Minutes of Meeting of the Standing Committee of Experts on Failure of Transmission Line Towers held in CEA, New Delhi on 02/12/2016 in respect of failure of towers in 132 kV & Higher Voltage Transmission Lines during the period from December, 2015 to September, 2016.

List of participants is at Annexure- I.

1. Chief Engineer PSE&TD & Chairman of the Standing Committee of Experts welcomed the participants including invitees of Transmission Licensees/Experts in the field and highlighted about the number of failure of towers of transmission lines of different voltage levels belonging to various Utilities, the various types of failure of towers during the period from December, 2015 to September, 2016. He informed that the representative from National Institute of Wind Energy (NIWE) was invited to discuss about sharing of the wind data from measuring/monitoring station of NIWE and how their data can be best used for the wind speed mapping of the country as NIWE have more than 800 wind data measuring stations all over the country. Due to some urgent engagement, NIWE representative could not attend the meeting.

2. Chief Engineer PSE&TD then requested invitees & experts to share their experience on failure of towers. Dr. M. Selvaraj, Joint Director of CPRI and Mr. B.B. Shah of M/s Adani made presentations (enclosed at Annexure-II & III) on failure of towers during testing and their observations on failure of towers, in general.

3. Representative from CPRI stated that most of the cases of failure of towers during testing has occurred under loading corresponding to security condition. The failed towers are generally strengthened and retested. But it is observed that in case of failure(s) under reliability condition, complete collapse of tower has taken place. He also stated that failure of towers have also taken place during the waiting period of five minutes under full load condition and hence suggested that tower should be tested as per provisions of relevant IS and observed until specified waiting period is over.

4. Representative from M/s. Adani Transmission Ltd. (ATL) stated that under full loading condition, deflection of tower increases continuously. The waiting period should be sufficient enough to transfer load from loading point to the base of the tower. Representative from CPRI replied that when load is removed, the tower is supposed to come back to its original position because it operates within elastic limit although some residual deflection will remain. Chief Engineer (PSE&TD) mentioned that deflection of tower is not specified in the design criteria for lattice structure, but in case of pole structure, deflection limit is specified. Representative from M/s. ATL suggested that the actual deflection can be measured using strain gauge method.

Representative from PGCIL stated that strain gauges also have limitations as it is difficult to determine the exact positions to put strain gauges on the tower body. Representative form SERC also supported his view and said that the strain gauges are also not reliable once the material exceeds yield stress limit. Representative from M/s. ATL added that a jerk is generally experienced on the tower body on removal of the applied load. It is always desirable to observe the behavior of structure/tower under loading conditions for waiting period as stated in the IS 802.

5. Representative from CPRI stated that limitation of deflection in Pole structure is not specified in the regulation. He also stated that the deflection of Pole structure may alter the clearance provided. Representative from M/s. ATL added that British code is followed in the design of Pole type towers in India but it does not specify about the residual deflection of tower. PGCIL representatives also seconded that there is no acceptance criteria for residual deflection. Representative from M/s. STERLITE supplemented that if the tower fails to return to its original position after application of load, it will certainly fail before the expected life time of the transmission line due to changing environmental conditions, particularly increase in wind speed in some part of the country.

6. Representative from CPRI stated that many a times, bolts are responsible for failure of tower during testing, because either number of bolts are not adequate in the design and/or proper care has not been taken during erection of tower. PGCIL representative mentioned that the bolts may fail during testing because of the fitment error.

7. CPRI representative mentioned that in the last 5 years, the average percentage of failure of towers (66 kV to 765kV) during testing is 23%. It is observed that the failure rates is more at higher voltage level.

8. PGCIL stated that the intensity of wind has changed in some part of the country, but the wind map of India has not been revised accordingly by BIS. Representative of SERC informed that revised map was submitted to BIS for inclusion in relevant standard, which has not incorporated so far. The members of the Committee decided that CEA should write to BIS for revision of wind map both in IS 875 and IS 802. Chief Engineer, PSE&TD informed the members that CEA would also request BIS to take initiative for formulating standard for the design of Steel Pole structures in line with international standards.

9. Then, Chief Engineer PSE&TD requested Mr. B.B. Shah from M/s. ATL to go ahead with his presentation (enclosed at Annexure-III). He highlighted various causes of failure of

transmission line towers. On query regarding the raising the chimney heights to about 5-6m, he stated that problem is being faced during erection of raised chimneys as proper stub setting becomes difficult. Director, TCD, CEA supported his views and said that the raised chimneys should be avoided as far as possible because a small error in stub setting may cause a change in stub angle leading to change in the slope of tower, which is not desirable. Representative from M/s. ATL highlighted further that the funnel effect of wind and increase in wind speed due to diversion/obstruction by trees, increase in terrain roughness coefficient for towers located near large water body, theft of tower members, local tornado effect, soil erosion around chimney and rusting of stub etc are some of the reasons for tower failure. He suggested that precautions like strengthening of suspension towers, immediate replacement of missing members, strengthening of existing members with additional Steel clamps, providing proper revetment & use of geosynthetic material in foundation, providing concrete encasing and painting of stub in water logging areas etc. should be taken up to reduce the failure rate.

10. The representative of SERC, Chennai informed the committee members about R&D initiative taken by SERC regarding strengthening of tower members without replacing the members or nuts & bolts. He said that SERC is developing Glass Fiber Reinforced Polymer (GFRP) based material for strengthening members of tower in existing line without requiring any nuts & bolts and minimizing the shut down time of line. Representative from PGCIL reported that they have taken up a pilot project for strengthening of tower members using steel clipping materials, but shut down would be required while using them. He supported the idea of SERC as it will be easier to use GFRP clipping arrangement compared to steel clipping which would be heavier in comparison to GFRP.

11. The committee observed that some of the failed towers of various lines of PGCIL were designed according to old IS:802(1977). Members of committee were of the opinion that PGCIL should check the adequacy of existing tower according to IS:802(2015). PGCIL stated that strengthening of old tower conforming to new IS:802(2015) would be difficult as the existing towers may not meet the design requirement according to new IS code and may need replacement, which is not desirable. PGCIL suggested to strengthen such towers by providing hip bracings up to bottom cross arm level.

12. Then the Utilities (Powergrid and DTL) discussed in detail on tower failure of the following lines:

(a) Transmission lines of Powergrid

(i) 400kV D/C (Quad) Nellore – Tiruvalem Transmission Line failed on 04.12.2015 (One tower at Location No: 13)

(ii) 400kV Rourkela – Sundargarh – Raigarh LILO – I Transmission Line failed on 24.01.2016 (Two towers at Location Nos. 21(DD+0) & 22(DA+0))

(iii) 400kV S/C Uri II – Wagoora Transmission Line failed on 26.01.2016 (One tower at location no. 135 (D+9))

(iv) 765 kV S/C Angul- Sundargarh Transmission Line-Ckt-I transmission Line failed on 12/02/2016 (1 no. Angle towers at Loc. No. 42A/0)

(v) 765 KV S/C Gaya-Varanasi-Fatehpur transmission line failed on 07.03.2016 (Location. No. 715 (A+3))

(vi) 400 kV S/C Jeypore- Indravati Transmission Line failed on 15.03.2016 (Two towers at Location Nos. Loc. No. 119 &120)

(vii) 765 kV S/C Moga-Meerut Transmission Line failed on 13-05-2016 (Location No.: 649)

(viii) 765 kV S/C Bina-Gwalior-III Transmission Line failed on 21.05.2016 (Location No. 614)

(ix) 765 kV S/C Jaipur(Fagi)-Bhiwani Ckt-I transmission line Failed On 23.05.2016 (Location No. 65/4 (SA+0), 66/0 (SE+0), 66/1(SA+0), 66/2 (SA+0), 67/0 (SD+0), 67/1 (SA+0), 67/2 (SA+0) and 67A/0 (SB+0))

(x) 400 kV D/C Jind - Bhiwani Transmission Line Failed on 23.05.2016 (Location No. 170) & on 29.05.2016(Four towers at location No.12, 13, 14 & 15 (all DA type))

(xi) 400 kV S/C Farakka-Sagardighi Transmission line failed on 27.05.2016 (Location no. 19 (A+0))

(xii) 220KV D/C Hisar-Hisar (I/A) Transmission Line failed on 29.05.2016 (Tower at Location No. 2 (DA+18))

(xiii) 765 kV S/C Meerut-Greater Noida Transmission Line failed on 13.06.2016 (Tower at Location No. 464 (A+3))

(xiv) 220KV D/C Kakrapar – Haldarwa Transmission Line failed on 04.07.2016 (Towers at location No. 7 (DD+0) and 8(DC+3))

(xv) 220 kV D/C Mariani-Mokokchung Transmission Line failed on 12.07.2016 (Location no. 56 (DC+3) & 57 (DC+0))

(xvi) 400 KV D/C (QUAD) Kishanganj - Patna transmission line failed on 26.07.2016 (Location No. 51 (DD+18))

(xvii) 400 KV D/C (QUAD) Kishanganj - Patna transmission line failed on 01.09.2016 (Location No. 128D/0 (DD+25), 128E/0 (DD+25), 128F/0 (DD+25), 128G/0 (DD+25) & 129/0 (DD+09))

(b) The Transmission Lines of DTL:

400 kV D/C Bamnauli-Jhatikara transmission line failed on 22.05.2016 (Location no. 169 (Dead End Tower))

13. Committee observed that major cause of failure of towers are as under:

a) The high wind velocity during storm, cyclone and local phenomenon of whirlwind and gale etc. might have exceeded the wind speed for which the tower is designed. This type of wind is difficult to predict. The probability of such occurrences is low & the tower design will be uneconomical if such situation is considered in the design.

b) Theft of tower members, generally the theft of secondary members (connected with one or two bolts) of the towers by the local people makes the tower structurally weak which ultimately leads to failure during storms/whirlwind/cyclone etc;

c) It is also difficult to take into account demolishing activities by miscreants like cutting/blasting the main members of the tower, during design or construction stage.

d) Many lines are in operation with towers designed according to old Indian Standards (IS: 802 -1977). The Indian Standard has been revised subsequently in the year 1995 and 2015 to incorporate new design concepts. Though suspension towers in some of the vulnerable lines have been strengthened, it is not prudent to abandon/strengthen all these lines currently in operation. However, based on frequency of failure, the towers need to be strengthened.

e) Lack of proper soil investigation and deficiency in design/construction of foundation of towers may also result in failure of towers.

f) Sometimes, proper protection has not been provided for foundation of towers in steep slope/hilly terrain. Many times landslide causes erosion of soil below foundation which in turn causes the failure of foundation and subsequently failure of towers.

14. Committee suggested the following remedial measures.

a) Utmost care must be taken during erection of towers to avoid failure due to erection deficiencies.

b) Regular patrolling of the lines is required for smooth and trouble free operation of line.

c) Frequency of patrolling of lines must be increased in theft prone areas and missing members should be replaced as early as possible to avoid failure of towers due to theft of tower members.

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

e) Possibility of strengthening of members of failed towers by adopting new technologies like live line clipping of members (GFRP clipping/steel clipping) should be explored as a pilot project.

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

g) 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).

h) The material test reports of members of the failed tower should be submitted to ascertain the quality of steel material used.

i) Powergrid should strengthen the failed towers of the 765kV S/C line [with Delta configuration and designed for wind zone-4] in line with 765kV S/C Gaya-Fatehpur transmission line as suggested by the Standing Committee in the previous meeting held on 08.12.2015.

j) 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.

k) Pile type foundations may be considered for towers in flood prone areas based on soil investigation reports and latest high flood data.

l) In case of damage of foundation of towers, the foundation design/construction and soil investigation report need to be examined.

m) DTL should take necessary action to replace the tower at location No.173 of Bamnauli – Ballabgarh 400kV line with a new tower along with new foundation and should take utmost care to avoid erection deficiencies and repetition of such failure of towers in future.

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

ANNEXURE-I

List of Participants

Central Electricity Authority

1. Shri. S.K.Ray Mohapatra , Chief Engineer, PSE&TD Division
2. Shri. Neeraj Kumar, Director, TCD Division
3. Shri. Amit Kumar, Deputy Director, TCD Division
4. Shri. C.N.Devarajan, Deputy Director, PSE&TD Division
5. Ms. Kavita Jha, Deputy Director, PSE&TD Division
6. Shri. Mohit Mudgal, Assistant Director, PSE&TD Division

Powergrid Corporation of India Ltd.

1. Shri. A. K. Vyas, Addl. GM (Engg.TL)
2. Shri. Abhishek, Asst. GM(Engg.TL)

Central Power Research Institute, Bengaluru

1. Dr. M. Selvaraj, Joint Director

Council of Scientific and Industrial Research

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

Wapcos Ltd.

1. Shri. Vijay Pal, Consultant

Delhi Transco Limited

1. Shri. Loveleen Singh, GM (T)

IEEMA

1. Shri. J. Pande, Sr. Director
2. Shri. Naveen Upreti, Sr. Executive officer

KPTL

1. Shri. Milind B. Nene, Sr. V.P.
2. Shri. P.K. Chaubey, V.P.

Sterlite Power

1. Shri. S.C. Ghosal, V.P.(Projects)
2. Shri. Jeetendra Bisht, Customer Decision Strategy
3. Shri. K.R. Suri, Consultant

Adani Transmission Limited

1. Shri. Bipin B Shah, Sr. V.P.