



THE CONCEPT PAPER ON INSULATED CROSS ARM

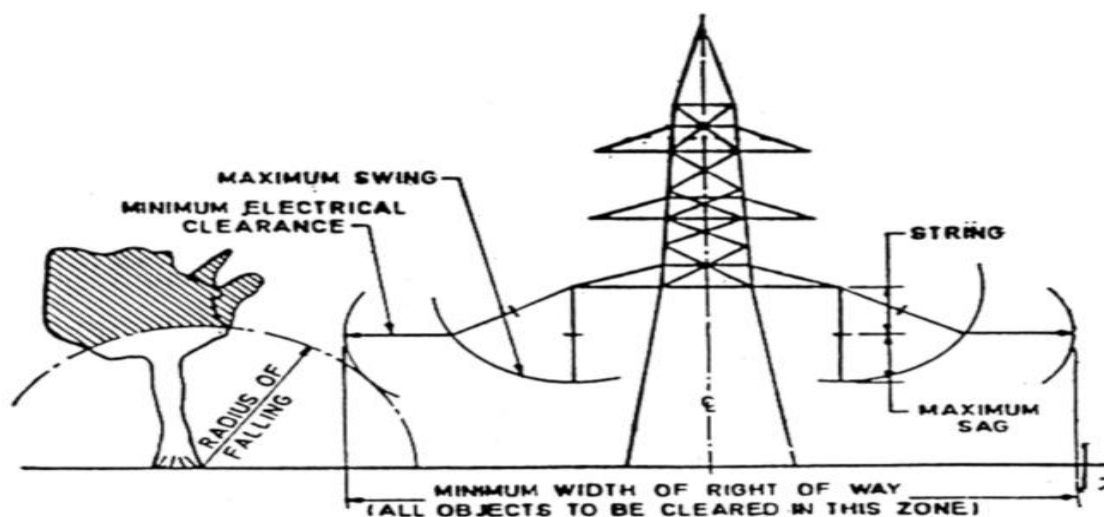
**GOVERNMENT OF INDIA
MINISTRY OF POWER
CENTRAL ELECTRICITY AUTHORITY
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Concept Paper on Insulated Cross Arm

1. Introduction

The transmission of power on overhead line will continue to dominate over other modes of power transmission due to techno-economic reasons. The availability of Right of Way (RoW) and the related compensation issues have become one of the major bottlenecks in construction of overhead transmission lines for most of the transmission utilities. RoW requirement for transmission line depends on following factors:

- Configuration of Tower [S/C (Horizontal / Delta / Vertical) or D/C (Vertical)]
- Span length
- Sag of Conductor, which depends on type of conductor used, maximum operating temperature of the conductor, and Span length
- Wind velocity and angle of swing
- Projection of Cross arm or distance of conductor attachment point from centre line of tower, which depends on wind speed, swing angle, metal clearance, cage width or tower body width at bottom conductor level
- Minimum horizontal & Vertical safety clearance as per CEA (Measures relating to safety and Electric supply) Regulations.
- Configuration of insulators [I / V / Y configuration] and Length of insulator string
- Electric field limits below bottom most conductor and at edge of RoW



Note: Portion of tree falling within clearance zone to be lopped or trimmed
Fig. 1 : Line clearance (Right-of-way) requirement

Optimization of RoW and pushing more quantum of Power per meter of RoW in identified corridor is the need of hour. Ministry of Power, vide its letter No.

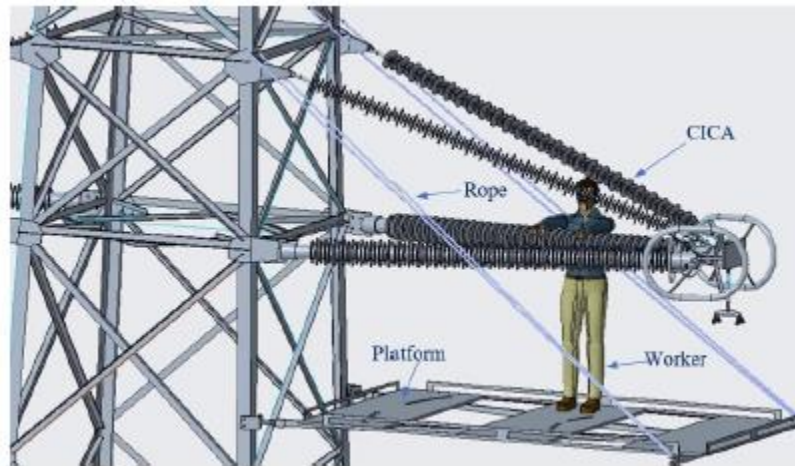
3/4/2016-Trans dated the 16th July, 2020 had issued guidelines for payment of compensation in regard to Right of Way (RoW) for transmission lines in urban areas and various design & technological options have been discussed in the afore mentioned guidelines for reduction of RoW. Reduction of RoW using Insulated Cross Arm (ICA) has been suggested as one of such technological options. At present, the use of insulated cross arm is not much in practice in Indian transmission system except few utilities in the states of Telangana and Kerala.

2. Insulated Cross Arm (ICA)

The installation / construction of new lines or the voltage up-gradation of existing transmission lines is often a special challenge because of ROW constraints and meeting the threshold values of audible noise, radio interference, electrical & magnetic field and the aesthetic requirement. The concept of compact line with insulated cross arms is a well-accepted solution for new lines for reduction in ROW, particularly in forest areas, city sections and along the highways etc. and for up gradation of existing transmission lines to higher voltage level wherein the traditional steel cross-arm is replaced by ICA without major changes in the tower and foundation. The compact lines with ICA can be constructed with conventional lattice towers or tubular poles. The first installation of compact lines with porcelain insulator was reported in the 70's from Canada and Greece. With the progress in the composite insulator technology, optimized solutions were developed and the introduction of composite interface phase spacers, in addition to insulated cross arms was considered for further line compaction. In 1998, the first 420 kV compact line section with Composite Insulated Cross Arm (CICA) was erected in Switzerland. The development of insulated cross arms up to 1000 kV has been successfully finished.

Composite Insulated Cross Arm (CICA)

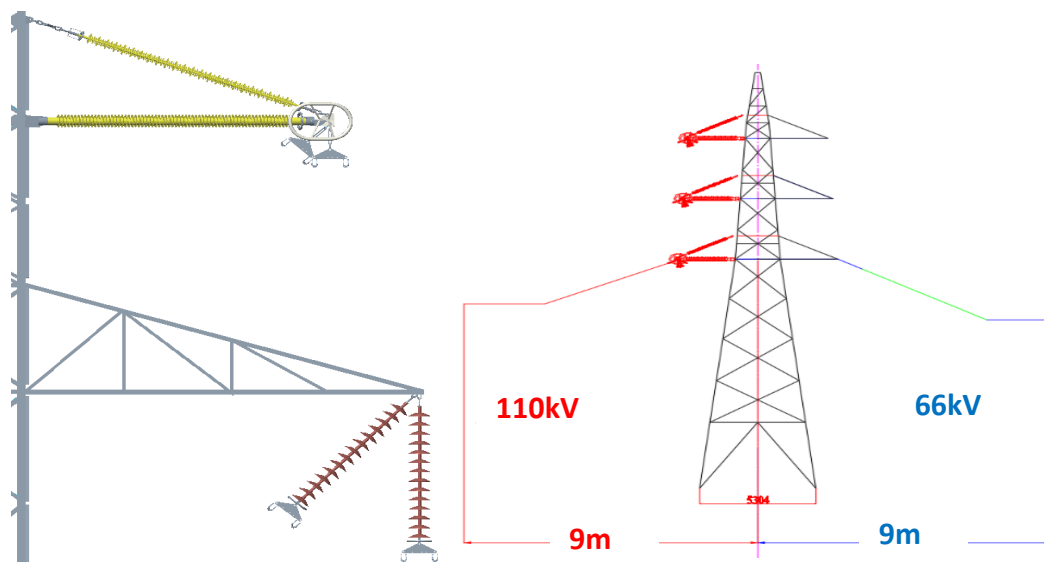
The Composite Insulated Cross Arm (CICA) is commonly used in overhead transmission lines as it offers number of advantages. The Composite Insulated Cross Arm (CICA) is composed of Fiber Reinforced Polymer (FRP) mandrel/ core, High Temperature Vulcanized (HTV) silicone rubber shed, associated fittings & accessories and is connected to the tower/ pole body through the flange node. The reliability & long-term performance of fiber reinforced core material was the matter of concern. However, Research & Development has improved the technology over the years resulting in enhancement of the reliability to a great extent. The damage to synthetic silicone rubber shed (over the fiber-reinforced core) by birds is still a matter of concern. However, R&D is under progress for improving the same.



The CICA with construction platform

3. Advantages of ICA

- a) The ICA replaces the conventional steel cross arm and eliminates the requirement of additional insulator strings (suspension/ tension) as required in case of conventional transmission lines and additional ground clearance is made available in suspension towers..
- b) Since ICA is insulated from metallic tower/ structure, the conductor of a suspension tower can be directly hung on the cross arm through short metal fittings, eliminating use of suspension insulators.



Attached fitting string for suspension CICA tower

- c) The elimination of long overhang lengths of suspension insulators brings up the attachment point in case of suspension towers making available additional ground clearance. Elimination of the wind-induced swings enables a compact tower geometry with a smaller footprint that is more aesthetic and easier to

integrate into the existing natural landscape. This also results in reduction in the tower height, base width of the tower, tower weight, saving of foundation volume and overall savings of basic tower & foundation material. The advantage of additional ground clearance can be used to increase the span between the towers.

- d) The reduced length of ICA in comparison to the length of conventional steel cross arm and elimination of suspension & tension insulator strings result in reduction in corridor width and RoW (as given in Table-1) due to less tower width.

Table-1

Sl. No.	Voltage	Configuration	Span (m)	ROW for Towers with CICA line (m)	ROW for Traditional line (m)	Difference	
1.	765kV D/C	Vertical	400	55	67	12m	18%
2.	400kV D/C	Vertical	400	38	46	8m	17%
3.	220kV D/C	Vertical	350	28	35	7m	20%
4.	132kV D/C	Vertical	320	22	27	5m	19%
5.	110V D/C	Vertical	320	18	22	4m	18%
6.	66kV D/C	Vertical	250	14	18	4m	22%

- e) ICA reduces the tower assembly time, shorten the construction period and reduce overall construction cost.
- f) ICA based tower reduces the use of traditional materials, less material for disposal at the end of service life and saves resources resulting in reduction of carbon emission. The smaller footprint of ICA based tower saves land resources and reduces damage to ecological environment.
- g) A crucial factor for the transmission capacity of long overhead lines is the surge impedance. The amount of power that can be transmitted on long (> 80 km) transmission lines is dictated by surge impedance. The lower this impedance, the higher is the natural power transmission capacity of the line. Due to the smaller spacing of the conductors, the surge impedance of the compact lines with ICA is significantly lower than in comparable standard lines. As a result, compact lines can achieve transmission capacities that are 15 to 20% higher.
- h) Conductors are often secured to cross arms with insulators. Conventional overhead lines have often one insulator per conductor. The compact lines with ICA, in general, use two insulators at EHV levels. This has a direct impact on supply reliability. If an insulator breaks, the conductor of a conventional line is

likely to snap, interrupting power transmission / supply. However, in a compact line, the second insulator holds the conductor in place, thereby maintaining the power supply.

- i) CICA with Fiber Reinforced Polymer core has some additional advantages. It is light in weight, corrosion resistance, easy to maintain and have very good pollution performance.
- j) **Voltage upgradation of line possible with existing towers by replacing steel cross-arm with ICA**

Upgradation of existing transmission line to next higher voltage level is possible by using ICA on same tower maintaining required clearances (Ground & Electrical live metal clearances) without changing / replacing foundation and without changing the tower geometry by providing a compact and reliable solution, thereby the power transmission capacity would be increased in the same corridor and construction / erection time for upgradation as well as the overall cost would be reduced.

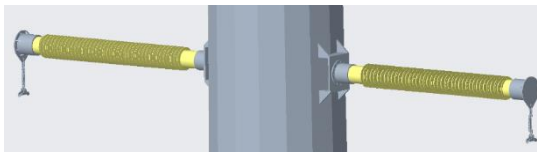
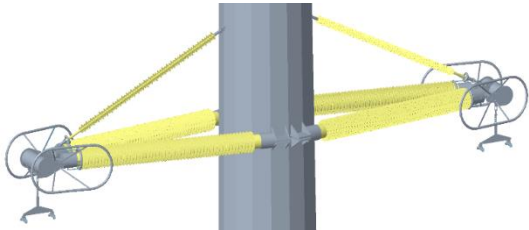
ICA can also be provided with the Pole Structures. Use of less foot print and additional ground clearances are advantages while using pole structures with ICA. The ICA with High Temperature Low Sag (HTLS) conductor with excellent sag characteristic can further raise the height of conductor above the ground, which can further contribute to voltage up-gradation to higher level.

4. Type / Configuration of CICA

The CICA can be single post without tension insulator or single post with single / multiple tension (or brace) insulators or double post single / multiple tension (or brace) insulators (as shown in Table-2) depending on voltage level and conductor configuration.

Table-2

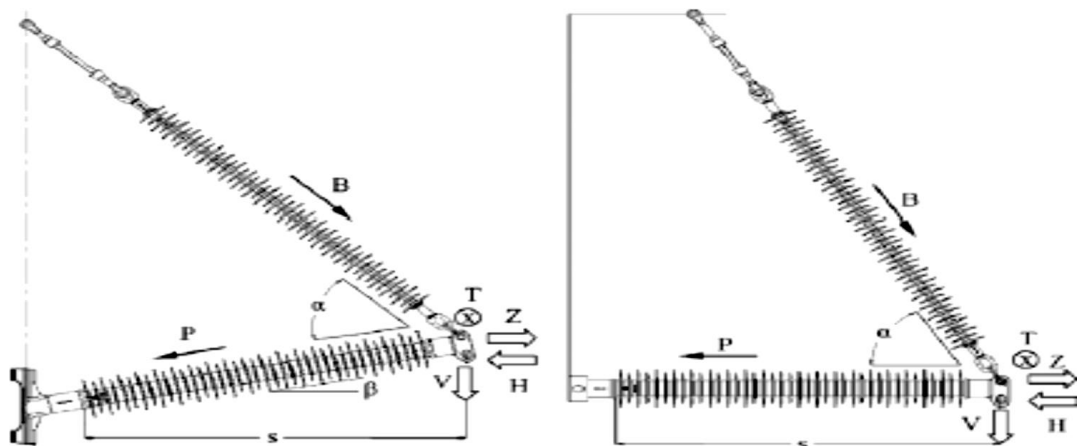
Type of CICA arrangement depending on Voltage level and Conductor loading	
Single post-single tension/brace for 66/110/132/220kV towers	
Single post-double tension/brace for 132/220kV towers	

Single post-triple tension/brace for 220/400kV towers	
Double post-double tension/brace for 220/400/765kV towers	
Single post for 66/132/220kV steel pole	
Double post-single tension/brace for 400kV steel pole	

In terms of attachment to the pole or the lattice structure/ tower, it is differentiated into braced line post (rigid) or horizontal Vee (pivoted). Rigid solutions with double posts and non-circular post cross section are in field trial.

The experience with compact line is thoroughly positive. This can also be attributed to the redundancy aspect, since a braced line post or horizontal Vee is a string of at least two insulators. Furthermore, the non-brittle nature of a large-diameter composite post provides additional safety in the case of a failing bracing long rod.

The schematic for braced line post (rigid type) and horizontal Vee (pivoted) is given below.



Braced line post (rigid – left) and a horizontal Vee (pivoted – right).

When comparing braced line post and horizontal Vee arrangements, their main difference lies in the fact that, in the case of a rigid connection, the post insulator also has to withstand forces in line direction, since its rigid fixing does not allow any rotation.

Rigid Insulated Cross Arms – Braced Line Post

In ICA having long posts and for lines of higher voltage levels significant deformations often occur. In the case of a rigid attachment, no movement of the post arrangement is possible; hence, an unbalanced longitudinal conductor situation can be the critical load case causing a bending load to the post. The brace is generally assumed to be pivoted at either end, in contrast to post, which was fixed in a rigid manner to the tower. The load of the brace should not be negative (compression) so as to prevent a buckling of the brace leading to contact between the metal fittings of the two insulators, the latter is inadmissible and could give rise to RIV disturbances.

Pivoted Insulated Cross Arms – Horizontal Vee

This is the most commonly used arrangement, in particular for higher voltages, since it has a high level of mechanical strength and is also fault-tolerant.

For a non-rigid or pivoted attachment, an unbalanced longitudinal load would cause a rotation about the cross arm axis, hence no bending load occurs, the load is a tensile load after the end position of rotation is reached.

The external loads which act on the tip of the cross arm in the horizontal and vertical direction are first decomposed into their respective components in the direction of the brace and of the post. The composite long rod in the brace is typically loaded purely by tension and can be dimensioned relatively easily. By contrast, the post is loaded by compression and, since it is articulated at both ends in this case can be calculated as a Euler buckling beam with the maximum tolerable compression load. However, when calculating the buckling, it must be

noted that by the practically unavoidable eccentric application of the compression load, the post insulator is additionally subjected to bending. The negative influence of this eccentricity can result to higher loads achieved from the conventional buckling formula. One possibility for reducing this harmful additional bending load is the use of special fittings.

The insulated cross arm should withstand the maximum allowable loads without permanent deformation or other damage. Important aspects of cross arms are dynamic loads for both pivoted and rigid as well as stability for pivoted ones.

Interphase Spacers

The line compaction is primarily based on the principle of minimizing interphase spacing. Since the interphase spacings are somewhat smaller than those encountered in the case of normal overhead transmission lines, there is greater risk of interphase flashover for a compact design when two conductors of different phases move closer to one another due to wind / ice shedding / short circuit. Interphase spacers (IPS) are used to avoid this. In the last few years, increased use of composite interphase spacers has been made possible due to the generally massive advances made in the development and acceptance of composite insulators.

5. The pros and cons of Compact Lines with ICA

The pros and cons of compact lines with braced line post or horizontal Vee arrangement can be summarized as follows:

Pros	Cons
Less RoW requirement	Often but not necessarily shorter span lengths
Cost savings for tower and foundation construction because of smaller bending moments due to the shorter insulation cross arms compared to conventional steel cross arms	Increased RIV or corona level possible because of shorter distances between phase conductors, if conductor configuration is inappropriate and/or inadequate hardware is installed.
Aesthetically pleasing tower configurations possible	More demanding conductor stringing process
Reduced electro-magnetic field at ground	Live-line-work can be an issue for double circuit towers.
Higher power transfer capacity because of lower surge impedance	Mechanical stability problems, when the number of horizontal Vees becomes too high in relation to in-situ wind scenarios.

Fail-safe redundancy because of the use of two insulators.	Braced line posts or horizontal Vees are more costly to conventional strings but additional costs are negligible compared to the savings realized.
CICA, due to its light in weight and ease of handling compared to porcelain based insulators, is the most preferred & commonly used in Emergency Restoration System (ERS) for temporary & fast restoration of transmission lines.	
Availability of FRP core with large diameter makes CICA possible to handle very high mechanical load requirement at EHV/UHV level.	

6. Loads acting on CICA

In CICA, the cylindrical insulating fiber glass based core in line post and bracing (if provided) bear the mechanical load. The loads are transmitted to the core by metal fittings. The polymer housing (outside the core) provides protection to insulating core of the line post/ bracings. The loads which act on an insulated cross arm, are (a) vertical loads(V) from the conductor and ice (if applicable), (b) horizontal loads(H) from the wind and angular pull (if present) and (c) longitudinal loads (T) from non-uniform conductor tension in the adjacent spans or from a broken conductor on one side (Broken wire Condition).

The insulated cross-arms can be rigid or pivoting, depending on how the post insulator is fixed to the tower. In both cases, the mechanical performance is a major concern, due to the high loads transmitted to the insulators. In general, the vertical loads are mainly taken by the brace, irrespective of the angle α between the brace & post and the horizontal loads are taken mainly by the post, which is loaded in buckling when these loads are compression loads. This makes the design of the post insulator a critical aspect, for which different solutions have been developed, like parallel posts, large rod diameter or hollow core insulators. In the pivoting cross-arms, the longitudinal movement of the conductors is allowed by using rotating connections, which allows the assembly to rotate about an inclined axis (inclined to create a restoring force when deflected).

The horizontal fixed (non-pivoting) base assembly is needed in structures that have to accommodate longitudinal loads (e.g. angle towers). Some national standards request this type of assembly in case of road or railway crossings. The longitudinal load performance depends strongly on the post diameter and on the geometry of the assembly. For high longitudinal loads (such as in the

case of conductor breakage) the post insulators may be arranged horizontally in V shape.

The post insulator works under compression, which makes it critical in the design, and the brace works under tension.

With the assumption of equilibrium of forces in longitudinal (line) direction ($T=0$) the insulator forces i.e. the force P on the post and the force B on the brace, are calculated using the following formulae:

$$P = H \frac{\cos(\varphi + \theta)}{\sin(\alpha)} + V \frac{\sin(\varphi + \theta)}{\sin(\alpha)}$$

$$B = H \left[\frac{\cos(\alpha)}{\sin(\alpha)} \cos(\varphi + \theta) - \sin(\varphi + \theta) \right] +$$

$$V \left[\frac{\cos(\alpha)}{\sin(\alpha)} \sin(\varphi - \theta) + \cos(\varphi + \theta) \right]$$

The load in line direction T only needs to be taken into consideration in the case of a rigid connection, but may be the decisive factor in the dimensioning of the cross arm. In addition to the use of high-strength posts, the use of a bottom fitting having a fail-safe base and suspension of the line using a load release clamp may also be of use. The failing of the post of an ICA does not lead to cascade effect, since the failing load of the remaining, healthy brace is normally sufficient to prevent the risk of line release.

The use of a single post is the preferred technical solution, however if the forces are too high for the rod diameter available, one of the other solutions has to be considered. In the case of a double single post, its flashover value under pollution conditions will be smaller in comparison to a single unit, because the power arc can develop on both units. However, if a housing with hydrophobicity material such as silicone rubber is employed, this situation is not very likely.

Mechanical design of ICA is considered to be more challenging. When the insulator length is defined, the Finite Element Method (FEM) of simulation provides the required rod diameters and the deformation under stress, where bending / buckling are the critical ones.

7. Maximum section length of line with ICA

In conventional Over Head Lines (OHL), the typical maximum section length with suspension / tangent towers is about 15 spans or 5 km in plain areas and 10 spans or 3 km in hilly areas to avoid cascade effect of failure of towers of the line. For OHL with ICA, the maximum section length may be 10 spans or 3 km.

8. Electric Field Stress

The satisfactory operation of a high voltage insulator is based on effective minimization of the electric field stress across its entire length, especially around metallic fittings and junctions. The challenge is that the increased voltage level causes higher electric fields resulting in possibly higher corona/ audible noise. High electric fields can give rise to discharges, such as corona, which could damage the sheds over prolonged periods of operation. This is the case in composite insulators with polymeric surfaces. Manufacturers of composite string insulators use stress relief devices, such as grading rings or corona rings to minimize corona related damage. The high voltage composite insulators are prone to ageing and failure due to corona and electric field stress, if not designed properly.

Particular care is required in designing areas where the metal end connections meet the insulator core. It is difficult to completely eradicate corona on any insulator. The introduction of corona rings, especially at the high voltage end of the composite insulator (Sometimes it may also be required at structure end.), is required to manage the magnitude of the electric field.

The electric field calculation should be verified by calculation using software as well as by full scale testing.

9. Tests

The Insulated Cross-Arm consists of Post and brace (Long Rod) Insulators along with Metal Fittings. The design tests, type tests, routine tests shall be applicable to insulated cross-arm and its components as per relevant IEC standard.

The influence of time on electrical & mechanical properties of components (core material, housing, interface etc.) and of complete composite insulators has been considered in specifying the design tests to ensure satisfactory life-time under normally known stress conditions of transmission lines. Design tests are intended to verify the suitability of the design, material and method of manufacturing (technology). A composite line post / brace insulator design is defined by the following elements:

- Material of the core, housing and their manufacturing method
- Material of the end fittings, their design and method of attachment (excluding the coupling)
- Layer thickness of the housing over the core (including a sheath where used)
- Diameter of the core

All design tests defined in IEC 62217 and additional specific mechanical tests covered in IEC 61952 are applicable for CICA.

Type Tests shall be conducted if design tests have passed / qualified.

The design tests, type tests, Routine tests and sample test are as follows:

1. Design tests

(a) Test on Core Material (as per IEC 62217)

- Dye Penetration test (porosity test)
- Water diffusion test (to check the core material for resistance to water attack)

(b) Test on Shed & Housing material (as per IEC 62217)

- Hardness test
- Accelerated weathering test (The insulator housing material shall be subjected to 1000h UV light test)
- Tracking and erosion test (1000h salt fog test)
- Flammability test (to check the housing material for ignition and self-extinguishing properties)

(c) Test on Interface & connection of end fittings (as per IEC 62217)

- Pre –stressing Thermal – mechanical pre-stressing
- Water immersion pre-stressing
- Verification tests
- Visual examination
- Steep-front Impulse voltage test
- Dry Power Frequency Voltage test

(d) Assembled core load-time tests (as per IEC 61952)

- Verification of Maximum Design Cantilever Load (MDCL)
- Tensile load test

2. Type tests (as per IEC 61952)

The insulator type is electrically defined by

- The arcing distance
- Creepage distance
- Shed inclination
- Shed diameter
- Shed spacing.

Similarly, the insulator type is mechanically defined by

- SCL
- Core material
- Core Diameter
- Method of attachment of the end fittings
- Coupling zone of the base end fittings

Electrical & mechanical type tests shall be performed on insulators satisfying above criteria of each type.

(a) Electrical Type tests:

- Wet Power frequency voltage withstand test

- Dry Lightning impulse voltage withstand test
- Wet Switching Impulse Voltage withstand test for $U_m > 300\text{kV}$

(b) Mechanical Type Tests:

- Cantilever failing load test (verifies that the rod or base end fitting does not fail at the specified cantilever load (SCL), though damage to core may occur)

3. Routine tests (as per IEC 61952)

- Visual Examination
- Tensile Load test
[Tensile load equal to or greater than 50% of STL or 5kN, whichever is greater, for at least 10s. This test provides some verification of the end fitting attachment process during production]]

4. Sample tests (as per IEC 61952)

- Verification of Dimensions
- Galvanizing test
- Verification of Specified Cantilever Load (SCL)
(Load increased rapidly but smoothly from zero to 75% of the SCL and then load is gradually increased in a time between 30s to 90s until SCL is reached.)

5. Full scale Testing

Full scale dielectric tests [corona, RIV, & Water Drop Induced Corona (WDIC) test, dry lightning impulse, wet switching impulse & wet power frequency tests], mechanical tests on CICA assembly (based on loads like vertical, transverse & longitudinal direction acting on CICA under different loading cases) and pollution test including 5000 hours tracking and erosion tests are required to be performed for ensuring long term performance of CICA. CICA requires full scale testing as mentioned above to ensure long term performance. Rapid Flash over (RFO) clean fog test in which the polluted insulator is simultaneously exposed to fog and voltage, where the latter is changed stepwise during the test in order to obtain the minimum flashover voltage, is widely used in different applications at present. The same test is also being conducted for testing of composite cross arm to make the test more time and cost effective. The WDIC test consists of application by standardized way of water drops in sensitive area of the composite insulator close to the high voltage fitting and simultaneous application of voltage.

10. Cost Benefit Analysis**11.1 New Transmission Line Project**

a) 765 D/C Line

[Assumptions:

Line length: 10kM, Average Span: 400m, Conductor: ACSR Hexa Zebra, Wind Zone-4, Reliability-2 & Terrain Category-2]

Sl.No.	Particulars	Traditional System (Crs.)	Composite Insulated Cross-Arm System (Crs.)
1.	Foundation Material	0.80	0.67
2.	Tower Material	7.00	5.87
3.	Conductor & Accessories	11.13	10.05
4.	Insulators & Hardware's	2.80	6.00
5.	Earth wire/OPGW & Hardware's	0.41	0.41
6.	Tower Accessories	0.02	0.02
7.	Construction/Foundation Works	6.00	5.45
8.	Erection and Stringing Works	2.50	1.94
9.	ROW Compensation & Statutory Approval Charges, etc.,	15.00	10.56
	Total for 10kM Line =	45.66 Crs.	40.97 Crs.
	Line cost per kM =	4.566 Crs./km	4.097 Crs./km *

Note: * 10% saving on overall Project cost

b) 400kV D/C Line

[Assumptions:

Line length: 10kM, Average Span: 400m, Conductor: ACSR Twin Moose, Wind Zone-4, Reliability-1 & Terrain Category-2]

Sl.No.	Particulars	Traditional System (Crs.)	Composite Insulated Cross-Arm System (Crs.)
1.	Foundation Material	0.44	0.37
2.	Tower Material	4.18	3.31
3.	Conductor & Accessories	6.36	6.18
4.	Insulators & Hardware's	0.53	1.84
5.	Earth wire/OPGW & Hardware's	0.34	0.34
6.	Tower Accessories	0.02	0.02
7.	Construction/Foundation Works	3.74	3.31

8.	Erection and Stringing Works	1.23	0.88
9.	ROW Compensation & Statutory Approval Charges, etc.,	6.24	4.48
	Total for 10kM Line =	23.09 Crs.	20.74 Crs.
	Line cost per kM =	2.309 Crs./km	2.074 Crs./km *

Note: * 10% saving on overall Project cost

c) 220kV D/C Line

[Assumptions:

Line length: 10 kM; Average Span: 350m; conductor: ACSR Zebra; Wind Zone-4; Reliability level-1 & Terrain Category-2.]

Sl.No.	Particulars	Traditional System (Crs.)	Composite Insulated Cross-Arm System (Crs.)
1.	Foundation Material	0.36	0.29
2.	Tower Material	1.43	1.29
3.	Conductor & Accessories	1.99	1.86
4.	Insulators & Hardware's	0.71	1.71
5.	Earth wire/OPGW & Hardware's	0.23	0.23
6.	Tower Accessories	0.03	0.03
7.	Construction/Foundation Works	2.29	2.00
8.	Erection and Stringing Works	0.36	0.26
9.	ROW & Compensation	7.14	5.50
10.	Transportation & Statutory Approval Charges	0.17	0.11
	Total for 10kM Line =	14.70 Crs.	13.27 Crs.
	Line cost per kM =	1.470 Crs./km	1.327 Crs./km

Note: * 10% saving on overall Project cost

d) 110kV D/C Line

[Assumptions:

Line length: 10 km; Average Span: 300 m; conductor: ACSR Wolf/Lynx;
Wind Zone-2; Reliability level-1 & Terrain Category-2.]

Sl.No.	Particulars	Traditional System (Crs.)	Composite Insulated Cross-Arm System (Crs.)
1.	Foundation Material	0.14	0.1
2.	Tower Material	0.79	0.62
3.	Conductor & Accessories	1.69	1.62
4.	Insulators & Hardware's	0.23	0.85
5.	Earth wire/OPGW & Hardware's	0.16	0.16
6.	Tower Accessories	0.02	0.02
7.	Construction/Foundation Works	1.25	1.04
8.	Erection and Stringing Works	0.2	0.15
9.	ROW & Compensation	4.42	3.5
10.	Transportation & Statutory Approval Charges	0.12	0.1
	Total for 10km Line =	9.02 Crs.	8.16 Crs.
	Line cost per km =	0.902 Crs./km	0.816 Crs./km

Note: * 10% saving on overall Project cost

11.2 Upgradation of Existing Line utilizing the existing Tower, Foundation & Corridor and simply replacing the existing steel cross arms by CICA

In general, the upgradation of existing line utilizing the existing Tower, Foundation & Corridor and simply replacing the existing steel cross arms by CICA would result in saving in overall project cost by about 25%.

i) Upgradation of existing 66kV D/C line to 110kV D/C Line

(Wind Zone-2, Reliability-1 & Terrain Category-2)

Sl.No.	Particulars	(Clearing existing line and new line construction) (Lakh.)	Composite Insulated Cross-Arm System Upgrade line using existing towers (Lakh.)
1.	Removable of Existing Towers, Foundation, Conductors & etc.,	15	7
2.	Foundation Material	14	6
3.	Tower Material	79	25

4.	Conductor & Accessories	162	162
5.	Insulators & Hardware's	23	100
6.	Earth wire/OPGW & Hardware's	16	16
7.	Tower Accessories	2	2
8.	Construction/Foundation Works	125	60
9.	Erection and Stringing Works	20	18
10.	ROW Compensation & Statutory Approval Charges, etc.,	354	244
	Total for 10kM Line =	8.1 Crs.	6.4 Crs.
	Line cost per kM =	81 lakh./km	64 lakh./km *

Note: * 20% saving on overall Project cost

ii) Upgradation of 110kV S/C line to 110kV D/C Line

(Wind Zone-2 under Reliability-1 & Terrain Category-2)

Sl.No.	Particulars	(Clearing existing line and new line construction) (Lakh.)	Composite Insulated Cross-Arm System Upgrade line using existing towers (Lakh.)
1.	Removable of Existing Towers, Foundation, Conductors & etc.,	15	7
2.	Foundation Material	14	5
3.	Tower Material	79	30
4.	Conductor & Accessories	162	160
5.	Insulators & Hardware's	23	100
6.	Earth wire/OPGW & Hardware's	16	16
7.	Tower Accessories	2	2
8.	Construction/Foundation Works	125	60
9.	Erection and Stringing Works	20	10
10.	ROW Compensation & Statutory Approval Charges, etc.,	354	210
	Total for 10kM Line =	8.1 Crs.	6.0 Crs.
	Line cost per kM =	81 lakh./km	60 lakh./km*

Note: * 25% saving on overall Project cost

- 11.3** It may be noted that the use of porcelain based Insulated Cross arm is not in use in Indian system and hence an indicative comparison of cost of new transmission line with conventional lattice structure with steel cross arm Vs CICA has been given. Moreover, the ICA can also be used for reduction of RoW of existing lines. In such cases, minor / no modification is required in the existing towers / pole structure & the foundation and hence cost associated with replacement of exiting steel cross arm by ICA will be different depending on voltage level on case to case basis.

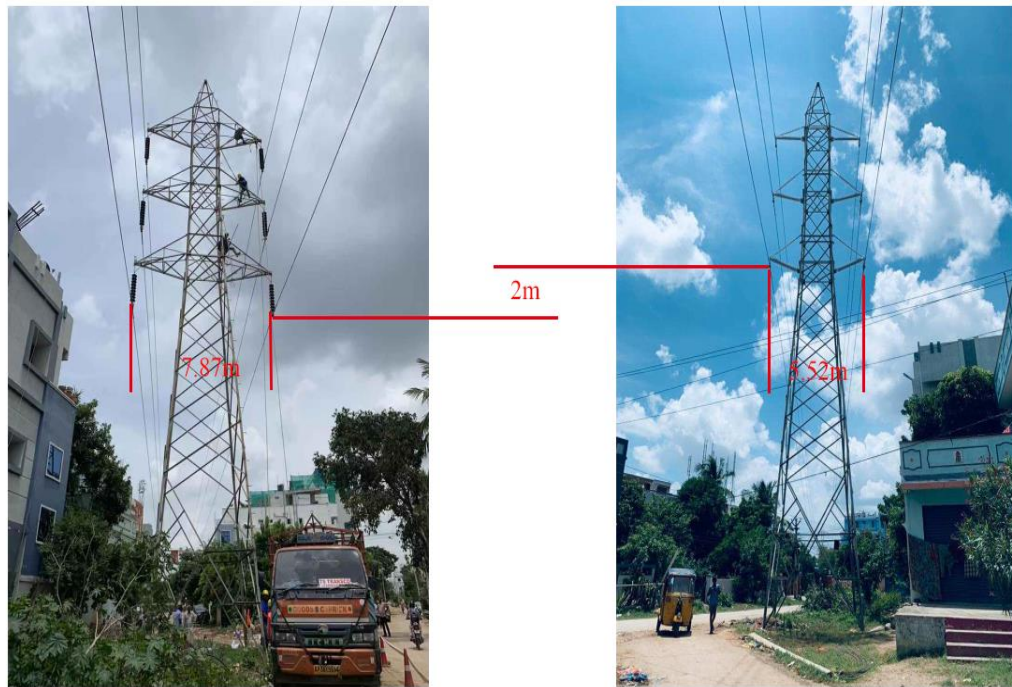
11. Applicable International Standard:

IEC: 61462, IEC: 61952, IEC: 61109, and IEC: 62231

12. Use of ICA in some EHV/UHV transmission Projects

- a) In Kerala (KSEB), the 66kV line (50km) was upgraded to 110kV using Composite Insulated Cross Arm (CICA), which is in operation since 2007 (14 years of operation). In Telangana (TSTRANSCO), the steel cross arm of the existing 132kV transmission line (Imlibun-Bandlaguda) was replaced in 2019 by CICA to reduce RoW, increase horizontal clearance to building and increase ground clearance. The Govt. of MP is also planning to upgrade the transmission line from 132kV to 220kV and similarly the KPTCL has also planned for upgradation of a transmission line from 220kV to 400kV. Even PGCIL and some private developers are also exploring the possibility of use of ICA technology.
- b) 1000kV UHV AC Transmission line with ICA under Ximeng - Shengli transmission project is in operation in China since 2016
- c) 765kV transmission line with ICA and +/- 800kV HVDC line (Lingzhou-Shaoxing) with ICA of State Grid of China are in operation since 2013 and 2015 respectively.
- d) European AC highest voltage: 420kV "diamond-type" composite insulators in Pole structures, applied to the British Hinkley nuclear power transmission project (the entire line involves a variety of tower shapes) of the British National Grid.
- e) 500kV D/C Transmission Line of Neoenergia, Brazil
- f) 220kV D/C Transmission Line of Adani Power, India
- g) **132kV AC Line (2019) of TSTRANSCO – Hyderabad**

Corridor width was reduced by 4.1m (31%) and Ground clearance was increased by 2m



h) 1000kV UHV AC Transmission line in China (2016)- Ximeng - Shengli transmission project:

- Saving in Line corridor width 22m (35%),
- Reduced exhalation height by about 8m (15%),
- Tower material saved 6.8 MT per tower &
- Saving on foundation concrete by about 20%



i) 750kV AC Transmission line in China (2013) - Hami South-Shazhou project:

- Saving in corridor width by 13m,
- The exhalation height Lowered by about 5m.
- Saving in of tower material 10 MT per tower.
- Saving in Basic concrete volume 10 m³ per leg.



j) 420kV AC Transmission line using Pole in Europe (British Hinkley nuclear power transmission project):

"Diamond-type" composite cross-arm in Pole structures



13. Typical Parameters of Traditional and Insulated Cross Arm

Sl.no.	SUSPENSION TYPE TOWER	66 kV D/C		132 kV D/C		220 kV D/C		400 kV D/C		765 kV D/C	
	Conductor type	Dog		Panther		Zebra		For Twin Moose		Hexa Zebra	
		Normal lattice Tower	Tower with Insulated Cross Arm	Normal lattice Tower	Tower with Insulated Cross Arm	Normal lattice Tower	Tower with Insulated Cross Arm	Normal lattice Tower	Tower with Insulated Cross Arm	Normal lattice Tower	Tower with Insulated Cross Arm
1.	Height of tower (in m)	20	18	27.5	25.1	36.25	33.4	53.5	49.3	69.4	59.8
2.	Width of Right of Way (in m) ROW	18	14	27	22	35	28	46	38	67	55
3.	Base width of Tower (in m)	3.0	2.2	4.5	3.8	6.5	5.5	11.95	10.40	18.40	16.60
4.	Weight of Tower (in MT)	1.8	1.4	2.2	1.8	5.0	4.0	16.92	12.58	30.12	23.50
5.	Electric Field (at 1.8 m above ground) (in kV/m)										
(a)	Below the bottom most Conductor point	NA	NA	1.26	0.94	1.86	1.42	3.79	2.87	10.36	8.83
(b)	At edge of new RoW-ROW			0.26	0.25	0.54	0.54	0.47	0.47	1.70	1.76
6.	Magnetic Field (at 1.8 m above ground) (in uT)										
(a)	Below the bottom most Conductor point	NA	NA	5.05	3.8	8.41	6.57	10.86	9.18	32.82	26.29
(b)	At edge of new RoW-ROW	NA	NA	1.33	1.05	2.85	2.37	2.62	2.3	10.14	9.26
7.	Phase to Phase spacing (in m)										
(a)	In Vertical Plane			3.9	3	5.5	3.9	8.5	6	15	11
(b)	In horizontal			7.7	5	10.8	7.8	16.6	10.92	24	15.8

	Plane										
8.	Tower span length (in m)			335	335	375	375	400	400	450	450
9.	Cost of tower (in Rs.)										
10.	Expected life of Insulated cross arm (in yrs)	Minimum 30 years as per aging test results & expected to meet 40 years lifetime									
11.	Any additional information	1. For the 66kV tower, the relevant research has not been done before, so the relevant data support cannot be provided.									

14. Some International Development

M/s Jiangsu Shemar Electric Co. Ltd. in 2010, developed the composite insulated cross-arm tower, which has greatly reduced the requirement of RoW, land and tower base etc. Shemar has developed 35kV - 1000kV AC and ± 800 kV HVDC towers with composite insulated cross-arm and successfully tested. State Grid Corporation of China and China Southern Power Grid jointly promote multiple pilot projects with CICA in association with Shemar.

In India, M/s Shemar Power Engineering (India) Pvt Ltd. have completed the erection of Insulated Cross arm in two nos. towers for TSTRANSCO (Telangana) 132kV project in 2019 and recently Shemar Power have got design & drawing for 765kV insulated cross-arm approved from PGCIL. Some of the private developers are also exploring the possibility of use of CICA in association with Shemar Power at 220kV level.

15. Indigenous Development

a) Insulated Cross Arm developed by M/s Deccan

M/s Deccan has design of line post insulator to cater to domestic and international and has developed, successfully type tested and supplied 210 numbers of line post insulators of 138kV, 15kN SCL to Nicaragua. They have also designed and developed following line post insulator (for 69kV, 161kV & 230kV) and braced line post insulator for 400kV. To meet electrical requirement. Different ratings are a combination of different length.

Sl. No.	Voltage level (kV)	SL (mm)	CD (mm)	DAD (mm)	Dry & wet power frequency flashover voltage (kVrms)	Critical Impulse Flashover voltage (+ve / -ve) (kVp)	SCL / STL (kN)	End fitting Tower end	End fitting conductor / live end
Line Post Insulator									
1	69	889	2057	655	240/230	424/467	26	Bendable gain	Horizontal Trunnion
2	138	1550	4495	1300	275	650	15	Curved gain base	Drop tongue
3	161	1727	4475	1509	654/564	959/1012	12	Bendable gain	Horizontal Trunnion
4	230	2438	6401	2116	884/750	1339/1399	8	Bendable gain	Horizontal Trunnion
Braced Line Post Insulator									
(a) Line Post	400	3500	13020	3162	680	1550/1650	5 (STL)	Twin base mounting	Two bundle yoke plate
(b) Braced Insulator	400	3826	13020	3271	680	1550/1650	160	Anchor shackle	Two bundle yoke plate

SL: Sectional Length, CD: Creepage Distance, DAD: Dry Arcing Distance, SCL: Specified Cantilever Load, STL: Specified Tensile Load

b) Long Rod Porcelain Based Insulated Cross Arm in the process of development by M/s Modern Insulator

Long Rod Porcelain insulator can also be used to replace the traditional steel cross-arm. M/s Modern Insulators Ltd. are in the process of development of long Rod Porcelain based insulated cross arm which can replace traditional steel cross arm enabling conductors to be attached directly to the cross arm with necessary fittings.

Porcelain Insulators Cross Arms (PICA) have the following advantages.

- The Porcelain Long Rod Insulators (PLRIs) are made of Alumina based porcelain and have a reasonably excellent compressive & tensile strength and do not buckle.
- Long Rod insulator is a puncture proof Type A insulator as per IEC.

- Porcelain long rods have a long life of about 40 years or more and do not deteriorate & age with time.
- The ingress of moisture has no impact on performance
- It can also withstand the highest salinity level (224 kg/m³ specified in IEC)
- The existing towers can be used without modification in tower dimension or profile as well as tower foundation.

The existing tower cage is to be fitted with thicker metallic strips. Hinge clamp is to be mounted on the same. Porcelain Long Rod can be connected to these clamps using clevis type end fittings. The yoke plate is to be used at the other end to connect horizontal and inclined members of insulators. The height of conductor attachment point in case of suspension towers would be raised by about 870mm (for 66kV), 1260mm (for 132kV) and 2050 (for 220kV).

Porcelain based Insulated Cross Arm may be limited to rating upto 220kV due to property and limitation associated with weight.

16. Manufacturer's Quality Plan (MQP)

A typical MQP is given at **Annexure-A** for reference and guidance.

17. Guaranteed Technical Particulars / data sheet for ICA

The Guaranteed Technical Particulars to be furnished by the Manufacturer could be as follows:

Guaranteed Technical Particulars / Data Sheet for ICA

Description	Unit	Purchaser's requirement	Data to be furnished / Guaranteed by manufacturer
Voltage level of the Transmission Line	kV	X	
Voltage level of the existing Transmission Line and voltage level of after upgradation (in case of upgradation)	kV	X	
RoW requirement	m		X
Type of Insulated Cross Arm (Composite ICA / Porcelain based Long Rod ICA)	kV		X
No. of circuits per tower / pole structure		X	
Conductor Details: Type of conductor (ACSR/AAAC/AL59/HTLS etc.) and no. of conductor(s) / sub-conductors per		X	

phase (in case of bundle conductor), overall diameter etc.			
Earthwire / OPGW details		X	
Configuration of ICA (single post without tension insulator or single post with single tension / multiple tension insulators or double post single / double tension insulators)			X
In terms of attachment to the pole or the lattice structure / tower [braced line post (rigid) or horizontal Vee (pivoted)].			X
Details of Post Insulator [Hollow / solid Fibre Reinforces Polymer core, diameter of core, core material, shed material (High Temperature Vulcanized silicone rubber shed / other material), Shed Diameter and No. of sheds, Creepage distance in mm/kV line to line voltage, % of silicone content in silicone rubber shed]			X
Details of brace insulator [Hollow / solid Fibre Reinforces Polymer core, diameter of core, core material, shed material (High Temperature Vulcanized silicone rubber shed / other material), Shed Diameter and No. of sheds, Creepage distance in mm/kV line to line voltage]			X
Boron content in FRP core			X
Specified Tensile Load (STL) of line post / brace	MPa		X
Maximum Design Cantilever Load (MDCL) of line post / brace	MPa		X
Specified Cantilever Load (SCL) of line post / brace	MPa		X
High Temperature Vulcanized Silicone Rubber			
(a) Tensile strength of	kN/m		X
(b) Tearing strength	MPa		X
(c) Elongation	%		X
(d) Silicone content	%		X
Corona rings or grading rings required at (live conductor end / structure end / at both end)			X
Dimension of Corona rings or grading rings			X
Failing Mechanical load of ICA	kN		X
Rated short duration power frequency withstand voltage of ICA	kV, r.m.s	X	X
Rated lightning impulse withstand voltage ICA		X	X
Rated Switching impulse withstand	kV,	X	X

voltage (if applicable) of ICA	peak		
Radio Interference Voltage level	dB above 1 μ V	X	X
System neutral	-	X	
System short-circuit level & duration	kA (sec)	X	
Galvanization			
Purity of Zn, Average masst (gm / sq.m) and thickness (microns) of Zinc coating on metal parts of end fittings	(gm / sq.m) & microns	X	X

18. Transport to Site, Storage and on-Site Handling of CICA

The transport to site, storage and on-site handling etc. needs to done properly. For example, the damage to the moisture seal (interface housing to metal) can precipitate complete mechanical and electrical breakdown. Rodent can inflict considerable damage to the insulator housing during transport and storage. Moreover, the damage may not be clearly visible and with the consequent mechanism of failure being time-related, unexpected fracture can occur after a few years of service. The guidelines of CIGRE Working Group 22.03 (Brochure No. 184, April 2001) on “Composite insulator handling Guide” may be referred.

19. Erection Aspect

The insulated cross arm is generally made of composite material and silicone rubber housing on which the line-man should not walk on The easy solution is the pre-assembly of the insulated cross arm at the ground level. The tubular pole has a modular structure and the insulated cross arms can also be preassembled at the ground level and fixed to the tower segments in order to simplify the erection process with considerable cost savings in comparison to a lattice tower. This method is considered as an efficient way of erection of ICA.

20. Some References

- (1) CIGRE Green Book on Over Head Lines
- (2) CIGRE Working Group 22.03 (Brochure No. 184, April 2001) on “Composite insulator handling Guide”
- (3) CIGRE Proceedings: B2-301—2016, B2-106-2014, B2-215-2020
- (4) Silicone Composite Insulator material, design, applications: Papailiou, Konstantin O., Schmuck, Frank, PFISTERER, Springer 2013

**STANDARD MANUFACTURING QUALITY PLAN (MQP) OF ICA AND ASSOCIATED COMPONENT**

Insulated cross-arm consists of line post & brace (long rod) insulators, associated metal fittings and corona or grading rings.

Sl. No.	Components/ Operations	Type of Check	Quantum of Check		Reference Document	Acceptance Norms	Inspection Agency			Remark
			M	C/A			M	C	A	
A.	RAW/INCOMING MATERIAL INSPECTION									
I.	Metal Fitting (socket and ball)									
1.	Visual Inspection	Physical	3%		Approved Specifications / Approved drawings	Free from defects	P	V	V	
2.	Socket and ball coupling Dimensions	Physical	3%			Conformance to gauges as per "GO" and "NO GO" gauges IEC 60120	P	V	V	
3.	Dimensions and tolerance	Physical	3%				P	V	V	
4.	Failing Mechanical Load Test	Mechanical	1/lot for $N \leq 500$ 3/lot for $N > 500$				P	V	V	
a.	70 KN					≥ 90 KN				
b.	90 KN					≥ 120 KN				
c.	120 KN					≥ 150 KN				
d.	160 KN					≥ 210 KN				
e.	210 KN					≥ 270 KN				
f.	320 KN					≥ 410 KN				
5.	Galvanizing									



a.	Mass of Zn coating	Physical	5/1000		Approved Specifications / Approved drawings	600g/m ² (85 micron)	P	V	V	
b.	Uniformity of zinc coating	Chemical	1/1000			Min. 6 dips of 1 min each IS2633	P	V	V	
c.	Adhesion Test	Physical	1/1000			IS 2629/ISO 1461	P	V	V	
d.	Purity of Zn of Zinc ingot used	Chemical	1/1000			Not less than 99.95% IS209/BS3436	P	V	V	
6.	Metallurgical Test						P	V	V	
a.	Ball fittings (Forging)	Chemical	1/lot of 3000		ISO 3703	ISO 3703	P	V	V	
	i. Carbon ii. Manganese iii. Silicon iv. Phosphorous					0.37-0.44% 1.4-1.8% 0.17-0.37% 0.035% Max				
b.	Grain size	Physical	1/lot of 30001/lot of 3000			ASTM E112	P	V	V	
c.	Non-metallic inclusion rating	Physical	1/lot of 3000			ASTM E 45-81	P	V	V	
d.	Microstructure (on lip portion)	Physical	1/lot of 3000			ASTM E 112	P	V	V	
e.	Grain flow (Applicable for drop forge only)	Physical	1/lot of 3000			Linear & uniform	P	V	V	
f.	MPI	Visual	10 Nos / 5000			No crack	P	V	V	
g.	Yield strength	Mechanical	1/Heat			ISO 3070 (>= 735Mpa)	P	V	V	
h.	Tensile strength	Mechanical	1/Heat			-do-	P	V	V	
i.	% Elongation	Mechanical	1/Heat			-do-	P	V	V	
j.	Hardness	Physical	1/Heat			-do-	P	V	V	



II.	ECR fiber-glass reinforced epoxy resin core rod					-do-	P	V	V	
1.	Visual Inspection	Physical	100%		Manufacturing Standard/ Approved Technical Specification	Transparent, uniform in color, be free from crack, flaw, air holes, foreign substance and defects	P	V	V	
2.	Diameter tolerance mm	Physical	2%/Lot			+ 0.1 mm & - 0 mm	P	V	V	
3.	Length tolerance mm	Physical	2%/Lot			+ 5 mm & - 0 mm	P	V	V	
4.	Tensile strength, Mpa	Mechanical	1/Lot			≥ 1100	P	V	V	
5.	Dye Penetration test. Min	Physical	1/Lot			IEC 61109	P	V	V	
6.	Water diffusion test (12kV 1Min)	Electrical	1/Lot			Leakage current ≤ 200 microA , No external flashover, no puncture occur	P	V	V	
7.	96 hours stress corrosion withstand test (1N-HNO ₃ and 80% specified mechanical load) 96h	Physical & Chemical	1/Lot			No fracture within 96 hours	P	V	V	
8.	Power frequency withstand voltage-test	Electrical	1/Lot			5 min 85% dry flashover	P	V	V	
9.	B ₂ O ₃ content%	Chemical	1/Lot			0, Boron free	P	V	V	
III.	Mixed silicone rubber inspection				Manufacturing Standard/ Approved Technical Specification					
1.	The physical properties of						P	V	V	



	mixed silicone rubber									
a.	Tearing strength KN/m	Physical	1/Lot		ISO 34-1	≥ 9	P	V	V	
b.	Tensile strength, Mpa	Physical	1/Lot		ISO 37	≥ 4	P	V	V	
c.	Elongation, %	Physical	1/Lot		ISO 37	≥ 100	P	V	V	
d.	Shore A Hardness	Physical	1/Lot		ISO 7619	62-72	P	V	V	
e.	Tracking & Erosion resistance	Physical	1/Lot		IEC 60587		P	V	V	
f.	Permanent deformity	Physical	1/Lot		ISO 2285	$\leq 4\%$	P	V	V	
g.	Dielectric strength kV	Physical	1/Lot		IEC 60243-3	≥ 21	P	V	V	
h.	Fire Resistance	Chemical	1/Lot		IEC 60707	$\geq$ FV-0	P	V	V	
i.	Recovery of Hydrophobicity	Electrical	1/Lot				P	V	V	
j.	Verification of content of silicone						P	V	V	
	a) Verification of Silicone	Physical	1/Lot		Approved specification/ Approved drawing	Being silicone rubber	P	V	V	
	b) Check of content of Silicone	Physical	1/Lot			> 30% by weight	P	V	V	
k.	Viscosity of Silicon Rubber	Chemical	1/Lot				P	V	V	
IV.	Grading ring									
1.	Material (Chemical Composition)	Chemical	1/Heat		ISO 2092	Aluminium Alloy Chemical Composition: 10-13% Al, Balance foreign material: Cu:0.3%, Mg:0.1% Zn:0.1%, Mn:0.5%, Ti:0.2%(Total foreign material: 1.6% Max.)	P	V	V	
2.	Visual Inspection	Physical	2%/Lot			Smooth	P	V	V	



						surface, be free from cracks, shrinks, air holes and rough edges				
3.	Dimensions	Physical	2%/Lot			Conformance to Drawings	P	V	V	
V.	Split Pin Stainless Steel, R-shaped						P	V	V	
1.	Visual Inspection	Physical	As per IEC372		AS per IEC372	IEC 372	P	V	V	
2.	Dimension check bending	Physical	As per IEC372		AS per IEC372	IEC 372	P	V	V	
3.	Verification of Resistance to bending	Physical	As per IEC372		AS per IEC372	IEC 372	P	V	V	
4.	Hardness	Mechanical	As per IEC372		AS per IEC372	≥ 150 (Vicker test ISO 6507)	P	V	V	
5.	Operation Test				AS per IEC372	IEC 383	P	V	V	
	a) Load F Min-Max				AS per IEC372	50N-500N	P	V	V	
	b) Fmax 500N				AS per IEC372	No removal	P	V	V	
6.	Chemical Composition OCr18Ni9 Stainless steel		1/Heat		AISI Standard	AISI Standard	P	V	V	
	a) Carbon b) Silicone c) Manganese d) Phosphorous e) Sulphur f) Nickel g) Chromium				0.07% Max 1% Max 2% Max 0.035% Max 0.03% Max 8-11% 17-19%					



B.	MANUFACTURING PROCESS						P	V	V	
I.	Semi-finished products inspection (Sheds after 1 st Vulcanization)				Manufacturing Standard/ Approved Standard/ Technical Specification		P	V	V	
1.	Visual Inspection	Physical	Once/3 day as per mould quantity		Manufacturing Standard/ Approved Technical Specification	Manufacturing standard/ Approved standard/ Technical Specification	P	V	V	
2.	Dimension Check	Physical	Once/3 day as per mould quantity		Approved specification/ Approved drawing	Approved specification/ Approved drawing	P	V	V	
II.	Semi-finished products inspection (Sheathed Core Rod after 1st Vulcanization)									
1.	Visual inspection	Physical	Once /day 3/lot		Manufacturing Standard/ Approved Standard/ Technical Specification	Manufacturing standard/ Approved standard/ Technical Specification	P	V	V	
2.	Dimension Check	Physical	Once /day 3/lot		Technical specification/ Approved drawing	Approved specification/ Approved drawing	P	V	V	
3.	The thickness of Sheath	Physical	1piece/ shift/ma		Approved specification/	≥ 3mm	P	V	V	



			chine/ rating		Approved drawing					
4.	Jointing check of Silicone Rubber and core rod by NDT Method	Physical	1piece/ shift/ma chine/ rating		Approved Procedure	No crack and bubble	P	V	V	
III.	End Fitting Compression						P	V	V	
1.	Compression Pressure	Mechanical	100%		Approved specification/ Approved drawing	Manufacturing standard/ Approved standard/ Technical Specification	P	V	V	
2.	Visual Dimension	Physical	100%		Approved specification/ Approved drawing	Manufacturing standard/ Approved standard/ Technical Specification	P	V	V	
3.	Routine Tensile test	Mechanical	100%		Approved specification/ Approved drawing	Manufacturing standard/ Approved standard/ Technical Specification	P	V	V	
C.	TESTING ON FINISHED PRODUCT									
I.	Routine Test									
1.	Identification of the composite Insulator	Physical	100%	100%	IEC 61109	IEC 61109	P	H	H	
2.	Visual inspection	Physical	100%	10%	IEC 61109	IEC 61109	P	H	H	
3.	Mechanical routine test (Tensile Load test)	Mechanical	100%	100%	IEC 61109	IEC 61109	P	H	H	
II.	Acceptance Test									



1.	Verification of dimension	Physical	IEC 61109	IEC 61109	Approved specification/ Approved drawing	IEC 61109	P	H	H	
2.	Galvanizing test									
	Mass of Zn Coating	Physical	IEC 61109, IEC 60383-1	IEC 61109, IEC 60383-1	Approved specification/ Approved drawing	600g/m ² (85 micron)	P	H	H	
3.	Verification of Specified Cantilever Load (SCL): Verification of the tightness of interface between end fittings and insulator housing and of SML	Mechanical & Physical	IEC 61109	IEC 61109	IEC 61109	IEC 61109	P	H	H	
4.	Verification of the locking system	Physical	IEC 61109, IEC 60383-1	IEC 61109, IEC 60383-1	IEC 61109, IEC 60383, Approved specification/ Approved drawing	IEC 61109, IEC 60383, Approved specification/ Approved drawing	P	H	H	
5.	Recovery of Hydrophobicity	Electrical	1 sample per lot	1 sample per lot			P	H	H	
6.	Verification of Silicone content						P	H	H	
	a) Verification of Silicone	Physical	Each offer lot	Each offer lot	Approved technical specification/ Approved drawing	Being silicone Rubber	P	H	H	
	b) Check of content of Silicone	Physical	Each offer lot	Each offer	Approved Technical	> 30% by weight	P	H	H	



				lot	specification/ Approved drawing					
7.	Tests on interface and connections of metal fittings i. Sudden load release prestressing ii. Thermal mechanical prestressing iii. Water immersion test iv. Steep front impulse voltage v. Dry power frequency voltage test	Electrical	Each offer lot	Each offer lot	IEC 61109	IEC 61109	P	H	H	
8.	Brittle Fracture Resistance Test	Physical	On any one lot	On any one lot	Approved specification	Approved specification	P	H	H	
9.	Dye Penetration test for core material	Physical	On any one lot	On any one lot	IEC 61109	IEC 61109	P	H	H	
10.	Water diffusion test for core material	Electrical	On any one lot	On any one lot	IEC 61109, IEC 62271	IEC 61109, IEC 62271	P	H	H	
D.	PACKING & DISPATCH (FINISH PRODUCT ONLY)	Visual Inspection	100%	100%	Plant Standard	Plant Standard	P	V		
		Physical Verification of Quantity / Packing details / Packing Slip	100%	100%	Packing List	Packing List		V		

LEGENDS:



M - MANUFACTURER/SUB-SUPPLIER; C - MAIN SUPPLIER, A - AUTHORIZED REPRESENTATIVE

P- PERFORM, V- VERIFICATION, H- HOLD POINTS TO BE WITNESSED