सत्यमेव जयते

क्षतिग्रस्त ट्रांसमिशन लाइन टॉवरों पर विशेषज्ञों की स्थायी समिति की रिपोर्ट

(अप्रेल २०१८ – मार्च २०१९)

REPORT OF THE STANDING COMMITTEE OF EXPERTS ON FAILURE OF EHV TRANSMISSION LINE TOWERS

(APRIL 2018 – MARCH 2019)




केविप्रा
cea

New Delhi

भारत सरकार

Government of India

केन्द्रीय विद्युत प्राधिकरण

Central Electricity Authority

विद्युत मंत्रालय

Ministry of Power

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New Delhi

(विद्युत अधिनियम,2003 की धारा 73(एल) के तहत के.वि.प्रा. के दायित्व का निर्वहन करते हुए)

(In fulfilment of CEA's obligation under section 73(l) of Electricity Act, 2003)

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EXECUTIVE SUMMARY

1.0 Introduction:

1.1 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(l) of Electricity Act 2003. Office order vide which Standing Committee was constituted is enclosed at Annexure-C.

1.2 The objective of Standing Committee is to visit site of EHV tower failure, investigate and analyze the probable causes 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 cases, where the visit to site of failure does not materialize, analysis of failure is done based on information provided by the utilities and their participation in the Standing Committee meeting.

1.3 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. In fact, number of failure cases remains unreported as many of the 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. This fact has been brought in to notice of Hon'ble Central Electricity Regulatory Commission (CERC) and State Electricity Regulatory Commission, Joint Electricity Regulatory Commission (JERC) and all State Electricity Regulatory Commissions.

1.4 The failure cases of EHV transmission towers, which are reported to CEA, of different power utilities are discussed during the meeting of standing committee of experts and inferences are drawn in respect of causes of failure of the transmission tower based on site investigation report, information/data provided by the concerned utilities and deliberations during the meeting and various recommendations are made to avert reoccurrence of such failure in future.

1.5 The meeting of the Standing Committee of the Experts was held in CEA on 28.05.2019 to discuss the cause of failure of the transmission line towers of different voltage levels belonging to various power transmission utilities which had failed during the period from April, 2018, to March, 2019. During this period, the failure of towers of EHV transmission lines of various utilities [PGCIL, M/s Sterlite Power, M/s MPPTC and M/s MSETCL] were reported to CEA. Accordingly, the Committee discussed in detail the nature and cause of failure of towers of transmission lines of these utilities. Minutes of the meeting are enclosed at Annexure-B.

2.0 Brief details of failure of towers of various transmission lines reported to CEA from April, 2018 to March, 2019

2.1 Failure of total 65 nos. of towers of twenty-three (23) transmission lines of PGCIL, M/s MSETCL, M/s MPPTCL and M/s Sterlite Power were reported to CEA during April 2018, to March 2019. Details, as furnished by the utilities, of these failures are given in Table-1 below:

Table-1

Sl. No.	Name of Transmission line	Name of utility	Date of failure	Year of Commissioning	Wind Zone	No. of towers failed	Configuration / Conductor
1.	400kV D/C Sundargarh- Raigarh transmission line	PGCIL	01-04-2018	2011	2	2	Vertical / Twin Moose
2	765 kV S/C Bilaspur – Dharamjaygarh (Ckt-I) transmission line	PGCIL	27.04.2018	2014	2	3	Delta / Quad Bersimis
3.	220 kV D/C Auraiya-Sikandara (Agra) transmission line	PGCIL	06.05.2018	1990	Medium	7	Vertical / Zebra
4	400 kV D/C Maithon-Maithon transmission line	PGCIL	10.05.2018	2010	4	3	Vertical / Twin Moose
5.	400 kV S/C Farakka-Durgapur II transmission line	PGCIL	10.05.2018	1992	Medium	2	Horizontal / Twin Moose
6.	765 kV S/C Gaya-Varanasi- transmission line	PGCIL	13.05.2018	2012	4	1	Delta/ Quad Bersimis
7.	765 kV S/C Fatehpur – Agra-I transmission line	PGCIL	13.05.2018	2012	4	1	Delta/ Quad Bersimis
8.	765 kV S/C Jhatikara-Bhiwani transmission line	PGCIL	16.05.2018	2012	4	1	Delta/ Quad Bersimis
9.	765 kV S/C Gaya-Varanasi- transmission line	PGCIL	28.05.2018	2012	4	3	Delta/ Quad Bersimis
10.	765 kV S/C Satna - Bina transmission line	PGCIL	30.05.2018	2012	4	1	Delta/ Quad Bersimis
11.	400 kV D/C Sasaram - Daltonganj transmission line	PGCIL	31.05.2018	2018	4	3	Vertical/ Twin Moose
12.	400 kV D/C Hisar - Kaithal transmission line	PGCIL	09.06.2018	2005	4	10	Vertical/ Triple

							SNOWBIRD
13.	400 kV D/C Damoh - Birsinghipur transmission line	PGCIL	12.06.2018	2012	2	3	Vertical / Twin Moose
14.	400 kV S/C Chamera-2 –Kishenpur Line	PGCIL	01.09.2018	1997	Medium	2	Horizontal / Twin Moose
15	400 kV D/C (Quad) Patna-Kishanganj Line	PGCIL	02.09.2018	2016	4	3	Vertical/ Quad Moose
16.	±500kV HVDC Talcher-Kolar Line	PGCIL	11.10.2018	Pole-I-2002 & Pole-II-2003	5	1	Vertical / Quad Bersimis
17.	400 kV D/C Srikakulum-Garivadi Line	PGCIL	11.10.2018	2018	5	2	Vertical / Quad Moose
18.	765 kV S/C Bhopal - Jabalpur transmission line	Sterlite Power	18.05.2018	2015	2	2	Vertical / Quad Bersimis
19.	400kV D/C Purnea-Biharsharif Line	Sterlite Power	10.08.2018	2013	4	1	Vertical / Twin Moose
20.	400kV D/C Purnea-Biharsharif Line	Sterlite Power	21.08.2018	2013	4	1	Vertical / Twin Moose
21.	400kV BBLR Dhule D/C (Ckt-1 and Ckt-2) line	MSETCL	01.06.2018	1995	Low	5	Vertical/ Twin Moose
22.	220kV D/C Chalisgaon – Kopargaon/ BBLR DC line	MSETCL	01.06.2018	2011	1	1	Vertical/ Zebra
23.	400 kV Katni – Damoh DCDS Line	MPPTCL	24.06.2018	1999	Medium	7	Vertical/ Twin Moose
Total No. of Failed Towers						**65**	

2.2 In addition to failure of transmission lines listed above, failure of eight (8) transmission lines with thirty-six (36) towers also took place during the failure events which occurred on 11th April 2018 & 2nd May 2018. The standing committee was apprised about the formation of separate high level committee in May 2018 in view of frequent failures of EHV transmission towers and substation equipment of PGCIL in and around Agra region in April & May 2018. Chairperson, CEA constituted this committee (vide CEA letter dated May 7, 2018) under Principal Chief Engineer-II, CEA comprising of members from NRPC, NPC, CEA (PSETD

Division), CPRI, SERC, UPPTCL, IMD and PGCIL. The TOR of the committee was to Study and Analyze the frequent failure incidents of EHV transmission towers & substation equipment of Power Grid in & around Agra area in recent times. The committee report was submitted in January 2019 and as such these failure incidents were not discussed in the standing committee meeting and are not covered in this report.

2.3 The number of suspension and tension towers at various voltage level, failed during the period from April 2018, to March 2019 and discussed in the Standing Committee meeting, are indicated in Table-2 below:

Table-2

Voltage Level	Utility	No. of affected Lines	No. of Towers failed					
			Suspension Towers	Tension Towers				Total no. of towers failed
			A	B	C	D	Total	
765 kV	PGCIL	6	10	-	-	-	-	10
	Sterlite Power	1	2	-	-	-	-	2
	Total	**7**	**12**	**-**	**-**	**-**	**-**	**12**
±500 kV HVDC	PGCIL	1	1	-	-	-	-	1
	Total	**1**	**1**					**1**
400 kV	PGCIL	9	18	4	1	7	12	30
	Sterlite Power	2	-	-	1	1	2	2
	MSETCL	1	4	1	-	-	1	5
	MPPTCL	1	7	-	-	-	-	7
	Total	**13**	**29**	**5**	**2**	**8**	**15**	**44**
220 kV	PGCIL	1	7	-	-	-	-	7
	MSETCL	1	1	-	-	-	-	1
	Total	**2**	**8**	**-**	**-**	**-**	**-**	**8**
TOTAL		**23**	**50**				**15**	**65**

2.4 Out of total 65 towers of 23 Nos. of transmission lines listed above in Table-1, 15 nos. of towers pertaining to 9 nos. of transmission lines failed within 5 years of commissioning. In two of these transmission lines (400 kV D/C Sasaram - Daltonganj transmission line and 400 kV D/C Srikakulum-Garivadi Line), tower failed within few months of commissioning.

2.5 Out of 65 Nos. of failed towers, 50 Nos. (77%) are of suspension type towers and rest 15 Nos. (23%) are tension type towers (fig.-1). All the fifteen (15) tension type towers failed

were of 400 kV voltage level and failure of tension type towers were not observed at any other voltage levels.

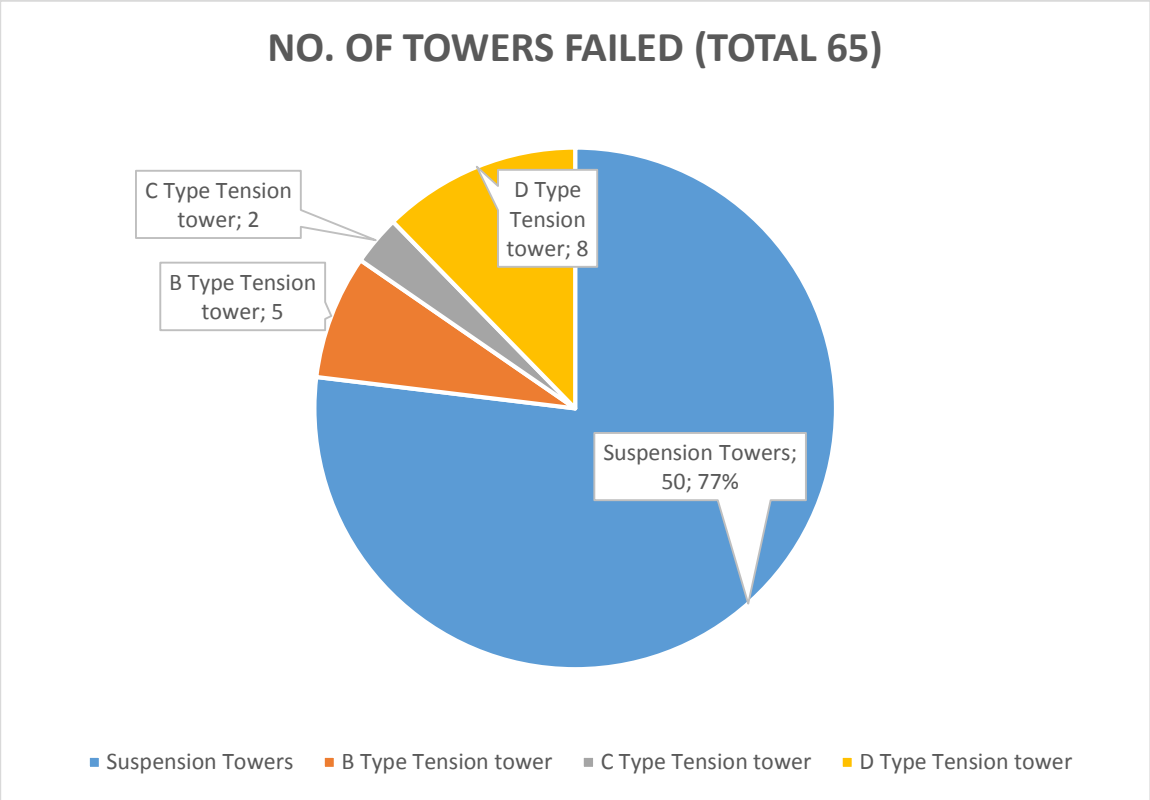


Fig.-1

2.6 It has been observed that the failure rate of suspension towers is much higher in comparison to tension towers. This may be because the Suspension towers are not designed to take horizontal forces in the longitudinal direction and hence the failures of one suspension type tower causes secondary failure of adjacent suspension towers due to the pulling force of conductors. In view of above, the loading criteria for the suspension type towers have been made more stringent and the longitudinal and transverse force acting on Suspension type towers under security condition has been increased in revised IS 802 (2015). It is noted that none of the transmission lines, failed during the period from April 2018 to March 2019, were designed as per revised IS 802 (2015). However, as reported by the utilities, in some of the transmission lines the suspension towers were designed considering narrow front wind condition and with 75% wind in security condition.

2.7 No. of transmission lines and towers failed during the period from April 2018 to March 2019 with respect to voltage level is given below (fig.-2). The maximum no. of failure of transmission lines and transmission towers was at 400 kV voltage level. Out of total 65 towers of 23 Nos. of transmission lines, 44 (68%) towers of 13 (56 %) transmission lines were of 400 kV level. This may be because out of 419395 circuit kilometers (ckm) of 220 kV & above voltage level transmission lines in India, 182608 circuit kilometers (43.54%) are of 400 kV level transmission lines (as per data available till October, 2019). Higher no. of failure of transmission lines of 400 kV voltage level is corollary to highest no. of transmission lines at 400 kV Voltage level in India.

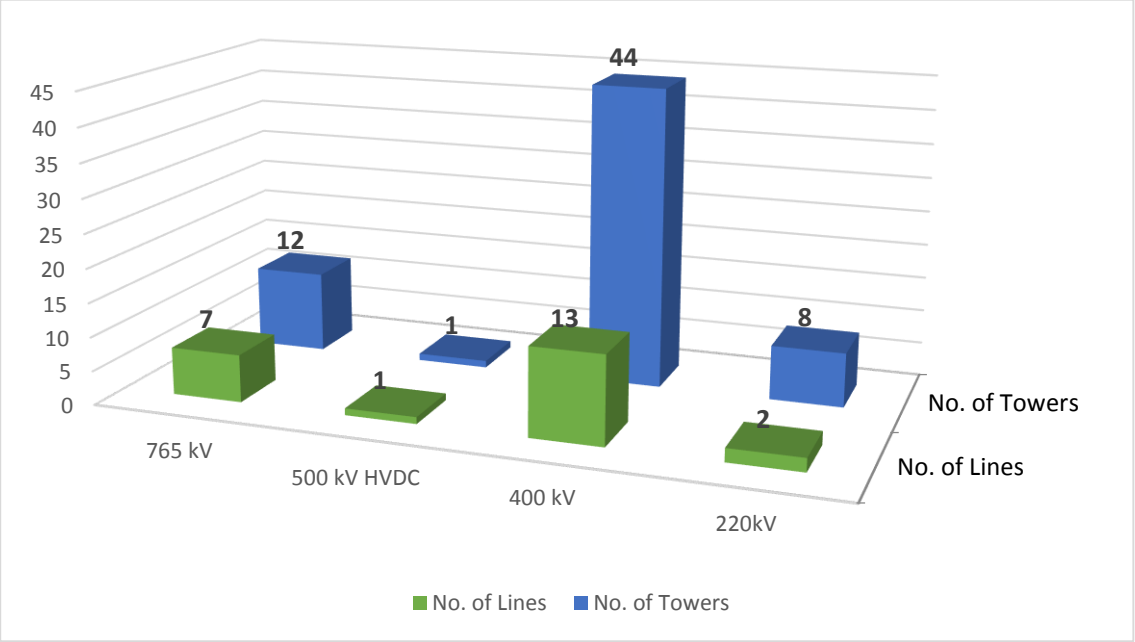


Fig.-2

2.8 Before the revision of IS 802 in 1995, the wind map of India was divided into three wind pressure zones i.e. light, medium & heavy. In the third revision of IS 802: 1995, 6 wind zones were specified dividing various regions on the basis of 3 second wind gust speed. No. of transmission lines and towers, failed during the period from April 2018 to March 2019 and designed according to various wind zones is given below (fig.-3). It can be seen that

a) The maximum no. of failure of towers have occurred for transmission lines which were designed for Wind Zone 4; and,

b) The maximum no. of transmission lines affected due to failure of towers are traversing through Wind Zone 4.It may be noted that maximum area of India is covered under this wind zone.

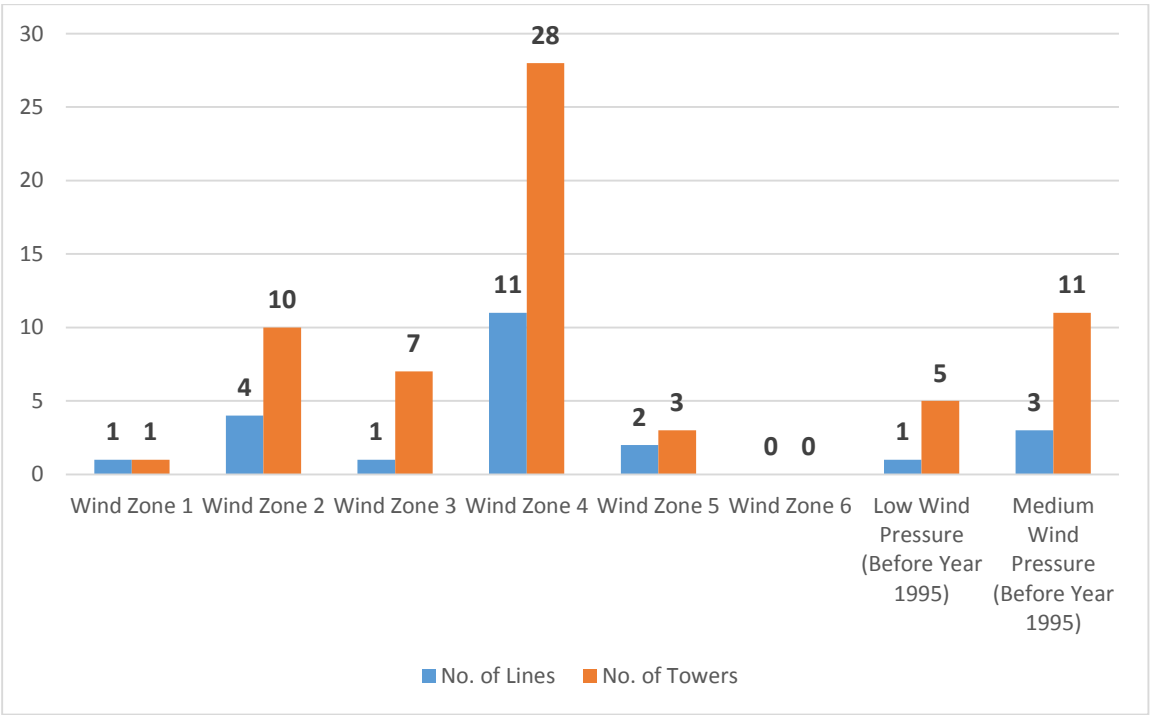


Fig.-3

2.9 Failure sites in respect of following transmission lines were jointly visited by representatives of CEA & PGCIL.

1. 400 kV D/C Hisar - Kaithal transmission line
2. 400 kV D/C Damoh- Birsinghipur transmission line

3.0 OBSERVATIONS OF THE COMMITTEE:

3.1 In most of the cases, the transmission utilities have attributed the cause of tower failure to high intensity wind. However, the utilities have failed to provide the wind data which could substantiate their reasoning. They have expressed their inability to make available the actual wind speed data on the day of failures. The standing committee observed that wherever reporting of tower failure is due to wind, the utility needs to get the wind data for the area which would serve as representative wind speed prevailing in that area at the time of failure. It was agreed that the high wind velocity during storm and local condition of whirl wind might have exceeded the design wind speed for which the tower is designed; however this needs to be verified. Assistance of IMD & other agencies involved in metrological field may be taken by the affected utilities in this regard and utilities may request for sharing of the wind data obtained from observatory/ Satellite/Radar.

3.2 During the meeting, the members of the Standing Committee were informed that a committee has been constituted by MoP for auditing of transmission towers under the chairmanship of Member (Power System),CEA and so far, five audits have been carried out for 15 transmission lines of various utilities. Standing Committee observed that various deficiencies, such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with soil, rusted stub/members etc., as observed by the Audit team could be due to Poor workmanship, Erection deficiency, O&M issues, which may have led to failure of some of the towers.

3.3 Few cases of failure of 765 kV Single circuit Delta configuration towers of PGCIL are observed. It was brought to the notice of Standing Committee that the failure pattern of the 765 kV Delta configuration suspension type tower of PGCIL have been examined in detail in the previous Standing Committee meetings which includes the design review analysis carried out by CPRI, SERC in association with PGCIL and the Standing committee had suggested strengthening of existing 765kV S/C suspension towers with delta configuration (of wind zone-4) by replacing the six (6) members with higher size members and adding two (2) more redundant members. PGCIL has got reviewed this design by M/s Minitoba Hydro, Canada and they have also suggested strengthening of some of the members. The inadequacy in tower structure coupled with the reported storm caused the failure of towers. However, during site visit to investigate the failure of towers in and around Agra it was observed that PGCIL had used steel clamping/clipping of some members of the existing towers for to strengthening. Members of the Committee pointed out that the strengthening mechanism used by PGCIL was not in line with the recommendations of standing committee. This needs detail analysis and review by PGCIL.

3.4 Over the years the Indian Standards for design of transmission line tower has undergone changes. As revision of codal provisions is a continuous process, the changes are to be implemented prospectively. Strengthening of towers of existing transmission line due to change in the codal provisions could be decided on case to case basis, if repeated failures are observed in a particular line.

3.5 The type of failure of towers of lines of various voltage levels can be broadly classified as under:

- Deformation in Legs of tower and cage portion of bottom cross arm level.
- Buckling of stub level leading to complete collapse of towers with/without damage to tower foundation.
- Buckling above 1st panel (normal tower) level with/without damage to tower foundation.
- Buckling from bottom cross arm level or top cross arm level or peak broken without any damage to lower portion of the tower and foundation.
- Damage to foundation as well as to tower structure due to increased water level and additional force due to water flow/velocity in the river/soil erosion and inadequate protection to foundation of towers.
- Shearing of stubs of leg members of towers.

3.6 The Draft report of the Standing Committee of Experts on failure of EHV transmission line towers (April 2018 – March 2019) was circulated among all the committee members vide CEA's mail dated 30th January 2020 for comments/observations. PGCIL vide its letter no. C/Engg/TL/CEA-SC/2018-19 dated 25.02.2020 submitted their comments/observations on the draft report (attached as Annexure-D) which have been appropriately incorporated in the report.

4.0 ANALYSIS OF FAILURE OF TOWERS OCCURRED DURING THE PERIOD FROM APRIL 2018, TO MARCH, 2019

4.1

1.a.	**400 KV D/C Sundargarh- Raigarh transmission line**	**PGCIL**
1.b.	***220 kV Auraiya- Sikandara (Agra) transmission line**	
1.c.	**400 KV D/C Maithon - Maithon transmission line,**	
1.d.	***400 kV S/C Farakka-Durgapur II transmission Line,**	
1.e.	**400 kV D/C Sasaram – Daltonganj transmission Line,**	
1.f.	**400 kV D/C Hisar - Kaithal transmission Line,**	
1.g.	**400 kV D/C Damoh – Birsinghipur transmission Line,**	
1.h.	***400 kV S/C Chamera-2 –Kishenpur transmission Line,**	
2	**765 kV S/C Bhopal - Jabalpur transmission line,**	**M/s Sterlite Power**
3.a.	***400 kV BBLR Dhule Ckt-1 and Ckt-2 transmission line,**	**M/s MSETCL**

3.b.	**220kV Chalisgaon – Kopargaon / BBLR D/C transmission line**	
4.	***400 kV Katni – Damoh DCDS transmission line**	**M/s MPPTCL**

The utilities (PGCIL, M/s Sterlite Power, M/s MSETCL & M/s MPPTCL) have attributed the failure of tower of aforementioned lines to occurrence of high speed wind, although they have not been able to provide credible wind data in this regard. They have expressed their inability to make available the actual wind speed data on the day of failures. In the absence of this information, it has become difficult to establish with sufficient confidence that the prevailing wind speed was higher than the wind speed for which the towers were designed. The high wind velocity might have induced the failure of towers but it may not be the sole reason for the failure incidences. In view of above the utility needs to get the wind data for the area (where tower failures have been reported) which would serve as representative wind speed prevailing in that area at the time of failure. It was desired that the concerned utility which are facing repeated failure of lines in a region due to high wind speed need to perform thorough study and analysis of wind speed data at the initial design stage itself for all the new transmission lines to avoid such failures.

[*Note: These lines were designed as per IS 802-1977 and were more than 20 years old. Standing Committee of Experts had advised to strengthen the towers designed according to IS 802:1977 by providing hip bracing in the bottom most panels/ upto bottom cross arm level if repeated failures are observed in the lines. However, no repeated failure of tower in these lines have been observed]

4.2

a.	**765 kV S/C Gaya- Varanasi transmission Line**	**PGCIL**
b.	**765 kV S/C Fatehpur – Agra-I transmission line**	
c.	**765 kV S/C Jhatikara-Bhiwani transmission line**	
d.	**765 kV S/C Satna - Bina transmission line**	

These transmission line were erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration.

The study and design review analysis of 765 kV S/C Delta configuration suspension type tower (of wind zone-4) of PGCIL was carried out by CPRI, SERC in association with PGCIL and Standing Committee had recommended for strengthening of few members above waist level by replacing the existing members by new members. In this regard, PGCIL stated that the strengthening activity is in process and is being taken up in phased manner as per the direction of Standing Committee. The inadequacy in structure of 765 kV S/C towers of Gaya-Fatehpur transmission line coupled with the reported storm caused the failure of towers. The above mentioned transmission lines designed with delta configuration suspension tower faced similar pattern of failure, needed proper strengthening as suggested by Standing Committee for 765kV Gaya-Fatehpur transmission line.

4.3 **765 kV S/C Bilaspur – Dharamjaygarh (Ckt- I) transmission Line [PGCIL]**

This transmission line was erected using 765 kV S/C Delta configuration designed for wind zone-2. Standing Committee in its previous meeting had recommended that the rate of failure of suspension towers (with delta configuration) of 765kV S/C line traversing through 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, review of design in line with 765 kV Gaya-Fatehpur S/C transmission line (for Wind Zone-4) with Delta configuration towers, has to be taken up by PGCIL for different wind zones for suspension towers (with delta configuration) of 765kV S/C line. The high wind velocity might have induced the failure of towers. In case further failures are observed in the line, PGCIL need to take up the exercise for review of design.

4.4 **±500 kV Talcher-Kolar transmission line &**
400 kV D/C Srikakulum-Garivadi transmission Line [PGCIL]

These transmission lines failed during high speed cyclone 'TITLI' which affected the coastal areas of Odisha and Andhra Pradesh on 11th October 2018. The data regarding actual wind speed from authenticated wind observatory was not made available by the transmission utility, however in view of the speed mentioned in the newspaper clippings and IMD press release issued regarding cyclone "TITLI", it was inferred that high speed cyclone "TITLI" had led to the tower failure.

4.5 **400 kV D/C (Quad) Patna-Kishanganj transmission Line [PGCIL]**
&
400 kV D/C Purnea- Bihar Sharif transmission line [M/s Sterlite Power]

Both the transmission lines are running almost parallel to each other and are crossing the river Ganga. The failed towers were located near bank of Ganga River. New water course was created due to flash / heavy flood and the soil below the foundation of towers were eroded causing damage to the foundation and failure of towers. Change in course of river due to flood, improper assessment of change in river course, lack of provision of Proper Protection (retaining wall, Gabion wall etc.) for towers near the river was observed as cause of failure. In view of above, it was observed that towers erected near river banks should be frequently patrolled and proper assessment should be made about the change in course of river based on trend of soil erosion and necessary protection should be provided to towers to avoid damage during such incident.

4.6 In addition to the above, the Committee deliberated that the following reasons of the failure of transmission line towers cannot be ruled out, though such deficiencies in tower structure are difficult to prove after failure of tower:

- Theft/sabotage of tower members, generally the theft of secondary members (connected with one or two bolts) of the towers, by the local people making the tower structurally weak and ultimately leading to failure during high speed wind/ storms/whirlwind/ cyclone etc.
- Failure of stubs due to shearing of leg members of towers due to torsional forces.
- Deficiency in design/construction of foundation of towers.
- Various deficiencies such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with soil, rusted stub/members

etc. as observed during the Audit of transmission towers due to Poor workmanship, Erection deficiency, O&M issues.

- Inadequacy in soil investigation and tower spotting.
- Improper coping of chimney and protruded steel reinforcement causing rusting of stubs and legs.

5.0 INSIGHTS INTO TOWER FAILURE INCIDENTS BETWEEN THE YEAR 2008 TO 2017

5.1 The details of previous transmission line and tower failure incidences which were reported to CEA and have been discussed in the previous Standing Committee meetings from the year 2008 onwards have been analyzed by CEA. It may be noted that many of the transmission utilities neither provide the transmission tower failure details to CEA nor participate in the Standing Committee meetings and hence several EHV tower failure incidents remain unreported. The analysis covered only the failure incidences of transmission towers which were reported to CEA.

5.2 The graph depicting the failures of towers occurred during past 10 years that have been discussed in the previous Standing committee meetings are shown below (Fig. 4). The maximum no. of failures i.e. 163 cases of tower failures occurred during year 2014. As has been observed in the previous Standing Committee meetings, the failure rate of suspension towers is much higher in comparison to tension towers. This may be because of the cascading effect of failure of suspension type towers i.e. secondary failure of adjacent suspension towers due to the pulling force of conductors which have been developed due to failure of another tower.

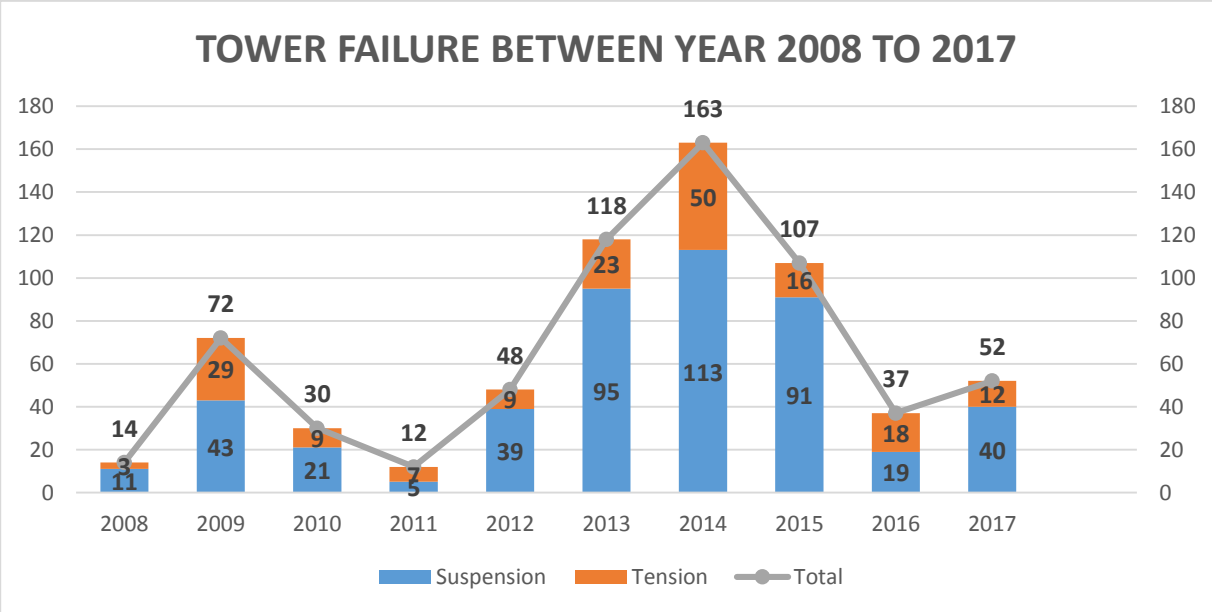
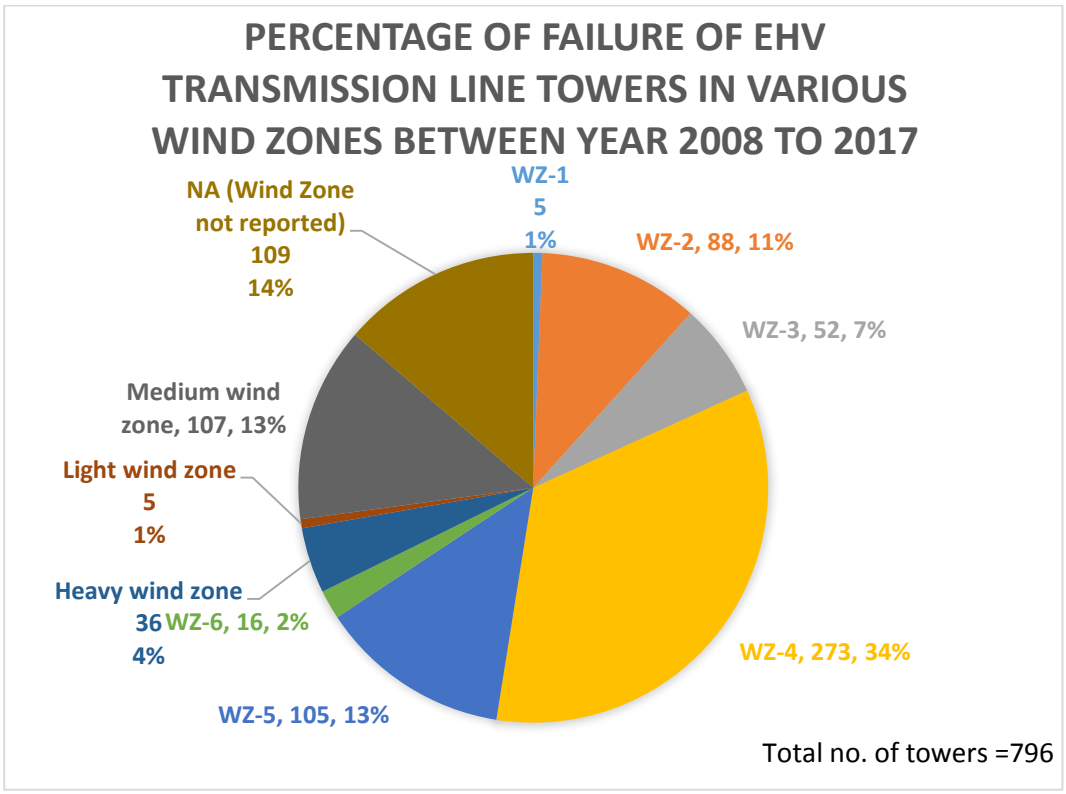


Fig.-4

5.3 Graph/Pie chart depicting percentage of failed EHV transmission towers with respect of various Wind zone of the country is shown below (Fig.5). The graph includes the details of transmission towers which were designed according to IS 802:1977 considering the three wind zones in the country namely, Light, Medium and High wind zones and failed after year 2005. The details of wind zones corresponding to 14% of towers are not

available in the records. Maximum percentage (34%) of towers which were failed were designed for wind speed of Wind Zone 4.



Wind Zone	Basic Wind Speed (m/s)
1	33
2	39
3	44
4	47
5	50
6	55

Fig.-5

5.4 The graph depicting the failures of towers at various voltage level that have occurred during past 10 years and intimated to CEA and have been discussed in the previous Standing committee meetings are shown below (Fig.6). It may be observed that towers of 400 kV voltage level have maximum incidences of failure. It may be noted that the mandate of the Standing Committee is to investigate failure of towers of 220 kV and above voltage class transmission line and the graph shows the details of only those transmission line failure which have been intimated to CEA and the large percentage of tower failure incidents reported to CEA pertains to PGCIL which has maximum no. of transmission lines at 400 kV level.

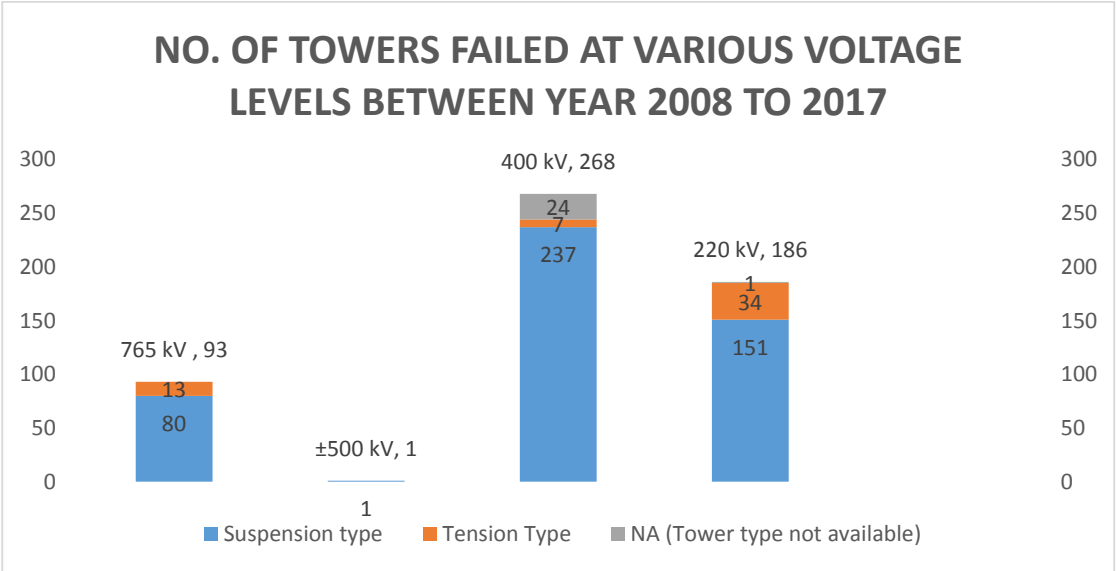


Fig.-6

5.5 All transmission utilities are being repeatedly requested to intimate the tower failure incidences to CEA so that a complete picture of the tower failure incidences can be depicted and discussed in the Standing committee meeting.

6.0 RECOMMENDATIONS & REMEDIAL MEASURES SUGGESTED BY THE COMMITTEE

After detailed deliberations/discussions among all participants, the committee has recommended/suggested the following remedial measures

(a) It is observed that intensity of wind has changed in some part of the Country due to climate change and the wind map was revised by SERC in 2009, the same has been incorporated in the National Building Code of BIS, however, IS 875 has not been amended to include revised wind map. Till the time IS 875 is not revised, utilities should follow wind map given in National Building Code for designing of towers.

(b) After every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD estimate the wind speed in affected area based on data obtained from observatory/ Satellite/Radar.

(c) In order to optimize the tower designs, the values of drag coefficient considered for flat sided tower members have been reduced in the revised version of IS:802 (Part-1/Section-1)- 2015. In the process the tower design margins got reduced. Hence, the lattice type towers shall be designed as per IS-802 (2015), however the drag coefficient considered for flat sided tower members shall be as follows:

Solidity Ratio	Drag Coefficient
Up to 0.05	3.6
0.1	3.4
0.2	2.9
0.3	2.5
0.4	2.2
0.5 and above	2.0

(d) Narrow Front Wind design condition incorporated in IS 802-2015 applies to tower structures only (and not on conductors & earthwire). Also, some of the parameters in the new code (IS 802-2015) have been diluted in comparison to previous IS-802 Part-I/Sec-I (1995) and rectification of the same is needed. These issues may be taken up with BIS for review of relevant provisions to avoid transmission line failures.

(e) As revision of codal provisions is a continuous process, the changes are to be implemented prospectively. Strengthening of existing transmission line towers due to change in the codal provisions could be decided on case to case basis by the Standing Committee, if repeated failures are observed in a particular line.

(f) Transmission lines to be laid within 50 Kms of the border of the wind zones may be designed with higher of the two zones. However, whether 50 km is appropriate or any change is required for this interface distance, shall be suggested by SERC based on studies.

(g) Under Research Scheme on Power (RSOP) a proposal from SERC on "Strengthening studies for performance enhancement of existing transmission line towers" is pending with CPRI since 2017. CPRI shall be asked to take a expeditious view on this proposal, as it shall be beneficial to transmission sector.

(h) CPRI / SERC may also take up some RSOP project to study and analyze typical tower failures. Standardization of tower type designs could also be another RSOP project. CPRI/SERC shall explore further on these matter.

(i) Due to climatic change, incidents of high winds are increasing. Transmission utilities need to take proactive measures such as increased line patrolling, immediate replacement of missing members/bolts.

(j) Various deficiencies such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with soil, rusted stub/members etc. has been observed during the Audit of various transmission towers of different utilities. These deficiencies may be attributed to poor workmanship, erection deficiency, O&M issues etc. Utilities shall take necessary precautions and carry out proper maintenance of their lines so as to avoid failure of towers due to such deficiencies.

(k) Coping of Chimneys of tower foundations, wherever required, should be taken up to avoid rusting of stubs.

(l) In case of towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear analysis of tower should be carried out.

(m) Modern technique/methods should be adopted for erection & stringing of towers.

(n) Pile type foundation may be considered for towers in flood prone area based on soil investigation report and latest high flood data.

(o) Additional precautions should be taken for routing of transmission lines so as to keep location of towers away from river banks. Pile type foundation shall be used for towers located in river or creek bed or on bank of river having scourable strata or in areas where river flow or change in river course is anticipated, based on detailed soil investigation and previous years' maximum flood discharge of the river, maximum velocity of water, highest flood level, scour depth & anticipated change in courser of river based on river morphology data of at least past 20 years to ensure availability and reliability of the transmission line.

(p) The transmission towers erected near river banks should be frequently patrolled and assessment based on history should be made to anticipate the change in course of river and necessary protection should be provided to towers to avoid its damage during such incident.

(q) Best practices in quality control process for raw material, manufacturing, transportation, construction, storage, erection and stringing of towers shall be adopted.

(r) Frequency of patrolling of transmission lines should be more for the vulnerable tower locations (for thunder & cyclonic prone area, towers located close to river banks).Proper protection shall be provided for towers located in areas affected by soil erosion.

(s) Utilities shall assess the condition of structure of towers, conductors, earthwire, all associated accessories, foundation and earthing system periodically using modern techniques & diagnostic tools and shall take appropriate action, wherever abnormality is noticed.

(t) All transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds.

(u) In case of damage of foundation of towers, the foundation design is required to be examined.

(v) Material test for failed members of the tower should be carried out in NABL accredited laboratory to ascertain the quality, composition and mechanical properties of the material. Impact tests should also be conducted.

(w) In case of repeated failure of towers of transmission lines [designed according to IS:802 (1977)] strengthening of towers need to be done by providing hip bracings up to the bottom cross arm level.

(x) Intensive care should be taken during erection and installation of towers (Slope correctness, filling unplugged holes, tightening of Bolts, Tack welding, straightness of tower members etc.).

(y) Regular patrolling of the lines is required for smooth and trouble free operation of line. During patrolling any unauthorized construction/use/storage under & around the towers should also be checked and if such activity is observed, local administrative authority should be immediately informed for assistance and necessary action.

(z) Providing proper revetment & use of geo-synthetic material in foundation, concrete encasing & painting of stub in water logging areas etc. may also be considered, wherever required.

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ANNEXURE-A

INVESTIGATION REPORTS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION UTILITIES

DETAILED REPORTS OF FAILURE OF TOWERS

DETAILED REPORTS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES FAILED DURING APRIL,2018 to MARCH 2019

The towers of following Transmission Lines had failed during above mentioned period. The relevant details of each transmission line has been provided in the subsequent clauses.

Sl. No.	Name of Transmission line	Date of occurrence of failure	No. of towers failed
PGCIL:			
1.	400 kV D/C Sundargarh- Raigarh transmission line	01.04.2018	2
2	765 kV Bilaspur-Dharamjaygarh (Circuit-I) transmission line	27.04.2018	3
3.	220 kV D/C Auraiya- Sikandara transmission line	06.05.2018	7
4	400 kV D/C Maithon -Maithon transmission line	10.05.2018	3
5.	400 kV S/C Farakka-Durgapur II transmission line	10.05.2018	2
6.	765 kV S/C Gaya- Varanasi transmission line	13.05.2018	1
7.	765 kV S/C Fatehpur – Agra-I transmission line	13.05.2018	1
8.	765 kV S/C Jhatikara-Bhiwani transmission line	16.05.2018	1
9.	765 kV S/C Gaya- Varanasi transmission line	28.05.2018	3
10.	765 kV S/C Satna - Bina transmission line	30.05.2018	1
11.	400 kV D/C Sasaram - Daltonganj transmission line	31.05.2018	3
12.	400 kV D/C Hisar - Kaithal transmission line	09.06.2018	10
13.	400 kV D/C Damoh - Birsinghipur	12.06.2018	3

	transmission line		
14.	400 kV S/C Chamera-2 –Kishenpur transmission line	01.09.2018	2
15.	400 kV D/C (Quad) Patna-Kishanganj transmission line	02.09.2018	3
16.	500kV HVDC Talcher-Kolar transmission line	11.10.2018	1
17.	400kV D/C Srikakulum - Garivadi transmission line	11.10.2018	2
M/s Sterlite Power:			
18.	765 kV S/C Bhopal - Jabalpur transmission line	18.05.2018	2
19.	400kV D/C Purnea- Biharsharif Line	10.08.2018	1
20.	400kV D/C Purnea- Biharsharif Line	21.08.2018	1
M/s MSETCL:			
21	400kV BBLR Dhule D/C (Ckt-1 and Ckt-2) line	01.06.2018	5
22	220kV D/C Chalisgaon – Kopargaon/ BBLR DC line	01.06.2018	1
M/s MPPTCL:			
23.	400 kV Katni – Damoh DCDS Line	24.06.2018	7

DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINE OF PGCIL:

1. 400kV D/C Sundargarh- Raigarh Transmission Line failed on 01.04.2018. [Location Nos.: 407(DA+0) & 417(DA+0)]

➢ **Brief Background**

400kV D/C Rourkela-Raigarh (Ckt#3&4) was commissioned on 29th June, 2011. Subsequently, Loop In Loop Out(LILO) of the line was done at 765/400kV Sundargarh Substation on 2nd January 2018 which resulted in 400kV D/C Rourkela-Sundargarh and 400kV D/C Sundargarh-Raigarh transmission lines. The 400 kV D/C Sundargarh- Raigarh (Original Rourkela-Raigarh Ckt#3&4) transmission line was constructed by M/s TATA Projects Ltd. The line was designed for wind zone 2 (basic wind speed 39 m/s) as per IS: 802-1995. The towers were designed in Vertical configuration with twin ACSR Moose Conductor. The suspension towers of this line were designed with "I" type suspension insulator string configuration.

➢ **Observations**

a. As informed by PGCIL, the area, in which the failed towers are located, experienced sporadic heavy whirl wind followed by localized cyclonic storm during the intervening night of 31st March 2018 & 1st April 2018. It was informed that patrolling team observed that main leg members along with many bracing members were deformed at Loc. No. 407(DA+0) and 417(DA+0) and these towers were in critical condition. However, complete failure and collapse of transmission towers did not occur.

b. **Tower at location no. 407 (DA+0)** was situated/ located in Forest patch near Village – Banjari under LakhanpurTahsil of Jharsuguda district, Odisha. Deformations were found in Leg A & D of the tower. The cage portion of bottom cross arm also deformed into a Rhombus like shape. It was reported that no members were found missing from the tower.

The details of tower spotting in the affected Section (Loc. No. 404 to Loc. No. 410) are as follows:

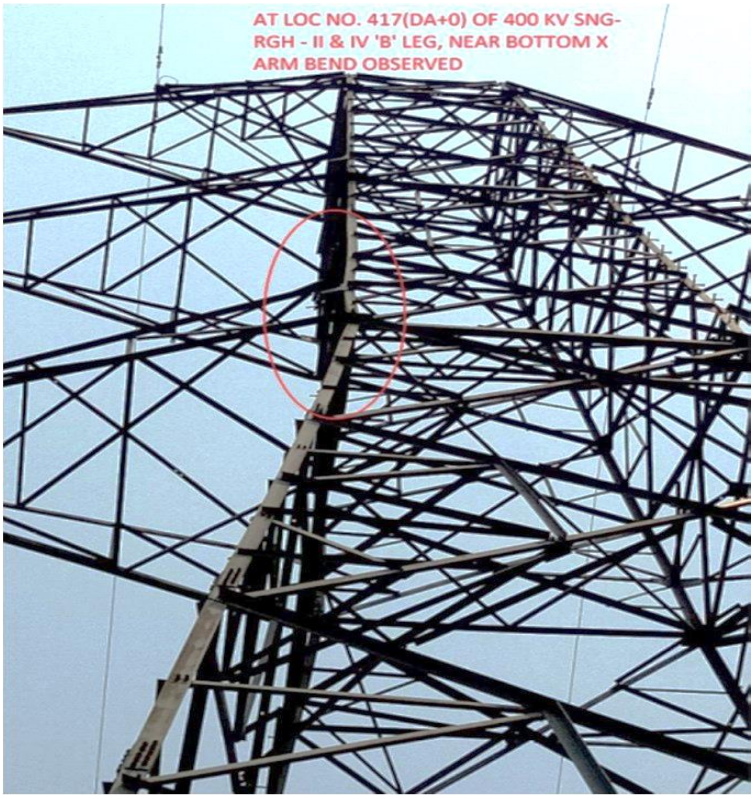
Sl. No.	Loc. No.	Type of Tower	Forward Span	Angle of Deviation
1	404	DD+0	335	33° 19' 23" RT
2	405	DA+0	355	
3	406	DA+3	355	
4	**407**	**DA+0**	**360**	
5	408	DA+3	340	
6	409	DA+0	350	
7	410	DC+3		17° 39' 04" RT

Tower at Loc. No. 407(DA+0)

c. **Tower at location no. 417 (DA+0)** was situated/ located in Reserve Forest Area on slope of the hill, around 30 M above from bottom of the hill, under Lakhanpur Tahsilwith with very few trees in the vicinity. Leg B of the tower was deformed near bottom cross arm cage portion. It was reported that no missing members were found in the tower.

The details of tower spotting in the affected Section (Loc. No. 416 to Loc. No. 428) are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span	Angle of Deviation
1	416	DD+0	263	33° 27' 12" RT
2	**417**	**DA+0**	**400**	
3	418	DA+3	390	
4	419	DA+0	360	



Tower at Loc. No. 417(DA+0)

- **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission due to which the leg members & few bracing members of the towers at Loc. No. 407 & Loc. No. 417 got deformed. It was noted that complete collapse of the towers was not observed in this case. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

The committee recommended that all transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds. It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future.

2. 765 kV Bilaspur – Dharamjaygarh (Ckt-I) Transmission Line failed on 27.04.2018 [Location Nos. 120(A+0), 121(A+0) & 122(A+0)]

➢ **Brief Background**

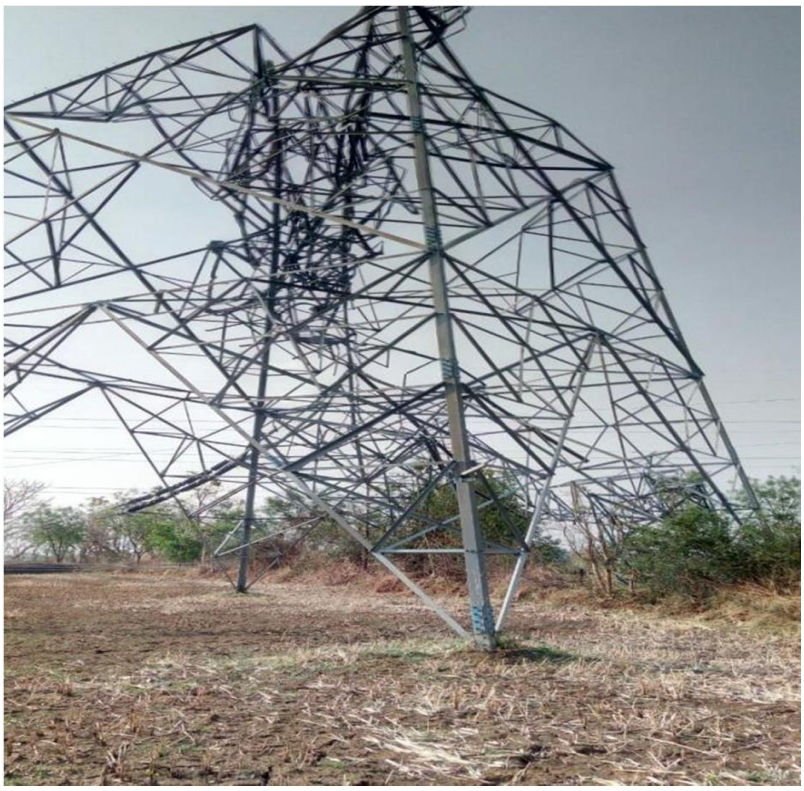
765 kV Bilaspur – Dharamjaygarh (Ckt-I) transmission line, was constructed by M/s L&T Ltd. and was commissioned on 1st April, 2014. The suspension towers of this line were designed for wind zone 2 (basic wind speed 39m/s) and reliability level 2. The towers were designed as per IS: 802:1995 additionally taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition. The towers were designed with Quad ACSR Bersimis Conductor. The suspension towers of this line were designed with Double "I-V-I" insulator string in Delta configuration. There has been no incident of tower failure reported in this transmission line since the commissioning.

➢ **Observations**

a. The details of tower spotting in the affected sections are as follows:

Sl. No.	Loc. No.	Type of tower	Forward span	Angle of Deviation
1	118	A+0	378	--
2	119	A+0	370	--
3	**120**	**A+0**	**360**	--
4	**121**	**A+0**	**345**	--
5	**122**	**A+0**	**339**	--
6	123	C+0	370	18°9'28"RT
7	124	A+3	380	--

b. **Tower at location no. 120(A+0)** was located in cultivated fields of village Charpara, Tehsil-Baloda, District Janjgir-Champa, Chhattisgarh. The tower had collapsed from second panel level. All the four stubs of the tower were intact.



Tower at Loc. No. 120

c. **Tower at location no. 121 (A+0)** had failed above waist level from the K frame portion of the tower. All the four stubs of the tower were found intact.

Tower at Loc. No. 121

d. **Tower at location no. 122 (A+0)** had collapsed from the third panel level and all the four stubs of the tower were intact.

Tower at Loc. No. 122

e. As reported, the PGCIL team which visited the tower failure site thoroughly checked the affected towers for any deficiencies and missing members, missing nut bolts or rusting of tower members were not observed in these towers.

f. As reported by PGCIL, discussion with the local people in the nearby villages revealed the exceptionally high cyclone wind condition prevailed at the time of tower collapse in the area. Lot of big and small trees in belt of about 100 meter width in the vicinity of transmission lines were broken/ uprooted due to the severity of the cyclone. As per newspaper reports, extensive disrupting normal routine life and damaged to property occurred in charpara village during the cyclone. Numerous cement/ steel poles of 11 KV line, signage boards were also damaged, disrupting local electricity supply.

➢ **Probable Cause of Failure**

The committee noted that this is the first tower failure incident of this line since commissioning. It was observed that towers at Loc. No. 120 & Loc. No. 122 failed and subsequently the tower at Loc. No. 121 damaged due to pulling force of the conductors of adjacent towers.

The Committee noticed that transmission line was erected using 765 kV S/C Delta configuration designed for wind zone-2. The high wind velocity might have induced the failure of towers. The Committee in its previous meeting had recommended that the rate of failure of suspension towers (with delta configuration) of 765kV S/C line traversing through 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, exercise for review of design, as has been done for 765 kV Gaya-Fatehpur S/C transmission line (Wind Zone-4) with Delta configuration towers, has to be taken up by PGCIL for different wind zones for suspension towers (with delta configuration) of 765kV S/C line. In case further failures are observed in the line, PGCIL need to take up the exercise for review of design.

3. 220 kV D/C Auraiya-Sikandara Transmission Line failed on 06.05.2018 [Location no. 266(DA+0), 267(DA+0),268 (DA+0), 269(DA+0), 270(DA+0), 271(DA+3) & to 272(DA+0)]

➢ **Brief Background**

220 kV D/C Auraiya – Sikandra (Agra) transmission line was constructed by M/S Dodsel and was commissioned on 19-12-1990. The towers of this line were designed as per IS: 802(1977) considering medium wind zone in Vertical Configuration with ACSR Zebra Conductor.

➢ **Observations:**

a. **Tower Spotting Details:** The details of tower spotting in the relevant sections are as follows:

○

Sl. No.	Loc. No.	Type of Tower	Forward Span(m)
1	265	DB+0	340
2	**266**	**DA+0**	**345**
3	**267**	**DA+0**	**340**
4	**268**	**DA+0**	**330**
5	**269**	**DA+0**	**330**
6	**270**	**DA+0**	**275**
7	**271**	**DA+3**	**325**
8	**272**	**DA+0**	**340**
9	273	DB+0	

b. **The towers at Loc. No. 266 (DA+0), 267 (DA+0) & 268 (DA+0)** were located in cultivated field with very few trees in the vicinity. It was observed that top cross-arm of these towers got damaged. However, all the four stubs of the tower were found intact. From the failure pattern, it appeared that these towers were damaged due to pulling force developed due to failure of adjacent tower at Loc. No. 270. As reported by PGCIL, no members were found missing at these towers.

Tower at Loc. No. 266

Tower at Loc. No. 267

Tower at Loc. No. 268

c. **Tower at location no. 269 (DA+0)** was located in cultivated field with some trees in the vicinity. The top cross arm of the tower was found damaged. As reported by PGCIL, from the failure pattern, it appeared that the tower had damaged due to pulling force from adjacent tower at Loc. No. 270 and there were no missing members at the tower except some broken bolts in the field which might be sheared during damage of the tower. It was observed that

that the conductor of the top cross arm swirled after breakage and was resting on the Earthwire.

Tower at Loc. No. 269

d. **Tower at location no. 270 (DA+0), 271 (DA+3) and 272 (DA+0)** were located in cultivated field with some trees in the vicinity. All the three towers had collapsed from the first panel in the transverse direction of the line. All the stubs of these towers were damaged. It was reported by PGCIL that there were no missing members at the towers except some broken bolts on the field which may be shared during collapse of towers.

Tower at Loc. No. 270

Tower at Loc. No. 271

Tower at Loc. No. 272

e. PGCIL informed that local people living near the location of failed tower informed that heavy wind prevailed during cyclone which caused heavy devastation in the area. Many trees were broken/ Uprooted in the vicinity and Poles of 11 kV lines and houses were also damaged

f. As reported by PGCIL, localized storm in a belt of about 50-meter width prevailed in the vicinity of transmission line with wind blowing in the transverse direction of line had initiated the failure at Location No. 270(DA+0), 271(DA+3) & 272(DA+0) and 04 nos. of towers were subsequently damaged due to pulling force of the conductors.

- **Probable Cause of Failure**

The committee noted that this transmission line is designed as per IS 802 (1977) and is around 29 years old. The committee observed that the high wind velocity might have prevailed in the vicinity of transmission line leading to failure of tower at location no. 270(DA+0), 271(DA+3) & 272(DA+0). However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Also, in such cases of repeated failures, the suspension type towers may be strengthened by providing hip bracing upto bottom cross arm level as suggested in the previous standing committee meetings for the transmission lines designed as per old IS 802 (1977).

4. 400 kV D/C Maithon-Maithon Transmission Line failed on 10.05.2018 [Location nos. 63(DD+25), 64(DD+25) &65(DD+25)]

➢ **Brief Background**

400 kV D/C Maithon-Maithon transmission line was constructed by M/s KEC and was commissioned in October, 2010. The total length of the line is 31.5 km. The towers of this line were designed for wind zone 4 (wind speed of 47 m/s) as per IS: 802:1995. The suspension towers were designed with suspension ('I') insulator string in Vertical configuration with twin ACSR Moose Conductor.

➢ **Observations**

a. The details of tower spotting in the affected sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)	Angle of Dev.
1	62	DD+18	400	40° 00' 00" LT
2	**63**	**DD+25**	**540**	**00° 00' 00''**
3	**64**	**DD+25**	**590**	**00° 00' 00''**
4	**65**	**DD+25**	**590**	**00° 00' 00''**
5	66	DD+9	400	34° 24' 00" RT

b. All the three failed towers were of DD type with +25 m body extension. These towers were provided with Pile type foundations and were not having any angle of deviation. These towers were located in isolated field near to the bank of river Barakar.

c. **Tower at location no. 63 (DD+25)** was damaged from bottom cross arm level and top portion of tower has fallen to the ground in transverse direction. Bottom portion of tower was

not damaged and was in erect position. All the stubs were not damaged. It was reported that there were no missing members at the tower.

Tower at Loc. No. 63

d. **Tower at location no. 64 (DD+25)** had completely fallen to the ground in transverse direction. All 4 stubs of the tower were damaged. However, pile foundations of all the legs were intact. It was reported that there were no missing members at the tower.

Tower at Loc. No. 64

e. **Tower at location no. 65 (DD+25)** had completely fallen to the ground in transverse direction. All 4 stubs of the tower were damaged. However, pile foundation of all the legs were intact. It was reported that there were no missing members at the tower.

Probable Cause of Tower at Loc. No. 64

f. As reported by PGCIL, a high intensity wind followed by rain fall was experienced in the area which damaged the thatched huts situated nearby to the tower locations. The same was confirmed by the local villagers.

- **Probable Cause of Failure:**

Committee noticed that the three failed towers were of DD type with +25 m body extension River crossing Towers at Barakar River. During the meeting, in response to the query regarding stub setting, PGCIL confirmed the correctness of stub and informed that the restoration/rectification of towers were done with the same stub setting template. Committee noted that these were high towers with +25 m body extension and pile type foundation which might have resulted in large wind load on phase conductors and earthwire as well as on tower itself under the high wind conditions.

The committee noticed that the high wind velocity might have induced the failure of towers but it may not be the sole reason for the occurrence of the incident. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. PGCIL need to review the design of DD type tower and the stub setting template used in the transmission line. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future.

5. 400 KV D/C Farakka-Durgapur II transmission line failed on 10.05.2018 [Location. No. 377 (A+0) & 378 (A+0)]

➢ **Brief Background**

400 kV D/C Farakka-Durgapur II Transmission line of PGCIL was constructed by M/s EMC and was commissioned in 1st August, 1992. The towers were designed as per IS: 802:1977 for medium wind zone. The single circuit horizontal towers were having "I-V-I" configuration with Twin Moose Conductor.

Observations:

a. The details of tower spotting in the affected sections is as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)	Angle of Dev.
1	376	C+0	360	15^0-55'-00"LT
2	**377**	**A+0**	**360**	**--**
3	**378**	**A+0**	**380**	**--**
4	379	A+0	350	--

b. **Tower at location No. 377 (A+0)** was located in cultivated field with very few trees in the vicinity. Tower had collapsed from 1st panel in transverse direction to the ground, although stubs were not damaged. No members were reported missing at the tower.

Tower at Loc. No. 377 (A+0)

c. **Tower at location no. 378 (A+0)** was located in cultivated field with very few trees in the vicinity. The failure pattern of location no. 378 was similar to that of location no. 377 and the tower collapsed from 1st panel. All the four stubs were found to be intact. No members were reported missing at the tower.

Tower at Loc. No. 378 (A+0)

➢ **Probable Cause of Failure**

The committee noted that this transmission line is designed as per IS 802 (1977) and is around 27 years old. The committee observed that the high wind velocity might have prevailed in the vicinity of transmission line leading to failure of tower at location no. 377(A+0) & 378(A+0). However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Also, in such cases of repeated failures, the suspension type towers may be strengthened by providing hip bracing upto bottom cross arm level as suggested in the previous standing committee meetings for the transmission lines designed as per old IS 802 (1977).

6. 765kV S/C Gaya-Varanasi-I Transmission Line failed on 13.05.2018 [Location Nos.368 (A+3)]

➢ **Brief Background**

765 kV S/C Gaya-Varanasi-I Transmission line was designed by PGCIL and executed by M/s KPTL and was commissioned on 31st March, 2012. The length of line is 263 Km. The Delta configuration suspension towers were designed as per IS: 802:1995 for wind zone-4 with Quad ACSR Bersimis Conductor with porcelain insulators. In addition to existing codal provisions the suspension towers have been designed considering narrow front wind condition and with 75% wind in security condition. It was informed by PGCIL officials that this line was earlier known as Gaya- Fatehpur transmission line and after the LILO to the Varanasi substation, it was renamed as Gaya-Varanasi-I transmission line.
The Gaya- Varanasi-I (earlier Gaya-Fatehpur) transmission line had earlier instances of failure, the details of which are as under:

Date of tower collapse	Section affected	No. of Towers affected
11/ 12th April' 2012	314 (A+0)	1
31st May' 2014	305(A+3), 306(A+0), 311(A+0), 315(A+3), 320(A+0), 321(A+0), 322(A+0), 323(A+0), 324(A+0), 325(A+0), 326(A+0), 327(A+0), 328(A+0), 329(A+0), 330(A+0)	15
14th May' 2015	283(A+3) , 284(A+0)	2
12th June' 2015	334 (A+0)	1
8th March 2016	715 (A+3)	1
17th May 2017	65 (A+3), 66 (A+0) ,67 (A+0), 68 (A+0) & 69 (C+0)	5

Observations

a. The tower at Location no. 368 (A+3) was failed from panel above the waist level and towards the left side when looked from towards Varanasi substation.
b. The details of tower spotting in the affected sections is as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span	Angle of Deviation
1	367	D+3	400	42° 10' 36" LT

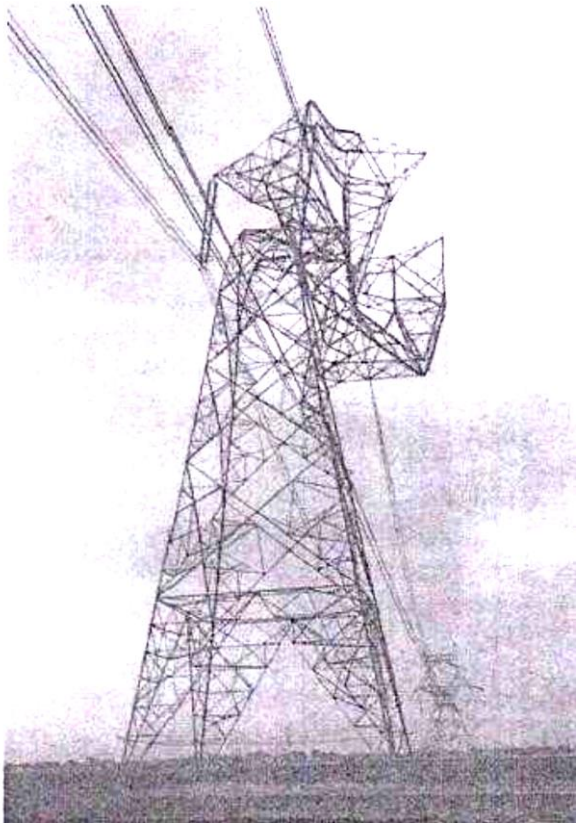
2	**368**	**A+3**	**400**	
3	369	A+0	400	
4	370	A+3	400	
5	371	A+3	400	
6	372	A+0	385	
7	373	C+0	340	21° 10’ 31” RT

c. The delta portion of the tower members got buckled and was resting on lower tower body. All the four Stubs of the tower were found intact. It was reported that no tower members, parts or nut-bolts were found missing in the visible section of the failed tower.

d. Tower at location no. 368 (A+3) failed from panel above waist level in similar failure pattern of delta towers as experienced in past. Previous failures of the 765 kV S/C Delta configuration towers had been investigated by Standing Committee and the Committee had suggested strengthening of these towers. It was informed by PGCIL that in this case the failed Tower at location no. 368 (A+3) was already strengthened.

e. It was reported by PGCIL that the site visiting team also checked the nearby (A+0) type tower at Loc. No. 369. The tower was found to be completely strengthened. No missing bolts/ members were observed.

f. It was reported that some trees were found uprooted and some LT poles were also found tilted/fallen in nearby area of the failed tower location.



Location no. 368 (A+3)

➢ **Probable Cause of Failure**

The Committee noticed that this transmission line has faced multiple failure incidents in the past. The failure of these 765 kV Gaya-Varanasi (earlier Gaya-Fatehpur) S/C transmission line (Wind Zone-4) with Delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were suggested. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.

Committee noted that the failed tower was already strengthened by PGCIL. When enquired by the Committee, PGCIL informed that so far no failure in any of the strengthened tower, in which replacement of existing tower member is done with new member as suggested by Standing Committee, has been observed. Committee directed that failed tower shall be replaced with already strengthened tower and PGCIL shall ensure that the strengthening mechanism adopted is in accordance with the method suggested by Standing Committee in previous meetings (i.e. by replacement of existing member with new member).

7. 765 kV S/C Fatehpur- Agra-I Transmission Line failed on 13.05.2018 [Location No.: 568 (A+0)]

➢ **Brief Background**

765 kV S/C Agra-Fatehpur-I Transmission line was designed by PGCIL and was constructed by M/S EMC and was commissioned on 01.06.2012. The suspension towers of this line were designed for basic wind speed of 47 m/sec corresponding to Wind Zone-4 and reliability level 2 as per IS 802-1995. In addition to existing codal provisions the suspension towers have also been designed considering narrow front wind condition and with 75% wind in security condition. The towers were designed in Delta configuration with Quad ACSR Bersimis Conductor. The suspension towers of this line were designed with Double "I-V-I" Polymer insulator string.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)
1	567	B+0	370
2	**568**	**A+0**	**374**
3	569	A+0	375

b. **The tower at location No. 568 (A+0)** collapsed from the waist level. The delta portion of the tower members got buckled and was resting on lower tower body. All the four Stubs of the tower were found intact. It was reported that no tower members, parts or nut-bolts were found missing in the visible section of the failed tower.

c. As reported by PGCIL, a high intensity localized cyclone in a belt of 50 meter width prevailed in the vicinity of transmission line which was confirmed by the local people from nearby villages and the local newspaper.

d. It was informed by PGCIL that Material tests were conducted on samples selected from site at CPRI, Bangalore. Results were found to be generally within the permissible limits as per IS.

e. It was informed by PGCIL that as per the advice of standing committee for strengthening of 765 kV Wind Zone-IV Delta configuration suspension (A type) towers, strengthening of towers of this line was in progress. However, strengthening of failed tower was pending.

Tower at Loc. No 568 (A+0)

- **<u>Probable Cause of Failure</u>**

The Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration. The failure of these 765 kV delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were suggested. The failed tower had not been strengthened. The pattern of failure of transmission towers from the waist level, i.e. from the K frame

section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.

8. 765 kV S/C Jhatikara-Bhiwani Transmission Line failed on 16.05.2018 [Location No.17 (A+0)]

➢ **Brief Background**

765kV S/C Jhatikara-Bhiwani transmission line was constructed by M/S.EMCO Ltd. and was commissioned on 01.10.2012. The towers of this line were designed for Wind Zone-4 (47 m/sec) and reliability level 2 as per IS 802-1995. In addition to existing codal provisions the suspension towers have also been designed considering narrow front wind condition and with 75% wind in security condition. The towers were designed with Quad ACSR Bersimis Conductor. The suspension towers of this line were designed with Double "I-V-I" Polymer insulator string in Delta configuration.

Observations:

a. The details of tower spotting in the affected sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)
1.	12	D+0	
2	13	A+0	385
3	14	A+0	385
4	15	A+0	385
5	16	A+0	385
6	**17**	**A+0**	**390**
7	18	A+0	360
8	19	A+0	386
9	20	A+0	388
10	21	C+0	386

b. **Tower at Loc. No. 17 (A+0)** was situated/ located in cultivated wheat field with very few trees in the vicinity. The tower had collapsed from the waist level. The delta portion of the tower members got buckled and was resting on lower tower body. All the four Stubs of the tower were found intact. It was reported that there were no missing members found however, few blank / unplugged holes were observed.

c. It was reported by PGCIL that during the site visit to the tower failure location back to back stub and diagonal dimensions along with level difference between the different legs of towers checked and no appreciable difference were observed when compared with the values indicated in the structural drawings.

d. As reported by PGCIL, a high intensity localized cyclone in a belt of 50 meter width prevailed in the vicinity of transmission line which was confirmed by the local people from nearby villages and the local newspaper.

e. It was informed by PGCIL that Material tests were conducted on samples selected from site at CPRI, Bangalore. Results were found to be generally within the permissible limits as per IS.

f. It was informed by PGCIL that as per the advice of standing committee for strengthening of 765 kV Wind Zone-IV Delta configuration suspension (A type) towers, strengthening of towers of this line was in progress. However, strengthening of failed tower was pending.

Tower at Loc. No. 17 (A+0)

- **<u>Probable Cause of Failure</u>**

The Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration. The failure of these 765 kV delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were suggested. The failed tower had not been strengthened. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.

9. 765kV S/C Gaya-Varanasi-I Transmission Line failed on 28.05.2018 [Location Nos. 184 (A+0), 185 (A+0) & 186 (A+0)]

➢ **Brief Background**

765 kV S/C Gaya-Varanasi-I Transmission line was designed by PGCIL and executed by M/s KPTL and was commissioned on 31st March, 2012. The length of line is 263 Km The Delta configuration suspension towers were designed as per IS: 802:1995 for wind zone-4 with Quad ACSR Bersimis Conductor with porcelain insulators. In addition to existing codal provisions the suspension towers have also been designed considering narrow front wind condition and with 75% wind in security condition. The suspension towers of this line were designed with Double "I-V-I" Porcelain insulator string in Delta configuration.
It was informed by PGCIL officials that this line was earlier known as Gaya- Fatehpur transmission line and after the LILO to the Varanasi substation, it was renamed as Gaya-Varanasi-I transmission line. The Gaya- Varanasi-I (earlier Gaya-Fatehpur) transmission line had earlier instances of failure, the details of which are as under:

Date of tower collapse	Section affected	No. of Towers affected
11/ 12th April' 2012	314 (A+0)	1
31st May' 2014	305(A+3), 306(A+0), 311(A+0), 315(A+3), 320(A+0), 321(A+0), 322(A+0), 323(A+0), 324(A+0), 325(A+0), 326(A+0), 327(A+0), 328(A+0), 329(A+0), 330(A+0)	15
14th May' 2015	283(A+3) , 284(A+0)	2
12th June' 2015	334 (A+0)	1
8th March 2016	715 (A+3)	1
17th May 2017	65 (A+3), 66 (A+0) ,67 (A+0), 68 (A+0) & 69 (C+0)	5
13th May, 2018	368 (A+3)	1

Observations

a. The transmission line was under restoration due to failure of tower at location no. 368 (A+3) on 13th May 2018, when three suspension towers at Location No. 184 (A+0), 185 (A+0) &186 (A+0) collapsed/ damaged on 28.05.2018.

The details of tower spotting in the affected sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span	Angle of Deviation
1	183	D+0	378	36° 19'02''
2	**184**	**A+0**	**378**	**--**
3	**185**	**A+0**	**378**	**--**
4	**186**	**A+0**	**378**	**--**
5	187	C+0	379	3° 17'49''

b. **Tower at Loc. No. 185 (A+0)** was situated/located in cultivated fields of village- Kajhwan, Block- Obera, District-. Aurangabad, Bihar. Tower had collapsed from second panel level and all the four stubs of the tower were intact.

Tower at Loc. No. 185

c. **Tower at Loc. No. 184 (A+0) & 186 (A+0)** were collapsed from below the waist level portion. All the four stubs of the tower were intact.

d. As informed by PGCIL, initially the tower at location no. 185 collapsed and subsequently the towers at Loc. No. 184 & 186 collapsed as secondary failure. This was as per the information gathered from the villagers.

e. It was reported that the affected towers were checked thoroughly for any deficiencies and no missing members/rusting of tower members were found in these towers.

f. As reported by PGCIL, a high intensity localized cyclone in a belt of 50 meter width prevailed in the vicinity of transmission line which was confirmed by the local people from nearby villages and the local newspaper.

g. During site visit, it was observed by PGCIL officials that a lot of devastation caused by the cyclonic wind storm near kajhwan village and few trees in a belt of about 110-meter width were broken/ uprooted due to the severity of the cyclone. Numerous concrete poles of 11 kV line were also damaged.The same was confirmed by local people and was reported in the local newspapers.

h. It was informed by PGCIL that Material tests were conducted on samples selected from site at CPRI, Bangalore. Results were found to be generally within the permissible limits as per IS.

Tower at Loc. No. 184

Tower at Loc. No. 186

➢ **Probable Cause of Failure**

The Committee noticed that this transmission line has faced multiple failure incidents in the past. The failure of these 765 kV Gaya-Varanasi (earlier Gaya-Fatehpur) S/C transmission line (Wind Zone-4) with Delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out by CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were suggested. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.
Committee noted that the failure of transmission towers of this transmission line is observed quite frequently. The Committee directed that failed tower shall be replaced with already strengthened tower and PGCIL shall expedite the process of strengthening of these towers as per method suggested by Standing Committee in previous meetings (i.e. by replacement of existing member with new member). Committee suggested that in case of

towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear analysis of tower should be carried out.

10. 765 kV S/C Satna – Bina Transmission line failed on 30.05.2018 [(Location no. 63 (A+0)]

➢ **Brief Background**

765 kV S/C Satna-Bina transmission line was constructed by M/s. KEC and was commissioned on 30-06-2012. The towers of this line were designed for Wind Zone-4 (basic wind speed of 47 m/sec) and reliability level 2 as per IS 802-1995, and also taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition. The towers were designed in Delta configuration with Quad ACSR Bersimis Conductor. The suspension towers of this line were designed with Double "I-V-I" insulator string in Delta configuration.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span(m)	Angle of Deviation
1	59	C+0	390	$26^0 08' 56''$ LT
2	60	A+0	390	-
3	61	A+0	390	-
4	62	A+0	390	-
5	**63**	**A+0**	**390**	-
6	64	A+3	390	-
7	65	A+0	390	-
8	66	A+0	380	$25^0 16' 08''$ LT

a. **Tower at Loc. no. 63 (A+0) (a)** was located in cultivated wheat field with very few trees in the vicinity. Hill of Maihar, Satna(MP) is in the backdrop of location**.** The tower collapsed from the first panel level and all the four stubs of the tower were bent. It was reported that no tower members, parts or nut-bolts were found missing in the visible section of the failed tower.

b. It was informed by PGCIL that as per the advice of standing committee for strengthening of 765 kV Wind Zone-IV Delta configuration suspension (A type) towers, strengthening of towers of this line was in progress. However, strengthening of failed tower was pending.

c. It was reported by PGCIL that during the site visit to the tower failure location back to back stub and diagonal dimensions along with level difference between the different legs of towers checked and no appreciable difference were observed when compared with the values indicated in the structural drawings.

d. As reported by PGCIL, the site visiting team discussed with the local people in the nearby villages about the wind and it revealed that exceptionally high storm prevailed at the time of tower collapse in the area and such high intensity localized storm is very uncommon in the locality. The effect of storm gets intensified because of presence of hill in the backdrop of location

e. It was informed by PGCIL that Material tests were conducted on samples selected from site at independent lab. Results were found to be generally within the permissible limits as per IS.

Tower at Loc. No. 63(A+0)

➢ **<u>Probable Cause of Failure</u>**

The Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration. The failure of these 765 kV delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were suggested. The failed tower had not been strengthened. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.

The Committee directed that failed tower shall be replaced with already strengthened tower and PGCIL shall expedite the process of strengthening of these towers as per method suggested by Standing Committee in previous meetings (i.e. by replacement of existing member with new member). Committee suggested that in case of towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear analysis of tower should be carried out.

11. 400 kV D/C Sasaram – Daltonganj Transmission Line failed on 31.05.2018 [Tower at Location No. 36 (DA+9), 37 (DA+0) &38 (DA+6)]

➢ **Brief Background**

400 kV D/C Sasaram–Daltonganj transmission line was constructed by M/s Tata Ltd. The circuit –II and Cicuit –I of the line were commissioned on 31.01.2018 and 01.02.2018 respectively. The suspension towers of this line were designed for Wind Zone-4 (basic wind speed of 47 m/sec) and reliability level 2 as per IS 802-1995 also taking into consideration narrow front wind on tower body and 75% wind in broken wire condition. The towers were designed in Vertical configuration with Twin ACSR Moose Conductor.

➢ **Observations**

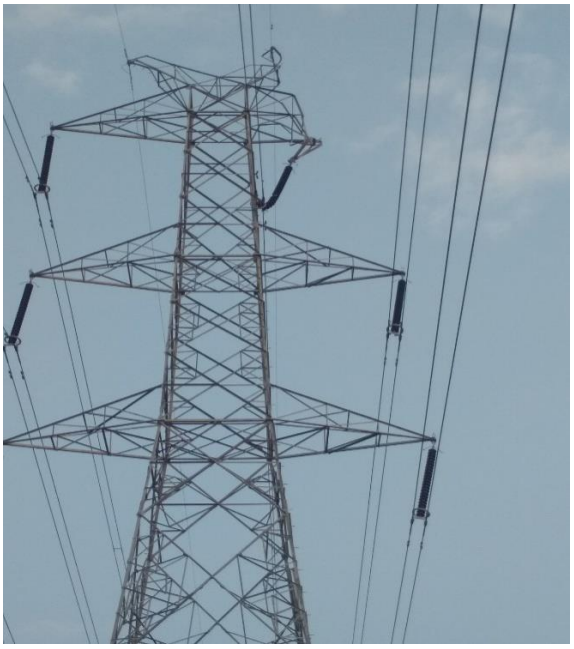
a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)	Angle of Dev.
1	35	DC+0	400	28° 56’ 04” RT
2	**36**	**DA+9**	**400**	**--**
3	**37**	**DA+0**	**400**	**--**
4	**38**	**DA+6**	**400**	**--**
5	39	DA+0	394	--
6	40	DA+3	396	--
7	41	DC+0	387	27° 15’ 37” RT

b. **Tower at Location No. 36 (DA+9)** was situated in the agricultural fields in Itahi Kahuaa village of Kudra tehsil in Kaimur district. Tower had collapsed from second panel level. The top portion above bottom cross arm level was bent and was resting on bottom tower structure due to support of the conductors. All the four stubs of the tower were intact.

Tower at Loc. No. 36

c. **Towers at Location No. 37 (DA+0) & 38 (DA+6)** were in erect position. Bending of few members at top cross arm level and in earth wire peak members were observed at these towers due to pulling force of the conductors.



Tower at Loc. No. 37

Tower at Loc. No. 38

d. It was reported that the above affected towers were checked thoroughly for any deficiencies and few redundant members and bolts were found missing/open.

e. As reported by PGCIL, a high intensity localized cyclone in a belt of 100-200 meter width prevailed in the vicinity of transmission line which was confirmed by the local people from nearby villages and the local newspaper. Several towers of 132 KV lines of State electricity boards were reported to be collapsed in the storm of 31.05.18

f. It was informed by PGCIL that material tests were conducted on samples selected from site at independent lab. Results were found to be generally within the permissible limits as per IS.

➢ **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of tower at location no. 36(DA+9) which led to secondary partial damages to nearby suspension type towers at location no. 37 (DA+0) and location no. 38 (DA+6) due to pulling force of the conductors. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Committee also noted that due to climatic change, incidents of high winds are increasing. Transmission companies need to take proactive measures such as increased line patrolling, immediate replacement of missing members/bolts etc. and intensive care should be taken during erection and installation of towers (Slope correctness, filling unplugged holes, tightening of Bolts, Tack welding, straightness of tower members etc.).

12.400 kV D/C Hisar-Kaithal (LILO) Transmission Line failed on 09.06.2018 [Tower at Location Nos. 54(DB+0), 55(DA+0), 56(DA+0), 57(DA+0), 58(DA+0), 59(DA+0), 60(DA+3), 61(DA+0), 62(DA+0), 63(DA+0).]

➢ **Brief Background**

400 kV D/C Hisar-Kaithal transmission line was constructed by M/s KPTL and was commissioned in 2005. The suspension towers of this line were designed for Wind Zone-4 (Basic wind speed of 47 m/sec) and reliability level 1 as per IS 802-1995. Strengthening of suspension towers was carried out considering narrow front wind on tower body. The towers were designed in Vertical configuration with triple SNOWBIRD Conductor with Suspension 'V type' Insulator string. The towers were having double peak configuration with two earthwires running parallel.

➢ **Observations**

a. The failed towers of the transmission line were located in cultivated fields of Dhabi Gujran/ Galoli villages of Patran/ Khanauri towns near Patran-Narwana road. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)	Angle of Dev.
1.	**54**	**DB+0**	**394**	10°30' LT
2.	**55**	**DA+0**	**412**	---
3.	**56**	**DA+0**	**405**	---
4.	**57**	**DA+0**	**399**	---
5.	**58**	**DA+0**	**397**	---
6.	**59**	**DA+0**	**416**	---
7.	**60**	**DA+3**	**417**	---
8.	**61**	**DA+0**	**393**	---
9.	**62**	**DA+0**	**338**	---
10.	**63**	**DA+0**	**397**	---
11.	64	DA+0	341	---
12.	65	DD+0	202	31°00' RT

b. **Tower at Location No. 54 (DB+0)** was in erect position. One of the earth wire peak was damaged. All the stubs and chimney were intact.

Tower at Loc. No. 54

c. **Tower at Location No. 55 (DA+0)** was located in agriculture field. The tower was completely collapsed from the stub level in transverse direction. All stubs were bent and damaged.

Tower at Loc. No. 55

d. **Tower at Location No. 56 (DA+0)** had collapsed from stub level in transverse direction. The portion of cage above bottom cross arm got detached from the tower body and fell apart. Three stubs of tower were bent/ damaged.

Tower at Loc. No. 56

e. **Tower at Location No. 57 (DA+0)** had collapsed from stub level in transverse direction and the portion of cage above bottom cross arm got detached and fell a few meters apart from the original standstill position of the tower. All the four stubs were bent.

Tower at Loc. No. 57

f. **Tower at Location No. 58 (DA+0)** had collapsed in transverse/ longitudinal direction and two stubs were bent/ damaged. Minor damages were observed in the chimneys.

Tower at Loc. No.58

g. **Tower at Location No. 59 (DA+0)** was located in Paddy field. The tower had collapsed in transverse/ longitudinal direction and two stubs were bent/ damaged

Tower at location no 59

h. Tower at Location No. 60 (DA+3) failed from above +3m body level in transverse direction and all four stubs were found intact.

Tower at Loc. No. 60

i. **Tower at Location No. 61 (DA+0)** failed above second panel level in transverse direction and all stubs were intact.

Tower at Loc. No. 61

j. **Tower at Location No. 62 (DA+0)** failed above first panel level in transverse direction and all stubs were found intact.

Tower at Loc. No. 62

k. **Tower at Location No. 63 (DA+0)** was failed above second panel level in transverse direction and all stubs were found intact.

Tower at Loc. No. 63

l. As reported by PGCIL, all of the 10 failed towers were inspected for missing members and bolts. No missing members and bolts were observed.

m. It was informed by PGCIL that Material tests were conducted on samples selected from site at CPRI, Bangalore. Results were found to be generally within the permissible limits as per IS.

n. Few poles of Distribution line located nearby to 400kV D/C Hisar-Kaithal Transmission Line was also found completely damaged. However, no damage was observed in 400kV D/C Kaithal-Patiala (LILO) Transmission Line which was also nearby to 400kV D/C Hisar-Kaithal (LILO) Transmission Line.

➢ **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of tower at location no. 56 (DA+0) and 57 (DA+0) which subsequently led to failure of towers at other 8 locations as a cascade failure. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind

speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Committee also noted that large no. of failure of tower observed in the line is due to cascading effect of failure of suspension type towers.

13. 400 kV D/C Damoh-Birsinghipur Transmission Line failed on 12.06.2018 [Tower at Location No. 218 (DB+0), 219 (DB+6) & 220 (DB+3)]

➢ **Brief Background**

400 kV S/C Damoh - Birsinghipur transmission line was constructed by M/s Kalpataru Power Transmission Ltd. KPTL and was commissioned on 30-06-2012. The towers of this line were designed by PGCIL for Wind Zone-2 (basic wind speed of 39 m/sec) and reliability level 1 as per IS 802-1995. The towers were designed with ACSR twin Moose Conductor. Tension towers of this line were contractor designed towers with Double Tension Porcelain insulator strings for terrain category-2.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span (m)	Angle of Dev.	Total Wt Span-Hot (m)	Total Wt Span-Cold (m)
1	217	DB+3		00°00'00"	327	198
			412			
2	**218**	**DB+0**		**00°00'00"**	**589**	**663**
			357			
3	**219**	**DB+6**		**00°00'00"**	**426**	**426**
			486			
4	**220**	**DB+3**		**00°00'00**	**353**	**320**
			400			
5	221	DA+3		00°00'00"	336	343

b. **Tower at Location No. 218 (DB+0**) was located on top of the hill. It was completely collapsed in the transverse direction and all of the stubs were bent. As per report of team visiting the tower failure site, between tower locations 218 & 219 a valley like shape was formed between the hills which might have increased the intensity of the winds. No missing members and bolts and nuts were observed at the tower except few step bolts and earthing bolts.

Tower at Loc. No. 218

c. **Tower at Location No. 219 (DB+6)** had collapsed from waist level in the transverse direction and two of the stubs were broken. As per report of team visiting the tower failure site, between tower locations 218 & 219 a valley like shape was formed between the hills which might have increased the intensity of the winds. No missing members and bolts and nuts were observed at the tower except few step bolts and earthing bolts, name plate bolts, danger plate bolts, phase sequence bolts.

Tower at Loc. No. 219

d. **Tower at Location No. 220 (DB+3)** was in erect position and was deformed at +3 M extension level and at bottom cross arm level. All stubs of the tower were intact. According to the team visiting to the failure site, the reason of deformation of the tower was pulling force imparted due to collapsing tower at location 219. No missing members and bolts and nuts observed in the tower except few earthing bolts.

Tower at Loc. No. 220

e. It was informed by PGCIL that material tests were conducted on samples selected from site at independent lab. Results were found to be generally within the permissible limits as per IS.

f. As reported by PGCIL, a high intensity localized cyclone in a belt of 50-meter width prevailed in the vicinity of transmission line which was confirmed by the local people from nearby villages and the local newspaper.

➢ **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of tower at location nos. 218 & 219 which led to secondary partial damages to nearby tower at location no. 220 due to pulling force of the conductors. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower

structure design to avert the recurrence of failure of towers in future. Committee also noted that all transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds.

14.400 kV S/C Chamera -2 –Kishenpur Transmission Line failed on 01.09.2018 [Tower at Location No. 238(C+9) & 239(D+6)]

➢ **Brief Background**

400 kV S/C Chamera 2 –Kishenpur transmission line was constructed by M/s Birla GTME limited and was commissioned on 01-10-1997.The towers of this line were supplied by Transpower Engg Ltd., Mumbai. The towers were designed in Horizontal configuration with ACSR Twin Moose Conductor for medium wind zone as per IS 802-1977.

➢ **Observations**

a. The failed towers were located near Bani Village in Basholi District (J&K). The towers were located in hilly terrain. The details of tower spotting in the relevant section are as follows:

Sl. No	Loc No.	Type of Tower	Span (m)	Angle of Dev.	Remarks
			244		
1	237	SB+0		07-50-00LT	Hilly Terrain
			250		
2	**238**	**SC+9**		**19-58-00RT**	**Hilly Terrain**
			612		
3	**239**	**SD+6**		**53-00-00RT**	**Hilly Terrain**
			282		
4	240	SC+0		15-10-00RT	Hilly Terrain

b. **Tower at Location No. 238** collapsed from waist level and was tilted across the line in transverse direction. Two no. of stubs of the tower were damaged.

Tower at Loc. No. 238

c. **Tower at Location No. 239** was partially damaged **as** the Earth wire Peak was damaged due to pulling force of the wires.

Tower at Loc. No. 239

d. It was reported by PGCIL that during the site visit adjacent towers were checked for missing/theft of tower members, bolts& nuts thoroughly but no tower members or bolt were found missing.

e. As reported by PGCIL, the site visiting team discussed with the local people in the nearby villages about the wind and it revealed that a severe localized storm coupled with thunderstorm and rains had occurred in the night of 01.09.2018.

➢ **Probable Cause of Failure**

The committee noted that this transmission line is designed as per IS 802 (1977) and is around 21 years old. The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of tower at location no. 238 (SC+9) and secondary failure of earthwire peak of tower at location no. 239 (SD+6). However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Committee also suggested that all transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds.

15. 400 kV D/C (Quad) Patna-Kishanganj Transmission Line failed on 02.09.2018 [Tower at Location No. 128G/0(DD+25), 129/0(DD+9), 129A/0(DD+0)]

➢ **Brief Background**

400 kV D/C (Quad) Patna-Kishanganj transmission line was constructed by M/s EMC Ltd and was commissioned in February,2016 under the transmission system scheme for transfer of power from generation projects in Sikkim to NR/WR(Part-B). The towers of this line have been designed for Wind Zone-IV as per IS: 802-1995. The length of the line is 346.72 Km. There were nine (9) nos. of pile foundations in Ganga River Crossing stretch in this line. The pile foundation works for the line was executed by M/s Simplex Ltd.

The transmission line had previously failed twice in the year 2016. On 26.07.2016 one tension tower (DD+18) at location no. 51 collapsed completely due to erosion of soil by flash floods in Kankai river and on 01.09.2016 five nos. towers on pile foundations (Location No. 128D/0 (DD+25), 128E/0 (DD+25), 128F/0 (DD+25), 128G/0 (DD+25) & 129/0 (DD+09) collapsed/damaged due to flood in Ganga river, including the present affected location no. 129/0. During 2016 flood, pile foundation at location no.-128G/0 was also damaged and tower was shifted at new location on pile foundation. As reported by PGCIL, in view of continuous bank erosion towards Patna side and imminent threat to location no-129/0 which was at that time approximately 300m away from river bank, a regional committee was constituted in May'18 to review the tower foundation and suggest remedial measures, if any, required for protection of this location. Based on the recommendation of regional committee and as pile foundation for location no-129/0 was designed considering required river parameters, no action was taken for protection of foundation.

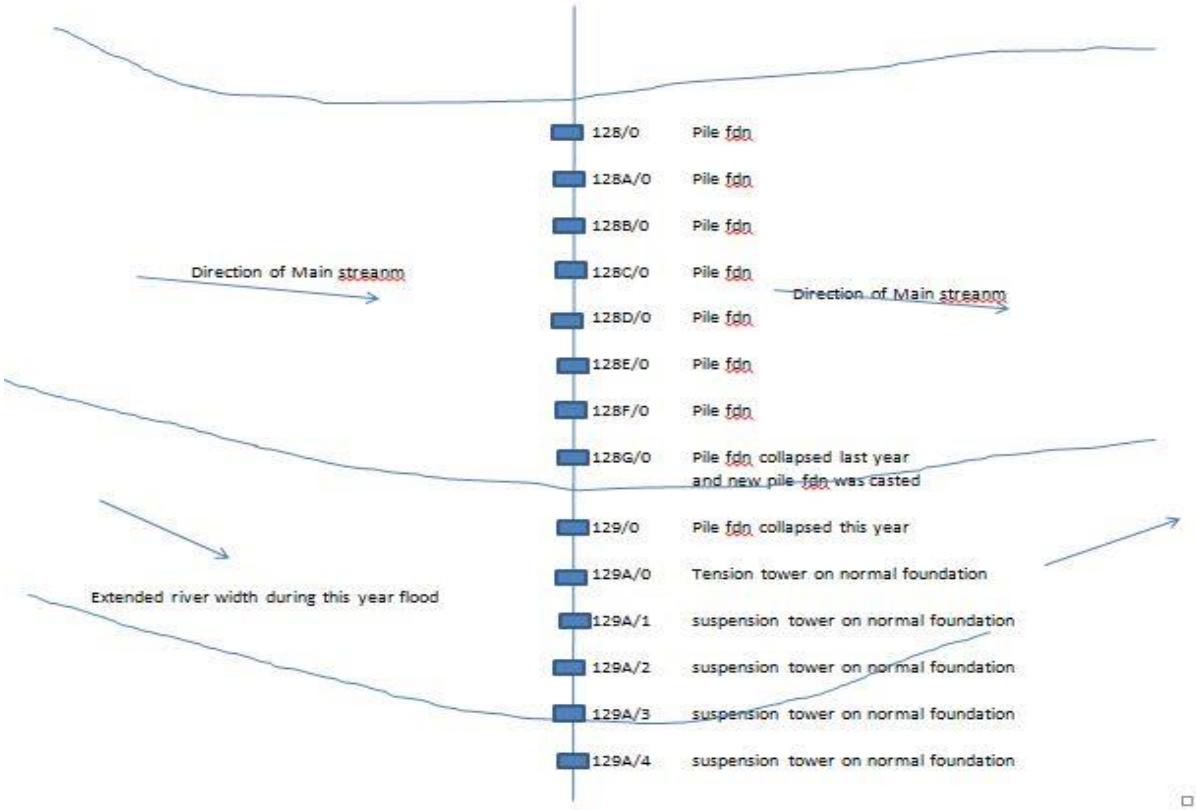
➢ **Observations**

a. The details of tower spotting in the relevant affected portion are as follows:

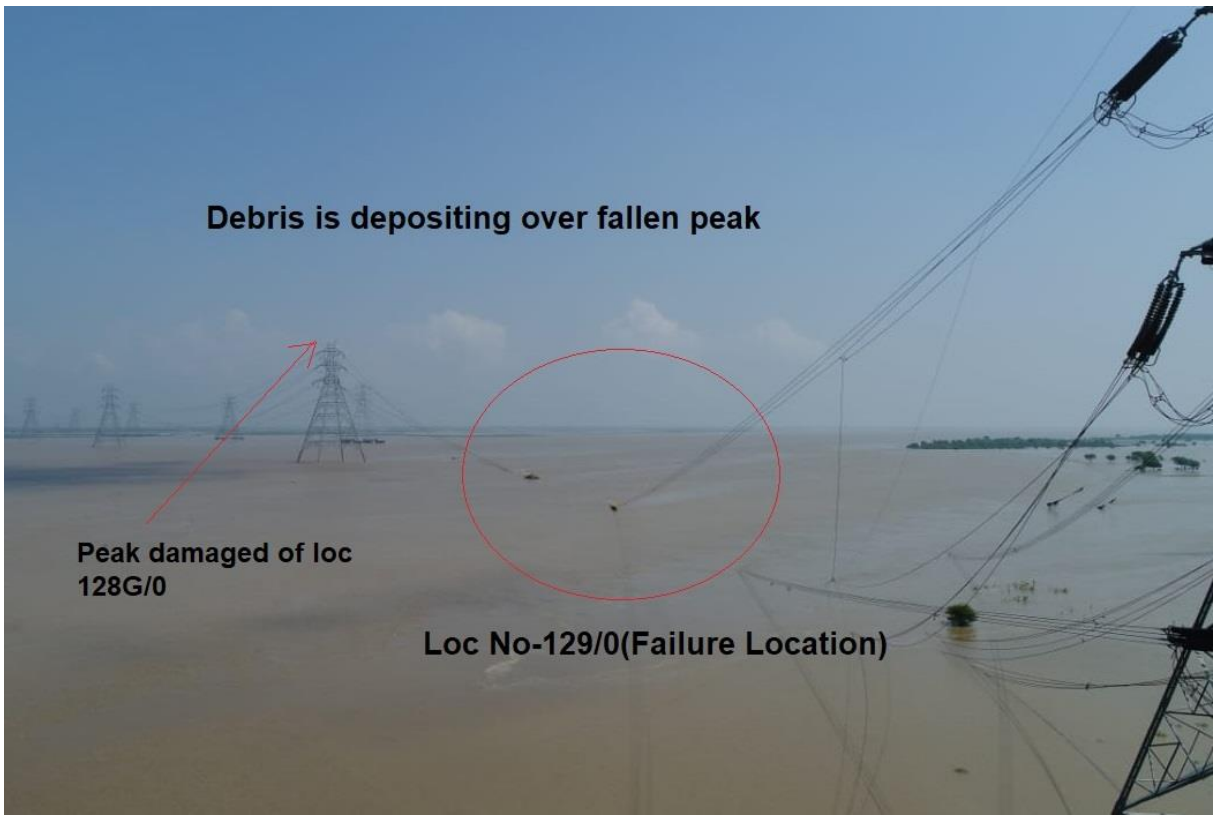
Sl. No.	Loc. No.	Type of Tower	Forward Span (m)	Angle of Dev.	Foundation Type	Remarks
1	128F/0	DD+25	600	0° 0' 0"	Pile type	Old pile Foundation in the main river course
2	**128G/0**	**DD+25**	**270**	**--**	**Pile type**	**New pile Foundation in the main river course**
3	**129/0**	**DD+9**	**398**	17°44'27"RT	Pile type	**Collapsed tower location**
4	**129A/0**	**DD+0**	**395**	**05°06'36"RT**	**Open cast type**	**Loc. is on the island within extended river course. Tower is submerged approx. 1m in water**

5	129A/1	DA+3	395	--	Open cast type	Loc. is on the island within extended river course. Tower is submerged approx. 1m in water
6	129A/2	DA+0	395	--	Open cast type	Loc. is on the island within extended river course
7	129A/3	DA+3	395	--	Open cast type	Loc. is on the island within extended river course
8	129A/4	DA+0	395	--	Open cast type	River is flowing near edge of water
9	129A/5	DA+3	395	--	Open cast type	submerged area
10	129A/6	DA+0	398	--	Open cast type	submerged area
11	130/0	DD+09		44°42'52"LT	Open cast type	submerged area

b. A schematic representation of plan indicating affected location on piles and normal foundation is shown below.



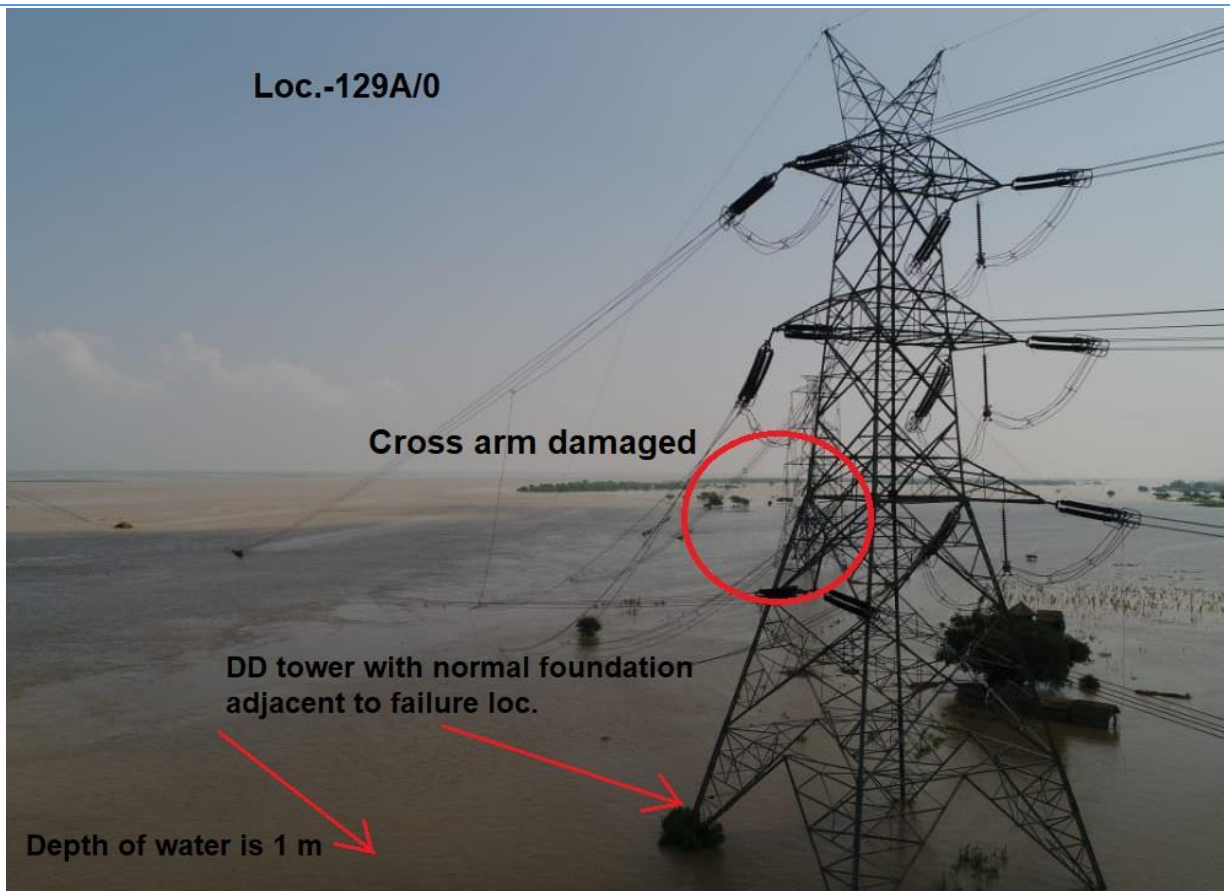
c. **Tower at Location No. 128G/0 (DD+25)** was located in mid-stream on newly constructed pile foundation. The earthwire peak and one side of bottom cross arm was damaged because of pulling of conductor/earthwire due to tower collapse at Loc. No. 129/0.



Tower at Loc. No. 128G/0 & 129/0

d. **Tower at Location No. 129/0 (DD+9)** was erected on pile foundation. It was informed that the location couldn't be reached during committee visit due to heavy current in the river and the observations were made from approx. 300 meter away from location no. 129/0. The tower collapsed completely and was fully submerged under the water. The location was in main course of the high speed river flow. The deposition of debris from flowing water over tower peak were observed.

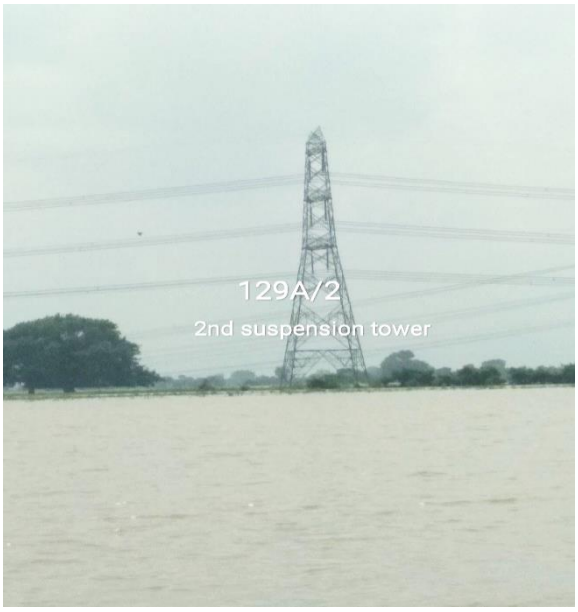
e. **Tower at Location No. 129A/0 (DD+0)** was constructed on normal open cast foundation. One side of bottom cross arm was observed to be damaged due of pull of conductor towards collapsed tower loc. no. 129/0. Presently the location was almost on the edge of an island towards the main river course. Bottom portion of about 1m portion of the tower was under flood water. It was informed that the foundation at this location had also become susceptible to failure due to eminent soil erosion by the main river course.



Tower at Loc. No -129A/0

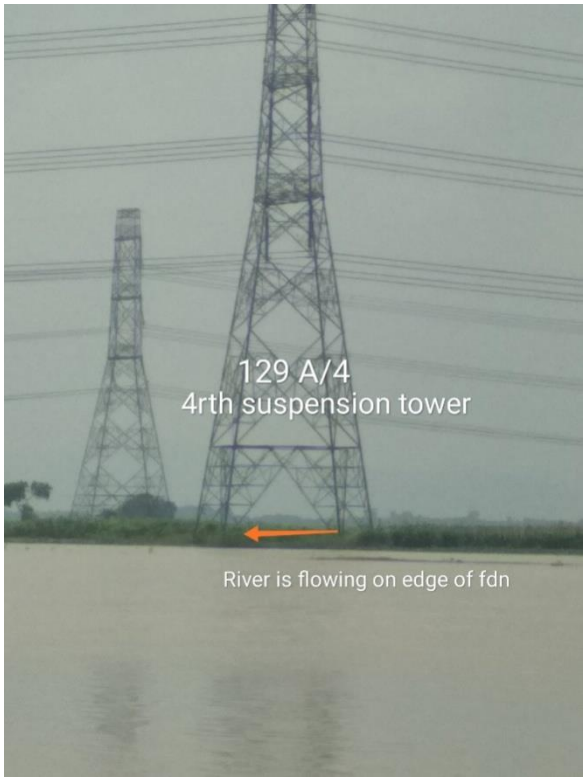
f. **Towers at Location Nos. 129A/1(DA+3), 129A/2(DA+0), 129A/3(DA+3) & 129A/4(DA+0)**: Bottom portion of towers (about 1m) at location no 129A/1(DA+3), 129A/2(DA+0), 129A/3(DA+3) was submerged in flood water. Location no-129A/4 has also come perilously close to river flow. As reported by PGCIL, the river formed flow channels around these locations and it was observed that all the above foundations became vulnerable to failure.

Tower at Loc. No. 129A/1



Tower at Loc. No. 129A/2

Tower at Loc. No. 129A/3

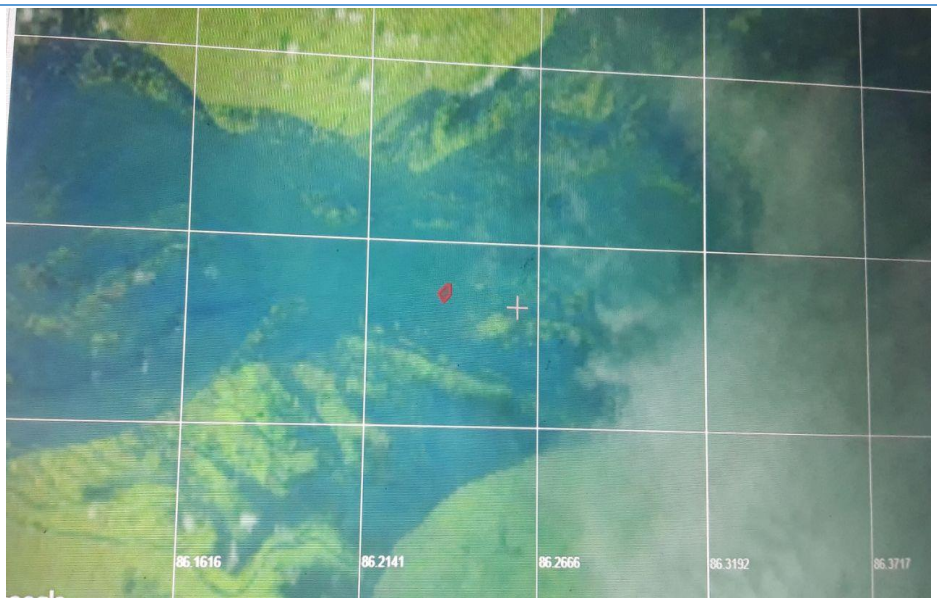


Tower at Loc. No. 129A/4

g. **Tower at Location No. 129A/5 and beyond (Approx. ten numbers)** were reported submerged in standing flood water (from 0.5 m to 1.0 m). There was no flow of river water around these locations and there was no threat from flood to these locations.

h. As reported by PGCIL, 400kV D/C Quad Biharsarif - Purnia Transmission line constructed by M/s Sterlite was running almost parallel to POWERGRID line (at a distance of about 400m). It was informed that two towers, one on pile foundation and other on normal open cast foundation of this line have also collapsed during this flood.

i. PGCIL informed that after discussion with the local people in the nearby villages, it was gathered that every year the river course is changing towards right bank (towards Patna). Analysis of Google Map for the change in river course during last five years at the crossing locations was done PGCIL. From the analysis, it was clear that there is continuous river bank erosion towards Patna side bank and the distance of river course from bank location no. 129/0 (tower no. 568) has reduced from 576m in Feb-2013 to 105m in Dec-2017. Further, satellite map of 10th Sept-2018 shown below also highlights the heavy soil erosion towards the collapsed tower location (marked as red dot).



➢ **Probable Cause of Failure**

Committee noted that the transmission line had had previously failed in the year 2016 in which the same segment of transmission line crossing the river Ganga was affected due to soil erosion by the changing river course. Committee observed that over the years, the course of river Ganga is continuously changing towards right bank (towards Patna). Committee also noted that the failed tower was casted on pile type foundation. Committee observed that course of water in Ganga river was diverted due to heavy flood and heavy soil erosion towards river bank (Patna side) was observed leading to collapse of tower at loc. No. 129/0 (DD+9). Earth wire peak and one side of bottom cross arm of tower at Location No. 128G/0 (DD+25)) & One side of bottom cross arm of tower at Location No. 129A/0 (DD+0) had been damaged due of pull of conductor towards collapsed tower at loc. No. 129/0 (DD+9)

Committee recommended that proper anticipation of change in course of river on the basis of river flow data of previous years shall be done by the transmission utilities. Additional precautions like routing of transmission lines few kilometers away from the river bank/ anticipated future river course, use of pile foundation/additional piles etc. shall be adopted by utilities. Moreover, in case of damage of foundation of towers, the foundation design is required to be examined. Committee also recommended that Pile type foundation may be considered for all towers in flood prone area based on soil investigation report and latest high flood data, to avoid this type of failure. Providing proper Protection (retaining wall, Gabion wall etc., proper revetment & use of geo-synthetic material in foundation, concrete encasing & painting of stub in water logging areas etc. may also be considered, wherever required.

16.± 500 kV HVDC Talcher-Kolar Transmission Line failed on 11.10.2018 [Tower at Location No. 952 (DA+3)]

➢ **Brief Background**

± 500 kV HVDC Talcher-Kolar transmission line was constructed by M/s Kalpataru Power Transmission Ltd (KPTL) and Pole-I & Pole-II of this line were commissioned on 01-12-2002 & 01-03-2003 respectively. The suspension towers of this line were designed for Wind

Zone-5 (basic wind speed of 50 m/sec) and reliability level 1 as per IS 802-1995 taking into consideration narrow front wind on tower body and 75% of wind in broken wire condition. The towers were designed with ACSR Quad Bersimis conductor. Suspension towers of this line were contractor designed towers with V String Porcelain insulator.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	Forward Span	Angle of Dev.
1	950	A+3		Nil
			400	
2	951	A+0		Nil
			400	
3	**952**	**A+3**		**Nil**
			400	
4	953	A+0		Nil
			390	
5	954	A+0		Nil

b. **Tower at Location No. 952 (DA+3)** was situated in plain field with few trees in vicinity surrounded by small hills (about 2.5 km away from tower). The tower had collapsed completely on the ground. No damage was observed to the stubs.

c. It was informed by PGCIL that the cyclone "TITLI" impacted the Orissa coast on 11.10.2018 and caused severe damage to the property which was widely covered in the news reports. PGCIL informed that the damage was also observed to APTRANSO's power system (Transmission lines & sub-station elements) due to the cyclone and discussion with the local people in the nearby villages revealed that exceptionally high speed winds were experienced during cyclone "TITLI" resulting in massive damage to trees, electric poles, and public properties.

d. PGCIL also informed about the press release issued by IMD dated 16.10.2018 regarding the intensity and speed of cyclone "TITLI" which stated that VSCS "TITLI" crossed north Andhra Pradesh & South Odisha coast on 11.10.2018 with the wind speed of 140-150 gusting to 165 kmph.

e. As per PGCIL report, due to the land topography, the intensity of the winds might have been intensified due to vicinity of the hills near to the affected locations. There were no missing members and bolts & nuts at the tower.

f. It was informed by PGCIL that Material tests were conducted on samples selected from site at CPRI, Bangalore. Results were found to be generally within the permissible limits as per IS.

Tower at location no 952 (DA+3)

Damaged APTRANSCO's transmission line

- **Probable Cause of Failure**

Committee noticed that the massive damage to trees, electric poles, and public properties were observed due to the Cyclone "TITLI" and as per the press release issued by IMD high gust wind speed were observed in the region. The Committee observed that the high speed wind prevailing in the area due to high speed cyclone "TITLI" initiated the tower failure at Loc. No. 952. The velocity of the wind might have been intensified due to the topography of the area (i.e. nearby hills).

Committee suggested that Frequency of patrolling of transmission lines should be more for the vulnerable tower locations (Thunder & cyclonic prone area).

17. 400 kV D/C Srikakulam-Garivadi transmission line failed on 11.10.2018 [Location no. 15/1 (DA+3) & 15/2 (DA+0)]

- **Brief Background**

400 kV D/C Srikakulam-Garivadi transmission line was constructed by M/s. TATA Projects LTD and both circuits of the line were commissioned on 04.08.2018. The suspension towers of this line were designed for basic wind speed of 50 m/s corresponding to Wind Zone-5 and reliability level 1 as per IS 802-1995, and also taking into consideration narrow front wind on

tower body and 75% of wind in broken wire condition. The towers were designed with ACSR Quad Moose Conductor. Suspension towers of this line were having Double I suspension string configuration with polymer insulator.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	**Forward Span (m)**	**Angle of Dev.**
1	14/3	DA+0		Nil
			389	
2	AP15/0	DD+0		30°35'08" (LT)
			400	
3	**15/1**	**DA+3**		**Nil**
			385	
4	15/2	DA+0		Nil
			360	
5	15/3	DA+3		Nil

b. **Tower at Location No. 15/1(DA+3)** was located in plain field with few trees in vicinity surrounded by small hills. The tower had collapsed completely on the ground. However, stubs were not damaged. As reported by PGCIL, no missing members and bolts & nuts were observed at the failed tower location.

Tower at location no 15/1

c. **Tower at Location No. 15/2 (DA+0)** was in erect position. One earth peak of the tower was sheared due to sudden force exerted by tower collapse at location no. 15/1. Rest tower was intact and no other damage was observed.

Tower at location no. 15/2

d. It was informed by PGCIL that the cyclone "TITLI" impacted the Orissa coast on 11.10.2018 and caused severe damage to the property which was widely covered in the news reports. PGCIL informed that the damage was also observed to APTRANSO's power system (Transmission lines & sub-station elements) due to the cyclone and discussion with the local people in the nearby villages revealed that exceptionally high speed winds were experienced during cyclone "TITLI" resulting in massive damage to trees, electric poles, and public properties.

e. PGCIL also informed about the press release issued by IMD dated 16.10.2018 regarding the intensity and speed of cyclone "TITLI" which stated that VSCS "TITLI" crossed north Andhra Pradesh & South Odisha coast on 11.10.2018 with the wind speed of 140-150 gusting to 165 kmph.

f. It was informed by PGCIL that Material tests were conducted on samples selected from site at CPRI, Bangalore. Results were found to be generally within the permissible limits as per IS.

➢ **Probable Cause of Failure**

Committee noticed that the massive damage to trees, electric poles, and public properties were observed due to the Cyclone "TITLI" and as per the press release issued by IMD high gust wind speed were observed in the region. The Committee observed that the high speed wind prevailing in the area due to high speed cyclone "TITLI" initiated the tower failure at Loc. No. 15/1(DA+3) and the deformation of peak at tower at Location no. 15/2(DA+0) was secondary failure due to pulling force of the wires.
Committee suggested that Frequency of patrolling of transmission lines should be more for the vulnerable tower locations (Thunder & cyclonic prone area).

DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINE OF M/s STERLITE POWER

18. 765 kV S/C Bhopal-Jabalpur transmission line failed on 18.05.2018 [Location no. 2A/3 (SA+9) & 2A/4 (SA+6)]

➢ **Brief Background**

765 kV S/C Bhopal-Jabalpur transmission line was designed by M/s Sterlite Power and executed by M/s. Simplex Infrastructures Limited and was commissioned on 08.06.2015. The length of the line is 259.7 km. This line was designed for wind zone 2 (basic wind speed of 39 m/s) as per IS 802:1995 with ACSR Quad Bersimis conductor. Suspension towers of this line were having Double I suspension string configuration with polymer insulators. This was the first incident of failure of tower in this transmission line.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	**Forward Span (m)**
1	2A/2	SB+30	
			442
2	**2A/3**	**SA+9**	
			370
3	**2A/4**	**SA+6**	
			443
4	2B/0	SB+3	

b. **Tower at Location No. 2A/3 (SA+9)** was located in plain field with few trees in vicinity surrounded by small hills. As reported by Sterlite Power, The tower failed from the third panel and was bent in transverse direction. Complete collapse of the tower body was arrested due to conductors attached to the tension towers. The stubs were bent however foundations were intact.

c. As reported by Sterlite Power, no missing members and bolts & nuts were observed in the tower before (during patrolling) and after the failure.

Tower at location no 2A/3

d. **Tower at Location No.** 2A/4 was in erect position. Peak of the tower was sheared due to sudden force exerted by tower collapse at location no. 15/1. Rest tower was intact and no other damage was observed.

e. As reported by Sterlite Power, Discussion with the local people in the nearby villages revealed that high wind condition prevailed for some time in the area and tower had collapsed during high wind conditions. The ground profile nearby the tower location intensified the wind speed

➢ **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of tower at location no. 2A/3 which led to secondary partial damages to nearby tower at location no. 2A/4 due to pulling force of the wires. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, M/s. Sterlite Power need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future.

19. 400kV D/C Purnea- Biharsharif transmission line failed on 10.08.2018 [Location no. 47/0 (DD+18)]

➢ **Brief Background**

400 kV D/C Purnea- Biharsharif transmission line was designed and executed by M/s Bajaj Electricals Limited and was commissioned on 13.09.2013. The length of the line is 231.7 km. This line was designed for wind zone 4 (basic wind speed of 47 m/s) as per IS 802:1995 with AAAC Quad Moose conductor. Polymer type insulators with four strings per phase were used in the transmission line. Power flow in the transmission line before the failure was 261 MWs. One tower of the transmission line was collapsed on 23.08.2016 due to flood in the river Ganga.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	**Forward Span (m)**
1	47/1	DD+30	
			490
2	**47/0**	**DD+18**	
			395
3	46/9	DC+6	
			370
4	46/8	DA+0	

b. As reported by Sterlite Power, the tower at location no. 47/0 was erected on pile type foundations. The tower was situated at the bank of river Ganga. As per discussion with the local people, high flood condition prevailed in the river leading to change in the course of river. The tower collapsed due to high velocity river water flowing near the tower location.

c. As reported by Sterlite Power, to take care of regular course change of river, the transmission line was diverted about 1.2 km with 9 Nos. of extra towers. Earlier the tower foundation was done using 4 Piles, but to take extra precaution in respect of change of course of river in future foundation has been done using 6 piles.

➢ **Probable Cause of Failure**

Committee noted that the transmission line had previously failed in the year 2016 in which the same segment of transmission line crossing the river Ganga was affected due to soil erosion by the changing river course. Committee noted that over the years, the course of river Ganga is continuously changing towards right bank (towards Patna). Committee also noted that the failed tower was casted on pile type foundation. Committee observed that course of water in Ganga river was changed due to heavy flood and heavy soil erosion towards river bank (Patna side) was observed leading to collapse of tower at loc. No. 47/0 (DD+18)

Committee recommended that proper anticipation of change in course of river on the basis of river flow data of previous years shall be done by the transmission utilities. Additional precautions like routing of transmission lines few kilometers away from the river bank/ anticipated future river course, use of pile foundation/additional piles etc. shall be adopted by utilities. Moreover, in case of damage of foundation of towers, the foundation design is required to be examined. Committee also recommended that Pile type foundation may be considered for all towers in flood prone area based on soil investigation report and latest high flood data, to avoid this type of failure. Providing proper Protection (retaining wall, Gabion wall etc., proper revetment & use of geo-synthetic material in foundation, concrete encasing & painting of stub in water logging areas etc. may also be considered, wherever required.

20. 400kV D/C Purnea- Biharsharif transmission line failed on 21.08.2018 [Location no. 46/9 (DC+6)]

➢ **Brief Background**

400 kV D/C Purnea- Biharsharif transmission line was designed and executed by M/s Bajaj Electricals Limited and was commissioned on 13.09.2013. The length of the line is 231.7 km. This line was designed for wind zone 4 (basic wind speed of 47 m/s) as per IS 802:1995 with AAAC Quad Moose conductor. Polymer type insulator with 4 strings were phase were used in the transmission line. The transmission line was under shutdown due to failure of tower at location no. 47/0 (DD+18) on 10.08.2018 due to change in flood in river Ganga.

➢ **Observations**

a. The details of tower spotting in the relevant sections are as follows:

Sl. No.	Loc. No.	Type of Tower	**Forward Span (m)**
1	47/1	DD+30	
			490
2	47/0	DD+18	
			395
3	**46/9**	**DC+6**	
			370
4	46/8	DA+0	

b. As reported by M/s. Sterlite Power, the tower at location no. 46/9 was erected on pile type foundations. The tower was situated at the bank of river Ganga. As per discussion with the local people, high flood condition prevailed in the river leading to change in the course of river. Due to flood in river Ganga on the 10.08.2018, the tower at location no. 47/0 had collapsed. The tower at location no. 46/9 collapsed due to high velocity river water flowing near the tower location.

c. As reported by Sterlite Power, to take care of regular course change of river, the transmission line was diverted about 1.2 km with 9 Nos. of extra towers. Earlier the tower foundation was done using 4 Piles, but to take extra precaution in respect of change of course of river in future foundation has been done using 6 piles.

➢ **Probable Cause of Failure**

Committee noted that the transmission line had previously failed in the year 2016 in which the same segment of transmission line crossing the river Ganga was affected due to soil erosion by the changing river course. Committee noted that over the years, the course of

river Ganga is continuously changing towards right bank (towards Patna). Committee also noted that the failed tower was casted on pile type foundation. Committee observed that course of water in Ganga river was changed due to heavy flood and heavy soil erosion towards river bank (Patna side) was observed leading to collapse of tower at loc. No. 47/0 (DD+18) on 10.08.2018. The tower at location no. 46/9 might have failed due to high velocity flow of river water and residual stresses develoved due to failure of adjacent tower located at loc. No. 47/0.

Committee recommended that proper anticipation of change in course of river on the basis of river flow data of previous years shall be done by the transmission utilities. Additional precautions like routing of transmission lines few kilometers away from the river bank/ anticipated future river course, use of pile foundation/additional piles etc. shall be adopted by utilities. Moreover, in case of damage of foundation of towers, the foundation design is required to be examined. Committee also recommended that Pile type foundation may be considered for all towers in flood prone area based on soil investigation report and latest high flood data, to avoid this type of failure. Providing proper Protection (retaining wall, Gabion wall etc., proper revetment & use of geo-synthetic material in foundation, concrete encasing & painting of stub in water logging areas etc. may also be considered, wherever required.

DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINE OF MAHARASHTRA STATE ELECTRICITY TRANSMISSION CO. LTD.(MSETCL)

21. 400kV Babhaleshwar(BBLR)-Dhule D/C (Ckt-1 and Ckt-2) transmission line failed on 01.06.2018
[Location no. 118(A+6), 196(B+0),120(A+3),121 (A+0) & 122 (A+0)]

- **Brief Background**

400 kV Babhaleshwar(BBLR)-Dhule D/C (Ckt-1 and Ckt-2) transmission line was constructed by MSETCL and was commissioned in 1995. The length of the line is 170 km. The towers of this line were designed as per IS 802 :1977 and were located in Low wind pressure Zone. The towers were designed with twin moose Conductor and twin peak configuration for two earthwires and were having I suspension string configuration with porcelain insulator. Power flow in the transmission line before the failure was 110 MWs on each circuit.

- **Observations**

As reported by utility, Five towers of the transmission line with location nos. 118 (A+6), 196(B+0),120(A+3),121 (A+0) & 122 (A+0) failed on 01.06.2018 at 16.42 Hrs. As informed by the utility, the towers were located in and around water submerged area for four to five months in a year. It was reported by utility that on the day of failure of towers strong stormy weather was observed in the areas of the transmission line which caused falling of trees, bill boards, roof tops etc. The foundations of tower were reported to be damaged. As per utility the heavy rain and cyclone observed in the area caused the failure of towers.

➢ **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of towers. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

22. 220kV D/C Chalisgaon – Kopargaon/ BBLR DC transmission line failed on 01.06.2018 [Tower at location no 196 (A+12)]

➢ **Brief Background**

220 kV Chalisgaon – Kopargaon/ BBLR DC transmission line was designed and executed by M/s. KPTL. The line was commissioned on 17.12.2011. The length of the Chalisgaon-Kopargaon line is 85 km and that of Chalisgaon –BBLR line is 115 km. The towers of this line were designed as per IS 802 and were located in wind Zone 1.. The towers were designed with Zebra Conductor and were having double I suspension string configuration with porcelain insulator. Power flow in the transmission line before the failure was 87 MW from Chalisgaon to Kopargaon circuit and 59 MW from Chalisgaon to BBLR circuit.

➢ **Observations**

As reported by utility, one suspension type tower at location no. 196(A+12) failed on 01.06.2018 at 16.42 Hrs. The tower was located in and around water submerged area for four to five months in a year. It was reported that on the day of failure of towers strong stormy weather was observed in the areas lying in vicinity of the transmission line which caused falling of trees, bill boards, roof tops etc. As per utility the heavy cyclone observed in the area caused the failure of tower.

➢ **Probable Cause of Failure**

The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line in the transverse direction leading to failure of towers. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINE OF M. P. POWER TRANSMISSION COMPANY LIMITED(MPPTCL)

23. 400 kV Katni – Damoh DCDS transmission line failed on 24.06.2018 [Towers at location no. 569(FD+0), 570(FD+0), 571(FD+0), 572(FD+0), 573(FD+0), 574(FD+3) & 575(FD+0)]

➢ Brief Background

Katni-Damoh transmission line was designed by MPPTCL and was strung with one circuit of 400 kV kV voltage level and another with 220 kV voltage level. The line was commissioned in 1999 and the length of the line is 115.6 km. The towers of this line were designed corresponding to Medium wind zone (45 kg/m^2) as per IS 802(1977). The towers were designed with Twin ACSR Moose Conductor and twin peak configuration for two earthwires and were having I suspension string configuration with porcelain insulator. Power flow in the transmission line before the failure was 515.4 MW.

➢ Observations

a. Tower schedule of tower damaged section of 400kV Katni-Damoh line

S.No	Location No.	Type of tower	Span (in Mtr.)	Section length (in Mtr.)	Remarks
1	564	FD30			
2	565	FD0	390		
3	566	FD0+3	400		
4	567	FD0	380		
5	568	FD0	350		
6	569	FD0	400		Partially damaged
7	570	FD0	380	4970 Meter	Tower collapsed
8	571	FD0	380		Tower collapsed
9	572	FD0	390		Partially damaged
10	573	FD0	390		Partially damaged
11	574	FD0+3	400		Partially damaged
12	575	FD0	410		Partially damaged
13	576	FD0	310		
14	577	FDT30	390		

b. As reported by utility, two suspension type towers at loc. No. 570 (FD0) & 571 (FD0) collapsed and five (5) towers at Loc. No. 569 (FD0), 572(FD0), 573 (FD0), 574 (FD0+3M) and 575 (FD0) were partially damaged. The stubs of the towers were damaged however the foundations were intact.

c. **Tower at Location 569 (FD0)** was in erect position. The earthwire peaks and Top cross arm of the tower got damaged due to pulling force of wires.

Tower at Loc. No. 569

d. **Tower at Location 570 (FD0) & 571 (FD0)** were completely collapsed and were lying on the ground.

Tower at Loc. No. 570

Tower at Loc. No. 571

e. **Tower at Location 572 (FD0) & 573 (FD0)** were in erect position. The towers were failed from bottom cross arm level.

Tower at Loc. No. 572 **Tower at Loc. No. 573**

f. **Tower at Location 574 (FD0+3) was** in erect position. The earthwire peaks and cross arms of the tower got damaged due to pulling force of wires.

Tower at Loc. No. 574

g. As informed by the utility, in the year 2004 near Damoh area the problem of localized wind storm was faced which was taken care of by adding additional hip bracing members in oblique view of suspension tower.

h. It was reported that on the day of failure of towers strong wind storm weather was observed in the areas lying in vicinity of the transmission line. As per utility the heavy cyclonic winds developed during the storm caused the failure of towers.

- **Probable Cause of Failure**

Committee noted that the failed towers were of suspension type designed as per old IS 802(1977) and were strengthened by adding additional hip bracing members in oblique view. The committee noticed that the high wind velocity might have prevailed in the vicinity of transmission line leading to failure of towers. However, wind speed data received from any authenticated observatory indicating speed of wind prevailing at the failure location at the time of the failure is not provided by the transmission utility. In absence of wind speed data from authenticated observatory, it is not possible to conclude that wind speed might have exceeded the design wind speed.

Committee noted that this is the failure of strenghthened towers. In case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, MPPTCL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future.

ANNEXURE -B

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 28.05.2019 to Analyse failure of towers in EHV transmission Lines during the period April, 2018 to March 2019.

The list of Participants is enclosed as Annex -II.

Chief Engineer (PSETD) & Chairman of the Standing Committee welcomed the participants and informed that during the period of April, 2018, to March, 2019, failure of 100 Nos. of transmission towers in 30 transmission lines of 220kV, 400 kV and 765 kV AC and ±500 kV HVDC voltage class has been reported to CEA. Out of these 100 Nos. of failed towers, 28 nos. of towers were of tension type while the rest were suspension type.

CE (PSETD) presented data of failure of towers during 2007-2018 and stated that although the number of reported failures reduced from 72 in 2009 to 12 in 2011, it again rose to 163 failures in 2014 then again showed a decline pattern till 2016 with 37 failures, however, again in the year 2018-2019, 100 Nos. of towers have failed and the maximum number of failures were in Wind Zone-IV and for towers of 400 kV transmission lines.

He further informed that a Committee has been constituted by MoP for auditing of transmission towers under the chairmanship of Member(PS) and so far, five audits were carried out for 15 transmission lines of various utilities. During audit, various deficiencies such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with soil, rusted stub/members etc. were observed in towers during audit of transmission towers. The photographs of these deficient towers were presented before the committee and utilities were requested to take necessary precautions and carry out proper maintenance of their lines so as to avoid failure of towers due to such deficiencies.

Further, CE(PSETD) stated that although the utilities attribute most of the tower failure cases to wind storm (exceedance of wind speed with respect to design wind speed) but other contributory factors like erection deficiency, quality of construction/material/workmanship also plays a role in tower failure incidents. After every failure the concerned utility needs to submit the actual wind velocity prevailed the affected area from concerned authorities so that the investigating team of standing committee could get reference wind speed prevailed over that area and in this era of technology there are number of options to get wind data including from radar stations, satellites etc. The wind speed data for the transmission lines failed during the period April, 2018 to March 2019 which are to be discussed in this meeting have not been provided by the utilities and the same shall be provided.

The standing committee was also apprised about the formation of separate high level committee in May 2018 in view of frequent failures of EHV transmission

towers and substation equipment of PGCIL in and around Agra region in April & May 2018. Chairperson, CEA constituted this committee under Principal Chief Engineer-II, CEA with members from NRPC, NPC, PSETD, CPRI, SERC, UPPTCL, IMD and PGCIL vide CEA letter dated May 7, 2018 with TOR of Study and Analyze the frequent failure incidents of EHV transmission towers & substation equipment of Power Grid in & around Agra area in recent times. This committee covered failure events of 11.4.18 & 2.5.18 involving 36 towers in 8 lines. The committee report has already been submitted in January 2019.

PGCIL and other transmission utilities, whose towers had failed, were requested to present before the Committee the details of the failures. PGCIL, MPPTCL and M/s Sterlite presented details of the failures (Presentations attached at Appendix-A) in their respective lines and the causes of failure of towers were discussed in detail and the outcome are summarised hereunder:

List of failed lines is provided at Annex-I.

1) PGCIL representatives made following observations and suggestions:

i) Most of the failed transmission line towers are designed as per IS: 802 -1995. However, in IS: 802-2015 some concepts such as diagonal wind factors i.e. wind in angular direction have been introduced. These new concepts are being taken into account for designing of new towers.

ii) In case of 765kV Delta tower same pattern of failure above waist level was observed in almost all failures.

iii) As discussed in previous meeting of the Standing Committee, for the transmission lines to be laid within 50 Kms of the border of the wind zones IV & V specified in SERC's latest Wind Map, towers shall be designed for the wind zone V. The same shall be extended to all wind zones and towers in areas upto 50 km from wind zone boundary should be designed for higher wind zone and this provision may be included in standard or CEA Regulations so that it would be easier for all transmission utilities to adopt the same.

In reply, CE (PSETD) informed that 50Km of overlap was not based on any study or codes but was suggested by experts in meetings as an interim measure to reduce failures, however SERC, Chennai was requested to make a study on this aspect and recommend a technically justified figure for wind zone border. The recommendations from SERC is awaited.

i) All over the world Nos. of failure of transmission towers due to high wind velocity has been reported and in most of the cases the tower collapse in transverse direction was observed. However, in some cases

towers failed in longitudinal direction which was resulted due to pulling of conductor of adjacent tower locations.

ii) Processing of steel is very important in ensuring its quality. However, after notification of Ministry of Steel, categorization of Primary and Secondary Steel producers has been removed. It is important that process and raw material quality of steel manufacturer is thoroughly assessed.

iii) In case of 400kV D/C Maithon-Maithon transmission line, three Nos. of DD+25m extension River crossing Towers at Barakar River failed. In query regarding correctness of stub setting by M/s Torrent Power, PGCIL replied that the stub was o.k. and the restoration/rectification of towers were done with the same stub setting template.

iv) In case of towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear model of tower should be checked. Load consideration for synoptic wind should be taken care of in design of tower.

v) PGCIL presented few slides in respect of failure of EHV towers experienced worldwide and remedial measures to avert failure of towers were suggested. Salient points of the presentation are as follows:

- As per CIGRE Technical Brochure 109 (Dec 1996), CIGRE collected data on tower failures during 1991-95 from around 40 utilities and wind and ice was found to be cause of failure in majority of the cases.

- As per CIGRE Technical Brochure 350 (June 2008), Localized High Intensity Winds (HIW) are caused during thunderstorms due to downdrafts & updrafts and do not generally get recorded at meteorological stations. Some countries have adopted design loading cases for localized HIW.

- As per CIGRE Technical Brochure No. 485 (Feb 2012), HIW are peak wind gusts that generally range from 100 m to 2500 m in width compared to the broader frontal system synoptic wind gusts. HIW are exceeding 45m/s and generally in range of 50–80 m/sec. Analyses of line failures in several countries have identified these high intensity wind events as the leading cause of transmission line failures.

- Matter to be taken up with BIS for review of IS-802 design criteria (in line with CIGRE technical brochure 350 & 485) for consideration of high intensity winds, microbursts etc. associated with thunderstorms, dust storms & other cyclonic/whirlwind activities frequently observed in many parts of the Country due to climate change.

- Narrow Front Wind design condition incorporated in IS-802;2015 covers wind on tower structure only (and not on conductors). Under this condition, wind on conductor & E/W with at least 70% span factor may also be considered to take care of localized HIW.

- Design of towers of all future transmission lines should be as per new wind zone map as well as revised design criteria. Revised wind zone map has already been incorporated in Specific Technical Requirements for TBCB projects issued by CEA.

2) IMD representatives made following observations and suggestions:

i) IMD has facility to measure wind data/information using physical observatories/ radar system/ satellite information arrangement. Any satellite with a radar scatterometer can be used to measure wind speed. Scatterometer provide wind speed and direction. However, long period sustained wind have been seen in case of tropical cyclone and to measure this kind of wind, High Speed Wind Recorder are placed in the coastal areas. IMD also, informed that bigger airports in country have automatic high speed wind recorder capable of measuring high speed wind.

ii) Cyclone is different activity which takes place towards coastal area. Wind phenomenon in other areas cannot be termed as cyclone. However, in case of localized high wind phenomenon due to cyclonic circulation thunder storm takes place. Thunderstorms are usually accompanied by strong winds, and often produce heavy rain. In the year 2018 in the month of April, May & June lots of thunder storm happened. However, in 2019 no such thundering activity has been observed so far.

iii) Now, a particular time record wind speed facility for recording of wind data has been introduced which was earlier not available and in future all data/information related to wind speed in the vicinity of failed tower may be asked to IMD and detailed report based on these data may be shared with the transmission licensee.

3) WRPC representative made following observations and suggestions:

i) WRPC is not convinced/satisfied with the reason given by transmission utility attributing high wind speed as major cause of tower failure in almost all of the cases as sufficient data in respect of actual wind speed is not provided.

ii) Based on the information on tower failure provided by the transmission utility, it is difficult to conclude whether failure is due to design/erection deficiencies or wind speed exceeding limits specified in wind zone categorisation. Every tower failure should not be categorized as failure due to wind. Poor workmanship, Erection deficiency, O&M issues are also contributory factors. All transmission licensees should take necessary action of these aspects.

iii) In most of the cases, the availability certificate is issued on the basis of benefit of doubt to utilities. It was also informed that in some cases, revised availability certificate has been issued by WRPC on request of PGCIL.

4) SRPC representative made following observations and suggestions:

i) O&M practice/ periodic inspection/patrolling of EHV transmission towers to be improved to avoid failure of towers due to rusting of members, erection deficiencies etc.

ii) The post-mortem model analysis after failure of tower should be carried out using non-linear analysis model so that every element of the failed tower may get analysed for better judgement for the cause of failure of tower.

5) M/S MPPTCL representatives presented details of failed towers of 400kV Katni-Damoh DCDS transmission line with wind storm as the reason of failure. He further stated that in the year 2004 near Damoh area the problem of localized wind storm was faced which was taken care of by adding additional hip bracing members in oblique view of suspension tower. He suggested that in case of tower with high extension of 25m or 35m, vertical component of conductor tension should be considered as load for tower design because of high elevation difference with adjacent towers.

6) SERC, Chennai representatives made following observations and suggestions:

i) Based on the data/information (related to wind velocity and wind pattern) provided by Indian Meteorological Department (IMD), SERC had generated the wind map of India in the year 2009 which has been included by BIS in National Building Code. SERC further added that

since the wind zone map was prepared in 2009, it has been re-evaluated and re-validated in Year 2016.

ii) It is observed from CEA data that maximum failures are in transmission lines of 400 kV and 765 kV. In cases where missing members are not found, systematic analysis of failed tower should be carried out to ascertain more realistic causes of failure.

iii) To assess wind overlapping zone, wind tunnel/CFD simulation study should be carried out.

A query was raised by CE(PSETD) on whether the revised wind map has been approved by the competent authority in GoI, which would mandate us for compulsory adoption in future lines. CEA has also sent a letter to SERC on this issue in May 2019, however the specific response is awaited. SERC mentioned that they would respond on this after verifying the facts & records.

7) M/S Sterlite Power representatives presented details of failed towers of 765 kV S/C Bhopal – Jabalpur transmission line and 400KV Purnea-Biharsharif transmission line and made following observations/suggestions:

i) All failed transmission lines of 220kV and above should be superimposed on the map of the Country for better clarity/ actual assessment of bordering WZ area and the region/belt where maximum failure occurred.

ii) In case of 400KV Purnea-Biharsharif transmission line of Sterlite, to take care of regular course change of river, line was diverted about 1.2 km with 9 Nos. of extra towers. Earlier the tower foundation was done using 4 Piles, but to take extra precaution in respect of change of course of river in future foundation has been done using 6 piles.

8) M/s Torrent Power representative made following observations and suggestions:

i) Cases of failure of suspension towers are more common due to lighter weight of tower, absence of hip bracing members etc. However, failure of angle/tension towers due to wind is a matter of concern. He suggested that narrow front wind should be specified in case of tension towers also with high body extension (+18 or +25m etc.) in addition to span utilization factor & deviation utilization factor.

ii) The stub-setting done by prop may not be accurate and the tower gets erected by force fitting of the Leg/Lattice members. M/s Torrent Power has developed the stub slope setting tool to check the slope of stub.

9) Chief Engineer (PSPM) stated that in one of the earlier meetings of the Standing Committee, the failure of 765kV S/C Delta configuration, suspension type tower was discussed in detail and review analysis of the same was carried out by CPRI and strengthening of some members above waist level were suggested by replacement of existing members with new members. He also, informed that strengthening was to be carried out by replacement of existing with new members no clamping or clipping arrangement was proposed. Afterwards, CE(PSPM) enquired about strengthening of 765kV Delta Tower as per CPRI suggestions and also asked if any failure was observed in strengthened tower. PGCIL replied that so far no failure in any of the strengthen tower (replacement of existing member with new member) has been observed.

10) After detailed deliberations / discussions among all participants, the committee observed the various causes which attributed to failure of EHV towers, some of which are listed below. The details of all failures shall be incorporated appropriately in the Report of the Committee which shall be circulated to all the Committee members and Stake holders.:

(a) Wherever, reporting of tower failure is due to wind, the utility needs to get the wind data for the area which would serve as representative wind speed prevailing in that area at the time of failure. It was agreed that the high wind velocity during storm, Cyclone and local condition of whirl wind might have exceeded the design wind speed for which the tower is designed, however this needs to be quantified. IMD and other agencies involved in metrological field would assist the affected utilities in this regard.

(b) The failure of the transmission lines having the same Delta configuration towers as in the 765kV S/C Gaya-Fatehpur renamed as Gaya-Varanasi-I transmission line had also been observed in earlier standing committee meetings. The standing committee of experts had established drawback in design of tower in the previous meetings. The inadequacy in design coupled with the reported storm caused the failure of towers.

(c) In one of the failure cases change in river course occurred. However, pile foundations have been provided. But Proper Protection (retaining wall, Gabion wall etc.) was not provided for towers near the river.

(d) Various deficiencies such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with

soil, rusted stub/members etc. as observed in the Audit of transmission towers due to Poor workmanship, Erection deficiency, O&M issues may be contributory to some of the tower failure incidents.

(e) In some of the lines, submergence of legs of various towers were found inside the earth which resulted in rusting of tower legs and stubs. Improper coping of chimney may also result into rusting of stubs and legs.

(f) In addition to the above, the Committee noticed the following reasons/causes which might have instigated the failure of transmission line towers:

i. 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 windstorms/whirlwind/ cyclone etc.

ii. Failure of stubs due to shearing of leg members of towers due to torsional forces.

iii. Deficiency in design/construction of foundation of towers may also result in failure of towers.

iv. Inadequacy in soil investigation and tower spotting also resulted in failure of towers.

(g) During deliberations/ discussions in the meeting, various suggestions emerged which shall be adopted to avert failure of towers and these shall be incorporated appropriately in the Report of the Committee which shall be circulated to all the Committee members and Stake holders. Some of these suggestions/deliberations are listed below:

(a) It is observed that intensity of wind has changed in some part of the Country due to climate change and the wind map was revised by SERC in 2009, the same has been incorporated in the Building Code by BIS, however, IS 875 has not been amended to include revised wind map.

(b) Technical specifications for TBCB projects has been revised and now specifies that transmission line shall be designed considering wind zones as specified in wind map given in National Building Code 2016, Vol. 1. The developer shall also make his own assessment of local wind conditions and frequent occurrences of high intensity winds (HIW) due to thunderstorms, dust-storms, downburst, etc. along the line route

and wherever required, higher wind zone than that given in wind map shall be considered for tower design for ensuring reliability of line.

(c) As revision of codal provisions is a continuous process, the changes are to be implemented prospectively. Strengthening of existing transmission line towers due to change in the codal provisions could be decided on case to case basis, if repeated failures are observed in a particular line.

(d) For the transmission lines to be laid within 50 Kms of the border of the wind zones may be designed with higher of these two zones. However, whether 50 km is appropriate or any change is required for this interface distance, shall be suggested SERC based on studies.

(e) Under Research Scheme on Power (RSOP) a proposal from SERC on "Strengthening studies for performance enhancement of existing transmission line towers" is pending with CPRI since 2017. CPRI shall be asked to take a expeditious view on this proposal, as it shall be beneficial to transmission sector.

(f) CPRI / SERC may also take up some RSOP project to study and analyse typical tower failures. Standardisation of tower type designs could also be another RSOP project. CPRI/SERC shall explore these further.

(g) Location of failure of transmission lines in previous years may be superimposed on the map of the Country to identify the locations where most failures are occurring.

(h) Due to climatic change, incidents of high winds are increasing. Transmission companies need to take proactive measures such as increased line patrolling, immediate replacement of missing members/bolts.

(i) Various deficiencies such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with soil, rusted stub/members etc. has been observed during the Audit of transmission towers. These deficiencies may be attributed to poor workmanship, erection deficiency, O&M issues etc. Utilities shall take necessary precautions and carry out proper maintenance of their lines so as to avoid failure of towers due to such deficiencies.

(j) Coping of Chimneys of tower foundations, wherever required, should be taken up to avoid rusting of stubs.

(k) After every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD requested to share the wind data obtained from observatory/ Satellite/Radar.

(l) In case of towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear analysis of tower should be carried out.

(m) Modern technique/methods should be adopted for erection & stringing of towers.

(n) Pile type foundation may be considered for towers in flood prone area based on soil investigation report and latest high flood data.

(o) Proper anticipation of change in course of river on the basis of river flow data of previous years shall be done by the transmission utilities. Additional precautions like routing of transmission lines few kilometers away from the river bank/ anticipated future river course, use of pile foundation/additional piles etc. shall be adopted by utilities.

(p) Best practices in quality control process for raw material, manufacturing, transportation, construction, storage, erection and stringing of towers shall be adopted.

(q) Frequency of patrolling of transmission lines should be more for the vulnerable tower locations (Thunder & cyclonic prone area).

(r) All transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds.

(s) In case of damage of foundation of towers, the foundation design is required to be examined.

(t) Material test for failed members of the tower should be carried out in NABL accredited laboratory to ascertain the quality, composition and mechanical properties of the material. Impact tests should also be conducted.

ANNEX-I

(a) Transmission Lines of PGCIL:

1. 400kV D/C Sundergarh – Raigarh, transmission line failed on 01-04-2018 at Location Nos.407(DA+0) & 417(DA+0)

2. 765 kV Bilaspur – Dharamjaygarh (circuit- I) transmission line failed on 27.04.2018 at Location Nos. 120(A+0),121(A+0),122(A+0).

3. 220 kV D/C Auraiya – Sikandara (Agra) transmission line failed on 6.04.2017 at Location Nos. 270(DA+0),271(DA+3) & 272(DA+0) 266 (DA+0), 267(DA+0), 268(DA+0) & 269(DA+0).

4. 400kV D/C Maithon – Maithon transmission line failed on 10.5.2018 at Location No. 63(DD+25),64(DD+25) & 65(DD+25).

5. 400kV S/C Farakka – Durgapur II transmission line failed on 10.5.2018 at Location No. 377(A+0) & 378(A+0).

6. 765 kV S/C Fatehpur – Agra- I transmission line failed on 13.05.2018 at location No. 568(A+0).

7. 765 kV S/C Gaya – Varanasi transmission line failed on 13.05.2018 at Location No. 368(A+3).

8. 765 kV S/C Jhatikara – Bhiwani transmission line failed on 16.05.2018 at Location No. 17(A+0).

9. 765 kV S/C Gaya – Varanasi transmission line failed on 29.05.2018 at Location Nos. 184,185,186 (all suspension towers).

10. 765 kV S/C Satna – Bina transmission line failed on 30.05.2018 at Location No. 63(A+0).

11. 400 kV D/C Sasaram – Daltonganj transmission line failed on 31.05.2018 at Location No. 36(DA+9), 37(DA+0), 38(DA+0).

12. 400 kV D/C Hisser – Kaithal transmission line failed on 09.06.2018 at Location No. 9 towers between 55 to 63 suspension tower (DA+0) with 60(DA+3).

13. 400 kV D/C Damoh – Birsinghipur transmission line failed on 12.06.2018 at Location No. 218(DB+0), 219(DB+6), 220(DB+3).

14. 400 kV S/C Kishenpur – Chamera transmission line failed on 01.09.2018 at Location No. 238(C+9).

15. 400 kV D/C (Quad) Patna – Kishanganj transmission line failed on 02.09.2018 at Location No. 129/0(DD+9), 129A/0(DD+0).

16. 500kV HVDC Talcher – Kolar transmission line failed on 11.10.2018 at Location No. 952(A+3).

17. 400 kV D/C Srikakulum – Garivadi transmission line failed on 11.10.2018 at Location Nos. 15/1(DA+3) & 15/2(DA+0)]].

(b) Transmission Line of MPPTCL:

1. 400kV Katni – Damoh DCDS Transmission line failed on 24.06.2018 at Location No. 570(FD0) & 571(FD0) partially damaged and 569(FD0),572(FD0),573(FD0),574(FD0+3M), 575(FD0).

(c) Transmission Line of M/s Sterlite Power:

1. 765 kV S/C Bhopal – Jabalpur transmission line failed on 18.05.2017 at Location No. 2A/3(SA+9)

2. 400 kV D/C Purnea – Biharsharif transmission line failed on 10.08.2017 at Location No. 47/0 (DD+18)

3. 400 kV D/C Purnea – Biharsharif transmission line failed on 21.08.2017 at Location No. 46/9(DC+0)

(d) Transmission Line of M/s MSETCL:

1. 400kV BBLR – Dhule Ckt-1 and Ckt-2 Transmission line failed on 01.06.2018 at Location No. 118(A+6), 119(B+0), 120(A+3), 121(A+0), & 122(A+0).

2. 220kV Chalisgaon – Kopargaon/ BBLR DC line Transmission line failed on 01.06.2018 at Location No. (A+12).

ANNEXURE -C

COMPOSITION OF STANDING COMMITTEE OF EXPERTS

Central Electricity Authority
Office of the Secretary

No.5-41/98/Secy/CEA / 809

Date 24/9/99
30

(Technical Committee No 16)

Office Memorandum

Subject: **Constitution of Standing Committee of Experts to investigate the Failure of Towers.**

Because of transmission line tower failures taking place in the country, resulting in disruption of power on large scale for long periods, it has been decided as per chapter-II, para 3 (viii) of the Electricity (Supply) Act. No 54 of 1948 to constitute a Standing Committee, consisting of experts in the field of EHV Transmission lines from CEA, Power Grid, CPRI, IIT Delhi, & SEB (of the State, where tower failure has taken place). In the event of any failure of towers for transmission lines of 220kV and higher voltages of power utilities, members of the committee should immediately visit the site to have first hand information and ascertain the causes of failure and give recommendations to prevent such recurrences in future.

2. The scope and terms of reference of the committee shall be as follows:

   (i) To investigate the causes of failure of towers.

   (ii) Recommendations to avert recurrences, of such failures in future.

3. Committee will submit its report within three months, from the date of failure.

4. Concerned power utility will provide all assistance, required by the committee in carrying out the meetings, make arrangements for immediate site visit after failure of towers by providing transport and travel facilities and preparation of the report.

5. All the Organisations/Power Utilities are requested to nominate their officers/alternate as their representative, and intimate to Chief Engineer STE, C

Every incident of Tower failure must be immediately reported to Chairman, CEA and Members of the Standing Committee.

8. This issues with the approval of Chairman, CEA.

3/5/99

(VIJOY KUMAR)
Secretary (CEA)

O/C

CMD Power Grid, New Delhi.

DG CPRI, Bangalore.

Head of Civil Engg. Deptt., IIT Delhi

Chairman of SEBs/Transmission Corporation/Grid Companies

PS to Chairman, CEA

PS to Member (PS), CEA

As per list Enclosed.

Copy to: Chief Engineer (GM), CEA

PS to Secy CEA

Scanned 1/10/99

भारत सरकार
केन्द्रीय विद्युत प्राधिकरण
सचिव का कार्यालय
सेवा भवन, आर0 के0 पुरम्,
नई दिल्ली - 110 066
****

(आइ.एस.ओ.: 9001:2000)

No.CEA/5-41(18)/Secy-2012 / 166 Dated: 06.08.2012

OFFICE ORDER

Subject: Re-composition of the Standing Committee of Experts to investigate failure of towers-Amendment - Reg.

Standing Committee of Experts was constituted vide this Office Memorandum (Techincal Committee No. 16) of even no. dated 30.09.1999 to investigate the causes of failure of towers. After the enactment of Electricity Act, 2003, it is felt necessary to re-compose the above said Committee. The revised Compostion of the Standing Committee of Experts to investigate failure of towers is given below:

1.	Chief Engineer, SETD, CEA	-	Chairperson
2.	Additional Director, (CPRI)	-	Member
3.	Head, Deptt. of Civil Engg, Delhi Technological University	-	Member
4.	Representative from Power Utility where Power failure occurred	-	Member
5.	Member Secretary, Regional Power Committee where Power failure occurred	-	Member
6.	Director (Transmission), SETD, CEA	-	Member Secretary

The other terms of reference shall remain the same as indicated in the above referred Office Memorandum.

(M.S. Puri)
Secretary, CEA
Tel. No.26108476

To:

1. Chief Engineer, SETD, CEA
2. Director (Transmission), SETD, CEA
3. Additional Director, Mechanical Enginering Division, Central Power Research Institute (CPRI), C.V. Raman Road, Banglore
4. Head, Deptt. of Civil Engineering, Delhi Technological University, Shahbad Daulatpur, Bawana Road, Delhi

Sh Talwar

7/8/12

5. Representative from Power Utility (as per list enclosed)
6. Member Secretary, Regional Power Committee (NRPC, WRPC, SRPC, ERPC & NERPC)

Copy for information to:

1. SA to Chairperson, CEA
2. SA to Member (PS), CEA

Copy for kind information to:

1. Secretary, Ministry of Power, Sharam Shakti Bhawan, Rafi Marg, New Delhi
2. Chairman and Managing Director, Powergrid Corporation of India Ltd., Saudamini, Plot No.2, Sector-29, Gurgaon

(M.S. Puri)
Secretary, CEA
Tel. No.26108476

ANNEXURE – D

COMMENTS/OBSERVATIONS OF PGCIL ON DRAFT REPORT RECEIVED VIDE LETTER NO. C/ENGG/TL/CEA-SC/2018-19 DATED 25.02.2020

पावरग्रिड
POWERGRID

पावर ग्रिड कॉर्पोरेशन ऑफ इंडिया लिमिटेड
(भारत सरकार का उद्यम)
POWER GRID CORPORATION OF INDIA LIMITED
(A Government of India Enterprise)

Ref: C/Engg/TL/CEA-SC / 2018-19

Date: 25-02-2020

To

Dy. Director (PSETD)
Central Electricity Authority
Sewa Bhawan,
R. K. Puram, New Delhi-110066

(Kind Attn.: Sh. Mohit Mudgal)

Sub: DRAFT REPORT OF THE STANDING COMMITTEE OF EXPERTS ON FAILURE OF EHV TRANSMISSION LINE TOWERS (APRIL 2018 – MARCH 2019)

Dear Sir,

This has reference to your email received dated 30-01-2020 vide which draft report of the standing committee of experts on EHV transmission line towers (April, 2018 to March, 2019) was forwarded.

In this regard, pl. refer our letter dated 10-12-2019 vide which POWERGRID's observations/ comments on the minutes of the meeting of the standing committee of experts held on 28-05-2019 at CEA Head Quarters were forwarded to CEA for kind consideration. However, the same have not been considered in draft report.

Draft report has been reviewed and POWERGRID's observations/ comments are enclosed at Annexure-I for kind consideration.

It is requested that final report of standing committee may please be reviewed & revised accordingly.

Thanking you,

25/2/20

(Surendra Kumar)

General Manager (Engg-TL)

Encl.: As above

POWERGRID comments/ observations on draft report of the standing committee of experts on failure of EHV transmission line towers

(April 2018-March 2019)

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
Para 3.1, page 8	In most of the cases the transmission utilities have pointed the cause of tower failure to high intensity wind. However, the utilities failed to produce wind data which could not substantiate their reasoning. They showed their inability to make available the actual wind speed data on the day of failures. The standing committee observed that wherever reporting of tower failure is due to wind, the utility needs to get the wind data for the area which would serve as representative wind speed prevailing in that area at the time of failure. It was agreed that the high wind velocity during storm and local condition of whirl wind might have exceeded the design wind speed for which the tower is designed, however this needs to be verified. Assistance of IMD and other agencies involved in metrological field may be taken by the affected utilities in this regard to share the wind data obtained from observatory/ Satellite/Radar.	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.
Para 3.3, page 8	Few cases of failure of 765 kV Single circuit Delta configuration towers of PGCIL are observed. It was brought to the notice of Standing Committee that the failure pattern of the 765 kV Delta configuration suspension type tower of PGCIL have been examined in detail in the previous Standing Committee meetings including the design review analysis carried out by CPRI and the Standing committee had suggested strengthening of suspension towers (with delta configuration) of 765kV S/C line by replacing the existing six (6) members with higher size members and adding two (2) more redundant members. PGCIL has got reviewed this design by M/s Minitoba Hydro, Canada and they have also suggested strengthening of some of the members. The inadequacy in tower structure coupled with the reported storm caused the failure of towers. However, it was observed during site visit to investigate failure of towers in and around Agra that PGCIL had been using the method of clamping/clipping of	As mentioned earlier, 765 kV S/C A type delta configuration tower (WZ-4) was designed as per IS: 802: 1995 and successfully prototype tested. As such, *"inadequacy in tower structure"* is not factually correct. Based on the discussions held during standing committee meetings, POWERGRID approached CPRI & Manitoba Hydro, Canada to explore the possibility of strengthening of tower to improve the performance of this tower at site during high wind conditions. Accordingly, strengthening was carried out to improve the performance in extreme conditions. Regarding clamping/ clipping of additional members for strengthening, it was also deliberated during earlier meetings of the standing committee of experts that strengthening of tower through

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
	additional members to some of the existing members of the towers, to strengthen the existing towers. Members of the Committee pointed out that the strengthening mechanism used by PGCIL is not complying with the recommendations of standing committee and it might not provide adequate strength to the towers. This needs to be reviewed by PGCIL.	replacement of some of the members is not possible without de-stringing and dismantling of upper portion of the tower. It is further to inform that as per the directive of standing committee, a full scale proto type testing of strengthened tower (as being done at site) picked from POWERGRID stores has been successfully conducted at CPRI, Bangalore on 07-02-2020. The non-strengthened tower when originally tested in 2004 withstood loads upto 105% whereas the strengthened tower withstood loads above 110%. This indicates that there is no inadequacy in tower/ tower design as such.
Para 4.1, page 9	Though, transmission utilities have blamed every tower failure to occurrence of high speed wind, they did not provide credible wind data in this regard. They showed their inability to make available the actual wind speed data on the day of failures. In the absence of this information, it cannot be ascertained with sufficient confidence that the prevailing wind speed was higher than the wind speed for which the towers were designed. The high wind velocity might have induced the failure of towers but it may not be the sole reason for the occurrence of the incident. In view of this it was observed that wherever reporting of tower failure is due to wind, the utility needs to get the wind data for the area which would serve as representative wind speed prevailing in that area at the time of failure. It was desired that the concerned utility which are facing repeated failure of lines in a region due to high wind speed incident need to perform thorough study and deep analysis of wind speed data in more realistic manner at the initial design stage itself for all the new transmission lines to avoid the failure cases.	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.
Para 4.2, page 10	These transmission line were erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration. The study and design review	As mentioned earlier, 765 kV S/C A type delta configuration tower (WZ-4) was designed as per IS: 802: 1995 and successfully prototype tested. As such, *"inadequacy in tower design"* is not factually

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
	analysis of 765 kV S/C Delta configuration suspension type tower of PGCIL was carried out by CPRI and strengthening of few members above waist level was proposed by replacing the existing members with new members. In this regard, PGCIL stated that the strengthening activity is being taken care in phased manner and is being continuing as per the direction of Standing Committee. The inadequacy in design of 765 kV S/C towers of Gaya-Fatehpur transmission line coupled with the reported storm caused the failure of towers. These mentioned transmission line designed with delta configuration faced similar pattern of failure, needed proper strengthening as suggested by Standing Committee in case of 765kV Gaya- Fatehpur transmission line.	correct. It is further to inform that as per the directive of standing committee, a full scale proto type testing of strengthened tower (as being done at site) picked from POWERGRID stores has been successfully conducted at CPRI, Bangalore on 07-02-2020. The non-strengthened tower when originally tested in 2004 withstood loads upto 105% whereas the strengthened tower withstood loads above 110%. This indicates that there is no inadequacy in tower/ tower design as such.
Para 6.0 (b), page 13	Technical specifications for TBCB projects has been revised and now specifies that transmission line shall be designed considering wind zones as specified in wind map given in National Building Code 2016, Vol. 1. The developer shall also make his own assessment of local wind conditions and frequent occurrences of high intensity winds (HIW) due to thunderstorms, dust-storms, downburst, etc. along the line route and wherever required, higher wind zone than that given in wind map shall be considered for tower design for ensuring reliability of line.	Such estimation by developer may not be possible.
Para 6.0 (c), page 14	After every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to share the wind data obtained from observatory/ Satellite/Radar.	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
Para 6.0 (i), page 14	Various deficiencies such as missing members, missing bolts, bent members, incorrect attachment of cross arm, chimney covered with soil, rusted stub/members etc. has been observed during the Audit of various transmission towers of different utilities. These deficiencies may be attributed to poor workmanship, erection deficiency, O&M issues etc. Utilities shall take necessary precautions and carry out proper maintenance of their lines so as to avoid failure of towers due to such deficiencies.	Very minor deficiencies were observed in POWERGRID lines audited by the committee. Further, no deficiency was observed in the lines in which tower failure occurred and were discussed during meeting of the standing committee held on 28-05-2019.
Para 6.0 (k), page 14	In case of towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear analysis of tower should be carried out.	POWERGRID towers are generally designed using ***itowers*** software which takes care of actual loads coming on the redundant members also. However, basic wind speed mentioned in IS-875 does not capture other wind conditions prevailing in Thunderstorm events.
Para-2, page-21	***The committee recommended that all transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds. It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future.***	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.
Para-4, page-31	***It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing***	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
	committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. PGCIL need to review the design of DD type tower and the stub setting template used in the transmission line. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future.	localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.
Para-3, page-33	***It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future and the suspension type towers may be strengthened by providing hip bracing upto bottom cross arm level as suggested in the previous standing committee meetings for the transmission lines designed as per old IS 802 (1977).***	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.
Para-1-2, page-36	***The Committee noticed that this transmission line has faced multiple failure incidents in the past. The failure of these 765 kV Gaya-Varanasi (earlier Gaya-Fatehpur) S/C transmission line (Wind Zone-4) with Delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower***	As mentioned earlier, 765 kV S/C A type delta configuration tower (WZ-4) was designed as per IS: 802: 1995 and successfully prototype tested. As such, *"inadequacy in tower structure"* is not factually correct. Regarding clamping/ clipping of additional members for strengthening, it was also deliberated during earlier meetings of the standing committee of experts that

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
	of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were proposed. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers. ***Committee noted that the failed tower was already strengthened by PGCIL. When enquired, PGCIL informed the Committee that so far no failure in any of the strengthen tower (replacement of existing member with new member) has been observed. Committee directed that failed tower shall be replaced with already strengthened tower and PGCIL shall ensure that the strengthening mechanism adopted is in accordance with the method suggested by Standing Committee in previous meetings (i.e. by replacement of existing member with new member).***	strengthening of tower through replacement of some of the members is not possible without de-stringing and dismantling of upper portion of the tower. It is further to inform that as per the directive of standing committee, a full scale proto type testing of strengthened tower (as being done at site) picked from POWERGRID stores has been successfully conducted at CPRI, Bangalore on 07-02-2020. The non-strengthened tower when originally tested in 2004 withstood loads upto 105% whereas the strengthened tower withstood loads above 110%. This indicates that there is no inadequacy in tower/ tower design as such.
Para-5, page-37	***The Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration. The failure of these 765 kV delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were proposed. The failed tower had not been strengthened. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar***	As mentioned earlier, 765 kV S/C A type delta configuration tower (WZ-4) was designed as per IS: 802: 1995 and successfully prototype tested. As such, *"inadequacy in tower structure"* is not factually correct.

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
	configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.	
Para-4, page-39	***The Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C (renamed as Gaya-Varanasi-I) transmission line (Wind Zone-4) with Delta configuration. The failure of these 765 kV delta configuration suspension type towers had been investigated by the Standing Committee of Experts for investigating failure of transmission line towers in the year 2015. Design review analysis of this type of tower of PGCIL was carried out CPRI on directions of the Standing Committee and strengthening of few members above waist level by replacing existing members with new members were proposed. The failed tower had not been strengthened. The pattern of failure of transmission towers from the waist level, i.e. from the K frame section, is similar to past failures of towers of similar configuration observed in previous years. The inadequacy in tower structure of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.***	As mentioned earlier, 765 kV S/C A type delta configuration tower (WZ-4) was designed as per IS: 802: 1995 and successfully prototype tested. As such, *"inadequacy in tower structure"* is not factually correct.
Para-4, page-44	***Committee noted that the failure of transmission towers of this transmission line is observed quite frequently. The Committee directed that failed tower shall be replaced with already strengthened tower and PGCIL shall expedite the process of strengthening of these towers as per method suggested by Standing Committee in previous meetings (i.e. by replacement of existing member with new member). Committee suggested that in case of towers in critical locations with regular high speed wind phenomenon, redundant members of tower should be designed with actual loads and non-linear analysis of tower should be carried out.***	Regarding clamping/ clipping of additional members for strengthening, it was also deliberated during earlier meetings of the standing committee of experts that strengthening of tower through replacement of some of the members is not possible without de-stringing and dismantling of upper portion of the tower. It is further to inform that as per the directive of standing committee, a full scale proto type testing of strengthened tower (as being done at site) picked from POWERGRID stores has been successfully conducted at CPRI, Bangalore on 07-02-2020. The non-strengthened tower when originally tested in 2004 withstood loads upto 105% whereas the strengthened tower withstood loads

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
		above 110%. Other wind conditions prevailing in Thunderstorm events should be considered besides synoptic wind.
Para-4, page-47	***It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Committee also noted that due to climatic change, incidents of high winds are increasing. Transmission companies need to take proactive measures such as increased line patrolling, immediate replacement of missing members/bolts and intensive care should be taken during erection and installation of towers (Slope correctness, filling unplugged holes, tightening of Bolts, Tack welding, straightness of tower members etc.).***	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.
Para-5, page-53	***It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert***	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.

Page No.	Recording as per draft report of the standing committee of experts	POWERGRID's comments/ Observations
	the recurrence of failure of towers in future. Committee also noted that large no. of failure of tower observed in the line is due to cascading effect of failure of suspension type towers.	
Para-4, page-60	***It was emphasized that after every failure the concerned utility needs to submit the actual wind velocity prevailed in the affected area so that the investigating team of standing committee could get reference wind speed prevailed over that area. In this matter, the respective utility may seek the help of IMD to get the wind data obtained from observatory/ Satellite/Radar. Moreover, in case of repeated failure /damage of towers due to high wind speed incident in the particular transmission line is observed, PGCIL need to perform thorough study and deep analysis of wind speed data with respect to the tower structure design to avert the recurrence of failure of towers in future. Committee also noted that all transmission towers should be checked on topmost priority after major wind event to remove fatigue and distortions, if any, so as to restore the original strength and avoid failures in subsequent event of high intensity winds.***	IMD observatories are generally far away from the site of collapse of towers. Therefore, it is not possible to get wind speed data in most of the cases. Further, in most of the incidents, high intensity localized winds are not captured by these observatories. As such, IMD observatory wind data will not serve as representative wind data of the area. Documentary evidence viz. photographs, newspaper/ media reports of the thunderstorm/ cyclonic incidents & associated damages/ loss to other infrastructure, trees, human/ cattle life etc. may be used to estimate the wind speed in the affected area.