



**Govt. of India**  
**Ministry of Power**  
**Central Electricity Authority**  
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**No: PSE&TD/405-F/2016/**

**Dt: 28/04/2016**

**To,**

As per list

**Sub: Final Report of Standing Committee of Experts to investigate failure of towers during the period October 2014 to June, 2015.**

**Sir,**

Please find enclosed herewith the Final Report of Standing Committee of Experts to investigate the Causes of failure/damage of towers for the following transmission lines of five utilities [PGCIL, RRVPNL, WBSETCL, UPPTCL & M/S JINDAL POWER LTD.] including the failure of 765 kV S/C Gaya-Fatehpur Transmission line on 30.05.2014 reported to CEA during the period October 2014 to June 2015 for further necessary action.

Sl. No.	Names of the Transmission Line	Date of Occurrence of failure	Name of utility
1.	765 kV S/C Satna-Bina-II Transmission line	02.10.2014	PGCIL
2.	400 kV D/C Jeypore-Gazuwaka Transmission line	12.10.2014	PGCIL
3.	400 kV D/C Vijaywada-Gazuwaka-I Transmission line	12.10.2014	PGCIL
4.	220 kV S/C Salal-Jammu-I Transmission line	01.04.2015	PGCIL
5.	400 kV D/C Raipur-KSK Transmission line	25.04.2015	PGCIL
6.	400 kV D/C Vindhyachal -Satna Transmission line	13.05.2015	PGCIL

7.	765 kV S/C Gaya-Sasaram-Fatehpur Transmission line	14.05.2015	PGCIL
8.	765 kV S/C Satna-Bina_I Transmission line	16.05.2015	PGCIL
9.	765 kV S/C Satna-Bina-II Transmission line	19.05.2015	PGCIL
10.	765 kV S/C Agra-Meerut Transmission line	19.05.2015	PGCIL
11.	400 kV S/C Farakka-Durgapur- II Transmission line	24.05.2015	PGCIL
12.	765 kV S/C Bina-Gwalior Transmission line-III	02.06.2015	PGCIL
13.	400kV Bhilai-Koradi Transmission line	06.06.2015	PGCIL
14.	765 kV S/C Fatehpur-Gaya Transmission line	12.06.2015	PGCIL
15.	765kV S/C Dharamjaigarh-New Ranchi-II Transmission line	16.06.2015	PGCIL
16.	765 kV Agra-Jhatikaran Transmission line	23.06.2015	PGCIL
17.	400 kV Akal(Jaisalmer)-Barmer Transmission line	15.02.2015	RRVNL
18.	765kV S/C Anta-Phagi Transmission line	14.03.2015	RRVNL
19.	220kV D/C Bap-Bhadla Transmission line	11.05.2015	RRVNL
20.	220 kV D/C Bikaner-Gajner Transmission line	19.05.2015	RRVNL
21.	132 kV D/C Bikaner-Pugal road & 132kV D/C Gajner-Pugal road Transmission line	19.05.2015	RRVNL
22.	132 kV D/C Nokha-Jasrasar Transmission line	19.05.2015	RRVNL



23.	LILLO of 132kV D/C Bikaner-Dulhasar line at GSS Sherera Transmission line	19.05.2015	RRVPL
24.	220 kV D/C Bharatpur-Dholpur Transmission line	19.05.2015	RRVPL
25.	220kV D/C Alwar-Badarpur Transmission line	19.05.2015	RRVPL
26.	400kV Mainpuri-Paricha-I & II Transmission line	31.05.2015	UPPTCL
27.	400kV Unnao-Lucknow Transmission line	28.04.2015	UPPTCL
28.	400kV D/C Sagardighi-Durgapur Transmission line	24.05.2015	WBSETCL
29.	400kV D/C Tamnar-Raipur Transmission line	25.04.2015	Jindal Power Ltd.

Yours faithfully,

*S.K. Ray Mohapatra*  
28/4/2016

(S.K. Ray Mohapatra)

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# REPORT OF THE STANDING COMMITTEE OF EXPERTS ON FAILURE OF TOWERS DURING OCTOBER 2014 TO JUNE 2015



केन्द्रीय विद्युत प्राधिकरण  
विद्युत मंत्रालय  
भारत सरकार  
नई दिल्ली

**CENTRAL ELECTRICITY AUTHORITY  
MINISTRY OF POWER  
GOVERNMENT OF INDIA  
NEW DELHI**

( विद्युत अधिनियम, 2003 की धारा 73(1) के तहत के. वि.प्रा. के सांविधिक आंशिक दायित्व का निर्वहन करते हुए )  
(In fulfillment of CEA's obligation under section 73(1) of Electricity Act, 2003)

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## EXECUTIVE SUMMARY

- 1.0 A Standing Committee of experts in the field of design & operation of EHV transmission line (from CEA, PGCIL & research/academic institutes) constituted by Central Electricity Authority in 1999 as per old Electricity (Supply) Act No. 54 of 1948, continues to carry out investigation of failure of transmission line towers of Power utilities as per the Section 73(1) of Electricity Act 2003.
- 1.1 Over the years the Indian Standards for design of transmission line tower has undergone changes. The three wind zones in the country have been modified to six wind zones and design is being revised accordingly. Further revision in Indian standard is likely to include the change in wind speed pattern in some part of the country (i.e) transmission line towers have to be designed for higher wind zones in such areas. Infact transmission lines designed according to old standards / old design philosophy are in operation in various parts of the country under different transmission utilities / transmission licensees which cannot be replaced in one go. Steps are being taken from time to time to strengthen such towers when any major failure occurs in those old lines. But all efforts are being made to design new transmission line as per latest standard and best practices.
- 1.2 The objective of Standing Committee is to visit site of failure, investigate the cause of failure and to discuss the cause of failure of towers of the transmission lines of power utilities in different parts of the country and recommend remedial measures to prevent repetition of such failures in future. In most of the cases, the visit to site of failure do not materialise and analysis of cause of failure is being done based on information provided by the utilities and their participation in the Standing Committee meeting. As per the requirement of the Standing committee, all utilities / transmission licensees are supposed to report the failure of towers of 220kV and above voltage class transmission lines to CEA. Infact number of failure cases remains unreported as many of Power Transmission utilities (State Transmission utilities, Private Transmission utilities/licensees) in the country neither report the failure of towers of transmission line nor participate in such national level meeting.
- 1.3 The meeting of Standing Committee of Experts was held in CEA on 8.12.2015 to discuss the cause of failure of the transmission line towers of different voltage levels belonging to various Power transmission utilities/licensees and failed during the period from October, 2014 to June 2015. During this period, the failure of towers of various transmission lines of only five utilities [PGCIL, WBSETCL, RRVPNL, UPPTCL & M/s Jindal Power Ltd.] including failure of 132kV lines of RRVPNL was reported to CEA. Neither the representative of UPPTCL participated in the Standing committee meeting nor the report of failure of towers has been submitted to the CEA. Therefore, the matter could not be discussed during the meeting. Accordingly, the Committee discussed in detail the nature and cause of failure of towers of transmission lines of other utilities. Apart from the discussion of tower failures during above mentioned period, the failure of 15 No. of towers of 765 kV Gaya-Fatehpur S/C transmission line on 31.05.2014 was also further deliberated and separate report was submitted to Hon'ble Central Electricity Regulatory Commission (CERC) on 25.01.2016.
- 1.4 The pattern of failure of towers of lines of various voltage levels can be broadly classified as under:

- Towers have buckled from stub level leading to complete collapse of towers with/without damage to tower foundation.
- Towers have buckled from the top of 1<sup>st</sup> panel(normal tower) level with/without damage to tower foundation.
- Towers have buckled from bottom cross arm level or top cross arm level or peak broken without any damage to lower portion of the tower and foundation.
- Uprooting of foundation Chimney.
- Damage to foundation as well as tower due to soil erosion and inadequate protection to foundation of towers.

#### **1.5 The major cause of failure of towers are as under:**

- a) The high wind velocity during storm, cyclone and local phenomenon of whirlwind and gale etc. might have exceeded the wind speed for which the tower is designed. This type of wind is difficult to predict. The probability of such occurrences is low & the tower design will be uneconomical if such situation is considered in the design.
- b) Theft/sabotage of tower members, generally the theft of secondary members (connected with one or two bolts) of the towers by the local people makes the tower structurally weak which ultimately leads to failure during high speed wind/ storms/whirlwind/ cyclone etc.
- c) It is also difficult to take into account demolishing activities by miscreants like cutting/blasting the main members of the tower, during design or construction stage.
- d) Many lines are in operation with towers designed according to old Indian Standards (IS: 802 -1977). (The Indian Standard has been revised subsequently to incorporate new design concepts to minimize the rate of the failure.)
- e) In some cases although the towers have been design according to IS 802 (1995), but 75% of wind load in broken wire condition may not have been considered for design of suspension towers.
- f) Lack of proper soil investigation and deficiency in design of foundation of towers sometimes lead to failure of towers.
- g) Lack of proper protection to foundation of towers sometimes causes damage to foundation as well as the towers.



## 2.0 BRIEF DETAILS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES REPORTED TO CEA

2.1 The number of towers failed & lines affected at various voltage levels during the period from October, 2014 to June, 2015 is tabulated below:

Sl. No.	Names of the Transmission Lines	Date of Occurrence of failure	No. of towers failed	Name of utility
1.	765 kV S/C Satna-Bina-II Transmission line	02.10.2014	2	PGCIL
2.	400 kV D/C Jeypore-Gazuwaka Transmission line	12.10.2014	29	PGCIL
3.	400 kV D/C Vijaywada-Gazuwaka-I Transmission line	12.10.2014	2	PGCIL
4.	220 kV S/C Salal-Jammu-I Transmission line	01.04.2015	1	PGCIL
5.	400 kV D/C Raipur-KSK Transmission line	25.04.2015	2	PGCIL
6.	400 kV D/C Vindhyachal -Satna Transmission line	13.05.2015	1	PGCIL
7.	765 kV S/C Gaya-Sasaram-Fatehpur Transmission line	14.05.2015	2	PGCIL
8.	765 kV S/C Satna-Bina_I Transmission line	16.05.2015	1	PGCIL
9.	765 kV S/C Satna-Bina-II Transmission line	19.05.2015	1	PGCIL
10.	765 kV S/C Agra-Meerut Transmission line	19.05.2015	1	PGCIL
11.	400 kV S/C Farakka-Durgapur-II Transmission line	24.05.2015	7	PGCIL
12.	765 kV S/C Bina-Gwalior Transmission line-III	02.06.2015	6	PGCIL
13.	400kV Bhilai-Koradi Transmission line	06.06.2015	1	PGCIL

14.	765 kV S/C Fatehpur-Gaya Transmission line	12.06.2015	1	PGCIL
15.	765kV S/C Dharamjaigarh-New Ranchi-II Transmission line	16.06.2015	1	PGCIL
16.	765 kV Agra-Jhatikaran Transmission line	23.06.2015	1	PGCIL
17.	400 kV Akal(Jaisalmer)-Barmer Transmission line	15.02.2015	5	RRVNL
18.	765kV S/C Anta-Phagi Transmission line	14.03.2015	7	RRVNL
19.	220kV D/C Bap-Bhadla Transmission line	11.05.2015	3	RRVNL
20.	220 kV D/C Bikaner-Gajner Transmission line	19.05.2015	15	RRVNL
21.	132 kV D/C Bikaner-Pugal road & 132kV D/C Gajner-Pugal road Transmission line	19.05.2015	7	RRVNL
22.	132 kV D/C Nokha-Jasrasar Transmission line	19.05.2015	3	RRVNL
23.	LILO of 132kV D/C Bikaner- Dulhasar line at GSS Sherera Transmission line	19.05.2015	25	RRVNL
24.	220 kV D/C Bharatpur-Dholpur Transmission line	19.05.2015	6	RRVNL
25.	220kV D/C Alwar-Badarpur Transmission line	19.05.2015	2	RRVNL
26.	400kV Mainpuri-Paricha-I & II Transmission line	31.05.2015	NA	UPPTCL
27.	400kV Unnao-Lucknow Transmission line	28.04.2015	NA	UPPTCL
28.	400kV D/C Sagardighi-Durgapur Transmission line	24.05.2015	5	WBSETCL
29.	400kV D/C Tamnar-Raipur Transmission line	25.04.2015	2	Jindal Power Ltd.

NA: Information not Available



- 2.2 Some of the failure sites in respect of transmission lines listed above i.e. the line at Sl. No. 5 was jointly visited by representatives of CEA & PGCIL, line at Sl. No. 18 was jointly visited by representative of CEA & RRVPNL and lines at Sl.No. 20, 21,22&23 were visited jointly by representatives of CEA, PGCIL & RRVPNL and preliminary reports on the finding were submitted.
- 2.3 The number of suspension and tension towers at various voltage level, failed during above mentioned period are indicated below:

Sl. No.	Voltage Level	No. of Lines affected	No. of Towers failed		
			Suspension Towers	Tension Towers	Total
1	765 kV	9	21	2	23
	PGCIL	8	15	1	
	RRVPNL	1	6	1	
2	400kV	11	49	5	54
	PGCIL	6	38	4	
	RRVPNL	1	4	1	
	UPPTCL	2	NA	NA	
	WBSETCL	1	5	0	
	Jindal Power Ltd	1	2	0	
3	220 kV	5	24	3	27
	PGCIL	1	0	1	
	RRVPNL	4	24	2	
4	132kV	3	29	6	35
	RRVPNL	3	29	6	
	Total	28	123	16	139

**NA: Information not available**

- 2.3.1 Out of 139 Nos. of failed towers,123Nos.(88%) are of suspension type towers and rest 16 Nos.(12%) are tension type towers.
- 2.3.2 In plain terrains, percentage of tangent / suspension towers are normally much more compared to tension / angle towers and hence there is tendency to optimize the design (without much safety margin in design) in order to economize the cost of transmission lines.
- 2.3.3 The efforts are being taken to incorporate new design concepts to minimise failure of suspension towers. At present the design of suspension towers takes into consideration the narrow front wind on tower body and 75% of wind in broken wire condition. In the process the failure rate has come down.
- 2.3.4 Further study has been carried out by SERC and it was brought to notice that there is change in wind speed pattern in some part of country and accordingly Indian standard is being revised to consider higher wind speed/zone for some part of country while designing transmission line towers.

- 2.3.5 It is planned to arrange meeting with National Institute of Wind Energy(NIWE), Structural Engineering Research Centre(SERC), PGCIL, other utilities to discuss about usefulness of wind data available with NIWE who have already established more than 800 wind data measuring stations covering all part of the country for Indian wind power mapping. The outcome from such discussion and exchange of wind data may provide some valuable input for improving the design of towers and may help in minimising the failure of towers in high speed storm/cyclone prone areas.
- 2.3.6 During the deliberations of the Standing committee held in 2014, the committee was of the opinion that towers of transmission lines in West Rajasthan, Delhi, Haryana, & Punjab should be designed for terrain Category -I
- 2.3.7 All such actions will definitely lead to positive outcome in minimising the rate of failure.

### **3.0 RECOMMENDATIONS & REMEDIAL MEASURES SUGGESTED BY THE COMMITTEE**

Details of failure including minutes of meeting photographs and other information relating to each transmission lines are given in subsequent sections of the report.

- 3.1 The recommendations and remedial measures to be taken by the concerned utilities in respect of their transmission lines is summarized as under:

#### **A. Failure of transmission lines of PGCIL**

##### **(i) 765kV Gaya-Fatehpur S/C Transmission Line**

- The towers with delta configuration shall be avoided to the extent possible in 765kV single Circuit (S/C) lines in future and as such most of the 765 kV lines shall be Double Circuit (D/C) lines with vertical configuration.
- In absence of meteorological data, it has become difficult to assess the actual wind velocity at site of failure in order to verify with the design value of wind speed. However, the detailed analysis of structural design of suspension tower (with delta configuration) of 765kV S/C line was carried out by CPRI and PGCIL using two different softwares [STAAD Pro and i-Tower]. The strengthening of suspension towers (with delta configuration) of 765kV S/C line traversing through wind Zone - 4 has to be carried out as indicated below by increasing the member / section size of six (6) members and adding two (2) more



redundant members. The drawing showing the member location is enclosed as **Annexure - II.**

<b>Member No.</b>	<b>Original Member size</b>	<b>Proposed Member size</b>	<b>Existing No. of Bolts</b>	<b>Proposed No. of Bolts</b>
D13	65x65x5 (MS)	65x65x6 (MS)	2 SS – 16Ø	2 SS – 16Ø
D16	80x80x6 (MS)	90x90x6 (MS)	2 SS – 16Ø	2 SS – 16Ø
D29	70x70x5 (MS)	90x90x6 (MS)	2 SS - 16Ø	3 SS - 16Ø
M51/52	100x100x8 (HT)	110x110x8(HT)	6 DS - 16Ø	6 DS - 16Ø
D12	75x75x6 (HT)	80x80x6 (HT)	3 SS - 16Ø	3 SS - 16Ø
New Redundant connected to M5	-	50x50x5 (MS)	-	1 SS - 16Ø
New Redundant connected to H3/H4	-	50x50x5 (MS)	-	1 SS - 16Ø

- Since strengthening of tower is to be done above bottom cross arm / waist level (near diamond section), long shutdown shall be required for replacement of members / sections of towers in existing line and the nature of work and the risk involved in replacement of member of towers in existing line is different from fabrication of towers afresh. The fabrication of fresh towers can be taken up easily. But replacement of members in the existing towers is very difficult and lot of risk is involved. Moreover, many of the executing agencies may not be interested to take up such difficult and risky task. Dismantling and replacement of the structural part above waist level of tower requires long shut down. Hence such activity shall be taken up during annual maintenance in a phased manner. PGCIL has to prioritize the areas / lines where such activity can be taken up. Accordingly planning has to be done by PGCIL.
- The patrolling of line needs to be increased / intensified in theft prone areas in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.
- The regions, where frequent failures of transmission line towers are observed, need to be identified and wind data logger stations may be installed by PGCIL in those areas on priority basis. PGCIL should expedite the installation of

Anemometers in substations, particularly in cyclone / high wind prone areas, as recommended earlier by the Standing Committee of experts on failure of transmission lines of 220kV and voltage level.

- (ii) **The committee also decided that PGCIL has to strengthen towers of other 765kV S/C lines, designed for wind Zone -4 with Delta configuration of towers, in line with Gaya – Fatehpur 765kV S/C line.**
- (iii) **The rate of failure of suspension towers (with delta configuration) of 765kV S/C line traversing through other wind zones (other than Wind Zone -4) and areas prone to cyclone / storm needs to be monitored. In case repeated failure is observed in those lines, similar exercise for review of design has to be taken up by PGCIL for different wind zones for suspension towers (with delta configuration) of 765kV S/C line.**
- (iv) The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.

**[For 400 kV Jeypore-Gazuwaka D/C line and 400 kV Vijaywada-Gazuwaka –I S/C Line]**

- (v) The committee recommended to review design of towers for strengthening, even though the towers were designed according to IS:802(1995), in case of more failure occurs in future.

**[For 400 kV Vindhyachal-Satna D/C Transmission Line]**

- (vi) The Committee requested Powergrid to increase the patrolling in the area and help of local people may also be taken in theft prone areas. Proper coping of tower foundations should be done for all towers. The procurement action for replenishment of spare towers may also be initiated by PGCIL

**[For 400 kV Raipur- KSK D/C Transmission Line]**



- (vii) Committee advised PGCIL to provide required protection for foundation of tower.

**[For 220kV Salal –Jammu –I S/C Transmission Line]**

- (viii) Committee recommended for early completion of strengthening of towers of this line.

**[For 400 kV Farakka-Durgapur-II S/C Transmission Line]**

- (ix) The committee advised PGCIL to submit detail report.

**[For 400 kV Bhilai- Koradi Transmission Line, 765 kV S/C Dharamjaigarh-New Ranchi-II Transmission Line and 765 kV Agra-Jhatikaran Transmission Line]**

#### **B. Failure of transmission lines of RRVPNL**

During the deliberation of Standing Committee held in 2014, the Committee was of the opinion that towers of transmission line in West Rajasthan area should be designed for terrain category-1 (instead of category-2). RRVPNL may consider the suggestion of the Committee while designing the EHV transmission line.

##### **(i). 400kV Akal (Jaisalmer)- Barmer Transmission line**

Committee recommended for

- Checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers
- Checking of angle of deviation in the section where towers have failed.
- Submission of foundation design of existing towers for further analysis.
- Considering the use of composite insulators in pollution prone areas to avoid the flashover across insulator discs.

##### **(ii). 765 kV Anta - Phagi S/C Transmission Line**

- (a) The failure pattern of seven (7) Nos. of suspension towers (with delta configuration) of Anta-Phagi 765kV S/c line in RRVPNL system was similar to 765kV Gaya – Fatehpur S/C line and design was provided by

PGCIL for wind Zone – 4 with delta configuration of towers. RRVPNL has to plan and carryout modifications by strengthening the members in line with above mentioned transmission line of PGCIL.

(b) The committee also recommended RRVPNL to review the design of foundation of towers.

(c) Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA who had visited the site of failure:

- To provide a path for rain water to drain away and to provide proper protection walls with weep holes all around the tower to avoid soil erosion and also to protect the foundation.
- To carry out detail soil investigation
- The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by RRVPNL and involved for safety of towers.
- Replacing the missing members and bolts and tag welding of bolts may be done.
- Coping of chimneys to avoid accumulation of rain water near stubs.
- Replacing missing ACD
- Providing proper earthingconnection for towers

(iii). Committee advised RRVPNL to review the design of suspension towers in line with latest revised Indian Standard (IS:802 - 1995) taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition. The strengthening of towers, if required, needs to be taken up and planned accordingly.

**[For 220 kV D/C Bap-Bhadlaline; 220 kV Bikaner-Gajner D/C line;132 kV Bikaner-Pugal road line; 132 kV Gajner-Pugal road line; 220 kV D/C Bharatpur-Dholpur line; 220 kV D/C Alwar-Badarpur Transmission line]**



(iv).Committee recommended RRVPNL to review the foundation design.

**[For 132 kV Bikaner-Pugal road line; 132 kV Gajner-Pugal line; and 220 kV D/C Alwar-Badarpur Transmission line]**

(v). The Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- Providing proper revetment for new foundations  
**[For 132 kV Bikaner-Pugal road line and 132 kV Gajner-Pugal road Transmission line]**
- Providing Anti climbing device (ACD)  
**[For 132 kV Bikaner-Pugal road line and 132 kV Gajner-Pugal road Transmission line]**
- Providing proper earthing connection for towers  
**[For 220 kV Bikaner-Gajner D/C line; 132 kV Bikaner-Pugal road line; 132 kV Gajner-Pugal road line; and 132 kV Nokha- Jasrasar transmission Line]**
- Providing coping for chimneys  
**[For 220 kV Bikaner-Gajner D/Cline;132 kV Bikaner-Pugal road line; 132 kV Gajner-Pugal road transmission Line]**
- Providing Cover plates of proper size at butt joint locations in leg members of towers  
**[For 132 kV Bikaner-Pugal road; 132 kV Gajner-Pugal; and 132 kV Nokha- Jasrasar transmission Line]**
- Redundant members need to be connected using bolts and nuts (instead of welding) and holes left in tower members need to be filled with nut and bolts.  
**[For 220 kV Bikaner-Gajner D/C transmission Line]**
- Proper protection for foundation needs to be provided and the soil / sand deposited on the chimney of foundation is to be removed or chimney height needs to be raised.  
**[For 132 kV Nokha- Jasrasar transmission Line]**

**(vi). LILO of 132 kV D/C Bikaner – Dulhasar line at GSS Sherera**

- (a) The committee recommended RRVPNL to review the design of tower as well as foundation. The strengthening of towers as well as foundation may be required in view of nature of failure. Committee also recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.
- (b) The Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:
- The tower may be strengthened by providing additional members from first panel up to bottom cross arm level and by providing hip bracing.
  - M20 concrete (1:1.5:3) nominal mix needs to be considered for casting of chimney and frustum.
  - Cover plate of proper size needs to be provided at butt joints in leg members of tower
  - In case of recasting / strengthening of the existing foundations, proper reinforcement may be provided in the foundation of Chimney and frustum and cleats attached with the stubs need to be designed as per requirement to provide adequate strength against uplift.
  - The earthwire needs to be fixed with suspension towers with proper clamps

- (vii).** Committee recommended RRVPNL to submit material test reports of failed towers.

**[For 220 kV D/C Bap-Bhadla line; 220 kV D/C Bharatpur-Dholpur line and 220 kV D/C Alwar-Badarpur Transmission line]**



**C. The transmission lines of WBSETCL:**

The Committee requested to PGCIL to submit material test report.

**[For 400 kV D/C Sagardighi-Durgapur Transmission Line failed on 24.05.2015]**

**D. The transmission Lines of M/s. JINDAL POWER LTD**

The committee recommended that the patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by JPL and involved for safety of towers.

**[For 400 kV Tamnar- Raipur D/C Transmission line on 25.04.2015]**

**3.2 After the detail discussions/deliberations in the meetings held in CEA, following decisions have also been taken by the Standing Committee.**

- a) The most of the failures are linked to high wind speed. The CE, PSE&TD informed that about 800 (as on August 2015) wind data measurement stations have been established by National Institute of Wind Energy (NIWE), Chennai covering all parts of the country for Indian wind Power Mapping. The wind data available with NIWE may be useful to obtain actual wind speed in the areas of tower collapse. The Committee suggested that CEA should arrange a meeting with NIWE, SERC, PGCIL etc. to discuss about the usefulness of wind data collected by NIWE for wind zone mapping and estimating actual wind speed in areas where towers have collapsed.
- b) The representative of SERC informed that during the material testing, other than testing of the material properties, measurement of thickness of members should be carried out. Wide variation in thickness should not be there. The area having minimum thickness is vulnerable to failure. He further highlighted that IS: 12427 / IS:1367 do not specify weight of nuts / bolts, which should be an important

parameter for bolt. The Committee also suggested CEA to write to BIS to review IS:7215 to specify required tolerance limits in respect thickness of member and IS:12427 / IS:1367 to specify weight of nuts / bolts as one of the parameter in addition to other parameters

- c) The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated and involved for safety of towers.
- d) The wind speed mapping for the entire country is under further revision by Bureau of Indian Standards (BIS) based on inputs from Structural Engineering Research Centre (SERC), Chennai due to change in wind speed pattern in some part of the country. The committee suggested CEA to write to BIS for early revision of the wind map of the country.



# **REPORT OF STANDING COMMITTEE OF EXPERTS TO INVESTIGATE FAILURE OF TOWERS DURING THE PERIOD OCTOBER 2014 to JUNE 2015**

1.0 As per CEA Order No. 5-41/98/Secy/CEA/809, dated 30.9.1999 and subsequent amendments thereof, a Standing Committee comprising of experts from CEA, PGCIL, CPRI, Academic Institute, SERC and State Utilities was constituted as per Chapter II Para 3 (viii) of the Electricity (Supply) Act No.54 of 1948 to investigate failure of transmission line towers of power utilities. As per the Electricity Act, 2003, CEA continues to be authorized under Section 73 (l) to carry out or cause to be carried out, any investigation for the purpose of generating or transmitting or distributing electricity. The scope and terms of reference of the Committee are as follows:

- To investigate the causes of failure of towers
- To avert recurrence of such failures in future

The meeting of Standing Committee of Experts was held in CEA on 8.12.2015 to discuss the cause of failure of the transmission line towers of different voltage levels belonging to various transmission utilities/licensees failed during the period from October, 2014 to June 2015. During this period, the failure of towers of various transmission lines of only five utilities [PGCIL, WBSETCL, RRVPNL, UPPTCL & M/s Jindal Power Ltd.] including failure of 132kV lines of RRVPNL was reported to CEA. Neither the representative of UPPTCL participated in the Standing committee meeting nor the report of failure of tower has been submitted to the CEA for above mentioned lines. Therefore, the matter could not be discussed during the meeting. Accordingly, the Committee discussed in detail the nature and cause of failure of towers of transmission lines of other utilities. Apart from the discussion of tower failures during above mentioned period, the failure of 15 towers of 765 kV Gaya-Fatehpur S/C transmission line on 31.05.2014 was also further deliberated and separate report was submitted to Hon'ble CERC.

The Committee normally investigates failure of towers of transmission lines of 220kV and above voltage class as per scope & terms of reference of the Committee. However, at the request of RRVPNL, the failure of towers of 132kV lines was also investigated.

As requested by RRVPNL, the detailed report on failure of towers in respect of various lines of RRVPNL (765kV, 220kV and 132kV lines), is being sent to RRVPNL separately.

## **2.0 OBSERVATIONS, RECOMMENDATIONS & REMEDIAL MEASURES SUGGESTED BY THE COMMITTEE ON FAILURE OF TOWERS OF VARIOUS POWER UTILITIES**

### **2.1 DETAILS OFFAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF POWERGRID**

**2.1.1** The towers of following 765kV, 400kV and 220kV Transmission Lines of POWERGRID had failed during above mentioned period.

<b>Sl. No.</b>	<b>Names of the Transmission Lines</b>	<b>Date of Occurrence of failure</b>	<b>No.of towers failed</b>
1.	765 kV S/C Satna-Bina-II Transmission line	02.10.2014	2
2.	400 kV D/C Jeypore-Gazuwaka Transmission line	12.10.2014	29
3.	400 kV D/C Vijaywada-Gazuwaka-I Transmission line	12.10.2014	2
4.	220 kV S/C Salal-Jammu-I Transmission line	01.04.2015	1
5.	400 kV D/C Raipur-KSK Transmission line	25.04.2015	2
6.	400 kV D/C Vindhyachal -Satna Transmission line	13.05.2015	1
7.	765 kV S/C Gaya-Sasaram-Fatehpur Transmission line	14.05.2015	2
8.	765 kV S/C Satna-Bina_I Transmission line	16.05.2015	1
9.	765 kV S/C Satna-Bina-II Transmission line	19.05.2015	1
10.	765 kV S/C Agra-Meerut Transmission line	19.05.2015	1
11.	400 kV S/C Farakka-Durgapur-IITransmissionline	24.04.2015	7
12.	765 kV S/C Bina-Gwalior Transmission line-III	02.06.2015	6
13.	400kV Bhilai-Koradi Transmission line	17.04.2014	1



14.	765 kV S/C Fatehpur-Gaya Tansmission line	12.06.2015	1
15.	765kV S/C Dharamjaigarh-New Ranchi-II Transmission line	16.06.2015	1
16.	765 kV Agra-Jhatikaran Transmission line	23.06.2015	1
<b>Total</b>			<b>59</b>

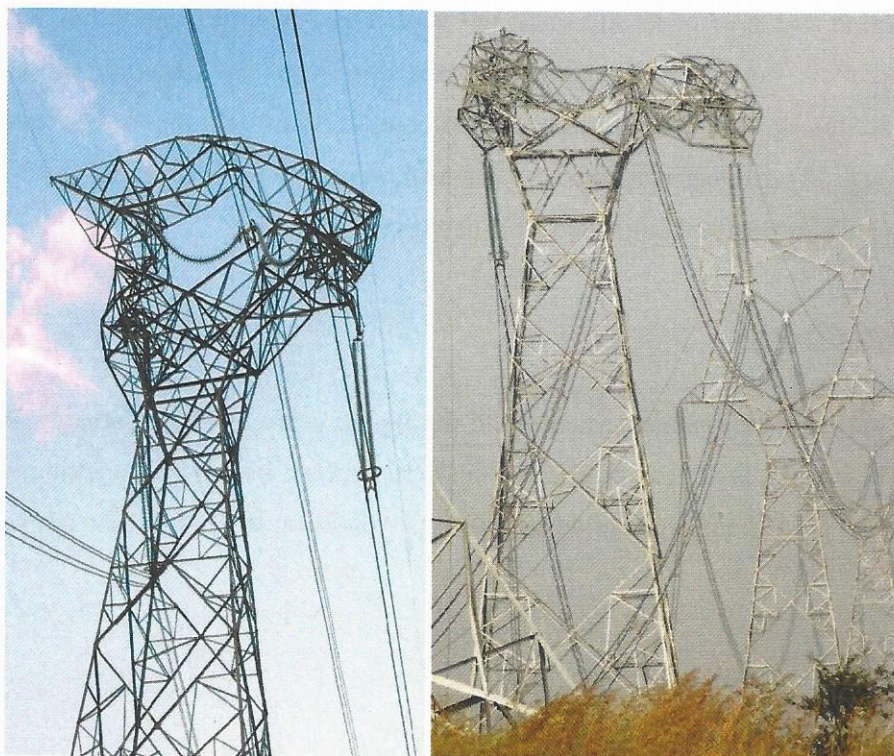
## 2.1.2 Details in respect of each transmission line of PGCIL

### 1. 765 kV S/C Satna- Bina –II transmission line failed on 02.10.2014

(Two towers at Location Nos. 313 & 314)

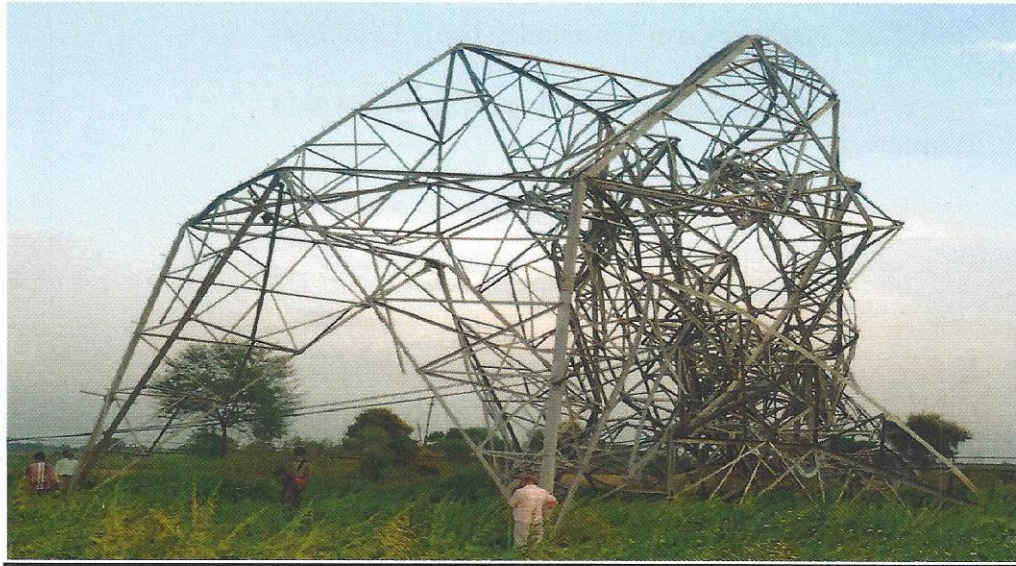
#### Brief Background

765 kV Satna-Bina-II S/C transmission line was constructed under Sasan UMPP scheme -II project by M/S KEC in 2012 and is in commercial operation since June 2012. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The suspension towers were designed for delta configuration for Quad Bersimis conductor (with double I-V-I insulator string). The line tripped on phase to phase fault on 02-10-2014 at 1427 hrs.



**Location No. 313**





**Location No. 314**

### **Observations**

During patrolling of the line, it was observed that two (2) nos. of suspension towers at location No. 313 & 314 had collapsed due to localized cyclone.

The Tower at location No.314 (A+0) has collapsed completely on the ground in transverse direction and three of its stubs also got bent. The Tower at location No. 313 (A+0) collapsed above bottom cross arm level / waist level (near the diamond section) and there was no damage to the foundations. Phase conductors of both the towers were partially damaged. No damage was apparent on earthwires. Both the affected towers were located in a plain stretch of cultivated field having very few trees.

### **Probable Cause of Failure**

The stretch might have experience critical wind during the storm. Failure/damages in locations/stretches might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earth wire as well as on tower itself exceeding the design values.

### **Restoration**

The Line was restored on normal towers on 10.10.2014.



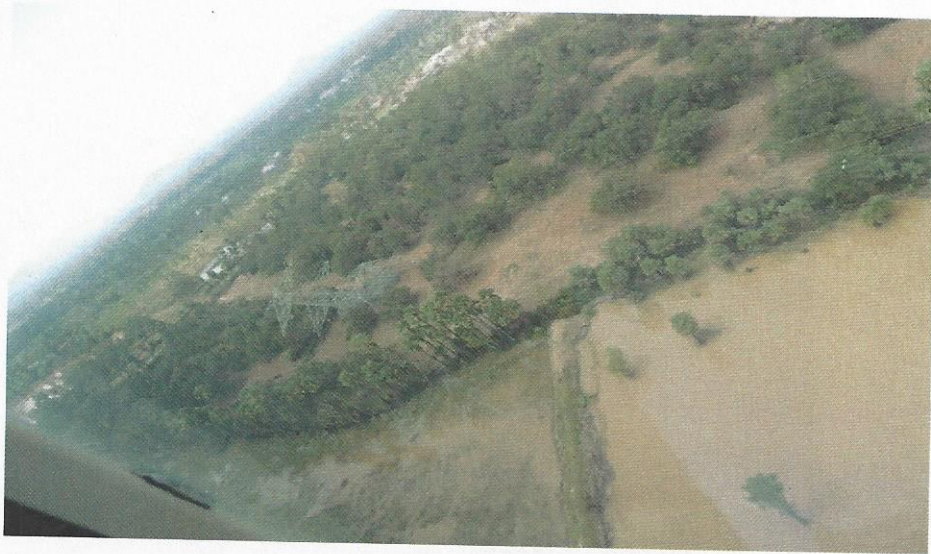
### **Recommendation of the Committee**

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

#### **2. 400 kV Jeypore-Gazuwaka D/C transmission line failed on 12.10.2014 (29 towers)**

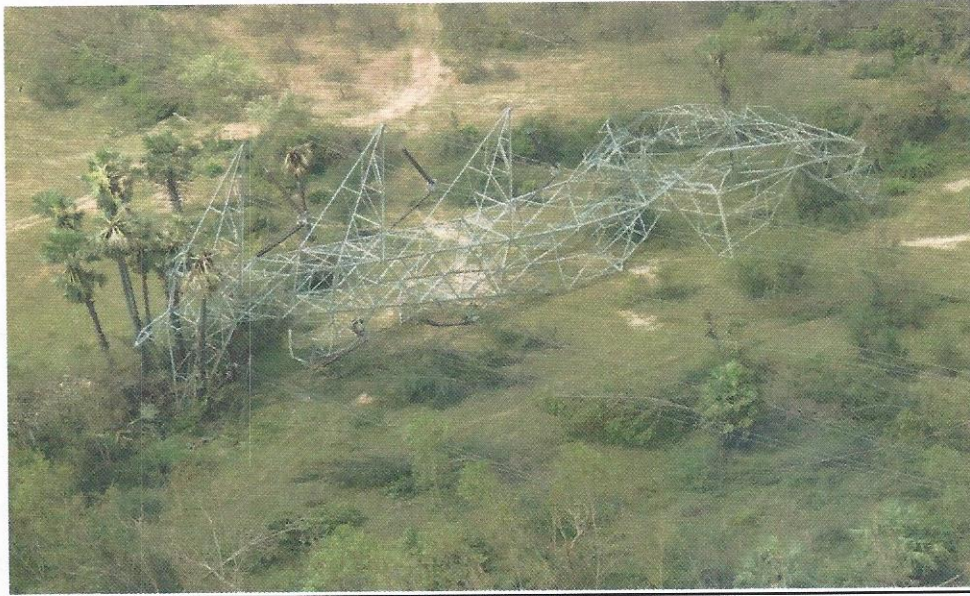
##### **Brief Background**

Jeypore - Gazuwaka I & II 400 kV D/C transmission line was constructed by M/S Jyoti Structures Ltd and is in commercial operation since September 1999. The towers of this line were designed for heavy wind zone as per old IS 802-1977. The suspension towers were designed for vertical configuration with twin moose conductor and V-V-V insulator strings. The line tripped on phase to earth fault on 12-10-2014 at 10:30 hrs.



**Location No. 489**





**Location No. 514**



**Location No.522**

### **Observations**

Twenty nine (29) numbers of towers were damaged due to HUD HUD cyclone on 12-10-2014. Twenty(20) nos. of suspension towers at location number 489(DA+25), 514(DA+6), 522(DA+0), 528(DA+6), 547(DA+6), 548(DA+0), 549(DA+0),



558(DA+0), 559(DA+6), 561(DA+6), 565(DA+6), 568(DA+9), 569(DA+6), 570(DA+3), 571(DA+0), 572(DA+0), 573(DA+0), 574(DA+0), 575(DA+0) & 583(DA+6) had collapsed. Two (2) nos. of tension towers at location number 512(DD+0) and 515(DD+0) and seven(7) nos. of suspension towers at location number 521(DA+3), 523(DA+0), 524(DA+0), 546(DA+0), 562(DA+0), 564(DA+0) and 566(DA+0) were partially damaged.

#### **Probable Cause of Failure**

The failure of towers was due to the unprecedented heavy wind loads on tower, conductors and earthwire due to HUD-HUD cyclone on 12-10-2014.

#### **Restoration**

The line was restored normal towers on 30.11.2014.

#### **Recommendation of the Committee**

The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.

### **3. 400 kV Vijaywada-Gazuwaka-I (on D/C Tower) transmission Line failed on 12.10.2014**

**(Two towers at Location No. 847 & 848)**

#### **Brief Background**

Vijaywada-Gazuwaka - I 400 kV S/C transmission line was constructed by M/S KEC International Ltd. and is in commercial operation since August 1991. The towers of this line were designed for medium Wind Zone as per old IS 802-1977. The double circuit towers(near entry to substation / dead end tower) were designed for vertical configuration with twin ACSR Moose conductor and V-V-V insulator strings. The line tripped on phase to phase fault on 12-10-2014 at 12:06 hrs.





**Location No.847**



**Location No.848**

### **Observations**

The Tower at location No. 847(DA+18) had collapsed completely on the ground in transverse direction. Tower at location No. 848 (DD+0) was twisted above cross arm level. No damage was observed on the stubs and foundations. In both cases, phase conductors were partially damaged. No damage was apparent on earthwires.

### **Probable Cause of Failure**

The failure of towers was due to the unprecedented heavy wind loads on tower, conductors and earthwire due to HUD-HUD Cyclone on 12-10-2014.



### **Restoration**

Line was restored on normal towers on 24.10. 2014.

### **Recommendation of the Committee**

The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.

#### **4. 220 kV Salal-Jammu – I S/C Transmission Line failed on 1.4.2015**

**(Location No. 64(B+0))**

#### **Brief Background**

Towers of 220 kV S/C Salal-Jammu-I Transmission Line were designed and constructed by M/s SAE and was put into commercial operation from 10.11.1987. The length of the line is 56.33 km. This is the first instance of tower failure in Salal-Jammu line. The Line tripped at around 16:30 hours on 01.04.2015 due to tower failure/collapse of tension tower at location Nos. 64(B+0).



**Location No.64**



### **Observations**

It was reported that continuous heavy unprecedented Rainfall and high speed wind were experienced in whole state of J&K including this area. Landslide has also occurred thereby exposing Tower foundations. Crate Protection wall was provided to the tower. Tension tower has fallen in the transverse direction above bottom cross arm level. There was no theft of the member from the towers and no damage to adjacent towers at location Nos. 63(A+0) and 65(B+0) was noticed.

### **Probable Cause of Failure**

The continuous heavy rains and high speed winds triggered the massive landslide downside of the tower exposing and damaging the Tower foundations resulting in failure of tower at location no. 64.

### **Restoration**

The line was restored on ERS and charged on 07.04.2015. The work for restoration of line on normal towers was also started.

### **Recommendation of the Committee**

Committee advised PGCIL to provide required protection for foundation of tower.

## **5. 400 kV Raipur – KSK D/C Transmission Line failed on 25.04.2015 (Two towers at Location Nos. 547 & 544)**

### **Brief Background**

400 kV D/C Raipur-KSK (Ckt. 3 & 4) Transmission Line was designed by POWERGRID and constructed by M/s KPTL, Gandhinagar. The length of the line is 134kms. The CKT-3&4 of the line was commissioned in October, 2010. The suspension towers of this line were designed in vertical configuration for wind zone 3 (44 m/s) as per IS:802-1995 for Twin ACSR MOOSE conductor with “I-I-I” insulator string. The line tripped at around 17:32 Hrs. on 25.04.2015. On patrolling, it was observed that there was damage/collapse of towers at location numbers 547(DA+0) & 544(DA+3). It was informed that during the patrolling on 8.4.2015, no visible theft of any members of tower was reported. The failed towers are part of section of the line between towers at Location Nos. 539 and 552 having sectional length of 4.97km. It was reported that in the same area, three towers of Raipur – Tamnar 400kV D/C line of M/s. Jindal Power Ltd. had also damaged due to heavy wind. The team of officers from Powergrid and CEA had visited the site of failure on 30.04.2015. The location of the tower failure was about 25 Km from Raipur.





**Location No. 547**



**Location No.544**



### **Observations**

The team of officers from Powergrid and CEA had visited the site of failure on 30-04-2015. The failed towers are in agricultural fields with open area all around within village Malipur in Durg District of Chhattisgarh, almost all the bracing and redundant members of first panel were cut by miscreants. These cut members were also missing and could not be found near the tower location. The Towers had completely collapsed at stub level and were lying on the ground and conductors were also touching the ground. The foundations of towers were intact. Insulators were broken. An FIR was lodged with the Nandini Police station. Incidence of high intensity wind and damage to property / trees and power lines was also published in local News Papers. Tower was so badly damaged that the foundation chimney were broken and stubs were bent. Barbed wire used for Anti Climbing Devices was badly mingled around towers. The peak of adjacent towers at location no. 548 and 543 was also found broken.

### **Probable Cause of Failure**

Due to cutting of tower members (main bracings & other members) by local miscreant and later coupled with high wind, might have caused the failure/collapse of towers at location No. 547 and 544. Due to such impact, peak of adjacent tower at loc. Nos. 548 and 543 was also damaged.

### **Restoration**

The line was restored on normal tower and recharged on 06/05/2015. The spare towers available at site were used for restoration of line.

### **Recommendation of the Committee**

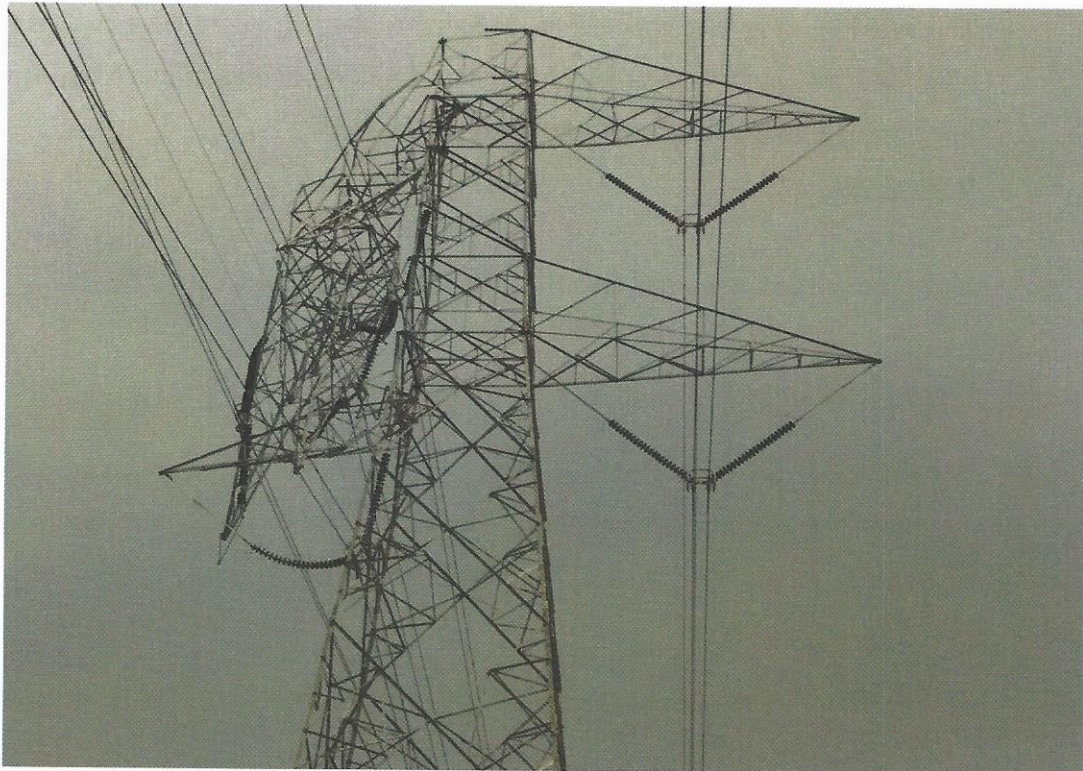
- The Committee requested Powergrid to increase the patrolling in the area and help of local people may also be taken in theft prone areas.
- Proper coping of tower foundations should be done for all towers.
- The procurement action for replenishment of spare towers may also be initiated by PGCIL.



**6. 400 kV Vindhyachal-Satna D/C Transmission Line Failed On 13-05-2015  
(Location no. 709)**

**Brief Background**

Vindhyachal-Satna 400 kV D/C line (267 kms) was designed and constructed by M/s Kalpataru Ltd. The line was commissioned on 01-08-99. The towers were designed and tested as per IS 802-1995 for wind zone -IV (47 m/sec). Line tripped at around 1335 Hrs. on 13-05-2015 due to partial damage of tower at loc no. 709(DA+6).



**Location No.709**

**Observations**

The location of failure is approximately 15 kms from Satna S/S end of transmission line and is situated in cultivated land near village Pondi in Distt. Satna (M.P.) and is accessible through village roads from Satna-Panna road. The tower at Location no. 709 (DA+6) was damaged. The left side middle cross arm of tower (looking from Vindhyachal to Satna) was partially damaged and top cross arm was fully damaged while bottom cross arm was intact. The right side Middle and bottom cross arms seemed to be damaged due to falling of top cross arms & earth wire peaks on right side cross



arms. No visible damage was observed below bottom cross arm level. Minor damage to the sub-conductors of phase was observed due to rubbing of conductor with tower body. About 50% of insulators damaged. No missing members were observed in collapsed tower/ nearby locations. The line was passing through low height hill situated on both the sides creating tunneling effect of wind across the line.

#### **Probable Cause of Failure**

The localized heavy wind condition prevailed in the vicinity of the village Pondi (Satna). This wind blowing in perpendicular direction to the line might have created tunneling effect and critical loading on towers due to disposition of hills in transverse direction of line resulting in damage to tower at Location No. 709.

#### **Restoration**

Line was restored on normal towers and charged on 25th May' 2015.

#### **Recommendation of the Committee**

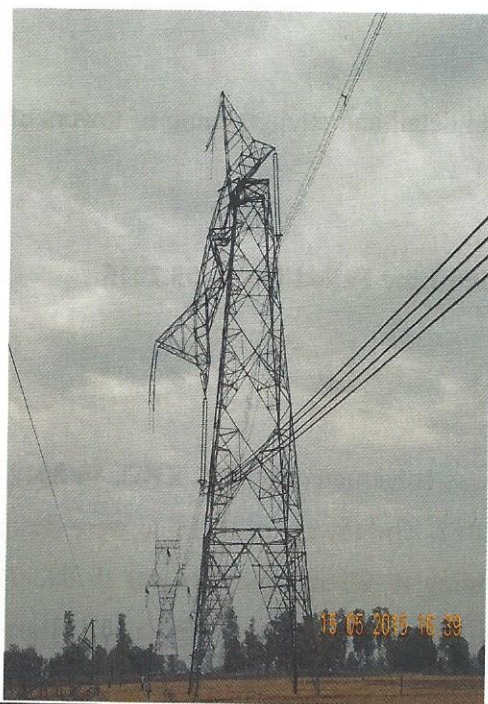
The committee recommended to review design of towers for strengthening, even though the towers were designed according to IS:802(1995), in case of more failure occurs in future.

### **7. 765 kV S/C Gaya-Sasaram -Fatehpur Transmission Line Failed On 14.05.2015 (Location Nos. 283 and 284)**

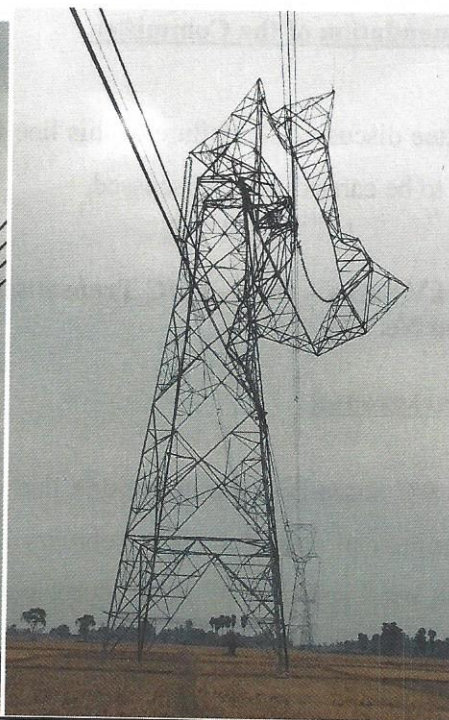
#### **Brief Background**

Gaya- Sasaram-Fatehpur 765 kV S/C line was constructed by M/s. Kalpataru. The line was commissioned on 31/03/2012. The towers of this line were designed for basic wind speed of 47 m/s corresponding to Wind Zone-4 as per IS 802-1995. The towers were designed in delta configuration with Quad ACSR BERSIMIS Conductor. The line had failed on earlier occasions on 11.04.2012 (1 Tower affected) and 31.05.2014(15 Towers affected). Line tripped at 1425 Hrs. on 14/05/2015 due to collapse of 2 nos. of towers at Location Nos. 283(A+3) & 284(A+0).





**Location No.283**



**Location No.284**

### **Observations**

Both of the affected towers have fallen in right side in transverse direction facing Sasaram. The affected towers were located in a plain stretch of cultivated field having very few trees. The stretch might have experienced critical wind during the storm. Both the towers at location No. 283 (Tower Type 'A+3') & Location No. 284 (Tower Type 'A+0') are suspension towers and were partially damaged and failed from waist level. All the four stubs of both the towers and with foundations were found intact. Many insulators of insulator strings were intact but some insulators were damaged. The phase conductors were partially damaged and no damage was noticed in earthwires.

### **Probable Cause of Failure**

The failure of towers might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earthwires as well as on tower itself exceeding the design values.

### **Restoration**

Restoration of the line on normal towers was done on 02-06-2015.



### **Recommendation of the Committee**

Committee discussed the failure of this line in detail and strengthening of towers of this line has to be carried out as discussed.

#### **8. 765 kV Satna – Bina - I S/C Transmission Line Failed On 16.05.2015 Location No. 82)**

##### **Brief Background**

765 kV S/C Satna-Bina-I transmission line was constructed by M/S KPTL in 2012 and is in commercial operation since February 2012. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The suspension towers were designed in delta configuration for Quad Bersimis conductor with double I-V-I insulator string.



**Location No. 82**



### **Observations**

The line tripped on Y-phase to Earth fault on 16-05-2015 at 1441 hrs. During patrolling of the line, it was observed that one suspension tower (A+0) at location number 82 had collapsed. The tower at location No. 82 had collapsed above bottom cross arm level / waist level (near the diamond section). The stubs and foundations were intact. Phase conductors were partially damaged. No damage was apparent on earth wires. Affected tower was located in a plain stretch of cultivated field having very few trees. The stretch might have experienced critical wind during the storm.

### **Probable Cause of Failure**

Failure/ damage to tower at location No. 82 could be due to localized whirlwind in the area resulting in large wind load on phase conductors and earth wires as well as on tower body itself exceeding the design values.

### **Restoration**

The line was restored on normal towers on 26-05-2015.

### **Recommendation of the Committee**

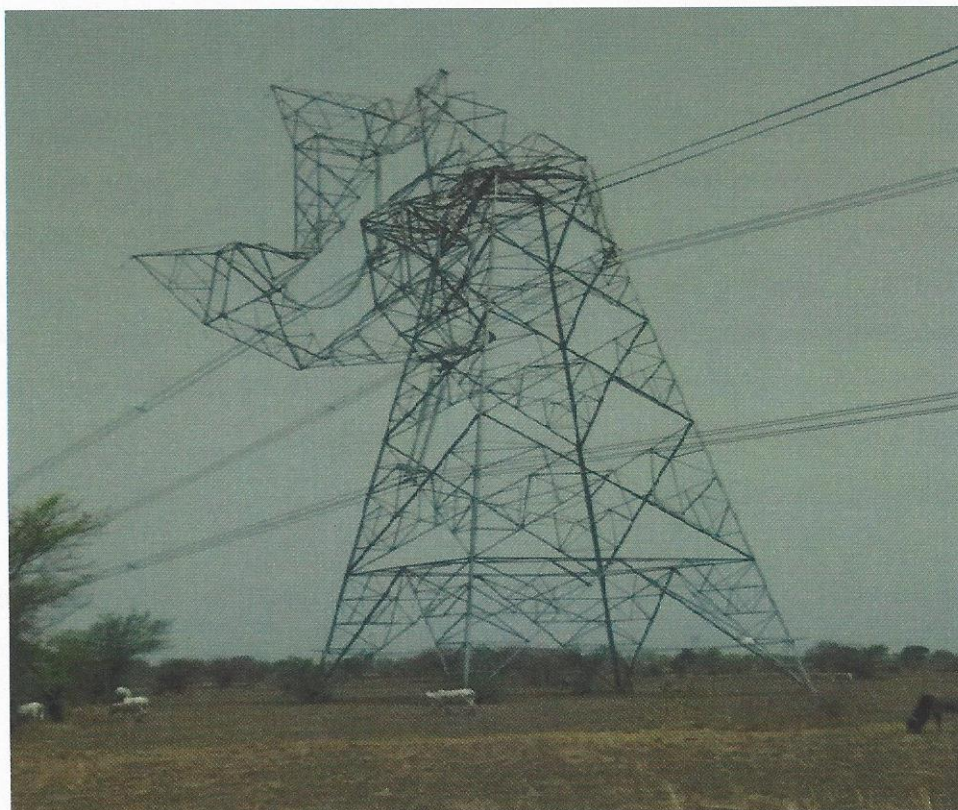
The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

## **9. 765 kV Satna – Bina - II S/C Transmission Line Failed on 19.05.2015 (Location No. 717)**

### **Brief Background**

765 kV S/C Satna-Bina-II transmission line was constructed under Sasan UMPP scheme -II project by M/S KEC in 2012 and is in commercial operation since June 2012. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The suspension towers were designed in delta configuration for Quad Bersimis conductor (with double I-V-I insulator string). The line tripped on R-phase to Earth fault on 19-05-2015 at 20:08 hrs.





**Location No. 717**

**Observations**

During patrolling of the line, it was observed that one suspension tower (A+0) at location No. 717 had collapsed. The tower has collapsed above bottom cross arm level / waist level (near the diamond section). The stubs and foundations were intact. The two suspension towers (at location nos.313 & 314) of above line had failed earlier on 2.10.2014.

**Probable Cause of Failure**

Failure/ damage at tower No. 717 might have been caused by localized whirlwind in the area resulting in large wind load on phase conductors and earth wire as well as on tower body itself exceeding the design values.

**Restoration**

Line was restored on conventional towers on 31-05-2015.



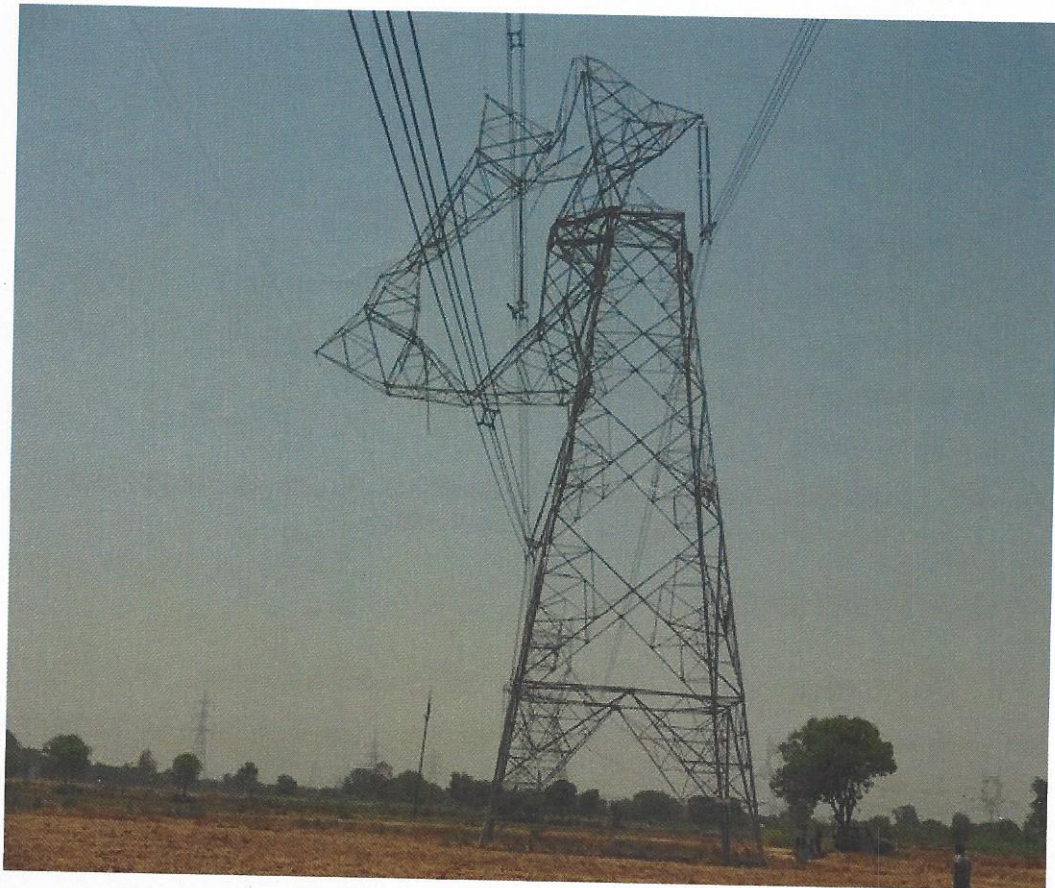
### **Recommendation of the Committee**

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

#### **10. 765 kV S/C Agra-Meerut Transmission Line Failed On 19.05.29015 (Location No. 35)**

### **Brief Background**

765 kV S/C Agra-Meerut line was constructed by M/s. EMCO. The line is in commercial operation since 01-06-2013. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995 using delta configuration with Quad ACSR BERSIMIS Conductor. No tower failure was reported in this line since commissioning. The line tripped at 19:23 Hrs. on 19/05/2015 due to collapse of 1 (one) tower at Location No. 35 (A+0).



**Locaion No.35**

### **Observations**

Tower at Location No. 35 (A+0) was partially damaged and failed from waist level. The tower had fallen in transverse direction. This tower was located in a plain stretch of cultivated field having very few trees. The stretch might have experienced critical wind during the storm. All the four stubs of the tower and foundation were found intact. Phase conductors were partially damaged near the tower due to rubbing of conductor with tower body during collapse of tower. All insulator strings were intact except breakage of one polymer insulator string of middle phase. No damage to earthwire was observed.

### **Probable Cause of Failure**

In local newspaper, it was reported that destruction/damage to properly had taken place due to high intensity wind velocity on 20.5.2015. Failure of tower might have been caused by localized cyclone near Agra resulting in large wind load on phase conductors and earthwire as well as on tower itself beyond the design values.

### **Restoration**

Line was restored on normal towers on 03-06- 2015.

### **Recommendation of the Committee**

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

## **11. 400 kV Farakka-Durgapur-II S/C Transmission Line Failed On 24.05.2015 (Seven towers at Location Nos. 180-184 & 186-187)**

### **Brief Background**

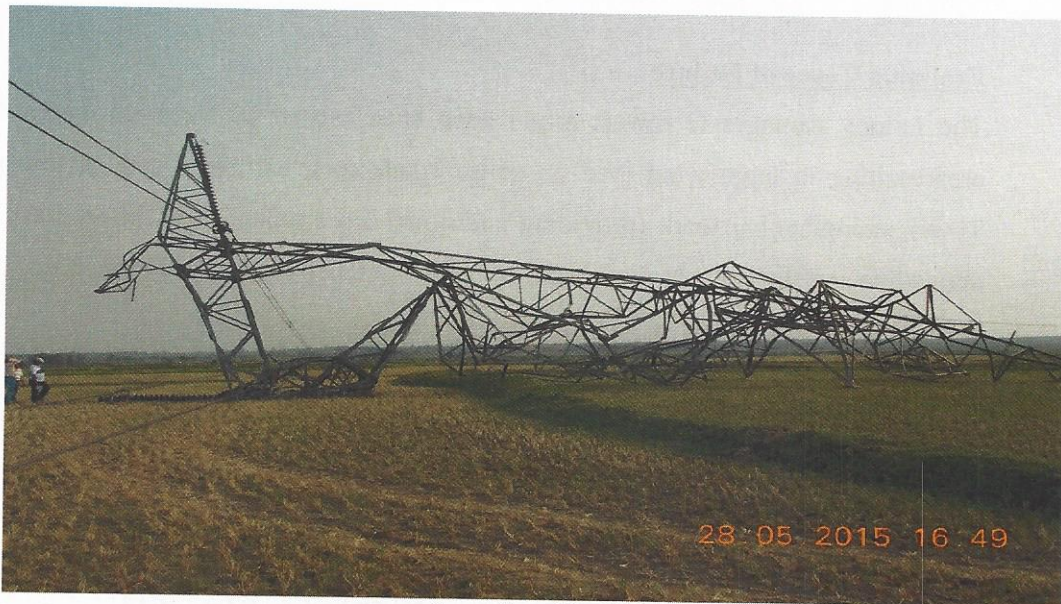
Farakka-Durgapur-II 400 kV S/C line was constructed by M/s. EMC. The line was commissioned on 01-08-1992. The towers of this line were designed for Medium wind zone as per IS 802-1977. The towers of the line were designed for horizontal configuration with twin Moose conductor and I-V-I insulator strings. The line tripped at 1810 Hrs. on 24/05/2015 due to collapse of 7 nos. of towers at Loc. No. 180(A+0), 181(A+0), 182(A+0), 183(A+0), 184(A+0), 186(A+0) and 187(A+3) during localized cyclone.



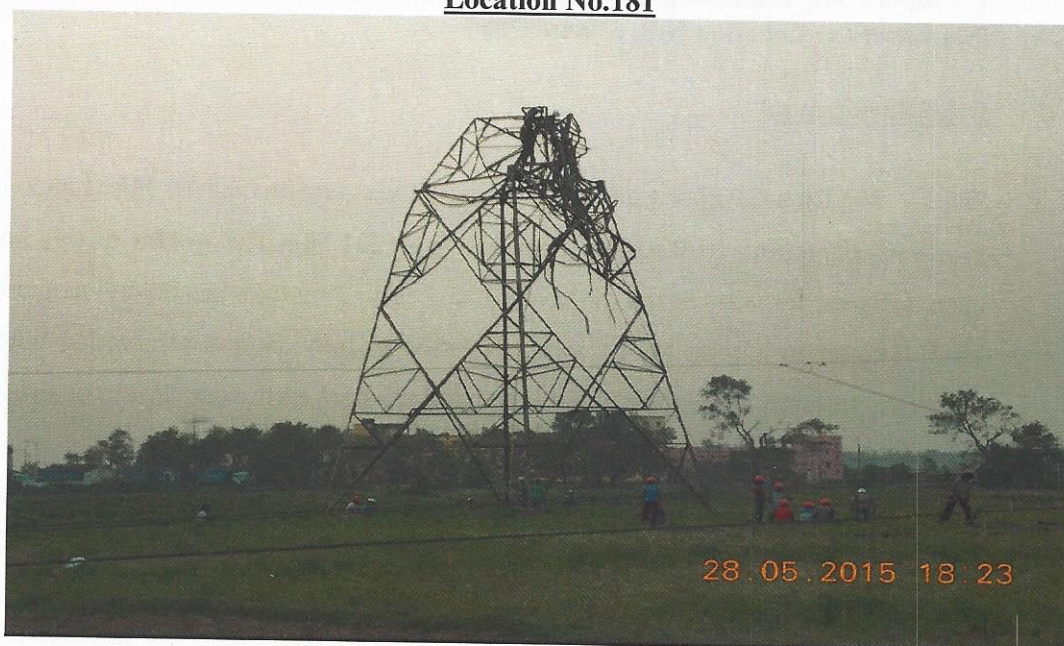
The previous history of tower collapse of this line is as follows:

	<b>Date of Collapse</b>	<b>Section affected</b>	<b>Type of Tower(s) affected</b>
1)	11th May, 2013	361	A type
2)	8th May, 2008	115, 116	A type
3)	4th June, 2005	361	A type
4)	1st May, 1999	354 to 357	A type
5)	4th June, 1998	360 to 362	A type

Due to repeated collapse of suspension towers in this line, work for strengthening of suspension towers was in progress (providing additional hip bracing). Strengthening of towers in affected section is likely to be completed in 2015.



**Location No.181**



**Location No.186**



### **Observations**

It was observed that four (4) numbers of towers at location Nos. 181, 182, 183 & 187 have collapsed from ground level with all four stubs bent whereas three (3) towers at location Nos. 180, 184 & 186 collapsed from upper level. The tower at location No. 180 had collapsed from 6m level with all four stubs bent, tower at location No. 184 had also collapsed from 6m level with two stubs bent and tower at location No.186 had collapsed from 9m level although all stubs were in tact. All these affected towers have fallen in left side in transverse direction facing Durgapur. All these affected towers were located in a plain stretch of cultivated field having very few trees.

### **Probable Cause of Failure**

The failure/ damages to towers might have been caused by localized cyclone in the arearesulting in large wind load on phase conductors, earthwire and on tower body. Tower strengthening work (providing additional hip bracings) was in progress for the above line and the strengthening work in failed stretches was yet to be taken up.

### **Restoration**

Restoration of the line on normal towers was expected to be complete by 15-06-2015.

### **Recommendation of the Committee**

Committee recommended for early completion of strengthening of towers of this line.

### **12. 765 kV S/C Bina-Gwalior Trans. Line –III Failed on 02.06.2015 (Six towers at Location Nos. 573 to 578)**

### **Brief Background**

765 kV S/C Bina-Gwalior transmission line-III was constructed by M/s. Lanco and the line was charged on 07/05/2014. Line length is 231.5km. The towers of this line have been designed for wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The single circuit towers were designed in horizontal configuration with Quad ACSR BERSIMIS Conductor and two galvanized steel earth wire. Insulator strings used for the horizontal configuration Suspension towers are “DI” “V” “DI” ( Double “I” having 120 kN glass insulators) whereas for tension towers it is “QT”(Quad tension) strings with 210KN glass insulator. Tripping of the line was reported on 02/06/2015 at around 5:18PM because of tower failure/collapse under severe storm.





**Location No. 577**



**Location No. 575**

### **Observations**

All the six tower at location Nos. 573(AH+0), 574(AH+0), 575(AH+0), 576(AH+3), 577(AH+0) and 578(EH+6) were of horizontal configuration type and were in open wheat field with hardly any trees.

Out of the six collapsed towers, two towers (at location nos. 574 & 575) had collapsed from above the first panel and rest four (4) towers had collapsed from just above the concrete level of chimney. Towers have fallen in the transverse direction of the line. Most of the tower members were in jumbled condition. Conductors and earthwire had snapped. Insulators were shattered and scattered all around. The towers at location Nos. 572 and 579 (adjacent to loc. Nos. 573 and 578) have not suffered any damage and are intact. There were no missing members.



Foundations of all the six failed tower locations (from 573 to 578) were designed for WET type foundation. All the Chimneys and foundations at location Nos.573, 574, 575 & 578 are intact. At tower location No.573, one of the stubs have been sheared just above the bracing attachment point, one stub had twisted and other stubs are intact. At tower location No.575, one of the stubs had minor bend. At tower location No.576, a small portion of one of the chimneys had broken off and all stubs were either bent or twisted. At tower location No.577 and 578, two chimneys had surfacialcracks, third one had partial damage in the top portion. Three stubs were bent to varying degree and fourth one was broken from just above the concrete level.

#### **Probable Cause of Failure**

It was reported that a very high intensity westerly storm with very high wind velocity was experienced in this area which was also reported in local newspaper and confirmed by local villagers. The high intensity/speed of wind might have exceeded the design limit of the tower leading to collapse of towers. It seems that the tower at the location No. 578(EH+6) had collapsed first from stub level and had fallen in the transverse direction. The tower at other locations might have failed subsequently because of cascading effect.

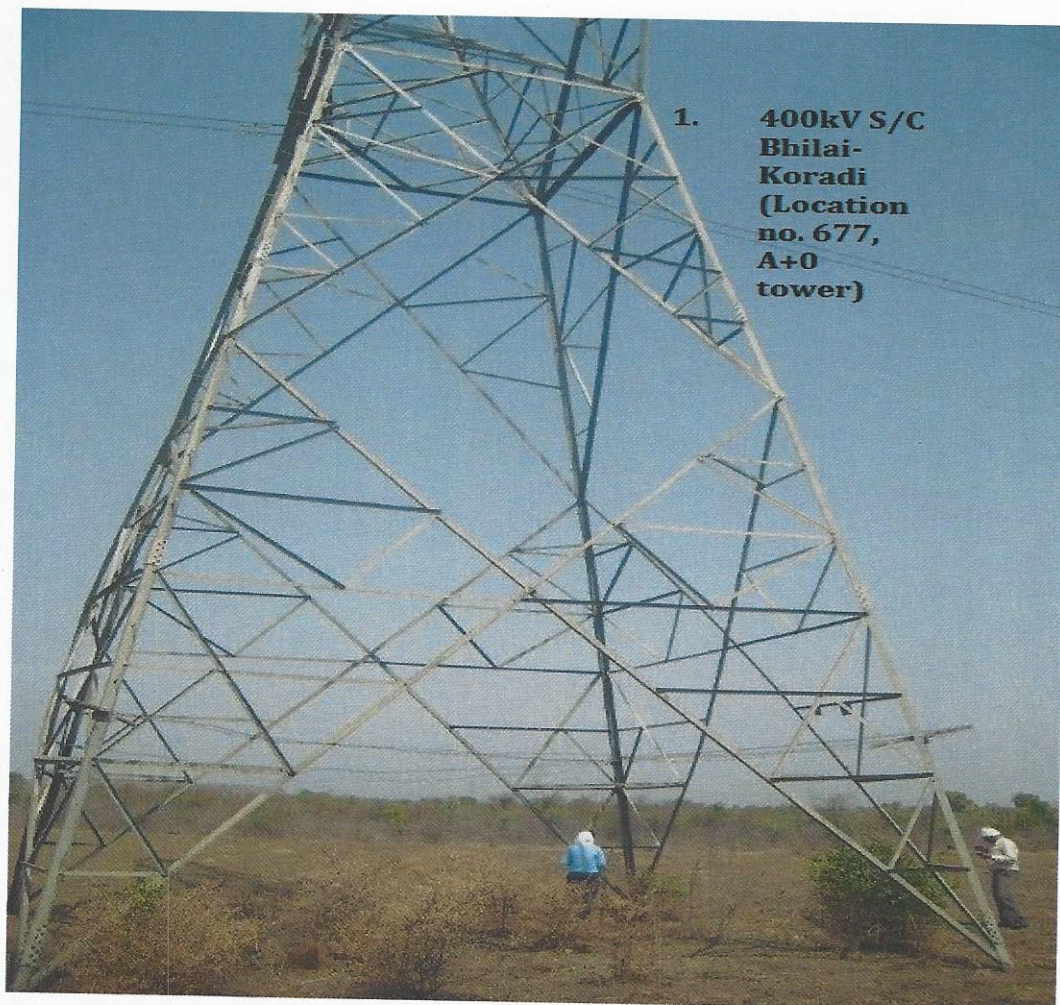
#### **Recommendation of the Committee**

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

#### **13. 400 kV Bhilai-Koradi transmission line**

During the meeting, officials of PGCIL informed that the line was taken under shut down on 06.06.2015 for rectification of deformed tower due to uneven settlement of foundation of legs of the tower. The bottom panel of the tower was deformed completely. The detail report has not been submitted by PGCIL.



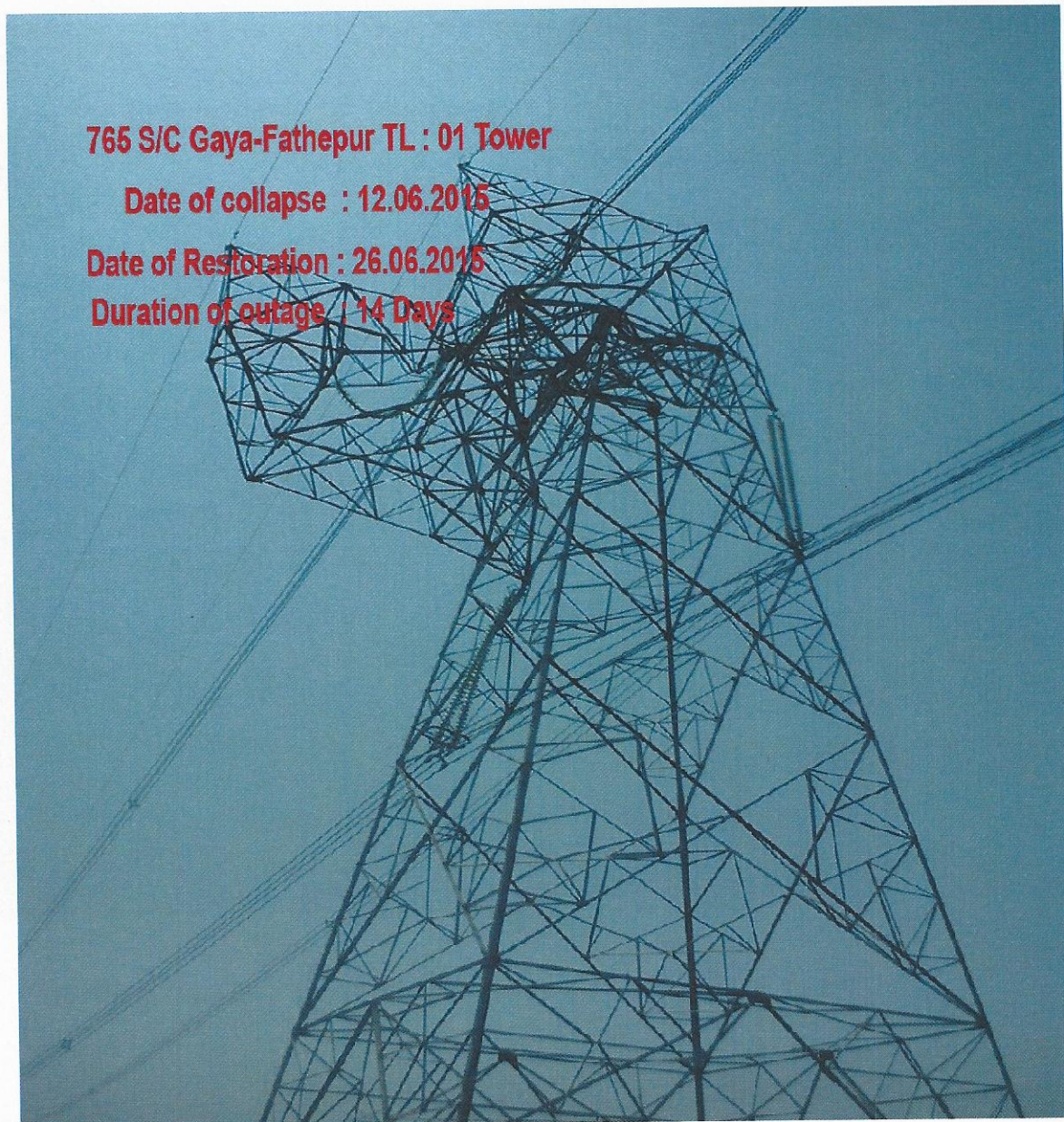


**14. 765 kV S/C Fatehpur- Gaya Transmission Line Failed on 12.06.2015  
(Location No. 334)**

**Brief Background**

Gaya-Sasaram-Fatehpur 765 kV S/C line was constructed by M/s. Kalpataru. The line was commissioned on 31/03/2012. The towers of this line were designed for basic wind speed of 47 m/s corresponding to Wind Zone-4 as per IS 802-1995. The towers were designed in delta configuration with Quad ACSR BERSIMIS Conductor. The line had failed in three earlier occasions on 11.04.2012 [one suspension tower at location No.314], on 31.05.2014 (15 towers affected) and 14.05.2015 [2 towers at location Nos. 283(A+3) & 284(A+0) affected]. The line tripped at 14:52 Hrs. on 12/06/2015 due to collapse of 1 (one) tower at Location No. 334(A+0).





#### Location No.334

##### Observations

The tower was partially damaged and failed from waist level and fallen in transverse direction. This tower was located in a plain cultivated field having very few trees. The stretch might have experienced critical wind during the storm exceeding the design limit. All the four stubs of the tower and foundation were found intact. Phase conductors were partially damaged, some insulators were also damaged and no damage to earthwires was observed.



### **Probable Cause of Failure**

The failure of towers might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earthwire as well as on tower itself exceeding the design values.

### **Restoration**

Line was restored on 26-06-2015.

### **Recommendation of the Committee**

Committee discussed the failure of this line in detail and strengthening of towers of this line has to be carried out as discussed.

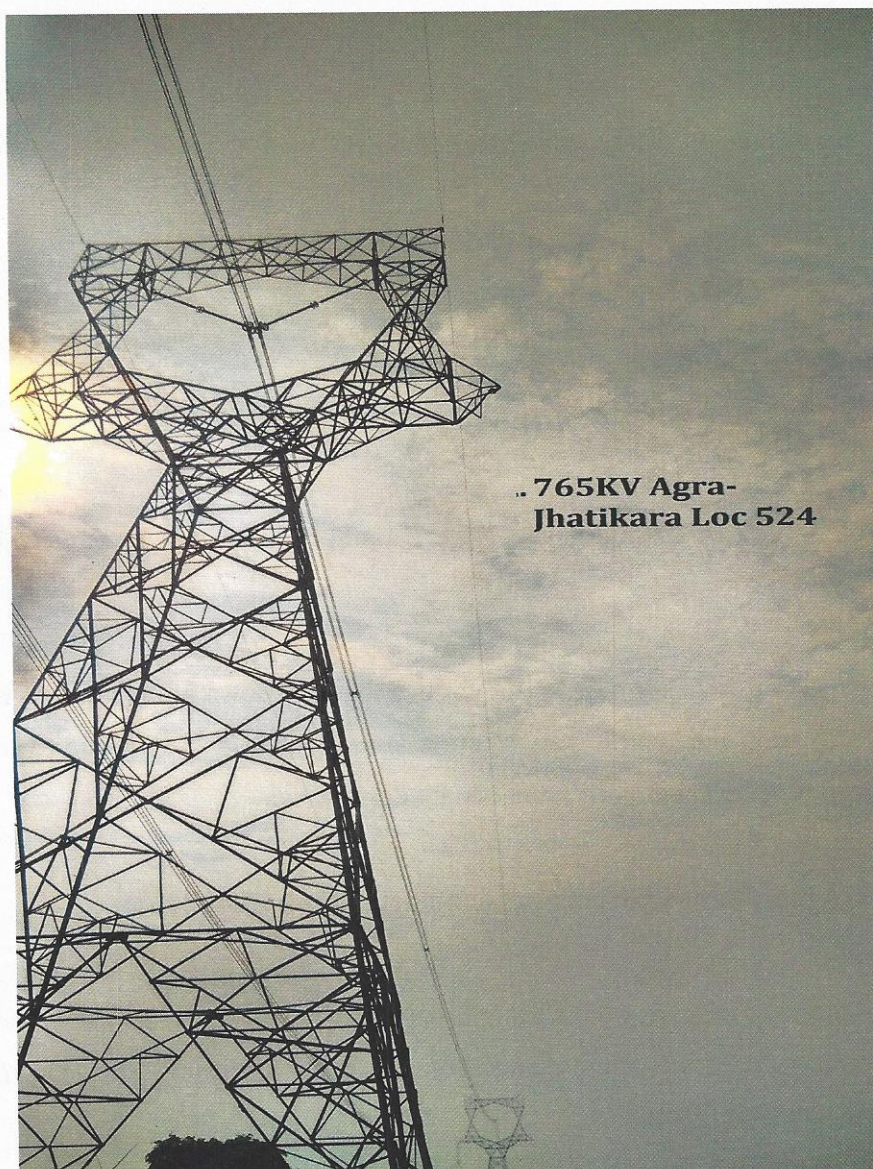
#### **15. 765 kV S/C Dharamjaigarh- New Ranchi-II transmission line failed on 16.06.2015**

During the meeting, officials of PGCIL informed that shut down of the line was taken on 16.06.2015 to carry out rectification of cross arm of tower damaged due to localized storm. Detail report has not been submitted by Power Grid.

#### **16. 765 kV Agra- Jhatikaran transmission line failed on 23.06.2015**

During the meeting, officials of PGCIL informed that shut down of the line was taken on 23.06.2015 for rectification of cross arm damaged due to localized storm. Detail report has not been submitted by PGCIL.





.. 765KV Agra-  
Jhatikara Loc 524

**17. Further Discussion on 765 kV Gaya – Fatehpur transmission line failed on 31-05-2014**

The failure of towers (15 towers at Location Nos : 320 to 330, 305, 306, 311 & 315) of 765 kV Gaya-Fatehpur Transmission line on 31.05.2014 was also further deliberated during the meeting on 08.12.2015 based on the input from CPRI and response of PGCIL in order to submit the final report on failure of towers as per the direction from Hon'ble Central Electricity Regulatory Commission (CERC) with reference to petition No. 9/SM/2014. The decision/recommendations of the Standing Committee are summarized below.



**(a) Brief Background**

The Gaya – Fatehpur 765kV S/C line (345 km) was constructed by M/s KPTL and commissioned on 31-03-2012. The towers of Gaya – Fatehpur 765kV S/C line was designed with delta configuration as per IS 802 (1995) with Wind Zone - 4 and reliability level 2 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for design of suspension towers as per decision in CBI&P forum. One tower of the line (at location No. 314) had failed on April 11/12, 2012 immediately after its commissioning in March 2012. During the heavy storm on 31-05-2014, fifteen (15) towers [3 towers in one section, 11 towers in 2nd section and one tower in 3<sup>rd</sup> section - consecutive three sections] of above line had failed at location Nos. 305,306, 311, 315, 320 to 330. All the failed towers were suspension towers and located in plain stretch of cultivated land. This is the second failure. Nine (9) towers had failed above bottom cross arm / waist level (near diamond section) and six (6) towers had completely collapsed & fallen on ground. The foundations were intact. All the failed towers were of 'A' type & located in plain stretch of cultivated land. Powergrid in their preliminary report had mentioned that the stretch might have experienced critical wind during the storm. POWERGRID official had informed that theft of tower members was also noticed in some tower locations. The line was restored on normal towers on 30-06-2014.

The Standing Committee of Experts had the meetings in CEA with utilities on 19.6.2014 and 12.09.2014 to discuss the failure of towers during April 2014- July 2014. Copy of the report was sent to Hon'ble commission. During the meetings the failure of towers of Gaya – Fatehpur 765kV line was also discussed.

The recommendations of the Committee were as follows:

- (i) The design of towers needs to be reviewed for further strengthening, even though the towers were designed according to IS:802(1995), in case of more failure occurs in such lines.
- (ii) The patrolling of line needs to be increased in theft prone areas in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.

- (iii) Coping of Chimneys, wherever required, needs to be done to avoid accumulation of water near stubs.

Hon'ble Central Electricity Regulatory Commission, New Delhi, vide their Record of Proceedings (RoP) against Petition no. 9/SM/2014 dated 14.10.2014, had directed PGCIL to investigate in coordination with CEA in detail the failures of towers considering the structural, and workmanship aspects, material used and O&M practices involving academia and submit a report on collapse of (15 nos.) towers of 765kV Gaya-Fatehpur line on 31.5.2014 suggesting remedial measures.

As per direction of Hon'ble commission, two meetings were held in CEA on 24-11-2014 and 28-04-2015 inviting members of the Standing Committee of Experts and special invitees from utilities and academia [POWERGRID; Delhi Transco Ltd.(DTL); Delhi Technological University(DTU); TCD Division of CEA; Central Power Research Institute(CPRI); Structural Engineering Research Center (SERC), Chennai; and IIT, Delhi ] to discuss in detail about the failures of towers of above 765kV transmission line on 31-05-2014.

As per decision of the 1<sup>st</sup> meeting, PGCIL had shared the design details of 765kV suspension tower, O&M practices, Photographs of tower failures with CEA, which were sent to DTU, CPRI, IIT Delhi, TCD division of CEA, and SERC, Chennai for analysis/study and suggestions.

In the 2<sup>nd</sup> meeting of experts, held in CEA on 28.04.2015, the observations of SERC, CPRI and TCD Division of CEA on the design document & drawings of 765kV S/C suspension tower was discussed further.

As per the decision taken in the 2<sup>nd</sup> meeting, the design input files (input file of STAAD Software & i-Tower Software) & structural drawings of the failed towers were shared by CPRI & PGCIL for further examination. CPRI had submitted the final report based on their analysis carried out with STAAD Software.



**(b) Discussion in Standing Committee Meeting held in CEA, New Delhi on December 8, 2015**

The Standing Committee had the meeting on December 8, 2015 in New Delhi and further discussed on the observations of CPRI and the response of PGCIL on the final report submitted by CPRI. The variation in tower member / section size in design document and structural drawing was noticed. The planning for strengthening of towers of existing line and for new line was also deliberated in the meeting.

**(c) During the meeting PGCIL has clarified as follow:**

- (i) In plain terrains, percentage of tangent / suspension towers are normally much more compared to tension / angle towers and hence there is tendency to optimize the design (without much safety margin in design) in order to economize the cost of transmission lines.
- (ii) PGCIL also brought to notice that lot of difficulties is being faced while erecting towers with delta configuration. Towers with horizontal configuration take about three (3) days for erection where as towers with delta configuration takes about ten (10) days for erection. Executing agencies have also requested to review the design for change of the configuration. In the meantime, POWERGRID has decided to modify the configuration of tower and towers with three cross arms [two cross arms at one level and 3rd cross arm at higher level] are being designed for 765kV S/C lines. The 765kV Raichur – Solapur S/C line, which connected WR with SR forming one synchronous National Grid, has been designed with such configuration. Hence in future the towers with delta configuration may not be used and as such most of the 765 kV lines will be D/C lines with vertical configuration. Towers with Double circuit configuration have already been designed and tested for wind zones 2, 3, 4 & 5. The towers for wind zone 1 & 6 shall be designed and tested as and when required.
- (iii) Regarding the variation in structural drawing and design with reference to member / section size, PGCIL clarified that member / section size mentioned in structural drawing has been used in the towers and the tower design has been

reviewed by CPRI & PGCIL taking into account the member / section size indicated in the structural drawing.

(iv) PGCIL informed that further strengthening of member No. M5, as suggested by CPRI, is not required after strengthening of member Nos. M51/ 52 & D12 and providing two (2) redundant members.

(v) PGCIL has agreed to revise the design of the 765kV Tower Type-A used in Gaya - Fatehpur line by strengthening the Tower [increasing the member / section size of six (6) members including three (3) members / sections as suggested by CPRI and adding two (2) more redundant members].

(vi) PGCIL further highlighted that since strengthening of tower is to be done above waist level, long shutdown shall be required for replacement of members / sections of towers in existing line. The nature of work and the risk involved in replacement of member of towers in existing line is different from fabrication of towers afresh. The fabrication of fresh towers can be taken up easily. But replacement of members in the existing towers is very difficult and risk is involved. Moreover, many of the executing agencies may not be interested to take up such difficult and risky job.

**(d) The recommendations of the Committee were as follows:**

(i) The towers with delta configuration shall be avoided to the extent possible in 765kV single Circuit (S/C) lines in future and as such most of the 765 kV lines shall be Double Circuit (D/C) lines with vertical configuration.

(ii) In absence of meteorological data, it has become difficult to assess the actual wind velocity at site of failure in order to verify with the design value of wind speed. However, the detailed analysis of structural design of suspension tower (with delta configuration) of 765kV S/C line was carried out by CPRI and PGCIL using two different softwares [STAAD Pro and i-Tower]. The strengthening of suspension towers (with delta configuration) of 765kV S/C line traversing through wind Zone - 4 has to be carried out as indicated below by increasing the member / section size of six (6) members and adding two



(2) more redundant members. The drawing showing the member location is enclosed as **Annexure - II**.

<b>Member No.</b>	<b>Original Member size</b>	<b>Proposed Member size</b>	<b>Existing No. of Bolts</b>	<b>Proposed No. of Bolts</b>
D13	65x65x5 (MS)	65x65x6 (MS)	2 SS – 16Ø	2 SS – 16Ø
D16	80x80x6 (MS)	90x90x6 (MS)	2 SS – 16Ø	2 SS – 16Ø
D29	70x70x5 (MS)	90x90x6 (MS)	2 SS - 16Ø	3 SS - 16Ø
M51/52	100x100x8 (HT)	110x110x8(HT)	6 DS - 16Ø	6 DS - 16Ø
D12	75x75x6 (HT)	80x80x6 (HT)	3 SS - 16Ø	3 SS - 16Ø
New Redundant connected to M5	-	50x50x5 (MS)	-	1 SS - 16Ø
New Redundant connected to H3/H4	-	50x50x5 (MS)	-	1 SS - 16Ø

(iii) Since strengthening of tower is to be done above bottom cross arm / waist level (near diamond section), long shutdown shall be required for replacement of members / sections of towers in existing line and the nature of work and the risk involved in replacement of member of towers in existing line is different from fabrication of towers afresh. The fabrication of fresh towers can be taken up easily. But replacement of members in the existing towers is very difficult and lot of risk is involved. Moreover, many of the executing agencies may not be interested to take up such difficult and risky task. Dismantling and replacement of the structural part above waist level of tower requires long shut down. Hence such activity shall be taken up during annual maintenance in a phased manner. PGCIL has to prioritize the areas / lines where such activity can be taken up. Accordingly planning has to be done by PGCIL.

(iv) The patrolling of line needs to be increased / intensified in theft prone areas in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.

(v) The rate of failure of suspension towers (with delta configuration) of 765kV S/C line traversing through other wind zones (other than Wind Zone -4) and areas prone to cyclone / storm needs to be monitored. In case repeated failure

is observed in those lines, similar exercise for review of design has to be taken up by PGCIL for different wind zones for suspension towers (with delta configuration) of 765kV S/C line.

- (vi) The regions, where frequent failures of transmission line towers are observed, need to be identified and wind data logger stations may be installed by PGCIL in those areas on priority basis. PGCIL should expedite the installation of Anemometers in substations, particularly in cyclone / high wind prone areas, as recommended earlier by the Standing Committee of experts on failure of transmission lines of 220kV and voltage level.
- (vii) The committee also decided that PGCIL has to strengthen towers of other 765kV S/C lines, designed for wind Zone -4 with Delta configuration of towers, in line with Gaya – Fatehpur 765kV S/C line.
- (viii) The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.



## 2.2 DETAILS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF RRVPNL

2.2.1 The towers of following 765kV, 400kV, 220kV and 132kV Transmission Lines of RRVPNL had failed during above mentioned period.

Sl. No.	Names of the Transmission Lines	Date of Occurrence of failure	No. of towers failed
1.	400 kV Akal(Jaisalmer)-Barmer Transmission line	15.02.2015	5
2.	765kV S/C Anta-Phagi Transmission line	14.03.2015	7
3.	220kV D/C Bap-Bhadla Transmission line	11.05.2015	3
4.	220 kV D/C Bikaner-Gajner Transmission line	19.05.2015	15
5.	132 kV D/C Bikaner-Pugal road & 132kV D/C Gajner-Pugal road Transmission line	19.05.2015	7
6.	132 kV D/C Nokha-Jasrasar Transmission line	19.05.2015	3
7.	LILO of 132kV D/C Bikaner-Dulhasar line at GSS Sherera Transmission line	19.05.2015	25
8.	220 kV D/C Bharatpur-Dholpur Transmission line	19.05.2015	6
9.	220kV D/C Alwar-Badarpur Transmission line	20.06.2016	2
<b>Total</b>			<b>73</b>

### Observation of Committee & recommendations

1. **400 kV Akal (Jaisalmer)- Barmer Transmission line failed on 15.02.2015 (Tower Nos. 227,228, 229,230 and 231 at location Nos. 16/7 to 16/10 and 17/0 respectively)**

#### Observations

As per the preliminary enquiry report submitted by RRVPNL, the towers had collapsed on 15.2.15 and heavy fog in the morning was observed on this day. Total five numbers

of towers of the line(4 Nos. Suspension + 1 No. Tension tower) were damaged in the incident. The tower Nos. 227&228 are having body extension of +9m and other towers are having body extension of +3m. The towers at location Nos. 16/7(227), 16/10(230),17/0(231) are designed for WET type foundation and towers at location Nos.16/8(228) and 16/9 (229) are designed for DFR type foundation. All three suspension type towers (with Sl. Nos.227, 228 and 229)had completely collapsed and fallen on the ground in transverse direction and one tension tower (with Sl.No. 231) was bent at stub level and chimney of the leg was found with cracks. The tower at Sl. No. 230, (SA+3) remained intact. However, the flashover marks were seen on disc insulators and decapping of insulator was observed on outer most phase. Insulator string had broken and found fallen on the ground. It was reported that due to failure of suspension Disc insulator at tower No. 230, the conductor of particular phase had snapped due to decapping of disc insulators of the string.

There was no report of heavy wind/storm in that area. As per the preliminary report, survey was supposed to be carried out to check angle of deviation of towers, span lengths etc. for existing locations covering tower Sl. No. 227 to 231 and the proposed locations where new towers are to be erected. Sample of concrete, type of soil was also to be checked for existing tower foundations at Sl. No. 227, 229 and 231. Sample from broken leg and tension plate of insulator string at Tower Sl. No. 231 was to be sent for chemical analysis. Tower foundation design was also supposed to be submitted for analysis.

#### **Probable Cause of Failure**

The details of tower were not available. There was no report of heavy wind/storm on the day of failure. Committee discussed in detail about probable cause of failure. The committee suggested RRVPNL to submit the above reports including foundation design for further analysis.

#### **Recommendations of the Committee**

Committee recommended for

- Checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers



- Checking of angle of deviation in the section where towers have failed
- Submission of foundation design of existing towers for further analysis
- Considering the use of composite insulators in pollution prone areas to avoid the flashover across insulator discs.

**2. 765 kV Anta - Phagi S/C Transmission Line failed on 14.03.2015  
(7 Towers at Location Nos. 18/0, 18/1 to 18/6)**

**Brief Background**

The 765kV Anta-Phagi S/C line (211.848km) with Quad ACSR Bersimis conductor was constructed by KEC Limited in 2014 and charged at 400kV level on 25-03-2014. Subsequently the line was charged at 765kV level on 14-01-2015. Seven (7) Nos. of suspension towers had failed on 14-03-2015 at 18:13 Hrs. The design was provided by PGCIL.



**Location No.18/0**

**Location No. 18/1**

**Observations**

The team of officers from CEA along with officers from RRVPNL had visited the tower failure sites on 28.03.2015. The towers at location Nos.18/0 (D+0), 18/1(A+0), 18/2 (A+0), 18/3(A+6) and 18/4 (A+3) had collapsed, stub part was bent and top portion of chimneys had crack. The tower at location No. 18/5(A+3) was partially damaged with peak and cross arm bent/damaged, but foundation was intact. In case of the tower at

location No. 18/6 (A+0), two leg members of first panel was found to be bent. The foundation was intact. However, the foundations need proper protection as erosion of soil was found near the foundation due to rain water flow. During the inspection, some members of the bottom panel was also found missing, i.e. stolen by some anti socialpeople / miscreants. Few holes left in the joints without bolts. Coping of chimneys was not done. ACD was found missing at tower location No. 18/6 (A+0). Earthing of the towers was not done properly. Tag welding was not done in bolts. Antitheft bolts were missing at few locations. The material test report of the failed tower members, received from RRVPNL, was found to be generally in order. It was reported that the maximum wind speed of 37kmph (at 20: 55Hrs) in NE direction was recorded at Kota A.P observatory on 14-03-2015.

### **Probable Cause of Failure**

Newspapers and local farmers and villagers reported that there was heavy rain, snow fall and speedy storm on the day of failure. The high speed wind / storm, heavy rain and missing members might have led to collapse of towers.

Committee discussed the issues and it was brought to notice that the design of the towers was provided to RRVPNL by PGCIL and the design is similar to Gaya-Fatehpur 765kV S/C line. The committee advised PGCIL to provide the details of strengthening of tower to RRVPNL. But damage of chimneys was exclusive to RRVPNL tower failures. The representatives of RRVPNL informed that a small nalla flows nearby this line / towers and hence during rainy season problem of water logging below the tower is seen. Due to this, the soil around the foundation got eroded and washed away exposing the foundation.

### **Recommendations of the Committee**

The failure pattern of seven (7) Nos. of suspension towers (with delta configuration) of Anta-Phagi 765kV S/c line in RRVPNL system was similar to 765kV Gaya – Fatehpur S/C line and design was provided by PGCIL for wind Zone – 4 with delta configuration of towers. RRVPNL has to plan and carryout modifications by strengthening the members in line with above mentioned transmission line of PGCIL. The committee also suggested RRVPNL to review the design of foundation of towers.



Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- To provide a path for rain water to drain away and to provide proper protection / retaining walls with weep holes all around the tower to avoid soil erosion and also to protect the foundation.
- To carry out detail soil investigation
- The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by RRVPNL and involved for safety of towers.
- Replacing the missing members and bolts and tag welding of bolts may be done.
- Copping of chimneys to avoid accumulation of rain water near stubs.
- Replacing missing ACD
- Providing proper earthing connection for towers

**3. 220 kV D/C Bap-Bhadla Transmission line failed on 11.05.2015  
(3 Towers at Location Nos. 41 to 43)**

**Brief Background**

Bap- Bhadla 220 kV D/C Transmission line was designed and constructed by RRVPN during 2013-14. The line was designed for wind zone 3 with ACSR Zebra Conductor. The length of the line is 52kms.

**Observations**

The Line tripped at 18:50 Hrs. on 11/05/2015. On patrolling, it was found that three (3) suspension towers at Location Nos. 41 (A+0), 42 (A+0) and 43 (A+0) had failed.

As per the preliminary enquiry report submitted by RRVPNL, tower at location Nos. 41(A+0), 42(A+0) and 43(A+0) had collapsed and lying on the ground. All the foundations of the damaged towers were found intact and there was missing member in first panel of tower at location No. 42. Wind speed/ gust detail obtained from wind observatory of nearby area showed its speed of 50 meter per second (180 Km/Hrs.)

### **Probable Cause of Failure**

The towers may have collapsed due to the high intensity wind produced due to the storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

The line was restored on normal towers on 22/5/2015.

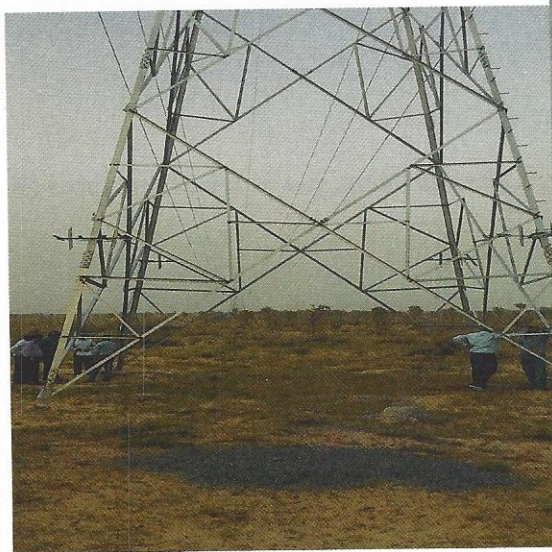
### **Recommendations of the Committee**

- Committee advised RRVPNL to review the design of 'A' type towers (suspension towers) in line with latest revised Indian Standard (IS:802) taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition. The strengthening of towers, if required, needs to be taken up and planned accordingly.
- RRVPNL was also requested to submit material test reports of failed towers

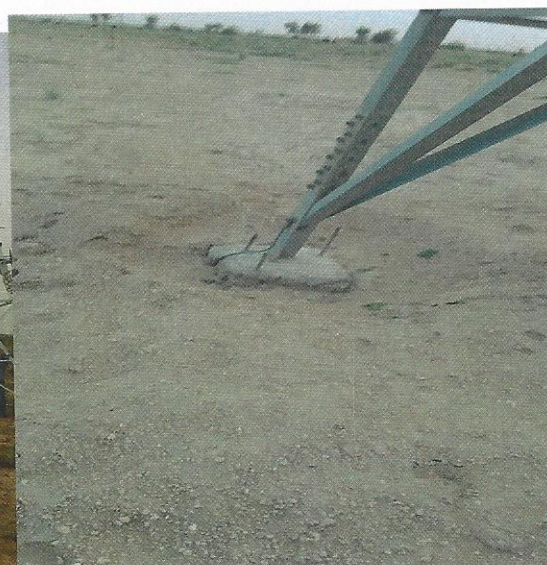
#### **4. 220 kV Bikaner-Gajner D/C transmission line failed on 19.5.2015 (15 towers at Location Nos. 47 to 49, 51 to 55, 84 to 87 and 91 to 93)**

### **Brief Background**

The Bikaner-Gajner 220 kV D/C line (58.637 km) was designed, executed by RRVPNL and was commissioned in 2013. This line comes under wind zone 3 (as reported by RRVPNL) and the towers were designed as per IS:802:1995. Line tripped at 13:15Hrs. on 19/05/2015. The power flow in each circuit was 13 MW prior to failure.



**Location No.51**



**Location No.52**



### **Observations**

It was reported that 15 towers (13 suspension + 2 tension) have failed due to heavy wind storm on 19.05.2015. The towers damages were at location Nos. 47, 48 & 49 (A type), 51 (B+6), 52 (D+6), 53 to 55 (A type), 84 to 87 (A type) and 91 to 93 (A type). There were no missing members reported in the line. A heavy wind storm was reported in the area on the date of collapse.

### **Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

The towers were erected and the line was restored on normal tower on 06/08/2015.

A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. The towers were already erected and line was restored before the team visited the site. However, after careful examination of the erected towers, the team noted that, in the newly erected towers earthing connection needs to be done properly. Copping of chimneys needs to be done, redundant members connected to bracings by welding need to be connected using bolts & nuts and holes left in tower members need to be filled with nut and bolts.

### **Recommendations of the Committee**

Committee recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- Providing proper earthing connection for towers
- Copping of chimneys
- Redundant members to be connected using bolts and nuts (instead of welding) and holes left in tower members to be filled with nut and bolts.

Although the towers might have been designed according to IS 802 (1995), Committee also advised RRVPNL to check the design whether narrow front wind on tower body and 75% of wind load in broken wire condition have been taken into consideration in the



design of suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.

5. **132 kV Bikaner-Pugal road D/C Transmission line & 132 kV Gajner-Pugal road D/C Transmission line Failed on 19.05.2015**  
(7 towers at Location Nos. 17 to 22, 54)

**Brief Background**

The length of Bikaner – Pugal road line and 132kV Gajner – Pugal road line are 20km and 45 km respectively. The line was constructed during 1996-1997. It was reported that seven (7) towers (5 Suspension type+ 2 Tension type) had collapsed due to heavy wind storm with whirlwind on 19.05.2015. The line comes under wind zone 4 and is in sand dune area. The towers were designed by RRVPNL (erstwhile RSEB) as per IS:802. The line was designed for D/C towers with ACSR Panther conductor. Two towers (at different locations) of above line had collapsed in 2007-08 due to whirlwind.



**Location No. 18**



### **Observations**

The towers at location no. 17 to 21 (all suspension / 'A' type towers) were bent below cross arm level. Angle towers at location No.54 (LILO Point tower) and location No. 22 had also collapsed. There were no missing members reported in the towers. A heavy wind storm was reported in the area on the date of collapse. The load / Power flow on Bikaner – Pugal road line and 132kV Gajner – Pugal road line were 82Amps. and 96 Amps. respectively prior to failure. The conductors and earthwire in few spans also got damaged.

### **Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

The Bikaner-Pugal road line and Gajner- Pugal road line were restored on normal towers on 02-06-2015 and 11-06-2015 respectively. Spare towers were used for replacement of failed towers.

A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. The towers were already erected and line was restored before the team visited the site. However, after careful examination of the erected towers, the team noted that, the newly erected towers were relocated by minor shifting from the original tower locations. Proper revetment for new foundations is required. Anti climbing device (ACD) needs to be provided, proper earthing connection (in some locations) and proper coping of chimneys needs to be done for the newly erected towers. The foundations have been made with plain cement concrete. Cover plates have not been provided at butt joint locations in the leg members of towers. Proper size of cover plate needs to be provided at butt joint locations.

### **Recommendation of the Committee**

Committee advised RRVPNL to review the design of 'A' type towers in line with latest revised Indian Standard (IS:802) taking into account narrow front wind on tower body and 75% wind load on broken wire condition and foundation design need be reviewed



also. The Committee as also recommended RRVPNL to take necessary action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure.

6. **132 kV Nokha- Jasrasar transmission Line failed on 19.05.2015**  
(Location Nos. 121, 123 and 124)

**Brief Background**

Nokha-Jasrasar 132 kV D/C transmission line (40km) was commissioned in 2011 by M/S Salasar Techno Pvt. Ltd. Ghaziabad. It was reported that the line tripped on 19-05-2015 at 13:58 Hrs. Three (3) numbers of suspension towers at location Nos. 121, 123 & 124 had collapsed due to thunder storm with hail. The line comes under wind zone 3 (as reported by RRVPNL). The towers were designed as per IS:802.



**Location No. 121**

**Observations**

The soil along the route of this line is mostly sandy. It was reported by RRVPNL that the towers were uprooted from chimney level. There were no missing members in the



towers due to theft. Foundations of the towers were found completely damaged from the chimney. A thunder storm with hail was reported in the area on 19/05/2015. All the damaged towers were of suspension Tower (Type 'A'). Two of the failed towers are normal tower (w/o extension) and third one is with +3 metre extension.

### **Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

Spare towers were used and the line was restored on normal towers on 02/06/2015 at 20:35 Hrs.

A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. The towers were already erected and line was restored before the team visited the site. However, after careful examination of the erected towers, the team noted that, proper protection for foundation needs to be provided and the soil / sand deposited on the chimney of foundation is to be removed or chimney height needs to be raised. Cover plates have not been provided at butt joint locations in leg members of the suspension towers. The cover plate of proper size needs to be provided at butt joints. Earthing connection needs to be done properly i.e. earthing pit / counterpoise wires were not connected properly with tower body.

### **Recommendation of the Committee**

The Committee recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

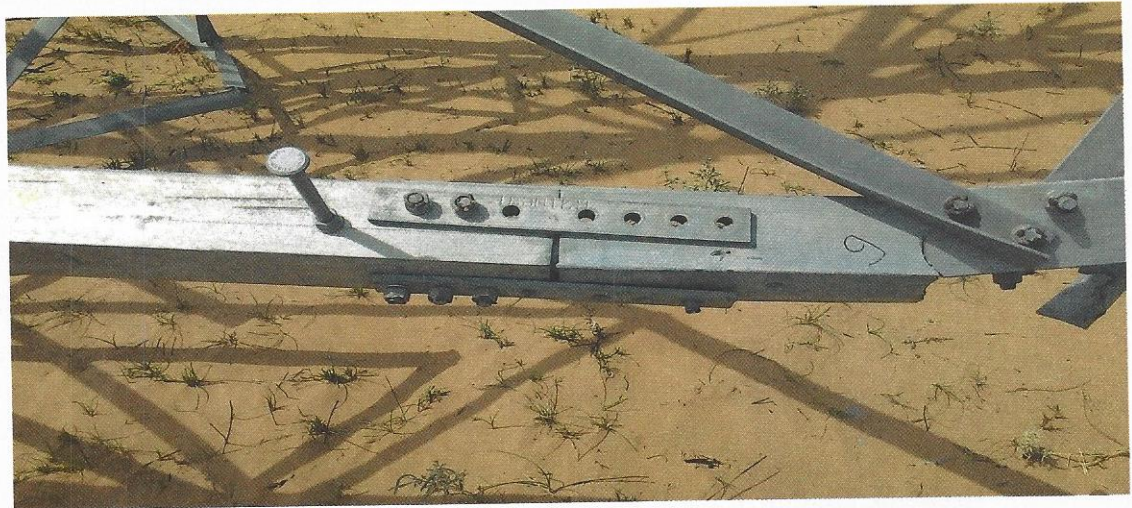
- Proper protection for foundation needs to be provided and the soil / sand deposited on the chimney of foundation is to be removed or chimney height needs to be raised.
- Provide Cover plates of proper size at butt joint locations in leg members of towers.
- Providing proper earthing connection for towers



7. **LILO of 132 kV D/C Bikaner – Dulhasar line at GSS Sherera, failed on 19.05.2015.**  
(25 towers at Location Nos. 8 to 19, 23 to 33, 36 and 39)

**Brief Background:**

The line was constructed during 2014-15 by M/S Jagdish Prasad Choudhary, Raisinghnagar, Rajasthan and is yet to be commissioned. It was reported that twenty five (25) nos. of towers (21nos. Suspension towers + 4 nos. tension towers) have collapsed due to heavy wind storm on 19.05.2015. The towers damaged were at location Nos. 8 to 19, 23 to 33, 36&39. Out of 25 Nos. of towers, 21 Nos. of towers were of suspension type, one tension tower with deviation angle of 15 – 30 degree and rest three towers were tension towers with angle of deviation of 2-15 degree. Out of 21 Suspension towers, 14 Nos. are of normal towers, 4 No. of towers are with +3m extension and rest 3 Nos. are with +6m extension. This line comes under wind zone 3 (as reported by RRVPNL) and the towers were designed as per IS 802:1995.



**Location No.9**





**Location No.11**



**Location No.15**





**Location No18**



**Location No18**

**Observations**

The line tripped on 19-05-2015 between 1:10 to 1:45PM. There was no missing of members due to theft. A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. During the visit to the site of failure, it was



noticed that damaged towers were lying on the ground and line was not restored. Most of the failed towers (Location Nos. 8 to 11, 15, 17, 18 to 20, 23 to 33, 36 & 39) were inspected except few towers which are located in agricultural field with standing crops. The team observed that in most of the cases of failed towers, two Chimneys of foundations out of four were damaged/crushed and tower was bent at stub level and other two chimneys had come out of foundation pit along with stub & cleat. The soil is sandy throughout the route of the line. The design of foundation has been done for normal dry soil with plain cement concrete. At couple of locations, the measurement of the chimney & frustum was made by the team and it was found that the actual dimensions were less than that of approved drawing.

Further it was noticed that proper protection has not been provided to the tower foundations, where the foundations are located at sloppy ground. At few locations, the main leg member was deformed & rusted after the failure. In few towers, earthwire 'U' clamps are missing and a rusted "J" shaped bolts have been used for clamping. Cover plates have not been provided at butt joints in leg members for tower type-A. Holes left in the members are to be filled with bolt & nut. The cover plates of proper size need to be used at butt joints in the leg members of tension towers.

It was informed that three samples each of few failed towers of this line were sent for testing at MSME-Testing station, Jaipur. The foundation concrete has been tested at site using Rebound Hammer test method by Govt. College of Engineering & Technology, Bikaner as per request of RRVPNL. The test report of Govt. college of Engineering & Technology shows that the compressive strength of concrete obtained during the test vary from 15.10 to 19.90MPa. ( $\text{N/mm}^2$ ). The specified characteristic compressive strength of M 15 concrete is  $15 \text{ N/mm}^2$  as per IS 456:2000- Plain & Reinforced cement concrete code of practice. The test report of MSME-Testing station, Jaipur shows that out of the three samples tested, the percentage of carbon content in one sample and percentage of phosphorous content in another sample are more than the permissible limits specified in IS: 2062-2011 for class 'A' quality structural steel (mild steel).

The visiting team had suggested strengthening of foundations of the existing towers by providing additional reinforced cement concrete in Chimney & frustum to increase weight of foundation to provide adequate strength against uplift. The foundation work of

chimneys of legs may be taken up one leg at a time by taking adequate safety measures for the stability of the tower structure.

The team had also suggested strengthening the tower by providing additional members from first panel up to bottom cross arm level and also to provide hip bracing. M20 concrete (1:1.5:3) nominal mix may be considered for casting of chimney and frustum. The Cover plate of proper size needs to be provided at butt joints in the leg members of tower.

In case of recasting of the foundations, vertical reinforcement joined with proper stirrups in the Chimney and horizontal reinforcement in both directions in frustum may be considered and interconnected prior to placing concrete. This will provide additional strength to the monolithic structure of frustum and chimney and such arrangement will not allow chimney to come out of the frustum due to the effect of compression and horizontal components of load. The cleat may be attached with the stub with required no. of (instead of one) to provide adequate strength against uplift.

#### **Probable Cause of Failure**

The towers failures might have been caused due to high velocity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit. The design of foundation also raises question.

#### **Recommendation of the Committee**

The committee recommended RRVPNL to review the design of tower as well as foundation. The strengthening of towers as well as foundation may be required in view of nature of failure. Committee also recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.

The Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- The tower may be strengthened by providing additional members from first panel up to bottom cross arm level and by providing hip bracing.
- M20 concrete (1:1.5:3) nominal mix needs to be considered for casting of chimney and frustum.



- Cover plate of proper size needs to be provided at butt joints in leg members of tower
- In case of recasting / strengthening of the existing foundations, proper reinforcement may be provided in the foundation of Chimney and frustum and cleats attached with the stubs need to be designed as per requirement to provide adequate strength against uplift.
- The earthwire needs to be fixed with suspension towers with proper clamps

**8. 220 kV Bharatpur-Dholpur D/C Transmission line Failed on 19.05.2015  
(6 Towers at Location Nos. 6,7,10,11,12 & 16)**

**Brief Background**

Bharatpur-Dholpur 220 kV D/C transmission line was constructed by M/s. Hythro Power Corporation Limited, Gurgaon. The line was commissioned on 28-08-2002. The tower was having double circuit configuration with ACSR Zebra Conductor. The line tripped at 15:39 Hrs. on 19/05/2015 due to collapse of 6 no. of suspension towers at Location Nos. 6/1 (A+0), 7/2 (A+6), 10/3 (A+0), 11/4(A+0), 12/5(A+0) and 16/6(A+3)

**Observations**

As per the preliminary enquiry report submitted by RRVPNL there was a heavy storm on 19/05/2015 causing submerged soil conditions thereby reducing soil resistance. The stubs of towers were twisted. Cracks were observed in the foundations of towers. No structural members / parts of tower were found missing.

**Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

**Restoration**

Line was restored on normal towers on 20.06.2015

### **Recommendation of the Committee**

- Committee recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.
- RRVPNL was also requested to submit material test reports of failed towers.

#### **9. 220 kV D/C Alwar-Badarpur Transmission line Failed on 19.05.2015 (2 Towers at Location Nos. 148, 149)**

##### **Brief Background**

The Alwar-Badarpur 220 kV D/C transmission line tripped on 19.05.2015 at 14.31 Hrs. on Single line to Ground fault. During patrolling it was observed that tower at Loc. Nos. 148 (Type-A) and 149 (Type-A) had collapsed/ uprooted and tower at loc. No. 147 (Type-B angle tower) was uplifted.

##### **Observations**

Towers at Loc. No. 148 (Type-A) and 149 (Type-A) got uprooted and their two chimney came-out of ground and towers collapsed. In case of Tower at loc. No. 147 (Type-B), two chimneys of the tower got disturbed though tower did not collapse. There was no theft / missing of members. A heavy wind storm was reported in the area on the date of collapse.

##### **Probable Cause of Failure**

The towers might have collapsed (uprooted) due to high velocity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit. The design of foundation also raises question.

##### **Recommendation of the Committee**

- Committee recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.
- The foundation design needs to be reviewed.
- RRVPNL was also requested to submit material test reports of failed towers.



## **2.3 DETAILS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF UPPTCL**

**2.3.1** The towers of following 400kV Transmission Lines of UPPTCL had failed during above mentioned period.

Sl. No.	Names of the Transmission Lines	Date of Occurrence of failure	No.of towers failed
1.	400kV Mainpuri-Paricha-I & II Transmissionline	31.05.2014	-
2.	400kV Unnao-Lucknow Transmision line	28.04.2015	-

**2.3.2** Neither the representative of UPPTCL participated in the Standing committee meeting nor the report of failure of tower been submitted to the CEA for above mentioned lines. Therefore, the matter could not be discussed during the meeting.

## **2.4 DETAILS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF WBSETCL**

**2.4.1** The towers of following 400kV Transmission Lines of WBSETCL had failed during above mentioned period.

Sl. No.	Names of the Transmission Lines	Date of Occurrence of failure	No.of towers failed
1	400kV D/C Sagardighi-Durgapur Transmission line	24.05.2015	5

**2.4.2 400 kV D/C Sagardighi-Durgapur Transmission Line failed on 24.05.2015 (Location nos. 139, 140 to 143)**

### **Background**

Powergrid officials informed that the Operations and Maintenance (O&M) of these lines are done by PGCIL. The 400 kV D/C Sagardighi-Durgapur line was constructed by M/s KEC. The line was commissioned on 28.04.2011. The Conductor configuration of the line is Twin Moose. The line tripped on 24.05.2015 due to collapse of 2(two) Nos. of



towers at location Nos. 141(DA+0) & 142 (DA+0) and partial collapse of 3 (three) no. towers at location Nos. 139(DA+0), 140(DA+3) & 143(DA+3) due to unprecedented cyclonic storm. The line had tripped earlier on 25.04.2012, in which six (6) towers [186(DB+9), 189(DC+6) and 187, 188, 190 & 248 are (DA+0)] fully collapsed and five(5) towers [185(DD+9), 191(DB+0) and 247, 249 & 255 are(DA+0)] were partially damaged.



### **Observations**

It was observed that towers at location Nos. 141 & 142 have collapsed from ground level whereas 3 towers collapsed from upper level. The tower at location No. 141 had collapsed fully. Similarly the tower at location No. 142 had collapsed with stub bent. The towers at location Nos. 139 & 143 had partially damaged with one of the top cross arm bent. But tower at location No. 140 had partially damaged with top, middle & bottom cross arm bent and earthwire peak damaged. All these affected towers were located in plain stretch of cultivated field having very few trees and might have experienced critical wind during the storm. All these affected towers have fallen in left side in transverse direction facing Durgapur. PGCIL informed that the suspension towers were designed for 75% wind load for broken wire condition and is being used widely across the country.



### **Probable Cause of Failure**

The tower failure might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

Line was to be restored on normal towers by 15<sup>th</sup> June 2015.

### **Recommendation of the Committee**

The Committee requested to PGCIL to submit material test report.

## **2.5 DETAILS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF JINDAL POWER LTD**

- 2.5.1** The towers of following 400kV Transmission Lines of M/S. Jindal Power Limited had failed during above mentioned period.

Sl. No.	Names of the Transmission Lines	Date of Occurrence of failure	No.of towers failed
1	400kV D/C Tamnar-Raipur Transmission line	25.04.2015	2

- 2.5.2** 400 kV Tamnar- Raipur D/C Transmission line on 25.04.2015  
[Two towers at Location Nos. 660 & 661]

### **Brief background**

During the meeting, PGCIL had informed that the line belongs to M/s Jindal Power Limited. None of the representative of M/s JPL was present in the meeting. M/s JPL was requested to submit the investigation report to CEA. The report was received in January 2016. The 400 kV Tamnar- Raipur D/C Transmission line belongs to M/s Jindal Power Ltd., the Transmission Licensee. Both the circuits of the line tripped on ground to earth fault on 25.04.2015 at 17:35 hrs due to failure of two suspension type towers at location No. 660 & 661.





### **Location No. 660 & 661**

#### **Observations**

As per the report submitted by M/s JPL, during patrolling it was observed that two suspension towers at location Nos. 660 & 661 (at a distance of 248 km from Tamnar) had collapsed. The bottom bracing members and main leg members of towers were cut and stolen. Villagers informed that there was heavy storm in the area, where the towers collapsed. FIR was lodged with the Nandini Police station. Similar incidents of theft of tower parts and subsequent collapse of tower had taken place the same day for PGCIL and CSPTCL's line in the same region. Police has informed M/s JPL that thieves were caught and stolen material has been recovered from them.

#### **Probable Cause of Failure**

The cutting of tower members and high wind / storm in the area might have caused the failure of towers at location No. 660 & 661.

#### **Restoration**

The Circuit-2 of the line was restored on Emergency Restoration System on 3.05.2015. After restoration of Circuit -2, action for removal of damaged tower and recasting of



civil foundation was taken up. Then circuit-1 was charged on newly erected towers on 23.05.2015 and subsequently circuit-2 was shifted from ERS and charged with newly erected towers on 27.05.2015. There was 28 days outage of circuit No. 1 and 7 days outage of circuit No. 2.

### **Recommendations of the Committee**

The committee recommended that the patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by JPL and involved for safety of towers.

### **3.0 General Observations and decisions of the Committee:**

#### **3.1 Committee observed that major cause of failure of towers are as under:**

- a) The high wind velocity during storm, cyclone and local phenomenon of whirlwind and gale etc. might have exceeded the wind speed for which the tower is designed. This type of wind is difficult to predict. The probability of such occurrences is low & the tower design will be uneconomical if such situation is considered in the design.
- b) Theft/sabotage of tower members, generally the theft of secondary members (connected with one or two bolts) of the towers, by the local people makes the tower structurally weak which ultimately leads to failure during high speed wind/storms/whirlwind/cyclone etc;
- c) It is also difficult to take into account demolishing activities by miscreants like cutting/blasting the main members of the tower, during design or construction stage.
- d) Many lines are in operation with towers designed according to old Indian Standards (IS: 802 -1977). (The Indian Standard has been revised subsequently to incorporate new design concepts to minimize the rate of the failure.)
- e) In some cases although the towers have been design according to IS 802 (1995), but 75% of wind load in broken wire condition may not have been considered for design of suspension towers.

- f) Lack of proper soil investigation and deficiency in design of foundation of towers sometimes lead to failure of towers.
- g) Lack of proper protection to foundation of towers sometimes causes damage to foundation as well as the towers.

**3.2 After the detail discussions/deliberations in the meetings held in CEA, following decisions have also been taken by the Standing Committee.**

- a) The most of the failures are linked to high wind speed. The CE, PSE&TD informed that about 800 (as on August 2015) wind data measurement stations have been established by National Institute of Wind Energy (NIWE), Chennai covering all parts of the country for Indian wind Power Mapping. The wind data available with NIWE may be useful to obtain actual wind speed in the areas of tower collapse. The Committee suggested that CEA should arrange a meeting with NIWE, SERC, PGCIL etc. to discuss about the usefulness of wind data collected by NIWE for wind zone mapping and estimating actual wind speed in areas where towers have collapsed.
- b) The representative of SERC informed that during the material testing, other than testing of the material properties, measurement of thickness of members should be carried out. Wide variation in thickness should not be there. The area having minimum thickness is vulnerable to failure. He further highlighted that IS: 12427 / IS:1367 do not specify weight of nuts / bolts, which should be an important parameter for bolt. The Committee also suggested CEA to write to BIS to review IS:7215 to specify required tolerance limits in respect thickness of member and IS:12427 / IS:1367 to specify weight of nuts / bolts as one of the parameter in addition to other parameters
- c) The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.



d) The wind speed mapping for the entire country is under further revision by Bureau of Indian Standards (BIS) based on inputs from Structural Engineering Research Centre (SERC), Chennai due to change in wind speed pattern in some part of the country. The committee suggested CEA to write to BIS for early revision of the wind map of the country.

#### **4.0 MINUTES OF MEETING, PRELIMINARY INVESTIGATION REPORT AND PHOTOGRAPHS OF FAILED TOWER**

The Minutes of meeting of Standing Committee are enclosed at **Annexure-B**. The Preliminary Investigation Reports on failure of tower(s) at different locations for the above lines along with photographs of failed towers are enclosed at **Annexure – C**.

*M.S. Satya*

**Director (PSE&TD) & Member Secretary  
Standing Committee of Experts  
to investigate failure of Towers**

*K. S. Sathya*  
27/4/2016

**Chief Engineer(PSE&TD)& Chairman  
Standing Committee of Experts  
to investigate failures of towers**

**Composition  
of  
Standing Committee  
of  
Experts**



**COMPOSITION OF STANDING COMMITTEE OF EXPERTS TO INVESTIGATE  
THE FAILURE OF TOWERS**

1. Shri S.K. Ray Mohapatra, Chief Engineer  
PSE&TD, CEA - Chairman
2. Additional Director,  
Central Power Research Institute  
Mechanical Engineering Division  
Post Box No. 8066, Prof. Sir C.V. Raman Road  
Sadashivnagar, Bangalore – 560 080  
Tel No. 080-23604664 / 23601905  
**Fax No. 080- 23601213** - Member
3. Head of Deptt.  
Deptt. Of Civil Engg.  
Delhi Technological University  
Bawana Road  
Delhi - 110042  
**Fax No. of VC - 27871023** - Member
4. Representatives from Power Utilities  
where tower failure occurred - Member
5. Member Secretary, Regional Power Committee  
where tower failure occurred - Member
6. Sh. M.S. Satija, Director  
PSE&TD, CEA - Member Secretary

**REPRESENTATIVES OF UTILITIES :**

<b><u>Name of the Organisation</u></b>	<b><u>Nominee and their address</u></b>
<b>CENTRAL SECTOR</b>	
PGCIL	General Manager (Engg - TL) Powergrid Corporation of India Ltd., SAUDAMINI, Plot No.2, Sector-29, Gurgaon Ph : 0124 - 2571794 Fax: 0124 – 2571951/809
<b><u>Name of the Organisation</u></b>	<b><u>Nominee and their address</u></b>
DVC	S.E. (E), PSR Deptt., Damodar Valley Corporation, DVC Towers, VIP Road, Kolkata – 700 054 Ph : 033 – 66072930 Fax: 033 - 23559618
<b>STATE SECTOR</b>	
<b>EASTERN REGION</b>	
Jharkhand	Chief Engineer (Transmission) Jharkhand State Electricity Board, Engineering Building, HEC, Dhurwa, RANCHI – 834 004 Fax:0651-2400008/2400799
Bihar	Chief Engineer (Transmission) Bihar State Electricity Board, Vidyut Bhawan, Baily Road, PATNA – 800 021 Fax:-0612-2504655/2504937/2504968 011-26711603



West Bengal	Chief Engineer (CPD) West Bengal State Electricity Transmission Company Limited, Vidyut Bhawan (9th floor), DJ Block, Sector-II Salt Lake Kolkata-700091, Fax-033-23591955/23373002
Odisha	Sr. General Manager (TP & C) Transmission Project and Construction Orissa Power Transmission Corpn., Ltd., Vidyut Bhawan, 1st Floor, Sahid Nagar Bhubaneshwar – 751 022 Fax No: 0674 -2547261/2541904
<b><u>Name of the Organisation</u></b>	<b><u>Nominee and their address</u></b>
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<b>WESTERN REGION</b>	
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**ANNEXURE –A**

**Minutes  
of the  
Meeting**



**Minutes of Meeting of the Standing Committee of Experts on Failure of Transmission Line Towers held in CEA, New Delhi on 8/12/2015 in respect of failure of towers in 132 kV & Higher Voltage Transmission Lines during the period from October, 2014 to June, 2015.**

List of participants is at Annexure- I.

Chief Engineer PSE&TD & Chairman of the Standing Committee of Experts welcomed the participants and briefed about the number of failure of towers of transmission lines of different voltage levels belonging to various Utilities and requested the Utilities to discuss in detail on the tower failures during the period October 2014 to June 2015.

Apart from the discussion of tower failures during above mentioned period, the failure of 15 towers of 765 kV Gaya-Fatehpur S/C transmission line on 31.05.2014 was also deliberated based on the input from CPRI and response of PGCIL in order to submit the final report on failure of towers as per the direction from Hon'ble Central Electricity Regulatory Commission (CERC) with reference to petition No. 9/SM/2014.

The record of discussion in respect of failure of towers of each failed transmission line (of different voltage levels) of various utilities is given as under.

**A. The lines of PGCIL:**

**1. 765 kV S/C Gaya -Fatehpur Transmission Line failed on 31.05.2014**

**(15 towers at Location Nos : 320 to 330, 305, 306, 311 & 315)**

**Brief Background:**

The Gaya – Fatehpur 765kV S/C line (345 km) was constructed by M/s KPTL and commissioned on 31-03-2012. The towers of Gaya – Fatehpur 765kV S/C line was designed with delta configuration as per IS 802 (1995) with Wind Zone - 4 and reliability level 2 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for design of suspension towers as per decision in CBI&P forum. One tower of the line (at location No. 314) had failed on April 11/12, 2012 immediately after its commissioning in March 2012. During the heavy storm on 31-05-2014, fifteen (15) towers [3 towers in one section, 11 towers in 2nd section and one tower in 3<sup>rd</sup> section - consecutive three sections] of above line had failed at location Nos. 305,306,

311, 315, 320 to 330. All the failed towers were suspension towers and located in plain stretch of cultivated land. This is the second failure. Nine (9) towers had failed above bottom cross arm / waist level (near diamond section) and six (6) towers had completely collapsed & fallen on ground. The foundations were intact. All the failed towers were of 'A' type & located in plain stretch of cultivated land. Powergrid in their preliminary report had mentioned that the stretch might have experienced critical wind during the storm. POWERGRID official had informed that theft of tower members was also noticed in some tower locations. The line was restored on normal towers on 30-06-2014.

The Standing Committee of Experts had the meetings in CEA with utilities on 19.6.2014 and 12.09.2014 to discuss the failure of towers during April 2014- July 2014. Copy of the report was sent to Hon'ble commission. During the meetings the failure of towers of Gaya – Fatehpur 765kV line was also discussed.

The recommendations of the Committee were as follows:

- (i) The design of towers needs to be reviewed for further strengthening, even though the towers were designed according to IS:802(1995), in case of more failure occurs in such lines.
- (ii) The patrolling of line needs to be increased in theft prone areas in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.
- (iii) Coping of Chimneys, wherever required, needs to be done to avoid accumulation of water near stubs.

Hon'ble Central Electricity Regulatory Commission, New Delhi, vide their Record of Proceedings (RoP) against Petition no. 9/SM/2014 dated 14.10.2014, had directed PGCIL to investigate in coordination with CEA in detail the failures of towers considering the structural, and workmanship aspects, material used and O&M practices involving academia and submit a report on collapse of (15 nos.) towers of 765kV Gaya-Fatehpur line on 31.5.2014 suggesting remedial measures.

As per direction of Hon'ble commission, two meetings were held in CEA on 24-11-2014 and 28-04-2015 inviting members of the Standing Committee of Experts and special



invitees from utilities and academia [POWERGRID; Delhi Transco Ltd.(DTL); Delhi Technological University(DTU); TCD Division of CEA; Central Power Research Institute(CPRI); Structural Engineering Research Center (SERC), Chennai; and IIT, Delhi ] to discuss in detail about the failures of towers of above 765kV transmission line on 31-05-2014.

As per decision of the 1<sup>st</sup> meeting, PGCIL had shared the design details of 765kV suspension tower, O&M practices, Photographs of tower failures with CEA, which were sent to DTU, CPRI, IIT Delhi, TCD division of CEA, and SERC, Chennai for analysis/study and suggestions.

In the 2<sup>nd</sup> meeting of experts, held in CEA on 28.04.2015, the observations of SERC, CPRI and TCD Division of CEA on the design document & drawings of 765kV S/C suspension tower was discussed further.

As per the decision taken in the 2<sup>nd</sup> meeting, the design input files (input file of STAAD Software & i-Tower Software) & structural drawings of the failed towers were shared by CPRI & PGCIL for further examination. CPRI had submitted the final report based on their analysis carried out with STAAD Software.

**Discussion in Standing Committee Meeting held in CEA, New Delhi on December 8, 2015**

The Standing Committee had the meeting on December 8, 2015 in New Delhi and further discussed on the observations of CPRI and the response of PGCIL on the final report submitted by CPRI. The variation in tower member / section size in design document and structural drawing was noticed. The planning for strengthening of towers of existing line and for new line was also deliberated in the meeting.

**During the meeting PGCIL has clarified as follow:**

- (a) In plain terrains, percentage of tangent / suspension towers are normally much more compared to tension / angle towers and hence there is tendency to optimize the design (without much safety margin in design) in order to economize the cost of transmission lines.

- (b) PGCIL also brought to notice that lot of difficulties is being faced while erecting towers with delta configuration. Towers with horizontal configuration take about three (3) days for erection where as towers with delta configuration takes about ten (10) days for erection. Executing agencies have also requested to review the design for change of the configuration. In the meantime, POWERGRID has decided to modify the configuration of tower and towers with three cross arms [two cross arms at one level and 3rd cross arm at higher level] are being designed for 765kV S/C lines. The 765kV Raichur – Solapur S/C line, which connected WR with SR forming one synchronous National Grid, has been designed with such configuration. Hence in future the towers with delta configuration may not be used and as such most of the 765 kV lines will be D/C lines with vertical configuration. Towers with Double circuit configuration have already been designed and tested for wind zones 2, 3, 4 & 5. The towers for wind zone 1 & 6 shall be designed and tested as and when required.
- (c) Regarding the variation in structural drawing and design with reference to member / section size, PGCIL clarified that member / section size mentioned in structural drawing has been used in the towers and the tower design has been reviewed by CPRI & PGCIL taking into account the member / section size indicated in the structural drawing.
- (d) PGCIL informed that further strengthening of member No. M5, as suggested by CPRI, is not required after strengthening of member Nos. M51/ 52 & D12 and providing two (2) redundant members.
- (e) PGCIL has agreed to revise the design of the 765kV Tower Type-A used in Gaya - Fatehpur line by strengthening the Tower [increasing the member / section size of six (6) members including three (3) members / sections as suggested by CPRI and adding two (2) more redundant members].
- (f) PGCIL further highlighted that since strengthening of tower is to be done above waist level, long shutdown shall be required for replacement of members / sections of towers in existing line. The nature of work and the risk involved in replacement of member of towers in existing line is different from fabrication of towers afresh. The fabrication of fresh towers can be taken up easily. But replacement of members in the



existing towers is very difficult and risk is involved. Moreover, many of the executing agencies may not be interested to take up such difficult and risky job.

The recommendations of the Committee were as follows:

- The towers with delta configuration shall be avoided to the extent possible in 765kV single Circuit (S/C) lines in future and as such most of the 765 kV lines shall be Double Circuit (D/C) lines with vertical configuration.
- In absence of meteorological data, it has become difficult to assess the actual wind velocity at site of failure in order to verify with the design value of wind speed. However, the detailed analysis of structural design of suspension tower (with delta configuration) of 765kV S/C line was carried out by CPRI and PGCIL using two different softwares [STAAD Pro and i-Tower]. The strengthening of suspension towers (with delta configuration) of 765kV S/C line traversing through wind Zone - 4 has to be carried out as indicated below by increasing the member / section size of six (6) members and adding two (2) more redundant members. The drawing showing the member location is enclosed as **Annexure - II**.

Member No.	Original Member size	Proposed Member size	Existing No. of Bolts	Proposed No. of Bolts
D13	65x65x5 (MS)	65x65x6 (MS)	2 SS - 16Ø	2 SS - 16Ø
D16	80x80x6 (MS)	90x90x6 (MS)	2 SS - 16Ø	2 SS - 16Ø
D29	70x70x5 (MS)	90x90x6 (MS)	2 SS - 16Ø	3 SS - 16Ø
M51/52	100x100x8 (HT)	110x110x8(HT)	6 DS - 16Ø	6 DS - 16Ø
D12	75x75x6 (HT)	80x80x6 (HT)	3 SS - 16Ø	3 SS - 16Ø
New Redundant connected to M5	-	50x50x5 (MS)	-	1 SS - 16Ø
New Redundant connected to H3/H4	-	50x50x5 (MS)	-	1 SS - 16Ø

- Since strengthening of tower is to be done above bottom cross arm / waist level (near diamond section), long shutdown shall be required for replacement of members / sections of towers in existing line and the nature of work and the risk involved in replacement of member of towers in existing line is different from fabrication of towers afresh. The fabrication of fresh towers can be taken up easily. But replacement of members in the existing towers is very difficult and lot of risk is involved. Moreover, many of the executing agencies may not be interested to

take up such difficult and risky task. Dismantling and replacement of the structural part above waist level of tower requires long shut down. Hence such activity shall be taken up during annual maintenance in a phased manner. PGCIL has to prioritize the areas / lines where such activity can be taken up. Accordingly planning has to be done by PGCIL.

- The patrolling of line needs to be increased / intensified in theft prone areas in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.
- The rate of failure of suspension towers (with delta configuration) of 765kV S/C line traversing through other wind zones (other than Wind Zone -4) and areas prone to cyclone / storm needs to be monitored. In case repeated failure is observed in those lines, similar exercise for review of design has to be taken up by PGCIL for different wind zones for suspension towers (with delta configuration) of 765kV S/C line.
- The regions, where frequent failures of transmission line towers are observed, need to be identified and wind data logger stations may be installed by PGCIL in those areas on priority basis. PGCIL should expedite the installation of Anemometers in substations, particularly in cyclone / high wind prone areas, as recommended earlier by the Standing Committee of experts on failure of transmission lines of 220kV and voltage level.
- The committee also decided that PGCIL has to strengthen towers of other 765kV S/C lines, designed for wind Zone -4 with Delta configuration of towers, in line with Gaya – Fatehpur 765kV S/C line.
- The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.



## **2. 765 kV S/C Satna- Bina –II transmission line failed on 02.10.2014**

**(Two towers at Location Nos. 313 & 314)**

### **Brief Background**

765 kV Satna-Bina-II S/C transmission line was constructed under Sasan UMPP scheme -II project by M/S KEC in 2012 and is in commercial operation since June 2012. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The suspension towers were designed for delta configuration for Quad Bersimis conductor (with double I-V-I insulator string). The line tripped on phase to phase fault on 02-10-2014 at 1427 hrs.

### **Observations**

During patrolling of the line, it was observed that two (2) nos. of suspension towers at location No. 313 & 314 had collapsed due to localized cyclone.

The Tower at location No.314 (A+0) has collapsed completely on the ground in transverse direction and three of its stubs also got bent. The Tower at location No. 313 (A+0) collapsed above bottom cross arm level / waist level (near the diamond section) and there was no damage to the foundations. Phase conductors of both the towers were partially damaged. No damage was apparent on earthwires. Both the affected towers were located in a plain stretch of cultivated field having very few trees.

### **Probable Cause of Failure**

The stretch might have experienced critical wind during the storm. Failure/damages in locations/stretches might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earth wire as well as on tower itself exceeding the design values.

### **Restoration**

The Line was restored on normal towers on 10.10.2014.

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

### **3. 400 kV Jeypore-Gazuwaka D/C transmission line failed on 12.10.2014**

**(29 towers)**

#### **Brief Background**

Jeypore - Gazuwaka I & II 400 kV D/C transmission line was constructed by M/S Jyoti Structures Ltd and is in commercial operation since September 1999. The towers of this line were designed for heavy wind zone as per old IS 802-1977. The suspension towers were designed for vertical configuration with twin moose conductor and V-V-V insulator strings. The line tripped on phase to earth fault on 12-10-2014 at 10:30 hrs.

#### **Observations**

Twenty nine (29) numbers of towers were damaged due to HUD HUD cyclone on 12-10-2014. Twenty(20) nos. of suspension towers at location number 489(DA+25), 514(DA+6), 522(DA+0), 528(DA+6), 547(DA+6), 548(DA+0), 549(DA+0), 558(DA+0), 559(DA+6), 561(DA+6), 565(DA+6), 568(DA+9), 569(DA+6), 570(DA+3), 571(DA+0), 572(DA+0), 573(DA+0), 574(DA+0), 575(DA+0) & 583(DA+6) had collapsed. Two (2) nos. of tension towers at location number 512(DD+0) and 515(DD+0) and seven(7) nos. of suspension towers at location number 521(DA+3), 523(DA+0), 524(DA+0), 546(DA+0), 562(DA+0), 564(DA+0) and 566(DA+0) were partially damaged.

#### **Probable Cause of Failure**

The failure of towers was due to the unprecedented heavy wind loads on tower, conductors and earthwire due to HUD-HUD cyclone on 12-10-2014.

#### **Restoration**

The line was restored normal towers on 30.11.2014.

The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.



**4. 400 kV Vijaywada-Gazuwaka –I (on D/C Tower) transmission Line failed on 12.10.2014**

**(Two towers at Location No. 847 & 848)**

**Brief Background**

Vijaywada-Gazuwaka - I 400 kV S/C transmission line was constructed by M/S KEC International Ltd. and is in commercial operation since August 1991. The towers of this line were designed for medium Wind Zone as per old IS 802-1977. The double circuit towers (near entry to substation / dead end tower) were designed for vertical configuration with twin ACSR Moose conductor and V-V-V insulator strings. The line tripped on phase to phase fault on 12-10-2014 at 12:06 hrs.

**Observations**

The Tower at location No. 847(DA+18) had collapsed completely on the ground in transverse direction. Tower at location No. 848 (DD+0) was twisted above cross arm level. No damage was observed on the stubs and foundations. In both cases, phase conductors were partially damaged. No damage was apparent on earthwires.

**Probable Cause of Failure**

The failure of towers was due to the unprecedented heavy wind loads on tower, conductors and earthwire due to HUD-HUD Cyclone on 12-10-2014.

**Restoration**

Line was restored on normal towers on 24.10. 2014.

The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.

## **5. 220 kV Salal-Jammu – I S/C Transmission Line failed on 1.4.2015**

**(Location No. 64(B+0))**

### **Brief Background**

Towers of 220 kV S/C Salal-Jammu-I Transmission Line were designed and constructed by M/s SAE and was put into commercial operation from 10.11.1987. The length of the line is 56.33 km. This is the first instance of tower failure in Salal-Jammu line. The Line tripped at around 16:30 hours on 01.04.2015 due to tower failure/collapse of tension tower at location Nos. 64(B+0).

### **Observations**

It was reported that continuous heavy unprecedented Rainfall and high speed wind were experienced in whole state of J&K including this area. Landslide has also occurred thereby exposing Tower foundations. Crate Protection wall was provided to the tower. Tension tower has fallen in the transverse direction above bottom cross arm level. There was no theft of the member from the towers and no damage to adjacent towers at location Nos. 63(A+0) and 65(B+0) was noticed.

### **Probable Cause of Failure**

The continuous heavy rains and high speed winds triggered the massive landslide downside of the tower exposing and damaging the Tower foundations resulting in failure of tower at location no. 64.

### **Restoration**

The line was restored on ERS and charged on 07.04.2015. The work for restoration of line on normal towers was also started. Committee advised PGCIL to provide required protection for foundation of tower.

## **6. 400 kV Raipur – KSK D/C Transmission Line failed on 25.04.2015**

**(Two towers at Location Nos. 547 & 544)**

### **Brief Background**

400 kV D/C Raipur-KSK (Ckt. 3 & 4) Transmission Line was designed by POWERGRID and constructed by M/s KPTL, Gandhinagar. The length of the line is



134kms. The CKT-3&4 of the line was commissioned in October, 2010. The suspension towers of this line were designed in vertical configuration for wind zone 3 (44 m/s) as per IS:802-1995 for Twin ACSR MOOSE conductor with "I-I-I" insulator string. The line tripped at around 17:32 Hrs. on 25.04.2015. On patrolling, it was observed that there was damage/collapse of towers at location numbers 547(DA+0) & 544(DA+3). It was informed that during the patrolling on 8.4.2015, no visible theft of any members of tower was reported. The failed towers are part of section of the line between towers at Location Nos. 539 and 552 having sectional length of 4.97km. It was reported that in the same area, three towers of Raipur – Tamnar 400kV D/C line of M/s. Jindal Power Ltd. had also damaged due to heavy wind. The team of officers from Powergrid and CEA had visited the site of failure on 30.04.2015. The location of the tower failure was about 25 Km from Raipur.

### **Observations**

The team of officers from Powergrid and CEA had visited the site of failure on 30-04-2015. The failed towers are in agricultural fields with open area all around within village Malipur in Durg District of Chhatishgarh, almost all the bracing and redundant members of first panel were cut by miscreants. These cut members were also missing and could not be found near the tower location. The Towers had completely collapsed at stub level and were lying on the ground and conductors were also touching the ground. The foundations of towers were intact. Insulators were broken. An FIR was lodged with the Nandini Police station. Incidence of high intensity wind and damage to property / trees and power lines was also published in local News Papers. Tower was so badly damaged that the foundation chimney were broken and stubs were bent. Barbed wire used for Anti Climbing Devices was badly mingled around towers. The peak of adjacent towers at location no. 548 and 543 was also found broken.

### **Probable Cause of Failure**

Due to cutting of tower members (main bracings & other members) by local miscreant and later coupled with high wind, might have caused the failure/collapse of towers at location No. 547 and 544. Due to such impact, peak of adjacent tower at loc. Nos. 548 and 543 was also damaged.

### **Restoration**

The line was restored on normal tower and recharged on 06/05/2015. The spare towers available at site were used for restoration of line.

The Committee requested Powergrid to increase the patrolling in the area and help of local people may also be taken in theft prone areas. Proper coping of tower foundations should be done for all towers. The procurement action for replenishment of spare towers may also be initiated by PGCIL.

## **7. 400 kV Vindhyachal-Satna D/C Transmission Line Failed On 13-05-2015**

**(Location no. 709)**

### **Brief Background**

Vindhyachal-Satna 400 kV D/C line (267 kms) was designed and constructed by M/s Kalpataru Ltd. The line was commissioned on 01-08-99. The towers were designed and tested as per IS 802-1995 for wind zone -IV (47 m/sec). Line tripped at around 1335 Hrs. on 13-05-2015 due to partial damage of tower at loc no. 709(DA+6).

### **Observations**

The location of failure is approximately 15 kms from Satna S/S end of transmission line and is situated in cultivated land near village Pondi in Distt. Satna (M.P.) and is accessible through village roads from Satna-Panna road. The tower at Location no. 709 (DA+6) was damaged. The left side middle cross arm of tower (looking from Vindhyachal to Satna) was partially damaged and top cross arm was fully damaged while bottom cross arm was intact. The right side Middle and bottom cross arms seemed to be damaged due to falling of top cross arms & earth wire peaks on right side cross arms. No visible damage was observed below bottom cross arm level. Minor damage to the sub-conductors of phase was observed due to rubbing of conductor with tower body. About 50% of insulators damaged. No missing members were observed in collapsed tower/ nearby locations. The line was passing through low height hill situated on both the sides creating tunneling effect of wind across the line.

### **Probable Cause of Failure**

The localized heavy wind condition prevailed in the vicinity of the village Pondi (Satna).

This wind blowing in perpendicular direction to the line might have created tunneling



effect and critical loading on towers due to disposition of hills in transverse direction of line resulting in damage to tower at Location No. 709.

### **Restoration**

Line was restored on normal towers and charged on 25th May' 2015.

The committee recommended to review design of towers for strengthening, even though the towers were designed according to IS:802(1995), in case of more failure occurs in future.

## **8. 765 kV S/C Gaya-Sasaram -Fatehpur Transmission Line Failed On 14.05.2015 (Location Nos. 283 and 284)**

### **Brief Background**

Gaya- Sasaram-Fatehpur 765 kV S/C line was constructed by M/s. Kalpataru. The line was commissioned on 31/03/2012. The towers of this line were designed for basic wind speed of 47 m/s corresponding to Wind Zone-4 as per IS 802-1995. The towers were designed in delta configuration with Quad ACSR BERSIMIS Conductor. The line had failed on earlier occasions on 11.04.2012 (1 Tower affected) and 31.05.2014(15 Towers affected). Line tripped at 1425 Hrs. on 14/05/2015 due to collapse of 2 nos. of towers at Location Nos. 283(A+3) & 284(A+0).

### **Observations**

Both of the affected towers have fallen in right side in transverse direction facing Sasaram. The affected towers were located in a plain stretch of cultivated field having very few trees. The stretch might have experienced critical wind during the storm. Both the towers at location No. 283 (Tower Type 'A+3') & Location No. 284(Tower Type 'A+0') are suspension towers and were partially damaged and failed from waist level. All the four stubs of both the towers and with foundations were found intact. Many insulators of insulator strings were intact but some insulators were damaged. The phase conductors were partially damaged and no damage was noticed in earthwires.

### **Probable Cause of Failure**

The failure of towers might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earthwires as well as on tower itself exceeding the design values.

### **Restoration**

Restoration of the line on normal towers was done on 02-06-2015.

Committee discussed the failure of this line in detail and strengthening of towers of this line has to be carried out as discussed.

## **9. 765 kV Satna – Bina - I S/C Transmission Line Failed On 16.05.2015**

**(Location No. 82)**

### **Brief Background**

765 kV S/C Satna-Bina-I transmission line was constructed by M/S KPTL in 2012 and is in commercial operation since February 2012. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The suspension towers were designed in delta configuration for Quad Bersimis conductor with double I-V-I insulator string.

### **Observations**

The line tripped on Y-phase to Earth fault on 16-05-2015 at 1441 hrs. During patrolling of the line, it was observed that one suspension tower (A+0) at location number 82 had collapsed. The tower at location No. 82 had collapsed above bottom cross arm level / waist level (near the diamond section). The stubs and foundations were intact. Phase conductors were partially damaged. No damage was apparent on earth wires. Affected tower was located in a plain stretch of cultivated field having very few trees. The stretch might have experienced critical wind during the storm.

### **Probable Cause of Failure**

Failure/ damage to tower at location No. 82 could be due to localized whirlwind in the area resulting in large wind load on phase conductors and earth wires as well as on tower body itself exceeding the design values.



### **Restoration**

The line was restored on normal towers on 26-05-2015.

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

### **10. 765 kV Satna – Bina - II S/C Transmission Line Failed on 19.05.2015**

**(Location No. 717)**

### **Brief Background**

765 kV S/C Satna-Bina-II transmission line was constructed under Sasan UMPP scheme -II project by M/S KEC in 2012 and is in commercial operation since June 2012. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The suspension towers were designed in delta configuration for Quad Bersimis conductor (with double I-V-I insulator string). The line tripped on R-phase to Earth fault on 19-05-2015 at 20:08 hrs.

### **Observations**

During patrolling of the line, it was observed that one suspension tower (A+0) at location No. 717 had collapsed. The tower has collapsed above bottom cross arm level / waist level (near the diamond section). The stubs and foundations were intact. The two suspension towers (at location nos.313 & 314) of above line had failed earlier on 2.10.2014.

### **Probable Cause of Failure**

Failure/ damage at tower No. 717 might have been caused by localized whirlwind in the area resulting in large wind load on phase conductors and earth wire as well as on tower body itself exceeding the design values.

### **Restoration**

Line was restored on conventional towers on 31-05-2015.

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

#### **11. 765 kV S/C Agra-Meerut Transmission Line Failed On 19.05.2015**

(Location No. 35)

##### **Brief Background**

765 kV S/C Agra-Meerut line was constructed by M/s. EMCO. The line is in commercial operation since 01-06-2013. The towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995 using delta configuration with Quad ACSR BERSIMIS Conductor. No tower failure was reported in this line since commissioning. The line tripped at 19:23 Hrs. on 19/05/2015 due to collapse of 1 (one) tower at Location No. 35 (A+0).

##### **Observations**

Tower at Location No. 35 (A+0) was partially damaged and failed from waist level. The tower had fallen in transverse direction. This tower was located in a plain stretch of cultivated field having very few trees. The stretch might have experienced critical wind during the storm. All the four stubs of the tower and foundation were found intact. Phase conductors were partially damaged near the tower due to rubbing of conductor with tower body during collapse of tower. All insulator strings were intact except breakage of one polymer insulator string of middle phase. No damage to earthwire was observed.

##### **Probable Cause of Failure**

In local news paper, it was reported that destruction/damage to properly had taken place due to high intensity wind velocity on 20.5.2015. Failure of tower might have been caused by localized cyclone near Agra resulting in large wind load on phase conductors and earthwire as well as on tower itself beyond the design values.

##### **Restoration**

Line was restored on normal towers on 03-06- 2015.



The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

## **12. 400 kV Farakka-Durgapur-II S/C Transmission Line Failed On 24.05.2015**

**(Seven towers at Location Nos. 180-184 & 186-187)**

### **Brief Background**

Farakka-Durgapur-II 400 kV S/C line was constructed by M/s. EMC. The line was commissioned on 01-08-1992. The towers of this line were designed for Medium wind zone as per IS 802-1977. The towers of the line were designed for horizontal configuration with twin Moose conductor and I-V-I insulator strings. The line tripped at 1810 Hrs. on 24/05/2015 due to collapse of 7 nos. of towers at Loc. No. 180(A+0), 181(A+0), 182(A+0), 183(A+0), 184(A+0), 186(A+0) and 187(A+3) during localized cyclone.

The previous history of tower collapse of this line is as follows:

	<b>Date of Collapse</b>	<b>Section affected</b>	<b>Type of Tower(s) affected</b>
1)	11th May, 2013	361	A type
2)	8th May, 2008	115, 116	A type
3)	4th June, 2005	361	A type
4)	1st May, 1999	354 to 357	A type
5)	4th June, 1998	360 to 362	A type

Due to repeated collapse of suspension towers in this line, work for strengthening of suspension towers was in progress (providing additional hip bracing). Strengthening of towers in affected section is likely to be completed in 2015.

### **Observations**

It was observed that four (4) numbers of towers at location Nos. 181, 182, 183 & 187 have collapsed from ground level with all four stubs bent whereas three (3) towers at location Nos. 180, 184 & 186 collapsed from upper level. The tower at location No. 180 had collapsed from 6m level with all four stubs bent, tower at location No. 184 had also collapsed from 6m level with two stubs bent and tower at location No.186 had collapsed from 9m level although all stubs were in tact. All these affected towers have fallen in left side in transverse direction facing Durgapur. All these affected towers were located in a plain stretch of cultivated field having very few trees.

### **Probable Cause of Failure**

The failure/ damages to towers might have been caused by localized cyclone in the area resulting in large wind load on phase conductors, earthwire and on tower body. Tower strengthening work (providing additional hip bracings) was in progress for the above line and the strengthening work in failed stretches was yet to be taken up.

### **Restoration**

Restoration of the line on normal towers was expected to be complete by 15-06-2015.

Committee recommended for early completion of strengthening of towers of this line.

### **13. 765 kV S/C Bina-Gwalior Trans. Line –III Failed on 02.06.2015**

(Six towers at Location Nos. 573 to 578)

### **Brief Background**

765 kV S/C Bina-Gwalior transmission line-III was constructed by M/s. Lanco and the line was charged on 07/05/2014. Line length is 231.5km. The towers of this line have been designed for wind speed of 47 m/sec corresponding to Wind Zone-4 as per IS 802-1995. The single circuit towers were designed in horizontal configuration with Quad ACSR BERSIMIS Conductor and two galvanized steel earth wire. Insulator strings used for the horizontal configuration Suspension towers are “DI” “V” “DI” ( Double “I” having 120 kN glass insulators) whereas for tension towers it is “QT”(Quad tension) strings with 210KN glass insulator. Tripping of the line was reported on 02/06/2015 at around 5:18PM because of tower failure/collapse under severe storm.

### **Observations**

All the six tower at location Nos. 573(AH+0), 574(AH+0), 575(AH+0), 576(AH+3), 577(AH+0) and 578(EH+6) were of horizontal configuration type and were in open wheat field with hardly any trees.

Out of the six collapsed towers, two towers (at location nos. 574 & 575) had collapsed from above the first panel and rest four (4) towers had collapsed from just above the concrete level of chimney. Towers have fallen in the transverse direction of the line.

Most of the tower members were in jumbled condition. Conductors and earthwire had



snapped. Insulators were shattered and scattered all around. The towers at location Nos.572 and 579 (adjacent to loc. Nos.-573 and 578) have not suffered any damage and are intact. There were no missing members.

Foundations of all the six failed tower locations (from 573 to 578) were designed for WET type foundation. All the Chimneys and foundations at location Nos.573, 574, 575 & 578 are intact. At tower location No.573, one of the stubs have been sheared just above the bracing attachment point, one stub had twisted and other stubs are intact. At tower location No.575, one of the stubs had minor bend. At tower location No.576, a small portion of one of the chimneys had broken off and all stubs were either bent or twisted. At tower location No.577 and 578, two chimneys had surfacial cracks, third one had partial damage in the top portion. Three stubs were bent to varying degree and fourth one was broken from just above the concrete level.

#### **Probable Cause of Failure**

It was reported that a very high intensity westerly storm with very high wind velocity was experienced in this area which was also reported in local news paper and confirmed by local villagers. The high intensity/speed of wind might have exceeded the design limit of the tower leading to collapse of towers. It seems that the tower at the location No. 578(EH+6) had collapsed first from stub level and had fallen in the transverse direction. The tower at other locations might have failed subsequently because of cascading effect.

The committee noted that the pattern of failure is similar to that of 765 kV Gaya-Fatehpur S/C Line (Designed for Wind Zone-4). The strengthening of towers has to be carried out in line with above mentioned line.

#### **14. 400 kV Bhilai-Koradi transmission line**

During the meeting, officials of PGCIL informed that the line was taken under shut down on 06.06.2015 for rectification of deformed tower due to uneven settlement of foundation of legs of the tower. The bottom panel of the tower was deformed completely. The detail report has not been submitted by PGCIL.

## **15. 765 kV S/C Fatehpur- Gaya Transmission Line Failed on 12.06.2015**

**(Location No. 334)**

### **Brief Background**

Gaya-Sasaram-Fatehpur 765 kV S/C line was constructed by M/s. Kalpataru. The line was commissioned on 31/03/2012. The towers of this line were designed for basic wind speed of 47 m/s corresponding to Wind Zone-4 as per IS 802-1995. The towers were designed in delta configuration with Quad ACSR BERSIMIS Conductor. The line had failed in three earlier occasions on 11.04.2012 [one suspension tower at location No.314], on 31.05.2014 (15 towers affected) and 14.05.2015 [2 towers at location Nos. 283(A+3) & 284(A+0) affected]. The line tripped at 14:52 Hrs. on 12/06/2015 due to collapse of 1 (one) tower at Location No. 334(A+0).

### **Observations**

The tower was partially damaged and failed from waist level and fallen in transverse direction. This tower was located in a plain cultivated field having very few trees. The stretch might have experienced critical wind during the storm exceeding the design limit. All the four stubs of the tower and foundation were found intact. Phase conductors were partially damaged, some insulators were also damaged and no damage to earthwires was observed.

### **Probable Cause of Failure**

The failure of towers might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earthwire as well as on tower itself exceeding the design values.

### **Restoration**

Line was restored on 26-06-2015.

Committee discussed the failure of this line in detail and strengthening of towers of this line has to be carried out as discussed.



**16. 765 kV S/C Dharamjaigarh- New Ranchi-II transmission line failed on 16.06.2015**

During the meeting, officials of PGCIL informed that shut down of the line was taken on 16.06.2015 to carry out rectification of cross arm of tower damaged due to localized storm. Detail report has not been submitted by Power Grid.

**17. 765 kV Agra- Jhatikaran transmission line failed on 23.06.2015**

During the meeting, officials of PGCIL informed that shut down of the line was taken on 23.06.2015 for rectification of cross arm damaged due to localized storm. Detail report has not been submitted by PGCIL.

**B. The Transmission Lines of RRVPNL:**

1. **400 kV Akal (Jaisalmer)- Barmer Transmission line failed on 15.02.2015**  
(Tower Nos. 227,228, 229,230 and 231 at location Nos. 16/7 to 16/10 and 17/0 respectively)

**Observations**

As per the preliminary enquiry report submitted by RRVPNL, the towers had collapsed on 15.2.15 and heavy fog in the morning was observed on this day. Total five numbers of towers of the line(4 Nos. Suspension + 1 No. Tension tower) were damaged in the incident. The tower Nos. 227&228 are having body extension of +9m and other towers are having body extension of +3m. The towers at location Nos. 16/7(227), 16/10(230),17/0(231) are designed for WET type foundation and towers at location Nos.16/8(228) and 16/9 (229) are designed for DFR type foundation. All three suspension type towers (with Sl. Nos.227, 228 and 229) had completely collapsed and fallen on the ground in transverse direction and one tension tower (with Sl.No. 231) was bent at stub level and chimney of the leg was found with cracks. The tower at Sl. No. 230, (SA+3) remained intact. However, the flashover marks were seen on disc insulators and decapping of insulator was observed on outer most phase. Insulator string had broken and found fallen on the ground. It was reported that due to failure of suspension Disc insulator at tower No. 230, the conductor of particular phase had snapped due to decapping of disc insulators of the string.

There was no report of heavy wind/storm in that area. As per the preliminary report, survey was supposed to be carried out to check angle of deviation of towers, span lengths etc. for existing locations covering tower Sl. No. 227 to 231 and the proposed locations where new towers are to be erected. Sample of concrete, type of soil was also to be checked for existing tower foundations at Sl. No. 227, 229 and 231. Sample from broken leg and tension plate of insulator string at Tower Sl. No. 231 was to be sent for chemical analysis. Tower foundation design was also supposed to be submitted for analysis.

### **Probable Cause of Failure**

The details of tower were not available. There was no report of heavy wind/storm on the day of failure. Committee discussed in detail about probable cause of failure. The committee suggested RRVPNL to submit the above reports including foundation design for further analysis. However, Committee recommended RRVPNL for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. Committee also suggested to use composite insulators in pollution prone areas to avoid the flashover across insulator discs.

## **2. 765 kV Anta - Phagi S/C Transmission Line failed on 14.03.2015 (7 Towers at Location Nos. 18/0, 18/1 to 18/6)**

### **Brief Background**

The 765kV Anta-Phagi S/C line (211.848km) with Quad ACSR Bersimis conductor was constructed by KEC Limited in 2014 and charged at 400kV level on 25-03-2014. Subsequently the line was charged at 765kV level on 14-01-2015. Seven (7) Nos. of suspension towers had failed on 14-03-2015 at 18:13 Hrs. The design was provided by PGCIL.

### **Observations**

The team of officers from CEA along with officers from RRVPNL had visited the tower failure sites on 28.03.2015. The towers at location Nos.18/0 (D+0), 18/1(A+0), 18/2 (A+0), 18/3(A+6) and 18/4 (A+3) had collapsed, stub part was bent and top portion of chimneys had crack. The tower at location No. 18/5(A+3) was partially damaged with peak and cross arm bent/damaged, but foundation was intact. In case of the tower at



location No. 18/6 (A+0), two leg members of first panel was found to be bent. The foundation was intact. However, the foundations need proper protection as erosion of soil was found near the foundation due to rain water flow. During the inspection, some members of the bottom panel was also found missing, i.e. stolen by some anti social people / miscreants. Few holes left in the joints without bolts. Copping of chimneys was not done. ACD was found missing at tower location No. 18/6 (A+0). Earthing of the towers was not done properly. Tag welding was not done in bolts. Antitheft bolts were missing at few locations. The material test report of the failed tower members, received from RRVPNL, was found to be generally in order. It was reported that the maximum wind speed of 37kmph (at 20: 55Hrs) in NE direction was recorded at Kota A.P observatory on 14-03-2015.

### **Probable Cause of Failure**

Newspapers and local farmers and villagers reported that there was heavy rain, snow fall and speedy storm on the day of failure. The high speed wind / storm, heavy rain and missing members might have led to collapse of towers.

Committee discussed the issues and it was brought to notice that the design of the towers was provided to RRVPNL by PGCIL and the design is similar to Gaya-Fatehpur 765kV S/C line. The committee advised PGCIL to provide the details of strengthening of tower to RRVPNL. But damage of chimneys was exclusive to RRVPNL tower failures. The representatives of RRVPNL informed that a small nalla flows nearby this line / towers and hence during rainy season problem of water logging below the tower is seen. Due to this, the soil around the foundation got eroded and washed away exposing the foundation.

Following actions were recommended by the Committee as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure.

- (a) To provide a path for rain water to drain away and to provide proper protection / retaining walls with weep holes all around the tower to avoid soil erosion and also to protect the foundation.
- (b) To carry out detail soil investigation
- (c) Regular patrolling of the line to avoid theft of tower members by miscreants.
- (d) Replacing the missing members and bolts and tag welding of bolts may be done.

- (e) Copping of chimneys to avoid accumulation of rain water near stubs.
- (f) Replacing missing ACD
- (g) Providing proper earthing connections for towers

**3. 220 kV D/C Bap-Bhadla Transmission line Failed on 11.05.2015  
(3 Towers at Location Nos. 41 to 43)**

**Brief Background**

Bap- Bhadla 220 kV D/C Transmission line was designed and constructed by RRVPN during 2013-14. The line was designed for wind zone 3 with ACSR Zebra Conductor. The length of the line is 52kms.

**Observations**

The Line tripped at 18:50 Hrs. on 11/05/2015. On patrolling, it was found that three (3) suspension towers at Location Nos. 41 (A+0), 42 (A+0) and 43 (A+0) had failed.

As per the preliminary enquiry report submitted by RRVPNL, tower at location Nos. 41(A+0), 42(A+0) and 43(A+0) had collapsed and lying on the ground. All the foundations of the damaged towers were found intact and there was missing member in first panel of tower at location No. 42. Wind speed/ gust detail obtained from wind observatory of nearby area showed its speed of 50 meter per second (180 Km/Hrs.)

**Probable Cause of Failure**

The towers may have collapsed due to the high intensity wind produced due to the storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

**Restoration**

The line was restored on normal towers on 22/5/2015.

Committee advised RRVPNL to review the design of 'A' type towers (suspension towers) in line with latest revised Indian Standard (IS:802) taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition. The strengthening of towers, if required, needs to be taken up and planned accordingly. RRVPNL was also requested to submit material test reports of failed towers



**4. 220 kV Bikaner-Gajner D/C transmission line failed on 19.5.2015  
(15 towers at Location Nos. 47 to 49, 51 to 55, 84 to 87 and 91 to 93)**

**Brief Background**

The Bikaner-Gajner 220 kV D/C line (58.637 km) was designed, executed by RRVPNL and was commissioned in 2013. This line comes under wind zone 3 (as reported by RRVPNL) and the towers were designed as per IS:802:1995. Line tripped at 13:15 Hrs. on 19/05/2015. The power flow in each circuit was 13 MW prior to failure.

**Observations**

It was reported that 15 towers (13 suspension + 2 tension) have failed due to heavy wind storm on 19.05.2015. The tower damages were at location Nos. 47, 48 & 49 (A type), 51 (B+6), 52 (D+6), 53 to 55 (A type), 84 to 87 (A type) and 91 to 93 (A type). There were no missing members reported in the line. A heavy wind storm was reported in the area on the date of collapse.

**Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

**Restoration**

The towers were erected and the line was restored on normal tower on 06/08/2015.

A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. The towers were already erected and line was restored before the team visited the site. However, after careful examination of the erected towers, the team noted that, in the newly erected towers earthing connection needs to be done properly. Coping of chimneys needs to be done, redundant members connected to bracings by welding need to be connected using bolts & nuts and holes left in tower members need to be filled with nut and bolts.

The Committee advised RRVPNL to take necessary action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure. Although the towers might have been designed according to IS 802 (1995), Committee also advised RRVPNL to check the design whether narrow front wind on tower body and 75% of wind load in broken wire condition have been taken into consideration in the design of suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.

**5. 132 kV Bikaner-Pugal road D/C Transmission line & 132 kV Gajner-Pugal road D/C Transmission line Failed on 19.05.2015  
(7 towers at Location Nos. 17 to 22, 54)**

**Brief Background**

The length of Bikaner – Pugal road line and 132kV Gajner – Pugal road line are 20km and 45 km respectively. The line was constructed during 1996-1997. It was reported that seven (7) towers (5 Suspension type+ 2 Tension type) had collapsed due to heavy wind storm with whirlwind on 19.05.2015. The line comes under wind zone 4 and is in sand dune area. The towers were designed by RRVPNL (erstwhile RSEB) as per IS:802. The line was designed for D/C towers with ACSR Panther conductor. Two towers (at different locations) of above line had collapsed in 2007-08 due to whirlwind.

**Observations**

The towers at location no. 17 to 21 (all suspension / 'A' type towers) were bent below cross arm level. Angle towers at location No.54 (LILO Point tower) and location No. 22 had also collapsed. There were no missing members reported in the towers. A heavy wind storm was reported in the area on the date of collapse. The load / Power flow on Bikaner – Pugal road line and 132kV Gajner – Pugal road line were 82Amps. and 96 Amps. respectively prior to failure. The conductors and earthwire in few spans also got damaged.

**Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.



### **Restoration**

The Bikaner-Pugal road line and Gajner Pugal road line were restored on normal towers on 02-06-2015 and 11-06-2015 respectively. Spare towers were used for replacement of failed towers.

A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. The towers were already erected and line was restored before the team visited the site. However, after careful examination of the erected towers, the team noted that, the newly erected towers were relocated by minor shifting from the original tower locations. Proper revetment for new foundations is required. Anti climbing device (ACD) needs to be provided, proper earthing connection (in some locations) and proper coping of chimneys needs to be done for the newly erected towers. The foundations have been made with plain cement concrete. Cover plates have not been provided at butt joint locations in the leg members of towers. Proper size of cover plate needs to be provided at butt joint locations.

Committee advised RRVPNL to review the design of 'A' type towers in line with latest revised Indian Standard (IS:802) taking into account narrow front wind on tower body and 75% wind load on broken wire condition and foundation design need be reviewed also. The Committee as also recommended RRVPNL to take necessary action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure.

#### **6. 132 kV Nokha- Jasrasar transmission Line failed on 19.05.2015 (Location Nos. 121, 123 and 124)**

### **Brief Background**

Nokha-Jasrasar 132 kV D/C transmission line (40km) was commissioned in 2011 by M/S Salasar Techno Pvt. Ltd. Ghaziabad. It was reported that the line tripped on 19-05-2015 at 13:58 Hrs. Three (3) numbers of suspension towers at location Nos. 121, 123 & 124 had collapsed due to thunder storm with hail. The line comes under wind zone 3 (as reported by RRVPNL). The towers were designed as per IS:802.

### **Observations**

The soil along the route of this line is mostly sandy. It was reported by RRVPNL that the towers were uprooted from chimney level. There were no missing members in the towers due to theft. Foundations of the towers were found completely damaged from the chimney. A thunder storm with hail was reported in the area on 19/05/2015. All the damaged towers were of suspension Tower (Type 'A'). Two of the failed towers are normal tower (w/o extension) and third one is with +3 metre extension.

### **Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

Spare towers were used and the line was restored on normal towers on 02/06/2015 at 20:35 Hrs.

A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. The towers were already erected and line was restored before the team visited the site. However, after careful examination of the erected towers, the team noted that, proper protection for foundation needs to be provided and the soil / sand deposited on the chimney of foundation is to be removed or chimney height needs to be raised. Cover plates have not been provided at butt joint locations in leg members of the suspension towers. The cover plate of proper size needs to be provided at butt joints. Earthing connection needs to be done properly i.e. earthing pit / counterpoise wires were not connected properly with tower body.

The Committee advised RRVPNL to take early necessary action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure and also to review the design of foundation of existing towers.



7. **LILO of 132 kV D/C Bikaner – Dulhasar line at GSS Sherera, failed on 19.05.2015.**  
(25 towers at Location Nos. 8 to 19, 23 to 33, 36 and 39)

**Brief Background:**

The line was constructed during 2014-15 by M/S Jagdish Prasad Choudhary, Raisinghnagar, Rajasthan and is yet to be commissioned. It was reported that twenty five (25) nos. of towers (21nos. Suspension towers + 4 nos. tension towers) have collapsed due to heavy wind storm on 19.05.2015. The towers damaged were at location Nos. 8 to 19, 23 to 33, 36&39. Out of 25 Nos. of towers, 21 Nos. of towers were of suspension type, one tension tower with deviation angle of 15 – 30 degree and rest three towers were tension towers with angle of deviation of 2-15 degree. Out of 21 Suspension towers, 14 Nos. are of normal towers, 4 No. of towers are with +3m extension and rest 3 Nos. are with +6m extension. This line comes under wind zone 3 (as reported by RRVNPL) and the towers were designed as per IS 802:1995.

**Observations**

The line tripped on 19-05-2015 between 1:10 to 1:45PM. There was no missing of members due to theft. A team comprising of officials from CEA and Powergrid was deputed to investigate the failure of this line. During the visit to the site of failure, it was noticed that damaged towers were lying on the ground and line was not restored. Most of the failed towers (Location Nos. 8 to 11, 15, 17, 18 to 20, 23 to 33, 36 & 39) were inspected except few towers which are located in agricultural field with standing crops. The team observed that in most of the cases of failed towers, two Chimneys of foundations out of four were damaged/crushed and tower was bent at stub level and other two chimneys had come out of foundation pit along with stub & cleat. The soil is sandy throughout the route of the line. The design of foundation has been done for normal dry soil with plain cement concrete. At couple of locations, the measurement of the chimney & frustum was made by the team and it was found that the actual dimensions were less than that of approved drawing.

Further it was noticed that proper protection has not been provided to the tower foundations, where the foundations are located at sloppy ground. At few locations, the main leg member was deformed & rusted after the failure. In few towers, earthwire 'Ú' clamps are missing and a rusted "J" shaped bolts have been used for clamping. Cover

plates have not been provided at butt joints in leg members for tower type-A. Holes left in the members are to be filled with bolt & nut. The cover plates of proper size need to be used at butt joints in the leg members of tension towers.

It was informed that three samples each of few failed towers of this line were sent for testing at MSME-Testing station, Jaipur. The foundation concrete has been tested at site using Rebound Hammer test method by Govt. College of Engineering & Technology, Bikaner as per request of RRVPNL. The test report of Govt. college of Engineering & Technology shows that the compressive strength of concrete obtained during the test varies from 15.10 to 19.90MPa. (N/mm<sup>2</sup>). The specified characteristic compressive strength of M 15 concrete is 15 N/mm<sup>2</sup> as per IS 456:2000- Plain & Reinforced cement concrete code of practice. The test report of MSME-Testing station, Jaipur shows that out of the three samples tested, the percentage of carbon content in one sample and percentage of phosphorous content in another sample are more than the permissible limits specified in IS: 2062-2011 for class 'A' quality structural steel (mild steel) .

The visiting team had suggested strengthening of foundations of the existing towers by providing additional reinforced cement concrete in Chimney & frustum to increase weight of foundation to provide adequate strength against uplift. The foundation work of chimneys of legs may be taken up one leg at a time by taking adequate safety measures for the stability of the tower structure.

The team had also suggested strengthening the tower by providing additional members from first panel up to bottom cross arm level and also to provide hip bracing. M20 concrete (1:1.5:3) nominal mix may be considered for casting of chimney and frustum. The Cover plate of proper size needs to be provided at butt joints in the leg members of tower.

In case of recasting of the foundations, vertical reinforcement joined with proper stirrups in the Chimney and horizontal reinforcement in both directions in frustum may be considered and interconnected prior to placing concrete. This will provide additional strength to the monolithic structure of frustum and chimney and such arrangement will not allow chimney to come out of the frustum due to the effect of compression and



horizontal components of load. The cleat may be attached with the stub with required no. of (instead of one) to provide adequate strength against uplift.

### **Probable Cause of Failure**

The towers failures might have been caused due to high velocity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit. The design of foundation also raises question.

The committee discussed the failure in detail and recommended RRVPNL to review the design of tower as well as foundation. Committee also recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly. The strengthening of towers as well as foundation may be required in view of nature of failure. The Committee advised RRVPNL to take into account the suggestions of the investigating team of CEA & PGCIL, who had visited the site of failure.

#### **8. 220 kV Bharatpur-Dholpur D/C Transmission line Failed on 19.05.2015 (6 Towers at Location Nos. 6,7,10,11,12 & 16)**

### **Brief Background**

Bharatpur-Dholpur 220 kV D/C transmission line was constructed by M/s. Hythro Power Corporation Limited, Gurgaon. The line was commissioned on 28-08-2002. The tower was having double circuit configuration with ACSR Zebra Conductor. The line tripped at 15:39 Hrs. on 19/05/2015 due to collapse of 6 no. of suspension towers at Location Nos. 6/1 (A+0), 7/2 (A+6), 10/3 (A+0), 11/4(A+0), 12/5(A+0) and 16/6(A+3)

### **Observations**

As per the preliminary enquiry report submitted by RRVPNL there was a heavy storm on 19/05/2015 causing submerged soil conditions thereby reducing soil resistance. The stubs of towers were twisted. Cracks were observed in the foundations of towers. No structural members / parts of tower were found missing.

### **Probable Cause of Failure**

The tower failure might have been caused due to high intensity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

### **Restoration**

Line was restored on normal towers on 20.06.2015

Committee recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly. RRVPNL was also requested to submit material test reports of failed towers.

## **9. 220 kV D/C Alwar-Badarpur Transmission line Failed on 19.05.2015 (2 Towers at Location Nos. 148, 149)**

### **Brief Background**

The Alwar-Badarpur 220 kV D/C transmission line tripped on 19.05.2015 at 14.31 Hrs. on Single line to Ground fault. During patrolling it was observed that tower at Loc. Nos. 148 (Type-A) and 149 (Type-A) had collapsed/ uprooted and tower at loc. No. 147 (Type-B angle tower) was uplifted.

### **Observations**

Towers at Loc. No. 148(Type-A) and 149 (Type-A) got uprooted and their two chimney came-out of ground and towers collapsed. In case of Tower at loc. No. 147(Type-B), two chimneys of the tower got disturbed though tower did not collapse. There was no theft / missing of members. A heavy wind storm was reported in the area on the date of collapse.

### **Probable Cause of Failure**

The towers might have collapsed (uprooted) due to high velocity wind / storm in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit. The design of foundation also raises question.

Committee recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required,



needs to be taken up and planned accordingly. The foundation design needs to be reviewed. RRVNPL was also requested to submit material test reports of failed towers.

**C. The transmission lines of UPPTCL Lines:**

1. 400 kV Mainpuri-Paricha-I & II Transmission Line failed on 31.05.2014
2. 400 kV Unnao-Lucknow Transmission Line failed on 28.04.2015

Neither the representative of UPPTCL participated in the Standing committee meeting nor the report of failure of tower been submitted to the CEA for above mentioned lines. Therefore, the matter could not be discussed during the meeting.

**D. The transmission lines of WBSETCL Lines:**

1. 400 kV D/C Sagardighi-Durgapur Transmission Line failed on 24.05.2015  
(Location nos. 139, 140 to 143)

**Background**

Powergrid officials informed that the Operations and Maintenance (O&M) of these lines are done by PGCIL. The 400 kV D/C Sagardighi-Durgapur line was constructed by M/s KEC. The line was commissioned on 28.04.2011. The Conductor configuration of the line is Twin Moose. The line tripped on 24.05.2015 due to collapse of 2(two) Nos. of towers at location Nos. 141(DA+0) & 142 (DA+0) and partial collapse of 3 (three) no. towers at location Nos. 139(DA+0), 140(DA+3) & 143(DA+3) due to unprecedented cyclonic storm. The line had tripped earlier on 25.04.2012, in which six (6) towers [186(DB+9), 189(DC+6) and 187, 188, 190 & 248 are (DA+0)] fully collapsed and five(5) towers [185(DD+9), 191(DB+0) and 247, 249 & 255 are(DA+0)] were partially damaged.

**Observations**

It was observed that towers at location Nos. 141 & 142 have collapsed from ground level whereas 3 towers collapsed from upper level. The tower at location No. 141 had collapsed fully. Similarly the tower at location No. 142 had collapsed with stub bent. The towers at location Nos. 139 & 143 had partially damaged with one of the top cross arm bent. But tower at location No. 140 had partially damaged with top, middle & bottom

cross arm bent and earthwire peak damaged. All these affected towers were located in plain stretch of cultivated field having very few trees and might have experienced critical wind during the storm. All these affected towers have fallen in left side in transverse direction facing Durgapur. PGCIL informed that the suspension towers were designed for 75% wind load for broken wire condition and is being used widely across the country.

#### **Probable Cause of Failure**

The tower failure might have been caused by localized cyclone in the area resulting in large wind load on phase conductors and earthwire as well as on tower body exceeding the design limit.

#### **Restoration**

Line was to be restored on normal towers by 15<sup>th</sup> June 2015.

The Committee requested to PGCIL to submit material test report.

#### **E. The transmission Lines of M/s JINDAL POWER**

**400 kV Tamnar- Raipur D/C Transmission line on 25.04.2015**  
**[Two towers at Location Nos. 660 & 661]**

#### **Brief background**

During the meeting, PGCIL had informed that the line belongs to M/s Jindal Power Limited. None of the representative of M/s JPL was present in the meeting. M/s JPL was requested to submit the investigation report to CEA. The report was received in January 2016. The 400 kV Tamnar- Raipur D/C Transmission line belongs to M/s Jindal Power Ltd., the Transmission Licensee. Both the circuits of the line tripped on ground to earth fault on 25.04.2015 at 17:35 hrs due to failure of two suspension type towers at location No. 660 & 661.

#### **Observations**

As per the report submitted by M/s JPL, during patrolling it was observed that two suspension towers at location Nos. 660 & 661 (at a distance of 248 km from Tamnar) had collapsed. The bottom bracing members and main leg members of towers were cut and stolen. Villagers informed that there was heavy storm in the area, where the towers collapsed. FIR was lodged with the Nandini Police station. Similar incidents of theft of tower parts and subsequent collapse of tower had taken place the same day for PGCIL and CSPTCL's line in the same region. Police has informed M/s JPL that thieves were caught and stolen material has been recovered from them.



### **Probable Cause of Failure**

The cutting of tower members and high wind / storm in the area might have caused the failure of towers at location No. 660 & 661.

### **Restoration**

The Circuit-2 of the line was restored on Emergency Restoration System on 3.05.2015. After restoration of Circuit -2, action for removal of damaged tower and recasting of civil foundation was taken up. Then circuit-1 was charged on newly erected towers on 23.05.2015 and subsequently circuit-2 was shifted from ERS and charged with newly erected towers on 27.05.2015. There was 28 days outage of circuit No. 1 and 7 days outage of circuit No. 2.

The committee recommended that the patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by JPL and involved for safety of towers.

### **Observations and Recommendations of the Committee:**

1. **Committee observed that major cause of failure of towers are as under:**
  - a) The high wind velocity during storm, cyclone and local phenomenon of whirlwind and gale etc. might have exceeded the wind speed for which the tower is designed. This type of wind is difficult to predict. The probability of such occurrences is low & the tower design will be uneconomical if such situation is considered in the design.
  - b) Theft of tower members, generally the theft of secondary members (connected with one or two bolts) of the towers, by the local people makes the tower structurally weak which ultimately leads to failure during storms/whirlwind/cyclone etc;
  - c) It is also difficult to take into account demolishing activities by miscreants like cutting/blasting the main members of the tower, during design or construction stage.

- d) Many lines are in operation with towers designed according to old Indian Standards (IS: 802 -1977). (The Indian Standard has been revised subsequently to incorporate new design concepts to minimize the rate of the failure.)
- e) In some cases although the towers have been design according to IS 802 (1995), but 75% of wind load in broken wire condition may not have been considered for design of suspension towers.
- f) Lack of proper soil investigation and deficiency in design of foundation of towers sometimes lead to failure of towers.
- g) Lack of proper protection to foundation of towers sometimes causes damage to foundation as well as the towers.

**2. After the detail discussions/deliberations in the meetings held in CEA, following decisions have been taken by the Standing Committee.**

- (a) The most of the failures are linked to high wind speed. The CE, PSE&TD informed that about 800 (as on August 2015) wind data measurement stations have been established by National Institute of Wind Energy (NIWE), Chennai covering all parts of the country for Indian wind Power Mapping. The wind data available with NIWE may be useful to obtain actual wind speed in the areas of tower collapse. The Committee suggested that CEA should arrange a meeting with NIWE, SERC, PGCIL etc. to discuss about the usefulness of wind data collected by NIWE for wind zone mapping and estimating actual wind speed in areas where towers have collapsed.
- (b) The representative of SERC informed that during the material testing, other than testing of the material properties, measurement of thickness of members should be carried out. Wide variation in thickness should not be there. The area having minimum thickness is vulnerable to failure. He further highlighted that IS: 12427 / IS:1367 do not specify weight of nuts / bolts, which should be an important parameter for bolt. The Committee also suggested CEA to write to BIS to review IS:7215 to specify required tolerance limits in respect thickness of member and IS:12427 / IS:1367 to specify weight of nuts / bolts as one of the parameter in addition to other parameters



- (c) The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.
- (d) The wind speed mapping for the entire country is under further revision by Bureau of Indian Standards (BIS) based on inputs from Structural Engineering Research Centre (SERC), Chennai due to change in wind speed pattern in some part of the country. The committee suggested CEA to write to BIS for early revision of the wind map of the country.

**(e) Failure of transmission lines of PGCIL**

**(i). 765kV Gaya-Fatehpur S/C Transmission Line**

- The towers with delta configuration shall be avoided to the extent possible in 765kV single Circuit (S/C) lines in future and as such most of the 765 kV lines shall be Double Circuit (D/C) lines with vertical configuration.
- In absence of meteorological data, it has become difficult to assess the actual wind velocity at site of failure in order to verify with the design value of wind speed. However, the detailed analysis of structural design of suspension tower (with delta configuration) of 765kV S/C line was carried out by CPRI and PGCIL using two different softwares [STAAD Pro and i-Tower]. The strengthening of suspension towers (with delta configuration) of 765kV S/C line traversing through wind Zone - 4 has to be carried out as indicated below by increasing the member / section size of six (6) members and adding two (2) more redundant members. The drawing showing the member location is enclosed as **Annexure - II**.

<b>Member No.</b>	<b>Original Member size</b>	<b>Proposed Member size</b>	<b>Existing No. of Bolts</b>	<b>Proposed No. of Bolts</b>
D13	65x65x5 (MS)	65x65x6 (MS)	2 SS – 16Ø	2 SS – 16Ø
D16	80x80x6 (MS)	90x90x6 (MS)	2 SS – 16Ø	2 SS – 16Ø
D29	70x70x5 (MS)	90x90x6 (MS)	2 SS - 16Ø	3 SS - 16Ø
M51/52	100x100x8 (HT)	110x110x8(HT)	6 DS - 16Ø	6 DS - 16Ø
D12	75x75x6 (HT)	80x80x6 (HT)	3 SS - 16Ø	3 SS - 16Ø
New Redundant connected to M5	-	50x50x5 (MS)	-	1 SS - 16Ø
New Redundant connected to H3/H4	-	50x50x5 (MS)	-	1 SS - 16Ø

- Since strengthening of tower is to be done above bottom cross arm / waist level (near diamond section), long shutdown shall be required for replacement of members / sections of towers in existing line and the nature of work and the risk involved in replacement of member of towers in existing line is different from fabrication of towers afresh. The fabrication of fresh towers can be taken up easily. But replacement of members in the existing towers is very difficult and lot of risk is involved. Moreover, many of the executing agencies may not be interested to take up such difficult and risky task. Dismantling and replacement of the structural part above waist level of tower requires long shut down. Hence such activity shall be taken up during annual maintenance in a phased manner. PGCIL has to prioritize the areas / lines where such activity can be taken up. Accordingly planning has to be done by PGCIL.
- The patrolling of line needs to be increased / intensified in theft prone areas in order to avoid failure due to theft of tower members. The local people should be educated by PGCIL and involved for safety of towers.
- The regions, where frequent failures of transmission line towers are observed, need to be identified and wind data logger stations may be installed by PGCIL in those areas on priority basis. PGCIL should expedite the installation of Anemometers in substations, particularly in cyclone / high wind prone areas, as recommended earlier by the Standing Committee of experts on failure of transmission lines of 220kV and voltage level.



- (ii). The committee also decided that PGCIL has to strengthen towers of other 765kV S/C lines, designed for wind Zone -4 with Delta configuration of towers, in line with Gaya – Fatehpur 765kV S/C line.
- (iii). The rate of failure of suspension towers (with delta configuration) of 765kV S/C line traversing through other wind zones (other than Wind Zone -4) and areas prone to cyclone / storm needs to be monitored. In case repeated failure is observed in those lines, similar exercise for review of design has to be taken up by PGCIL for different wind zones for suspension towers (with delta configuration) of 765kV S/C line.
- (iv). **400 kV Jeypore-Gazuwaka D/C transmission line**

The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.

- (v). **400 kV Vijaywada-Gazuwaka –I S/C transmission Line**

The towers have been designed according to old IS:802 (1977). Committee advised PGCIL to check the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers and the strengthening of towers, if required, needs to be taken up and planned accordingly, in case more failure occurs in future. Powergrid was also requested to submit material test reports of failed towers.

- (vi). **400 kV Raipur – KSK D/C Transmission Line**

The Committee requested Powergrid to increase the patrolling in the area and help of local people may also be taken in theft prone areas. The procurement action for replenishment of spare towers may also be initiated by PGCIL.

**(vii). 400 kV Vindhyachal-Satna D/C Transmission Line**

The committee recommended to review design of towers for strengthening, even though the towers were designed according to IS:802(1995), in case of more failure occurs in future.

**(f) Failure of transmission lines of RRVPNL**

**(i). 400kV Akal (Jaisalmer)- Barmer Transmission line**

Committee recommended for

- Checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers
- Checking of angle of deviation in the section where towers have failed
- Submission of foundation design of existing towers for further analysis
- Considering the use of composite insulators in pollution prone areas to avoid the flashover across insulator discs.

**(ii). 765 kV Anta - Phagi S/C Transmission Line failed on 14.03.2015**

The failure pattern of seven (7) Nos. of suspension towers (with delta configuration) of Anta-Phagi 765kV S/c line in RRVPNL system was similar to 765kV Gaya – Fatehpur S/C line and design was provided by PGCIL for wind Zone – 4 with delta configuration of towers. RRVPNL has to plan and carryout modifications by strengthening the members in line with above mentioned transmission line of PGCIL. The committee also suggested RRVPNL to review the design of foundation of towers.

Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:



- To provide a path for rain water to drain away and to provide proper protection / retaining walls with weep holes all around the tower to avoid soil erosion and also to protect the foundation.
- To carry out detail soil investigation
- The patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by RRVPNL and involved for safety of towers.
- Replacing the missing members and bolts and tag welding of bolts may be done.
- Coping of chimneys to avoid accumulation of rain water near stubs.
- Replacing missing ACD
- Providing proper earthing connection for towers

**(iii). 220 kV D/C Bap-Bhadla Transmission line**

Committee advised RRVPNL to review the design of 'A' type towers (suspension towers) in line with latest revised Indian Standard (IS:802) taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition. The strengthening of towers, if required, needs to be taken up and planned accordingly. RRVPNL was also requested to submit material test reports of failed towers

**(iv). 220 kV Bikaner-Gajner D/C transmission line failed on 19.5.2015**

Committee recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- Providing proper earthing connection for towers
- Coping of chimneys
- Redundant members to be connected using bolts and nuts (instead of welding) and holes left in tower members to be filled with nut and bolts.

Although the towers might have been designed according to IS 802 (1995), Committee also advised RRVPNL to check the design whether narrow front wind on tower body and 75% of wind load in broken wire condition have been taken into consideration in the

design of suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.

**(v). 132 kV Bikaner-Pugal road Transmission line & 132 kV Gajner-Pugal road Transmission line Failed on 19.05.2015**

Committee advised RRVPNL to review the design of 'A' type towers (suspension towers) in line with latest revised Indian Standard (IS:802) taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition. The strengthening of towers, if required, needs to be taken up and planned accordingly. The foundation design need be reviewed also.

The Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- Proper revetment for new foundations
- Providing Anti climbing device (ACD)
- Providing proper earthing connection for towers
- Coping of chimneys
- Provide Cover plates of proper size at butt joint locations in leg members of towers.

**(vi). 132 kV Nokha- Jasrasar transmission Line failed on 19.05.2015**

The Committee recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- Proper protection for foundation needs to be provided and the soil / sand deposited on the chimney of foundation is to be removed or chimney height needs to be raised.
- Provide Cover plates of proper size at butt joint locations in leg members of towers.
- Providing proper earthing connection for towers

**(vii). LILO of 132 kV D/C Bikaner – Dulhasar line at GSS Sherera, failed on 19.05.2015.**



The committee recommended RRVPNL to review the design of tower as well as foundation. The strengthening of towers as well as foundation may be required in view of nature of failure. Committee also recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly.

The Committee also recommended RRVPNL to take following action as suggested by the investigating team of CEA & PGCIL, who had visited the site of failure:

- The tower may be strengthened by providing additional members from first panel up to bottom cross arm level and by providing hip bracing.
- M20 concrete (1:1.5:3) nominal mix needs to be considered for casting of chimney and frustum.
- Cover plate of proper size needs to be provided at butt joints in leg members of tower
- In case of recasting / strengthening of the existing foundations, proper reinforcement may be provided in the foundation of Chimney and frustum and cleats attached with the stubs need to be designed as per requirement to provide adequate strength against uplift.
- The earthwire needs to be fixed with suspension towers with proper clamps

**(viii). 220 kV D/C Bharatpur-Dholpur Transmission line**

Committee recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly. RRVPNL was also requested to submit material test reports of failed towers.

**(ix). 220 kV D/C Alwar-Badarpur Transmission line Failed on 19.05.2015**

**(2 Towers at Location Nos. 148, 149)**

Committee recommended for checking the design of tower according to latest IS:802 taking into consideration narrow front wind on tower body and 75% of wind load in broken wire condition for suspension towers. The strengthening of towers, if required, needs to be taken up and planned accordingly. The foundation design needs to be reviewed. RRVPNL was also requested to submit material test reports of failed towers.

**(g) The transmission lines of WBSETCL:**

**400 kV D/C Sagardighi-Durgapur Transmission Line failed on 24.05.2015**

The Committee requested to PGCIL to submit material test report.

**(h) The transmission Lines of M/s JINDAL POWER**

**400 kV Tamnar- Raipur D/C Transmission line on 25.04.2015**

The committee recommended that the patrolling of line needs to be carried out on regular basis and special patrolling should be done in the month of February & March before onset of likely period of storm / heavy wind etc. But in theft prone areas, frequency of patrolling needs to be increased / intensified in order to avoid failure due to theft of tower members. The local people should be educated by JPL and involved for safety of towers.

**The meeting ended with a vote of thanks to the chair.**



**List of Participants**

**Central Electricity Authority**

1. Shri. S.K.Ray Mohapatra , Chief Engineer, PSE&TD Division
2. Shri. M.S.Satija, Director,PSE&TD Division
3. Shri. S.P.Singh, Deputy Director, TCD Division
4. Shri. C.N.Devarajan, Deputy Director, PSE&TD Division
5. Ms. Noopur Chaudhary, Assistant Director, PSE&TD Division
6. Shri. Mohit Mudgal, Assistant Director, PSE&TD Division

**Powergrid Corporation of India Ltd.**

1. Shri. Gopal Ji, GM(Engg.TL)
2. Shri. Raj Kumar Singh, Asst. GM (Engg.TL)

**Central Power Research Institute, Bengaluru**

1. Shri. D. Revanna, Joint Director, MED

**Council of Scientific and Industrial Research**

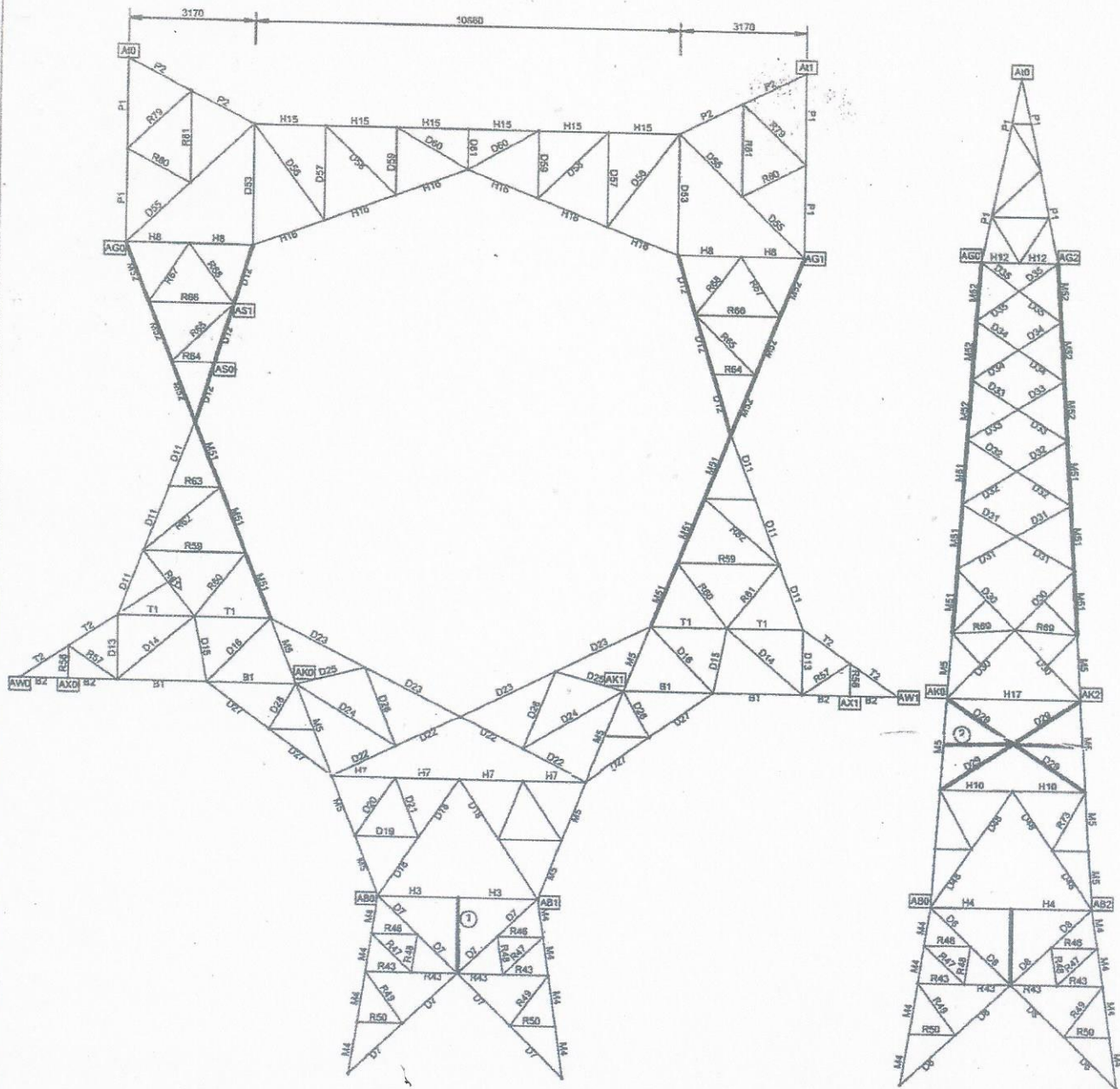
1. Dr. P.K.Umesha, Chief Scientist, Head, TTRS

**Rajasthan Rajya Vidyut Prasaran Nigam Limited**

1. Shri. A.K.Verma, XEN

**Wapcos Ltd.**

1. Ms. Sippy Srivastava, Engineer



Member	Section	Bolts
D13	65*65*6 MS	2 S/S - 16Ø
D16	90*90*6 MS	2 S/S - 16Ø
D29	90*90*6 MS	3 S/S - 16Ø
① ②	50*50*5 MS	1 S/S - 16Ø
M51/52	110*110*8 HT	6 D/S - 16Ø
D12	80*80*6 HT	3 S/S - 16Ø

Rev. 1 Typographical error in grade of M51/52, p12 corrected Grade HT, 25

POWER GRID CORPORATION OF INDIA LTD. - New Delhi.			
DESCRIPTION		STRENGTHENING SCHEME FOR SPARE TOWER PROCUREMENT 765 KV S/C TOWER TYPE-A (DELTA CONFIGURATION) WIND ZONE = 4 (47 m/sec)	
SCALE	N.T.S.	DRG. NO.	SHEET NO.
DESIGN	anw/2	C-ENGG:TL	1
CHECKED		REV SYM	2
<p>Rev. 1 Typographical error in grade of M51/52, p12 corrected Grade HT, 25</p>		<p>DRG. NO. 110/115 C-ENGG:TL REV SYM 1</p>	

ANNEXURE - 2