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Development, Design and Testing of a Retrofit Composite Insulated Cross Arm

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SUMMARY

As we navigate through the ongoing energy transition, the modernization and upgrading of transmission network which serves a vital connection between energy producers and consumers is an emerging bottle-neck towards achieving sustainability goals. Today, the transmission grid needs to overcome a number of pressing challenges such as, year on year increase in energy demand, rapid integration of bulk renewable energy and hardening against erratic environmental events and climate change. Unlike other infrastructure in the energy system which are largely concentrated in a specific area, transmission lines are linear facilities which traverse hundreds of miles over public and private land often crossing territorial boundaries. Some of the main obstacles for the modern transmission network consist of technical complications in upgrading of existing line coupled with high cost and carbon foot print of building new lines, complications in gaining right-of-way and approvals from numerous agencies and stakeholders, together with an over overall public opposition due to visual impact, loss of real estate value and concerns pertaining to environmental impacts.

Although two-dimensional insulated cross-arms in the form of line post and braced line post insulators have been used on high voltage overhead network for many decades as a means to building compact lines and to some extent for upgrading, these cross-arm constructions are inherently limited in their bending load withstand and compressive buckling capabilities. When employed, the transmission line engineer has to design the line so that service loads remain below the load withstand capabilities of these cross-arms – commonly defined by the combined load curves. This means that the span lengths, conductor bundle type, line deviation angles and allowance for security loads (broken wire, heavy unsymmetrical ice etc.) maybe limited and true line optimization is restricted. Moreover, for upgrading or retrofit applications, the capabilities of two-dimensional insulated cross-arms may not be compatible with the loading criteria and requirements of an existing line.

This paper presents some of the key considerations during development, design and testing of a spatially three-dimensional double Vee composite insulated cross-arm. This high strength composite insulated cross-arm has been developed primarily for retrofitting on an existing transmission line to achieve ground clearance mitigation. The developed insulated cross-arm provides a like-for-like replacement for the bottom steel cross-arms on the lattice towers, removing the need for the suspension insulator string and thereby lifting the span conductor attachment point and increasing the ground clearance.

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The increase in ground clearance with insulated cross-arm retrofit represents a more cost-effective, practical and straight forward solution compared to other alternatives such as elevating the towers, replacing suspension insulator string with suspended dead-end sets or re-conductoring the spans. The retrofitted insulated cross-arm requires minimal modification of the existing tower, can be worked on while energized and is easily customizable for different configurations and site-specific requirements. Other potential uses of the developed insulated cross-arm include retrofitting and replacement of all steel cross-arms on the lattice tower for more extreme clearance corrections, overcoming corridor constraints by reducing the required ROW compared to designs with I-strings, use in designs of compact new builds that require greater longitudinal load capacity than typical two-dimensional braced line posts and for thermal or voltage uprating projects.

A holistic turn-key retrofit solution was developed including specification of suspension hardware, tower structural analysis and the design of composite insulated cross-arm where FEA simulations and analysis were extensively employed. Integrated protective rings were used on the high side to provide necessary electric field grading and power arc withstand and sizes of insulator FRP core were selected on the basis of simulated loaded cases and corresponding damage limit and withstand considerations. The cross-arm was subjected to a comprehensive testing program which comprised of component level tests corresponding to product standards and full-scale assembly level tests including corona and RIV tests, insulation withstand tests, power arc test, static load and special cyclic load tests to verify conformance to electrical and mechanical performance requirements and ratings.

KEYWORDS

Composite insulated cross-arms, CICA, insulator, retrofit, transmission lines, upgrading.

1. INTRODUCTION

Retrofitting of existing transmission structure steel cross-arms with composite insulated cross-arm are being undertaken by a number of utilities to solves issues of ground clearance infringements and for vital capacity upgrades. In this work the development of such a retrofit composite insulated cross-arm is reported.

A high strength double Vee composite insulated cross-arm with superior longitudinal load withstand characteristics as compared to standard braced line posts was developed to meet the performance requirements and to keep the structural modifications to the existing tower at a minimum. The innovation is envisioned to support utilities in implementing hardening and upgrade retrofits more efficiently.

2. SOLUTION DEVELOPMENT

A comparison between the original double circuit 230 kV lattice tower and modified tower whose bottom phases are retrofitted with composite insulated cross arms is shown in Figure 1. The insulated cross-arm replaces the existing steel lattice arm and ceramic suspension insulator set resulting in a ground clearance improvement of 2.2 meters which roughly equal to length of original insulator string.

Considering the connection form of the original angle steel cross-arm with the tower body, it was decided to use a double Vee configuration of insulated cross-arm composed of two line post insulators (compression members) braced by two suspension insulators (tension members). By designing the insulated cross-arm in this configuration, on one hand it can basically retain the original stress mode in the existing tower and on the other hand, it can also keep the modifications of the existing structure to a minimum. The retrofitted insulated cross arm attaches to the tower body at exactly the same position as the original steel cross arms and the connection flange of cross-arm line post insulators were designed to match the bolt hole drilling pattern of the tower attachment points. To further improve the obtained conductor-to-ground clearance, the line post insulators of the cross-arm were upswept by an angle of 12° with respect to the horizontal. According to the user's requirement, the horizontal length of insulated cross-arm was kept unchanged and consistent with the original cross-arm.

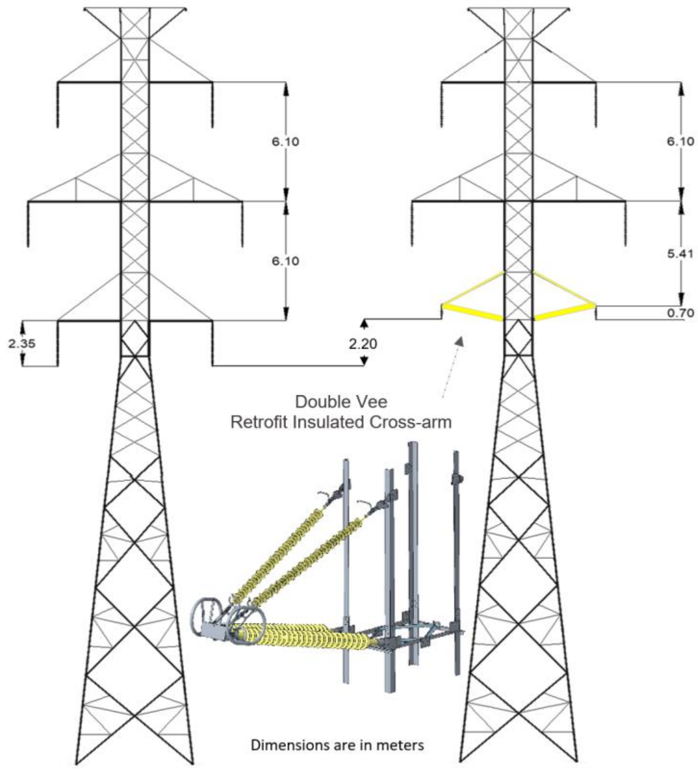


Figure 1. Original tower (left) and retrofitted tower (right) with insulated cross-arm.

In traditional arrangements, the suspension insulator can swing freely in the longitudinal direction to alleviate unbalance loads due to unsymmetrical ice loading or broken wire conditions. This load alleviation is typically quantified by a residual static load (RSL) factor of 0.7 in structure loading trees. For this retrofit application, an important consideration was about type of connection of the twin conductor bundle to the node hardware of the insulated cross-arm on the high voltage side. Two options exist for conductor assembly attachment to the insulated cross-arms. The first one is an integrated cross-arm node where the conductor suspension clamps attach directly to the node without any intervening hardware. The advantage of this design is that it provides that most compact geometry and maximizes the achievable conductor-to-ground clearance but since the conductors are attached rigidly to the cross-arm, longitudinal load transferred to the cross-arm, tower structure and foundation would increase. The other option is to connect the conductor bundle yoke through suspension hardware fittings. The length (L) of the suspension hardware string can be adjusted by adding links to achieve the desired load alleviation effect, however this arrangement comes at a detriment to maximum attainable ground clearance. The two cross-arm node designs are shown in Figure 2.

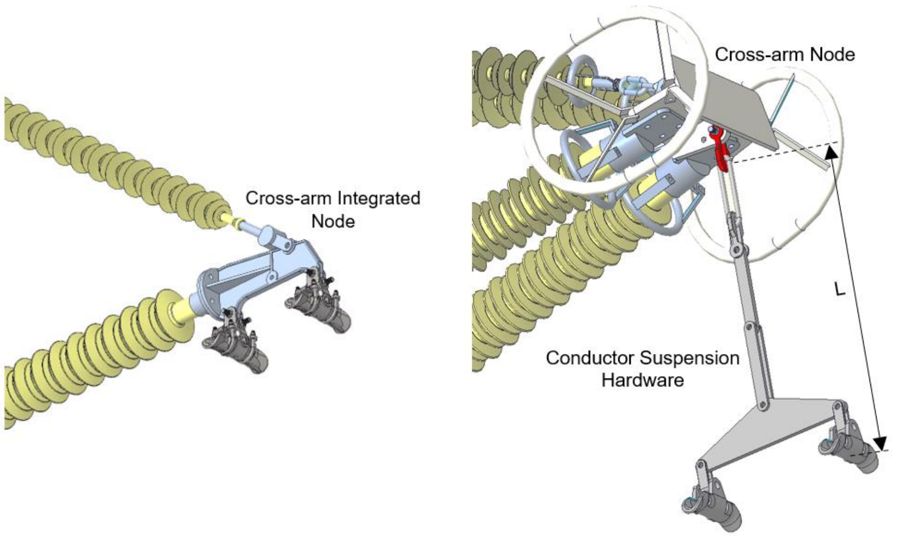


Figure 2. Insulated cross-arm node design options and conductor attachment assemblies.

The above two conductor assembly attachment options were evaluated with respect to their implications on structural loads. A 7-continuous-span profile model was created to simulate the unbalance load condition for the insulated cross-arm with different suspension hardware lengths. It can be seen from the results given in Table 1 that the longitudinal loads increase sharply when the suspension string is shortened below 700 mm in length. After concurrent consideration of the longitudinal load, its effect on cross-arm design, capacity of existing structure, wind induced swing displacement and ground clearance improvement, a good balance between these parameters was achieved with the selection of a 700 mm long freely suspended conductor attachment assembly.

Table 1. Longitudinal load in non-uniform ice and broken wire conditions

Suspension Hardware Length (mm)	**Unsymmetrical Ice Condition** (N)	**Broken Wire Condition** (2/2 conductors in twin bundle) (N)	**Broken Wire Condition** (1/2 conductors in twin bundle) (N)
1800	2617	26767	2263
900	5642	32233	5168
700	7400	33712	6961
450	12260	35968	11192

Nonlinear structural analysis of the retrofitted tower was carried out using PLS TOWER under the same loading conditions as the original tower. The focus of these design calculations as shown in Figure 3 was on the structural capacity of the existing towers with the modified insulated cross-arm to ensure compatibility and capacity. For the typical simulated load cases, the structural analysis showed that internal forces in the original and retrofitted tower were comparable and indicated some overstressed members in both the original and retrofitted tower. The usage of these overstressed members increased by approximately 2% after modification with insulated cross-arm which was considered permissible. The situation described is for generic tower loading conditions, in case of practical applications, the actual project specific loading would govern and overstressed members (if any) would be reinforced.

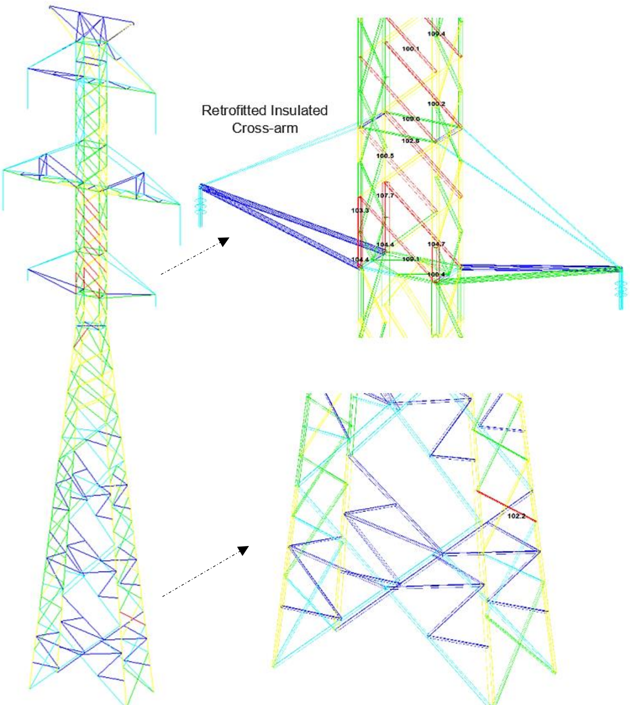


Figure 3. Position and percentage usage of overstressed tower members (in red).

3. ELECTRICAL DESIGN OF INSULATED CROSS-ARM

3.1 Insulation Coordination

Insulation coordination is generally the first step in the design of an insulated cross arm where the basic aim is to set the minimum possible clearances in order to reduce the cross-arm length and maximize compaction. Phase-to-ground clearances on an insulated cross arm can be classified as dry arc distances and strike distances. Dry arc distances are the air-gap across the cross-arm insulators or any other internal static air-gap from the energized to grounded hardware not influenced by the action of wind induced movements. Whereas, strike distance is the clearance between the freely swinging conductor fittings to the grounded hardware or tower structure. The location of the limiting (minimum) phase-to-ground clearance distance can vary from one cross-arm design to another and is also dependent on the type and sizes of electrical field grading devices. On structures with insulating cross arms, steel members do not separate phases and therefore the specification of minimum phase-to-phase clearances is also needed.

The use of composite insulated cross arms also presents some unique insulation optimization opportunities. Compact lines with insulated cross arms produce a stronger electro-magnetic coupling between overhead shielding wire(s) and phase conductors leading to improved back-flashover performance [1] which may be leveraged to get a reduction in insulation clearances. Composite insulated cross arm also offers a more seamless way to integrate externally gapped line surge arresters (EGLA) which can enable an even more compact line design and/or permit elimination of overhead shieldwires. In addition, the well-known hydrophobic properties of silicone rubber suppresses leakage current flow and the inclined/horizontal orientation of the cross-arm insulators promotes natural self-cleaning imparting an overall improvement in pollution withstand performance. Though, a marginal decrease in the pollution flashover voltage due to the presence of multiple insulators (four in case of double Vee cross-arm) electrically connected in parallel to each other should be taken in consideration.

In this work, a minimum dry arc distance of 1970 mm was required to deliver the defined lightning performance. Figure 4 presents the clearance envelopes with coordination of phase-to-ground strike distances for steady state, moderate wind and high wind cases. It is evident that from purely an insulation withstand point of view, the length of the insulated cross arm could be further reduced. However, in this retrofit application it was decided to retain the original horizontal displacement of 3.2 m between the conductor attachment point with the tower structure so as to fulfil the safe live line climbing clearance.

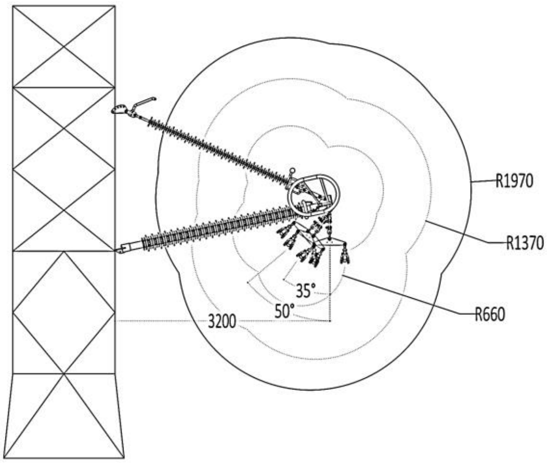
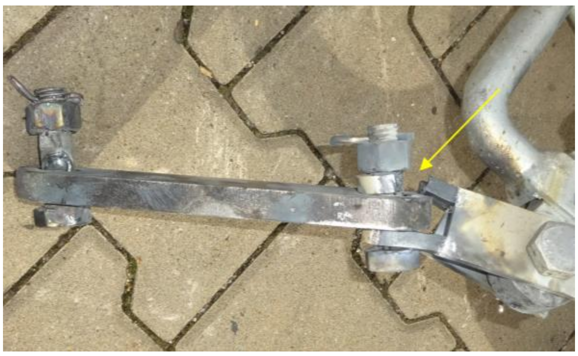


Figure 4. Phase-to-ground air clearances on the insulated cross-arm (dimensions in mm).

3.2 Power Arc Withstand

Power arcs on transmission line insulators can be initiated due to transient overvoltages or pollution induced flashovers. The magnitude and duration of the resulting arc current depends on a host of network parameters which includes the short circuit level (network strength), location of fault along the line and operating settings of protection circuit breakers. The design aim for successful power arc withstand is to control the movement and position of arc burning points (root) away from the vulnerable composite insulators and to size the metal fittings and hardware (in path of current flow) to withstand the effects of arc current without loss of mechanical strength. Figure 5 show some examples of failures during power arc events when the above two criteria are not met.

For this particular composite insulated cross-arm application, the power arc protection was rated at 40 kA (r.m.s) 1.0 second. Since lightning overvoltages were considered to be the most dominant cause of flashover, only the suspension insulators which represent the shortest dry arc distance in cross arm assembly were protected. In addition to shorter insulation distance, simulation showed the arcing rings of suspension insulators to have the highest electric field gradient compared to other grading/shielding rings, thus also increasing the likelihood of overvoltage flashovers to occur across the suspension insulators.



(a) Inadequate fitting cross-section leading to mechnical speration.

(b) Uncontorlled arc buring resulting in insulator damage.

Figure 5. Typical examples of failures during power arcs.

Figure 6 illustrates the power arc protection scheme on the insulated cross arm. Due to the fact that aluminum is more easily pulverized under thermal heating, the use of steel is preferred for arc protection devices. As a design basis, threshold current density of 70 A/mm^2 for load bearing fittings and 80 A/mm^2 for protection devices (without mechanical load) was adopted as per [2] and the arc protection devices were designed to be fixed on an intermediary fitting instead of being directly mounted on insulator crimped end fittings. On the high voltage side, an integrated arcing ring with in-tandem functions of arc withstand and electric field grading (as opposed to a combination of separate grading ring and arcing horn) was applied due to its enhanced arc control characteristics and overall compactness. With this device, once the arc root moves on to the arcing sphere the power is fed unidirectionally allowing the arc movement to stabilize and restricts it away from the venerable insulator housing and seal. Moreover, the opening in the ring allows easy removal and installation where replacement of the arcing ring becomes necessary. The final dimensioning of the arc protection devices should take into account both the current carrying capacity as well as the electric field stress. The arcing spheres and horns are oriented upward to take advantage of the thermal buoyancy of the arc bow.

Figure 6. Power arc protection on the composite insulated cross arm.

3.3 Electric Field Grading

The strength and distribution of electric field on the insulated cross arm needs to be carefully controlled and graded to limit radio and audible noise generation due to corona on metallic hardware and to avoid the inception of water droplet induced corona on insulator housing which is known to cause pre-mature ageing of composite insulators. Due to the differences in physical anatomy, asymmetrical geometry and compact line applications, traditional design of grading rings derived from empirical experience may not be fully adequate for composite insulated cross arms.

For this application, the design and positioning of grading devices were parametrically optimized through comprehensive finite element method (FEM) simulations where the insulated cross-arm, suspension fittings of the conductor bundle, phase conductors and the transmission tower were modelled. The voltage boundary condition for the insulated cross arm was set at 153 kV corresponding to the rated phase-to-ground voltage of the system. Maximum permissible electric fields proposed by EPRI/STRI [3] were implemented, where the electric field on the insulator housing and triple point seal is limited to 4.2 kV/cm (averaged over any 10 mm) and 3.5 kV/cm respectively. A maximum electric field value of 18 kV/cm was used for metallic hardware. Figure 7 illustrates results of electric field simulation of the composite insulated cross arm with the final grading system.

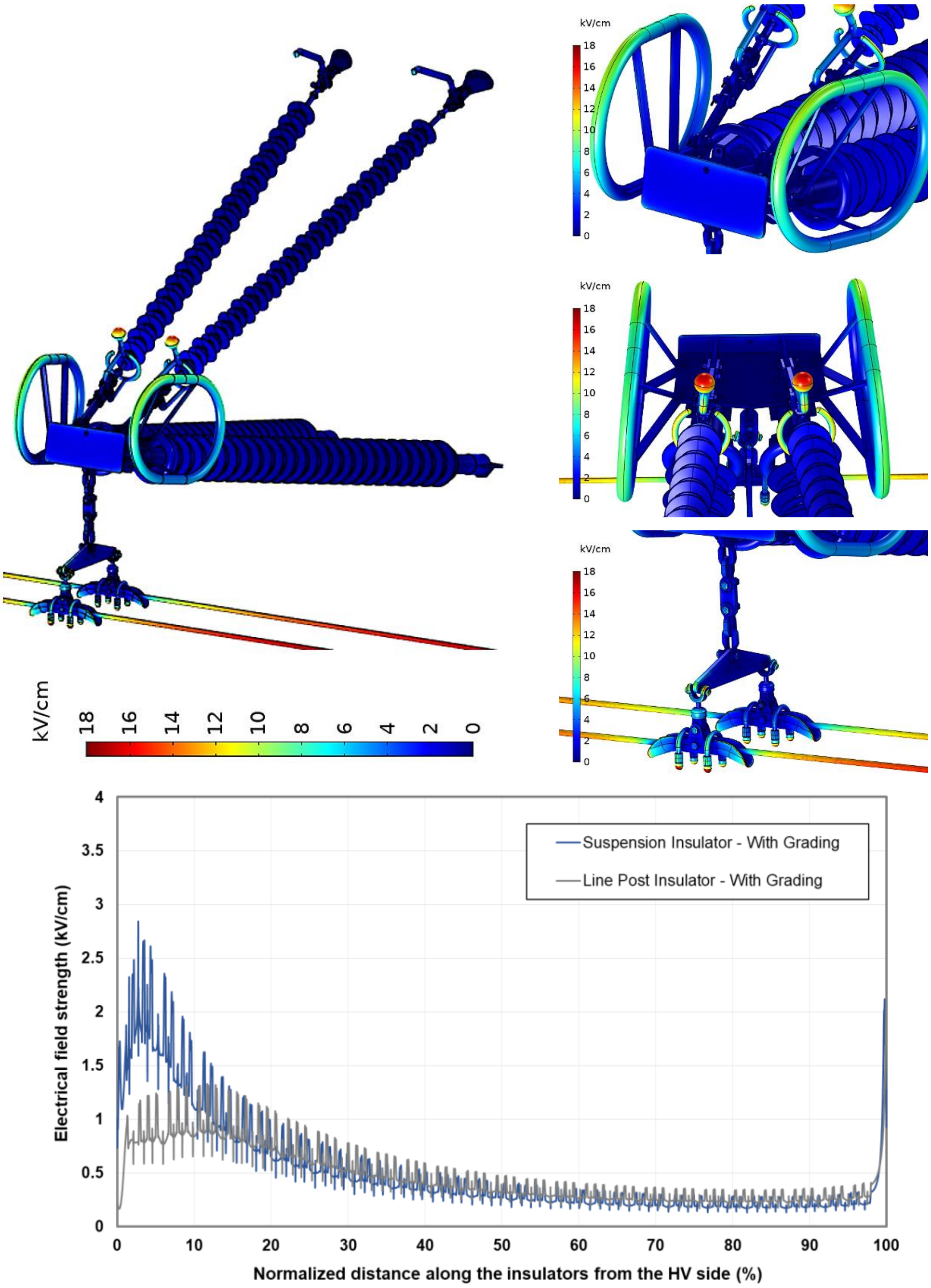


Figure 7. Electric field distribution with optimized grading rings at 264/sqrt(3) kV.

4. MECHANICAL DESIGN

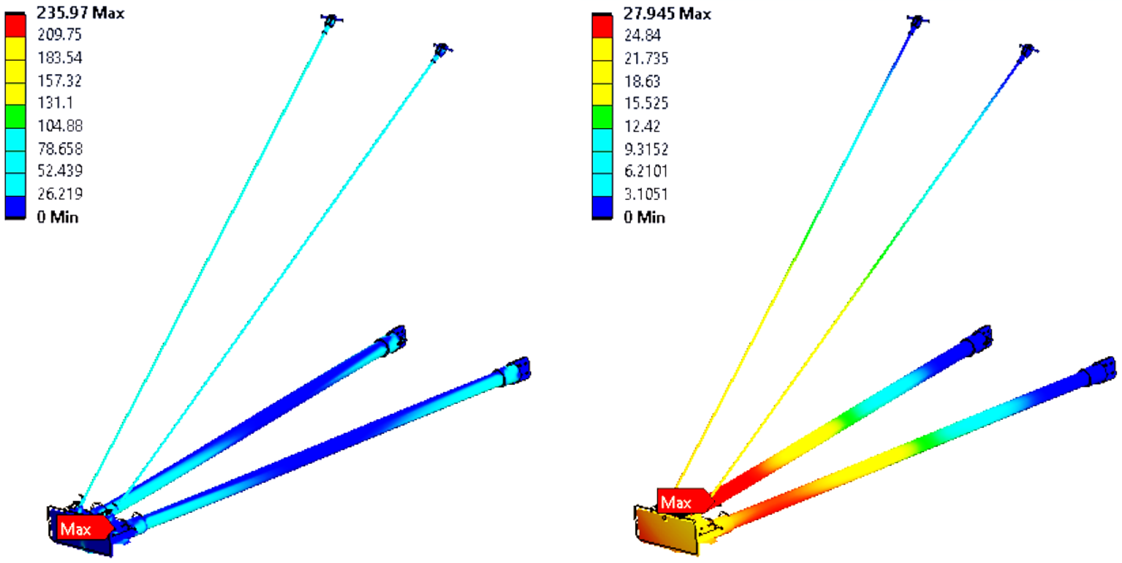
Analytical equations describing the mechanical load performance are provided in the IEEE Guide for Braced Insulator Assemblies [4]. For a double Vee cross-arm, more precise component loading and mechanical characteristics can be obtained through FEM simulations. The insulated cross-arm is designed and rated mechanically as a 'system' where the strength and stability of the insulator FRP cores, metallic hardware, fittings and bolted connections are considered and sized to provide required load withstand performance. Table 2 presents the analyzed load cases and approximate insulator loads. These load cases were categorized into repeatable loads and security loads. A strength factor of 0.5 was adopted for repeatable loads in-line with NESC recommendations so that the insulation and the hardware were not loaded beyond their damage limit. For security load cases which involved un-balanced longitudinal loading, the composite insulation and hardware may be loaded beyond their damage limit but must withstand the ultimate loads to avoid a cascade failure. For this reason, it was considered appropriate to use a strength factor of 1.0 to determine the cross-arm capacity for security loads.

The most important aspect in mechanical design of this cross-arm was the sizing of line post insulator against compression buckling. For a post insulator buckling length of 3.25 m, an SCoL (Specified Compression Load) rating of 170 kN (which includes a safety factor of 2.0 per user's request), resulted in post insulator FRP core diameter of 90 mm. The brace suspension insulators are articulated at either ends with suitable fittings to provide two rotational degrees of freedom ensuring these insulators are only loaded in tension and thus their sizing is relatively forward and involves the selection of the suitable SML (Specified Mechanical Load) rating.

Table 2. Design load cases and insulator reaction forces

Load Case	**Vertical** (kN)	**Transverse** (kN)	**Longitudinal** (kN)	**Max. Post Compression** (kN)	**Max. Brace Tension** (kN)
Ice	37	0	0	31	33
Ice & Unbalanced Tension	22.3	0	17.8	85	15
Wind	15.2	18.0	0	20	12
Wind & Un-balanced Tension	9.2	10.8	17.8	78	2
Ice & Wind	36.2	21.0	0	19	29

Figure 8 shows the typical FEM simulation output with loads of V = 22.3 kN and L = 17.8 kN applied to the node of the double Vee cross-arm.



(a) Stress (units: MPa) (b) Deformation (units: mm)

Figure 8. Stress distribution and deformation of insulated crossarm under ice and unbalanced tension load case.

5. LABORATORY TESTS

5.1 Testing Philosophy and Plan

For verification of the overall design and performance, the composite insulated cross arm was subjected to a host of laboratory tests. Given that the composite insulated cross arm is made of different types of insulators, fittings and hardware which are integrated together to from a complete assembly as shown in Figure 9, the technical and testing provisions for the cross arm are split into component level and assembly requirements.

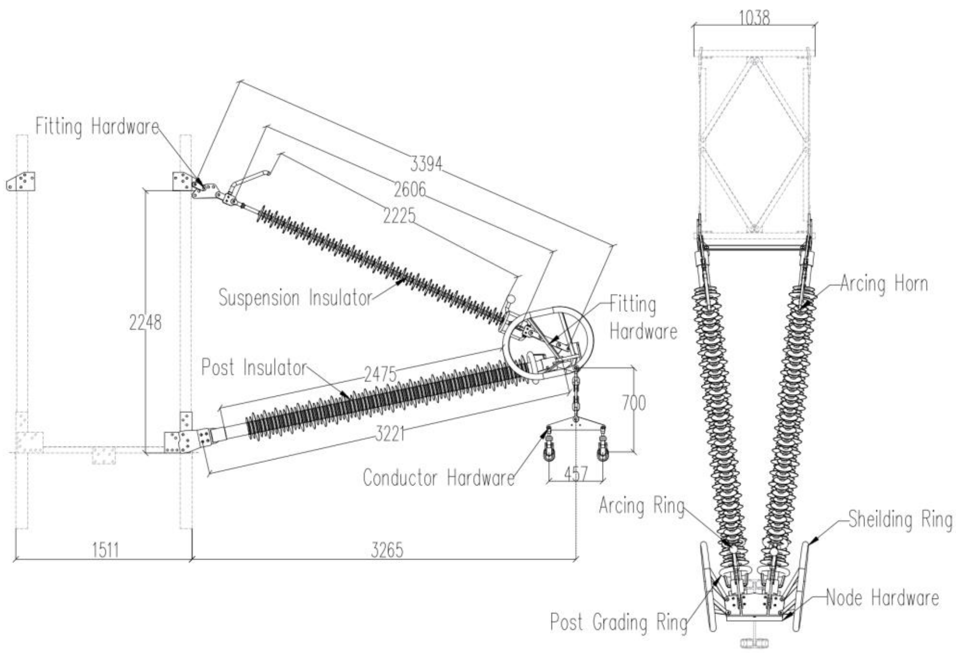


Figure 9. Outline drawing of insulated crossarm (all dimensions in mm).

Each primary component of the insulated cross arm i.e., composite suspension insulator, composite line post insulator and metallic hardware (grading devices, suspension & link fittings and node) must fulfill the requirements corresponding to their own product standard. Then at an assembly level, the electrical and mechanical ratings of the insulated cross arm are validated through type tests (following existing standards) and its dimensions are verified in the form of a sample test. No design or routine tests are involved at the assembly level. Table 3 and Table 4 present the component and assembly levels tests performed alongwith the corresponding applied standards (when available).

Table 3. Component level tests of composite insulated cross arm.

Component	Applied Standard	Design Tests	Type Tests	Sample Tests	Routine Tests
Composite Suspension Insulator	IEC 61109	✓	Only mechanical (1)	✓	✓
Composite Line Post Insulator	IEC 61952	✓	Only mechanical (1)	✓	✓
Metallic Hardware	IEC 61284	n/a	Corona & RIV excluded (1)	✓	✓

(1) Electrical type test at component level do not provide any useful test information. These tests are carried out at assembly level.

Table 4. Assembly level tests of composite insulated cross arm.

Classification	Tests	Applied Standard
Electrical Type Tests	Wet power frequency voltage test	IEC 60383-2 and IEC 60060-1
	Dry lightning impulse voltage test	IEC 60383-2 and IEC 60060-1
	Wet switching impulse voltage test	IEC 60383-2 and IEC 60060-1
	Corona extinction voltage test	IEC 61284 and CSA C411.4
	Radio interference voltage test	IEC 60437
	Water droplet induced corona test	Reference [5]
	Power arc test	IEC 61467
Mechanical Type Tests	Post insulator ultimate capacity test	User specification
	Assembly combined static load test	
	Post insulator cyclic load test	
	Assembly cyclic load test	
Sample Tests	Verification of dimensions	User specification
	Proof of fit test	

It should be noted that component and assembly level test requirements can refer to any existing system of international standards such as IEC, ANSI, IEEE or CSA etc. as preferred by the user. Moreover, additional assembly level testing per user's request or requirements, such as: artificial pollution withstand, ice flashover withstand, short circuit testing, dynamic load testing etc. may also be performed according to actual service requirements. In this paper details of only the full-scale assembly type tests of the insulated cross arm are presented.

5.2 Insulation Withstand Tests

The insulated cross arm was tested for power frequency, lightning and switching impulse withstand characteristics. The mounting arrangement used for these tests was devised to be representative of actual service condition. The specified wet power-frequency withstand voltage of 510 kV was applied to the insulated cross arm for one minute. No external flashover or puncture was observed. In addition, wet power frequency flashover voltage of 778 kV was determined as the average of five consecutive flashover voltages. The 50% critical flashover voltage (CFO) of both positive and negative polarities was determined by the up and down method with 30 impulses of lightning impulse and switching impulse. The calculated 10% withstand voltages exceeded the specified dry lightning impulse withstand voltage of 1050 kV and wet switching impulse withstand voltage of 650 kV. Figure 10 shows the test set-up for wet power frequency voltage test and Figure 11 shows an example of lightning impulse testing of the cross arm.

Figure 10. Arrangement for wet power frequency voltage test of insulated cross arm.

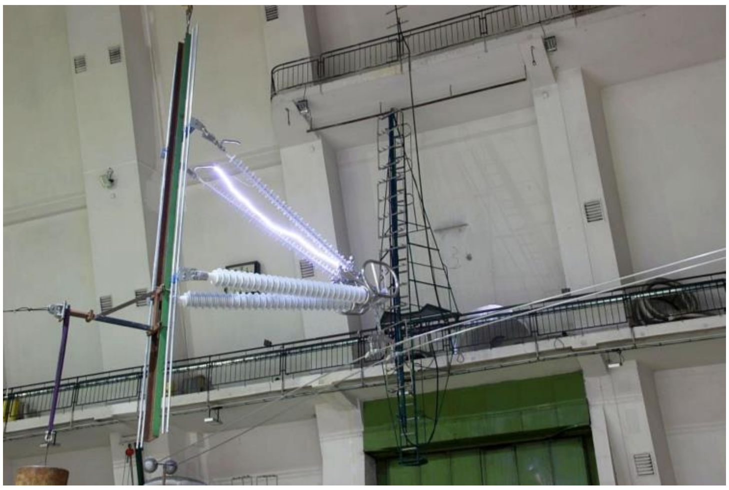
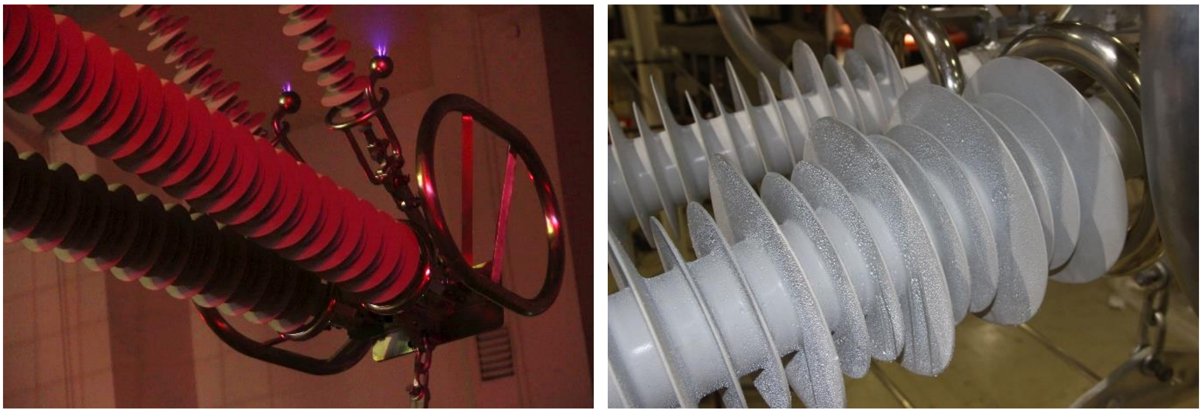


Figure 11. Dry lightning impulse flashover test of insulated cross arm.

5.3 Corona and RIV Tests

Corona extinction voltage, radio interference voltage (RIV) and water droplet induced corona (WDIC) tests were performed with an aim to evaluate the performance of the electric field grading rings. During the corona extinction voltage test, a test voltage of 220 kV was applied to obtain a test conductor surface gradient of 1.2 * 17.25 kV/cm and the insulated cross arm was found to be corona-free. At higher voltages, the location of corona inspection corresponded well with the stress regions identified in the FEM electric field simulations. RIV of 39 dB/1µV (1.0 MHz frequency) was measured at an applied voltage of 168 kV (1.1 times the rated phase-to-ground voltage of the system) which was well below the maximum specified value of 52 dB/1µV. In the WDIC test, the housing of cross arm composite insulators was sprayed with water before the application of test voltage and no visible WDIC was observed upto to maximum specified voltage as shown in Figure 12.



(a) Visible corona inspection on cross arm hardware at 281 kV.

(b) Absence of water droplet corona at 153 kV (max. phase-to-ground system voltage).

Figure 12. Corona tests of composite insulated cross arm.

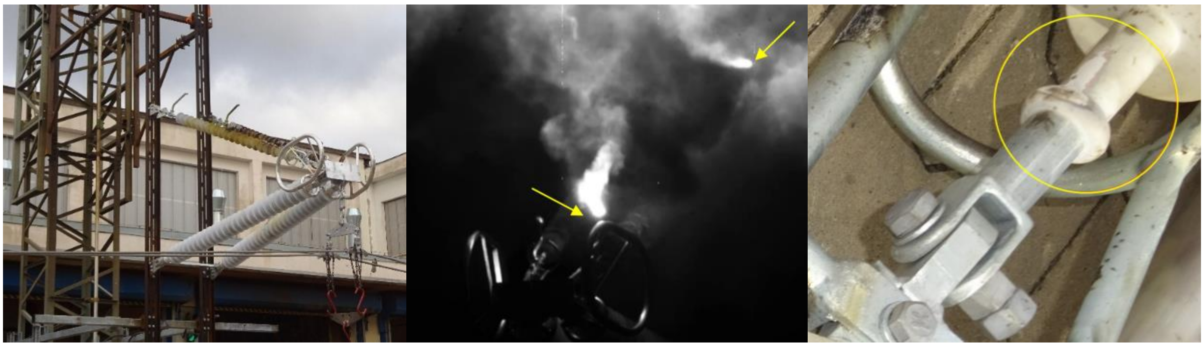
5.4 Power Arc Test

For power arc testing, the complete insulated cross arm assembly with grading/arcing rings and suspension fittings was firmly mounted on a grounded steel support structure. Test circuit C, comprised of balanced supply and unbalanced return circuit with specified arc current of 20 kA (In = 0.5* Isys) was used. This test condition represents a fault in the mid-section of the transmission line and provides a broader coverage of the actual service conditions. A dead weight of more than 5 kN was suspended from the cross-arm node to simulate service load and to produce electrical contact between fittings and metallic hardware. The overall arrangement for power arc testing is shown in Figure 13.

Three arc applications of 20 kA 0.2 sec, 20 kA 0.2 sec and 20 kA 1.0 sec were applied on the same suspension insulator of the cross arm. This concept of repeated arc application of on the same insulator of the cross arm is similar to how conventional multiple insulator sets are tested. Arc ignition was made by fusible copper wire wrapped on the insulator housing. Wrapping of the fusible wire around the insulator housing is intended to reproduce pollution induced power arc flashover which represents a more severe condition from the point of view of arc control.

Visual inspection after the arc test found the housing and triple point seal of the composite insulator to be fully intact (no exposre of fibre glass core). There was no mechnical seperation or adverse damage to metallic hardware which experienced only partial metling and surface buring. Further more, analysis of high speed video showed that the position of arc root and burning was effectively controlled by the arcing ring and arcing horn protective devices. Finally, the suspension insuslators were mechnically tested upto 70% of their SML rating. Figure 14 shows a still-image from the power arc test high-speed video and conditon of the composite insulated cross arm after the test.

Figure 13. Arrangement for power arc test of insulated cross arm.



(a) Insulated cross-arm after arc test (b) Postion of arc roots (c) Condition of insulator triple point

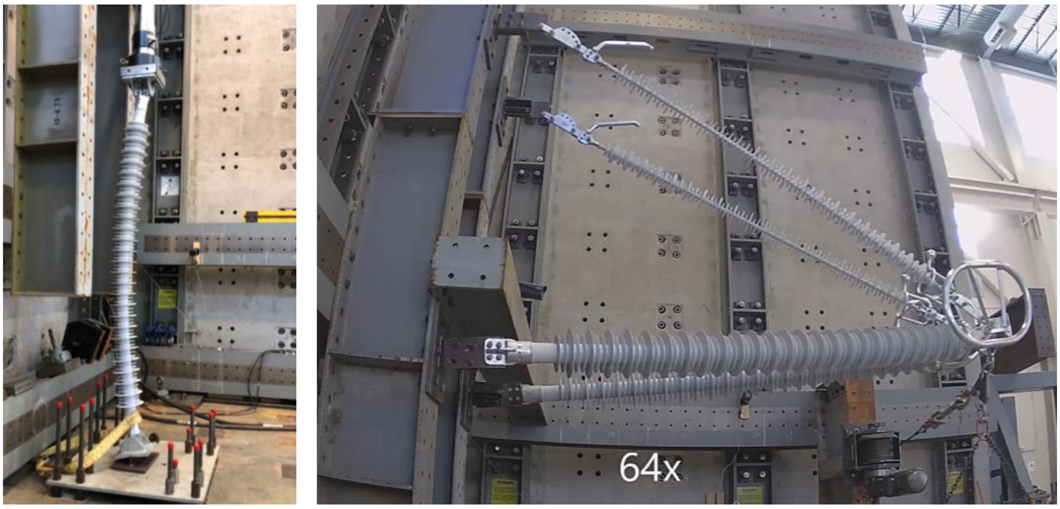
Figure 14. Condition of insulated cross-arm after test and still of high-speed video depicting control of arc burning points.

5.5 Mechanical Tests

Static load tests for the insulated cross-arm involved confirmation of the buckling capacity of post insulators and subjecting the whole assembly to the most critical load case. The compression test on the post component of the cross-arm included loading the insulator to 100% of the SCoL rating and then to failure. Conservative assumptions were made to simulate the end conditions of the post insulator where one end of the insulator was fully fixed, while the other end was allowed to rotate freely. Three samples of post insulator were tested all of which met the specified requirements.

In the full assembly combined static load test, the insulated cross-arm was mounted on reaction wall and a combination of vertical, transverse, and longitudinal load was applied to the insulated cross-arm. Out of all the design load cases, the ice + unbalanced longitudinal load case was identified as the most demanding on the cross-arm. Vertical load was simulated by a suspended free weight block while the longitudinal load was impressed by a hydraulic winch connected to the cross-arm node via a shackle arrangement. During the test, failure occurred following the application of 22.3 kN vertical load and a 49.9kN longitudinal load, which equates to 175% of the resultant design load vector. Test set-ups for the post insulator compression buckling capacity and the full assembly combined static load test are shown in Figure 15.

In addition to static load tests, the insulated cross-arm was also subjected to two cyclic load tests. The purpose of cyclic testing was to determine if end fittings remain firmly connected to the composite rods under expected repeated loads during the design life of the line. In the high cycle test, a sinusoidal compression load varying from 1.3 kN to 16.5 kN at 2 Hz frequency was applied to the cross-arm post insulator for up to 300,000 cycles. On the full cross-arm assembly a low cycle test based on repeated wind loading was performed. In this test a constant vertical load of 15.2 kN was applied while a +/- 12 kN amplitude transverse load was sinusoidally varied at frequency of 0.03 Hz for upto 3,000 cycles. Both cyclic load tests were passed without any discernable slippage of end fittings or change in deflection measurements.



(a) Post insulator ultimate compression capacity test

(b) Full insulated cross-arm assembly static load test

Figure 15. Static load tests of composite insulated cross-arm.

6. TRAIL FIT

Installation and constructability trail of the developed composite insulated cross-arm on an actual lattice tower was organized to iron-out any issues before the mass-deployment of the solution and also to possibly identify any further design improvements. Some views of the trail fit are shown in Figure 16. The entire retrofit operation which included dismantling of the old steel cross-arm and then ground assembly, hoisting and bolting the retrofit insulated cross-arm in place was undertaken by a four-man crew and completed in less than three hours. It is expected that as the line crews become more familiar with handling and installation of the insulated cross-arms, this time will be further reduced. The overwhelming comments by the crew very favorable especially on how easy it was to assemble and install the retrofit composite insulated cross-arm compared to the double dead-end assembly previously being used for this purpose.

Figure 16. Trail fit of retrofit composite insulated cross-arm.

CONCLUSIONS

Composite insulated cross-arms are an ideal solution for clearance mitigation, upgrading and new compact lines. This work describes the development of a high strength insulated cross-arm with double Vee configuration which is aptly suited for lattice tower applications. The cross-arm design was conducted in close cooperation between the end-user and the supplier which resulted in a holistic ready-to-fit solution compatible with the vintage tower. The electrical and mechanical design of the insulated cross-arm has been analyzed extensively with FEM simulations and full-scale assembly tests have proven its rigorous performance and ratings. The developed retrofit composite insulated cross-arm offers a useful solution to transmission utilities which are actively engaged in augmenting their network capacity and overcoming technical constraints.

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