Report of First Pilot audit of Transmission Tower by the audit team of the committee constituted for audit of transmission towers with respect to design and the life of the towers (on a 5% sampling basis).

Constitution of Committee:

The Committee for the audit of transmission towers with respect to design and the life of the towers (on a 5% sampling basis) was formed under the Chairmanship of Member (Power System), CEA as per MoP letter No. 3/5/2017-Trans. Dated 07.08.2017. As proposed by MoP, the other Members of the Committee includes Chief Electrical Inspector, CEA as Member Secretary, COO, CTU, PGCIL, representative from CPRI and SERC under CSIR.

The Committee under the chairmanship of Member Power System, CEA had its first meeting on 19.9.2017 wherein the terms and conditions and the procedure for carrying out the tower audit was discussed. The Committee also felt the need for inducting some Members from CEA and State Electricity Departments for facilitating its working and also for having a better view regarding the transmission line that needs to be covered under audit in the State. Accordingly, the Committee decided to induct the members from the following States in the Committee:

Member from CEA

(i) Chief Engineer, PSE&TD

Members from the State TRANSCOs in the Committee:

(i) Maharashtra
(ii) Chief Engineer Trans. GETCO, Gujarat
(iii) Director Transmission/Projects, TANTRANSCO, Tamil Nadu
(iv) Director Projects WBSECL, West Bengal
(v) Addl. Chief Engineer (MPT&S), RVPN, Jaipur, Rajasthan

The Committee held its second meeting on 14.11.2017. The meeting discussed the procedure for carrying out the audit and the check-list that was required for carrying out the Audit. The Members discussed the issues for carrying out the Tower Audit and were of the view that carrying out the tower audit on pan India basis would be cost intensive and would be difficult to be carried out by the Committee Members of their own. However, to start with, pilot audit of some transmission towers nearby Delhi NCR areas belonging to M/s POWERGRID and Delhi Transco could be taken up by the Members themselves. These would give the audit team the required understanding and would provide the base for taking up future Tower Audit.

Accordingly, a team to carry out the transmission tower audit of various utilities were identified. The team comprises of the following members:

i) Chief Engineer, PSE&TD
ii) Member each from CPRI
iii) Member from SERC and POWERGRID.

It was decided that while carrying out the tower audit of the State utilities, the Members from the respective State would be involved for obtaining the required information's and logistic support for carrying out the audit.

The Audit Committee decided that to start with a Pilot audit with some of the critical line of POWERGRID and Delhi TRANSCO, which are close to Delhi NCR may be chosen for carrying out the audit. Subsequently, the lines from other region could be taken up for auditing. Based on the information and the experience gained out of the pilot audit, the detailed programme for future audit of transmission towers in other states would be chalked out.

In line with the decision of the the 2nd meeting of the tower audit Committee, it was decided that the first pilot audit of the transmission towers of POWERGRID would be carried out on 9th and 10th January, 2018. Following members participated in the First Pilot audit of the tower.

i) Shri Goutam Roy, Chief Engineer, CEI, CEA
ii) Shri Sanjay Srivastava, Chief Engineer, PSE&TD, CEA
iii) Shri D Revanna, Representative of CPRI
iv) Shri P K Umesha, Representative of SERC under CSIR
v) Shri Ram Niwas, General Manager, POWERGRID

The Committee inspected the towers of the following lines based on the check list prepared by the Committee Members:

i) 400 kV Bawana - Abdullapur Double circuit line- Year of construction 2000
ii) 400 kV Dadri - Panipat Double circuit line-II- Year of construction 2006
iii) 400 kV Dadri - Malerkotla Single circuit line- Year of construction 1992

The towers were selected based on their accessibility by roads and as far as possible towers of more than 15 years old lines were audited.

A. Methodology adopted for tower audit:

1. Verticality of tower:

Measurements were taken to find out any eccentricity/leaning of the tower taken place due to weakness in the tower members by wind load or excessive line loading. The procedure adopted for this was first by identifying the center of the tower. The same was obtained by measuring the transverse & longitudinal axes intersection of bracings of bottom panel of the tower and then tracking through the height of the tower up to the intersection of bracings of top panel of the tower by use of Total Station from both the directions. If no undue deflection is found, then there is no problem of verticality of the tower. The measurements regarding verticality are given at **Section 5, Part A of Annexure.** While erection care should be taken that the stubs should be casted in the correct position and all the legs should be at the same level as per the approved drawing. The surface near the tower footing shall be regularly inspected and maintained in proper condition and no cutting of the soil near the tower should be allowed. The chimney should be 225mm above the ground and no soil should come over the chimney. Due care shall be taken during stringing to maintain the correct sag tension coordination for a given span.

Fig. 1.1. Measurement of verticality using Total Station

Fig. 1.2. Larger view of the tower for inspecting verticality

2. **Differential settlements of towers:**

The foundation settlement occurs when the soil beneath a tower leg/ footings cannot bear the load of the tower structure due to improper design parameters of the soil for foundation design. The settlement of a tower leg is the amount, it sinks after construction differently from the other footings or these are differential settlement of footings. In case of uniform settlement of tower/s there may not be much problem for the structure. However, differential settlements of legs/ footings become a big problem when the foundation settles unevenly causing additional stress in the tower members. The more uneven in the settlement, the greater stress on the tower structure & the lesser the reliability, causing premature failures even under the normal condition for which the line/towers are designed.

Water tube method was used to find the differential settlement of the tower. The level of the stubs of all the four legs of the tower was measured and compared with reference to the one leg. The measurements regarding differential settlement are given at **Section 4, Part A of Annexure.**

Differential settlements may lead to following problems: -

i) Tower may tilt towards settled side that may in turn produce strain in erected conductors and may cause snapping.
ii) Tower may collapse that will have cascading effect and adjacent towers may also be affected.

To avoid the differential settelement of towers, the surface at the tower footing shall be dry and intact to provide strength to the soil. Water logging shall be avoided if the foundations of a given tower location is not designed for wet condition or for partially/fully submerged condition. Before erection soil testing should be carried out to know the characteristics and strength of the soil and wherever required, the treatment of the soil should be done and the tower design aspect should take care of the condition.

Fig. 2.1. Measurement of differential settlement of tower

3. **<u>Visual inspection of the tower for missing members and bolts-</u>**

The towers were inspected with the use of binoculars for missing members and bolts if any. The anti-climbing arrangement/device of the towers was also inspected. The anti-climbing arrangement/device prevents un-authorized climbing on the tower. The observations regarding visual inspection are given at **Section 2, Part A of Annexure.**

Any missing redundant members in the structure will cause uneven distribution of forces in the force bearing members to which they are connected thus reducing the capacity of force bearing members. It will cause more stress in the members & may lead to failure even under normal climatic conditions for which the line/towers are designed.

Similarly missing bolts of member will cause loose fitting of joints and will cause excessive stresses in the other joint, leading to the failure of the joint/s & in-turn may lead to failure of tower. Inspection / patrolling of towers to be carried out regularly. Any members & or bolts and nuts, if found missing should be replaced immediately to keep the line in healthy condition.

Fig. 3.1. Visual inspection of towers by binoculars

Fig. 3.2. Unplugged holes observed at Dadri Panipat Line (tower No. 274 A)

Fig. 3.3. Unplugged holes observed at Dadri Panipat Line (tower No. 274 A)

4. **Dimensions of the base width, diagonal length, leg members, bracing members of the bottom panel:**

The exact overall dimensions of tower structure as a whole like base width & diagonal are necessary for ensuring actual strength of tower for the normal functioning. Similarly, the dimension of tower members shall be as per the drawing. The measurements of tower footings, stubs, and reachable members were taken to find out any deviation. The measurements are given at **Section 3, Part A & Column B, Part B of the Annexure.**

Tower Drawings shall be followed during entire process of erection. It is essential to carry out pre stringing /charging inspection for each of the tower of a line and record the same.

5. **Galvanized coating details of members in the bottom panel:**

The galvanized coating protects the tower material from corrosion due to various pollutants present in air. The reduction/erosion of coating may lead to further corrosion and reduction in original dimensions of tower member/s thus reducing the load bearing capacity of the member/s and may leads to failure of tower. The thickness of coating was measured with the use of **Alcometer**. The measurements are given at **Column E, Part B of Annexure.**

Coating thickness shall be measured periodically and prompt action shall be taken to protect the tower/structure from corrosion by applying anti corrosive painting.

6. **Corrosion of tower members:** Corrosion is a natural process, which converts a metal to its oxides, hydroxides, or sulfides. It is the gradual destruction of materials due to exposure to environment. Corrosion leads to loss of section size of structure and in turn reduces the strength of structure. The observations for corrosion are given at **Column H, Part B of Annexure.**

The towers were observed for corrosion. The thickness of the corroded members/stubs was measured at corroded section and also at normal section of the same member/stub with the use of Screw gauge to make a quantitative comparison of intensity of corrosion.

Fig. 6.1. Corroded leg of tower

Fig. 6.2. Corroded member of tower

B. Analysis of the tower audit:

1. **400 kV Bawana - Abdullapur Double circuit line:** Three towers of Abdullapur end and two towers of Bawana end were inspected as per the criteria decided.

   Conclusions:

   i) **Visual inspection of the tower for missing members and bolts:**

   No damage to any of the towers was found. Lower panel bracings of Tower no. 381 DA found bulging outwards. Rest of the tower members was in proper shape. No members on the tower was found missing. No bolts on the tower was found missing.

   ii) **Dimensions of the base width, diagonal length, leg members, bracing members of the bottom panel:**

   Deviation in the size of stub, leg & members was found generally within tolerance limit.

   iii) **Differential settlements of towers**

   Tower No. 29 DC & 36 DB had differential settlement at stub level. Differential settlements were found within permissible limit.

   iv) **Galvanized coating details of members in the bottom panel**

   Galvanizing thickness was found generally more than required.

   v) **Corrosion of tower members**

   Leg No 440SH, bracing 443 (trans face), bracing 444 (long face) of tower no 378 DD and bracing 1515 (trans face), bracing 1589 (long face) of tower no 36 DB was found corroded. The tower footing has not been maintained in required condition. Soil deposition were observed over the Chimney leading to corrosion of the element due to prolonged exposure of the moisture.

   vi) **Verticality of tower**:

   Longitudinal axis deflection of tower no. 378 was found. However, no deflection was observed in tower no. 381.

   Recommendation: To avoid the differential settelement of towers, the surface at the tower footing shall be dry and compact to provide strength to the soil. Water logging shall be avoided if the foundations of a given tower location is not designed for wet

condition, partially/fully submerged condition. Powergrid should take notice of the differential settlement and should take necessary measure.

To avoid the eccentricity & deviation in verticality, the stubs to be casted in the correct position (Base width and Diagonal) & to the correct inclination (slope). The surface near the tower footing shall be regularly inspected and maintained in condition to withhold the tower. Due care shall be taken during stringing to maintain the correct sag tension coordination for a given span.

To avoid the corrosion, Zinc Coating of the tower element shall be as per IS 4759. Water logging/moist soil at the Chimney should be avoided. Periodical inspection and anti-corrosive painting shall be applied to the tower members where ever corrosion is noticed.

2. **400 kV Dadri - Panipat Single circuit line-II:** One tower (Tower No. 274, Type A) of this line was audited.

Observation: The recorded readings are given at **Annexure**.

Conclusions:

i) **Visual inspection of the tower for missing members and bolts:**

No damage to the tower was found. No bending/buckling was found. No members on the tower was found missing. No bolts on the tower was found missing. Leg slope of towers was aligned. Unplugged holes were found in the members of tower.

ii) **Dimensions of the base width, diagonal length, leg members, bracing members of the bottom panel:**

Deviation in the size of stub, leg & members was found within tolerance limit.

iii) **Differential settlements of towers**

Tower No. 274 A had differential settlement at stub level.

iv) **Galvanized coating details of members in the bottom panel**

Galvanizing thickness was found more than required.

v) **Corrosion of tower members**

No Corrosion on tower members was found.

vi) **Verticality of tower**:

Longitudinal axis deflection of tower no. 274 was found within tolerance limit

Recommendation: To avoid the differential settelement of towers, the surface at the tower footing shall be dry and intact to provide strength to the soil. Water logging shall

be avoided if the foundations of a given tower location is not designed for wet condition, partially/fully submerged condition. Powergrid should take notice of the differential settlement and should take necessary measure. Unplugged holes should be closed with suitable nut and bolt arrangement.

3. **400 kV Dadri - Malerkotla Single circuit line:** One tower (245 B) of this line has been audited.

   Observation: The recorded readings are given at **Annexure**.

   Conclusions:

   i) Visual inspection of the tower for missing members and bolts:

   No damage to the tower was found. No bending/buckling was found. No members on the tower were found missing. No bolts on the tower was found missing. Leg slope of towers was aligned.

   ii) Dimensions of the base width, diagonal length, leg members, bracing members of the bottom panel:

   Deviation in the size of stub, leg & members was found within tolerance limit.

   iii) Differential settlements of towers

   Tower No. 245 B had differential settlement at stub level.

   iv) Galvanized coating details of members in the bottom panel

   Galvanizing thickness was found more than required.

   v) Corrosion of tower members

   No Corrosion on tower members was found.

   vi) Verticality of tower:

   Verticality of tower was not measured.

   Recommendation: To avoid the differential settelement of towers, the surface at the tower footing shall be dry and intact to provide strength to the soil. Water logging shall be avoided if the foundations of a given tower location is not designed for wet condition, partially/fully submerged condition. Powergrid should take notice of the differential settlement and should take necessary measure.

Annexure

Observations and Measurements of Transmission towers audited on 9th-10th January 2018

Part A

1.General Information	400 kV Double Circuit (Tripple Conductor)					400 kV Single Circuit (Panipat-2)	
Line name	Abdulapur - Bawana Transmission Line					DAD -PNP2	DAD -MLR
Tower number	378	381	29	36	37	274	245
Tower Type	DD	DA	DC	DB	DA	A	B
location	Bawana End	Bawana End	Abdulapur End	Abdulapur End	Abdulapur End		
Audit Date:	09.01.2018	09.01.2018	10.01.2018	10.01.2018	10.01.2018	09 .01.2018	09 .01.2018
2.Visual Observations							
S/C D/C M/C	D/C	D/C (V-String)	D/C	D/C	D/C (V-String)	S/C	S/C
Configuration Vertical/ Horizontal	Vertical Configuration	Vertical Configuration	Vertical Configuration	Vertical Configuration	Vertical Configuration	Horizontal Configuration	Horizontal Configuration
Damage to Tower	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Bending / buckling	Nil	Lower panel Bracings Found bulging outward	Nil	Nil	Nil	Nil	Nil
Missing Members	Nil	Nil	Nil	Nil	Nil	Nil	Nil
Missing bolts/nuts	Nil	Nil	Nil	Nil	Nil	Nil	Nil
3.Measured Tower Base width							
Btn. Stub 1&2	Not measured	12450 B/B Top of Stub	15935 B/B Top of Stub	14530 B/B Top of Stub	Not measured	8410 B/B Top of Stub	9180 B/B Top of Stub
Btn. Stub 2&3		12450 B/B Top of Stub	15935 B/B Top of Stub	14530 B/B Top of Stub		8350 B/B Top of Stub	9180 B/B Top of Stub
Btn. Stub 3&4		12450 B/B Top of Stub	15935 B/B Top of Stub	14530 B/B Top of Stub		8450 B/B Top of Stub	9180 B/B Top of Stub
Btn. Stub 4&1		12450 B/B Top of Stub	15935 B/B Top of Stub	14530 B/B Top of Stub		8450 B/B Top of Stub	9180 B/B Top of Stub
4.Stubs levelling difference (mm) at Top of Stub							
Btn. Stub 1&2	Not measured	Not measured	-24.7mm down	Not measured	Not measured	23.8mm up	5mm up
Btn. Stub 1&3			-6.9mm down			14.6mm down	20mm up
Btn. Stub 1&4			+4mm up			2.8mm up	16.79mm up
Net difference			28.7mm			38.4mm	20mm
Tolerance limit			15.935mm			8.410mm	9.18mm
Conclusion for differential settlement			differential settlement found more than tolerance limit			differential settlement found more than tolerance limit	differential settlement found more than tolerance limit
5.Deflection /Verticality							
Tower Height (in meter)	49.5	50.33	48.7	48	50.33	30.958	Not measured
Transverse Axis defelection (measured)	0	0	Not measured	Not measured	Not measured	0	
Longitudinal axis deflection (measured)	308mm	49mm				52mm	
Tolerance (unloaded condition)	137.5 mm	139.8mm				85.994	
Conclusion for verticality	Deflection is more	Deflection is within limit				Deflection is within limit	

Annexure

Part B

MEASUREMENTS OF PARTS OF AN INDIVIDUAL TOWER

A	B	C	D	E	F	G	H
400 kV Bawana - Abdullapur Double circuit line							
Tower - 378 DD							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/conclusion**	**Condition**
Footing	L200x200x24	200x200x24	No deviation found	91	87	thickness found adequate	One stub found corroded above CL
Leg							
440SH	L200x200x24.4, 24.21, 24.27	200x200x24	Deviation within tolerance limit	91	87	thickness found adequate	Corroded
Bracing							
Trans face 443	110.4x110x8.86, 8.6, 8.1,8.35	110x110x8	Deviation within tolerance limit	61	87	thickness found less than required	108mm length corroded
Long face 444	100.29x100.73x7.16,7.2	100x100x7	Deviation within tolerance limit	83	87	thickness found less than required	154.85mm length corroded;corroded part dimension: L99.78x100.02x6.93
Tower - 381 DA							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/colclusion**	**Condition**
Footing	L148x150.79x16.3, 16.28	L150x150x16	Deviation within tolerance limit	120	87	thickness found adequate	No significant issue found
Leg							
301SH	L131.4x131.2x12.07, 12.4, 12.1	L130x130x12	Deviation within tolerance limit	131	87	thickness found adequate	No significant issue found
Bracing Mark. No							
Trans Face 304	L70.9x70.3x5, 5.6	L70x70x5	Deviation within tolerance limit	124	87	thickness found adequate	No significant issue found
Long Face 323	L65.264.9x4.25	L65x65x4	Deviation within tolerance limit	133	87	thickness found adequate	No significant issue found

Part B							
MEASUREMENTS OF PARTS OF AN INDIVIDUAL TOWER							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Tower - 29 DC							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/colclusion**	**Condition**
Footing	L150x150x20.89	L150x150x20	Deviation within tolerance limit	93	87	thickness found adequate	No significant issue found
Leg							
1501	L151.74x152.03x20.4, 19.9	L150x150x20	Deviation within tolerance limit	114-118	87	thickness found adequate	No significant issue found
Bracing Mark. No							
Trans face 1515	L112.3x111x8.68,8.54	L110x110x8	Deviation within tolerance limit	106	87	thickness found adequate	No significant issue found
Long face 1589	L119.88x121.97x10.5, 10.6	L120x120x10	Deviation within tolerance limit	96	87	thickness found adequate	No significant issue found
Tower - 36 DB							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/colclusion**	**Condition**
Footing	L150x150x16	L150x150x15	Deviation within tolerance limit	89	87	thickness found adequate	No significant issue found
Leg							
1501	L151.8x150.6x16.7	L150x150x15	Deviation within tolerance limit	83-104	87	thickness found adequate	No significant issue found
Bracing Mark. No							
Trans face 1515	110.56x111.5x10.7	L110x110x10.7	Deviation within tolerance limit	90	87	thickness found adequate	thickness at corroded spot was found 6.1 mm
Long face 1589	131.78x131.4x11	L130x130x10	Deviation within tolerance limit	93	87	thickness found adequate	thickness at corroded spot was found 5.9mm; dimension at corroded spot was found 125.78x7.4

Part B							
MEASUREMENTS OF PARTS OF AN INDIVIDUAL TOWER							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Tower - 37 DA+9							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/colclusion**	**Condition**
Footing	L150x150x16	L150x150x16	Deviation within tolerance limit	Not measured	-	-	No significant issue found
Leg	L151.8x150.6x16.39, 16.16	L150x150x16	Deviation within tolerance limit		-	-	No significant issue found
Bracing Mark. No					-	-	
Trans Face	DL78.28x81.8x6.56,6.56	80x80x6	Deviation within tolerance limit		-	-	No significant issue found
Long Face	DL60x61x4.2,4.6	60x60x4	Deviation within tolerance limit		-	-	No significant issue found
400 kV Dadri - Panipat Double circuit line-II							
Tower - 274 A							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/conclusion**	**Condition**
Footing	L100.09x100.13x8.19	100x100x8	Deviation within tolerance limit	96	87	thickness found adequate	No significant issue found
Leg							
	L100.02x101.04x8.99, 8.74, 8.89	100x100x8	Deviation within tolerance limit	103	87	thickness found adequate	No significant issue found
Bracing							
Trans Face	L64.13x65.42x5.5, 5.42	65x65x5	Deviation within tolerance limit	120	87	thickness found adequate	No significant issue found
Long Face	L65.18x64.85x5.14, 5.2	65x65x5	Deviation within tolerance limit	90	87	thickness found adequate	No significant issue found
400 kV Dadri - Malerkotla Single circuit line							
Tower - 245 B							
Parameter	**Size as per measurement (mm)**	**Size as per drawing (mm)**	**Size devaition/conclusion**	**Galvanising Thickness measured (microns)**	**Galvanising Thickness required as per specifications (microns)**	**Galvanizing thickness deviation/colclusion**	**Condition**
Footing	Not measured	-	-	122	87	thickness found adequate	No significant issue found

Part B							
MEASUREMENTS OF PARTS OF AN INDIVIDUAL TOWER							
A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Leg							
	L132.5x132.7x10.61,11.28	132x132x10	Deviation within tolerance limit	100	87	thickness found adequate	No significant issue found
Bracing							
Trans Face	L81.0x79.65x6.56,6.6	80x80x6	Deviation within tolerance limit	106	87	thickness found adequate	No significant issue found
Long Face	L80.1x80.61x6.21,6.18	80x80x6	Deviation within tolerance limit	163	87	thickness found adequate	No significant issue found

Tolerance Limit		
Description	**Size**	**Tolerance**
Flange length/leg length	</=45mm	+/- 1.5mm
	>45mm & >/= 100mm	+/- 2.0mm
	>100mm	+/- 2%
Galvanising Coating thickness	610 g/sq.m	Min. thickness 87 microns
Diff in Elevation of Stubs:	-	</= (1/1000)*base width
Verticality of Tower	-	</=1/360*height