

Report of 3rd Pilot audit of Transmission Tower by the audit team of the committee for Audit of Transmission Tower

1. Background

In pursuance of Ministry of Power Letter No. 3/5/2017-Trans. Dated 07.08.2017, for the audit of the transmission towers with respect to design and the life of the towers (on a 5% sampling basis), the 3rd pilot audit was carried out for the towers of the transmission lines (tabulated below) on 20th, 21st & 22nd April, 2018, wherein the following members participated:

- i) Shri Sanjay Srivastav, Chief Engineer, PSE&TD, CEA (on 22.04.18)
- ii) Shri Santosh Kumar, Deputy Director, CEI, CEA
- iii) Smt Kavita Jha, Deputy Director, PSE&TD, CEA (on 20.04.18 & 21.04.18)
- iv) Shri Faraz, Assistant Director, PSE&TD, CEA (on 20.04.18 & 21.04.18)
- v) Shri Mukul Kumar, Assistant Director, CEI, CEA
- vi) Shri D Revanna, Representative of CPRI
- vii) Shri Nitish Kumar Sinha, Asst. General Manager, PGCIL

The members selected the towers in these lines for auditing based on its locational criticality like Highway crossings, in irrigated land, accessibility, etc. The details of the audit of tower of following lines with tower locational information are given below: -

Sl no.	Name of Transmission line	Utility	Tower no. (its location)	Year of commissioning	Audit date
1	400 kV Jalandhar-Sambha D/C Transmission Line	Sterlite Power Trans Ltd.	a. 7 (Near NH Crossing) b. 15 (near irrigated land) c. 20 (near irrigated land)	2016	20.04.18

2	400 kV Malerkotla- Amritsar D/C Transmission Line	Essel Infra Projects Ltd.	a. 91/3 (in irrigated field) b.94/0 (near irrigated land) c. 90/0 (near irrigated land)	2016	21.04.18
3.a.	400 kV Agra (PG)-Agra (UP) D/C Transmission Line	PGCIL	a. 36.b (in agricultural field)	2008	22.04.18
3.b.	765 kV Agra – Jhatikara S/C Transmission Line	PGCIL	a.172 (in agricultural field)	2015	

2. Following tests/ checks were conducted for tower audit: -

a. Visual inspection of the tower

The towers were inspected with the naked eye and with the use of binoculars for missing members and bolts, buckling, etc. Danger plate which is for safety, number plate, phase sequence markings which is for convenience and anti-climbing arrangement/device which prevents un-authorized climbing on the tower were also inspected.

Any missing force bearing members will cause uneven distribution of forces in the leg and the capacity of the leg will be reduced which in turn harm the safety of the tower & causes failure of towers/ cascading of failures if it is in the angle/section towers.

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 leads to failure of towers even if the field/climatic conditions are normal for which the line/towers are designed.

Similarly, missing bolts of member's connection will cause reduction in strength of joint and causing excessive stresses in the intact bolt of a joint leading failure of joint/s & in-turn may lead to failure of tower.



Figure 1. Missing bolt in bracing

Observation & Conclusion: Buckling of a secondary member in tower no. 20, Anti climbing devices (ACD) were found partially damaged in the tower no. 15 & 20 of 400 kV Jalandhar-Sambha D/C Transmission Line. Anti-climbing device was absent in the tower no. 91/3 & 94/0 of 400 kV Malerkotla- Amritsar D/C Transmission Line, bending of a member and also step bolts were found below ACD level in all the towers of this line. Moreover, the peak was damaged, bolts were missing & ACD was absent in the tower of 400 kV Agra (PG)-Agra (UP) and a bracing was found to be missing from 765 kV Agra – Jhatikara S/C Transmission Line, details of which can be referred from **Annexure**.

Conclusion: Some parameters of Tower structure were not found in adequate condition as mentioned in **Annexure**.

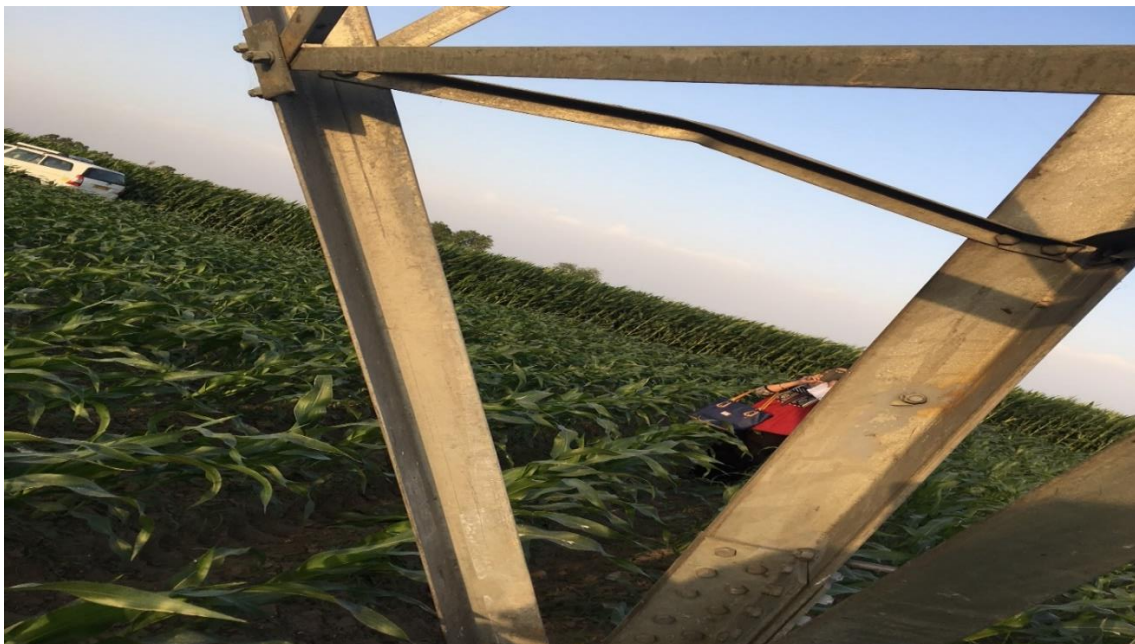


Figure 2. Buckled member

Recommendation: Missing ACD shall be installed, step bolts below ACD shall be removed,

Bent/buckled members to be replaced at the earliest, Dummy bolts, missing step bolts need to be plugged in order to keep the line in healthy condition. Inspection / patrolling of towers to be carried out regularly.



Figure 3. Damaged Anti Climbing Device (ACD)

b. 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 normal functioning of tower for which it is designed. Similarly, the size of tower members shall be within the tolerance limit so that the strength of tower as whole will not be under threat.

The measurements of tower footings, stubs, and reachable members were taken. The length, width and diagonal measurements of tower structure were also taken.

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

Conclusion: Except the bracings of tower no. 36b of 400 kV Agra (PG)-Agra (UP) D/C Transmission Line & tower no. 172 of 765 kV Agra – Jhatikara S/C Transmission Line, rest dimension of other members of the towers of this line were within limits.

Recommendation: 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. The members having dimensions not within limits shall be replaced by the members having correct dimensions.

c. Galvanized coating details of members in the leg portion

The galvanized coating protects the tower material from corrosion due to various pollutants persistent in air. The reduction/erosion of coating may lead to corrosion and reduction in

original dimensions of tower member/s thus reducing the capacity of member/s which may lead to failure of tower. The thickness of coating was measured with the use of Alcometer.

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

Conclusion: inadequate Coating thickness were found at few locations at leg of tower no. 15 of 400 kV Jalandhar-Sambha D/C Transmission Line.

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

d. Corrosion to members

Corrosion is a natural process, which converts a refined metal to a more chemically-stable form, such as its oxide, hydroxide, or sulfide. 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 towers were observed for corrosion.

Observation: No Corrosion were found on the members of the transmission towers.

Conclusion: The members shall be maintained in adequate condition.

Recommendation: The members, stub shall be maintained in dry condition. Water logging shall be avoided. Periodical inspection and anti-corrosive painting shall be applied for the tower members where ever onset of corrosion is noticed.

e. Differential settlements of towers

The foundation settlement occurs when the soil beneath a structure/ footings cannot bear the force imposed by the tower structure and conductor or the design parameters for foundation as per the soil under consideration turns erroneous. The settlement of a structure is the amount that the structure sinks after construction in all the four footings or 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 shortcoming on the safety of the structure & the reliability causing premature failures, even when the field conditions are normal and all deviations are within limits. Water tube method was used to know the differential settlement of the tower. The level of the stubs of all the four legs of the tower was measured and compared with respect to each other.



Figure 4. unexposed chimney

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.

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



Figure 5. Measurement of base width

Conclusion:

Sl no.	Name of Transmission line	Tower whose Differential settlement were found not within limits
1	400 kV Jalandhar-Sambha D/C Transmission Line	Tower no. 15
2	400 kV Malerkotla- Amritsar D/C Transmission Line	Tower no. 91/3, 94/0, 90/0
3a.	400 kV Agra (PG)-Agra (UP) D/C Transmission Line	Tower no. 36b

while the rest of the towers were within permissible limit.

Recommendation: The land around tower footing shall be compact, levelled and kept dry 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, condition and also suitable corrective measures shall be taken for the towers where the differential settlement is not within permissible limits.

f. Verticality of tower

This test was done to find out any undue eccentricity/leaning of the tower created due to constructional problem if any and or created by wind, excessive line loading buckling of towers, differential settlement of foundation, etc. The procedure adopted for this was by identifying the center of the tower and then measuring through the transverse & longitudinal axes taking reference of the intersection of bracings of bottom panel of the tower and tracking through the overall height of the tower up to the intersection of bracings of top panel of the tower by use of Total station in both the directions.

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

Conclusion: The deviation in verticality for tower no. 90/0 of 400 kV Malerkotla- Amritsar D/C Transmission Line could not be measured as measurement was not feasible there and the deviation in verticality for rest all towers were well within limits.

Recommendation: To avoid the eccentricity & deviation in verticality, the stubs to be casted to the correct position (Base width and Diagonal) & to the correct inclination (slope) and also at common level. 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.



Figure 6. Transverse view of Verticality

Data Sheet of Audited Transmission towers

Annexure

Part A

General Information	400 kV Double Circuit						765 kV Single Circuit	
Line name	400 kV Jalandhar-Sambha D/C Transmission Line (Sterlite Power Transmission Ltd.)			400 kV Malerkotla- Amritsar D/C Transmission Line (Essel Infra Projects)		400 kV D/C Agra (PG)-Agra (UP) (PGCIL)	765 kV S/C Agra - Jhatikara (PGCIL)	
Tower number	7	15	20	91/3	94/0	90/0	36 B	172
Tower Type	DD+3	DA+6	DB	DA+0	DD+0	DC+0	DA+0	SC+0
location	near NH crossing	near Irrigated land	near Irrigated land	in irrigated field	near Irrigated land	near Irrigated land	in Agricultural field	in Agricultural field
Audit Date:	20.04.18	20.04.18	20.04.18	21.04.18	21.04.18	21.04.18	22.04.18	22.04.18
Visual Observations								
S/C D/C M/C	D/C	D/C	D/C	D/C	D/C	D/C	D/C	S/C
Configuration Vertical/ Horizontal,	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical	Vertical
Damage to Tower	Nil	Nil	Nil	Nil	Nil	Nil	yes, Peak damaged	Nil
Bending / buckling	Nil	Nil	Buckling found in one member	Nil	Nil	Nil	Nil	Nil
Missing Members	Nil	Nil	Nil	Nil	Nil	Nil	Nil	bracing no. AJC 714 missing on Leg 4
Missing bolts/nuts	Nil	Nil	Nil	Nil	Nil	Nil	yes, 3 bolts in leg 3 & 1 bolt in leg 1	Nil
Step bolts	Appropriately placed	Appropriately placed	Appropriately placed	Found below ACD level	Found below ACD level	Found below ACD level	Appropriately placed	Appropriately placed
Anti Climbing Device	Present & intact	Partially damaged	Partially damaged	Absent	Absent	intact	absent	Present & intact
Measured Tower Base width								
Btn. Stub 1&2	19.8 metre	12.4 metre	14.825 metre	10.93 metre	18.2 metre	16.3 metre	11.45 metre	18.08 metre
Btn. Stub 2&3	19.8 metre	12.4 metre	14.825 metre	10.93 metre	18.3 metre	16.28 metre	11.45 metre	18.04 metre
Btn. Stub 3&4	19.8 metre	12.4 metre	14.825 metre	10.942 metre	18.15 metre	16.18 metre	11.45 metre	18.06 metre
Btn. Stub 4&1	19.8 metre	12.4 metre	14.825 metre	10.93 metre	17.93 metre	16.15 metre	11.45 metre	18.01 metre
Stubs levelling difference (mm) at Top of Stub								
Btn. Stub 1&2	17mm	5 mm	0 mm	10 mm	32 mm	30 mm	62 mm	8 mm
Btn. Stub 1&3	1 mm	5 mm	1 mm	3 mm	15 mm	27 mm	10 mm	10 mm
Btn. Stub 1&4	3 mm	15 mm	0 mm	16 mm	23 mm	28 mm	23 mm	10 mm
Tolerance limit	19.8 mm	12.4 mm	14.82 mm	10.94 mm	18.3 mm	16.3 mm	11.45 mm	18.08 mm
Conclusion for differential settlement	within limit	not within limit	within limit	not within limit	not within limit	not within limit	not within limit	within limit
Deflection / Verticality								
Tower Height (in meter)	49.835	52.91	46.335	47.235	47.22	46.62	46.068	50.9
Transverse Axis defelection (measured)	10 mm	70 mm	10 mm	2 mm	30 mm	verticality measurement was not feasible here	0 mm	0 mm
Longitudinal axis defelection (measured)	25 mm	nil	20 mm	3 mm	nil	verticality measurement was not feasible here	2 mm	0 mm
Tolerance	355.96	377.93	330.96	337.39	337.29	333.00	329.06	363.57
Conclusion for verticality	within limit	within limit	within limit	within limit	within limit	Not Applicable	within limit	within limit

Part B							
MEASUREMENTS OF INDIVIDUAL TOWER							
Tower no. 7 Jalandhar-Sambha D/C Transmission Line (Sterlite Power Transmission Ltd.)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/conclusion	Condition (for corrosion)
Stubs	150x150x20 mm	150*150*20 mm	within limit	160	>86 micron (IS :2629)	adequate thickness	normal
Leg	150X150X20.87 mm	150*150*20 mm	within limit	143			
Bracing	90x90x6.3 (double angle B/B) (Trans)	90*90*6 mm	within limit	97			
	75x75x5.3 (doubleangle B/B) (Long)	75*75*5 mm	within limit				
Tower no. 15 Jalandhar-Sambha D/C Transmission Line (Sterlite Power Transmission Ltd.)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/colclusion	Condition
Stubs	Not measured	130*130*10 mm	not applicable	150	>86 micron (IS :2629)	inadequate thickness at leg	normal
Leg	130x130x10mm	130*130*10 mm	within limit	61.277			
Bracing	75.5x75.5x5mm (Trans.)	75*75*5 mm	within limit	222.22			
	75x75x5mm (Long.)	75*75*5 mm	within limit				
Tower no. 20 Jalandhar-Sambha D/C Transmission Line (Sterlite Power Transmission Ltd.)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/colclusion	Condition
Stubs	150x150x15mm	150*150*14 mm	within limit	150	>86 micron (IS :2629)	adequate thickness	normal
Leg	150x150x15mm	150*150*14 mm	within limit	102.12			
Bracing	100x100x7mm (Trans)	100*100*7 mm	within limit	260.4			
	100x100x6.5mm (Long.)	100*100*6 mm	within limit				
Tower no. 91/3 400 kV Malerkotla- Amritsar D/C Transmission Line (Essel Infra Projects)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/colclusion	Condition
Stubs	130x129x10 mm	130x130x10 mm	within limit	Measuring instrument was not provided by the utility	>86 micron (IS :2629)	Not Applicable	normal
Leg	130x130x10 mm	130x130x10 mm	within limit				
Bracing	65x65x4mm (Trans.)	65x65x4mm (Trans.)	within limit				
	65x65x4mm (long.)	65x65x4mm (long.)	within limit				

Tower no. 94/0 400 kV Malerkotla- Amritsar D/C Transmission Line (EsSEL Infra Projects)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/conclusion	Condition
Stubs	200x200x15 mm	200x200x15 mm	within limit	Measuring instrument was not provided by the utility	>86 micron (IS :2629)	Not Applicable	normal
Leg	200x200x15 mm	200x200x15 mm	within limit				
Bracing	100x100x7mm (Trans)	100x100x7mm (Trans)	within limit				
	90x90x7mm(long.)	90x90x7mm(long.)	within limit				
Tower no. 90/0 400 kV Malerkotla- Amritsar D/C Transmission Line (EsSEL Infra Projects)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/conclusion	Condition
Stubs	150x150x16mm	150x150x16mm	within limit	Measuring instrument was not provided by the utility	>86 micron (IS :2629)	Not Applicable	normal
Leg	150x150x16mm	150x150x16mm	within limit				
Bracing	100x100x6mm (Trans.)	100x100x6mm (Trans.)	within limit				
	90x90x6.0mm(long.)	90x90x6mm(long.)	within limit				
Tower no. 36 B 400 kV D/C Agra (PG)-Agra (UP) (PGCIL)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/conclusion	Condition
Stubs	Not measured	130X 130X12	not applicable	180-200	>86 micron (IS :2629)	adequate thickness	normal
Leg	Not measured	130X 130X12	not applicable	186-194			
Bracing	56.5 X 5 Long face	75X5	not within limit	81-91			
	62.5 X 5 Trans face	75X5	not within limit				
Tower no. 172 765 kV S/C Agra - Jhatikara (PGCIL)							
Parameter	Size as per measurement (mm)	Size as per drawing (mm)	Size deviation/conclusion	Galvanising Thickness measured (microns)	Galvanising Thickness required as per specifications (microns)	Galvanizing thickness deviation/conclusion	Condition
Stubs	Not measured	200X 200X16	not applicable	180-200	>86 micron (IS :2629)	adequate thickness	normal
Leg	Not measured	200X 200X16	not applicable	131-202			
Bracing	69.6 X 6.4 Long face	80X6 LF	not within limit	110-193			
	71 X 6.5 Trans face	90X6 TF	not within limit				

Description	Size	Tolerance
Flange length/leg length	$\leq 45\text{mm}$	$\pm 1.5\text{mm}$
	$>45\text{mm} \ \& \ \geq 100\text{mm}$	$\pm 2.0\text{mm}$
	$>100\text{mm}$	$\pm 2\%$
Galvanising Coating thickness:	610 g/sq.m	Min. thickness 87 microns
Diff in Elevation of Stubs:		$\leq (1/1000) \cdot \text{base width}$
Verticality of Tower		$\leq 1/360 \cdot \text{height}$ (under test bed/ without stringing) $\leq 1/140 \cdot \text{height}$ with stringing (up to 60 m height) * Suggested by CSIR-SERC