सत्यमेव जयते

क्षतिग्रस्त ट्रांसमिशन लाइन टॉवरों पर विशेषज्ञों की स्थायी समिति की रिपोर्ट

(अक्टूबर २०१६ – मार्च २०१८)

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

(OCTOBER 2016 – MARCH 2018)




केविप्रा
cea

भारत सरकार

Government of India

केन्द्रीय विद्युत प्राधिकरण

Central Electricity Authority

विद्युत मंत्रालय

Ministry of Power

नई दिल्ली

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)

ACKNOWLEDGEMENT

The report of the Standing Committee of Experts on Failure of EHV Transmission Line Towers has been brought out for the failures occurred in the period from October 2016 to March 2018. The prime objective of Standing Committee is to visit site of failure, investigate the cause of failure, discuss the cause of failure of various substation / switchyard equipment of Power utilities in the meeting, recommend remedial measures to prevent recurrence of such failures in future and prepare a compendium of all failures. This objective can not be achieved without the help of transmission utilities.

I would like to express my sincere thanks to NRPC, WRPC, PGCIL, Delhi Transco Ltd., Central Power Research Institute, Structural Engineering Research Center, M/s Sterlite Power, M/s Adani Transmission, M/s L&T, M/s Darbhanga Motihari Transmission Company and M/s KEC International for active participation and providing valuable inputs during deliberations of the Committee.

I am thankful to Shri P.S.Mhaske, Chairperson, CEA, for motivation and guidance from time to time. I am also thankful to Shri Sanjay Srivastava, Chief Engineer(PSE&TD) and Chairman of the Standing Committee, Shri S.K.Ray Mohapatra, Chief Engineer(PSPM), Shri Narender Singh, Chief Engineer (TPE&CC), Shri R. S. Ram, Chief Engineer (TCD) and Shri Neeraj Kumar, Director (TCD) for providing valuable suggestions to be adopted to avoid failures which have been incorporated in the report.

Furthermore I would also like to appreciate the efforts put in by Deputy Directors (PSE&TD) Smt. Kavita Jha & Shri Faraz, Assistant Directors (PSE&TD) Shri Mohit Mudgal, Ms. Bhaavya Pandey & Shri Karan Sareen and WAPCOS engineer Ms. Sippy Srivastava in preparing this report.

(Yogendra Kumar Swarnkar)
Director (PSE&TD) and
Member Secretary of the Standing Committee

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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(1) 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 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 to 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 20.07.2018 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 October, 2016, to March, 2018. During this period, the failure of towers of EHV transmission lines of various utilities [PGCIL, DTL, M/s Sterlite Power, M/s L&T, M/s Adani and M/s Essel Infra Ltd.] 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 Annxure-B.

2.0 Brief details of failure of towers of various transmission lines reported to CEA from October, 2016 to March, 2018

2.1 Failure of total 52 nos. of towers of sixteen (16) transmission lines of PGCIL, DTL, Sterlite Power, Adani Transmission Ltd, L&T and Darbhanga Motihari Transmission Company Ltd. (M/s Essel Infra Ltd) were reported to CEA during October, 2016, to March, 2018. Details 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	Configration/ Conductor
1.	400 kV D/C Dadri - Panipat transmission line	PGCIL	26.02.2017	1984	Medium	5	Vertical/Twin Moose
2	400 kV D/C Silchar-Purba Kanchan Bari transmission line	PGCIL	2.04.2017	2015	6	8	Horizontal/ Twin Moose
3.	765 kV D/C Wardha – Nizamabad transmission line	PGCIL	6.04.2017	2017	3	1	Vertical/Hexa Zebra
4	400 kV D/C Koderma-Bokaro transmission line	PGCIL	13.5.2017	2014	2	3	Vertical/Twin Moose
5.	400 kV D/C Farakka - Kahalgaon I & II transmission line	PGCIL	15.5.2017	1992	Medium	4	Vertical/Twin Moose
6.	765 kV S/C Gaya- Varanasi-I transmission line	PGCIL	17.05.2017	2012	2	5	Delta/Quad Bersimis
7.	765 kV S/C Bina- Gwalior transmission line	PGCIL	5.06.2017	2014	4	2	Horizontal/ Quad Bersimis
8.	765 kV S/C Bina- Indore transmission line	PGCIL	14.06.2017	2012	2	4	Delta/Quad Bersimis
9.	765 kV S/C Agra- Jatikara transmission line	PGCIL	14.06.2017	2013	4	3	Delta/Quad Bersimis

10.	400 kV S/C Singrauli-Lucknow transmission line	PGCIL	16.06.2017	1986	Medium	2	Horizontal/Twin Moose
11.	765 kV S/C Bhiwani-Jhatikra transmission line	PGCIL	19.06.2017	2012	4	1	Delta/Quad Bersimis
12.	400 kV D/C Tikrikalan-Bawana transmission line	Delhi Transco Ltd. (DTL)	14.05.2017	2000	4	1	Vertical/ ?
13.	765 kV S/C Jabalpur-Bina transmission line	Sterlite Power	5.06.2017	2015	2	5	Vertical/Quad Bersimis
14.	±500 HVDC Mundra - Mohindergarh transmission line	Adani Transmission Ltd. (ATL)	24.07.2017	2012	4	1	Horizontal/ Moose
15	(i)400kV D/C Barh -Motihari Transmission Line (ii) 400kV D/C Motihari-Gorakhpur Transmission line	Darbhanga Motihari Transmission Company Ltd. (DMTCL) (Essel Infra Ltd.)	14.08.2017	2017	4	1 1	Vertical/Quad AAAC Vertical/Quad AAAC
16	765KV D/C Narendra (New)– Madhugiri (Tumkur) Transmission Line (Hexa Zebra)	L&T	24.05.2018	2016	1	5	Vertical/Hexa Zebra
Total No. of Failed Towers						**52**	

2.2 The number of suspension and tension towers at various voltage level, failed during above mentioned period are indicated in Table-2 below:

Table-2

Sl. No.	Voltage Level	Utility	No. of affected Lines	No. of Towers failed					
				Suspension Towers	Tension Towers				Total no. of towers failed
					B	C	D	Total	
1	765 kV								
		PGCIL	6	10		2	2	4	14
		Sterlite Power	1	4		1		1	5
		L&T	1	5				0	5
		TOTAL	8	19				5	24
2	±500 kV HVDC	Adani Transmission Ltd. (ATL)	1	1				0	1
3	400 kV								
		PGCIL	5	18	1		5	6	24
		DTL	1	0		1		1	1
		DMTCL	1	2				0	2
		TOTAL	7	20				7	27
	Total		**16**	**40**	**1**	**4**	**7**	**12**	**52**

2.3 It is observed that out of 52 towers of 16 Nos. of transmission lines listed above in Table-1, 41 nos. of towers pertaining to 12 nos. of transmission lines failed within 5 years of commissioning.

2.4 Out of 52 Nos. of failed towers, 40 Nos. (77%) are of suspension type towers and rest 12 Nos. (23%) are tension type towers (fig.-1). It is 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.

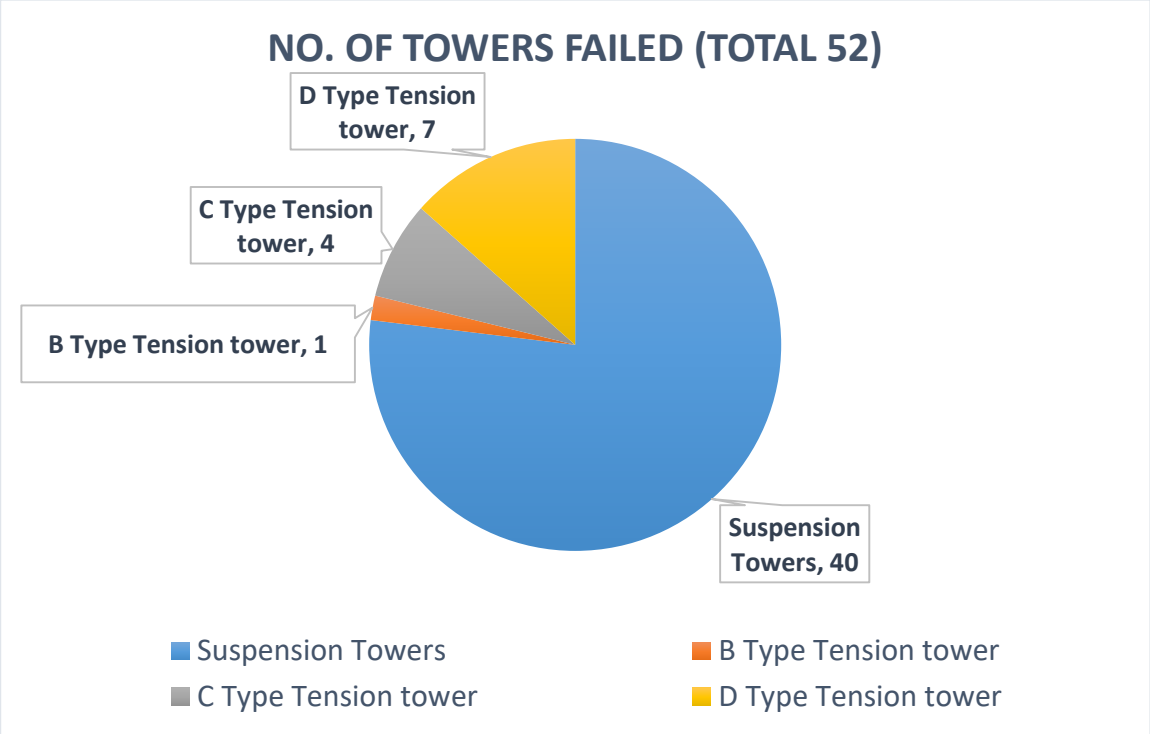


Fig.-1

2.5 Before the revision of IS 802 in 1995, Indian map 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 October, 2016 to March, 2018 with respect to various wind speed zones corresponding to which they were designed is given below (fig.-2). It can be seen that the maximum no. of failure of towers have occurred for transmission lines which were designed considering Wind Zone 2. However, the maximum no. of transmission lines affected due to failure of towers traverse through Wind Zone 4. It may be noted that the large percentage of the area of India is covered by these two wind zones.

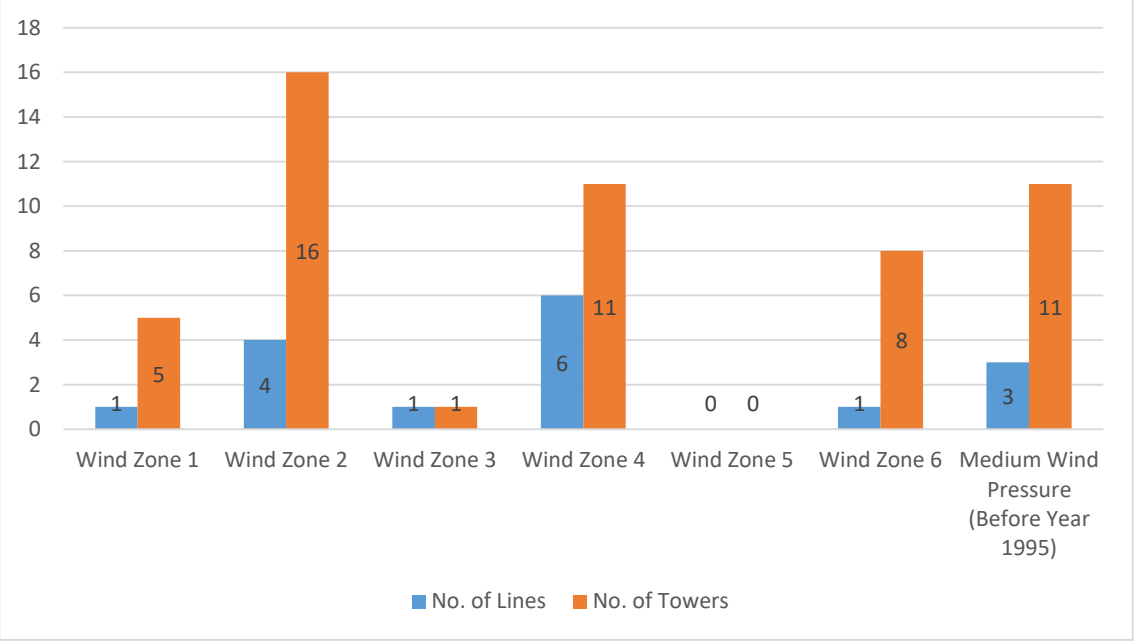


Fig.-2

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

1. 400 kV D/C Dadri - Panipat transmission line
2. 400 kV D/C Silchar-Purba Kanchan Bari transmission line
3. 400 kV D/C Koderma-Bokaro transmission line
4. 400 kV D/C Farakka -Kahalgaon I & II transmission line
5. 765 kV S/C Gaya- Varanasi-I transmission line
6. 765 kV S/C Bina- Gwalior transmission line
7. 765 kV S/C Bina- Indore transmission line
8. 765 kV S/C Agra- Jatikara transmission line
9. 400 kV S/C Singrauli-Lucknow transmission line
10. 765 kV S/C Bhiwani-Jhatikra transmission line

3.0 OBSERVATIONS OF THE COMMITTEE:

3.1 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.

3.2 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. Since strengthening of tower is to be done above waist level, such activity shall be taken up during annual maintenance in a phased manner. PGCIL had to prioritize the areas / lines where such activity can be taken up. However, it was observed that PGCIL had been using the method of clamping/clipping of additional members to some of the existing members of the towers, to strengthen the existing towers. Members 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.

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

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

- Shearing of stubs of leg members of towers.

3.4 The structural integrity of transmission towers depends on many factors including adequacy of technical standard/stipulated codal requirement considered for designing the transmission tower, quality of material grade used in tower body, Construction methodology, workmanship and erection practices, Operations & Maintenance practices of the transmission utilities etc. High speed of wind in conjunction with lacunae in one or more of the above mentioned aspects appears to be the cause of instigation of transmission tower failures in most of the cases. In order to take care of these issues in rational manner and to suggest other remedies for avoiding transmission line failure, it was decided to constitute a Sub-group which will examine in detail the above mentioned issues and submit the report to the standing committee. Based on the recommendations of the Sub-group, the Standing Committee will issue guidelines which are to be followed by all power utilities. The TOR of the Sub Group is as under:

Terms of Reference (TOR):

The objective of the Sub-Committee shall be to carry out thorough study and analyze the following w.r.t. failure of EHV Transmission Lines:

1. Review of BIS codal provisions pertaining to EHV transmission line and figure out misprints errors. Also, to suggest additional provisions to reduce tower failure rate and make tower more resistant to High Intensity Winds (HIW)
2. Guidelines on tower material grades, manufacturing process & shop tests to ensure quality of manufactured tower material.
3. Guideline for constructional methodology site testing and O&M of EHV transmission lines.
4. Methodology and Procedure for Audit of transmission towers.
5. To standardize protocol for investigation of tower failure cases.

4.0 ANALYSIS OF FAILURE OF TOWERS OCCURRED DURING THE PERIOD FROM OCTOBER, 2016, TO MARCH, 2018

4.1 **765 kV D/C Wardha-Nizamabad-I and II transmission Line, 400 kV D/C Koderma-Bokaro transmission Line, 400 KV D/C Farakka- Kahalgaon-I&II transmission line, 765 kV S/C Bina-Gwalior transmission Line, 765 kV S/C Jabalpur Bina transmission line & 765KV D/C Narendra (New) – Madhugiri (Tumkur) transmission line & 400 kV S/C Singrauli - Lucknow Transmission line***

Though transmission utilities have blamed every tower failure to occurrence of high speed wind, they failed to provide credible wind data in this regard. 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 desired that the concerned utility which are facing repeated failure of lines due to high wind speed incident need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases in more realistic manner.

[*Note: This line was designed as per IS 802-1977 and was not strengthened by providing hip bracing in the bottom most panels. Absence of hip bracing with a large number of unplugged holes might have made the tower vulnerable.]

4.2 **765 kV S/C Gaya- Varanasi-I transmission line, 765 kV S/C Bina- Indore transmission line, 765 kV S/C Agra- Jatikara transmission line & 765 kV S/C Bhiwani-Jhatikra transmission line**

The study and design review analysis of 765 kV S/C Delta configuration suspension type tower of PGCIL have been carried out by CPRI and they proposed strengthening of few members above waist level by replacing the existing members with new members. However, strengthening of towers carried out by PGCIL is through clipping/clamping of additional member to the existing members of the tower. The committee felt that the strengthening of delta towers by clamping method is not proper and may not fulfil the objective as clamping of additional member to the original members may provide instability to the geometry of tower. The inadequacy in design of 765 kV S/C towers of Gaya-Fatehpur renamed as Gaya-Varanasi-I transmission line coupled with the reported storm caused the failure of towers.

4.3 **±500 kV Mundra- Mohindergarh HVDC transmission line**

Due to heavy rain and flood, tower foundation of tower No. 941 was severely damaged leading to the collapse of the tower. Earthwire and OPGW peak of the adjacent tower was also damaged due to pulling force of conductors. New water course was created due to heavy rains. Improper anticipation of change in river course, lack of provision of Pile type foundation & Proper Protection (retaining wall, Gabion wall etc.) for towers near the river was observed as cause of failure.

4.4 **400 kV D/C Tikrikalan-Bawana transmission line**

The tower lies within the gated plot and was damaged due to fire in the unauthorized storage of inflammable material (plastic) underneath the tower. Lack of proper patrolling of transmission line by the utilities resulted in unauthorised usage of tower base area.

4.5 **400 kV D/C Dadri - Panipat transmission line**

A dumper had collided with the transmission tower which destabilized the structure of tower causing its failure. It was observed that a black tar road was constructed between legs of the tower. The utility should have taken appropriate action with local administration before time as it was a dangerous situation involving human safety.

4.6 **400 kV D/C Silchar-Purba Kanchan Bari transmission line**

Erection deficiencies, such as missing cover plates, rusted stubs, missing bolts in joints in leg member, unplugged holes, etc. were observed during site visit. It was observed that even erection trolley (used for stringing) was hanging from the conductor. All these deficiencies reduced the overall strength of the tower structure which could not withstand a windy event.

4.7 **400 kV D/C Barh – Motihari transmission line & 400 kV D/C Mothihari - Gorakhpur transmission line**

Towers were located near river bank. During flash floods soil below the foundation eroded causing damage to the foundation and failure of towers. Lack of provision of Proper Protection (retaining wall, Gabion wall etc.) for towers near the river was observed as cause of failure.

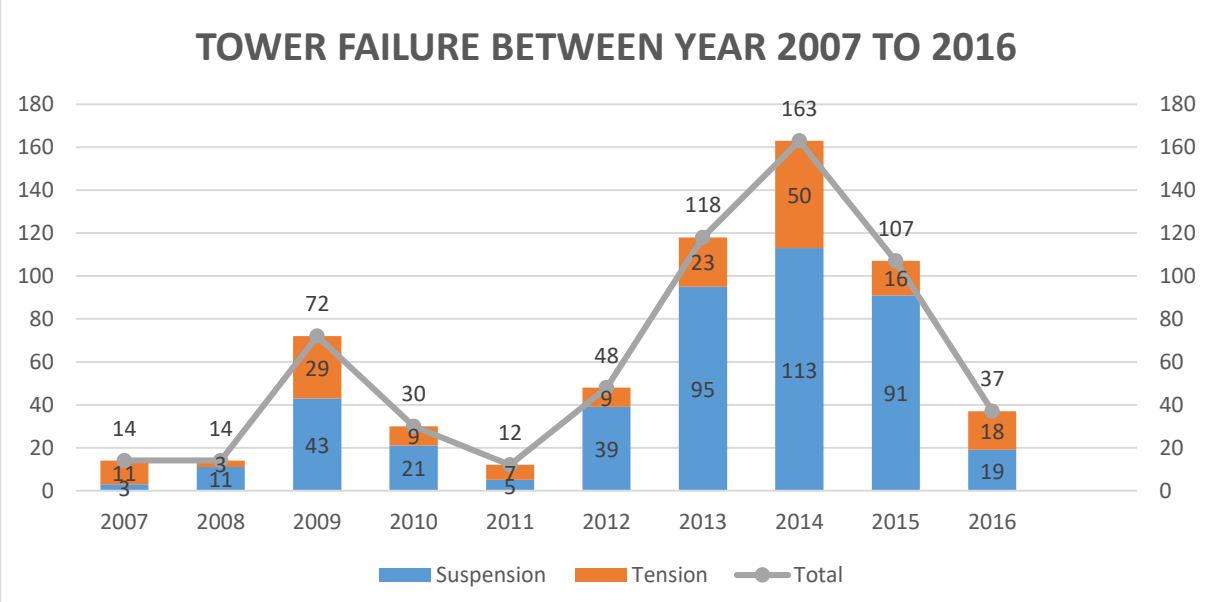
4.8 In addition to the above, the Committee noticed the following reasons/causes which might have instigated the failure of transmission line towers:

- Theft/sabotage of tower members, generally the theft of secondary members (connected with one or two bolts) of the towers, by the local people makes the tower structurally weak which ultimately leads to failure during high speed wind/ storms/whirlwind/ cyclone etc.
- Failure of stubs due to shearing of leg members of towers due to torsional forces.
- Deficiency in design/construction of foundation of towers may also result in failure of towers.
- Inadequacy in soil investigation and tower spotting also resulted in failure of towers.
- Improper coping of chimney and protruded steel reinforcement may result into rusting of stubs and legs.

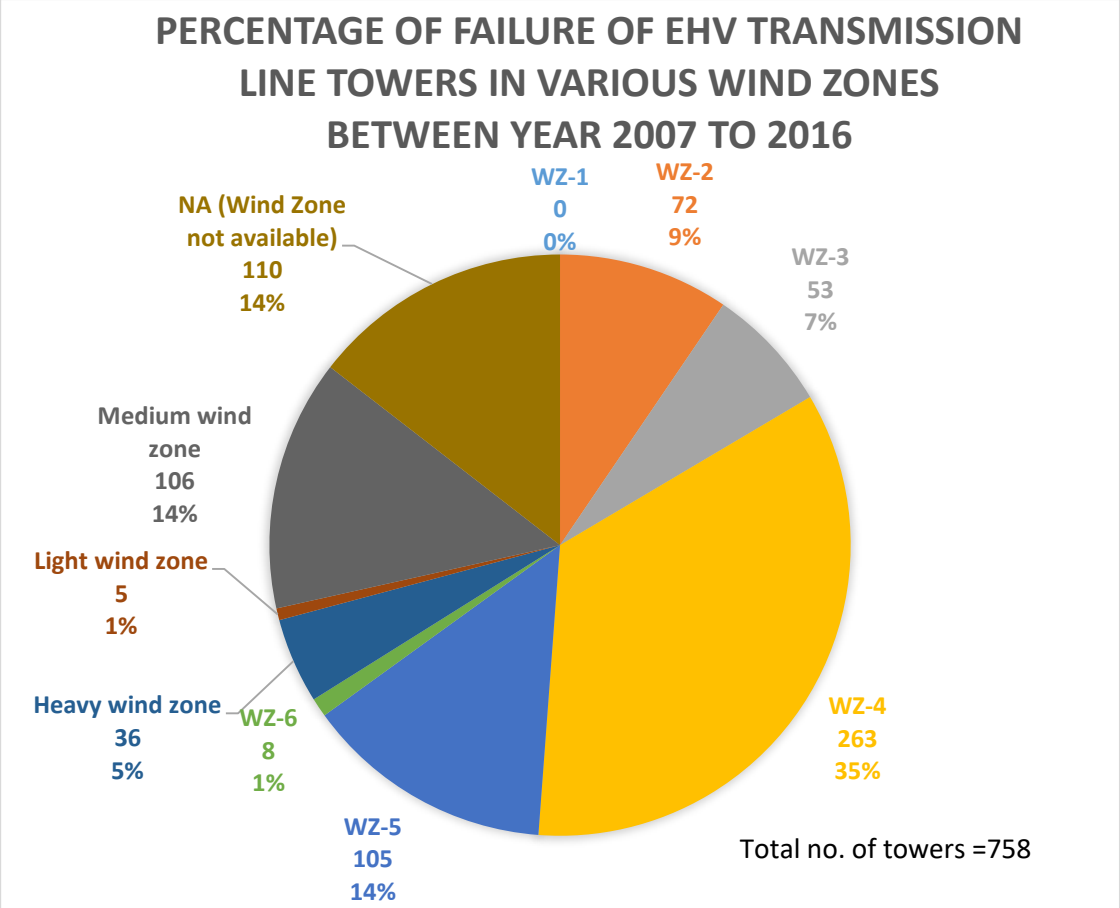
5.0 INSIGHTS INTO TOWER FAILURE INCIDENTS BETWEEN THE YEAR 2005 TO 2016

5.1 The details of previous transmission line and tower failure incidents which were reported to CEA and have been discussed in the previous Standing Committee meetings from the year 2007 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 of incidents covered only those transmission tower failure incidents records of which were available in CEA records.

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. 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/s. However, this makes the case for further strengthening for the design parameters considered for designing of suspension type towers.

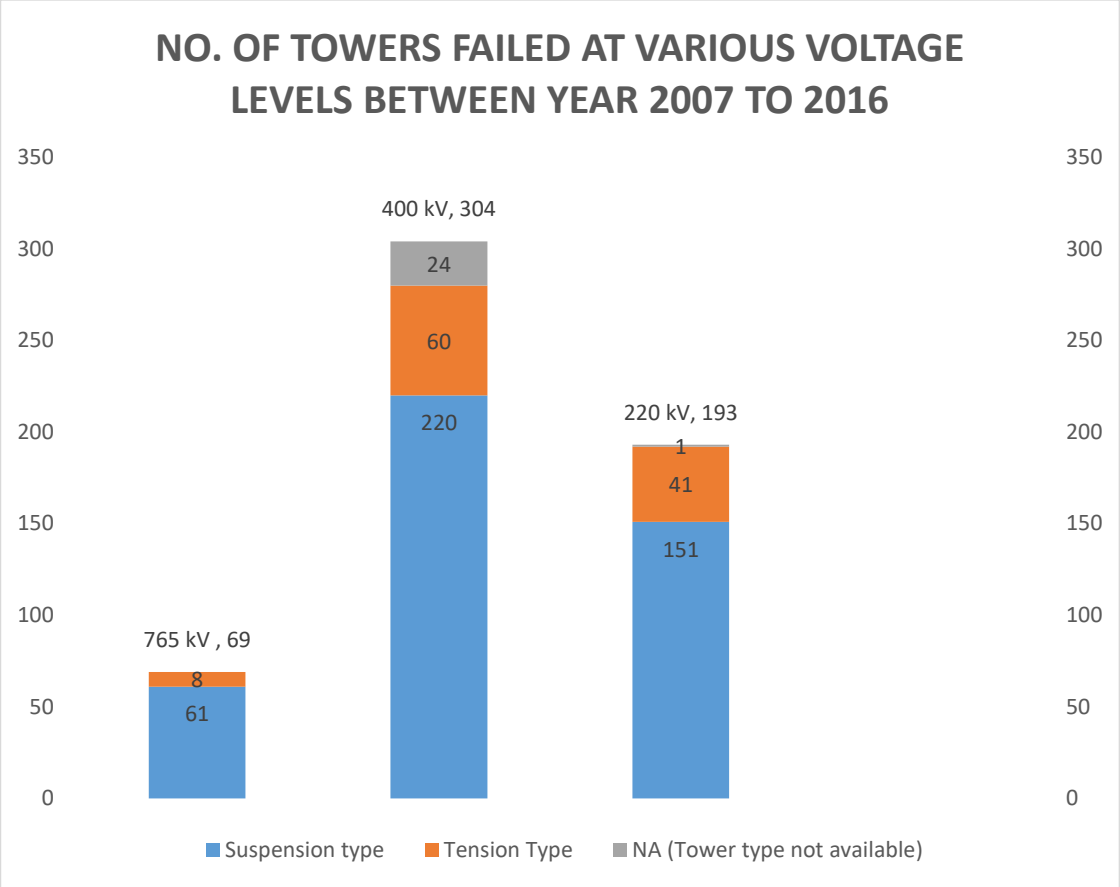


5.3 Graph/Pie chart depicting percentage of failed EHV transmission towers with respect of various Wind zone of the country in is shown below. The graph includes the details of transmission towers which were designed according to IS 802:1997 considering the three wind zones in the country namely, Light, 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. The maximum percentage (35%) of towers which were failed were designed corresponding to wind speed considered for Wind Zone 4.



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

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. It may be observed that towers of 400 kV voltage level have maximum incidents 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 of 400 kV voltage level.



5.5 All transmission utilities are repeatedly requested to intimate the tower failure incidents to CEA so that a complete picture of the tower failure incidents 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) Wind speed map was revised by SERC in 2009, however it not clear whether the revised wind map has been notified by concerned Ministry/Department through executive order. The revised wind map has so far not been incorporated by BIS in IS 875, though this map has been included in National Building Code. Pending the clarifications from IMD/SERC regarding approval of revised wind map by competent authority, it was recommended that as a safeguard measure, all future tower design of lines shall be done as per revised wind map and revised wind map of SERC may be included in RFP documents for TBCB projects. However, revised wind map being an important document for the country, the issue needs to be taken up with appropriate authority regarding status of its vetting/approval and its applicability in transmission sector, this would clear the way for its mandatory adoption by BIS and other stakeholders.

(b) Towers in India are designed for 50, 150 or 500 return period as per IS-802. There is huge gap between return periods of 150 and 500. The option of introducing return period of 250 was deliberated by the Committee. It was also deliberated to explore option of introduction of suitable factor for high intensity wind conditions.

(c) There are some misprints and error in BIS code 802- Part-I/Sec-I-2015. 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 as presently most of the power utilities and transmission licensee have started using the new version of IS: 802 Part-I/Sec-I (2015) for design and analysis of towers and there are chances of design inadequacy due to reduction of parameters such as Drag Coefficient in new IS.

(d) In view of above, it was suggested to constitute a subgroup to look into any deficiencies in present IS 802 and suggest suitable provisions to BIS for incorporation. Sub group would also be tasked with the work of preparing guidelines for construction methodology and operation & maintenance practices.

(e) IMD may be requested to install more wind stations all over India so that more reliable and accurate wind data could be collected for analysis and wind mapping.

(f) PGCIL may install 3-component Anemometers in some of its substations in the areas where failure rate of towers is higher and failure is mostly attributed to Wind.

(g) 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.

(h) 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.

(i) Number of tower failures are attributed to extreme wind event and the same is happening on regular basis. Hence, it is advised to design the TL towers considering the variability present in loading estimates, modeling and member capacity calculations. For the existing tower, it is suggested to perform reliability analysis in order to estimate the associated risk of failure for the variations in wind load.

(j) 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.).

(k) 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.

(l) Frequency of patrolling of transmission lines should be more for the vulnerable tower locations (Thunder prone, cyclonic prone area) and in theft prone areas. Missing members should be replaced as early as possible to avoid failure of towers.

(m) Assistance of local people should be taken in theft prone areas to minimize the theft and damage to towers.

(n) Additional factors in the design may be incorporated based on the experience of utility in respect of safety of Towers installed in wind prone area (resulting increase in margin of safety of tower members).

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

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

(q) The material test report of failed towers should be examined to ascertain the quality of the material.

(r) Coping of chimneys of tower foundation, wherever required, should be taken up to avoid rusting of stubs.

(s) Proper drainage and protection work/retaining walls should be provided for tower foundations especially in steep slope/hilly terrain to avoid damage to foundations of tower(s).

(t) 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

1. DETAILED REPORTS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF PGCIL

1.1 The towers of following 765kV and 400kV Transmission Lines of PGCIL had failed during above mentioned period.

Sl. No.	Name of Transmission line	Date of occurrence of Failure	No. of towers failed
1.	400 kV D/C Dadri - Panipat transmission line	26.02.2017	5
2	400 kV D/C Silchar-Purba Kanchan Bari transmission line	2.04.2017	8
3.	765 kV D/C Wardha – Nizamabad transmission line	6.04.2017	1
4	400 kV D/C Koderma-Bokaro transmission line	13.5.2017	3
5.	400 kV D/C Farakka-Kahalgaon I & II transmission line	15.5.2017	4
6.	765 kV S/C Gaya- Varanasi- I transmission line	17.05.2017	5
7.	765 kV S/C Bina - Gwalior transmission line	5.06.2017	2
8.	765 kV S/C Bina- Indore transmission line	14.06.2017	4
9.	765 kV S/C Agra- Jatikara transmission line	14.06.2017	3
10.	400 kV S/C Singrauli-Lucknow transmission line	16.06.2017	2
11.	765 kV S/C Bhiwani- Jhatikra transmission line	19.06.2017	1

1.2 DETAILS IN RESPECT OF EACH TRANSMISSION LINE

1. 400kV D/C Dadri – Panipat Transmission Line failed on 26.02.2017. [Location Nos.: 50(DA+0), 51(DA+9), 52(DB+25), 53(DD+0) & 54(DA+0)]

➢ **Brief Background**

400 kV D/C Dadri-Panipat transmission line was designed and executed by M/s SAE. The line was commissioned in October, 1984. The length of the line is 33.098 kms. The line was designed for medium wind zone (45 kg/m2) as per old Indian standard (IS: 802-1977). This is the first case of tower failure of the line. The suspension towers of this line were designed with single suspension insulator string with polymer insulator in vertical configuration and tension towers with double polymer insulator for Twin Moose 'ACSR' conductor. The line tripped at 18:47 hrs. on 26.02.2017 due to collapse of Tower at Location no. 52 (DB+25).

➢ **Observations**

The tower at Loc. No. 52 with DB+25M body extension was accidently hit by a dumper (with the projected dumping part) while crossing through the legs of the tower. It was reported that there was a Kachha road right below the tower since construction of the line which was later on converted into black top tar road. The Tower had collapsed in transverse direction from Stub level. The lower portion of the tower was supported by fully triangulated hip bracings All the four stubs got bent, coping was found broken in all four legs and cracks in one of the chimney of the foundations was observed. Rusting was noticed in stub portion at the coping level which came out due to cracking of chimneys.

Towers at location No. 50 (DA+0), 51(DA+9), 53(DD+0) & 54(DA+0) were also damaged. Tower at location No. 50 (DA+0) failed at peak level. Both the ground wire peaks got damaged. At location No. 51(DA+9), it was observed that the tower failed above middle cross-arm level. Top cross-arm and both the ground wire peaks were damaged. At location No. 53(DD+0), it was observed that the tower got damaged top cross-arm and both the ground wire peaks were damaged. At location No. 54(DA+0), minor damage in the peak (OPGW) of the tower was observed. It was reported that the earthing of tower was embedded in the foundation, as the same was not visible from outside. PGCIL officials informed that a FIR has been lodged with the local police station regarding the failure incident.

➢ **Probable Cause of Failure**

Tower at loc. No. 52 was failed due to hitting by dumper (with projected dumping part) in lower most panel of transverse face and the tower became unstable resulting in buckling of the members of the tower. The tower got damaged and fell in transverse direction from Stub level. All other towers at adjacent locations (50, 51, 53 & 54) got damaged partially as a secondary failure.

The committee advised PGCIL to take utmost care in future to avoid failure of the tower from unreasonable/accidental failure (hitting of Dumper etc.) by regular patrolling and taking timely assistance from local administrative authority if any illegal activity under and around the line is observed.

2. 400kV D/C Silchar- Purba Kanchan Bari Transmission Line failed on 02.04.2017 [Location Nos. 124 - 128 and 137-139]

➢ **Brief Background**

400 kV D/C Silchar-Purba Kanchan Bari transmission line, which is 127 km long, was designed by PGCIL and executed by M/S Jyoti Structures Limited. It was commissioned in August, 2015. This line traverses through plain terrain in wind zone 6 (wind speed 55m/s). The towers were designed as per IS: 802:1995 with twin ACSR Moose Conductor. The line tripped at 06:00 Hrs. on 02.04.2017.

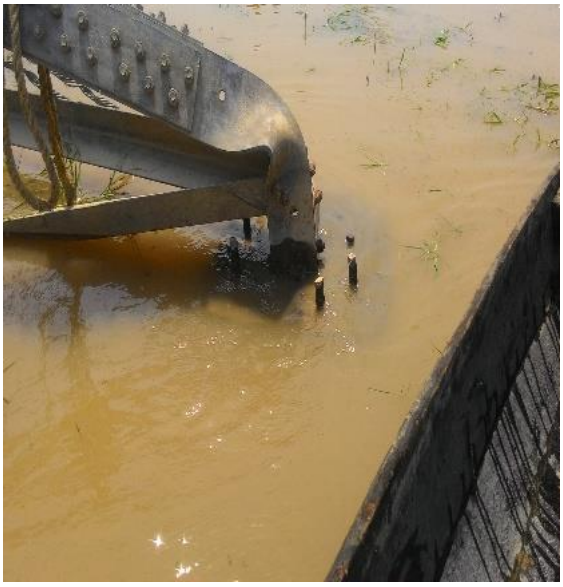
➢ **Observations**

The towers at location no. 124(DA+0), 125 (DA+0), 126 (DA+0) 137 (DA+0), 138 (DA+0), and 139(DD+0) got damaged during the wind storm on 02.04.2017. Further towers at location no. 127(DD+6) & 128(DD+9) were deformed in superstructure. The location wise details are given below:

a. **Tower at location no. 124(DA+0)** was located in plain terrain and completely collapsed to the ground from the stub level in transverse direction. All the 4 stubs got damaged. Three of the chimneys were broken. Coping of the chimneys was not done & Steel reinforcement got exposed in the chimneys. The tower was in water logged area and foundations of the tower

were partially submerged in water. Tack welding of the bolts was not done and some of the bolts in butt joints in leg members were missing. Few numbers of holes were left unfilled in some members of the tower. Anti-climbing device was not provided.

b. **Tower at location no. 125 (DA+0)** was completely collapsed on ground to the left side in transverse direction when observed facing P K Bari. Foundations of the tower were partially submerged in water. Tack welding of bolts and nut was not done. Tower legs had sheared from the 2nd panel level. The stubs were bent. ACD was not provided. Coping of chimneys was not done and steel reinforcement was protruding from them. One foundation chimney had cracked. As reported that the location was used to be water logged during rains.



c. **Tower at location no. 126 (DA+0)** was completely collapsed on ground to the left side when observed facing P K Bari. All the four legs were submerged in water. The tower got bent from 2nd panel level and had fallen in transverse direction to the line. Tack welding of bolt & nuts was not done. Cover plate was not provided in one of the joint in all the four legs. The two stubs were bent and the remaining two were intact. Few numbers of bolts were missing in the leg joints. The stubs got rusted due to water logging.

d. **Tower location No. 127(DD+6)** was in water logging area. All the cross arms of one side of the tower got damaged.

e. **Tower location No. 128 (DD+9)** was slightly bent above 1st panel level. The tower was in water logging area.

f. **Tower location no. 137 (DA+0)** fell in the transverse direction. All the stubs of tower were bent and Two chimneys were broken. Many bolts were missing in the joints of leg members. ACD was not available. Extra holes in the main leg members were not plugged. One of the stub was sheared. Coping of the chimneys was not done properly.

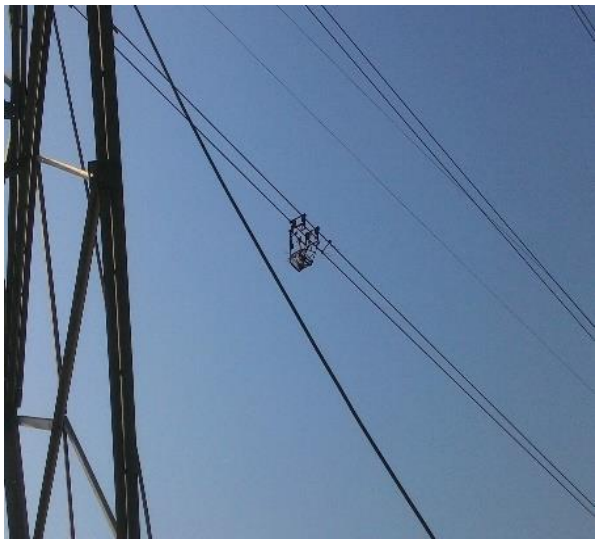


g. **Tower at location no. 138 (DA+0)** had collapsed from the stub level towards left side when observed facing P K Bari. Unplugged holes were present in the members of the tower which were. Coping of the chimneys were not done. Two stubs were bent & other two were intact. Few numbers of bolts in the joints of bracings and leg members were missing. Anti-climbing device was not provided. The area surrounding the failed tower was water logged.



h. **Tower at location no. 139 (DD+0)** was in erect position with members above bottom cross arm level twisted and bent towards right side in transverses direction when observed facing P K Bari. Members above first section got buckled & the foundations were intact. Coping of chimneys was not done. Steel reinforcement was protruding from three of the chimneys. A number of holes in tower members were not plugged. Few numbers of bolts were missing in

the leg member joints. A trolley which might have been used while stringing the conductors was not removed from the wires and was still hanging in air. The line was charged without removing this trolley.



i. It was informed that some of the towers had fallen in previous year also during the construction of the line.

j. PGCIL officials informed about theft of the members of tower by local miscreants and an FIR was lodged with the police.

k. The 400 kV D/C Silchar- Palatna transmission line of NETC was running parallel to the 400 kV Silchar- P K Bari transmission line and no damage was reported in this line due to the storm.

➢ **Probable Cause of Failure**

The erection deficiencies such as missing cover plates, missing bolts in butt joints of leg member, unplugged holes, rusted stubs due to water logging etc. might have resulted in reduced strength of tower and combined with localized wind storm might have caused the failure of towers. It was observed that the line was charged without taking proper caution as

a trolley which was used during erection was still hanging on the live wires near tower location No. 139(DD+0).

The committee recommended that 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). In theft prone areas, frequency of patrolling should be increased and assistance of local people should be taken to avoid failure of towers.

3. 765 kV D/C Wardha-Nizamabad-I and II Transmission Line failed on 06.04.2017 [Location no. 175/8(DCT+0)]

- **Brief Background**

Affected section of 765 kV D/C Wardha-Nizamabad-I and II transmission line was constructed by M/s. Tata Projects. The line was commissioned on 04-04-2017. The towers were designed as per IS 802-1995 for basic wind speed of 44m/sec (Wind Zone -3) in Vertical Configuration with ACSR Hexa Zebra Conductor. The line tripped on earth fault at 1610 Hrs. on 06.04.2017. It was informed that peak and top cross arms of D/C transposition tower at location number 175/8 was found damaged during post fault patrolling of the line.

- **Observations:**

A team comprising of PGCIL officials visited the tower at location no. 175/8(DCT+0) and observed that the tower was damaged above bottom cross arm level. It was further observed that transverse belt connecting upper member of top cross arms failed under tension (i.e. mark no.809 & 810 section HT 100*100*8) and subsequently earth wire peak wire and top cross arms got damaged. Any missing bolts/ nuts/ tower parts was not observed.

➢ **Probable Cause of Failure**

As reported by PGCIL, the failure of tower might have been due occurrence of High intensity localized whirl wind increasing the forces on tower members. The failure might has initiated from transverse belt connecting upper member of top cross arms (mark no.809 & 810 section HT 100*100*8) failed under tension and resulted in subsequent damage to earth wire peak and top cross arms.

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 in case of repeated failure of towers due to high wind speed incident, PGCIL need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases.

4. 400 kV D/C Koderma – Bokaro Transmission Line failed on 13/05/2017 [Location nos.172(DA+0), 173(DA+0) & 175(DD+9)]

➢ **Brief Background**

400 kV D/C Koderma-Bokaro transmission line, which was commissioned in December, 2014, was designed by PGCIL and executed by M/S Jyoti Structures Limited. The length of line was 99.5 Km. This line traverse through undulated terrain in wind zone 2 (wind speed of 39 m/s) and the towers were designed as per IS: 802:1995 with Twin ACSR Moose Conductor in Vertical configuration.

➢ **Observations**

The towers at location no. 172(DA+0), 173(DA+0) and 175 (DD+9) were damaged during storm on 13.05.2017. It was observed that the tower at location no. 173 (DA+0) was completely collapsed & lying on ground, tower at location no. 172(A+0) was damaged above the first panel level and at location no. 175(DD+9) earthwire peak of tower was damaged. PGCIL officials present during site visit were requested to submit wind data of nearby IMD observatory for failure of above towers on 13.05.2017. However, they communicated that only forecast of heavy wind was given by IMD but measured wind speed data was not available. The location wise details are given below:

a. **Tower at location no. 172(DA+0)** had collapsed above first panel in transverse direction. The foundations were intact. Hip bracings, Tack welding of bolt & nut, Anti-theft bolts and coping of chimneys were provided. Earthing arrangement of the tower was not visible.

b. **Tower at location no. 173 (DA+0)** collapsed at stub level and fell in the transverse direction. At the time of inspection, it was observed that the tower was removed by gas cutting and repairing of all the four chimneys was in progress to replace the damaged stubs. No missing of members observed.

c. **Tower at location no. 174(DA+6)** and all its four foundations were intact. Few bolts were missing in joints. Some extra holes in leg members were not plugged with bolt & nut. ACD was not available. Some of the redundant members were disconnected from the joints and were hanging. Coping of chimneys was not done properly.

d. **Tower at Location No. 175 (DD+9)** was in erect condition and one of the peaks of the tower was damaged. Few bolts were missing at joints. Some extra holes in leg members were not plugged with bolt & nut. Foundation reinforcement was exposed. Coping of chimneys was not done properly.

➢ **Probable Cause of Failure**

The tower at location No. 173(DA+0) might have fallen first, causing secondary failure to the tower at location No.172 (DA+0) and 175(DD+9).

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.

PGCIL may install 3-component Anemometers in some of its substations in the areas where failure rate of towers is higher and failure is mostly attributed to Wind. It was also emphasized that in case of repeated failure of towers due to high wind speed incident, PGCIL need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases.

5. 400 KV D/C Farakka- Kahalgaon-I&II transmission line failed on 15.05.2017 [Location. No. 142 (DA+0), 143 (DA+0), 144(DA+6) & 145 (DA+0)]

- **Brief Background**

400 kV D/C Farakka-Kahalgaon-I & II Transmission line of PGCIL was designed and executed by M/s KEC International and was commissioned in December, 1992. The length of line is 97.74 Km which traverses through plain terrain surrounded by small hills. The towers were designed as per IS: 802:1977 for medium category wind zone with twin ACSR Moose Conductor in single I suspension configuration with glass type insulators. It was the first incidence of failure of towers of this line since its commissioning.

- **Observations**

The towers were located near the Borio-Barhait Road, at around 50 km distance from Kahalgaon, Bihar. The towers at location no. 142 (DA+0), 143 (DA+0), 144(DA+6) & 145 (DA+0) got damaged. It was observed that the towers at location nos. 142, 143 & 144 had completely collapsed and at location no. 145 tower peak got damaged. No missing members were reported from the towers.

The location wise details are given below:

a. **Tower at location No. AP 142 (DA+0)** was completely collapsed in transverse direction towards right side of the transmission line when watched towards Farakka Substation and was lying on the ground. Two of the stubs were bent, third stub got bent & sheared and fourth stub was covered under the ground. Minor damages were observed in the chimneys and few cracks appeared on them. Coping of two of the chimneys was not done.

b. **Tower at location no. AP 143 (DA+0)** was completely collapsed in transverse direction towards right side of the transmission line when watched towards Farakka Substation and was lying on the ground. Three of the stubs were bent and the fourth stub got bent and sheared. Anti-climbing device was not provided. Signs of flash over at right bottom cross arm insulator were observed. Minor damages were observed in one of the chimneys. The foundations were found to be intact.

c. **Tower at location no. AP 144 (DA+6)** was completely collapsed towards right side of the transmission line when watched towards Farakka Substation and was lying on the ground. Three of the stubs were bent and fourth stub was not visible as it was under the ground. It was

observed that three of the tower legs were recently excavated. The members of the leg and connecting bracings were rusted. Anti-climbing devices was not provided. The foundations were found to be intact.

d. **Tower at location no. AP 145 (DA+ 0)** was located at the vicinity Borio-Barhait Road and had one of the span crossing the road. The tower was in erect position. Right side peak of the tower, when watched towards Farakka, got buckled. The Coping of the chimneys were not done. All the chimneys were intact. One of the chimney was under the ground. Few no. of bolts in the joints of bracings were missing. Anti-climbing device was not provided.

PGCIL officials were requested to submit wind data of nearby IMD observatory for 15.05.2017 and were requested to take immediate steps to take care of the continuous submergence of tower legs of various towers inside the earth which had resulted in rusting of tower legs and stubs. No information regarding wind speed data from nearby IMD observatory was provided.

- **Probable Cause of Failure**

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.

PGCIL may install 3-component Anemometers in some of its substations in the areas where failure rate of towers is higher and failure is mostly attributed to Wind. It was also emphasized that in case of repeated failure of towers due to high wind speed incident, PGCIL need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases.

6. 765kV S/C Gaya-Varanasi-I Transmission Line failed on 17.05.2017 [Location Nos. 65 (A+3), 66 (A+0) ,67 (A+0), 68 (A+0) & 69 (C+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 in March, 2012. The length of line is 263 Km. This line traverses through plain terrain. The towers with Delta configuration were designed as per IS: 802:1995 for wind zone-2 with Quad ACSR Bersimis Conductor with porcelain insulators. The towers were having double peak configuration with one Earthwire and one OPGW. 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- 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

- **Observations**

The towers were located in the plain terrain near the Mathurapur village at about 60 kms from 765/400/220 kV Gaya substation of PGCIL. The towers at location no. 65 (A+3), 66 (A+0), 67 (A+0), 68 (A+0) & 69 (C+0) got damaged. It was observed that the towers at location no. 68 had completely collapsed and the towers at location nos. 67 and 66 had bent & collapsed from the 1st section level. In case of tower at location no. 65, delta section of the tower got damaged. No missing members were reported from the towers. The location wise details are given below:

a. **Tower at location no. AP 65 (A+3)** was in erect position and the delta section of the tower was bent and converged towards the tower body in the direction towards Varanasi substation. It was observed that the insulator of the left cross arm had broken and the conductor bundle had completely detached from the insulator and was resting on the tower body at the first panel level. The right side conductor was attached to the insulator at the cross arm level. The foundations of tower were covered with sand.

b. **Tower at location No. AP 66 (A+0)** had bent and collapsed from the first section level, towards right side of the transmission line, when watched towards Gaya Substation. The tower members of the first section level were buckled and sheared. One of the Leg member of the tower and its stub got bent while other three stubs were intact. Foundations were found to be intact and were covered with sand. Some of the holes made for step bolts were left unplugged/unfilled.

c. **Tower at location no. AP 67(A+0)** was bent and collapsed from the first section level, towards right side of the transmission line, when watched towards Gaya Substation. All the stubs were found to be intact. The tower members of the first section level were bended and sheared. No damage was observed in the foundations.

d. **Tower at location no. AP 68 (A+ 0)** was completely collapsed from the stub level and was lying on the ground towards right side of the transmission line when watched towards Gaya Substation. All the four stubs were bent. Foundations were found to be intact and were covered with sand. It was observed that some of the holes made for step bolts were left unplugged/unfilled.

e. **Tower at location no. AP 69 (C+0)** was in erect position. Two members of the delta section of the tower had buckled, and the tower body above them had tilted towards tower at location no. AP 68. Foundations were found to be intact and were covered with sand.

f. Two other 765 kV transmission lines, namely Gaya- Balia transmission line, having Delta configuration, and Gaya- Varanasi –II transmission line, having horizontal configuration were also traversing through the same terrain. It was reported that no failure has been reported in these lines.

g. Powergrid officials were requested to submit wind data of site from IMD records for 17.05.2017, however, no the information was provided by PGCIL.

➢ **Probable Cause of Failure**

The 765kV S/C Gaya-Fatehpur renamed as Gaya-Varanasi-I transmission line with delta configuration earlier also 5 times failed. The failure of the line investigated by standing committee of experts established drawback in design of tower. The inadequacy in design coupled with the reported storm might have caused the tower no. 68 to fall in transverse direction. However, other suspension towers failed due to cascading effect. Tower at loc. No. 69 failed in delta section due to pull of conductor.

Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C 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 inadequacy in design of 765 kV S/C towers of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.

7. 765 kV S/C Bina-Gwalior Transmission Line failed on 05-06-2017 [Location No.: 511 (A+3) & 512 (D+0)]

➢ **Brief Background**

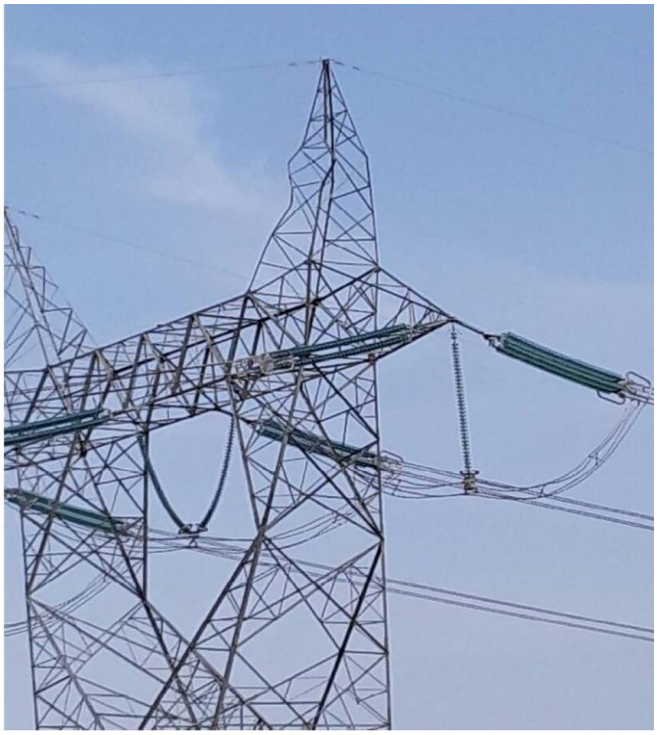
765 kV S/C Bina-Gwalior Transmission line-III was designed by PGCIL and was constructed by M/s LANCO and was commissioned on 07.05.2014. The length of the line is 231.38 kms. The towers were designed as per IS 802:1995 for wind zone 4 (wind speed of 47 m/sec.) with ACSR Quad Bersimis conductor in Horizontal configuration.

➢ **Observations**

The failure site was located near Badijav village about 7 km from Dabra-Bhitarwar main road. The towers at location no. 511 (A+3) was completely collapsed and 512 (D+0) was partially damaged at one of the earthwire peak during localized storm with heavy rain on 05.06.2017. The location wise details are given below:

a. **The tower at location No. 511** fell in the longitudinal direction towards tower location No. 512. Many tower members were found twisted. The tower was removed by gas cutting of all the four stubs at ground level and the peaks, cross arms etc. were detached from the tower body.

b. **Tower location at No. 512** was damaged at one of the earthwire peak due to the collapse of tower at location No. 511. All the foundations were intact; however, coping of chimneys was not done properly resulting in rusting of the stubs. There were few dummy holes left in the leg joints connecting stubs which have not been plugged. Also, there were many bolts holes in tie members.



c. Powergrid officials were requested to submit wind data of site from IMD records for 17.05.2017, however, no the information was provided by PGCIL.

➢ **Probable Cause of Failure**

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.

PGCIL may install 3-component Anemometers in some of its substations in the areas where failure rate of towers is higher and failure is mostly attributed to Wind. It was also emphasized that in case of repeated failure of towers due to high wind speed incident, PGCIL need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases.

8. 765 kV S/C Bina-Indore Transmission Line failed on 14.06.2017 [Location Nos. 235 (A+0), 236(A+3), 237(A+0) and 238(D+0)]

➢ **Brief Background**

765kV S/C Bina-Indore transmission line was constructed by M/s. Jyothi Structure Ltd. The line was commissioned on 01.04.2012. The towers of this line were designed for Wind Zone-2 (basic wind speed of 39m/sec) as per IS 802-1995. The towers were designed in Delta configuration with Quad ACSR BERSIMISE Conductor.

➢ **Observations**

The towers were situated in cultivated field with very few trees in the vicinity. Towers at location No. 235(A+0), 236(A+3) & 237(A+0) were completely collapsed to the ground and minor damage in one Earth wire peak of tower no. 238(D+0) was observed. One stub for tower no. 235(A+0), three stubs for tower no. 236 (A+3) and all the four stubs for tower no. 237(A+0) were bent.

➢ **Probable Cause of Failure**

Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C 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 probable inadequacy in design of 765 kV S/C towers of 765 kV S/C Delta configuration suspension type towers coupled with the reported storm caused the failure of towers.

9. 765 kV S/C Agra-Jatikara Transmission Line Failed on 14.06.2017 [(Location No. 506 (A+0), 507 (A+0) and 508 (A+0)]

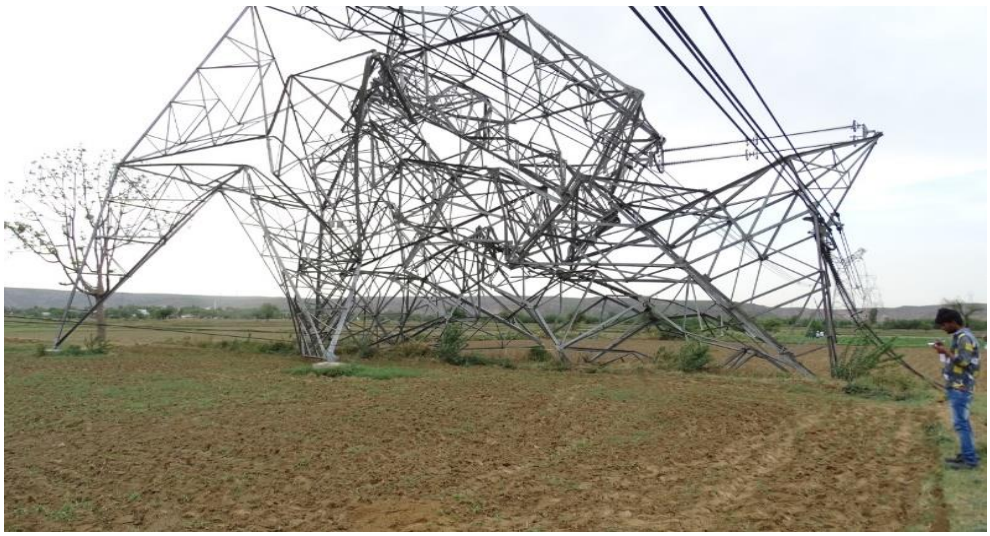
➢ **Brief Background**

765 kV S/C Agra-Jatikara transmission line, designed by PGCIL and constructed by M/s. ASTER, was commissioned on 01-05-2013. The towers of this line were designed for basic corresponding to Wind Zone-4 (wind speed of 47 m/sec)a nd 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.

➢ **Observations**

a. **Tower at Loc. No. 506 (A+0)** was located in cultivated field with very few trees in the vicinity. Tower was in erect position and tower members at the delta section of tower were buckled and converged on the tower body. All the four stubs of the tower were intact. From the failure pattern, it appeared that this tower was collapsed due to pulling force of conductor generated due to failure of tower at Loc. No. 507.

b. **Tower at Loc. No. 507 (A+0)** was located in cultivated field with very few trees in the vicinity. Tower collapsed from first panel and two stubs of the tower were intact whereas two stubs of the tower were bent. From the failure pattern, it appears that failure was initiated from this tower.



c. **Tower at Loc. No. 508 (A+0)** was in erect position and all the four stubs of the tower are intact. The members of tower at cross arm level were bent and sheared and were resting on the

tower body. From the failure pattern, it appeared that this tower was collapsed due to pulling force conductor generated due to failure of tower at Loc. No. 507.

➢ **Probable Cause of Failure**

Committee noticed that this transmission line was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C 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 and were vulnerable and in addition high intensity localized wind conditions might have prevailed in the vicinity of transmission line with wind blowing in the transverse direction of line which initiated the failure of tower.

10. 400 kV S/C Singrauli - Lucknow Transmission line failed on 16.06.2017 [(Location no. 929 (A+3) & 930 (A+0)]

➢ **Brief Background**

400 kV S/C Singrauli - Lucknow transmission line was constructed by M/s. KEC. The line was commissioned on 01-06-1986. The Length of line is 408.6 km. The towers of this line were designed for medium wind speed as per IS 802-1977 for horizontal configuration of twin

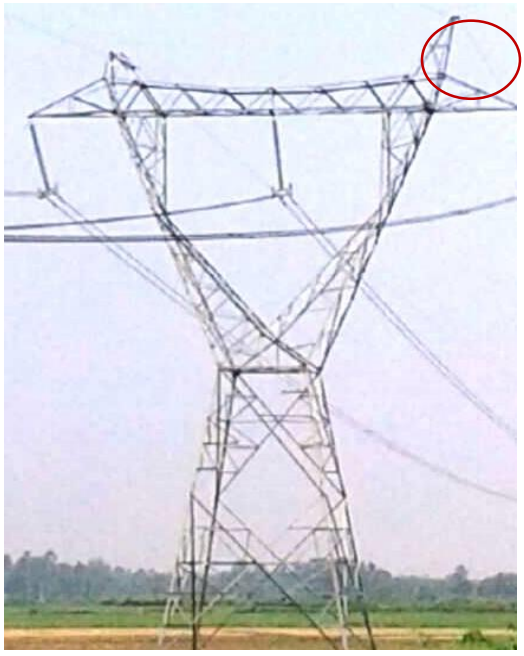
moose ACSR Conductor and were having double peak configuration with one Earthwire and one OPGW. Insulator strings used for the suspension tower are in horizontal ("I-I-I", 120 kN glass insulators) configuration insulator whereas for tension towers it is "DT" (Double tension) strings with 160KN glass insulator. There is no history of failure of tower in this line since commissioning.

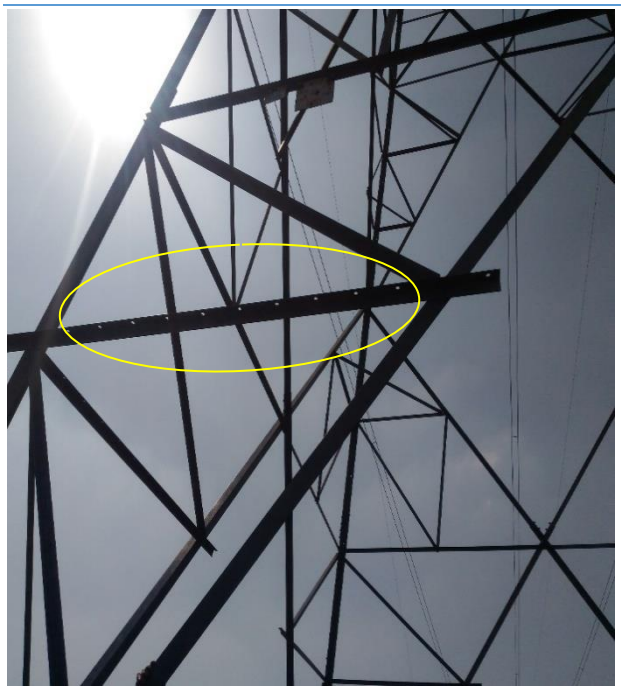
- **Observations**

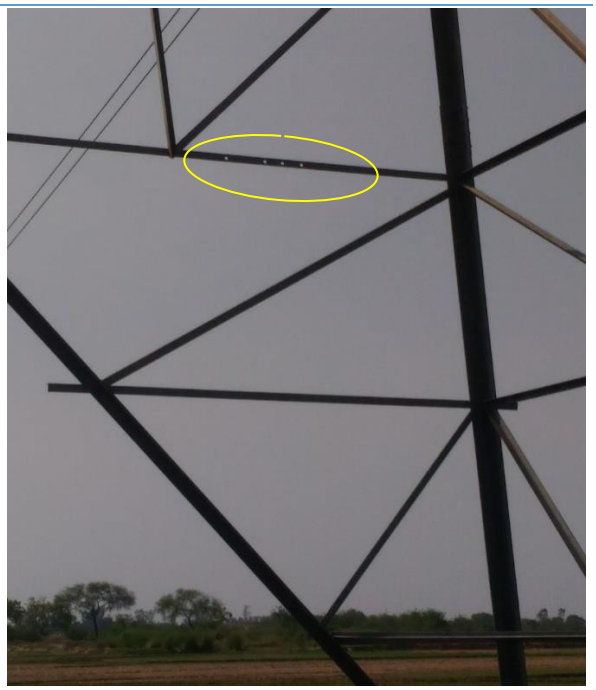
The collapsed tower is situated in a plain area. During site visit, it was informed that the farmers excavate the soil from their fields to facilitate inflow of water from surrounding areas to their fields for cultivation of rice. Abundant growth of grass was observed around tower base which might have corroded the stubs significantly. The failed towers were checked for missing/ theft of tower members and bolts & nuts thoroughly to the extents possible despite constraints due to jumbling / entangling of many members and shearing of some nuts and bolts. No tower members were found missing. However, all step bolts were missing at the time of investigation and the step holes were left unplugged. Location specific observations with respect to damaged/failed towers are as follows: -

a. **Tower at location no. 929 (A+3)** was collapsed above extension portion from the first panel in the transverse direction. The foundations of tower were not visible due to waterlogging and presence of grass around the base. Hence, the extent of damage to the foundations could not be ascertained. The failed tower was designed as per IS 802-1977 and was not strengthened by providing hip-bracing.

b. **Tower at Loc. no. 930 (A+0)** One of the earth wire peak (left side) when seen from loc. 929, was damaged. However, rest of the tower was intact and no other damages were observed to any other members/stubs. Anti-climbing device was missing allegedly due to theft. PGCIL Officials informed that theft was frequent in the area. Holes in few members were left unplugged.







➢ **Probable Cause of Failure**

The committee noted that this line was designed as per IS 802-1977 and was not strengthened by providing hip bracing in the bottom most panels. Absence of hip bracing with a large number of unplugged holes might have made the tower vulnerable and combined with localized wind storm might have caused the failure of tower at location No. 929 and damage to the ground wire peak of tower at location No. 930 was secondary failure. 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 emphasized that the PGCIL, which are facing repeated failure of lines due to high wind speed incident need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases in more realistic manner.

11. 765 kV S/C Jatikara-Bhiwani Transmission Line failed on 19.06.2017 [Tower at Location No. 9 (A+0)]

➢ **Brief Background**

765 kV S/C Jhatikara-Bhiwani transmission line was constructed by M/s EMCO and was commissioned on 01-10-2012. The length of line is 85 km. The suspension towers of this line were designed by PGCIL for Wind Zone-4 (basic wind speed of 47 m/sec) and reliability level 2 as per IS 802-1995 taking into consideration the 75% narrow front wind on tower body in broken wire condition. The towers were designed in Delta configuration with Quad ACSR BERSIMIS Conductor. The towers were having double peak configuration with one Earthwire and one OPGW. The previous failure in this transmission line was on 30.05.2014.

➢ **Observations**

Tower at Location No. 9 (A+0) failed from hamper level, where slope changes, in transverse direction towards right side while facing Bhiwani. The stubs and chimneys of the tower were intact. Tack welding of the bolts was not done. Few bolts in some joints were missing. Few

numbers of holes in some of the members were left unplugged. Coping of one of the chimney was not done. The holes made for step bolts and in universal connection plate, used for connecting bracings, were left unplugged. No damage was reported in two other transmission lines of 765 kV level namely, 765 kV Kanpur-Jatikara transmission line (Vertical configuration) and 765 kV Agra-Jhatikara transmission line (Delta configuration) traversing in the vicinity of the location of the failed tower. PGCIL officials were requested to submit wind data of nearby IMD observatory for 19.06.2017. No information was provided in this regard.

- **Probable Cause of Failure**

The 765 kV S/C Jatikara-Bhiwani transmission line with delta configuration was erected using same tower design as in the 765 kV Gaya-Fatehpur S/C 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 and were vulnerable and in addition high intensity localized wind conditions might have prevailed in the vicinity of transmission line with wind blowing in the transverse direction of line which initiated the failure of tower.

12. DETAILED REPORTS OF FAILURE OF TOWERS OF TRANSMISSION LINE OF DELHI TRANSCO LIMITED(DTL)

400 kV D/C Tikrikalan-Bawana transmission line failed on 14.05.2017
[Location no. T-116 (DC+0)]

- **Brief Background**

The line was designed and executed by KEC in the year 2000. The length of line is 18.267 km. The tower was designed for Quad Bersimis conductor for wind zone-4 (basic wind speed of 47 m/sec). No previous failure of the line has been reported.

- **Observations**

As per the report submitted by DTL, the tower at location No. 116 of 400 kV Tikrikalan-Bawana transmission line got damaged due to intense fire underneath the tower on 14.05.2017. The leg members of tower were bent and damaged. However, the tower was in erect condition due to pull force of conductor on either side of tower. The fire was caught by plastic waste present underneath the tower causing a high temperature and subsequently bulging of tower leg members. Adjacent tower span was crossing NH-10 and DMRC elevated corridor. The foundations of legs were found intact.

- **Probable Cause of Failure**

The tower was damaged due to fire in the unauthorized storage of material underneath the tower. Lack of proper patrolling of transmission line by the utilities resulted in unauthorised possession and improper usage of tower base area.

Committee suggested 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.

13. DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINE OF STERILITE POWER

765 kV S/C Jabalpur Bina transmission line failed on 05.06.2017
[Location no. 110/7 (A+0), 110/8 (A+0), 110/9 (A+0), 110/10 (A+0) & 111/0(C+0)]

➢ Brief Background

765 kV S/C Jabalpur Bina transmission line was constructed by M/s. Unitech Power Transmission Limited and commissioned on 30.06.2015 The length of line is 235.194 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.

➢ Observations

As per the report submitted by M/s Sterlite, towers at location 110/9(A+0) and 110/10(A+0) were totally collapsed and adjacent three towers at location no. 110/7(A+0), 110/8(A+0) and 111/0 (C+0) were severely damaged during the wind storm on 05.06.2017. 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. No missing members/bolts were found at the tower locations. The towers were situated in cultivated field with very few trees in the vicinity.

As reported in the investigation report, foundations were intact, there were small crack in the chimney above surface & stubs were bent. Location wise observations are as under:

a. **Tower at Location no 110/7 (A+0):** Tower was in erect condition. All the three cross-arm of the tower got bent. The foundations were intact.

Loc. No. 110-7

Loc. No. 110-8

b. **Tower at Location no 110/8 (A+0):** Tower was in erect condition. Both (left & right) bottom cross-arm got bent. The foundations were intact.

c. **Tower at Location no 110/9 (A+0):** The tower was completely collapsed.

d. **Tower at Location no 110/10 (A+0)**: The tower was completely collapsed.

e. **Tower at Location no 111/0 (C+0):** Top to middle section of the tower got bend.

➢ **Probable Cause of Failure**

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 has not been provided by the transmission utility, in spite of several requests. 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 in case of repeated failure of towers due to high wind speed incident, M/s. Sterlite Power need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases in more realistic manner.

14. DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINES OF ADANI TRANSMISSION LIMITED(ATL):

+/- 500 kV Mundra Mohindergarh HVDC transmission line failed on 24.07.2017 [(Location no. 941(DA+0)]

➢ **Brief Background**

The +/- 500 kV Mundra Mohindergarh HVDC transmission line was designed and executed by M/s. Jyoti Structures Ltd. and commissioned in the year 2012. The length of line is 990km. The line is designed for wind zone 4 (for basic wind speed of 47 m/s) with ACSR Bersimis square Quad bundle conductor per pole.

➢ **Observations**

Tower at location no. 941(DA+0) was collapsed completely to the ground. As reported in investigation report submitted by M/s ATL, the failure of tower occurred on 24.07.2018 but due to flood like conditions the repair team could reach the locations on 26.07.2108. The tower foundations were severely damaged and were displaced from original locations. Earthwire and OPGW peak of the adjacent tower was also damaged due to pulling force of conductors.

➢ **Probable Cause of Failure**

Committee noted new water course was created due to heavy rains. Improper anticipation of change in river course, lack of provision of Pile type foundation & Proper Protection (retaining wall, Gabion wall etc.) for towers near the river was observed as cause of failure.

Committee recommended that Pile type foundation may be considered for towers in flood prone area based on soil investigation report and latest high flood data, to avoid this type of failure. 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.

15. DETAILS OF FAILURE OF TOWERS OF VARIOUS TRANSMISSION LINES OF DMTCL:

1. 400 kV D/C Barh – Motihari transmission line failed on 14.08.2017 [Location no. 26/1(DQC+9)]

➢ **Brief Background**

The line was executed by Darbhanga Motihari Transmission Company Ltd. and was commissioned in August 2017. The length of line is 37.5 km. The tower was designed by M/s Jyoti Structures Ltd. as per IS: 802:1995 for wind zone-4 (for basic wind speed of 47m/s) and terrain category 2 with Quad AAAC conductor (31.95 mm dia.). Pile foundation was designed by KND, Kolkata.

➢ **Observations**

Tower at location no. 26/1 (DQC+9) failed due to high flood in the Gandak river. As reported by the company the water level of Gandak river was 600 mm above HFL and 2000 mm above danger level. Leg C pile of the tower washed away due to high water level.

➢ **Probable Cause of Failure**

Water level of Gandak river was 600 mm above HFL and 2000 mm above danger level. Committee observed that Towers were located near river bank. Due to the sudden release of water from the barrage, the velocity of the water might have been very high and some rock might have hit the foundation of tower in Gandak river, causing damage to the tower foundations.

Committee recommended that in case of damage of foundation of towers, the foundation design is required to be examined.to avoid this type of failure. 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.

400 kV D/C Mothihari - Gorakhpur transmission line failed on 14.08.2017

[Location no. 27/1(DQC+9)]

- **Brief Background**

- The line was executed by Darbhanga Motihari transmission Company Ltd. and was commissioned in August 2017. The length of line is 38.12 km. The tower was designed by M/s Jyoti Structures Ltd. as per IS: 802:1995 for wind zone-4 (for basic wind speed of 47m/s) and terrain category 2 with Quad AAAC conductor (31.95 mm dia.). Pile foundation was designed by KND, Kolkata. No previous failure of the line was reported.

- **Observations**

Tower at location no. 27/1 (DQC+9) failed due to high flood in the Gandak river. As reported by the company the water level of Gandak river was 600 mm above HFL and 2000 mm above danger level. Leg D pile of the tower got tilted due to high water level. However, no damage has been reported to tower body structure.

- **Probable Cause of Failure**

Water level of Gandak river was 600 mm above HFL and 2000 mm above danger level. Committee observed that Towers were located near river bank. Due to the sudden release of water from the barrage, the velocity of the water might have been very high and some rock might have hit the foundation of tower in Gandak river, causing damage to the tower foundations.

Committee recommended that in case of damage of foundation of towers, the foundation design is required to be examined.to avoid this type of failure. 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.

16. DETAILS OF FAILURE OF TOWERS OF TRANSMISSION LINES OF L&T:

765KV D/C Narendra (New) – Madhugiri (Tumkur) transmission line failed on 24.05.2018 [Location no. 27/2 (DS+0), 27/3(DS+0), 27/4(DS+0), 27/5(DS-1.5) & 27/6(DS+0)]

- **Brief Background**

The 765KV D/ Narendra (New) – Madhugiri (Tumkur) transmission line was designed by M/S L&T Construction (Power transmission & Distribution) Ltd. and was commissioned on 21.09.2016. The towers were designed as per IS: 802-1995 for wind zone-1 and Plain Terrain Category with Hexa ACSR Zebra in vertical configuration. At the time of failure, the transmission line was charged at 400kV voltage level. The length of the transmission line is 379.48 kms.

- **Observations**

As reported by L&T all the collapsed towers were in the cultivated land and the land inside the tower legs was also used for farming. Based on the tower failure it appeared that the wind had blown in the direction from the left to the right side when the towers are seen from AP27 to AP28. No missing of bolts & nuts and theft of members were found. Heavy rainfall along with wind occurred in that region and notable soil erosion occurred along the mud roads near the tower locations. L&T reported that the tower and conductors might have faced localized winds with varying intensity over small stretches and different spans in the section might have been affected by varying intensity of wind, hence creating an unbalanced loading on the tower. Since the suspension towers are not designed for unbalanced loading under everyday condition, the tower is likely to have experienced loading higher than the design load. L&T informed that they have carried out a detailed analysis on the tower model by varying the wind intensity and applying the differential load. Based on the above analysis it was found that due to the unbalanced longitudinal loading under reliability condition the suspension tower experienced forces higher than the designed forces which results in initiation of tower failure.
Location wise damaged are detailed as under:

a. **Tower at loc. No. 27/2(DS+0)** was collapsed completely & laid on the ground. All four Stubs got bent & broken. Cracks were observed in the foundation chimney above ground level.

b. **Tower at loc. No. 27/3(DS+0)** was collapsed completely & was laying on the ground. All four stubs got bent. Cracks were seen in the foundation chimney above ground level & reinforcing bars were exposed.



c. **Tower at loc. No. 27/4 (DS+0)** was collapsed fully & was laying on the ground. All four stubs got bent & laid down along with the tower. Cracks were seen in the foundation chimney above ground level.


d. **Tower at Loc. No. 27/5 (DS-1.5)** was collapsed from first panel and above. All four stubs & foundation were found intact.


e. **Tower at Loc. No. 27/6(DS+0)** was collapsed completely & was laying on the ground. All four stubs got bent. Cracks were observed in the foundation chimney above GL.



f. L&T vide its letter no. L&T IDPL/KTL/CEA/02-12/18 dated 17.12.2018 submitted the investigation report to CEA. The report included the wind data obtained from local wind energy firm M/s. Vena Energy. It was reported that the wind speed was observed by the mast located at Kushtagi. From the data it is observed that the wind speed was 16 m/s at 22:10 hrs. i.e. at the time of failure of towers. The maximum wind speed measured was 29.37 m/s at around 21:20 hrs. on 24.05.2018 However, the speed measured by the mast is below the design wind speed of 33 m/s considered for Wind zone-1.

➢ **Probable Cause of Failure**

The committee noticed that Wind speed data provided by the utility indicates that the wind speed was 16 m/s at 22:10 hrs. i.e. at the time of failure of towers. The maximum wind speed measured was 29.37 m/s at around 21:20 hrs on 24.05.201 which is below the design wind speed of 33 m/s considered for Wind zone-1. 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 non-availability of the actual wind speed data at the failure location, L&T need to perform reliability analysis of existing towers and for new transmission lines thorough study and deep analysis of wind speed data is needed at the initial design stage itself to avoid the failure cases in more realistic manner.

ANNEXURE -B

MINUTES

OF THE

MEETING

Minutes of Meeting of the Standing Committee of Experts on Failure of Transmission Line Towers held in C.E.A., New Delhi on 20.7.2018 to Analyze failure of towers in EHV transmission Lines during the period October 2016 to March 2018.

List of participants is enclosed at Annex- I.

Chief Engineer (PSETD) & Chairman of the Standing Committee welcomed the participants and informed that during the period of October 2016 to March 2018, failure of 48 Nos. of transmission towers in 16 transmission lines of 400 kV, 765 kV AC and ±500 kV HVDC voltage class has been reported to CEA. In these lines 48 towers failed and out of these 12 nos. towers were of tension type while rest were suspension type. He also informed that since April 2014, failure of 395 nos. of towers of transmission lines of 220 kV and above voltage class have been reported. He emphasized that attention is needed in respect of the factors like wind, design & material inadequacies, erection & O&M deficiencies which in majority of cases contribute to the failure. However, utilities mostly put blame on high wind as cause of failure, this needs to be minutely deliberated in the meeting.

In context of wind data /information, he informed that IMD was consulted regarding the measurement of wind speed, periodicity, squall, Gust wind, wind at any specific site etc. In reply IMD informed that the wind speed is measured by anemometers installed at various IMD stations across the Country, however the IMD stations are limited, which becomes a major constraint in estimating the wind speed at any specific tower location. IMD informed that wind data measurement is also possible using Radar if convective clouds are formed in that area. IMD informed that wind data is shared with SERC so that the same can be used for further analysis and wind mapping.

He requested the invitees & experts to share their experience in respect of major causes of failure of towers of various EHV transmission lines. PGCIL and other transmission utilities were requested to explain the details of failure pattern of failed towers with PPT presentations.

Based on the presentations of PGCIL, DTL and other transmission licensee the causes of failure of towers in various transmission lines were discussed in detail and the outcome are summarised hereunder:

Cases of failures discussed in the meeting are at Annex-II.

1) In the case of accidental failure of DB+25m tower at location No. 52of 400 kV D/c Dadri-Panipat transmission line of PGCIL, the failure was attributed to hitting of the lower most panel of the tower by a dumper due to which the tower became unstable and fell from stub level in transverse direction. It was reported that there was a kachha road right below the tower since construction of the line which was later on converted into black top tar road. Member Secretary, NRPC, stated that after noticing the construction of road below the tower during regular patrolling of the transmission line, PGCIL should have reported the matter to district administration & CEA. They should have requested district administration for proper administrative action for shifting of road from the tower location (DB+25) to avoid such type of accidents. It was pointed that proactive action by PGCIL could have prevented such incidence. PGCIL stated that the FIR has been lodged for the failure incident with local police station.

Member Secretary (NRPC) emphasized about the need of thorough study of wind speed data as in most of the failure cases wind speed exceeding design value was found /anticipated as the main cause of failure and suggested that deep study & analysis of wind data should be carried out by the concerned utility at the initial design stage itself and should not be taken as de facto cause for every failure.

In view of more nos. of failure of 765 kV S/C Delta configuration tower of PGCIL, the design review analysis of 'A' type tower was carried out by CPRI as per the decision taken in earlier standing committee meeting in CEA. On the basis of examination and analysis of 'A' type delta tower, strengthening of few members above waist level was proposed by CPRI which was recommended in the earlier meeting of the standing committee of experts.

In this regard, Member Secretary (NRPC) informed that the strengthening at site done by PGCIL as clamping of additional member to the original members may provide instability to the geometry of tower. As such, it is not the proper method of strengthening and may not fulfil the objective. He further indicated that during site visit in connection with failure of towers in Agra region, cases of strengthened towers also being failing was observed.

2) Representatives from M/s Sterlite Power made the following observations and suggestions in respect of failure of towers:

i) There are some misprints and error in BIS code 802- Part-I/Sec-I-2015. The incorrect clauses are to be rectified and corrected.

ii) The wind data available is not reliable. More analysis of wind data and understanding of design & analysis in view of repeated failure of 765 kV S/C towers revealed some lacuna in design & analysis, which needs to be analyzed thoroughly to avoid such type of repeated failure because 765 kV voltage level EHV transmission lines are very vital in respect of reliability of grid and outages of these lines may not be repeatedly tolerated as the same have got huge commercial implications. Apart from wind, there may be other factors contributing to the failure of towers. It was suggested that external consultant may be hired for proper analysis of failures.

iii) Wind map suggested by SERC should be incorporated in the IS 875. Wind zone of Delhi has changed from wind zone- 3 to wind zone- 5, similarly there might be change in wind zone for other areas also. Most of the failures take place in the Months of April to June. Till next season, some changes are required to be done so that further collapsing of towers due to wind could be stopped.

iv) Video streaming of Erection and patrolling through Drone should be carried out.

v) It was also suggested that the failure analysis of tower should be carried out simulating the similar loading condition to draw realistic inferences about causes of failure.

3) Representatives from M/S KEC made the following broad observations and suggestions:

i) M/s KEC also pointed out about misprints and several errors in IS: 802 Part-I/Sec-I 2015 and stated that 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 requested early rectification of the same. He informed, that presently most of the power utilities and transmission

licensee have started using the new version of IS: 802 Part-I/Sec-I (2015) for design and analysis of towers and there are chances of design inadequacy because of less loading considered during design due to reduced Drag Coefficient in new IS.

ii) He stated that the wind data /load considered for design of towers in Indian condition are appropriate and is considered almost in the same manner as the world-wide practice. Apart from changing wind pattern, design and analysis with proper load modelling of tower is essential as the tower is subjected to these loading conditions at site in exposed environment through-out its service life.

iii) M/s KEC suggested for placing of anemometer on towers at regular intervals for real recording of wind data and its interpretation. In case of difficulty, provision of installation of anemometer should be done at each substation.

iv) He also emphasized framing of guidelines for construction of tower erection methodology and stringing so that the same may be made available to Contractor to follow for quality establishment in construction and installation of tower. In this regard a small committee should be constituted to formulate the strategy for making guidelines.

v) For towers in the areas where whirlwind is a regular phenomenon, span length may be reduced.

4) Representatives from M/S Adani made the following observations and suggestions:

i) Due to High Intensity Winds (HIW), torsional loads on towers are generated initiating failure because towers are generally not designed for such type dynamic wind loading condition. The use of tubular section (similarly like microwave/cellular towers) which are more effective in withstanding sustain local cyclonic wind which is dynamic in nature was suggested.

ii) Video streaming of Erection through Drone for better quality of installation.

iii) Suggested rectification/correction in IS: 802 –Part-I/Sec-I (2015).

5) Representatives from M/S L&T made the following observations and suggestions:

i) Suspension towers are more prone to failure than tension towers. Study is required to analyze these failures and suggesting strengthening measures.

ii) Wind pattern is changing during last few years, it should be studied for better wind mapping. Wind map suggested by SERC has been included in the revised National Building Code by BIS, however, no change has been carried out in IS 875. Utilities are advised to design the tower as per revised wind map of India as suggested by SERC.

6) PGCIL representatives made the following observations and suggestions:

i) PGCIL stated that intensity of wind/ wind speed has been changed in some region of India due to climate change. In this regard, SERC also carried out study in the year 2009 in respect of changing wind speed / pattern and categorization of wind zones accordingly in the wind map of India. The revised wind map was submitted to BIS for incorporation in the IS 875, but the same has not been incorporated. Although these changes have been suitably incorporated in National Building code. PGCIL further added that since 2009,

wind speed might have further changed and SERC may take up further revision in wind map after study.

ii) PGCIL requested that the issue of change in wind speed/wind zone should be taken up at priority basis with BIS for revision in Indian standard. Due to change in wind pattern / phenomena some area of WZ-4 has been covered under WZ-5, whereas towers were designed considering loading condition of WZ-4 and because of higher loading on conductor, earth wire and tower and the towers might fail.

iii) If the revision of wind map form BIS is delayed, in future onwards the tower design should be done in as per revised wind map to safeguard towers against wind failures. It was suggested that revised wind map of SERC may be included in RFP documents for TBCB projects.

iv) IMD & SERC should study the changing Wind Pattern in the country and its impact on Transmission Towers.

v) In IEC 826 the effect of longitudinal wind on loading of tower is considered whereas IS 802-Part-I/Sec-I (1995) wind load on transverse face is being considered. The same need to be addressed.

vi) Study for analysis of design of 765 kV transmission towers has been given to CPRI and they recommended to strengthen few members above waist level. The strengthening of 765kV Delta configuration tower are being done accordingly.

7) SERC representatives made the following observations and suggestions:

i) SERC informed that based on the data/information (related to wind velocity and wind pattern) provided by Indian Meteorological Department (IMD) detailed analysis is carried out using software to arrive at wind zones. They told that in normal condition there is less/nil wind at the ground level which increases gradually with increase in height. However, during cyclonic condition the pattern of wind is quite uniform and doesn't vary much with the height. Wind characteristic is different in thunderstorm/downburst. 3-component anemometer is required to be installed to measure vertical component of the wind.

ii) As per IS 875, importance factor for cyclonic region i.e. k4 factor is used to include impact of cyclonic storm in a belt of 60 km from coastal area. However, this factor is not considered for tower design. It was informed that one pilot project in Nellore to study the cyclonic wind pattern and based on analysis K4 factor may be introduced to take care of cyclonic wind condition.

iii) For better clarity on wind data/speed and reliability, radar based data gives more accurate information for proper analysis of wind pattern/changing climatic condition.

8) Chief engineer (TPE&CC) emphasized that all the time exceeding wind speed /localized storm cannot be sole reason of failure of towers. Some more insight is needed to focus on other issues such as adequacy of design and analysis, quality of erection & stringing, O&M practices etc. in order to protect the tower. He further elaborated, that although IS code is required to be followed for design and analysis of towers, based on the past experience of type / pattern of failure transmission utility should be capable to analyse the case and take

sound decision in respect of safety of tower. He suggested PGCIL to do thorough study in respect of design analysis of 765 kV transmission towers as a particular type of tower is failing frequently.

9) Member Secretary (WRPC) made following observations and suggestions:

i) Exceeding wind speed should not be only cause of failure of tower. Poor workmanship during erection and stringing of tower is also a major issue.
ii) Issue of erection deficiency like improper tack welding, missing bolts and missing members, unplugged holes etc. need to be addressed.

10) CPRI representatives made the following observations and suggestions:

i) CPRI had carried out design review analysis for 765 kV S/C Delta configuration tower wherein strengthening of few members above waist level was recommended by replacement of existing members. However, strengthening by clamping of additional member to existing member, a methodology adopted by PGCIL, was not suggested by CPRI.

ii) Many times bolts are responsible for tower failures as number of bolts are found inadequate. Sometimes member theft, erection deficiency etc. may also be the cause of failure. Workmanship in tower erection is also very important.

11) Chief engineer (PSPA-II) stated that there was design issue in 765kV delta configuration tower which has already been established as per the design review analysis done by CPRI. He further elaborated that report submitted by CPRI to CERC recommended strengthening of few members above hamper level by replacement of existing member which is to be implemented by Powergrid in phase manner. As present condition, there is need to address the actual behaviour of strengthen tower to draw more realistic approach for next course of action. The main objective now is to strengthen existing tower in such manner so that failure to the best extent could be minimized.

12) After detailed deliberations / discussions among all participants the committee observed the following causes which attributed to failure of EHV towers:

1. 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.

2. The erection deficiency, such as missing cover plates, missing bolts in joints in leg member, unplugged holes, hanging erection trolley (used for stringing) etc.

3. 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.

4. The 765kV S/C Gaya-Fatehpur renamed as Gaya-Varanasi-I transmission line with delta configuration earlier also 5 times failed. The failure of the line investigated by standing committee of experts established drawback in design of tower. The inadequacy in design coupled with the reported storm caused the failure of tower.

5. One of the causes for failure tower was observed as due to intense fire underneath (in private premises) the tower (DTL).

6. In one of the failure cases, change in river course occurred. In such cases pile foundation would have been provided. Proper Protection (retaining wall, Gabion wall etc.) was also not provided for towers near the river.

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

8. Improper coping of chimney and protruded Steel reinforcement may result into rusting of stubs and legs.

13) 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. Although the wind map was revised by SERC in 2009, the same has not been incorporated by BIS in IS 875. However, this map has been included in National Building Code. Although Chief Engineer, PSE&TD vide letter No. CEA/PSE&TD/302-J/2017/332-33 had requested BIS for revision of wind map in IS 875, no action has been taken so far. The matter may be taken up again with BIS.

(b) Towers in India are designed for 50, 150 or 500 return period as per IS-802. There is huge gap between return periods of 150 and 500. The option of introducing return period of 250 was deliberated by the Committee. It was also deliberated to explore option of introduction of suitable factor for high intensity wind conditions. It was suggested to constitute a subgroup to look into any deficiencies in present IS 802 and suggest suitable provisions to BIS for incorporation. Sub group would also be tasked with the work of preparing guidelines for material procurement and operation & maintenance practices.

(c) IMD may be requested to install more wind stations all over India so that more reliable and accurate wind data could be collected for analysis and wind mapping.

(d) For the transmission lines to be laid within 50 Kms of the border of the wind zones may be designed with higher these two zones. SERC shall give a view on this.

(e) Number of towers have failed due to extreme wind event and the same is happening on regular basis. Hence, it is advised to design the TL towers considering the variability present in loading estimates, modelling and member capacity calculations. For the existing tower, it is suggested to perform reliability analysis in order to estimate the associated risk of failure for the variations in wind load.

(f) Changing climatic condition/wind pattern should be deeply studied with the help of wind experts in India.

(g) Erection of towers (Slope correctness, filling unplugged holes, tightening of Bolts, Tack welding, straightness of tower members etc.) needs strict quality control.

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

(i) Incorporation of additional factors based on the experience of utility in respect of safety of Towers installed in wind prone area (resulting increase in margin of safety of tower members).

(j) Timely assistance from local administrative authority and to protect the tower from unreasonable/accidental failure (hitting of Dumper etc.) as it is huge commercial loss of national asset.

(k) Earlier study of SERC in respect of wind map of India was carried out in year 2009. During last 9 years more changes may be expected. Further study to draw inferences may be carried out by SERC for better clarity on wind data.

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

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

(n) The material test report of failed towers should be examined to ascertain the quality of the material.

(o) PGCIL should submit PLS-TOWER version of File (design of 765 kV Tower) to CEA for cross analysis.

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

ANNEX - I

List of Participants

1. **CEA:**

    1. Shri Sanjay Srivastava, Chief Engineer (PSE&TD) and Chairman of the Committee
    2. Shri S. K. Ray Mohapatra, Chief Engineer (PSP&PA-II)
    3. Shri R. S. Ram, Chief Engineer (TCD)
    4. Shri Narender Singh Chief Engineer (TPE&CC)
    5. Shri Neeraj Kumar, Director (TCD)
    6. Shri Y. K. Swarnkar, Director (PSE&TD)
    7. Smt. Kavita Jha, Deputy Director (PSE&TD)
    8. Mr. Faraz, Dy. Director (PSE&TD)
    9. Ms. Bhaavya Pandey, Assistant Director – II (PSE&TD)
    10. Shri Karan Sareen Assistant Director- II (PSE&TD)
    11. Ms. Sippy Srivastava, Engineer (WAPCOS India Ltd.)

2. **NRPC, Katwaria Sarai:**

    1. Shri M.A.K.P. Singh, Member Secretary
    2. Shri Upendra Kumar, SE

3. **WRPC, Mumbai:**

    1. Shri A. Balan, Member Secretary

4. **Powergrid Corporation of India Ltd. (PGCIL):**

    1. Shri Anish Anand, General Manager(Engg-TL)
    2. Shri A.K. Vyas, Addl. General Manager(Engg-TL)
    3. Shri Rajeev Kumar, Deputy General Manager
    4. Shri Abhishek, Deputy General Manager
    5. Shri Manoj Kumar Singh, Assistant General Manager

5. Delhi Transco Limited (DTL):

    1. Shri Loveleen Singh, General Manager, Delhi Transco Ltd.

6. **CSIR- SERC, Chennai:**

    1. Shri G. I. Palani Chief Scientist & Head
    2. Shri P. Harikrishna, Senior Principal Scientist

7. **CPRI, Bengaluru:**

    1. Dr. M. Selvaraj, Joint Director

8. **M/S. KEC International Limited, Mumbai:**

1. Shri E.V. Rao, Vice President
2. Shri R.R. Patel

9. M/S. Sterlite Power

1. Shri T. A. N. Reddy, Vice President
2. Dr. Deepak Lakhapati, Chief Design Officer
3. Shri Rohit Gera, Deputy Manager

10. **M/S. Adani Transmission Limited**:

1. Shri Bipin Shah, Sr. Vice President(Engineering)

11. M/S. L&T Ltd.:

1. Shri P. G. Suresh Kumar, Head Transmission (Business)
2. Shri Ojes.C. Madappattu, Senior Manager (Projects)
3. Shri C. Rathinavel, Engg. Manager
4. Shri C. Suresh Balu Reddy, Head Engineer

ANNEX-II

(a) Transmission Lines of PGCIL:

1. 400kVD/C Dadri - Panipath, transmission line failed on 26.02.2017 at Location Nos.50(DA+0), 51(DA+9), 52(DB+0), 53(DD+0) and 54(DA+0).

2. 400kV D/C Silchar-Purba Kanchan Bari transmission line failed on 2.04.2017 at Location Nos.124(DA+0), 125(DA+0), 126(DA+0), 127(DD+6), 128(DD+9), 137(DA+0), 138(DA+0) & 139(DD+0).

3. 765 kV D/C Wardha – Nizamabad – 1 & 2 transmission line failed on 6.04.2017 at Location No.175/8 DCT (509).

4. 400kV S/C Koderma- Bokaro transmission line failed on 13.5.2017 at Location No. 172(DA+0), 173(DA+0), 174 (DA+6) & 175 (DD+9).

5. 400kV D/C Farakka-Kahalgaon I & II transmission line failed on 15.5.2017 at Location No. 142(DA+0), 143(DA+0), 144(DA+6) & 145(DA+0).

6. 765 kV S/C Gaya- Varanasi- I transmission line failed on 17.05.2017 at locations AP-65 (A+3), AP-66 (A+0), AP-67 (A+0), AP-68 (A+0), & AP-69 (C+0).

7. 765 kV S/C Bina -Gwalior transmission line failed on 5.06.2017 at Location No 511(A+3) & 512 (D+0).

8. 765 kV S/C Bina- Indore transmission line failed on 14.06.2017 at Location No. 235(A+0), 236 (A+3), 237 (A+0) & 238 (D+0).

9. 765 kV S/C Agra- Jatikara transmission line failed on 14.06.2017 at Location No. 506(A+0) 507(A+0) & 508(A+0).

10. 400 kV S/C Singrauli- Lucknow transmission line failed on 16.06.2017at Location No. 929(A+3) 930 (A+0)

11. 765 kV S/C Bhiwani- Jhatikra transmission line failed on 19.06.2017 at Location No. 9(A+0).

(b) Transmission Line of DTL:

1. 400kV D/C Tikrikalan- Bawana Transmission line failed on 14.05.2017 at Location No.116 (DC+0).

(c) Transmission Line of M/s Sterlite:

1. 765 kV S/C Jabalpur- Bina transmission line failed on 5.06.2017at Location Nos. 110/7 (A+0), 110/8 (A+0), 110/9 (A+0), 110/10 (A+0) & 111/0 (C+0)

(d) Transmission Line of M/s Adani

1. ±500 HVDC Mundra- Mohindergarh Transmission line failed on 24.07.2017 at location No. 941(A type).

(e) Darbhanga- Motihari Transmission Co. Ltd. (Essel Infra Projects):

1. 400kV D/C Barh-Motihari Transmission Line failed on 14.08.2017 at Loc. No. 26/1.
2. 400kV D/C Motihari-Gorakhpur Transmission line failed on 14.08.2017 at Loc. No. 27/1.

ANNEXURE -C

COMPOSITION OF STANDING COMMITTEE OF EXPERTS

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