details are explained in the report revealed that presently the utilities generally depend on conventional methods for maintenance of insulators of transmission lines in the polluted stretches like manual cleaning, washing etc. In order to ensure satisfactory pollution performance of insulators, the insulators in all the polluted stretches are required to be cleaned immediately prior to onset of winter and there should not be much time gap between the time of cleaning and the occurrence of dense fog conditions so that considerable amount of pollutants are not again deposited on insulator surfaces affecting its performance under dense fog. Therefore only limited time is available on the part of the utility to

commence and complete the insulator cleanings. It appears that the conventional means of cleaning is not offering the desired levels of productivity and efficiency specifically when large number of locations are involved and the transmission stretches are also increasing. The fact that polluted stretches are also showing increasing trend further aggravates the problem. As many of the lines as per original design are installed with insulators suitable for only light pollution levels, it is probably not able to sustain the situation in spite of cleaning because the pollutant accumulating again on the surface after cleaning may exceed the tolerable limits by the time the fog condition arrives.

8.2 The inspection of insulator strings from ground level by use of binocular may not reveal points of power arc, discoloration of disc etc. Inspection of insulator string at the probable locations of flashovers need be carried out from top or from the location of cross arm.

8.3 Committee also realize that 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 training of operators / supervisors is therefore essential. The committee therefore recommends that operators /supervisors may be provided training in cleaning / replacement of insulator strings with de-energised line or live line working by CPRI and / or HLTC.

8.4 Not providing bird guards does not result in significant economy. Providing them later during operational stage is relatively costly. It is proposed that bird guards may be provided on all new lines. For existing lines bird guards are to be provided progressively on all towers. Bird guards may be immediately provided at 1.0 km on either side of locations of identified bird droppings. On the cross arm above Vee strings these be provided for length not less than 1.5 meters on either side from centre line of Vee string.

8.5 Transmission lines may be surveyed atleast once every 2 years using thermo vision camera to locate hot spots if any and to take remedial measures during subsequent maintenance outage. While cleaning insulators or replacing insulators, marks of strands of conductor and earthwire showing giving way due to fatigue shall also be checked.

8.6 Detection of punctured insulators needs to be carried out using hot line puncture detectors and program for changing punctured insulators so identified be and implemented before onset of winter. Adequate number of pincture detectors needs to be arraged for the same.

8.7 For changing insulators as far as possible hot line techniques are to be followed. Necessary hot line tools and trained manpower needs to be arranged/ developed progressively by the Utilities.

8.8 Where Silicon composite (polymer) insulators are installed care shall be taken to avoid stepping on it during maintenance and approach to the line conductor / clamps etc. has to be done through ladders as no weight which consequently damaged the insulators is put on these insulators.

9.0 OTHER RELATED ISSUES

9.1 As fog related trippings affect the reliability and security of the system there is a curtailment on STOA by NRLDC. Due to these trippings consumers, discoms (because of load shedding due to less availability, reduction in STOA) and generating companies (because of their curtailment in generation) suffer substantial loss while availability of transmission system is not affected significantly. The committee express its concern and recommends that CTUs / STUs shall endeavor to reduce fog related tripping by adopting modern O&M practice including replacement of insulators by high creepage distance and/or polymer (SIR) insulators, cleaning /washing of insulators (including that by high pressure jets / use of helicopter), changes in maintenance and design practices

The modern O&M practices as recommended by the committee will entail additional capital cost and /or extra O&M costs. For central transmission utility (CTU) and state transmission utility (STU), this will require approval respectively of CERC and SERC for additional capital cost and its reflection, including extra O&M expenses, in their transmission tariff. The committee is of the view that this need to be taken up on priority so that its recommendations are implemented quickly and fog related trippings and consequent revenue loss to generators, discoms and power availability to consumers are avoided and therefore the committee proposes that the matter may be taken up on priority and it is in their (constituents) interest to agree in principle implementation of the remedial measures pending finalization tariff aspects. The committee is of the view that CTU and STU's should approach appropriate forum / regulatory commission.

9.2. While analyzing the trippings on 27.1.07 and discussions with field engineers, the committee has observed some mal-operation or non operation as under and has given its recommendations:

(1) It is observed that time of fault recorded at both ends of Dadri-Panipat line for trippings at 6.23, 6.57, 7.03 , 7.47 and 8.12 hours and Mandola – Bawana line at 6.47, 7.52 & 7.54 hours did not match. There is time difference up to 2 minutes indicating that disturbance / event recorders have not been time syncronised and if syncronised has drifted which has not been rectified. Though in this extent case it is not material but in case of grid failure such non syncronisation would have been made it difficult to construct sequence of events leading to grid failure and to analyse cause of grid failure. The Committee suggests that time syncronisation of disturbance recorders and event loggers should be checked at 0.00 hours daily and wherever required their clock shall be reset.

(2) It is observed that autoreclose lockout had taken place at one end of the line at the time indicated below while other end there had been no tripping. These indicate false tripping caused by receipt of false direct tripping signal from other end. Cause needs to be ascertained and PLCC equipments need be tested periodically.

1. Bawana – Narela ckt-1 8.52 hours
2. Bawana – Narela ckt-2 8.53 hours

(3) In some cases trippings has not been effected at both ends as per details given below. This indicate that protection scheme at one end had detected the fault due to flashover while other end had not detected it. Non operation of protection schemes need to be investigated:

(1) Bawana – BahadurGarh 5.53 hours
(2) Bawana – Mandola ckt-2 6.55 hours
(3) Bawana – Narela ckt -1 8.52 hours
(4) Bawana – Bamnauli ckt -2 11.24 hours
(5) Samaypur – Palwal ckt -2 7.14 hours.
(6) Samaypur – Palwal ckt -1 7.39 hours.

(4) BBMB officers were of the view that autoreclosing on faults places heavy duty on breakers and may be avoided. The committee would like to state that while autoreclosing on fault does places heavy duty on the breaker but this needs to be considered against the background that firstly every autoreclosing may not be effected on fault and secondly if autoreclosing is not effected there is likelyhood of system separation or grid failure and its consequence may be colossal. From the consideration of grid security, the Committee proposes that auto reclosing may also be resorted in 220kV system. Single pole auto reclosing may manifest restrike in case ionization in arc path is not fully quenched before the instant of autoreclosing due to low zero sequence impedance of the system. Where such a phenomenon is observed auto reclosing time may be increased and if it persists then 3 pole auto reclosing be affected.

9.3 The details of four incidents of bus bar faults mentioned at clause 3.2 are as under:

(1) 400KV Dadri - Muradnagar line autoreclosed at Dadri end six times between 07:23 to 08:11 hrs. But at 8:12 hrs 400KV main breaker of line had failed to open on fault. LBB protection operated and tripped all 400KV breaker connected to Bus II. All lines connected to Bus II continued to remain is service through tiebreakers. Main breaker of line did not trip as there was low pressure on account of air leakage.

(2) At 7:42 hrs at Bawana 400KV s/s Bus fault in 200KV Bus section 'F' has occurred due to snapping of jumber. Bus bar protection operated but breaker feeding to the faulty bus section did not trip where as fault was cleared on backup protection of all the 400KV/220KV ICTs and 220KV Bawana – Shalimarbag II. It was reported by DTL that there was some problem in DC wiring of bus bar protection scheme of bus bar section 'F' and. the backup protection of 220KV Bawana –Shalimarbag II has seen the fault in reverse direction.

(3) At 08:44Hrs direct trip single was received on 220KV Agra – Auraiya line II at Auraiya end but line breaker did not trip. LBB protection operated and GT2, GT3, ST2 and ICT-I connected to 220KV Bus II had tripped. It was reported by NTPC that during servicing of line breaker some stickiness in control valve assembly was noticed and after servicing breaker is operating successfully.

(4) At 09:00:50 Hrs bus bar protection of both 220KV bus I and bus II operated at 400KV /220KV Panipat substation of BBMB.All 220KV line eminating from the substation and generating unit I, 2,3,and 4 at Panipat thermal station of Haryana had tripped. Simultaneously 220KV Panipat Narela II had also tripped on R- phase earth fault No fault / damaged was noticed at 220KV switchyard of 400/220KV Panipat substation. It appears that Bus bar protection might have operated on through fault.

10.0 RECOMMENDATIONS

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

10.1 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 – 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.

10.2 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 $\pm$ 2 kms (as per distance to fault locator or visual inspection) where atleast 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 $\pm$ 2 kms where atleast 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 $\pm$ 2 kms where more than 3 flashovers has been observed in one single foggy day with high creepage distance porcelain/ toughened discs.

10.3 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.

10.4 In respect of lines in operation, insulator strings shall be progressively replaced as per 10.3 above depending upon pollution levels.

10.5 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.

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

10.7 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.

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

10.9 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 upto 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 upto 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

10.10 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.

10.11 No detergent or soap water be used for cleaning of line insulators under energized conditions. If used for cleaning during unenergised 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.

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

10.12 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.

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

10.14 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.

10.15 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.

10.16 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.

10.17 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

10.18 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

10.19 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

10.20 The time synchronization of disturbance recorders and event loggers should be checked and wherever required their clock shall be reset.

10.21 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.

10.22 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.

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