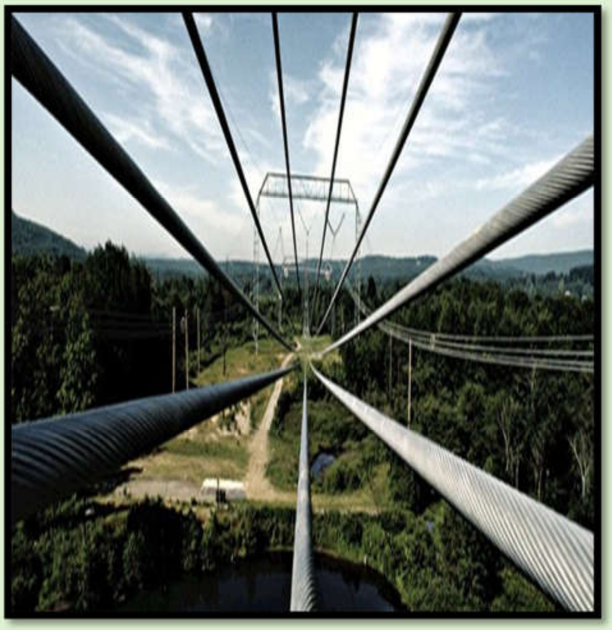
सत्यमेव जयते

Guidelines For Rationalised Use Of High Performance Conductors



भारत सरकार

Government of India

केन्द्रीय विद्युत प्राधिकरण

Central Electricity Authority

विद्युत मंत्रालय

Ministry of Power

नई दिल्ली

New Delhi

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By

Power System Engineering & Technology Division

Central Electricity Authority

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Foreword

To achieve the transmission capacity target and to solve the eminent issues like growing congestion in existing corridor of transmission / distribution network and Right of Way (RoW) problems, use of New generation High Performance Conductors (HPC) for enhancement in power transmission capacity in existing corridor has become the preferred solution. An effort has been made to comprehensively evaluate the various High Temperature Low Sag (HTLS) conductors available in the Indian market and to rationalize their effective use by the various transmission Utilities.

It is a matter of great pleasure to bring to you the Guidelines on use of HTLS conductors in the Indian Transmission system. These guidelines provide the detailed description of High performance conductors, including their Ampacity comparison, Application areas, issues to be considered before their installation, Cost benefit analysis, Criteria for technical evaluation of Bids and manufacturing and testing facilities available in India pertaining to High performance conductors.

I am sure that these guidelines would be quite helpful to the transmission utilities to gain the technical insight to the technology available and will certainly give them confidence to judiciously use these conductors for the betterment of Indian transmission and Distribution system.

(Prakash Mhaske)

PREFACE

Though India ranks 5th from top in terms of installed capacity & 3rd in electricity production in the world but at the same time we are among the bottom most when we compare our self with world major economies on per capita electricity consumption basis. However, the power consumption could rise multifold in times to come due to faster rate of GDP growth and ambitious targets for capacity additions in renewable sector. The rising demand coupled with our aging transmission infrastructure particularly in state sector points to need for exploration of newer technologies in transmission to transfer more power per unit RoW in a given corridor.

To look into the technology of high power conductors and frame guidelines for their rationalised use, a group was formed under Chief Engineer(PSETD) with members drawn from CPSUs, STUs and manufacturers. The issues were deliberated in great detail and the comments were invited from stakeholders on draft guidelines before finalizing.

These guidelines comprehensively cover various aspects of High Power Conductors and considerations to be made before taking decision on usage of such conductors. It covers topics like options for increasing transmission capacity, ampacity comparison, application areas, HTLS conductor types, installation issues, technical evaluation of bids and cost-benefit analysis, etc. For the benefit of stakeholders, this document also provides outline of typical technical specifications for HPC conductors & hardware, GTPs and currently available test facilities in India.

At the end, I thank Shri Prakash Mhaske, Chairperson, CEA for guiding at every step in preparation of this document. Special thanks to all the Committee members & manufacturers for sharing valuable information on high power conductors and my predecessor Shri S.K.Ray.Mohapatra, Chief Engineer(PSPM) for initiating the committee work and contributing immensely to this document. I also thank my colleagues Shri Y.K.Swarnkar, Director, Smt. Kavita Jha & Mr. Faraz, Dy.Directors and Asstt. Directors Shri Mohit Mudgal, Ms. Bhaavya. Pandey & Karan Sareen, engineer Ms. Sippy Srivastava and staff of PSETD Division for working tirelessly to accomplish the task.

S. Srivastava
14/2/2019.

14th February, 2019
New Delhi

(Sanjay Srivastava)
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1.0 INTRODUCTION:

1.1 Indian power sector is growing at a very rapid pace both in supply and demand side. Transmission capacity needs to be enhanced to commensurate with the rapid urbanization and consequent increase in demand. The most common way to raise transmission capacity is to construct new lines. However, increased environmental constraints and public opposition to new overhead lines has made it very difficult to get Right of Way (RoW) for new lines and the cost of RoW is also escalating due to rapid urbanization. Apart from addition of new transmission system, there is urgent need of enhancement of the capacity of the existing transmission system to cater to the increase in demand. The problem in getting RoW has necessitated to utilize existing RoW in more efficient way to enhance quantum of power in the same RoW. Wherever transmission constraints are felt and enhancement in power transmission capacity in existing corridor becomes necessity, alternative means such as use of higher size conductor, voltage increase technologies, circuit addition, HVDC, dynamic line rating etc. need to be explored. One such emerging technology is the use of new generation High Performance Conductors (HPC), which include High Temperature (HT) conductors and High Temperature Low Sag (HTLS) conductors, and these conductors have been proven successful globally.

1.2 In India, ACSR and AAAC conductors are commonly used for transmission of power on overhead lines for transmission and distribution system. Conductors constitutes about 30% to 40% of total cost of overhead EHV transmission lines and type of conductors plays an important role in quantum of power flow, Transmission & Distribution (T&D) losses, height & design of towers, span length, , and hence cost of the transmission line. HPC conductors are being used by several Indian utilities, however, there is need to adopt such conductors rationally to suit India's Transmission and Distribution Sector requirement. These HPC conductors could help electric power delivery system to meet the desired objective. Apart from its use in enhancement of power transmission capacity in existing corridor, such conductors could also be used in new lines where higher power flow is required which otherwise is not possible through ACSR or AAAC conductors. As such, a judicious decision is needed while selecting a particular type of New Generation conductor for new lines as well as for uprating the existing corridors in Transmission and Distribution segment keeping in mind the techno-economic benefits.

1.3 The conventional ACSR and AAAC conductors are currently designed to operate at maximum temperature of 85^{o} C and 95^{o} C respectively. The thermal limit of the conductor is established by the fact that further heating anneals the conductor. The ordinary hard drawn aluminium used in conventional ACSR starts annealing and losing strength at above 93^{o}C and is not suitable for use at temperature above this. Thus, the ampacity of these conductors is restricted by above mentioned temperature and further enhancement of ampacity is not possible. Ampacity in the same transmission line can be enhanced by use of either higher size conductor or High Performance Conductors (HPC). Each option needs to be thoroughly evaluated including requirement of changes to be made in existing infrastructure.

1.4 High Performance Conductors are designed to operate continuously at temperature of at least 150^{o} C. Some of these conductors can continuously operate at temperature as high as 250^{o} C without any degradation in mechanical or electrical properties. Because of their operation at high temperature, these conductors can carry higher current (typically 1.5 to 2 times that of ACSR) without exceeding size & weight of existing conductor and offering similar or better tensile strength, hence allowing use of same structure without any or with minimal modification resulting into short erection period.

1.5 In India, for last few years, the need of use of High Performance Conductors in some corridors has been felt. The power flow in these corridors has increased and congestion has been reduced by using such conductors. Such conductor would be required where the power transfer over the line is constrained due to consideration of thermal loading.

1.6 High Performance Conductors can be considered for reconductoring of existing lines and can also be used in new lines. Depending on the type of conductor, the cost of such conductor may vary between 1.5 to 5 times the cost of conventional ACSR/ AAAC conductors. Other than the cost of power conductor, cost of additional ohmic loss at elevated temperature, conductor accessories, insulator hardware, de-stringing of conventional power conductor, re-stringing & installation of High Performance Conductors are to be considered before deciding whether installation of High Performance Conductors is economically justifiable. The terminal equipment rating at substations also needs to be examined for enhancement of power transfer in a line. Moreover, for new lines, proper system studies need to be carried out to identify the corridors for use of such conductor. The use of HPC conductors need to be considered on case to case basis based on techno-economic analysis over the life cycle. After considering the life-cycle cost, the overall project costs may, in some cases, be less even after higher cost of the conductor and accessories.

1.7 A Technical Committee comprising representatives from CEA, CPRI, IEEMA, PGCIL, State utilities, and conductor manufacturers was constituted under the Chairmanship of Chief Engineer, Power System Engineering & Technology Development Division of CEA vide order No. CEA/SETD/323/2016/23 dated 18.01.2016 to "Discuss and rationalize the effective use of new generation High Performance Conductor (HPC) [High Temperature / High Temperature Low Sag (HTLS) Conductor] in Indian Transmission & Distribution System". Office order vide which the Committee was constituted is enclosed at Annexure-V.

1.8 The first meeting of the Committee was held on 29.01.2016. Second meeting was held on 12.05.2017 in which the comments on draft document were discussed. Based on deliberations in these meetings and information collected from utilities, conductor manufacturers and other sources, this document has been prepared. As the technology of High Performance Conductors (HPC) [High Temperature / High Temperature Low Sag (HTLS) Conductor] are ever evolving and improvements are being made due to improved metallurgy of conducting part as well as core material, the technical parameters indicated in this document may experience changes or new type of conductors get introduced, which may not be covered in this document. As such, at the time of procurement of such conductors, utilities have to make their own assessment of need and techno-economic benefits.

1.9 Manufacturing of new generation High Performance Conductors is still evolving and newer core materials & conductors are being introduced by the manufacturers. Only few High Performance Conductors which are being used in India have been discussed in this document. Description of various conductors has been provided based on information gathered from utilities, manufacturers, publications etc.

1.10 Some of the scenarios where uprating by use of High Performance Conductors may be adopted and the scenarios where use of High Performance Conductors may not be a good option as compared to other technological options have been included in the document for the reference of the utilities. However, utilities may carry out their own analysis and make a decision as per their requirement to use any conductor which has or has not been mentioned in this document.

1.11 A sample technical specification for HTLS conductor and hardware accessories has been provided as Annexure- II & III respectively for the guidance to utilities. The values of parameters have been left blank and the same may be filled and technical specification may be modified by the utilities as per their requirement.

1.12 Correct assessment of current in various conditions needs to be made over life cycle be made and levelized accordingly for the purpose of loss loadings, alternatively time percentages of nominal expected current may be considered. However, the loss loading should not consider unrealistic flows as it can potentially disturb the inter-se ranking of bidders and utility may ultimately have to incur higher cost.

1.13 The list of tests required to be conducted on HPC conductors is included in the technical specification and technical data sheets to be filled by bidders has been provided at Annexure-IV. Some tests will be common for all HPC conductors while some tests will be exclusive for any specific conductor because of their specific metallurgical/electro-mechanical properties.

1.14 ***The purpose of this document is to provide basic information about High Performance Conductors to the utilities and create awareness so as to empower them to rationalize the effective use of such conductors in Indian Transmission & Distribution System. This document, by no means, promote or endorse any particular type of conductor or manufacturer.***

2.0 Options for Increasing Transmission Capacity

As transmission capacity (MVA) is a product of voltage (kV) and current (kA), the increase in capacity could be achieved by either increasing voltage or current or both of them. Various methods are available to increase the rating of an existing overhead line, each of these have unique cost-benefit ratio and the utility has to make studies before arriving at alternative best suited to them. Some of the options available for increasing the transmission capacities are as under:

(a) **Use of higher size conductor:** The most obvious method to improve ampacity of existing line is to replace the existing conductor with a higher size conductor that will run at the same operating temperature. However, size increase may warrant strengthening or replacement of the support structure. This approach is considered to be one step short of a wholesale replacement of the line and it can be considered that all that is salvaged by the change is the right-of-way itself.

(b) **Circuit addition**: Another solution for delivering more power between terminals is the addition of a circuit to a line. However, it is rare to find space on existing structures that would allow the addition of another circuit without serious revision to the structures. The most promising situation is the conversion of a single circuit line of vertical or delta configuration to a double circuit configuration. Conversion of an existing single circuit framing to a double circuit framing requires that enough spacing for phase to phase and phase to ground clearance is available so that after conversion regulatory and technical requirement of clearances is met.

(c) **Voltage Increase Technologies:** Wherever site situation permits, operation of an overhead line at a higher voltage level is a very effective way to increase the transmission capacity. Changing to a higher voltage level will increase the line capacity by the direct ratio of the voltage change and would reduce the energy losses by the voltage ratio squared. However, this approach requires either the presence of voltage options at the line ends (stations), or it requires a considerable expenditure on this end equipment replacement to accept the new line voltage. Additionally, to increase the lines voltage significantly, the structures also need revision. Also, to install longer insulators while maintaining the required clearances for the higher voltages, additional space would be needed which may not be available on structures.

Newer technologies like providing insulated cross-arms in existing towers provide advantages in maintaining the conductor swing and electrical clearances, thereby possibility of employing next higher voltage in existing lines with appropriate modifications. The ROW calculations with insulated cross arm also show space advantages. By changing both transmission voltages to next level and also replacing existing conventional conductor to HTLS conductor, the power transfer capacity of transmission line could increase multifold. These options may be explored by utilities in case substantial increase in power transfer capability of transmission line is required in a given corridor, while retaining the basic structure.

Often, conductor size may limit voltage uprating, as it may be necessary to replace existing conductors with larger diameter or additional conductors per bundle while increasing the voltage because of Corona effect, thereby further increasing the power transfer capability of line.

Voltage uprating is especially suited to converting a double circuit line into a single circuit line. Also, the phase to phase distance can be easily obtained by the conversion of a double circuit line into a single circuit line.

(d) **Use of HVDC :** Another technology for quantum increase in power transfer capability is the deployment of HVDC. However, the planning of such lines is an intricate and rigorous exercise. This option may prove to be very costly considering requirement of converters at both ends and associated DC network.

(e) Capacity **i**ncre**ase by Real Time Monitoring S**ystems **& Dynamic Line Ratings (DLR)**: Applying dynamic ratings based on real-time monitoring of weather conditions or conductor properties to determine (by calculations or direct measurement) the ground clearance at any time can allow higher power capacities in 'beneficial' weather conditions. Enhancement of ampacity can also be obtained from the difference between the ambient temperature used for the line design (e.g. 45°C) and the average ambient temperature of the region (e.g. 25°C). On an average, the increase in the thermal rating of lines using real time systems is about 10 to 15%.

(f) **High Surge Impedance Lines:** There are technologies that apply almost exclusively to long EHV lines, as power transfer capacity of these types of lines are generally limited by surge impedance. One such method involves reshaping of the line's physical configuration to revise its natural surge impedance to the advantage of its capacity. It provides a higher Surge Impedance Loading (SIL) than conventional line configurations offer. The HSIL lines concept can be applied either to new lines or to existing lines. In practice, this can be done by:

- Adding sub-conductors per phase
- Increasing the bundle size for each phase (Expanded Bundle Technology (EXB)
- The use of asymmetric bundles
- Decreasing the phase to phase distance

(g) HPC **conductor:** Reconductoring an existing line with HPC conductor is yet another alternative. Since HPC conductors are more expensive than conventional aluminum stranded conductors, they are not suitable in every uprating situation. Reconductoring with HPC conductors is not economically justified in each & every case of capacity enhancement and the decision shall be made by the concerned utility based on their specific requirement, system study and techno-economic analysis. Some scenarios where uprating by HPC Conductor may or may not be used are provided in para 3.8.

When increasing the ampacity of a circuit, it is important to check that all components of the circuit are appropriate for the new ampacity and if necessary change some of them (e.g. circuit breakers, current transformers, joints and clamps). Additionally, requirement of safe level of electric and the magnetic field beneath lines and RoW needs to be ensured.

3.0 Description of High Performance Conductors

3.1 As mentioned earlier, the ordinary hard drawn aluminium used in conventional ACSR starts annealing and losing strength at above 93^{o}C and not suitable for long term use at temperature above this. To avoid annealing, two options are used in conductor design. One option is to anneal the conductor's aluminum intentionally in the factory before purchase and installation. The other option is to alloy the aluminum with zirconium in varying degrees to produce TAL, ZTAL/UTAL and XTAL designated alloys. Alloying of aluminium slightly increases the resistivity whereas annealing of aluminium lowers resistivity thereby having better conductivity.

3.2 High Performance Conductors are manufactured using any of the above two options and are designed to operate continuously at temperature of 150o C and higher. Some of these conductors can be operated at as high as 250o C. High Performance Conductor is stranded with combination of annealed aluminium or aluminium alloy wires for conductivity, and reinforced by core wires. Al-Zr alloy wires have similar conductivity and tensile strength as ordinary Electrical Conductor (EC) Grade aluminium wire but can operate continuously at temperatures up to 150oC – 200oC. Fully annealed aluminium wires are chemically identical to ordinary hard drawn aluminum and have much reduced tensile strength, but can operate indefinitely at temperatures even higher than 250oC without any change in mechanical properties of aluminium. As shown in Table-I, the wire materials used for High Performance Conductors are capable of continuous operation at temperatures in excess of 1000C with stable electrical and mechanical properties.

Table-I

Type	Aluminium Conductor	Tensile strength (MPa)	Conductivity (% IACS)	Maximum continuous operating temperature (°C)	Emergency operating temperature (°C) (<10 hrs. per year)
Fully Annealed	1350-O (Fully annealed)	42 to 98	61.8	200	250
Thermal Resistant	TAL or 60 TAL (AT1)	159 to 169	60	150	180
HS Thermal Resistant	KTAL (AT2)	225 to 248	55	150	180
Ultra Thermal Resistant	ZTAL or UTAL (AT3)	159 to 176	60	210	240

Extra Thermal Resistant	XTAL (AT4)	159 to 169	58	230	260

3.3 The core material used in High Performance Conductors include galvanized steel, aluminium cladded steel, mischmetal steel, INVAR steel (Fe-Ni alloy), high strength steel, metal matrix composites and polymer matrix composites (e.g. carbon fiber composite). For High Performance Conductors with annealed aluminum strands, the conductor stiffness and breaking strength is largely determined by the core. For High Performance Conductors with Zirconium aluminum strands, the composite conductor strength and stiffness depends on both the reinforcing core and the aluminum strand layers. Properties of various core materials have been shown in Table-II.

Table-II

Description	Modulus of Elasticity (GPa)	Tensile Strength (MPa)	Coefficient of Expansion ($x10^{-6}/°C$)	Unit weight (mg/mm^3)
HS Steel	200	1379-1448	11.5	7.778
EHS Steel	200	1517	11.5	7.778
EXHS Steel, Galfan coated	200	1965	11.5	7.778
Aluminum clad 20.3% IACS	162	1103-1345	13	6.588
Galvanized Invar alloy	162	1034-1069	1.5-3.0	7.778
Aluminum clad Invar	152	932-1080	3.7 - 10.8	7.1
Mischmetal (Std, HS)	200(I) - 186(F)	1379-1448 1517-1620	11.5	7.778

Metal Matrix	215	1310	6.0	3.322
Polymer Matrix	112.3	2158	1.6	1.88

3.4 An High Performance Conductor can be manufactured by using any of the following combinations:

(a) Steel/ coated steel/ steel alloy core with an envelope of thermal-resistant aluminium alloys
(b) Steel/ coated steel/ steel alloy core with an envelope of annealed aluminium
(c) Metal-matrix composite (MMC) core with an envelope of thermal-resistant aluminium alloys
(d) Polymer-matrix composite (PMC) core with an envelope of annealed aluminium/ thermal-resistant aluminium alloy

3.5 A combination of the properties of the envelope and the reinforcing core decides the operating temperature limit of a High Performance Conductor. Normally, a compromise between the operating temperature limits and loss of tensile strength of the envelope is made. The operating temperature limitation of the conductor also factors in the possible deterioration of the connectors and associated hardware. So, the operating temperature limits for High Performance Conductors are normally less than or equal to the operating temperature limits of the individual component materials.

3.6 A brief description, which includes construction, pros & cons, erection issues, etc., of all major type of High Performance Conductors presently available are given in following section.

(A) Steel/ coated steel/ steel alloy core with an envelope of thermal-resistant aluminium alloys
[Typical conductors: ZTACSR, ZTACIR (INVAR), GZTACSR]

(a) (Z)TACSR

(Z)TACSR conductor has the same construction as conventional ACSR conductor, with galvanized steel wires for the core and TAL (thermal-resistant aluminium alloy) wires or ZTAL (thermal-resistant aluminium alloy wires with zirconium added) wires as envelope. TAL and ZTAL aluminium strands have the same conductivity and tensile strength as ordinary electrical conductor-grade aluminium strand but can operate continuously at temperatures up to 150o C and 210o C, respectively, without any loss of tensile strength over time.

(Z)TACSR is not, by design, a low-sag conductor. It has the same thermal elongation behavior as ACSR. The main advantage of (Z)TACSR is that its aluminium alloy wires do not anneal at temperatures up to 150oC for TAL and 210oC for ZTAL. (Z)TACSR can be used to uprate existing lines where some additional clearance is available.

(b) (Z)TACIR / STACIR: (Conductor with INVAR core)

As with (Z)TACSR, (Z)TACIR/STACIR has a conventional stranded construction identical to ACSR, making use of material innovations to give properties allowing the conductor to be operated at high temperatures. In place of the steel strands of (Z)TACSR, it has galvanized or aluminium-clad invar alloy steel wires for the core and (Z)TAL wires surrounding them. Invar is an iron-nickel alloy (Fe-36%Ni) with a very small coefficient of thermal expansion. Geometrically identical to conventional ACSR, with the only differences being a slightly reduced conductivity and a much increased maximum allowable temperature as the aluminium alloy wires do not lose strength at high temperature.

(Z)TACIR/SATCIR has a maximum continuous operating temperature of 210°C and can have twice the current capacity of ACSR conductor. The coefficient of thermal expansion of invar wire is around one-third that of galvanized or aluminium-clad steel wire. However, tensile strength of invar wire (1080 MPa) is lower than galvanized steel wire. Tensile strength of the conductor is about 8% lower than normal ACSR conductor. (Z)TACIR/SATCIR Conductor has equivalent sag-tension properties to conventional ACSR. The installation methods and accessories for the conductor are similar to those used for conventional ACSR. A slight lengthening of compression type accessories is required only to satisfy increased current carrying requirements. Pre-stressing can effectively lower the temperature of the knee-point. Cladding may be done to improve conductivity.

(c) G(Z)TACSR (GAP Conductor)

G(Z)TACSR i.e. gap type conductor uses a galvanized steel core surrounded by a thermo-resistant aluminium alloy. The wires of the innermost layer of aluminium are always of trapezoidal shape, and sized such that the inside diameter of the resulting tube is slightly larger than the external diameter of the core so as to maintain slight gap in between. The radial gap between the core and the envelope allows independent movement between the two. The gap is filled with heat-resistant grease (filler) to reduce friction between the steel core and the aluminum layer and to prevent water penetration & corrosion. The outer layers can be made trapezoidal also to maintain compact stranding and to minimize electrical resistance and increase the effective cross-sectional area on aluminum strands.

Gap-type conductor exhibits the same properties (corrosion, electrical, etc.) as a TACSR and its low sag behavior will allow it to be operated at much higher temperatures than ACSR. Knee point of the conductor is at erection temperature which means sag of the conductor is fully dependent on sag of steel core allowing to maximize use of low sag properties at very high temperature. However, if sections are erected at different temperatures (on different days) then their sag/temperature behavior will be different in the different sections. The expansion coefficient of the conductor above the knee-point temperature will be that of the steel core (11.5 x10-6/°C).

The installation of this conductor is more complex and labor intensive than ACSR. During erection, the conductor has to be stripped bare and hanged from the steel for 8-12 hours during stringing. Although this special erection technique is different from that employed with conductors of standard construction (i.e., ACSR), the compression splices and bolted suspension clamps are similar albeit suitable for elevated temperature.

Grease used in the gap type conductor should have elevated drop point (at least 300o C) and oil separation point to prevent migration of the grease to the outer surface; should retain its properties over a specified temperature range and under varied environmental conditions; and should comply with the requirements of relevant standards.

Trapezoidal wires (TW) may be used for outer layer of the conductor for snow bound areas, as these are less sensitive to snow accretion.

(B) Steel/ coated steel/ steel alloy core with an envelope of annealed aluminium

[Typical conductors: Aluminium Conductor Steel Supported (ACSS) and ACSS/TW (trapezoidal wire)]

ACSS conductor consists of fully annealed strands of aluminium around a stranded steel core. In appearance, ACSS conductors are essentially identical to standard ACSR conductors. ACSS is typically available in “Standard Round Strand” construction or “Trapezoidal Aluminium Wire” construction with equal area or equal diameter to conventional round wire construction. The steel core may be of High Strength (HS), Extra High Strength (EHS), Ultra High Strength (UHS) steel, mischmetal or aluminium Clad Steel core.

Annealed aluminium (61.8% IACS) has higher conductivity than hard-drawn aluminium wires (61% IACS) used in ACSR thereby increasing the existing current capacity of the line. However, the tensile strength of fully annealed aluminium is lower than hard-drawn aluminium. This may be mitigated by using high strength steel core or higher steel core area or both. Since the tension in the annealed aluminium wires is low, the thermal elongation is essentially that of the steel core alone thereby providing reduced sag up to 250°C. Also, due to low tension in the aluminium strands, it does not creep under everyday tension loading.

Galvanizing is prone to degradation above 200^{o}C, however, aluminium-clad or mischmetal (Al-Zinc alloy) clad cores are more robust against heat degradation. The Mischmetal Coating on the steel core may also be used which can withstand up to 250^{o}C temperature for continuous operation. Mechanical and physical properties of Mischmetal steel wire are similar to that of the galvanized steel wires. Corrosion resistance of Mischmetal steel wires are better than that of galvanized steel wires.

The reduced strength of the annealed aluminium wires results in a relatively low knee-point for the conductor. It can be significantly reduced by pre-stressing the conductor, which has the effect of imparting a permanent plastic deformation to the aluminium wires, such that an even greater proportion of stress is carried by the steel core. This helps to reduce or prevent vibration fatigue damage in challenging installations such as river crossings.

Although the splicing, installation, and termination is no more complicated than for ACSR conductors, however, the annealed strands, being very soft, should be handled with care and should not be dragged across the bare ground, over rocks, or fences etc. Parallel jaw grips should be closely sized to the conductor diameter and the clamp surface needs to be clean to minimize strand distortion. Also because of the annealed aluminum strands, the two-stage compression splice is somewhat longer than those designed for an ACSR conductor. They require no special suspension clamp design, and tension-stringing installation is straightforward. High temperature tolerant suspension clamps must be used to allow the maximum operating temperature that these HTLS conductors are capable of reaching.

(C) Metal-Matrix Composite (MMC) core with an envelope of thermal-resistant aluminium alloys
[Typical conductors: ACCR]

These conductors are made of Metal Matrix Composite (MMC) Core with envelope of thermal-resistant aluminium alloys. The core is made of wires composed of alumina fibers in an aluminium matrix, forming a composite material. The core wire looks physically similar to steel core, but it is eight times stronger than aluminum and about the same stiffness as the steel core. Each core wire contains thousands of small-diameter and ultra-high-strength aluminum oxide fibers. These fibers are continuously oriented in the direction of the wire, and fully embedded within high-purity aluminum.

Both the composite core and the outer strands contribute to the overall conductor strength and conductivity. The composite core material provides a substantially lower coefficient of thermal expansion above its knee-point in comparison to steel core, thereby significantly reducing the expansion coefficient of the conductor as a whole. The core material is significantly lighter than steel, resulting in a lower weight, while at the same time being both stronger and having a higher elastic modulus. Conductivity is also significantly greater than steel.

These conductors can be operated continuously at temperatures up to 210°C and emergency up to 240°C with AT3 alloy wires. The conductor is essentially all-aluminium, and the lack of a steel core removes the possibility of galvanic corrosion. It also exhibits very little creep. It has no undesirable magnetic properties unlike conductors with a ferrous core which experience increase in resistance due to magnetic effects. This magnetic effect is eliminated in MMC core with thermal resistant aluminium alloys.

The compression-type hardware for the dead-end assembly of these conductors uses a modified two-part approach, as in the ACSR conductor. One part grips the core, and then an outer sleeve grips the aluminum strands. This approach prevents notching of the core wires. The gripping method ensures that the core remains straight to evenly load the wires, and also ensures that the outer aluminum strands suffer no lag in loading relative to the core. The composite materials are highly anisotropic, i.e., they have good tensile strength but lower shear, transverse & torsional strength and have a more limited ability to conform to a low bend radius than conventional engineering metals and alloys, such as steel & aluminium. Thus composite materials require careful handling and care needs to be taken in choosing the correct diameter sheaves (i.e. travellers), bullwheel sizes, pulling tension and conductor reels sizes, to prevent excessive bending radius during installation.

(D) Polymer-matrix composite (PMC) core with an envelope of annealed aluminium/ thermal-resistant aluminium alloy (Carbon Composite Core (*CCC) Conductor)*

[Typical conductors: ACCC, CFCC, HVCRC, ACFR etc.]

The core is made of a polymer matrix composite (PMC), usually carbon fibers in a resin or epoxy resin matrix, with annealed aluminium or thermal resistant aluminium alloy envelope. The polymer matrix can be made with thermoplastic or thermosetting compounds. The core is protected against galvanic corrosion by either an annular sleeve made up of glass fibers, all in the same resin matrix, or protected by an aluminium alloy welded tube or other methods while the envelope can be round, trapezoidal or Z-shaped.

PMC cores have higher tensile strength compared to steel and compensate for the lower strength of fully annealed aluminium wires. While the aluminum strands are fully annealed, offering the highest degree of conductivity for any aluminum available today, the composite core offers a very low coefficient of thermal expansion than steel core which allows for less sag at high temperature operation. Less sag and low weight can be utilized to have increased spans on fewer/shorter structures along with reduced line losses. Generally, the composite core used is a solid, single-piece rod with no interstices. However, stranded configuration does also exist. As the core has a smooth surface and it bears the overall tensile strength of the conductor, the dead-end assembly has been designed to create a stronger crimp compared to that of ACSR conductor that forms a very solid aluminum press that fits around the composite core. The core resists degradation from vibration, corrosion, ultraviolet radiation, corona, chemical and thermal oxidation and, most importantly, cyclic load fatigue. However, the core made of multiple strands may be more susceptible to thermal oxidation. Although CCC has significantly less thermal sag than other High Performance Conductor designs, its core is quite elastic and sags more than other designs under ice load. For ice loading condition, core with higher modulus has to be designed. For very heavy ice loading regions, extra high strength composite core should be used to improve Sag values. This conductor requires special fittings, such as splice and dead-end connections which are patented. The composite materials are highly anisotropic, i.e., they have good tensile strength but lower shear, transverse & torsional strength and have a more limited ability to conform to a low bend radius than conventional engineering metals and alloys, such as steel & aluminium. Thus composite materials require careful handling and care needs to be taken in choosing the correct diameter sheaves (i.e. travellers), bullwheel sizes, pulling tension and conductor reels sizes, to prevent excessive bending radius during installation. The manufacturer's recommendations/procedures should be adhered to during installation so as to avoid any damage to the core of the CCC conductor which may lead to snapping of conductor.

4.0 Ampacity comparision of various High Performance Conductors

High Performance Conductors typically consist of aluminum wires enveloping a reinforcing core. The comparative performance of the HPC viz-a-viz ACSR conductors depends on the degree to which the aluminum strand and reinforcing core's physical properties are stable at high temperature and on the elastic, plastic and thermal elongation of the combined HPC. As such, the current carrying capacity/ ampacity at different operating temperature is helpful to ensure optimum use of their advantages.

Typical values of Ampacity and AC Resistance at various temperatures for corresponding diameter of various conductors equivant to ACSR Moose, Panther and Zebra conductors at following assumptions is given below in Tables III, IV and V. AAAC and Al59 conductors have also been included in the table for comparison purpose.

Ambient temperature:	45° C
Solar radiations :	1045 W/m2
Wind Speed :	0.56 m/s
Absorption Coefficient :	0.8
Emissivity Coefficient :	0.45

These values have been provided for reference purpose only. Values may change depending upon material properties, size and shape of the conductor strands, diamtere of the conductor etc. Different manufaturers may have different sizes for any particular conductor. Utilities should do due dilligence to arrive at ampacity, resistance and losses of any conductor in consultation with the manufacturer.

Table-III

Typical values of Ampacity and AC Resistance at various temperatures for ACSR Moose and Equivalent AAAC, Al59 & High Performance Conductors

S. No.	Conductor	Dia (mm)	Resistance at 20° C (Ohm/km)	Weight (kg/km)	Parameter	Operating Temperature								
						75°C	85°C	95°C	125°C	150°C	180°C	200°C	210°C	250°C
1.	ACSR Moose	31.77	0.05552	2004	Ampacity (A)	620	794							
					R_{ac} (Ohm/km)	0.06906	0.07125							
2.	AAAC	31.95	0.0568	1666	Ampacity (A)	619	795	933						
					R_{ac} (Ohm/km)	0.0694	0.0714	0.0733						
3.	Al59	31.77	0.0497	1648	Ampacity (A)	656	841	987						
					R_{ac} (Ohm/km)	0.0617	0.0636	0.0655						
4.	TACSR	31.77	0.0556	1997	Ampacity (A)	620	794	931	1237	1430				
					R_{ac} (Ohm/km)	0.06907	0.07131	0.0735	0.0801	0.0855				
5.	ACCC	31.77	0.0418	1990	Ampacity (A)	710	910	1068	1421	1644	1866			
					R_{ac} (Ohm/km)	0.05265	0.05426	0.05588	0.0607	0.06477	0.06962			
6.	STACIR	28.95	0.0599	2001	Ampacity (A)	585	744	869	1149	1324	1499	1601	1649	
					R_{ac} (Ohm/km)	0.0743	0.0766	0.079	0.08612	0.09203	0.09913	0.1037	0.10623	
7.	GZTACSR (Gap)	29.9	0.05134	2004	Ampacity (A)	629	801	937	1242	1433	1623	1735	1787	
					R_{ac} (Ohm/km)	0.0663	0.0684	0.07052	0.0769	0.0822	0.08861	0.09287	0.09501	
8.	ACSS	31.77	0.0521	2000	Ampacity (A)	633	810	950	1261	1457	1652	1766	1820	2018
					R_{ac} (Ohm/km)	0.06494	0.0669	0.06903	0.07516	0.08027	0.0864	0.09049	0.09245	0.10071

Table-IV

Typical values of Ampacity and AC Resistance at various temperatures for ACSR Zebra and Equivalent AAAC, Al59 & High Performance Conductors

S. No.	Conductor	Dia (mm)	Resistance at 20° C (Ohm/km)	Weight (Kg/km)	Parameter	Operating Temperature								
						75°C	85°C	95°C	125°C	150°C	180°C	200°C	210°C	250°C
1.	ACSR Zebra	28.62	0.06868	1621	Ampacity (A)	552	702							
					R_{ac}(Ohm/km)	0.0849	0.0876							
2.	AAAC	28.62	0.0706	1337	Ampacity (A)	550	700	819						
					R_{ac} (Ohm/km)	0.0855	0.08806	0.0905						
3.	Al59	28.62	0.0618	1337	Ampacity (A)	583	741	866						
					R_{ac} (Ohm/km)	0.07616	0.07853	0.08089						
4.	TACSR	28.62	0.0685	1621	Ampacity (A)	554	703	822	1086	1253				
					R_{ac} (Ohm/km)	0.0846	0.0873	0.09	0.0981	0.1048				
5.	ACCC	28.14	0.0536	1565	Ampacity (A)	624	792	925	1221	1408	1593			
					R_{ac} (Ohm/km)	0.0662	0.0683	0.0705	0.0769	0.0822	0.0888			
6.	STACIR	25.4	0.0775	1587	Ampacity (A)	513	648	754	989	1138	1286	1373	1412	
					R_{ac} (Ohm/km)	0.09545	0.0985	0.1016	0.1108	0.1185	0.1261	0.1338	0.1369	
7.	GZTACSR (Gap)	27.1	0.0676	1621	Ampacity (A)	547	691	806	1063	1225	1385	1479	1523	
					R_{ac} (Ohm/km)	0.08552	0.0883	0.09105	0.09936	0.1063	0.1146	0.1202	0.12294	
8.	ACSS	28.04	0.0684	1619	Ampacity (A)	552	700	818	1080	1254	1409	1505	1550	1717
					R_{ac} (Ohm/km)	0.08456	0.08727	0.0899	0.09813	0.1049	0.1130	0.1185	0.1212	0.1321

Table-V

Typical values of Ampacity and AC Resistance at various temperatures for ACSR Panther and Equivalent AAAC, Al59 & High Performance Conductors

S. No.	Conductor	Dia (mm)	Resistance at 20° C (Ohm/km)	Weight (Kg/km)	Parameter	Operating Temperature								
						75°C	85°C	95°C	125°C	150°C	180°C	200°C	210°C	250°C
1.	ACSR Panther	21	0.139	974	Ampacity (A)	374	465							
					R_{ac}(Ohm/km)	0.1703	0.17588							
2.	AAAC	21	0.114	720	Ampacity (A)	416	518	600						
					R_{ac}(Ohm/km)	0.13752	0.14163	0.1457						
3.	Al59	21	0.1143	720	Ampacity (A)	413	514	595						
					R_{ac}(Ohm/km)	0.1394	0.1438	0.1483						
4.	TACSR	21	0.1386	973	Ampacity (A)	375	466	539	703	807				
					R_{ac}(Ohm/km)	0.1698	0.1754	0.1809	0.1975	0.2115				
5.	ACCC	20.5	0.1024	834	Ampacity (A)	434	539	623	813	931	1049			
					R_{ac}(Ohm/km)	0.1258	0.1299	0.134	0.146	0.1565	0.1689			
6.	STACIR	20.7	0.1408	966	Ampacity (A)	370	460	532	694	796	896	955	982	
					R_{ac}(Ohm/km)	0.1725	0.1782	0.1835	0.2001	0.2149	0.2319	0.2432	0.2488	
7.	GZTACSR (Gap)	20.6	0.1224	974	Ampacity (A)	397	493	570	743	852	959	1022	1051	
					R_{ac}(Ohm/km)	0.1501	0.155	0.1599	0.1745	0.1867	0.2014	0.2112	0.2161	
8.	ACSS	20.5	0.1355	925	Ampacity (A)	377	469	542	707	810	896	972	1000	1103
					R_{ac}(Ohm/km)	0.166	0.17144	0.1768	0.1931	0.2067	0.2203	0.2339	0.2393	0.2611

5.0 Application areas for High Performance Conductors

(A) Some applications for reconductoring with High Performance Conductors may involve the following scenarios:

(a) The state utilities have a large number of transmission lines of 33 kV/66 kV/132 kV etc. These lines are very old and are not able to carry more power. Uprating of such transmission lines to carry more power at the same voltage.

(b) If the structures and foundations are in good condition, and the minimum increase in thermal rating in excess of 20% is required, then High Performance Conductors are likely to be a good choice.

(c) Many of such lines which were once upon a time outside the urban boundaries are now inside the urban boundaries due to rapid urbanization. Changing the tower and/or foundation is almost impossible in such crowded streets.

(d) For short lines, which experience occasional high electrical loads, High Performance Conductors are often an excellent method of uprating. For reconductoring short lines, increase in electrical losses may not be significant, and the use of HPC conductors is usually a reasonable and economic option.

(e) For longer lines, reconductoring with High Performance Conductors may also be economic, if the frequency and duration of high current loads are less.

(f) In Intra-State Transmission System, requirement of such conductor is expected at 220kV, 132kV and 66kV level. The requirement of such conductor may not be much in Inter-State Transmission System (ISTS), which is dominated by 400kV and 765kV network. In case of ISTS lines, the High Performance Conductors would be a good substitute to Quad bundle ACSR and AAAC conductor, particularly at 400 kV level when line length is short.

(g) For long river crossing spans, the valleys & major high way crossings and in ravines, the conventional conductor will sag more and result into excess height of tower and cost of foundation. If new generation low sag conductors are used, situation can be addressed.

(h) Reconductoring existing transmission/distribution network with HPC conductors is a viable option as it enhances the existing power transfer capability of the line without involving RoW issues.

(i) Due to oceanic and/or industrial pollution, the existing conductors of the line show sizable degradation. It may be necessary to replace such conductors by new conductors, which may be resistant to such vagaries and simultaneously can carry higher current.

(B) Similarly, some scenarios wherein an alternative method of uprating will be more attractive than reconductoring with HTLS are the following:

i) Structures or foundations of the existing line are in poor condition.

ii) Existing line is in good physical condition, and the rating is to be increased by less than 20%.

iii) If the line is above 400 kV, reconductoring with HTLS conductors is not typically required because the existing thermal rating is already much higher than the limits on power flow related to voltage drop and phase shift.

(C) Quad bundle ACSR conductors are being used in HVDC line not only to meet the requirement of higher current but electric field as well. Hence, application of High Performance Conductors is not cost effective for HVDC system.

(D) High Performance Conductors can be considered for use in distribution system where there is congestion, such as in urban areas, and space is not available for addition of new overhead lines. High Performance Conductors can also be useful, if chosen judiciously, to get more benefits in terms of technical losses. However, due to less electrical clearance requirement and proximity from households/buildings, the impact of operation of High Performance Conductors at high temperature need to be assessed properly. The demand from distribution sector is yet to come from utilities because of high initial investment cost, however, the same can be recovered in a short span of time depending on load flow and other factors.

6.0 Issues to be considered before installation of High Performance Conductors

6.1 The transmission conductor must meet the minimum electrical clearance requirement, throughout the life of the line, under all environmental conditions including high wind and/or ice loading and high temperature. When reconductoring an existing line with HTLS conductor, sag clearance calculations must consider the initial sag of the replacement conductor, its plastic elongation over time, and it elastic and thermal elongation relative to its final sag position. The increase in sag due to thermal elongation at high conductor temperature and elastic increase in sag due to ice or wind load is based on the final sag not the initial. HTLS conductors must not only elongate less in response to high temperature, they must also be strong enough (elastic modulus) to limit elastic sag increase under ice and wind load and they must not exhibit high plastic elongation in response to high tension or long term application of more modest tension.

6.2 When uprating existing lines by replacing the conductors, an assessment must be made of the present capability of the structures. Replacing the conductors of an existing line should only be attempted if it has been demonstrated that the structures are capable of supporting the required loads for the lifetime required of the new conductor system and increased load during pre-tensioning of conductor. In some cases, this might involve carrying out repairs or improvements to the structures.

6.3 When replacing conductors, use of a larger conductor imposes greater loads on the existing structures and may reduce the reliability of the line unless the structures are reinforced. However, by use of replacement conductor having nearly same diameter as original conductor capable of operating at higher temperature which remains within existing sag clearance and loss-of-strength constraints, need for extensive reinforcement of structure can be avoided.

6.4 When reappraising the loading criteria for an uprated line, the line designer should consider changing the conductor design, wire materials, and making changes in the tension limits under both every day and extreme conditions.

6.5 Reconductoring normally leaves the original ground level electric field, electric induction, corona discharge levels, and audible noise levels unchanged. However, the ground level magnetic field and magnetic induction levels will increase if the line current increases as a result of the higher line thermal rating.

6.6 Knee Point of operation of different types of HT/HTLS conductors:

When the temperature of a composite conductor is increased, the aluminium (or aluminium alloy) envelope wires usually expand at a higher rate than the core. This expansion is accompanied by a corresponding reduction in its share of the total tensile load on the conductor. With increasing temperature, the aluminium will transfer its mechanical load to the core resulting in the core carrying most, if not all, of the mechanical load. At a given temperature, the envelope becomes mechanically "unloaded", the conductor being supported only by its core. This temperature is called Knee Point. This is the point below which the conductor sag-tension relationship is determined by the whole conductor whereas above this point it is governed by the core. For High Temperature conductors, since aluminium has a larger Coefficient of Thermal Expansion (CTE) than core, the thermal elongation properties of the core control the maximum sag of the conductor. The knee point is different for different types of HT/HTLS conductors. It depends on the installation conditions and for some conductor technologies, the knee-point can be shifted to a lower temperature by pre-tensioning. This is more effective with conductors containing annealed aluminium. The knee-point is not a fixed value and depends on many factors like span length, mechanical tension, ruling conditions, conductor constituent characteristics (e.g. proportion of envelope section over total section, coefficient of thermal expansion, modulus of each component). It should be further noted that creep in the conductor will also shift the conductor knee point to lower temperatures over time, because conductor creep is primarily driven by the aluminium constituent, and the tensile load in the envelope shifts to the core while it elongates (due to creep). For a HT conductor to be fully effective, the rated temperature of the line needs to be above the knee-point if there is to be full benefit from having a low-expansion core.

6.7 As a consequence of the use of HT conductors, higher conductor temperatures will be reached that may affect the insulator performance. The conductor temperature will also influence the temperature of the conductor clamp, links and shackles, the insulator hardware and the insulator body itself. The extent of this influence also depends on the specific design of the insulator. Apart from insulator, assessment should be made for use of conductor accessories of original conductor with replacement conductor. If required, new accessories suitable for high temperature operation of replacement conductor should be installed.

6.8 If HTLS conductors with annealed aluminum strands are pre-stressed, then their self-damping properties are good and initial stringing sags may be quite small without causing vibration fatigue. If not pre-stressed, high initial tension levels may lead to premature failure from vibration fatigue unless dampers are installed.

6.9 All transmission line source and end point connections involve terminal equipment. The primary terminal equipment generally consists of circuit breakers, disconnectors, current and voltage transformers, and in some cases power line communication coupling equipment, insulators etc. Considerations for the uprating of transmission lines must include a review of the rating of the terminal equipment to ensure compatibility with the line rating.

6.10 Sometimes the power utilities in India are going for one specific type of conductor although other types of conductors are also available to cater to similar requirements. Moreover, it is understood that there is a wide variation in cost of various types of High Performance Conductors (HPC). In the process, the utilities are not getting the product at a competitive price as competition gets restricted and as a result the overall cost of the project gets jacked up. Competition invariably leads to significant benefits to consumers through reduction in capital cost and facilitate the price to be determined competitively.

7.0 Cost-benefit analysis

7.1 In general, the use of HPC conductor is justified due to offering increased current capacity than ACSR or AAAC conductor and in case of re-conductoring, reduction in the cost due to minimal modifications in the towers. There are variety of HTLS conductors, description of which has been provided in relevant sections of this document, available in India. Certain replacement conductor characteristics may be attractive, but it may not necessarily be "cost-effective" i.e. the additional cost of the special conductor may not be justified by the increase in line rating.

7.2 There does not appear to be a compelling reason to choose one of the HTLS conductors over the others except possibly for cost. Following factors should be considered for replacement of existing conductor with HPC conductor:

- Cost of electrical losses
- Frequency and magnitude of occasional high current loads
- Purchase and labor costs of replacing the existing conductors
- The cost of structure reinforcement
- Availability of replacement conductor
- Existing clearance buffer
- Likelihood of vibration fatigue problems
- Severity of ice and wind load conditions
- Cost/Benefit ratio of increased capacity
- Availability of additional right-of-way

7.3 When only conductor cost is considered, the cost of INVAR, ACCR etc. is about five times the cost of conventional ACSR while the cost of Gap type conductors is almost twice. CCC Conductors are about 3.5 times costlier, ACSS is approximately 1.5 times and TACSR is about 1.15 times that of ACSR conductors. But other than the cost of power conductor, cost of ohmic loss, conductor accessories, insulator hardware, de-stringing of conventional power conductor, re-stringing & installation of High Performance Conductors are to be considered before deciding whether installation of High Performance Conductors is economically justifiable.

7.4 Depending on the project and its environmental configuration, the utility will have to compare the total life-cycle costs of conductor replacement and reinforcement of towers to that with the building of a new line. After considering the life-cycle cost, the overall project costs may, in some cases, be less even after higher cost of the conductor.

7.5 Hence, before deciding whether or not to opt High Performance Conductors, the utilities need to have the information on the comparative costs to upgrade an existing line section using different High Performance Conductors, comparative costs of operation which shall include cost of power losses, and lifetime costs when installing and operating networks using High Performance Conductors with respect to conventional ACSR conductors. Impact of new conductor types on the Sag calculations, existing tower design and necessary engineering changes when designing, shipping, handling, installing, inspecting, and maintaining these conductors will have to be examined as well. In some cases, special tools and measures like pre-tensioning may be needed and various additional factors like effect of erection tension and stringing have to be considered while installing. Special handling precautions may have to be taken when shipping conductors to a site or while on site. Cost implication of all these requirements has to be included to evaluate the total expenses.

8.0 Criteria for technical evaluation of bids for different types of High Performance Conductors

8.1 Criteria for technical evaluation of bids for different types of High Performance Conductors is based on assumption that no specific conductor type, for reconductoring of existing transmission or distribution line, has been specified by the utility, no change in existing structure is envisaged, maximum sag is equal to or less than existing sag and regulatory requirement of electrical clearances are complied.

8.2 It needs to be checked that the data furnished by the bidder in Guaranteed Technical Particulars/Technical Data Sheet is equal to or better than those required as per specification.

8.3 The offered High Performance Conductor shall be capable of carrying the current specified by the utility at a continuous operating conductor temperature not exceeding the maximum permissible operating temperature of the offered High Performance Conductor without exceeding the level of permissible sag of the existing Conductor while satisfying other specified technical requirements/ parameters.

8.4 The calculations for Ampacity shall be based on latest edition of IEEE Standard 738. The bidder in his bid shall furnish calculations for the ampacity based on the above Standard for the proposed High Performance Conductor. These calculations should be checked by the utility.

8.5 The utilities shall consider capitalization of average ohmic loss at continuous operating current specified by the utility and corresponding AC resistance. Based on the conductor parameters guaranteed by the bidders, average ohmic losses for different type of conductors for all three phases of one circuit of a transmission line offered by the bidders shall be calculated as per the following formula:

Average Ohmic loss (kW) = Loss Load Factor × 3 × Line Length × No. of sub conductors per bundle × (Continuous operating current specified by utility)^2 × AC Resistance corresponding to continuous operating current specified by utility

Values of various parameters of this formula shall be taken by the utilities as per system studies and system requirement. In case, loss load factor has not been derived by utility, the same may be taken as 0.3. Differential price evaluation for the conductors offered by the bidders shall be carried out considering the average ohmic losses calculated as above and considering capitalisation cost (₹ per kW) as specified by the utility in the bidding document. Cost of capitalisation may vary from utility to utility depending upon their cost of energy, cost of borrowing etc. However, capitalisation cost normally remains in the range of ₹1.5 lac to ₹1.6 lac per kW.

The best parameter of loss (lowest ohmic loss for conductor) corresponding to lowest AC resistance quoted among bidders by any technically responsive and qualified bidder shall be taken as basis and that quoted by the particular bidder shall be used to arrive at differential price to be applied for each bid.

9.0 Use of High Performance Conductors by various utilities

As per information available, the Central Transmission Utility (CTU)/ PGCIL, few State Transmission Utilities like UPPTCL (UP), MSETCL (Maharashtra), WBSETCL (West Bengal), OPTCL (Odisha), JUSNL (Jharkhand), PTCUL (Uttarakhand), KPTCL (Karnataka), GETCO (Gujarat), RRVPNL (Rajasthan) and some private utilities like Tata Power, Torrent Power, CESC have already used Gap, Invar, ACCR & ACCC conductor in transmission line corridors which are getting overloaded / exceeding the thermal loading limits of the existing conductor. Some more projects of re-conductoring as well as of new lines using High Performance Conductors are underway.

It is difficult to comment on performance of such conductor as current / power flow in the line has not reached the level for which it has been designed.

10.0 Conductor accessories for various types of High Performance Conductors

The High Performance Conductor & accessories must be designed to operate reliably in demanding conditions that combine high temperature operation under a broad spectrum of mechanical and electrical load. The conductor and accessories must resist wide range of transient mechanical & thermal loads such as fault current, lightning strikes, galloping events and ice loading. The contact between dissimilar materials may cause excessive corrosion in some environments. The hardware and accessories (connected electrically and mechanically to the conductor) should be designed and tested to ensure that conductor retain its performance with accessories under normal as well as under emergency conditions and are compatible for the conductor.

Some manufacturers in India have started manufacturing of accessories for different High Performance Conductors. With increase in demand for High Performance Conductors, few more manufacturers may show interest to manufacture the accessories and hardware fittings for such conductors.

11.0 Manufacturing facility for High Performance Conductors in India

Various conductor manufacturers have set up facility for manufacturing of different High Performance Conductors. The INVAR core and polymer composite matrix core of CCC conductor are presently being imported, although, envelope of these conductors is manufactured indigenously. Some manufacturers in India have started manufacturing of accessories for different High Performance Conductors. Many manufacturers such as M/s Apar Industries, M/s Sterlite Power, M/s Gupta Power, M/s Hindustan Urban Infrastructure Ltd., M/s JSK Industries, M/s Shashi Cables Ltd., M/s Lumino Industries etc. have indigenous facility for supply of High Performance Conductors. It is noted that every manufacturer may not necessarily have all types of High Performance Conductors in their product portfolio. Some of these manufacturers have not supplied some types of High Performance Conductors, however, those conductors have been type tested and facility to manufacture them is available with these manufacturers. Some manufacturers have supplied High Performance Conductors for transmission lines of various utilities which are in operation and some manufacturers are in process of supply.

12.0 Testing facility

The constituent materials used in High Performance Conductors vary; some cores are common steel strands coated with zinc (galvanized), zinc alloy or aluminium (aluminium clad, aluminium-5% mischmetal). Other conductors utilize relatively new materials such as fiber reinforced aluminium composites or fiber reinforced polymer composites. The required tests and test methods will differ depending on materials. Presently facility for all type test is not available in India and many of the type tests are being carried out outside the country which adds to the cost of project. However, ERDA and CPRI are in the process of establishing testing facilities for High Performance Conductors. List of all tests for which facilities are available in CPRI and ERDA and list of tests for which facilities are being developed is given at Annexure-I. Some manufacturers also have NABL accredited test laboratories. However, information regarding test facilities available at these labs is not available. M/s Tag Corporation, Chennai, also has some testing facilities for conductor accessories.

13.0 Recommendations of the Committee

Based on the deliberations, the recommendations of the Committee are as follows:

13.1 High Performance Conductors can address issues like growing congestion in existing corridor of transmission / distribution network and can help in enhancement of power flow per unit Right of Way (RoW).

13.2 High Performance Conductors should be considered in those corridors where the power transfer over the line is constrained due to thermal loading of conductor. In Intra-state transmission system, requirement of such conductor is expected at 220kV, 132kV and 66kV level. However, application of High Performance Conductors may not be cost effective for HVDC system and for 765kV voltage level.

13.3 The power utilities should invite bids without specifying type of High Performance Conductor as several types of such conductors are available and could bring techno-economic benefits. Also, generic name of conductor like CCC, GAP conductor etc. should only be specified by the power utilities instead of patented names of manufacturer or conductor.

13.4 High Performance Conductors can be considered for reconductoring of existing lines and can also be used in new lines. The terminal equipment rating at substations needs to be examined for enhancement of power flow in a line. However, for new lines, proper system studies need to be carried out to identify the corridors for use of such conductor.

13.5 The use of High Performance Conductors need to be considered on case to case basis based on techno-economic analysis over the life cycle.

13.6 High Performance Conductors may also be considered for use in distribution system where utility can get more benefits in terms of technical loss although initial investment cost will be high.

13.7 Testing facilities for some of the type tests required for high performance conductors are not available in the country. These needs to be established on priority.

13.8 The erection of High Performance Conductors should be carried out under the supervision of conductor supplier / manufacturer. The manufacturers' recommendation should be followed during erection and commissioning of High Performance Conductors.

13.9 The state utilities should go for vendor development program for manufacturers who want to develop manufacturing facility for high performance conductors for promoting complete indigenization of the product and its hardware.

13.10 The core of High Performance Conductors is presently being imported by almost all the manufacturers, however other processes in making the finished product including the envelope are carried out within the country.

13.11 It is observed that even though some manufacturers have proper manufacturing & testing facility for making HPC and also got their product type tested from accredited labs are not able to participate in the bidding process due to lack of supply or relevant experience of in-service operation of High Performance Conductors thereby do not meet qualifying requirement specified by the utilities. In such a scenario only few manufacturers compete and utilities do not get the competitive price. The utilities should devise a mechanism to allow such experienced manufacturers to participate, without compromising their interest and quality of the product.

13.12 Environment impact assessment of HPC lines passing through forest areas needs to be done.

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ANNEXURE-I

LIST OF TEST FACILITES IN INDIA

Annexure-I

Test Facilities presently available for HT/HTLS Conductor and accessories in India

Sr. No.	Test Facility
i)	**On Complete Conductor**
1.	D.C. Resistance test on stranded conductor
2.	UTS test on stranded conductor
3.	Lay ratio & Lay direction
4.	Stress-Strain test on stranded conductor and core at room temperature
5.	Salt Spray Test
6.	Radio interference voltage test (dry)
7.	Corona extinction voltage test (dry)
8.	Aeolian Vibration test
9.	Galloping test
10.	Corona resistance test on conductor and strands
11.	Fault current test
12.	Dye penetration test
ii)	**On Individual Wire/Strand**
1.	Measurement of the diameter of the individual wire
2.	Breaking load test on individual wire
3.	Elongation test on individual wire (steel)
4.	Torsion Test

5.	Wrapping test
6.	Galvanizing Test
7.	Radial Crush Test
8.	Grass transition temperature test
9.	Heat resistance test on aluminium alloy strands or core
10.	Coefficient of linear expansion on core and core strands
11.	Flexural strength on composite core
12.	Strand Brittle Fracture test
iii)	**Accessories**
1.	Visual & verification of dimension
2.	Galvanizing & electroplating
3.	Wet power frequency voltage withstand test
4.	Impulse voltage withstand test
5.	Mechanical strength
6.	Ozone test on elastomeric
7.	Electrical resistance
8.	Clamp slip / torque / slip strength
9.	Hardness / grain size / inclusion ratings / NDT
10.	Shore hardness for elastomeric
11.	Bend test / resilience test
12.	Vibration damper tests

Test facilities being developed

Sr. No.	Test Facility
1	Stress-strain test at controlled temperature
2	Stress-strain test at elevated temperature
3	Creep test at controlled temperature
4	Creep test at elevated temperature
5	Sheaves Test
6	Axial Impact Test
7	Torsional Ductility Test
8	Temperature Cycle Test
9	Bending Test on Composite core
10	Resistance Test
11	Grease drop test
12	Magnetic power loss test
13	Glass transition temperature of core
14	UTS test on complete conductor at elevated temperature

ANNEXURE-II

TECHNICAL SPECIFICATION FOR HIGH PERFORMANCE CONDUCTORS

Annexure-II

TECHNICAL SPECIFICATION FOR HT/HTLS CONDUCTOR

1.0 Description of High Temperature (HT)/ High Temperature Low Sag (HTLS) Conductor and its Technical Requirements

1.1 The offered HT/HTLS Conductor shall be capable of carrying the minimum specified Current (--- Amp. e.g. 1574 Amps.) at a continuous operating conductor temperature not exceeding the maximum permissible operating temperature of the offered HT/ HTLS Conductor without exceeding the level of maximum permissible sag of the existing ……Conductor (e.g. ACSR MOOSE) as indicated in Cl. 1.2.1.

The physical and operating performance requirements of the transmission line with HT/ HTLS conductor are mentioned below. The bidder shall offer HT/ HTLS conductor complying with the specified requirements. The Bidder shall indicate particulars of the proposed conductor in the relevant GTP schedule along with calculations to establish compliance with the specified requirements.

1.2 Current Carrying Capacity /Ampacity Requirements

1.2.1 Each conductor / sub conductor in the bundle of HT/ HTLS conductor shall be suitable to carry minimum specified 50 Hz alternating current (--- Amps. e.g. 1574Amps.) under the ambient conditions and maximum conductor sag specified below while satisfying other specified technical requirements/ parameters:

Elevation above sea level	-----------m
Ambient temperature	---------- ^{o}C (e.g. 45 ^{o}C)
Solar Absorption coefficient	0.8
Solar Radiation	1045 watt/sq.m
Emissivity Constant	0.45
Wind velocity	0.56 m/sec
Effective angle of incidence of sun's rays	90 degree

Maximum permissible Conductor sag for ----m (e.g. 400m for 400kV line) span at steady state conductor temperature and nil wind corresponding to specified 50 Hz alternating current (---Amps. e.g. 1574Amps.) per conductor / sub conductor under ambient conditions specified above shall be ---- m (e.g. 13.26 m for 400kV)

The calculations for Ampacity shall be based on latest edition of IEEE Standard 738. The bidder in his bid shall furnish calculations for the ampacity based on the above Standard for the proposed HT/ HTLS conductor. The AC resistance and DC resistance for HT/ HTLS conductor shall be calculated as follows:

$R_{ac} = R_{dc} \times (1+ 0.00519 \text{ X } (mr)^n \times k_1 + k_2)$ where,

$mr = 0.3544938/ (R_{dc})^{½}$

if $mr < 2.8$, then $n = 4- 0.0616 + 0.0896 \text{ X } mr – 0.0513 \text{ X}(mr)^2$

if $2.8 < mr < 5.0$, then $n = 4+ 0.5363 -0.2949\text{X } mr +0.0097 \text{ X}(mr)^2$

$k_1 = \{\cos (90 (d/D)^p)\}^{2.35}$ where,

$p = 0.7 + 0.11\text{X}mr – 0.04\text{X}mr^2 + 0.0094\text{X}mr^3$

k_2 = 0.15 for single aluminium layer INVAR type HTLS conductor

= 0.03 for three aluminium layer INVAR type HTLS conductor

= 0.003 for two or four aluminium layer INVAR type HTLS conductor

= 0 for carbon fiber composite core type HTLS conductor

where,

D= conductor outer diameter in meters

d = conductor inner diameter in meters

R_{dc} = dc resistance of conductor at given temperature, ohms/ km

R_{ac} = ac resistance of conductor at given temperature, ohms/ km

The bidder in his bid shall furnish calculations for the ampacity based on the above for the proposed HT/ HTLS conductor.

1.2.2 The design of conductor shall be suitable for operation at a steady state conductor temperature experienced for a sub-conductor for specified AC current flow (----Amps. e.g. 1574Amps.) under the above ambient conditions based on ampacity calculations mentioned above. The bidder shall also indicate the maximum permissible conductor temperature for continuous operation without any deterioration of its electrical, mechanical & metallurgical properties. The bidder shall also furnish the maximum permissible conductor temperature for short term operations including permissible duration of such short term operation. The UTS of conductor at ambient temperature and maximum continuous operating temperature shall be declared in the GTP. Further, UTS of conductor achieved at maximum continuous operating temperature shall not be less than 80% of UTS at ambient temperature declared in the GTP.

1.3 Technical Particulars of HTLS Conductor

The HTLS conductor shall meet the following minimum requirements:

Overall diameter of complete conductor	Not exceeding existing conductor overall diameter (--mm e.g. 31.77mm for 400kV line) and Not less than (----mm e.g. 28.62 mm)
Approx. mass of complete conductor (kg/km)	Less than or equal to existing conductor weight per unit length (-----kg/km e.g. 2004kg/km for ACSR MOOSE)
Direction of lay of outer layer	Right Hand

The bidder shall indicate the technical particulars and details of the construction of the conductor in the relevant schedule of GTP. The bidder shall also guarantee the DC resistance of conductor at 20 deg C and AC resistance at the calculated temperature corresponding to 50Hz specified alternating current flow (--- Amps. e.g. 1574 Amps.) per sub conductor at specified ambient conditions (maximum continuous operating temperature).

The bidder shall submit the supporting calculations for the AC resistance indicating details & justifications of values of temperature coefficient of resistance & DC to AC resistance conversion factor(s) with due reference to construction / geometry of the conductor.

1.4 Sag-Tension Requirements

1.4.1 The HTLS conductor shall meet the following sag tension requirements for ruling span of ---- meters (e.g. 400m for 400kV line)

Particulars	Limiting value
Tension at every day condition (32°C, no wind)	Not exceeding 25% of UTS of proposed conductor
Sag at maximum continuous operating temp (corresponding to specified current --- Amps. e.g. 1574 Amps. per conductor / sub-conductor and ambient conditions specified at 1.2.1)	≤---- meters (e.g. 13.26 m)
Tension at 32°C, full wind (---- kg/m2 e.g. 203.2 kg / m^2)	≤ ----kgs and not exceeding 70% of UTS of proposed conductor (e.g. 9421 kgs for 400kV line)
Tension at designed maximum temperature and no wind condition	Not exceeding 25% of UTS at designed maximum temperature
Tension at designed maximum temperature and full wind	≤ --- kgs and not exceeding 70% of UTS at designed maximum temperature of proposed conductor
Tension at knee point temperature & no wind	Not exceeding 40% of UTS of core* of proposed conductor

*UTS of core shall be equal to the Breaking strength of individual core wires after stranding X no. of wires in the core of offered conductor.

Sag-Tension calculation for HTLS conductor can be carried out by using PLSCAD. Following values shall be considered for the purpose of sag-tension calculations:-

(i) Final values of modulus of elasticity of Aluminium/ Aluminium alloy/core, Coefficient of Linear Expansion of Aluminium/ Aluminium alloy/ core, Stress-Strain coefficients & Creep coefficients of aluminium/ Aluminium alloy/ core in the cable data (.wir file) used for calculation of sag in PLSCAD shall be based on either of the following:

a) Existing '.wir' files for offered conductor as available on PLS website.
b) A file derived from existing standard file for conductor of equivalent/ near equivalent stranding.
c) A file derived from type test conducted on conductor of same stranding.

In each of the above cases, proper justification in the form of test reports/ calculations/ print out of '.wir' file as available on PLS website, etc. shall be required to be submitted during detailed engineering.

(ii) PLSCAD Sagging criteria/conditions shall be based on the sag tension limits specified above at Clause 1.4.1 and shall be carried out in a manner that the above mentioned sag-tension limits are met in 'After Creep' as well as in 'After Load' condition.

However, for INVAR type HTLS conductor, following conventional methodology may also be adopted for sag-tension calculations.

This methodology is illustrated at Appendix-B to the section. Following values shall be considered for the purpose of sag tension calculation:

i) Modulus of Elasticity of Thermal resistant Al alloy strands: 55 GPa to 61.8 GPa (one value from the above specified range to be selected conforming to the Al alloy strands in the offered conductor)

ii) Modulus of Elasticity of INVAR core strands: 155 Gpa

iii) Coefficient of Linear Expansion of Thermal resistant Al. Alloy: 23 X 10-6/oC

iv) Coefficient of Linear Expansion of INVAR core strands (max): 3.7 X 10-6/oC

v) Initial temperature in manufacturing conductor- not less than 15oC. In case the bidder proposes the coefficient of linear expansion of INVAR core strands less than 3.7 X 10-6/ oC, proper justification in the form of test reports, documents, etc. shall be submitted during detailed engineering.

1.4.2 Various conductor parameters (viz. modulus of elasticity, coefficient of linear expansion, stress-strain and creep, etc.) considered above in the sag tension calculation shall be verified during detailed engineering based on type tests conducted.

1.4.3 The Contractor shall also furnish sag & tensions under no wind for various temperatures starting from 0^{o}C to designed maximum temperature in steps of 5^{o}C during detailed engineering

1.4.4 After award of the contract, the Supplier shall submit Sag-Tension calculations corresponding to various conditions given above for all the spans as per detailed survey and spans ranging from 100 m to 1100 m in intervals of 50 m.

1.4.5 Besides above, the Supplier shall also furnish details of creep characteristics in respect of HTLS conductor based on laboratory investigations/ experimentation (creep test as per IEEE1138 or IEC 61395) conducted on similar type of conductor and shall indicate creep strain values corresponding to 1 month, 6 months, 1 year 10 years & 20 years creep at everyday tension and at maximum continuous operating temperature as well as room temperature.

1.5 Workmanship

1.5.1 All the conductor strands shall be smooth, uniform and free from all imperfections, such as spills and splits, cracks, die marks, scratches, abrasions, rust etc.

1.5.2 The finished conductor shall be smooth, compact, uniform and free from all imperfections including kinks (protrusion of wires), wire cross over, over riding, looseness (wire being dislocated by finger/hand pressure and/or unusual bangle noise on tapping), material inclusions, white rust, powder formation or black spot (on account of reaction with trapped rain water etc.), dirt, grit etc.

1.6 Joints in Wires

1.6.1 Aluminium Alloy Wires

1.6.1.1 During stranding, no Aluminium Alloy wire welds shall be made for the purpose of achieving the required conductor length.

1.6.1.2 No joints shall be permitted in the individual wires in the outer most layer of the finished conductor. However, joints are permitted in the inner layer(s) of the conductor unavoidably broken during stranding provided such breaks are not associated with either inherently defective wire or with the use of short lengths of Aluminium Alloy wires. Such joints shall not be more than four (4) per conductor length and shall not be closer than 15 meters from joint in the same wire or in any other Aluminium Alloy wire of the completed conductor. A record of such joints for each individual length of the conductor shall be maintained by the Contractor for Owner's review.

1.6.1.3 Joints shall be made by cold pressure butt welding and shall withstand a stress of not less than the breaking strength of individual strand guaranteed.

1.6.2 Core Wires

There shall be no joint of any kind in the finished wire entering into the manufacture of the strand. There shall also be no joints or splices in any length of the completed solid or stranded core

1.7 Tolerances

Manufacturing tolerances on the dimensions to the extent of one percent (+/- 1%) shall be permitted for individual strands and the complete conductor.

1.8 Materials

The materials used for construction of the conductor shall be such that the conductor meets the specified technical and performance requirements.

1.8.1 Outer layer

1.8.1.1 The material of outer layer of HTLS conductor shall be of high temperature resistant aluminum alloy added with zirconium or any other suitable element(s) etc. to electrolytic aluminium having purity not less than 99.5% and a copper content not exceeding 0.04%. The strands shall be manufactured through appropriate manufacturing process to ensure consistent electrical mechanical and metallurgical properties under continuous high temperature operation. Bidder shall guarantee the chemical composition in the schedule GTP of BPS and also furnish description of the manufacturing process in the Bid.

1.8.1.2 In case of fully annealed type (0 tempered) aluminium / alloy strands round/ trapezoidal /Z-shaped wire shall be accepted.

1.8.2 Core

The core wire strand(s) shall be of galvanized steel wires/ aluminium clad steel wires / Zinc – 5% Aluminium – Misch metal alloy coated invar wire / galvanized invar wires/ aluminium clad invar wires/ composite materials etc. and shall have properties conforming to the technical performance requirements of the finished conductor. In case, the designed maximum temperature of the offered HTLS conductor exceeds 180 deg C, ordinary zinc coating/ galvanizing of the Steel/Invar core wires shall not be accepted and only aluminium clad or Misch metal coated wires shall be permitted. Bidder shall furnish properties and composition of the core wire strand(s)in the GTP.

The zinc used for galvanizing in case of steel /invar core shall be electrolytic High Grade Zinc of 99.95% purity. It shall conform to and satisfy all the requirements of IS:209. The minimum mass of zinc coating shall be as per requirements of Class-1 coating as per IEC-888. Zinc – 5% Aluminium – Misch metal alloy coating if used, shall conform to all requirements of ASTM B803 / B 958.

The aluminium cladding of invar/ steel wires shall be with aluminum having purity not less than 99.5 % and shall be thoroughly bonded to the core wire strand(s). The minimum thickness of aluminium cladding shall be 0.07mm to achieve a minimum conductivity of 14% of IACS.

Where composite material for core is offered, the material shall be either of High strength grade or extra high strength grade as per ASTM B987. The materials shall be of shall be of such proven quality that its properties are not adversely influenced by the normal operating conditions of a ---- kV transmission line in tropical environment conditions as experienced by the existing line. The bidder shall provide adequate details including specifications/test reports/operating experience details/performance certificates etc. in support of the suitability of the offered materials.

1.9 Conductor Length

1.9.1 The standard length of the conductor shall be indicated in the guaranteed technical particulars of offer. A tolerance of +/-5% on the standard length offered by the Bidder shall be permitted. Standard Length shall not be more than 2500 meters. All lengths outside this limit of tolerance shall be treated as random lengths.

1.9.2 Random lengths will be accepted provided no length is less than 70% of the standard length and the total quantity of such random lengths shall not be more than 10% of the total quantity ordered. At no point, the cumulative quantity supplied of such random lengths shall be more than 12.5% of the total cumulative quantity supplied including such random lengths. However, the last 20% of the quantity ordered shall be supplied only in standard lengths as specified.

1.9.3 Bidder shall also indicate the maximum single length, above the standard length, he can manufacture in the guaranteed technical particulars of offer. This is required for special stretches like river crossing etc. The Employer reserves the right to place orders for the above lengths on the same terms and conditions applicable for the standard lengths during the pendency of the Contract.

1.10 Evaluation of Ohmic Losses and Differential Price Loading

1.10.1 Based on the conductor parameters guaranteed by the bidders, average ohmic losses for different type of conductors for all three phases of one circuit of a transmission line offered by the bidders shall be calculated as per the following formula:

Average Ohmic loss (kW) = Loss Load Factor × 3 × Line Length × No. of sub conductors per bundle × (Continuous operating current specified by utility)^2 × AC Resistance corresponding to continuous operating current specified by utility

Differential price evaluation for the conductors offered by the bidders shall be carried out considering the average ohmic losses calculated as above and considering capitalisation cost……….₹ per kW.

The best parameter of loss (lowest ohmic loss for conductor) corresponding to lowest AC resistance quoted among bidders by any technically responsive and qualified bidder shall be taken as basis and that quoted by the particular bidder shall be used to arrive at differential price to be applied for each bid.

2.0 Tests and Standards

2.1 Type Tests

2.1.1 Type Tests on Stranded Conductor/ Stranded wire

The following tests shall be conducted once on sample/samples of conductor from each manufacturing facility:

On complete Conductor		
a)	DC resistance test on stranded conductor	As per Appendix-A
b)	UTS test on stranded conductor at	As per Appendix-A

	i) Room temperature ii) Elevated temperature	
c)	Radio interference voltage test (dry) [for 400kV line]	As per Appendix-A
d)	Corona extinction voltage test (dry) [for 400kV line]	As per Appendix-A
e)	Stress- Strain test on stranded conductor and core at room temperature	: IEC 1089
f)	Stress-strain test on stranded conductor and core at elevated temperature	As per Appendix-A
g)	High temperature endurance & creep test on stranded conductor	As per Appendix-A
h)	Sheaves Test	As per Appendix-A
i)	Axial Impact Test	As per Appendix-A
j)	Radial Crush Test	As per Appendix-A
k)	Torsional Ductility Test	As per Appendix-A
l)	Aeolian Vibration Test	As per Appendix-A
m)	Temperature Cycle Test	As per Appendix-A
On Conductor Strand/core		
a)	Heat resistance test on Aluminium Alloy strands or core	As per Appendix-A
b)	Bending test on core	As per Appendix-A
c)	Compression test on core	As per Appendix-A
d)	Coefficient of linear expansion on core/ core strands	As per Appendix-A
e)	Strand Brittle fracture test (for polymer composite core only)	As per Appendix-A

Type tests specified above shall not be required to be carried out if a valid test certificate is available for the offered design. The tests conducted earlier should have been conducted in accredited laboratory (accredited based on ISO/IEC guide 25/17025 or EN 45001 by the National Accreditation body of the country where laboratory is located) or witnessed by the representative (s) of a Utility. In the event of any discrepancy in the test report (i.e., any test report not applicable due to any design / material/manufacturing process change including substitution of components or due to non-compliance with the requirement stipulated in the Technical Specification) the tests shall be conducted by the Contractor at no extra cost to the Employer/ Purchaser.

2.2 **Acceptance Tests**

a)	Visual and dimensional check on drum	As per Appendix-A
b)	Visual check for joints scratches etc. and length measurement of conductor by rewinding	As per Appendix-A
c)	Dimensional check on core strands/ composite core and Aluminium Alloy strands	As per Appendix-A
d)	Check for lay-ratios of various layers	As per Appendix-A
e)	Galvanizing test on core strands (if applicable)	As per Appendix-A
f)	Thickness of aluminum on aluminium clad wires	As per Appendix-A
g)	Torsion and Elongation tests on core strands/composite core	As per Appendix-A
h)	Breaking load test on core strands and Aluminium / Aluminium Alloy strands	As per Appendix-A
i)	Wrap test on core strands and Aluminium Alloy strands	As per IEC:888 and IEC:889

j)	Resistivity test on thermal resistant Aluminium Alloy/Aluminium strands	As per IEC : 889
k)	Procedure qualification test on welded joint of Aluminium Alloy/Aluminium strands	As per Appendix-A
l)	Heat resistance test on Aluminium Alloy strands	As per Appendix-A
m)	Ageing test on filler (if applicable)	As per Appendix-A
n)	Resistivity test on aluminium clad core strands	As per Appendix-A
o)	Glass transition temperature test (For Polymer Composites only)	As per Appendix-A
p)	Flexural Strength test (For Polymer Composites only)	As per Appendix-A
q)	Bending test on polymer composite core	As per Appendix-A
r)	Galvanic Protection Barrier Layer Thickness test (on polymer composite core)	As per ASTM B987
s)	Coating Test on Zinc – 5% Al -Mischmetal alloy Coating (if applicable)	As per ASTM B803/ B958
t)	Adherence of Coating Test on Zinc – 5% Al - Mischmetal alloy Coating (if applicable)	As per ASTM B803/ B958

Note: All the above tests except (k) shall be carried out on Aluminium /Aluminium Alloy and core strands after stranding only.

2.3 Routine Test

a)	Check to ensure that the joints are as per Specification
b)	Check that there are no cuts, fins etc., on the strands.
c)	Check that drums are as per Specification
d)	All acceptance tests as mentioned above to be carried out on 10 % of drums

2.4 Tests During Manufacture

a)	Chemical analysis of zinc used for galvanizing	As per Appendix-A
b)	Chemical analysis of Aluminium alloy used for making Aluminium Alloy strands	As per Appendix-A
c)	Chemical analysis of core strands (not on polymer composite core)	As per Appendix-A

2.5 Testing Expenses

2.5.1 No type test charges shall be payable to the supplier.

2.5.2 Bidder shall indicate the laboratories in which they propose to conduct the type tests. They shall ensure that adequate facilities are available in the laboratories and the tests can be completed in these laboratories within the time schedule guaranteed by them.

2.5.3 In case of failure in any type test the Supplier is either required to manufacture fresh sample lot and repeat the entire test successfully once or repeat that particular type test three times successfully on the sample selected from the already manufactured lot at his own expenses. In case a fresh lot is manufactured for testing then the lot already manufactured shall be rejected.

2.5.4 The entire cost of testing for the acceptance and routine tests and Tests during manufacture specified herein shall be treated as included in the quoted unit price of conductor, except for the expenses of the inspector/Owner's representative.

2.5.5 In case of failure in any type test, if repeat type tests are required to be conducted, then all the expenses for deputation of Inspector/Owner's representative shall be deducted from the contract price. Also, if on receipt of the Supplier's notice of testing, the Owner's representative does not find material/ testing facilities to be ready for testing the expenses incurred by the Owner for re-deputation shall be deducted from contract price.

2.5.6 The Supplier shall intimate the Owner about carrying out of the type tests along with detailed testing program at least 3 weeks in advance (in case of testing in India) and at least 6 weeks in advance (in case of testing abroad) of the schedule date of testing during which the Owner will arrange to depute his representative to be present at the time of carrying out the tests.

2.6 Additional Tests

2.6.1 The Owner reserves the right of having at his own expenses any other test(s) of reasonable nature carried out at Supplier’s premises, at site or in any other place in addition to the aforesaid type, acceptance and routine tests to satisfy himself that the materials comply with the Specifications.

2.6.2 The Owner also reserves the right to conduct all the tests mentioned in this specification at his own expense on the samples drawn from the site at Supplier’s premises or at any other test centre. In case of evidence of non-compliance, it shall be binding on the part of Supplier to prove the compliance of the items to the technical specifications by repeat tests, or correction of deficiencies, or replacement of defective items all without any extra cost to the Owner.

2.7 Sample Batch for Type Testing

2.7.1 The Supplier shall offer material for selection of samples for type testing only after getting Quality Assurance Plan approved from Owner's Quality Assurance Deptt. The sample shall be manufactured strictly in accordance with the Quality Assurance Plan approved by Owner.

2.7.2 The Supplier shall offer at least three drums for selection of sample required for conducting all the type test.

2.7.3 The Supplier is required to carry out all the acceptance tests successfully in presence of Owner's representative before sample selection.

2.8 Test Reports

2.8.1 Copies of type test reports shall be furnished in at least three copies along with one original. One copy will be returned duly certified by the Owner only after which the commercial production of the material shall start.

2.8.2 Record of routine test reports shall be maintained by the Supplier at his works for periodic inspection by the Owner's representative.

2.8.3 Test Certificates of tests during manufacture shall be maintained by the Supplier. These shall be produced for verification as and when desired by the Owner.

2.9 Inspection

2.9.1 The Owner's representative shall at all times be entitled to have access to the works and all places of manufacture, where conductor shall be manufactured and representative shall have full facilities for unrestricted inspection of the Supplier's works, raw materials and process of manufacture for conducting necessary tests as detailed herein.

2.9.2 The Supplier shall keep the Owner informed in advance of the time of starting and of the progress of manufacture of conductor in its various stages so that arrangements can be made for inspection.

2.9.3 No material shall be dispatched from its point of manufacture before it has been satisfactorily inspected and tested, unless the inspection is waived off by the Owner in writing. In the latter case also the conductor shall be dispatched only after satisfactory testing for all tests specified herein have been completed.

2.9.4 The acceptance of any quantity of material shall in no way relieve the Supplier of any of his responsibilities for meeting all requirements of the Specification, and shall not prevent subsequent rejection it such material is later found to be defective.

2.10 Test Facilities

2.10.1 The following additional test facilities shall be available at the Supplier's works:

a) Calibration of various testing and measuring equipment including tensile testing machine, resistance measurement facilities, burette, thermometer, barometer etc.

b) Standard resistance for calibration of resistance bridges.

c) Finished conductor shall be checked for length verification and surface finish on separate rewinding machine at reduced speed (variable from 8 to 16 meters per minute). The rewinding facilities shall have appropriate clutch system and free of vibrations, jerks etc. with traverse laying facilities.

2.11 Packing

2.11.1 The conductor shall be supplied in non-returnable, strong, wooden/painted steel/hybrid (painted steel cum wood) drums provided with lagging of adequate strength, constructed to protect the conductor against all damage and displacement during transit, storage and subsequent handling and stringing operations in the field. The Supplier shall select suitable drums for supply of conductor and shall be responsible for any loss or damage to conductor and/or drum during transportation handling and storage due to improper selection of drum or packing.

2.11.2 The drums shall be suitable for wheel mounting and for letting off the conductor under a minimum controlled tension of the order of 5 kN.

2.11.3 The Bidder should submit their proposed drum drawings along with the bid.

2.11.4 One standard length only shall be wound on each drum.

2.11.5 The conductor ends shall be properly sealed and secured on the side of one of the flanges to avoid loosening of the conductor layers during transit and handling.

2.11.6 All wooden components shall be manufactured out of seasoned soft wood free from defects that may materially weaken the component parts of the drums. Preservative treatment shall be applied to the entire drum with preservatives of a quality which is not harmful to the conductor.

2.11.7 The flanges shall be of two ply construction with each ply at right angles to the adjacent ply and nailed together. The nails shall be driven from the inside face flange, punched and then clenched on the outer face. The thickness of each ply shall not vary by more than 3mm from that indicated in the figure. There shall be at least 3 nails per plank of ply with maximum nail spacing of 75mm. Where a slot is cut in the flange to receive the inner end of the conductor the entrance shall be in line with the periphery of the barrel.

2.11.8 The wooden battens used for making the barrel of the conductor shall be of segmental type. These shall be nailed to the barrel supports with at least two nails. The battens shall be closely butted and shall provide a round barrel with smooth external surface. The edges of the battens shall be rounded or chamfered to avoid damage to the conductor.

2.11.9 Barrel studs shall be used for the construction of drums. The flanges shall be holed and the barrel supports slotted to receive them. The barrel studs shall be threaded over a length on either end, sufficient to accommodate washers, spindle plates and nuts for fixing flanges at the required spacing.

2.11.10 Normally, the nuts on the studs shall stand protruded of the flanges. All the nails used on the inner surface of the flanges and the drum barrel shall be counter sunk. The ends of barrel shall generally be flushed with the top of the nuts.

2.11.11 The inner cheek of the flanges and drum barrel surface shall be painted with a bitumen based paint.

2.11.12 Before reeling, card board or double corrugated or thick galvanized water-proof bamboo paper shall be secured to the drum barrel and inside of flanges of the drum by means of a suitable commercial adhesive material. After reeling the conductor, the exposed surface of the outer layer of conductor shall be wrapped with water proof thick galvanized bamboo paper to preserve the conductor from dirt, grit and damage during transport and handling.

2.11.13 A minimum space of 75 mm for conductor shall be provided between the inner surface of the external protective tagging and outer layer of the conductor.

2.11.14 Each batten shall be securely nailed across grains as far as possible to the flange, edges with at least 2 nails per end. The length of the nails shall not be less than twice the thickness of the battens. The nails shall not protrude above the general surface and shall not have exposed sharp, edges or allow the battens to be released due to corrosion.

2.11.15 The nuts on the barrel studs shall be tack welded on the one side in order to fully secure them. On the second end, a spring washer shall be used.

2.11.16 A steel collar shall be used to secure all barrel studs. This collar shall be located between the washers and the steel drum and secured to the central steel plate by welding.

2.11.17 Outside the protective lagging, there shall be a minimum of two binders consisting of hoop iron/ galvanized steel wire. Each protective lagging shall have two recesses to accommodate the binders.

2.11.18 As an alternative to wooden drum, Bidder may also supply the conductors in returnable/ non-returnable painted steel drums. After preparation of steel surface according to IS:9954, synthetic enamel paint shall be applied after application of one coat of primer. Wooden/Steel drum will be treated at par for evaluation purpose and accordingly the Bidder should quote in the package.

2.11.19 In case of returnable steel drums for conductor, following clauses shall apply:

(a) The ownership of the empty conductor drums shall lie with the conductor supplier who shall ultimately take back the empty conductor drum from the Project site(s) from the erection contractor's designated stores after the running out of conductor from the drum.

(b) The erection contractor shall intimate the Conductor supplier and Employer regarding empty steel drums at their designated stores. Necessary coordination for taking back the empty steel drums in this regard shall be done by the Conductor Supplier with the erection Contractor.

(c) The empty drum shall be taken back by the conductor supplier from the stores of erection contractor as & when these are available after usage of conductor. Conductor supplier shall be required to take back the empty steel drum within a period of one month from date of information by erection contractor regarding availability of the drums at erection contractor stores. However, 2% of the total drums shall not be returned to the conductor supplier as these may be used for storage of spare conductor by the Purchaser.

(d) The steel drums may get damage and wear & tear due to transportation, normal handling & operation at site, which shall be rectified by the conductor supplier before re-use. However, 2% of the total drums shall not be returned on account of damages / wastage for which no compensation will be payable. The wastage beyond 2% shall be reimbursed by Erection Contractor. Thus, 4% of total drums shall not be returnable to the conductor supplier.

2.11.20 As an alternative to outer wooden lagging, in case of returnable/ non-returnable steel drums, solid polypropylene sheet (of min 5mm thickness) can be used for outer covering of conductor. In case of PP sheets are proposed to be used by the supplier, the conductor supplier shall supply two nos. additional binders per drum for re-wrapping PP sheet with each lot of conductor and 5 nos. crimping machines with the first lot of conductor for crimping the binders at site.

2.11.21 Marking

Each drum shall have the following information stenciled on it in indelible ink along with other essential data:

(a) Contract/Award letter number
(b) Name and address of consignee
(c) Manufacturer's name and address
(d) Drum number
(e) Size of conductor
(f) Length of conductor in meters

(g) Arrow marking for unwinding
(h) Position of the conductor ends
(i) Distance between outer-most Layer of conductor and the inner surface of lagging.
(j) Barrel diameter at three locations & an arrow marking at the location of the measurement.
(k) Number of turns in the outer most layer.
(l) Gross weight of drum after putting lagging.
(m)Tear weight of the drum without lagging.
(n) Net weight of the conductor in the drum.
(o) CIP/MICC No.

The above should be indicated in the packing list also.

2.12 Verification of Conductor Length

The Owner reserves the right to verify the length of conductor after unreeling at least ten (10) percent of the drums in a lot offered for inspection.

2.13 Standards

2.13.1 The conductor shall conform to the following Indian/International Standards, which shall mean latest revisions, with amendments/changes adopted and published, unless specifically stated otherwise in the Specification.

2.13.2 In the event of the supply of conductor conforming to standards other than specified, the Bidder shall confirm in his bid that these standards are equivalent to those specified. In case of award, salient features of comparison between the standards proposed by the Supplier and those specified in this document will be provided by the Supplier to establish their equivalence.

S.no.	Indian/ International Standard	Title
1.	IS: 209-1992	Zinc Ingot- Specification
2.	IS: 398-1982	Aluminium Conductors for Overhead Transmission Purposes- Specification

3.	IS:398-1990 Part-II	Aluminum Conductor Galvanized Steel Reinforced
4.	IS:398-1992 Part-V	Aluminum Conductor - Galvanized Steel-Reinforced For Extra High Voltage (400 kV and above)
5.	IS : 1778-1980	Specification for Reels and Drums for Bare Conductors
6.	IS : 1521-1991	Method for Tensile Testing of Steel Wire
7.	IS : 2629-1990	Recommended Practice for Hot Dip Galvanizing of Iron and Steel
8.	IS : 2633-1992	Method for Testing Uniformity of Coating on Zinc Coated Articles
9.	IS : 4826-1992	Specification for hot-dipped galvanized coatings on round steel wires
10.	IS : 6745-1990	Methods for Determination of Weight of Zinc Coating on Zinc Coated Iron and Steel Articles
11.	IS : 8263-1990	Method for Radio Interference Tests on High Voltage Insulators
12.	IS : 9997-1988	Aluminium Alloy Redraw Rods for electrical purposes- Specification
13.	IEC : 888-987	Zinc Coated steel wires for stranded Conductors
14.	IEC : 889-1987	Hard drawn Aluminium wire for overhead line conductors
15.	IS:398 (Part-IV)	Aluminium alloy stranded conductors (aluminium-magnesium-silicon type) - specification
16.	IEC:1232	Aluminium clad steel wires for electrical purposes
17.	IEC:468	Method of measurement of resistivity of metallic materials
18.	IEEE738	Standard for Calculating the Current-Temperature Relationship of Bare Overhead Conductors
19.	IEC 62004	Thermal-resistant aluminium alloy wire for overhead line conductor
20.	ASTM B498	Standard Specification for Zinc-Coated (Galvanized) Steel Core Wire for Use in Overhead Electrical Conductors

21.	ASTM B606	Standard Specification for High-Strength Zinc-Coated (Galvanized) Steel Core Wire for Aluminum and Aluminum-Alloy Conductors, Steel Reinforced
22.	ASTM B502	Standard Specification for Aluminum-Clad Steel Core Wire for Use in Overhead Electrical Aluminum Conductors
23.	ASTM B388	Standard Specification for Thermostat Metal Sheet and Strip
24.	ASTM B753	Standard Specification for Thermostat Component Alloys
25.	ASTM A856	Standard Specification for Zinc-5% Aluminum-Mischmetal Alloy-Coated Carbon Steel Wire
26.	ASTM A857	Standard Specification for Steel Sheet Piling, Cold Formed, Light Gage
27.	ASTM B230	Standard Specification for Aluminum 1350–H19 Wire for Electrical Purposes
28.	ASTM B398	Standard Specification for Aluminum-Alloy 6201-T81 and 6201-T83 Wire for Electrical Purposes
29.	ASTM B609	Standard Specification for Aluminum 1350 Round Wire, Annealed and Intermediate Tempers, for Electrical Purposes
30.	SS 424 0813	Aluminium alloy wire for stranded conductors for overhead lines – Al 59 wire
31.	SS 424 0814	Aluminium alloy stranded conductors for overhead lines – Al 59 wire
32.	BS EN 50540	Conductors for overhead lines. Aluminium conductors steel supported (ACSS)
33.	ASTM B 941	Standard Specification for Heat Resistant Aluminum-Zirconium Alloy Wire for Electrical Purposes
34.	ASTM B 957	standard Specification for Extra-High-Strength and Ultra-High-Strength Zinc-Coated (Galvanized) Steel Core Wire for Overhead Electrical Conductors
35.	ASTM B 802	Standard Specification for Zinc–5 % Aluminum-Mischmetal Alloy-Coated Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR)
36.	ASTM B 958	Standard Specification for Extra-High-Strength and Ultra-High-Strength Class A Zinc–5% Aluminum-Mischmetal Alloy-Coated Steel Core Wire for Use in Overhead Electrical Conductors

37.	ASTM B 976	Standard Specification for Fiber Reinforced Aluminum Matrix Composite (AMC) Core Wire for Aluminum Conductors, Composite Reinforced (ACCR)
38.	ASTM B987-17	Standard Specification for Carbon Fiber Thermoset Polymer Matrix Composite Core (CFC) for use in Overhead Electrical Conductors

Appendix-A

1. Tests on Conductor

1.1 UTS Test on Stranded Conductor at a) room temperature b) elevated temperature

a) UTS Test on Stranded Conductor at room temperature

Circles perpendicular to the axis of the conductor shall be marked at two places on a sample of conductor of minimum 5 m length between fixing arrangement suitably fixed by appropriate fittings on a tensile testing machine. The load shall be increased at a steady rate up to 50% of minimum specified UTS and held for one minute. The circles drawn shall not be distorted due to relative movement of strands. Thereafter the load shall be increased at steady rate to minimum UTS and held for one minute. The Conductor sample shall not fail during this period. The applied load shall then be increased until the failing load is reached and the value recorded.

*The test is to be conducted at ambient temperature, between minimum and maximum ambient temperature of 0 deg C and 50 deg C respectively.

b) UTS Test on Stranded Conductor at elevated temperature

UTS Test on Stranded Conductor shall be conducted as per clause no. 1.1(a) specified above keeping conductor temperature at the designed maximum temperature.

1.2 Corona Extinction Voltage Test [for 400kV System]

Two samples of conductor of minimum 5 m length each shall be strung in horizontal twin bundle configuration with spacing of 450 mm between sub-conductors at a height not exceeding 8.84m above ground. The twin bundle assembly when subjected to 50 hz power frequency voltage shall have a corona extinction voltage of not less than 320 kV (rms) line to ground under dry condition. There shall be no evidence of corona on any part of the samples. The test should be conducted without corona control rings. However, small corona control rings may be used to prevent corona in the end fittings. The voltage should be corrected for standard atmospheric conditions.

1.3 Radio Interference Voltage Test [for 400kV System]

Under the conditions as specified under (1.2) above, the conductor samples shall have radio interference voltage level below 1000 microvolts at one MHz when subjected to 50 Hz AC voltage of 305 kV line to ground under dry conditions. This test may be carried out with corona control rings and arcing horns.

1.4 D.C. Resistance Test on Stranded Conductor

On a conductor sample of minimum 5m length two contact-clamps shall be fixed with a predetermined bolt torque. The resistance shall be measured by a Kelvin double bridge or using micro ohm meter of suitable accuracy by placing the clamps initially zero meter and subsequently one meter apart. The test shall be repeated at least five times and the average value recorded. The value obtained shall be corrected to the value at 20oC as per IS:398-(Part-IV)/(Part-V). The resistance corrected at 20deg C shall conform to the requirements of this Specification.

1.5 Stress-strain test at elevated temperature

Stress-strain test as per IEC-61089 shall be conducted keeping conductor temperature at designed maximum temperature. UTS for this test shall be 80% of the UTS guaranteed in the GTP.

1.6 High Temperature endurance & creep test

Two conductor samples of length equal to at least 100 X d + 2 X a (where, d is the conductor diameter and a is the distance between the end fitting and the gauge length) shall be strung at tension equal to 25 % of conductor UTS. The distance, a, shall be at least 25 % of the gauge length or 2 m whichever is the smaller. The conductor samples shall be subjected to tests as indicated below:

(i) On one of the conductor samples, the conductor temperature shall be maintained at 20 deg C for 1000 hours. The elongation/creep strain of the conductor during this period shall be measured and recorded at end of 1 hour, 10 hour, 100 hour and subsequently every 100 hour up to 1000 hours time period.

(ii) On other conductor sample, the conductor temperature shall be increased to designed maximum temperature in

steps of 20 deg. C and thermal elongation of the conductor sample shall be measured & recorded at each step. The temperature shall be held at each step for sufficient duration for stabilization of temperature. Further, the temperature of the conductor shall be maintained at designed maximum temperature +10 Deg. C for 1000 hours. The elongation/creep strain of the conductor during this period shall be measured and recorded at end of 1 hour,
10 hour, 100 hour and subsequently every 100 hour upto 1000 hours time period. After completion of the above, the core of the conductor sample shall be subjected to UTS test as mentioned above at clause 1.1. The conductor core shall withstand a load equivalent to 95 % of UTS. In case of polymer composite core conductor, the flexural strength & glass transition temperature of the core shall also be evaluated and the same shall not be degraded by more than 10 % over the initial value. The supplier shall plot the thermal elongation with temperature.

The supplier shall furnish details of creep characteristic in respect of the conductor based on laboratory test and other laboratory investigations/experimental conducted on similar type of conductor and shall indicate creep strain values corresponding to 1 month, 6 month, 1 year, 10 year & 20 year creep at everyday tension & designed maximum temperature as well as room temperature.

1.7 Sheaves Test

The conductor sample of minimum length of 35 meter shall be tensioned at 25 % of the UTS and shall be passed through pulleys having diameter of 32 times that of the conductor with angle of 20 deg. between the pulleys. The conductor shall be passed over the pulleys 36 times a speed of 2 m/sec. After this test UTS test on the conductor shall be carried out as mentioned above at clause 1.1. In case of polymer composite core conductors, the core shall be inspected for any sign of damage or cracking through dye penetration test as per ASTM D5117.

1.8 Axial Impact Test

The conductor sample shall be suspended vertically and load applied by dropping a 650 kgs from an elevation of 4 meters above the sample. The impact velocity shall be not be less than 8 m/sec. with an initial pre-tension of 200 kgs. The curve for load vs time shall be recorded and recorded load of failure for core shall not be less than UTS of core.

1.9 Radial Crush Test

A section of conductor is to be crushed between two six-inch steel plates. Load shall be held at 350 kgs for 1 minute and then released. All the strands shall be subsequently disassembled and tensile tested. All the strands shall exhibit full strength retention

1.10 Torsional Ductility Test

The conductor sample of 10-15 m shall be loaded to 20% of UTS and then rotated in increasing steps of +/-180 deg. The entire conductor shall withstand at least 16 such rotation and there shall not be any damage to Aluminium Alloy or core wires. In case of composite core conductors, after 4 rotations or after separation of aluminium strands, the aluminium wires shall be cut and removed from the conductor and the exposed core shall be twisted and shall withstand up to 16 rotations.

1.11 Aeolian Vibration Test

The conductor and supporting hardware shall be loaded to _25% of UTS. A dynamometer, load cell, calibrated beam or other device shall be used to measure the conductor tension. Some means should be provided to maintain constant tension to allow for temperature fluctuations during the testing. The overall span between system terminations shall be a minimum of 30 m. The span shall be supported at a height such that the static sag angle of the cable to horizontal is (1.5 + 0.5) deg in the active span. Means shall be provided for measuring and monitoring the mid-loop (antinode) vibration amplitude at a free loop, not a support loop. An electronically controlled shaker shall be used to excite the conductor in the vertical plane. The shaker armature shall be securely fastened to the conductor so it is perpendicular to the conductor in the vertical plane. The shaker should be located in the span to allow for a minimum of six vibration loops between the suspension assembly and the shaker.

The test shall be carried out at one or more resonance frequencies (more than 10 Hz) . The amplitude at the antinode point shall be one third of conductor diameter. The assembly shall be vibrated for not less than 10 million cycles without any failure. After the test, the conductor should not exhibit any damage (broken strands). The conductor shall be tested to demonstrate that it retains at least 95% UTS.

1.12 Temperature Cycle Test

The purpose of this test is verification of degradation characteristics of metallic and non-metallic material when subjected to thermal cycling temperature cycling can create large internal stresses due to thermal expansion mismatch between constituents.

Test Methods:-

- Mechanical tension, 20 % UTS, marks on the conductor at the edge of the conductor
- 100 cycles from room temperature up to designed maximum temperature. Hold at designed maximum temperature + 2.5 deg. C for 5 minutes.
- After the above mentioned 100 cycle, Mechanical tension shall be increased up to 70 % UTS at room temperature and kept at this tension for 24 hours. Thereafter, release to 20% UTS.
- This cycling test shall be repeated 5 times.
- During the test, temperature of connectors, conductor and resistance are recorded according to ANSI C 119.
- A breaking load test is applied at the end of the test. Conductor strength has to be higher than 95 % UTS.
- In case of polymer composites, the flexural strength should not degrade by more than 10 % and the Glass Transition temperature shall not degrade by more than 10 % after

thermal cycling. Flexural strength shall be obtained on the basis of test procedure indicated at 1.32 below.

1.13 Heat Resistance test on Aluminium Alloy wire

Breaking load test as per clause 1.25 below shall be carried out before and after heating the sample in uniform heat furnace at following temperature for one hour. The breaking strength of the wire after heating shall not be less than the 90% of the breaking strength before heating:

Maximum continuous operating temperature of the conductor	Test Temperature
Upto 150 deg. C	230 degC (+5/-3 degC)
More than 150 deg. C & up to 210 deg. C	280 degC (+5/-3 degC)
More than 210 deg. C & up to 230 deg. C	400 degC (+5/-3 degC)

1.14 Bending test on aluminium clad core strand

A sample of aluminium clad invar strand measuring 30 cm in length shall be subject to bending with help of a vise. The vised length of wire should be 5 cm and radius of bend 4.8 mm. The bending should be first 90 degrees left and 90 degree right. After this operation the strand should cut at the bending point. There should be no separation of core and aluminium at the bending point after this operation.

1.15 Compression test on aluminium clad strand

A sample of aluminium clad core strand 10 mm in length is to be compressed by a plate with a load of 3600 kgs. The aluminium and core strand should not break.

1.16 Coefficient of linear expansion for core/core strands

The temperature and elongation on a sample shall be continuously measured and recorded at interval of approximately 15 degree C from 15 degree C to maximum continuous operating temperature corresponding to rated current (------e.g. 1574 A) by changing the temperature by suitable means. Coefficient of linear expansion shall be determined from the measured results.

1.17 Strand Brittle fracture test (for polymer composite core only)

The sample shall be tensioned to approx. 25% of UTS with simultaneous application of 1N-HNO3 acid directly in contact with naked polymer composite core. The contact length of acid shall not be less than 40mm and thickness around the core not less than 10mm.The rod shall withstand 80% of SML for 96 hours.

1.18 Visual and Dimensional Check on Drums

The drums shall be visually and dimensionally checked to ensure that they conform to the approved drawings.

1.19 Visual Check for Joints, Scratches etc.

Conductor drums shall be rewound in the presence of the Owner. The Owner shall visually check for scratches, joints etc. and that the conductor generally conform to the requirements of this Specification. Ten percent (10%) drums from each lot shall be rewound in the presence of the Owner's representative.

1.20 Dimensional Check on Core Strands and Aluminium Alloy Strands

The individual strands shall be dimensionally checked to ensure that they conform to the requirement of this Specification.

1.21 Check for Lay-ratios of Various Layers

The lay-ratios of various layers shall be checked to ensure that they conform to the guaranteed values furnished by the Contractor.

1.22 Galvanizing Test

The test procedure shall be as specified in IEC: 888. The material shall conform to the requirements of this Specification. The adherence of zinc shall be checked by wrapping around a mandrel four times the diameter of steel wire.

1.23 Aluminum thickness on aluminum clad wires

The thickness of aluminium of the specimen shall be determined by using suitable electrical indicating instruments operating on the permeameter principle, or direct measurement. Measurements shall be read to three decimal places, and number rounded to two decimal places is considered as measured thickness. For reference purposes, direct measurement shall be used to determine aluminium thickness on specimens taken from the end of the coils.

1.24 Torsion and Elongation Tests on Core wires/composite core

The test procedures for Torsion and Elongation Tests on Core wires shall be as per clause No. 6.3.3 and 6.3.2 b) of IEC 61232 respectively. In torsion test, the number of complete twists before fracture shall not be less than the value specified in the GTP on a length equal to 100 times the standard diameter of the strand. In case test sample length is less or more than 100 times the stranded diameter of the strand, the minimum number of twists will be proportioned to the length and if number comes in the fraction then it will be rounded off to next higher whole number. In elongation test, the elongation at fracture of the strand shall not be less than the value specified in the GTP for a gauge length of 250 mm. In case of composite core HTLS conductor, the following procedure shall be applicable:

(i) Elongation Test: The elongation of the composite core sample at shall be determined using extensometer. The load along the core shall be gradually increased. The elongation achieved on reaching the tensile strength of the core shall not be less than the value guaranteed in the GTP.

(ii) Torsion Test : The purpose of the test is to determine the resilience of the composite core to twisting and to show that after the composite core has experienced the prescribed twisting, it will not crack or have a loss in tensile strength due to the twisting. A sample length that is 170 times the diameter of the composite core being tested is mounted in the gripping fixtures. One grip shall then be fixed so that it does not twist and the other end shall be twisted a full 360 degrees and then fixed in this position for 2 minutes. Once the twist time is completed, the core is untwisted and inspected for any crazing or other damage. If no damage is observed, the composite core is then tensile tested to failure and the final load recorded. For the test to be accepted, the composite core must withstand at least 100% of its rated tensile strength. Two samples need to be completed in order to satisfy the testing requirement.

1.25 Breaking load test on Aluminium Alloy & Core strands and DC Resistance test on Aluminium Alloy wire

The above tests shall be carried out as per IEC: 888/889 and the results shall meet the requirements of the specification.

1.26 Wrap test on Core wires (Applicable for steel/Al clad Steel/invar core only)

The wrap test on steel strands shall meet the requirements of IEC: 888. In case of aluminium clad core wire, the same shall be wrapped around a mandrel of diameter of five times that of the strand to form a helix of eight turns. The strand shall be unwrapped. No breakage of strand shall have occurred.

1.27 Resistivity test on thermal resistant aluminium alloy strands

Resistivity test as per IEC-468/IEC 889 shall be conducted to confirm minimum conductivity as per specification requirement.

1.28 Procedure Qualification test on welded Aluminium Alloy strands.

Two Aluminium Alloy wire shall be welded as per the approved quality plan and shall be subjected to tensile load. The breaking strength of the welded joint of the wire shall not be less than the guaranteed breaking strength of individual strands.

1.29 Ageing Test on Filler (if applicable)

The test shall be done in accordance with Grease drop point test method. The specimen should be drop as a droplet when kept at a temperature 40 deg. C above designed maximum operating temperature of the conductor for 30 minutes. The temperature shall then be increase till one droplet drops and the temperature recorded.

1.30 Resistivity test on aluminium clad wire

Resistivity test as per IEC-468 shall be conducted to confirm minimum conductivity as per specification requirement.

1.31 Glass Transition Temperature Test (for polymer composite core only)

Test shall be conducted as per ASTM B987. The minimum glass transition temperature shall be either (i) the design maximum continuous operating temperature of the offered HTLS conductor + 35 deg C or (ii) minimum glass transition temperature as per ASTM B987 i.e.180 deg. C + 25 deg C ; Whichever is lower.

In case, the design maximum continuous operating temperature of the offered HT/HTLS conductor is more than the minimum glass transition temperature as per ASTM B987 i.e. more than 180 deg. C then, the test shall be conducted as per ASTM B987 & the minimum glass transition temperature shall be the design maximum continuous operating temperature of the offered HTLS conductor + 25 deg C.

1.32 Flexural Strength Test (for polymer composite core only)

Test method shall be as per ASTM D7264, ASTM D4475 or ISO 14125. The flexural strength shall not be less than the value guaranteed in the GTP.

1.33 Chemical Analysis of Aluminium Alloy and Core

Samples taken from the Aluminium and core coils/strands shall be chemically/spectrographically analyzed. The same shall be in conformity to the particulars guaranteed by the bidder so as to meet the requirements stated in this Specification.

1.34 Chemical Analysis of Zinc

Samples taken from the zinc ingots shall be chemically/ spectrographically analyzed. The same shall be in conformity to the requirements stated in the Specification.

1.35 Bending test on polymer composite core (Type test):

Bending test on polymer composite core (CFC) before stranding shall be performed as per ASTM B987/B987M-17 on polymer composite core samples taken from composite core at conductor manufacturing unit before stranding of conductor. Alternatively Bending test on polymer composite core (CFC) before stranding may be performed at the core manufacturing unit on the samples taken from the same reel being supplied to conductor manufacturer subject to proper traceability of the same at the conductor manufacturers works.

Bending test on polymer composite core (CFC) shall also be performed as per ASTM B987/B987M-17 on polymer composite core samples taken from stranded conductor. For test after stranding the diameter of cylindrical mandrel shall be as following:

1) For high strength grade CFC – 60 times the diameter of CFC
2) For Extra high strength grade CFC – 70 times the diameter of CFC

1.36 Bending test on polymer composite core (Acceptance test):

Bending test on polymer composite core (CFC) shall be performed as per ASTM B987/B987M-17 on polymer composite core samples taken from stranded conductor. For test after stranding the diameter of cylindrical mandrel shall be as following:

1) For high strength grade CFC – 60 times the diameter of CFC
2) For Extra high strength grade CFC – 70 times the diameter of CFC

Appendix-B

Calculation of sag and tension for INVAR type HTLS conductor

Range of temperature t	$t < t_c$	$t = t_c$	$t_c < t \le 230$	$230 < t$
Tension equation	$f^2\left[f - \left\{K - \alpha E\left(t - t_{max}\right)\right\}\right] = M$ where $K = f_{max} - \frac{E}{24}\left(\frac{q\delta S}{f_{max}}\right)^2$ $M = \frac{E}{24}(\delta S)^2$ $f = \frac{T}{A}$ $f_{max} = \frac{T_{max}}{A}$ $\delta = \frac{W_c}{A}$ $q = \frac{W_{max}}{W_c} = \frac{\sqrt{(W_c + W_s)^2 + W_w^2}}{W_c}$ t_{max} : Temperature at T_{max} W_s ; Snow ice weight W_w ; Wind load	$f_c^2\left[f_c - \frac{\alpha_c - \alpha}{\alpha_c}\{K - \alpha E(t_0 - t_{max})\}\right] - \frac{\alpha_c - \alpha}{\alpha_c} M$ where $K = f_{max} - \frac{E}{24}\left(\frac{q\delta S}{f_{max}}\right)^2$ $M = \frac{E}{24}(\delta S)^2$ $f_C = \frac{T_C}{A}$ $f_{max} = \frac{T_{max}}{A}$ $\delta = \frac{W_C}{A}$ $q = \frac{W_{max}}{W_c} = \frac{\sqrt{(W_c + W_s)^2 + W_w^2}}{W_c}$ t_{max} : Temperature at T_{max} W_s ; Snow ice weight W_w ; Wind load After tension equation was solved, t_c is calculated by $t_c = \frac{f_c}{E(\alpha_c - \alpha)} + t_0$	$f^2\left[f - \left\{K - \alpha_{i1} E_i\left(t - t_c\right)\right\}\right] = M$ where $K = f_u - \frac{E_i}{24}\left(\frac{\delta_i S}{f_u}\right)^2$ $M = \frac{E_i}{24}(\delta_i S)^2$ $f = \frac{T}{A_i}$ $f_u = \frac{T_c}{A_i}$ $\delta_i = \frac{W_c}{A_i}$	$f^2\left[f - \left\{K - \alpha_{i2} E_i\left(t - 230\right)\right\}\right] = M$ where $K = f_{230} - \frac{E_i}{24}\left(\frac{\delta_i S}{f_{230}}\right)^2$ $M = \frac{E_i}{24}(\delta_i S)^2$ $f = \frac{T}{A_i}$ $f_{230} = \frac{T_{230}}{A_i}$ $\delta_i = \frac{W_c}{A_i}$ T_{230} : Tension at 230°C
Sag of conductor d	$d = \frac{\delta S^2}{8f}$	$d = \frac{\delta S^2}{8f}$	$d = \frac{\delta S^2}{8f}$	$d = \frac{\delta S^2}{8f}$

Definitions of symbols are as follows:-

ΔL	Elongation and thermal expansion of conductor (m)
ΔL_a	Elongation and thermal expansion of aluminum part (m)
ΔL_i	Elongation and thermal expansion of invar core (m)
α	Equivalent coefficient of linear expansion for conductor (1/℃)
α_a	Coefficient of linear expansion for aluminum alloy wire (1/℃)
α_{i1}	Coefficient of linear expansion for aluminum-clad invar wire between room temperature and 230℃ (3.7×10^{-6} 1/℃)
α_{i2}	Coefficient of linear expansion for aluminum-clad invar wire between 230℃ and 290℃ (10.8×10^{-6} 1/℃)
E	Equivalent modulus of elasticity for conductor (kgf/mm^2)
E_a	Modulus of elasticity for aluminum alloy wire (6.300 kgf/mm^2)
E_i	Modulus of elasticity for aluminum-clad invar wire (15.500 kgf/mm^2)
A	Nominal cross sectional area of conductor (mm^2)
A_i	Nominal cross sectional area of invar core (mm^2)
W_c	Nominal weight of conductor (kg/ m)
T	Tension of conductor (kgf)
t_0	Initial temperature in manufacturing conductor (=15℃)
S	Span length (m)

Sample Calculation

Actual calculation of sag and tension for Linnet ZTACIR/AS

(1) Calculation condition

i) Properties of Linnet ZTACIR/AS

D (Diameter of conductor)	18.2 mm
A (Nominal cross sectional area of conductor)	196.5 mm²
A_i (Nominal cross sectional area of invar core	37.16 mm²
W (Nominal weight of conductor)	0.7066kg/m
E (Equivalent modulus of Elasticity for conductor)	8040 kgf/mm² (78.8 GPa)
E_i (Modulus of Elasticity for aluminum-clad invar wire)	15,500 kgf/mm² (152.0 GPa)
α (Equivalent coefficient of linear expansion for conductor)	16.0×10^{-6} 1/°C
α_a (Coefficient of linear expansion for aluminum alloy wire)	23×10^{-6} 1/°C
α_{i1} (Coefficient of linear expansion for aluminum-clad invar wire between transition temp.and 230°C)	3.7×10^{-6} 1/°C

ii) Loading condition under maximum tension

Temperature under maximum tension	15°C
Wind pressure	100kgf/m²
Thickness of snow ice (snow ice weight)	0mm(0kg/m)
Maximum tension	2,300 kgf (22.6 kN)

iii) Span length

S=300m

(2) Calculation of sag and tension at continuous operation temperature

The sag and tension at the continuous operation temperature (205°C) are calculated by the method described in Table

i) Tension at the transition temperature T_c

$$q = \frac{W_{max}}{W_c} = \frac{\sqrt{0.7066^2 + (18.2\times100/1000)^2}}{0.7066}$$

$$= 2.7630$$

$$f_{max} = \frac{T_{max}}{A} = \frac{2300}{196.5}$$

$$= 11.705$$

$$\delta = \frac{W_c}{A} = \frac{0.7066}{196.5}$$
$$= 3.5959 \times 10^{-3}$$
$$K = f_{max} - \frac{E}{24}\left(\frac{g\delta S}{f_{max}}\right)^2 = 11.705 - \frac{8040}{24} \times \left(\frac{2.7630 \times 0.0035959 \times 300}{11.705}\right)^2$$
$$= -10.018$$
$$M = \frac{E}{24}(\delta S)^2 = \frac{8040}{24} \times (0.0035959 \times 300)^2$$
$$= 389.85$$
$$\frac{\alpha_s - \alpha}{\alpha_s} = \frac{23 - 16.0}{23} = 0.30435$$

$\therefore$

$$f_c^2\left[f_c - 0.30435 \times \left\{-10.018 - 16.0 \times 10^{-6} \times 8040 \times (15 - 15)\right\}\right] = 0.30435 \times 389.85$$
$$f_c^2\left[f_c + 3.0490\right] = 118.65$$
$$f_c = 4.0796$$
$$T_c = f_c A = 4.0796 \times 196.5$$
$$= 801.64 \text{ kgf}$$

ii) Transition temperature t_c

$$t_c = \frac{4.0796}{8040 \times (23 - 16.0) \times 10^{-6}} + 15$$
$$= 87.49\ ^\circ C$$

iii) Sag d and tension T at the continuous operation temperature (205°C)

$$f_{ic} = \frac{T_{max}}{A_i} = \frac{801.64}{37.16}$$
$$= 21.573$$
$$\delta_i = \frac{W_c}{A_i} = \frac{0.7066}{37.16}$$
$$= 1.9015 \times 10^{-2}$$
$$K = f_{ic} - \frac{E_i}{24}\left(\frac{\delta_i S}{f_{ic}}\right)^2 = 21.573 - \frac{15500}{24} \times \left(\frac{0.019015 \times 300}{21.573}\right)^2$$
$$= -23.585$$
$$M = \frac{E_i}{24}(\delta S)^2 = \frac{15500}{24} \times (0.019015 \times 300)^2$$
$$= 21016$$

$\therefore$

$$f^2\left[f - \left\{-23.585 - 3.7 \times 10^{-6} \times 15500 \times (205 - 87.49)\right\}\right] = 10901$$
$$f^2\left[f + 30.324\right] = 21016$$
$$f = 20.362$$
$$T = fA_i = 20.362 \times 37.16$$
$$= 756.7 \text{ kgf at } 205^\circ C\ (7.42 kN)$$
$$d = \frac{\delta S^2}{8f} = \frac{0.019015 \times 300^2}{8 \times 20.362}$$
$$= 10.51 \text{ m at } 205^\circ C$$

ANNEXURE-III

TECHNICAL SPECIFICATION
FOR
HARDWARE FITTINGS ANDACCESSORIES

Annexure-III

TECHNICAL SPECIFICATION FOR HARDWARE FITTINGS AND ACCESSORIES

1. **Technical Description of Hardware Fittings**

1.1 General

This section details technical particulars of fittings viz. suspension clamps and compression type dead end clamps for the HTLS Conductor to be supplied by the bidder. Each fitting shall be supplied complete in all respects.

1.2 The fittings shall be suitable for attachment to suspension and tension insulator strings along with hardware fittings and shall include 2.5 % extra fasteners and Aluminum filler plugs. The supplier shall be responsible for satisfactory performance of complete conductor system along with fittings offered by them for continuous operation at the designed maximum temperature specified by them for the conductor.

1.3 **Corona and RI Performance [for 400kV]**

Sharp edges and scratches on all the hardware fittings shall be avoided. All surfaces must be clean, smooth, without cuts and abrasions or projections. The Supplier shall be responsible for satisfactory corona and radio interference performance of the materials offered by him.

1.4 **Maintenance**

1.4.1 The hardware fittings offered shall be suitable for employment of hot line maintenance technique so that usual hot line operations can be carried out with ease, speed and safety. The technique adopted for hot line maintenance shall be generally bare hand method & hot stick method.

1.5 **Split Pins**

1.5.1 Split pins shall be used with bolts & nuts.

1.6 **Suspension Assembly**

1.6.1 The suspension assembly shall be suitable for the HTLS Conductor, the bidder intends to supply. The technical details of the conductor shall be as proposed by the bidder.

1.6.2 The suspension assembly shall include either free center type suspension clamp along with standard preformed armour rods or armour grip suspension clamp.

1.6.3 The suspension clamp along with standard preformed armour rods set shall be designed to have maximum mobility in any direction and minimum moment of inertia so as to have minimum stress on the conductor in the case of oscillation of the same.

1.6.4 The suspension clamp suitable for various type of Conductor along with standard preformed armour rods/armour grip suspension clamp set shall have a slip strength in conformity with relevant Indian/ International standards.

1.6.5 The suspension clamp shall be designed for continuous operation at the temperature specified by the bidder for conductor.

1.6.6 The suspension assembly shall be designed, manufactured and finished to give it a suitable shape, so as to avoid any possibility of hammering between suspension assembly and conductor due to vibration. The suspension assembly shall be smooth without any cuts, grooves, abrasions, projections, ridges or excrescence which might damage the conductor.

1.6.7 The suspension assembly/clamp shall be designed so that it shall minimize the static & dynamic stress developed in the conductor under various loading conditions as well as during wind induced conductor vibrations. It shall also withstand power arcs & have required level of Corona/RIV performance.

1.6.9 **Free Centre Type Suspension Clamp**

For the Free Centre Suspension Clamp seat shall be smoothly rounded and curved into a bell mouth at the ends. The lip edges shall have rounded bead. There shall be at least two U-bolts for tightening of clamp body and keeper pieces together.

1.6.10 **Standard Preformed Armour Rod Set**

1.6.10.1 The Preformed Armour Rods Set shall be used to minimize the stress developed in the sub-conductor due to different static and dynamic loads because of vibration due to wind, slipping of conductor from the suspension clamp as a result of unbalanced conductor tension in adjacent spans and broken wire condition. It shall also withstand power arcs, chafing and abrasion from suspension clamp and localized heating effect due to magnetic power losses from suspension clamps as well as resistance losses of the conductor.

1.6.10.2 The preformed armour rods set shall have right hand lay and the inside diameter of the helics shall be less than the outside diameter of the conductor to have gentle but permanent grip on the conductor. The surface of the armour rod when fitted on the conductor shall be smooth and free from projections, cuts and abrasions etc.

1.6.10.3 The pitch length of the rods shall be determined by the Bidder but shall be less than that of the outer layer of conductor and the same shall be accurately controlled to maintain uniformity and consistently reproducible characteristic wholly independent of the skill of linemen.

1.6.10.4 The length and diameter of each rod shall be furnished by the bidder in the GTP. The tolerance in length of the rods between the longest and shortest rod in complete set should be within the limits specified in relevant Indian/International Standards. The ends of armour rod shall be parrot billed.

1.6.10.5 The length and diameter of each rod shall be specified in the GTP. The tolerance in length of the rods in complete set should be within 13 mm between the longest and shortest rod. The ends of armour rod shall be parrot billed.

1.6.10.6 The number of armour rods in each set shall be supplier's design to suit HTLS conductor offered Standards. Each rod shall be marked in the middle with paint for easy application on the line.

1.6.10.7 The armour rod shall not lose their resilience even after five applications.

1.6.10.8 The conductivity of each rod of the set shall not be less than 40% of the conductivity of the International Annealed Copper Standard (IACS).

1.6.11 **Armour Grip Suspension Clamp**

1.6.11.1 The armour grip suspension clamp shall comprise of retaining strap, support housing, elastomer inserts with aluminium reinforcements and AGS preformed rod set.

1.6.11.2 Elastomer insert shall be resistant to the effects of temperature up to designed maximum conductor temperature guaranteed by the bidder corresponding to peak current, Ozone, ultraviolet radiations and other atmospheric contaminants likely to be encountered in service. The physical properties of the elastomer shall be of approved standard. It shall be electrically shielded by a cage of AGS performed rod set. The elastomer insert shall be so designed that the curvature of the AGS rod shall follow the contour of the neoprene insert.

1.6.11.3 The supplier shall submit relevant type/performance test certificates as per applicable standard/product specifications for elastomer to confirm suitability of the offered elastomer for the specified application.

1.6.11.4 The AGS preformed rod set shall be as detailed in clause 1.6.10.4 to 1.6.10.7 in general except for the following.

1.6.11.4 The length of the AGS preformed rods shall be such that it shall ensure sufficient slipping strength as detailed under clause 1.6.4 and shall not introduce unfavorable stress on the conductor under all operating conditions. The length of the AGS preformed rods shall be indicated in the GTP.

1.7 **Envelope Type Suspension Clamp**

1.7.1 The seat of the envelope type suspension clamp shall be smoothly rounded & suitably curved at the ends. The lip edges shall have rounded bead. There shall be at least two U-bolts for tightening of clamp body and keeper pieces together. Hexagonal bolts and nuts with split-pins shall be used for attachment of the clamp.

1.8 **Dead end Assembly**

1.8.1 The dead end assembly shall be suitable for the offered HTLS Conductor.

1.8.2 The dead end assembly shall be of compression type with provision for compressing jumper terminal at one end. The angle of jumper terminal to be mounted (including angle of pad) should be 30° with respect to the vertical line. The area of bearing surface on all the connections shall be sufficient to ensure positive electrical and mechanical contact and avoid local heating due to I^2R losses. The resistance of the clamp when compressed on Conductor shall not be more than 75% of the resistance of equivalent length of Conductor.

1.8.3 Die compression areas shall be clearly marked on each dead-end assembly designed for continuous die compressions and shall bear the words 'COM PRESS FIRST' suitably inscribed near the point on each assembly where the compression begins. If the dead end assembly is designed for intermittent die compressions it shall bear identification marks 'COMPRESSION ZONE' AND 'NON-COMPRESSION ZONE' distinctly with arrow marks showing the direction of compressions and knurling marks showing the end of the zones. Tapered aluminium filler plugs shall also be provided at the line of demarcation between compression & non-compression zone. The letters, number and other markings on the finished clamp shall be distinct and legible. The dimensions of dead end assembly before & after compression along with tolerances shall be guaranteed in the relevant schedules of the bid and shall be decided by the manufacturer so as to suit the conductor size & conform to electrical & mechanical requirement stipulated in the specification. These shall be guaranteed in the relevant schedules of bid.

1.8.4 The assembly shall not permit slipping of, damage to, or failure of the complete conductor or any part thereof at a load less than 95% of the ultimate tensile strength of the conductor.

1.8.5 Jumper bolting arrangement between jumper terminal/cone and terminal pad/plate of dead end assembly of tension hardware fittings shall be designed to suit the specification requirement of -----A current and shall conform to the relevant Indian/International standards

1.8.6 For composite core HTLS conductor, dead end assembly shall inter-alia include collets, collet housing, inner sleeve etc., suitable for the offered design of HTLS conductor

1.9 **Fasteners: Bolts, Nuts and Washers**

1.9.1 All bolts and nuts shall conform to IS 6639. All bolts and nuts shall be galvanized as per IS 1367 (Part-13)/IS 2629. All bolts and nuts shall have hexagonal heads, the heads being forged out of solid truly concentric, and square with the shank, which must be perfectly straight.

1.9.2 Bolts up to M16 and having length up to 10 times the diameter of the bolt should be manufactured by cold forging and thread rolling process to obtain good and reliable mechanical properties and effective dimensional control. The shear strength of bolt for 5.6 grade should be 310 MPa minimum as per IS 12427. Bolts should be provided with washer face in accordance with IS 1363 (Part-1) to ensure proper bearing.

1.9.3 Nuts should be double chamfered as per the requirement of IS 1363 Part-III 1984. It should be ensured by the manufacturer that nuts should not be over tapped beyond 0.4 mm oversize on effective diameter for size up to M16.

1.9.4 Fully threaded bolts shall not be used. The length of the bolt shall be such that the threaded portion shall not extend into the place of contact of the component parts.

1.9.5 All bolts shall be threaded to take the full depth of the nuts and threaded enough to permit the firm gripping of the component parts but no further. It shall be ensured that the threaded portion of the bolt protrudes not less than 3 mm and not more than 8 mm when fully tightened. All nuts shall fit and tight to the point where shank of the bolt connects to the head.

1.9.6 Flat washers and spring washers shall be provided wherever necessary and shall be of positive lock type. Spring washers shall be electro-galvanized. The thickness of washers shall conform to IS:2016.

1.9.7 The Contractor shall furnish bolt schedules giving thickness of components connected, the nut and the washer and the length of shank and the threaded portion of bolts and size of holes and any other special details of this nature.

1.9.8 To obviate bending stress in bolt, it shall not connect aggregate thickness more than three time its diameter.

1.9.9 Bolts at the joints shall be so staggered that nuts may be tightened with spanners without fouling.

1.9.10 To ensure effective in-process Quality control it is essential that the manufacturer should have all the testing facilities for tests like weight of zinc coating, shear strength, other testing facilities etc., in-house. The manufacturer should also have proper Quality Assurance system which should be in line with the requirement of this specification and IS-.14000 services Quality System standard.

1.9.11 Fasteners of grade higher than 8.8 are not to be used and minimum grade for bolt shall be 5.6.

1.10 **Materials**

The materials of the various components shall be as specified hereunder. The Bidder shall indicate the material proposed to be used for each and every component of hardware fittings stating clearly the class, grade or alloy designation of the material, manufacturing process & heat treatment details and the reference standards.

1.10.1 The details of materials for different component are listed as in Table No-1.

1.11 **Workmanship**

1.11.1 All the equipment shall be of the latest design and conform to the best
modern practices adopted in the Extra High Voltage field. The Bidder shall offer only such equipment as guaranteed by him to be satisfactory and suitable for ---kV transmission lines and will give continued good performance. For employer's review of the offered design of clamps/ fittings, the supplier shall submit document/design details of similar type of clamps/ fittings used in past for similar type of HTLS conductor application

1.11.2 High current, heat rise test shall be conducted by the supplier to determine the maximum temperature achieved in different components of fittings under simulated service condition corresponding to continuous operation of conductor at designed maximum temperature. The material of the components should be suitable for continued good performance corresponding to these maximum temperatures. The supplier shall submit relevant type/performance test certificates as per applicable standards/product specifications to confirm suitability of the offered material.

1.11.3 The design, manufacturing process and quality control of all the materials shall be such as to give the specified mechanical rating, highest mobility, elimination of sharp edges and corners to limit corona and radio-interference, best resistance to corrosion and a good finish.

1.11.4 All ferrous parts including fasteners shall be hot dip galvanized, after all machining has been completed. Nuts may, however, be tapped (threaded) after galvanizing and the threads oiled. Spring washers shall be electro galvanized. The bolt threads shall be undercut to take care of the increase in diameter due to galvanizing. Galvanizing shall be done in accordance with IS 2629 / IS 1367 (Part-13) and shall satisfy the tests mentioned in IS 2633. Fasteners shall withstand four dips while spring washers shall withstand three dips of one minute duration in the standard Preece test. Other galvanized materials shall have a minimum average coating of zinc equivalent to 600 gm/sq.m., shall be guaranteed to withstand at least six successive dips each lasting one (1) minute under the standard preece test for galvanizing.

1.11.5 Before ball fittings are galvanized, all die flashing on the shank and on the bearing surface of the ball shall be carefully removed without reducing the dimensions below the design requirements.

1.11.6 The zinc coating shall be perfectly adherent, of uniform thickness, smooth, reasonably bright, continuous and free from imperfections such as flux, ash rust, stains, bulky white deposits and blisters. The zinc used for galvanizing shall be grade Zn 99.95 as per IS:209.

1.11.7 Pin balls shall be checked with the applicable ‚GO' gauges in at least two directions. one of which shall be across the line of die flashing, and the other 90o to this line. "NO GO" gauges shall not pass in any direction.

1.11.8 Socket ends, before galvanizing, shall be of uniform contour. The bearing surface of socket ends shall be uniform about the entire circumference without depressions of high spots. The internal contours of socket ends shall be concentric with the axis of the fittings as per IS:2486/IEC : 120.

The axis of the bearing surfaces of socket ends shall be coaxial with the axis of the fittings. There shall be no noticeable tilting of the bearing surfaces with the axis of the fittings.

1.11.7 In case of casting, the same shall be free from all internal defects like shrinkage, inclusion, blow holes, cracks etc. Pressure die casting shall not be used for casting of components with thickness more than 5 mm.

1.11.8 All current carrying parts shall be so designed and manufactured that contact resistance is reduced to minimum.

1.11.9 No equipment shall have sharp ends or edges, abrasions or projections and cause any damage to the conductor in any way during erection or during continuous operation which would produce high electrical and mechanical stresses in normal working. The design of adjacent metal parts and mating surfaces shall be such as to prevent corrosion of the contact surface and to maintain good electrical contact under service conditions.

1.11.9 All the holes shall be cylindrical, clean cut and perpendicular to the plane of the material. The periphery of the holes shall be free from burrs.

1.11.10 All fasteners shall have suitable corona free locking arrangement to guard against vibration loosening.

1.11.11 Welding of aluminium shall be by inert gas shielded tungsten arc or inert gas shielded metal arc process. Welds shall be clean, sound, smooth, uniform without overlaps, properly fused and completely sealed. There shall be no cracks, voids incomplete penetration, incomplete fusion, under-cutting or inclusions. Porosity shall be minimized so that mechanical properties of the aluminium alloys are not affected. All welds shall be properly finished as per good engineering practices.

1.12 **Bid Drawings**

1.12.1 The Bidder shall furnish full description and illustrations of materials offered.

1.12.2 Fully dimensioned drawings of the hardwares and their component parts shall be furnished --- copies along with the bid. Weight, material and fabrication details of all the components should be included in the drawings.

1.12.3 All drawings shall be identified by a drawing number and contract number. All drawings shall be neatly arranged. All drafting & lettering shall be legible. The minimum size of lettering shall be 3 mm. All dimensions & dimensional tolerances shall be mentioned in mm.

The drawings shall include:

(i) Dimensions and dimensional tolerance.

(ii) Material, fabrication details including any weld details & any specified finishes & coatings. Regarding material designation & reference of standards are to be indicated.

(iii) Catalogue No.

(iv) Marking

(v) Weight of assembly

(vi) Installation instructions

(vii) Design installation torque for the bolt or cap screw.

(viii) Withstand torque that may be applied to the bolt or cap screw without failure of component parts.

(vi) Installation instructions

(ix) The compression die number with recommended compression pressure.

(x) Placement charts for spacer/spacer damper and damper

(xi) All other relevant technical details

1.12.4 After placement of award, the Contractor shall submit fully dimensioned drawing including all the components in ----- copies to the Owner for approval. After getting approval from the Owner and successful completion of all the type tests, the Contractor shall submit ------ more copies of the same drawings to the Owner for further distribution and field use at Owner's end.

TABLE-1

(Details of Materials)

Sl. No.	Name of item	Material treatment	Process of Standard	Reference	Remarks
1.	Security Clips	Stainless Steel/ Phospher Bronze	-	AISI 302 or 304-L/ IS-1385	
2.	**For Free Centre /Envelope type clamps**				
(a)	Clamp Body, Keeper Piece	High Strength Al. Alloy 4600/ LM-6 or 6061/65032	Casted or forged & Heat treated	IS:617or ASTM-B429	
(b)	Cotter bolts/ Hangers, Shackles, Brackets	Mild Steel	Hot dip galvanized	As per IS-226 or IS-2062	
(c)	U Bolts	Stainless Steel or High Strength Al alloy 6061/ 65032	Forged & & Heat treated	AISI 302 or 304-L ASTM-B429	
(d)	P. A. Rod	High Strength Al. Alloy 4600/ LM-6 or 6061/65032	Heat treatment during manufacturing	ASTM-B429	Min. tensile strength of 35 kg/mm^2
3.	**For AGS type clamp**				
(a)	Supporting House	High Strength Corrosion resistant Al. Alloy 4600/ LM-6 or 6061/65032	Casted or forged & Heat treated	IS:617or ASTM-B429	
(b)	Al insert & Retaining strap	High Strength Al. Alloy 4600/ LM-6 or 6061/65032	Casted or forged & Heat treated	IS:617or ASTM-B429	High Strength Al. Alloy 4600/ LM-6 or

					6061/650 32
(c)	Elastomer	Moulded on Al. reinforcement			
4.	**For Dead End Assembly**				
(a)	Outer Sleeve	EC grade Al of purity not less than 99.50%			
(b)	Steel Sleeve	Mild Steel	Hot Dip Galvanized	IS:226/ IS-2062	
5.	Ball & Socket Fittings,	Class-IV Steel	Drop forged & normalized Hot dip galvanized	As per IS: 2004	
6.	Yoke Plate	Mild Steel	Hot dip galvanized	As per IS-226 or IS-2062	
7.	Sag Adjustment plate	Mild Steel	Hot dip galvanized	As per IS-226 or IS-2062	
8(a)	Corona Control ring/ Grading ring	High Strength Al. Alloy tube (6061/ 6063/1100 type or 65032/ 63400 Type)	Heat treated Hot dip galvanized	ASTM-B429 or as per IS	Mechanical strength of welded joint shall not be less than 20 kN
8(b)	Supporting Brackets & Mounting Bolts	High Strength Al Alloy 7061/ 6063/ 65032/63400 Type) or Mild Steel	Heat treated Hot dip galvanized	ASTM-B429 or as per IS:226 or IS:2062	

Note : Alternate materials conforming to other national standards of other countries also may be offered provided the properties and compositions of these are close to the properties and compositions of material specified. Bidder should furnish the details of comparison of material offered viz a viz specified in the bid or else the bids are liable to be rejected.

2.0 **Accessories for the HTLS Conductor**

2.1 **General**

2.1.1 This portion details the technical particulars of the accessories for Conductor.

2.1.2 2.5% extra fasteners, filler plugs and retaining rods shall be provided.

2.1.3 The supplier shall be responsible for satisfactory performance of complete conductor system along with accessories offered by him for continuous operation at temperature specified for the HTLS Conductor.

2.2 **Mid Span Compression Joint**

2.2.1 Mid Span Compression Joint shall be used for joining two lengths of conductor. The joint shall have a resistively less than 75% of the resistivity of equivalent length of conductor. The joint shall not permit slipping off, damage to or failure of the complete conductor or any part thereof at a load less than 95% of the ultimate tensile strength of the conductor. It must be able to withstand the continuous design temperature of conductor.

2.2.2 The dimensions of mid span compression joint before & after compression along with tolerances shall be shall be guaranteed in the relevant schedules of the bid and shall be decided by the manufacturer so as to suit the conductor size & conform to electrical & mechanical requirement stipulated in the specification. For composite core conductor, suitable sleeve, collets, collet housing shall be used for core jointing.

2.3 **Repair Sleeve**

Repair Sleeve of compression type shall be used to repair conductor with not more than two strands broken in the outer layer. The sleeve shall be manufactured from 99.5% pure aluminium / aluminium alloy and shall have a smooth surface. It shall be able to withstand the designed maximum operating temperature of conductor. The repair sleeve shall comprise of two pieces with a provision of seat for sliding of the keeper piece. The edges of the seat as well as the keeper piece shall be so rounded that the conductor strands are not damaged during installation. The dimensions of Repair sleeve along with tolerances shall be guaranteed in the relevant schedules of the bid and shall be decided by the manufacturer so as to suit the conductor size & conform to electrical & mechanical requirement stipulated in the specification.

2.4 **Vibration Damper**

2.4.1 Vibration dampers of 4R-stockbridge type with four (4) different resonances spread within the specified Aeolian frequency band width corresponding to wind speed of 1 m/s to 7 m/s are installed in the existing line at suspension and tension points on each conductor in each span along with bundle spacers to damp out Aeolian vibration as well as sub- span oscillations. One damper minimum on each side conductor / sub-conductor in a bundle for suspension points and one / two dampers minimum on each side conductor / sub-conductor in a bundle for tension points has been used for a ruling design span of --- meters.

2.4.2 The bidder shall offer damping system including Stockbridge type dampers and bundle spacers for HTLS conductor for its protection from wind induced vibrations which could cause conductor fatigue /strand breakage near a hardware attachment, such as suspension clamps.

Alternate damping systems with proven design offering equivalent or better performance also shall be accepted provided the manufacturer meets the qualifying requirements stipulated in the Specifications. Relevant technical documents including type test reports to establish the technical suitability of alternate systems shall be furnished by the Bidder along with the bid.

The damper shall be designed to have minimum 4 nos of resonance frequencies to facilitate dissipation of vibration energy through inter-strand friction of the messanger cable and shall be effective in reducing vibration over a wide frequency range (depending upon conductor dia) or wind velocity range specified above. The vibration damper shall meet the requirement of frequency or wind velocity range and also have mechanical impedence closely matched with the offered HTLS conductor. The vibration dampers shall be installed at suitable positions to ensure damping effectiveness across the frequency range. The power dissipation of the vibration dampers shall exceed the wind power so that the vibration level on the conductor is reduced below its endurance limit i.e. 150 micro strain. The bidder shall clearly indicate the method for evaluating performance of dampers including analytical and laboratory test methods. The bidder shall indicate the type tests to evaluate the performance of offered damping system.

2.4.5 The clamp of the vibration damper shall be made of high strength aluminium alloy of type LM-6. It shall be capable of supporting the damper and prevent damage or chafing of the conductor during erection or continued operation. The clamp shall have smooth and permanent grip to keep the damper in position on the conductor without damaging the strands or causing premature fatigue failure of the conductor under the clamp. The clamp groove shall be in uniform contact with the conductor over the entire clamping surface except for the rounded edges. The groove of the clamp body and clamp cap shall be smooth, free from projections, grit or other materials which could cause damage to the conductor when the clamp is installed. Clamping bolts shall be provided with self-locking nuts and designed to prevent corrosion of threads or loosening in service.

2.4.6 The messenger cable shall be made of high strength galvanized steel/stain less steel with a minimum strength of 135 kg/sqmm. It shall be of preformed and postformed quality in order to prevent subsequent drop of weight and to maintain consistent flexural stiffness of the cable in service. The number of strands in the messenger cable shall be 19. The messenger cable other than stainless steel shall be hot dip galvanized in accordance with the recommendations of IS:4826 for heavily coated wires.

2.4.7 The damper mass shall be made of hot dip galvanized mild steel/cast iron or a permanent mould cast zinc alloy. All castings shall be free from defects such as cracks, shrinkage, inclusions and blowholes etc. The surface of the damper masses shall be smooth.

2.4.8 The damper clamp shall be casted over the messenger cable and offer sufficient and permanent grip on it. The messenger cable shall not slip out of the grip at a load less than the mass pull-off value of the damper. The damper masses made of material other-than zinc alloy shall be fixed to the messenger cable in a suitable manner in order to avoid excessive stress concentration on the messenger cables which shall cause premature fatigue failure of the same. The messenger cable ends shall be suitably and effectively sealed to prevent corrosion. The damper mass made of zinc alloy shall be casted over the messenger cable and have sufficient and permanent grip on the messenger cable under all service conditions.

2.4.9 The damper assembly shall be so designed that it shall not introduce radio interference beyond acceptable limits.

2.4.10 The vibration damper shall be capable of being installed and removed from energized line by means of hot line technique. in addition, the clamp shall be capable of being removed and reinstalled on the conductor at the designated torque without shearing or damaging of fasteners.

2.4.11 The contractor must indicate the clamp bolt tightening torque to ensure that the slip strength of the clamp is maintained between 2.5 kN and 5 kN. The clamp when installed on the conductor shall not cause excessive stress concentration on the conductor leading to permanent deformation of the conductor strands and premature fatigue failure in operation.

2.4.12 The vibration analysis of the system, with and without damper and dynamic characteristics of the damper as detailed under Appendix-I, shall have to be submitted. The technical particulars for vibration analysis and damping design of the system are as follows:

Sl. No.	Description	Technical particulars
1.	Span length in meters	
i)	Ruling design span	---meters (e.g. 400m)
ii)	Maximum span	1100 meters
iii)	Minimum span	100 meters
2.	Configuration	----[e.g. Double Circuit twin bundle conductor per phase in vertical configuration]
3.	Tensile load in Conductor at temperature of minimum temperature and still air	As per Sag – tension calculations

4.	Armour rods used	Standard preformed armour rods/AGS
5.	Maximum permissible dynamic strain i.e. endurance limit.	+/- 150 micro strains

2.4.14 The damper placement chart shall be submitted for spans ranging from 100m to 1100m. Placement charts should be duly supported with relevant technical documents and sample calculations.

2.4.15 The damper placement charts shall include the following

(1) Location of the dampers for various combinations of spans and line tensions clearly indicating the number of dampers to be installed per conductor per span.

(2) Placement distances clearly identifying the extremities between which the distances are to be measured.

(3) Placement recommendation depending upon type of suspension clamps (viz Free center type/Armour grip type etc.)

(4) The influence of mid span compression joints, repair sleeves and armour rods (standard and AGS) in the placement of dampers.

2.5 Bundle Spacer

2.5.1 Armour grip bundle spacers shall be used to maintain the spacing of 450 mm between the sub-conductors [for 400kV] of each bundle under all normal working conditions.

2.5.2 Spacers offering equivalent or better performance shall also be accepted provided offer meets the qualifying requirements stipulated in the Specification.

2.5.3 The offer shall include placement charts recommending the number of spacers per phase per span and the sub span lengths to be maintained between the spacers while installing on the bundle conductors.

2.5.3.1 The placement of spacers shall be in such a way that adjacent sub spans are sufficiently detuned and the critical wind velocity of each sub span shall be kept more than 30 km/hr. and to avoid clashing of sub conductors. The placement shall ensure bundle stability under all operating conditions.

2.5.3.2 The placement chart shall be provided for spans ranging from 100 m to 1100m. The number of spacers recommended for a ruling design span of 400m [for 400kV] shall however be seven with no sub-span greater than 70m and no end sub-span longer than 40m.

2.5.3.3 The Bidder may offer more number of spacers per ruling design span than the specified. However, in such case, suitable price compensation shall be considered for evaluation. For the purpose of price compensation, all the spans shall be assumed to be ruling design spans.

2.5.3.4 The Bidder shall also furnish all the relevant technical documents in support of their placement charts along with the bid.

2.5.4 Jumpers at tension points shall also be fitted with spacers so as to limit the length of free conductor to 3.65 m and to maintain the sub conductor spacing of 450 mm [for 400kV] for bundle conductors. Bidder shall quote for rigid spacer for jumper. It shall meet all the requirements of spacer used in line except for its vibration performance. Spacers requiring retaining rods shall not be quoted for jumpers.

2.5.5 The spacer offered by the Bidder shall satisfy the following requirements.

2.5.5.1 Spacer shall restore normal spacing of the sub-conductors after displacement by wind, electromagnetic and the electrostatic forces under all operating conditions including the specified short circuit level without permanent deformation damage either to conductor or to the assembly itself. They shall have uniform grip on the conductor

2.5.5.2 For spacer requiring retaining rods, the retaining rods shall be designed for the specified conductor size. The preformed rods shall be made of high strength, special aluminium alloy of type 6061/65032 and shall have minimum tensile strength of 35 kg/sq.mm. The ends of retaining rods should be ball ended. The rods shall be heat-treated to achieve specified mechanical properties and give proper resilience and retain the same during service.

2.5.5.3 Four number of rods shall be applied on each clamps to hold the clamp in position. The minimum diameter of the rods shall be 7.87 $\pm$ 0.1 mm and the length of the rods shall not be less than 1100 mm.

2.5.5.4 Where elastomer surfaced clamp grooves are used, the elastomer shall be firmly fixed to the clamp. The insert should be forged from aluminium alloy of type 6061/65032. The insert shall be duly heat treated and aged to retain its consistent characteristics during service.

2.5.5.5 Any nut used shall be locked in an approved manner to prevent vibration loosening. The ends of bolts and nuts shall be properly rounded for specified corona performance or suitably shielded.

2.5.5.6 Clamp with cap shall be designed to prevent its cap from slipping out of position when being tightened.

2.5.5.7 The clamp grooves shall be in uniform contact with the conductor over the entire surface, except for rounded edges. The groove of the clamp body and clamp cap shall be smooth and free of projections, grit or other material which cause damage to the conductor when the clamp is installed.

2.5.5.8 For the spacer involving bolted clamps, the manufacturer must indicate the clamp bolt tightening torque to ensure that the slip strength of the clamp is maintained between 2.5 kN and 5 kN. The clamp when installed on the conductor shall not cause excessive stress concentration on the conductor leading to permanent deformation of the conductor strands and premature fatigue failure in operation.

2.5.5.9 Universal type bolted clamps, covering a range of conductor sizes, will not be permitted.

2.5.5.10 No rubbing, other than that of the conductor clamp hinges or clamp swing bolts, shall take place between any parts of the spacer. Joint incorporating a flexible medium shall be such that there is no relative slip between them.

2.5.5.11 The spacer shall be suitably designed to avoid distortion or damage to the conductor or to themselves during service.

2.5.5.12 Rigid spacers shall be acceptable only for jumpers.

2.5.5.13 The spacer shall not damage or chafe the conductor in any way which might affect its mechanical and fatigue strength or corona performance.

2.5.5.14 The clamping system shall be designed to compensate for any reduction in diameter of conductor due to creep.

2.5.5.15 The spacer assembly shall not have any projections, cuts, abrasions etc. or chattering parts which might cause corona or RIV.

2.5.5.16 The spacer tube shall be made of aluminium alloy of type 6061/65032. If fasteners of ferrous material are used, they shall conform to and be galvanized conforming to relevant Indian Standards.

2.5.5.17 Elastomer, if used, shall be resistant to the effects of temperature up to the designed maximum temperature specified for the conductor, ultraviolet radiation and other atmospheric contaminants likely to be encountered in service. It shall have good fatigue characteristics. The physical properties of the elastomer shall be of approved standard. The supplier shall submit relevant type/ performance test certificate as per applicable standard/ product specification for elastomer to confirm suitability of the offered elastomer for the specified application.

2.5.5.18 The spacer assembly shall have electrical continuity. The electrical resistance between the sub-conductor across the assembly in case of spacer having elastomer clamp grooves shall be suitably selected by the manufacturers to ensure satisfactory electrical performance and to avoid deterioration of elastomer under all service conditions.

2.5.5.19 The spacer assembly shall have complete ease of installation and shall be capable of removal/reinstallation without any damage.

2.5.5.20 The spacer assembly shall be capable of being installed and removed from the energized line by means of hot line technique.

2.6 Spacer Damper (Alternative to Vibration Damper & Bundle Spacer)

2.6.1 Suitable spacer dampers for HTLS conductor can be offered as an alternative to the combination of Vibration Damper and Bundle Spacer. The spacer damper covered by this specification shall be designed to maintain the bundle spacing of 450 mm under all normal operating conditions and to effectively control Aeolian vibrations as well as sub span oscillation and to restore conductor spacing after release of any external extraordinary load. The nominal sub conductor spacing shall be maintained within ±5 mm.

2.6.2 The spacer damper shall restore the normal sub-conductor spacing due to displacement by wind, electromagnetic and electrostatic forces including the specified short circuit level without permanent deformation or damage either to bundle conductors or to spacer damper itself.

2.6.3 The design offered shall be presented as a system consisting of spacer dampers and their staggering scheme for spans ranging from 100 m to 1100 m.

2.6.4 Under the operating conditions specified, the spacer damper system shall adequately control Aeolian vibrations throughout the life of the transmission line with wind velocity ranging from 0 to 30 km per hour in order to prevent damage to conductor at suspension clamps, dead end clamps and spacer damper clamps.

2.6.5 The spacer damper system shall also control the sub-span oscillations in order to prevent conductor damage due to chaffing and severe bending stresses at the spacer damper clamps as well as suspension and dead end clamps and to avoid wear to spacer damper components.

2.6.6 The spacer damper shall consist of a rigid central body called the frame linked to the conductor by two articulated arms terminated by suitable clamping system. The articulation shall be designed to provide elastic and damping forces under angular movement of the arms. The dynamic characteristics of the articulations shall be maintained for the whole life of the transmission line.

2.6.7 The clamping system shall be designed to provide firm but gentle and permanent grip while protecting the conductor against local static or dynamic stresses expected during normal operating conditions. The clamping system shall be designed to compensate for any reduction of conductor diameter due to creep.

2.6.8 Bolted type clamps shall allow installation without removal of the bolts or the clamps from clamp body. Locking mechanism shall be suitable to prevent bolt loosening. Clamp locking devices with small loose components shall not be accepted. Nut cracker, hinged open or boltless type clamps are acceptable provided adequate grip can be maintained on the conductor.

2.6.9 Bolts and nuts shall be of mild steel, stainless steel, or high strength steel in accordance with the design of the spacer damper.

2.6.10 Where elastomer surfaced clamps are used, the elastomer elements shall be firmly fixed to the clamp. The insert should be forged from aluminium alloy of type 6061 or equivalent aluminium alloy having minimum tensile strength of 25 kg/mm2. The insert shall be moulded on the insert surface. The insert shall be duly heat treated and aged to retain its consistent characteristics during service. The grain flow of the forged insert shall be in the direction of the maximum tension and compression loads experienced.

2.6.11 If clamps involving preformed rods are used, these rods shall be designed for specific conductor size. They shall be made of high strength aluminium alloy of type 6061 or equivalent aluminium alloy having a minimum tensile strength of 35 kg/mm3. The rods shall be ball ended. The rods shall be heat treated and aged to achieve specified mechanical properties and to retain the same during service. The length of the rods shall be such that the ends fall inside the imaginary square whose sides are vertical and horizontal outer tangents to the conductor sections.

2.6.12 The spacer damper body shall be cast/ forged from suitable high strength corrosion resistant aluminum alloy. The aluminium alloy shall be chosen in relation with the process used.

2.6.13 The rubber components involved in the design such as damping elements shall be made with rubber compound selected specifically for that particular application. The Contractor shall submit a complete list of physical and mechanical properties of the elastomer used. This list shall make reference to all applicable ASTM standards.

2.6.14 The rubber components used shall have good resistance to the effects of temperature up to the designed maximum temperature of the conductor and to ultraviolet radiation, ozone and other atmospheric contaminants. The rubber shall have good wear and fatigue resistance and shall be electrically semi-conductive.

2.6.15 The spacer damper involving ferrous material shall not have magnetic power loss more than 1 watt.

2.6.16 The spacer damper assembly shall have electrical continuity. The electrical resistance between the sub-conductors across the assembly in case of spacer damper involving elastomer surfaced clamps shall be suitably selected by the manufacturer to ensure satisfactory electrical performance and avoid deterioration of elastomer under service conditions.

2.6.17 The spacer damper assembly shall have complete ease of installation and shall be capable of removal/reinstallation without any damage.

2.6.18 The spacer damper assembly shall be capable of being installed and removed from the energized line by means of hot line techniques. The Bidder shall supply with the bid the complete description of the installation, removal and reinstallation procedure.

2.6.19 The Bidder shall recommend the staggering scheme for installation of spacer dampers on the line which shall ensure most satisfactory fatigue performance of the line as specified. The scheme shall indicate the number of spacer dampers per phase per span and the sub span lengths to be maintained between spacer dampers while installing on the bundle conductors.

2.6.20 The staggering scheme shall be provided for spans ranging from 100 m to 1100 m. The number of spacer dampers for a nominal ruling span of 400 m [for 400kV] shall not be less than six.

2.6.21 No sub span shall be greater than 70 m and no end sub span shall be longer than 40 m.

2.6.22 The staggering scheme shall be such that the spacer dampers be unequally distributed along the span to achieve sufficient detuning of adjacent subs pans for oscillations of sub span mode and to ensure bundle stability for wind speeds up to 60 km/hr.

2.6.23 The manufacturer / supplier shall supply free of cost 25 number fixed setting torque wrench (of torque as per spacer damper design) along with 1st batch of supply of spacer dampers for installation of spacer damper on the line by the tower contractors.

2.6.24 The Bidder shall furnish all the relevant technical documents in supports of the staggering scheme recommended for the spacer damper.

2.7 Material and Workmanship

2.7.1 All the equipment shall be of the latest proven design and conform to the best modern practice adopted in the extra high voltage field. The Bidder shall offer only such equipment as guaranteed by him to be satisfactory and suitable for --- kV transmission line application with / without bundle conductors and will give continued good performance at all service conditions. For employer's review of the offered design of accessories, the supplier shall submit document/design details of similar type of accessories used in past for similar type of HTLS conductor application

2.7.2 The design, manufacturing process and quality control of all the materials shall be such as to achieve requisite factor of safety for maximum working load, highest mobility, elimination of sharp edges and corners, best resistance to corrosion and a good finish.

2.7.3 High current, heat rise test shall be conducted by the supplier to determine the maximum temperature achieved in different components of fittings/ accessories under simulated service condition corresponding to continuous operation of conductor at designed maximum temperature. The material of the components should be suitable for continued good performance corresponding to these maximum temperatures. The supplier shall submit relevant type/ performance test certificates as per applicable standards/product specifications to confirm suitability of the offered material.

2.7.4 All ferrous parts shall be hot dip galvanized, after all machining has been completed. Nuts may, however, be tapped (threaded) after galvanizing and the threads oiled. Spring washers shall be electro galvanized as per grade 4 of IS-1573. The bolt threads shall be undercut to take care of increase in diameter due to galvanizing. Galvanizing shall be done in accordance with IS:2629/ IS-1367 (Part-13) and satisfy the tests mentioned in IS-2633. Fasteners shall withstand four dips while spring washers shall withstand three dips. Other galvanized materials shall have a minimum average coating of Zinc equivalent to 600 gm/sq.m and shall be guaranteed to withstand at least six dips each lasting one minute under the standard Preece test for galvanizing unless otherwise specified.

2.7.5 The zinc coating shall be perfectly adherent, of uniform thickness, smooth, reasonably bright, continuous and free from imperfections such as flux, ash, rust stains, bulky white deposits and blisters. The zinc used for galvanizing shall be of grade Zn 99.95 as per IS:209.

2.7.6 In case of castings, the same shall be free from all internal defects like shrinkage, inclusion, blow holes, cracks etc.

2.7.7 All current carrying parts shall be so designed and manufactured that contact resistance is reduced to minimum and localized heating phenomenon is averted.

2.7.8 No equipment shall have sharp ends or edges, abrasions or projections and shall not cause any damage to the conductor in any way during erection or during continuous operation which would produce high electrical and mechanical stresses in normal working. The design of adjacent metal parts and mating surfaces shall be such as to prevent corrosion of the contact surface and to maintain good electrical contact under all service conditions.

2.7.9 Particular care shall be taken during manufacture and subsequent handling to ensure smooth surface free from abrasion or cuts.

2.7.10 The fasteners shall conform to the requirements of IS:6639-1972. All fasteners and clamps shall have corona free locking arrangement to guard against vibration loosening.

2.8 **Compression Markings**

Die compression areas shall be clearly marked on each equipment designed for continuous die compressions and shall bear the words 'COMPRESS FIRST' 'suitably inscribed on each equipment where the compression begins. If the equipment is designed for intermittent die compressions, it shall bear the identification marks 'COMPRESSION ZONE' and 'NON-COMPRESSION ZONE' distinctly with arrow marks showing the direction of compression and knurling marks showing the end of the zones. The letters, number and other markings on finished equipment shall be distinct and legible.

3.0 Tests and Standards

3.1 Type Tests

3.1.1 On Suspension Clamp

a) Magnetic power loss test : As per Appendix-I

b) Clamp slip strength Vs torque test : As per Appendix-I

c) Ozone Test on elastomer : As per Appendix-I

d) Vertical damage load & Failure load test : IEC:61284

3.1.2 On Dead end Tension Assembly

a)	Electrical resistance test for dead end Assembly	: As per IS:2486-(Part-I)
b)	Heating cycle test for dead end Assembly	: As per Appendix-I
c)	Slip strength test for dead end assembly	: As per Appendix-I
d)	Ageing test on filler (if applicable)	: As per Appendix-I

3.1.3 Mid Span Compression Joint for Conductor

a)	Chemical analysis of materials	: As per Appendix-I
b)	Electrical resistance test	:As per IS:2121 (Part-II)
c)	Heating cycle test	: As per Appendix-I
d)	Slip strength test	: As per Appendix-I
e)	Corona extinction voltage test (dry)[for 400kV]	: As per Appendix-I
f)	Radio interference voltage test (dry) [for 400kV]	: As per Appendix-I

3.1.4 Repair Sleeve for Conductor

a)	Chemical analysis of materials	: As per Appendix-I
b)	Corona extinction voltage test (dry) [for 400kV]	: As per Appendix-I
c)	Radio interference voltage test (dry) [for 400kV]	: As per Appendix-I

3.1.5 Vibration Damper for Conductor

a)	Chemical analysis of materials	: As per Appendix-I
b)	Dynamic characteristics test*	: As per Appendix-I
c)	Vibration analysis	: As per Appendix-I
d)	Clamp slip test	: As per Appendix-I

e) Fatigue tests : As per Appendix-I

f) Magnetic power loss test : As per Appendix-I

g) Corona extinction voltage test (dry) [for 400kV] : As per Appendix-I

h) Radio interference voltage test (dry) [for 400kV] : As per Appendix-I

i) Damper efficiency test : As per IS:9708

* Applicable for 4 R Stockbridge dampers. For alternate type of vibration dampers (permitted as per clause 2.4.2), as an alternative to dynamic characteristic test, damper efficiency test as per IEEE-664 may be proposed/ carried out by the supplier.

3.1.6 Bundle Spacer for line

a) Chemical analysis of materials : As per Appendix-I

b) Clamp slip test : As per Appendix-I

c) Vibration Test : As per Appendix-I

(i) Vertical vibration : As per Appendix-I

ii) Longitudinal vibration : As per Appendix-I

iii) Sub-span oscillation : As per Appendix-I

d) Magnetic power loss test (if applicable) : As per Appendix-I

e) Compressive and Tension Test : As per Appendix-I

f) Corona extinction voltage test (dry) [for 400kV] : As per Appendix-I

g) Radio interference voltage test (dry) [for 400kV] : As per Appendix-I

h) Ozone test on elastomer : As per Appendix-I

3.1.7 Rigid spacer for jumper

a) Chemical analysis of materials : As per Appendix-I

b)	Clamp slip test	: As per Appendix-I
c)	Magnetic power loss test (if applicable)	: As per Appendix-I
d)	Tension-compression Test	: As per Appendix-I
e)	Corona extinction voltage test (dry) [for 400kV]	: As per Appendix-I
f)	Radio interference voltage test (dry) [for 400kV]	: As per Appendix-I

3.1.8 Spacer Damper (Alternative to combination of Vibration Damper & Bundle spacer)

a)	Chemical analysis of materials	: As per Appendix-I
b)	Clamp slip test	: As per Appendix-I
c)	Vibration Test	: As per Appendix-I
	(i) Vertical Vibration	: As per IS 10162
	(ii) Longitudinal Vibration	: As per IS 10162
	(iii)Sub-span oscillation	: As per IS 10162
d)	Dynamic characteristics test	: As per Appendix-I
e)	Fatigue tests	: As per Appendix-I
d)	Magnetic power loss test (if applicable)	: As per Appendix-I
e)	Compressive and Tension Test	: As per Appendix-I
f)	Corona extinction voltage test (dry) [for 400kV]	: As per Appendix-I
g)	Radio interference voltage test (dry) [for 400kV]	: As per Appendix-I
h)	Ozone test on elastomer	: As per Appendix-I
k)	Log decrement test	: As per Appendix-I

Type tests specified above shall not be required to be carried out if a valid test certificate is available for a same design, i.e., tests conducted earlier should have been conducted in accredited laboratory (accredited based on ISO/IEC guide 25/17025 or EN 45001 by the National Accreditation body of the country where laboratory is located) or witnessed by the representative (s) of a Utility.

In the event of any discrepancy in the test report (i.e., any test report not applicable due to any design / material/manufacturing process change including substitution of components or due to non-compliance with the requirement stipulated in the Technical Specification) the tests shall be conducted by the Contractor at no extra cost to the Employer/ Employer/ Purchaser.

3.2 **Acceptance Tests**

3.2.1 **On Both Suspension Clamp and Tension Assembly**

a)	Visual Examination	: As per IS:2486-(Part-I)
b)	Verification of dimensions	: As per IS:2486-(Part-I)
c)	Galvanizing/Electroplating test	: As per IS:2486-(Part-I)
d)	Mechanical strength test of each component	: As per Appendix-I
e)	Mechanical Strength test of welded joint	: As per Appendix-I
f)	Chemical analysis, hardness tests, grain size, inclusion rating & magnetic particle inspection for forgings/castings	: As per Appendix-I

3.2.2 **On Suspension Clamp only**

a)	Clamp Slip strength Vs Torque test for suspension clamp	: As per Appendix-I
b)	Shore hardness test of elastomer cushion for AG suspension clamp	: As per Appendix-I
c)	Bend test for armour rod set	: As per IS:2121(Part-I), Clause 7.5,7,10 & 7.11
d)	Resilience test for armour rod set	: As per IS:2121(Part-I), Clause 7.5,7,10 & 7.11
e)	Conductivity test for armour rods set	: As per IS:2121(Part-I),

Clause 7.5,7,10 & 7.11

3.2.3 **On Tension Hardware Fittings only**

a)	Slip strength test for dead end assembly	: As per Appendix-I
d)	Ageing test on filler (if applicable)	: As per Appendix-II

3.2.4 **On Mid Span Compression Joint for Conductor**

a)	Visual examination and dimensional verification	: As per IS:2121 (Part-II), Clause 6.2, 6.3 7 6.7
b)	Galvanizing test	: As per Appendix-II
c)	Hardness test	: As per Appendix-II
d)	Ageing test on filler (if applicable)	: As per Appendix-II

3.2.5 **Repair Sleeve for Conductor**

a)	Visual examination and dimensional verification	: As per IS:2121(Part-II) Clause 6.2, 6.3

3.2.6 **Vibration Damper for Conductor**

a)	Visual examination and dimensional verification	: As per IS:2121(Part-II) Clause 6.2, 6.3 7 6.7
b)	Galvanizing test	: As per Appendix-II
	(i) On damper masses	: As per Appendix-II
	ii) On messenger cable	: As per Appendix-II
c)	Verification of resonance frequencies	: As per Appendix-II
d)	Clamp slip test	: As per Appendix-II
e)	Clamp bolt torque test	: As per Appendix-II
f)	Strength of the messenger cable	: As per Appendix-II
g)	Mass pull off test	: As per Appendix-II
h)	Dynamic characteristics test*	: As per Appendix-II

* Applicable for 4 R Stockbridge dampers. For alternate type of vibration

dampers (permitted as per clause 2.4.2), as an alternative to dynamic characteristic test, damper efficiency test as per IEEE-664 may be proposed/ carried out by the supplier.

3.2.7 **Bundle Spacer for line / Rigid spacer for Jumper for conductor**

a)	Visual examination and dimensional verification	: As per IS:2121(Part-II) Clause 6.2, 6.3 7 6.7
b)	Galvanizing test	: As per Appendix-II
c)	Movement test (except for spacer jumpers)	: As per Appendix-II
d)	Clamp slip test	: As per Appendix-II
e)	Clamp bolt torque test	: As per Appendix-II
f)	Compression-tension test	: As per Appendix-II
g)	Assembly torque test	: As per Appendix-II
h)	Hardness test for elastomer (if applicable)	: As per Appendix-II

3.2.8 **Spacer Damper for Conductor/ Rigid spacer for Jumper**

a)	Visual examination and dimensional verification	: As per IS:2121(Part-II) Clause 6.2, 6.3 7 6.7
b)	Galvanizing test	: As per Appendix-II
c)	Movement test (except for spacer jumpers)	: As per Appendix-II
d)	Clamp slip test	: As per Appendix-II
e)	Clamp bolt torque test	: As per Appendix-II
f)	Compression-tension test	: As per Appendix-II
g)	Assembly torque test	: As per Appendix-II
h)	Hardness test for elastomer (if applicable)	: As per Appendix-II

3.3 **Routine Tests**

3.3.1 **For Hardware Fittings**

a)	Visual examination	IS:2486-(Part-I)
b)	Proof Load Test	: As per Appendix-I

3.3.1 **For conductor accessories**

a)	Visual examination and dimensional verification	: As per IS:2121(Part-II) Clause 6.2, 6.3 7 6.7

3.4 **Tests During Manufacture on all components as applicable**

a)	Chemical analysis of Zinc used for galvanizing	IS:2486-(Part-I)
b)	Chemical analysis mechanical metallographic test and magnetic particle inspection for malleable castings	: As per Appendix-I
c)	Chemical analysis, hardness tests and magnetic particle inspection for forging	: As per Appendix-I

3.5 **Testing Expenses**

3.5.1 Testing charges for the type test specified shall be indicated separately in the prescribed schedule.

3.5.2 Bidder shall indicate charges for all type tests covered under Clause No. 3.1.1 to 3.1.7 separately. The charges for each type test shall be separately indicated.

3.5.6 Bidder shall indicate the laboratories in which they propose to conduct the type tests. They shall ensure that adequate facilities for conducting the tests are available in the laboratory and the tests can be completed in these laboratories within the time schedule guaranteed by them in the appropriate schedule.

3.5.7 The entire cost of testing for acceptance and routine tests and tests during manufacture specified herein shall be treated as included in the quoted Ex-works/CIF Price.

3.5.8 In case of failure in any type test, repeat type tests are required to be conducted, then, all the expenses for deputation of Inspector/ Owner's representative shall be deducted from the contract price. Also if on receipt of the Contractor's notice of testing, the Owner's representative/Inspector does not find material & facilities to be ready for testing the expenses incurred by the Owner's for re-deputation shall be deducted from contract price.

3.5.9 The Contractor shall intimate the Owner about carrying out of the type tests along with detailed testing program at least 3 weeks in advance (in case of testing in India and at least 6 weeks advance in case of testing abroad) of the scheduled date of testing during which the Owner will arrange to depute his representative to be present at the time of carrying out the tests.

3.6 **Sample Batch For Type Testing**

3.6.1 The Contractor shall offer material for sample selection for type testing only after getting Quality Assurance Programme approved by the Owner. The Contractor shall offer at least three times the quantity of materials required for conducting all the type tests for sample selection. The sample for type testing will be manufactured strictly in accordance with the Quality Assurance Programme approved by the Owner.

3.6.2 Before sample selection for type testing the Contractor shall be required to conduct all the acceptance tests successfully in presence of Owner's representative.

3.7 **Schedule of Testing and Additional Tests**

3.7.1 The Bidder has to indicate the schedule of following activities in their bids

(a) Submission of drawing for approval.

(b) Submission of Quality Assurance programme for approval.

(c) Offering of material for sample selection for type tests.

(d) Type testing.

3.7.2 The Owner reserves the right of having at his own expense any other test(s) of reasonable nature carried out at Contractor's premises, at site, or in any other place in addition to the aforesaid type, acceptance and routine tests to satisfy himself that the material comply with the specifications.

3.7.3 The Owner also reserves the right to conduct all the tests mentioned in this specification at his own expense on the samples drawn from the site at Contractor's premises or at any other test centre. In case of evidence of non-compliance, it shall be binding on the part of Contractor to prove the compliance of the items to the technical specifications by repeat tests, or correction of deficiencies, or replacement of defective items, all without any extra cost to the Owner.

3.8 **Test Reports**

3.8.1 Copies of type test reports shall be furnished in at least six copies along with one original. One copy shall be returned duly certified by the Owner , only after which the commercial production of the concerned material shall start.

3.8.2 Copies of acceptance test report shall be furnished in at least six copies. One copy shall be returned, duly certified by the Owner, only after which the materials will be dispatched.

3.8.3 Record of routine test report shall be maintained by the Contractor at his works for periodic inspection by the Owner's representative.

3.8.4 Test certificates of tests during manufacture shall be maintained by the Contractor. These shall be produced for verification as and when desired by the Owner.

3.9 **Inspection**

3.9.1 The Owner's representative shall at all times be entitled to have access to the works and all places of manufacture, where the material and/or its component parts shall be manufactured and the representatives shall have full facilities for unrestricted inspection of the Contractor's, sub-Contractor's works raw materials. manufacturers of all the material and for conducting necessary tests as detailed herein.

3.9.2 The material for final inspection shall be offered by the Contractor only under packed condition as detailed in clause 4.11 of this part of the Specification. The engineer shall select samples at random from the packed lot for carrying out acceptance tests.

3.9.3 The Contractor shall keep the Owner informed in advance of the time of starting and of the progress of manufacture of material in its various stages so that arrangements could be made for inspection.

3.9.4 Material shall not be dispatched from its point of manufacture before it has been satisfactorily inspected and tested unless the inspection is waived off by the Owner in writing. In the latter case also the material shall be dispatched only after all tests specified herein have been satisfactorily completed.

3.9.5 The acceptance of any quantity of material shall in no way relieve the Contractor of his responsibility for meeting all the requirements of the Specification, and shall not prevent subsequent rejection, if such material are later found to be defective.

3.10 **Packing and Marking**

3.10.1 All material shall be packed in strong and weather resistant wooden cases/crates. The gross weight of the packing shall not normally exceed 200 Kg to avoid handling problems.

3.10.2 The packing shall be of sufficient strength to withstand rough handling during transit, storage at site and subsequent handling in the field.

3.10.3 Suitable cushioning, protective padding, dunnage or spacers shall be provided to prevent damage or deformation during transit and handling.

3.10.4 Bolts, nuts, washers, cotter pins, security clips and split pins etc. shall be packed duly installed and assembled with the respective parts and suitable measures shall be used to prevent their loss.

3.10.5 Each component part shall be legibly and indelibly marked with trade mark of the manufacturer and year of manufacture.

3.10.6 All the packing cases shall be marked legibly and correctly so as to ensure safe arrival at their destination and to avoid the possibility of goods being lost or wrongly dispatched on account of faulty packing and faulty or illegible markings. Each wooden case/crate shall have all the markings stenciled on it in indelible ink.

3.11 **Standards**

3.11.1 The Hardware fittings; conductor and earthwire accessories shall conform to the following Indian/International Standards which shall mean latest revisions, with amendments/changes adopted and published, unless specifically stated otherwise in the Specification.

3.11.2 In the event of the supply of hardware fittings; conductor and earthwire accessories conforming to standards other than specified, the Bidder shall confirm in his bid that these standards are equivalent to those specified. In case of award, salient features of comparison between the Standards proposed by the Contractor and those specified in this document will be provided by the Contractor to establish their equivalence.

Sl. No.	Indian Standard	Title	International Standard
1.	IS: 209-1992	Specification for zinc	BS:3436-1986
2.	IS:398	Aluminum Conductor Galvanized Steel- Reinforced For Extra High Voltage	IEC:1089-1991 BS:215-1970
3.	IS 1573	Electroplated Coating of Zinc on iron and Steel	
4.	IS : 2121 (Part-II)	Specification for Conductor and Earthwire Accessories for Overhead Power lines: Mid-span Joints and Repair Sleeves for Conductors	
5.	IS:2486 (Part-I)	Specification for Insulator Fittings for Overhead power Lines with Nominal Voltage greater than 1000 V: General Requirements and Tests	
6.	IS:2629	Recommended Practice for Hot Dip Galvanizing of Iron and Steel	
7.	IS:2633	Method of Testing Uniformity of Coating on Zinc Coated Articles	
8.		Ozone test on Elastomer	ASTM- D1 171
9.		Tests on insulators of Ceramic material or glass for overhead lines with a nominal voltage greater than 1000V	IEC:383-1993
10.	IS:4826	Galvanized Coating on Round Steel Wires	ASTM A472-729 BS:443-1969
11.	IS:6745	Methods of Determination of Weight of Zinc Coating of Zinc Coated Iron and Steel Articles	BS:433 ISO : 1460 (E)

12.	IS:8263	Method of Radio Interference Tests on High Voltage Insulators	IEC:437 NEMA:107 CISPR
13.	IS:6639	Hexagonal Bolts for Steel Structures	ISO/R-272
14.	IS:9708	Specification for Stock Bridge Vibration Dampers for Overhead Power Lines	
15.	IS:10162	Specification for Spacers Dampers for Twin Horizontal Bundle Conductors	

Appendix - I

1.0 Tests on Hardware Fittings

1.1 Magnetic Power Loss Test for Suspension Assembly

Two hollow aluminium tubes of 32 mm diameter for the conductor shall be placed 450 mm (for 400kV) apart. An alternating current over the range of 1200 to 1800 amps shall be passed through each tube. One hollow aluminium tubes of 29mm diameter for the conductor shall be used for 132kV. An alternating current over the range of 300 - 700 amps shall be passed through the tube. The reading of the wattmeter with and without suspension assemblies along with line side yoke plate, clevis eye shall be recorded. Not less than three suspension assemblies shall be tested. The average power loss for suspension assembly shall be plotted for each value of current. The value of the loss corresponding to ---A (at steady state conductor temperature) shall be read off from the graph and the same shall be limited to the value guaranteed by the supplier.

1.2 Galvanizing/Electroplating Test

The test shall be carried out as per Clause no. 5.9 of IS: 2486-(Part-1) except that both uniformity of zinc coating and standard preecee test shall be carried out and the results obtained shall satisfy the requirements of this specification.

1.3 Mechanical Strength Test of Each Component

Each component shall be subjected to a load equal to the specified minimum ultimate tensile strength (UTS) which shall be increased at a steady rate to 67% of the minimum UTS specified. The load shall be held for five minutes and then removed. The component shall then again be loaded to 50% of UTS and the load shall be further increased at a steady rate till the specified UTS and held for one minute. No fracture should occur. The applied load shall then be increased until the failing load is reached and the value recorded.

1.4 Mechanical Strength Test of Welded Joint

The welded portion of the component shall be subjected to a Load of 2000 kgs for one minute. Thereafter, it shall be subjected to die-penetration/ ultrasonic test. There shall not be any crack at the welded portion.

1.5 Clamp Slip Strength Vs Torque Test for Suspension Clamp

The suspension assembly shall be vertically suspended by means of a flexible attachment. A suitable length of conductor shall be fixed in the clamp. The clamp slip strength at various tightening torques shall be obtained by gradually applying the load at one end of the conductor. The Clamp slip strength vs torque curve shall be drawn. The above procedure is applicable only for free center type suspension clamp. For AG suspension clamp only clamp slip strength after assembly shall be found out. The clamp slip strength at the recommended tightening torque shall be as indicated in the GTP. [e.g. for 400kV: more than 20 kN but less than 29 kN.]

1.6 Heating Cycle Test

Heating cycle test shall be performed in accordance with IS 2486 (Part-I) with following modifications:

i) Temperature of conductor during each cycle: 40 deg. C above designed maximum operating temperature of the conductor, but not exceeding the emergency temperature of the conductor.

ii) Number of cycle: 100

iii) Slip strength test shall also be carried out after heating cycle test.

1.7 Slip strength test for dead end assembly

The test shall be carried out as per IS:2486 (Part-I) except that the load shall be steadily increased to 95% of minimum ultimate tensile strength of conductor/earthwire and retained for one minute at this load.

1.8 Ageing Test on Filler (if applicable)

The test shall be done in accordance with Grease drop point test method. The specimen should be drop as a droplet when kept at a temperature 40 deg. C above designed maximum operating temperature of the conductor for 30 minutes. The temperature shall then be increase till one droplet drops and the temperature recorded.

1.9 Shore Hardness Test for Elastomer Cushion for AG Suspension Assembly

The shore hardness at various points on the surface of the elastomer cushion shall be measured by a shore hardness meter and the shore hardness number shall be between 65 to 80.

1.10 Proof Load Test

Each component shall be subjected to a load equal to 50% of the specified minimum ultimate tensile strength which shall be increased at a steady rate to 67% of the UTS specified. The load shall be held for one minute and then removed. After removal of the load the component shall not show any visual deformation.

1.11 Tests for Forging Casting and Fabricated Hardware

The chemical analysis, hardness test, grain size, inclusion rating and magnetic particle inspection for forging, castings and chemical analysis and proof load test for fabricated hardware shall be as per the internationally recognized procedures for these tests. The sampling will be based on heat number and heat treatment batch. The details regarding test will be as in the Quality Assurance programme.

1.12 Ozone Test for Elastomer

This test shall be performed in accordance with ASTM D-1171 by the Ozone chamber exposure method (method B). The test duration shall be 500 hours and the ozone concentration 50 PPHM. At the test completion, there shall be no visible crack under a 2 x magnification.

2.0 Tests on Accessories for Conductor

2.1 Mid Span Compression Joint for Conductor

(a) Slip Strength Test

The fitting compressed on conductor shall not be less than one metre in length. The test shall be carried out as per IS:2121 (Part-ii)-1981 clause 6-4 except that the load shall be steadily increased to 95% of minimum ultimate tensile strength of conductor/earthwire and retained for one minute at this load. There shall be no movement of the conductor/ earthwire relative to the fittings and no failure of the fit tings during this one minute period.

(b) Heating Cycle Test

Heating cycle test shall be performed in accordance with IS 2121 (Part-II-1981) with following modifications:-

i) Temperature of conductor during each cycle: 40 deg. C above designed maximum operating temperature of the conductor.

ii) Number of cycle: 100

iii) Slip strength test shall also be carried out after heating cycle test.

2.2 Vibration Damper for Conductor

(a) Dynamic Characteristics Test

The damper shall be mounted with its clamp tightened with torque recommended by the manufacturer on shaker table capable of simulating sinusoidal vibrations for Aeolian vibration frequency band ranging from 0.18/d to 1.4/d where d is the conductor diameter in meters. The damper assembly shall be vibrated vertically with a $\pm$ 1 mm amplitude from 5 to 15 Hz frequency and beyond 15 Hz at ± 0.5mm to determine following characteristics with the help of suitable recording instruments:

(i) Force Vs frequency
(ii) Phase angle Vs frequency
(iii) Power dissipation Vs frequency

The Force Vs frequency curve shall not show steep peaks at resonance frequencies and deep troughs between the resonance frequencies. The resonance frequencies shall be suitably spread within the Aeolian vibration frequency-band between the lower and upper dangerous frequency, limits determined by the vibration analysis of conductor without dampers.

Acceptance criteria for vibration damper:

(i) The above dynamic characteristics test on five damper shall be conducted.
(ii) The mean reactance and phase angle Vs frequency curves shall be drawn with the criteria of best fit method.
(iii) The above mean reactance response curve should lie within 0.191 f to 0.762 f Kgf/mm limits where f is frequency in Hz.
(iv) The above mean phase angle response curve shall be between 25o to 130o within the frequency range of interest.
(v) If the above curve lies within the envelope, the damper design shall be considered to have successfully met the requirement.
(vi) Visual resonance frequencies of each mass of damper is to be recorded and to be compared with the guaranteed values.

(b) Vibration Analysis

The vibration analysis of the conductor shall be done with and without damper installed on the span. The vibration analysis shall be done on a digital computer using energy balance approach. The following parameters shall be taken into account for the purpose of analysis:

(i) The analysis shall be done for single conductor without armour rods as per the parameters given under clause 2.5.13 and 3.3.8 of this part of the Specification. The tension shall be taken from Sag & Tension calculation (0 deg. C & no wind condition and -----m ruling span) for a span ranging from 100 m to 1100.

(ii) The self-damping factor and flexural stiffness (El) for conductor shall be calculated on the basis of experimental results. The details for experimental analysis with these data should be furnished.

(iii) The power dissipation curve obtained from Dynamic Characteristics Test shall be used for analysis with damper.

(iv) Examine the aeolian vibration level of the conductor with and without vibration damper installed at the recommended location or wind velocity ranging from 0 to 30 Km per hour, predicting amplitude, frequency and vibration energy input.

(v) From vibration analysis of conductor without damper, anti-node vibration amplitude and dynamic strain levels at clamped span extremities as well as antinodes shall be examined and thus lower and upper dangerous frequency limits between which the Aeolian vibration levels exceed the specified limits shall be determined.

(vi) From vibration analysis of conductor with damper/dampers installed at the recommended location, the dynamic strain level, at the clamped span extremities, damper attachment point and the antinodes on the conductor shall be determined. In addition to above damper clamp vibration amplitude and anti-node vibration amplitudes shall also be examined.

The dynamic strain levels at damper attachment points, clamped span extremities and antinodes shall not exceed the specified limits. The damper clamp vibration amplitude shall not be more than that of the specified fatigue limits.

(c) Clamp Slip and Fatigue Tests

(i) Test Set Up

The clamp slip and fatigue tests shall be conducted on a laboratory set up with a minimum effective span length of 30 m. The conductor shall be tensioned at tension corresponding to minimum temperature & no wind condition and ruling span ----m from sag –tension calculation and shall not be equipped with protective armour rods at any point. Constant tension shall be maintained within the span by means of lever arm arrangement. After the conductor has been tensioned, clamps shall be installed to support the conductor at both ends and thus influence of connecting hardware fittings are eliminated from the free span. The clamps shall not be used for holding the tension on the conductor. There shall be no loose parts, such as suspension clamps, U bolts on the test span supported between clamps mentioned above. The span shall be equipped with vibration inducing equipment suitable for producing steady standing vibration. The inducing equipment shall have facilities for stepless speed control as well as stepless amplitude arrangement. Equipment shall be available for measuring the frequency, cumulative number of cycles and amplitude of vibration at any point along the span.

(ii) Clamp Slip test

The vibration damper shall be installed on the test span. The damper clamp, after tightening with the manufacturer's specified tightening torque, when subjected to a longitudinal pull of 2.5 kN parallel to the axis of conductor for a minimum duration of one minute shall not slip i.e. the permanent displacement between conductor and clamp measured after removal of the load shall not exceed 1.0 mm. The load shall be further increased till the clamp starts slipping. The load at which the clamp slips shall not be more than 5 kN.

(iii) Fatigue Test

The vibration damper shall be installed on the test span with the manufacturer's specified tightening torque. It shall be ensured that the damper shall be kept minimum three loops away from the shaker to eliminate stray signals influencing damper movement.

The damper shall then be vibrated at the highest resonant frequency of each damper mass. For dampers involving resonant frequencies, tests shall be done at torsional modes also in addition to the highest resonant frequencies at vertical modes. The resonance frequency shall be identified as the frequency at which each damper mass vibrates with the maximum amplitude on itself. The amplitude of vibration of the damper clamp shall be maintained not less than ± 25/f mm, where f is the frequency in Hz.

The test shall be conducted for minimum ten million cycles at each resonant frequency mentioned above. During the, test if resonance shift is observed the test frequency shall be tuned to the new resonant frequency.

The clamp slip test as mentioned hereinabove shall be repeated after fatigue test without re-torquing or adjusting the damper clamp, and the clamp shall withstand a minimum load equal to 80% of the slip strength for a minimum duration of one minute.

After the above tests, the damper shall be removed from conductor and subjected to dynamic characteristics test. There shall not be any major deterioration in the characteristic of the damper. The damper then shall be cut open and inspected. There shall not be any broken, loose, or damaged part. There shall not be significant deterioration or wear of the damper. The conductor under clamp shall also be free from any damage.

For the purpose of acceptance, the following criteria shall be applied.

I. There shall not be any frequency shift by more than $\pm$2 Hz for frequencies lower than 15 Hz and ± 3 Hz for frequencies higher than 15 Hz.
II. The force response curve shall generally lie within guar anteed % variation in reactance after fatigue test in comparison with that before fatigue test by the Contractor.
III. The power dissipation of the damper shall not be less than guaranteed % variation in power dissipation before fatigue test by the Contractor. However, it shall not be less than minimum power dissipation which shall be governed by lower limits of reactance and phase angle indicated in the envelope.

2.3 Spacer/ Spacer Damper

(a) Vibration Tests

The test set up shall be as per Clause No. 2.2(c) (i) of Appendix-I. The spacer/spacer damper assembly shall be clamped to conductor. During the vibration tests the axis of the clamp of sample shall be maintained parallel to its initial static position by applying a tension (Tension form sag-tension calculation at minimum temperature & no wind condition and 400 m ruling span). The spacer/spacer damper assembly shall be free to vibrate and shall not be re-torqued or adjusted between the tests.

All the vibration tests mentioned hereunder shall be conducted on the same sample on the same test span. The samples shall withstand the vibration tests without slipping on the conductor. loosening, damage or failure of component parts. After each vibration test, clamp slip test shall be carried out as per the procedure given in Clause No *2*.4 (b) below:

(a) Longitudinal Vibration Test

The stationary conductor and the vibrating conductor/equivalent diameter of aluminium alloy tube shall be restrained by fixed clamps. The displacement of the vibrating conductor shall be 25 mm minimum on either side. The longitudinal movement shall be parallel to the conductor at frequency not less than 2 Hz for minimum one million cycles.

(b) Vertical Vibration Test

The spacer/spacer damper shall be installed in the middle of the test span and the frequency chosen so as to get an odd number of loops. The shaker shall be positioned at least two loops away from the test specimen to allow free movement of the conductor close to the test specimen. One conductor shall be connected to the shaker and vibrated to an amplitude such that

$f^{1.8}$ Ymax > 1000 mm/sec.

Where Ymax being the antinode displacement (mm) and f is the test frequency (Hz). The test frequency shall be greater than 24 Hz and the total number of cycles shall be more than 10 million.

(c) Sub-span Oscillation Test

The test shall be conducted for oscillation in horizontal plane at frequency higher than 3 Hz for minimum one million cycles. The amplitude for oscillation shall be kept equivalent to an amplitude of 150 mm for a full sub-span of 80m. Both the conductor shall be vibrated 180 deg. out of phase with the above minimum amplitude.

(b) Clamp Slip Test

The spacer assembly shall be installed on test span of twin conductor bundle string at a tension of tension at 0 deg. C & No wind. In case of spacer for jumper, the. clamp of sample shall be tightened with a specified tightening torque. One of the sample clamps, when subjected to a longitudinal pull parallel to the conductor axis for a minimum duration of one minute, shall not slip on the conductor i.e. the permanent displacement between the conductor and the clamp of the sample measured after removal of the load shall not exceed specified values. The minimum slip under longitudinal pull varies with clamp type according to the following table:

Clamp Type	**Longitudinal Load (kN)**	**Maximum Slip (mm)**
Metal-Metal bolted	6.5	1
Rubber loaded	2.5	2.5
Clamp using Preformed rods	2.5	12

(c) Compressive and tensile test

This test shall be conducted on 3 (three) nos samples The spacer assembly shall withstand ultimate compressive load of 14 kN and tensile load of 7.0 kN applied between sub-conductor bundle and held for one minute without failure. Line distance between clamps shall be recorded during each of the compression and tension test. Measurement shall be recorded at (i) no load (ii) with load (iii) after release of load. The center line distance under load shall be within ± 100 mm of the nominal design spacing. After release of load it shall be possible to retain the clamps at their original position using only slight hand pressure. There shall be no deformation or damage to the spacer assembly which would impair its function of maintaining the normal spacing.

(d) Dynamic Characteristic Test (for Spacer Damper only)

The purpose of this test is to obtain quantitative information regarding the dynamic characteristics of the spacer damper. The values obtained during this test will serve as references to evaluate the behavior of the same spacer damper under the fatigue test.

The test will consist in the application of sinusoidal movement of the spacer-damper articulation and measuring the force (F), displacement (X) and phase angle (Ø) between these two, from these values, the stiffness (K) and the damping factor (n) will be calculated.

$$K = \frac{F}{X} \cos Ø; \; n = \tan Ø$$

The test frequency shall not be higher than 3 Hz. The test shall be performed at five different displacement amplitudes. The amplitudes shall be selected to reproduce 10, 20, 40, 60 and 90 percent of the maximum displacement permitted by the spacer-damper design.

The test shall be performed on three samples.

(e) Fatigue Test (for Spacer Damper only)

The purpose of this test is to evaluate the capacity of the spacer damper to sustain without damage the cyclic movements which can be induced by vibrations.

The spacer damper articulation shall be subjected to cyclic motions for a total of 10 million cycles. The test frequency shall be between 2 and 3 Hz. The amplitude of motion shall be established on the following basis :

I. the load applied on the spacer damper clamp shall not be less than ± 300 N.
II. the clamp displacement under the applied load shall not be less than 60% of the maximum displacement permitted by the design.
III. if the 300 N load generates movement exceeding the maximum permitted displacement, the load can be reduced to limit the movement to 95% of the maximum displacement.
IV. After the test, the sample shall be subjected to a second dynamic characteristic test. This test shall be performed at two amplitudes, 10% and 60% of the maximum displacement.
V. The spacer damper shall show no signs of cracks or deterioration, loosening of bolts or abnormal wear.

The dynamic characteristics (k and n) shall not be less than 60% of the values measured before the fatigue test. The test shall be performed on three samples.

(f) Ozone Test

The test shall be performed in accordance with ASTM D-1171 by the ozone chamber exposure method (method B). The test duration shall be 500 hours and the ozone concentration 50 PPHM. At the test completion, there shall be no visible crack under a 2xmagnification.

(g) Log Decrement test (for spacer damper only)

The spacer damper assembly shall be mounted on test span of conductor bundle at a tension of 0 deg. C and no wind and ruling span of 400 m. The test span shall be instrumented to continuously monitor and record the horizontal motion of the sub-conductor in the sub-span between suspension point and the fist sample.

The log decrement test shall be made with an initial peak to peak amplitude of four to six times the conductor diameter in the middle of the sub-span being considered. The conductor shall be excited in a horizontal one loop per sub-span resonant mode with a slow and steady buildup of amplitude that minimizes harmonics and other distortions. After achieving a steady state motion, the conductor excitation shall be discontinued leaving the conductor undisturbed. The motion shall be recorded until it reduces to an amplitude of half of the conductor diameter. The logarithmic (log) decrement shall be the value for a minimum reduction of 80 % in amplitude. The minimum acceptable log decrement average for five or more excitation shall be 0.04 based upon the following formula for decay.

$$\text{Log}_e \frac{A_n}{A_{n+1}} = \frac{1}{n} \text{Log}_e \frac{A_0}{A}$$

Where A0 is the initial amplitude and An is the amplitude ‘n’ cycles later

2.4 Magnetic Power Loss Test for Spacer

The sample involving ferrous parts shall be tested in a manner to simulate service conditions for 50 Hz pure sine-wave. The test should be carried out at various currents ranging from 1200 to 1800 amperes per sub-conductor (for 400kV) the magnetic power loss at various currents should be specified in tabulated graphical form. The difference between the power losses without and with sample at room temperature shall be limited to value guaranteed by the supplier for --- Amperes current (rms) [at steady state conductor temperature]. The losses shall be determined by averaging the observations obtained from at least four samples.

2.5 Corona Extinction Voltage Test (Dry) [for 400kV]

The sample when subjected to power frequency voltage shall have a corona extinction voltage of not less than 320 kV rms line to ground under dry condition. There shall be no evidence of corona on any part of the sample. The atmospheric condition during testing shall be recorded and the test results shall be accordingly corrected with suitable correction factor as stipulated in IS:731- 1971.

2.6 Radio Interference Voltage Test (Dry) [for 400kV]

Under the conditions as specified under (3.8) above, the sample shall have a radio interference voltage level below 1000 microvolts at one MHz when subjected to 50 Hz AC voltage of 305 kV rms line to ground under dry condition. The test procedure shall be in accordance with IS:8263.

2.7 Chemical Analysis Test

Chemical analysis of the material used for manufacture of items shall be conducted to check the conformity of the same with Technical Specification and approved drawing.

3.0 Tests on All components (As applicable)

3.1 Chemical Analysis of Zinc used for Galvanizing

Samples taken from the zinc ingot shall be chemically analyzed as per IS-209-1979. The purity of zinc shall not be less than 99.95%.

3.2 Tests for Forgings

The chemical analysis hardness tests and magnetic particle inspection for forgings, will be as per the internationally recognized procedures for these tests. The, sampling will be based on heat number and heat treatment batch. The details regarding test will be as discussed and mutually agreed to by the Contractor and Owner in Quality Assurance Programme.

3.3 Tests on Castings

The chemical analysis, mechanical and metallographic tests and magnetic particle inspection for castings will be as per the internationally recognized procedures for these tests. The samplings will be based on heat number and heat treatment batch. The details regarding test will be as discussed and mutually agreed to by the Contractor and Owner in Quality Assurance Programme.

Appendix-II

Acceptance Tests

1. Mid Span Compression Joint for Conductor

(a) Hardness Test

The Brinnel hardness at various points on the steel sleeve of conductor core and tension clamp shall be measured.

2. Vibration Damper for Conductor

(a) Verification of Resonance Frequencies

The damper shall be mounted on a shaker table and vibrate at damper clamp displacement of +/-0.5 mm to determine the resonance frequencies. The resonance shall be visually identified as the frequency at which damper mass vibrates with maximum displacement on itself. The resonance frequency thus identified shall be compared with the guaranteed value. A tolerance of ± 1 Hz at a frequency lower than 15 Hz and ± 2 Hz at a frequency higher than 15 Hz only shall be allowed.

(b) Clamp Slip Test

Same as Clause 2.2 (c) (ii) of Appendix-I.

(c) Clamp Bolt Torque Test

The clamp shall be attached to a section of the conductor/earthwire. A torque of 150 percent of the manufacturer's specified torque shall be applied to the bolt. There shall be no failure of component parts. The test set up is as described in Clause 2.2 (c) (i), Appendix-I.

(d) Strength of the Messenger Cable

The messenger cable shall be fixed in a suitable tensile testing machine and the tensile load shall be gradually applied until yield point is reached. Alternatively, each strand of messenger cable may be fixed in a suitable tensile testing machine and the tensile load shall be gradually applied until yield point is reached. In such a case, the 95% of yield strength of each wire shall be added to get the total strength of the cable. The load shall be not less than the value guaranteed by the Contractor.

(e) Mass Pull off Test

Each mass shall be pulled off in turn by fixing the mass in one jaw and the clamp in the other of a suitable tensile testing machine. The longitudinal pull shall be applied gradually until the mass begins to pull out of the messenger cable. The pull off loads shall not be less than the value guaranteed by the Contractor.

(f) Dynamic Characteristics Test

The test will be performed as acceptance test with the procedure mentioned for type test with sampling mentioned below:

Vibration Damper :

- 1 Sample for lot of 1000 Nos. & below
- 3 Samples for lot above 1000 & up to 5000 nos.
- Additional 1 sample for every additional 1500 pieces above 5000.

The acceptance criteria will be as follows:

(i) The above dynamic characteristics curve for reactance & phase angle will be done for frequency range of 5 Hz to 40 Hz.
(ii) If all the individual curve for dampers are within the envelope as already mentioned for type test for reactance & phase angle, the lot passes the test.
(iii) If individual results do not fall within the envelope, averaging of characteristics shall be done.
(iv) Force of each damper corresponding to particular frequency shall be taken & average force of three dampers at the frequency calculated.
(v) Similar averaging shall be done for phase angle.
(vi) Average force Vs frequency and average phase Vs frequency curves shall be plotted on graph paper. Curves of best fit shall be drawn for the entire frequency range.
(vii) The above curves shall be within the envelope specified.

3. Spacer/ Spacer Damper

(a) Test Set up

The test set up for the test described hereunder shall be as per clause 2.3 (a) of Appendix-I.

(b) Movement Test

The spacer assembly shall be capable of the following movements without damaging the conductor, assuming one conductor is fixed and the other moving:

(i)	Longitudinal movement parallel to the conductor	± 50 mm
(ii)	Vertical movement in a vertical direction at right angle to the conductor	± 25 mm
(iii)	Torsional movement/angular movement in a vertical plane parallel to the conductor	± 5 deg.

(c) Compressive and Tensile Test

The spacer assembly shall withstand ultimate compressive load of 14 kN and tensile load of 7.0 kN applied between sub-conductor bundle and held for one minute without failure. Line distance between clamps shall be recorded during each of the compression and tension test. Measurement shall be recorded at (i) no load (ii) with load (iii) after release of load. The center line distance under load shall be within ± 100 mm of the nominal design spacing. After release of load it shall be possible to retain the clamps at their original position using only slight hand pressure. There shall be no deformation or damage to the spacer assembly which would in pair its function of maintaining the normal spacing.

(d) Clamp Slip Test

Same as clause 2.3(b) of Appendix-I.

(e) Clamp Bolt Torque Test

The spacer assembly shall be attached to conductor. A torque of 150 per cent of the manufacturer's specified tightening torque shall be applied to the clamp bolts or cap screws. There shall be no failure of the component parts.

(f) Assembly Torque Test

The spacer assembly shall be installed on conductor. The same shall not rotate on either clamp on applying a torque of 0.04 kN in clockwise or anti-clockwise direction.

(g) Hardness test for Elastomer

The shore hardness at different points on the elastomer surface of cushion grip clamp shall be measured by shore hardness meter. They shall lie between 65 to 80.

(h) UTS of Retaining Rods

The ultimate tensile strength of the retaining rods shall be measured. The value shall not be less than 35 kg/sq.mm.

(i) Ageing Test on filler (if applicable)

Same as clause 1.8 of Appendix-I.

ANNEXURE-IV

GUARANTEED TECHNICAL PARTICULARS/ TECHNICAL DATA SHEET

(TO BE FILLED BY BIDDER)

Annexure-IV

GUARANTEED TECHNICAL PARTICULARS OF HTLS CONDUCTOR

Sl.	**Description**	**Unit**	**Value guaranteed by the Bidder**
1.	Name & address of Manufacturer		
2.	Construction of conductor/ Designation of conductor as per IEC:1089		
3.1	**PARTICULARS OF RAW MATERIALS**		
3.1	Outer Layers a) Applicable Standard(if any) b) Type of Aluminum alloy c) Minimum purity of aluminum d) Maximum Copper content e) Zirconium content i) Maximum ii) Minimum f) Other elements---------- i) ---------- ii) ----------	 % % % % % %	
3.2	Inner Core a) Applicable Standard(if any) b) Material of core c) Chemical composition of core i) ---------- ii) ----------	 % %	
3.3	Zinc used for galvanization of inner core (if applicable) a) Minimum purity of zinc	 %	
3.4	Chemical Composition of Misch Metal coating on core wires (if applicable) i) Zinc ii) Aluminium iii) Other elements----------	 % % %	

3.5	Aluminium used for Aluminium Cladding (if applicable) a) Minimum purity of aluminum b) Maximum Copper content c) Other elements---------- i) ---------- ii)………..	 % % % %	
4.	**STRANDS OF OUTER CONDUCTING PART (AFTER STRANDING)**		
4.1	Number of outer layers	Nos.	
4.2	Number of strands a) 1st Layer from core b) 2nd Layer from core c) 3rd Layer from core …………………… ………………………..	 Nos. Nos. Nos. ……. ……..	
4.2	Diameter of strands a) Nominal b) Maximum c) Minimum	 mm mm mm	
4.3	Minimum Breaking load of strand a) Before stranding b) After stranding	 kN kN	
4.4	Resistance of 1m length of strand at 20 deg. C	Ohm	
4.5	Final Modulus of elasticity	Kg/sq. mm	
4.6	Final Coefficient of linear expansion	Per ^{0} C	
5	**INNER CORE STRANDS/ INNER CORE (AFTER STRANDING)**		
5.1	Number of layers in inner core (excluding central wire)		
5.2	Number of strands a) 1st Layer from centre (excluding central wire) b) 2nd Layer from centre c) 3rd Layer from centre …………………… ………………………..	 Nos. Nos. Nos. ……. ……..	
5.3	Diameter a) Nominal	 mm	

	b) Maximum c) Minimum	mm mm	
5.3	Minimum Breaking load of strand/Core a) Before stranding b) After stranding	 kN kN	
5.4	Resistance of 1m length of strand at 20 deg. C	Ohm	
5.5	Final Modulus of elasticity	Kg/sq. mm	
5.6	Final coefficient of linear expansion	Per ^{0} C	
5.7	**Aluminum cladding of INVAR core (if applicable)**		
	a) Thickness of cladding		
	i) Maximum	mm	
	ii) Minimum	mm	
	b)Minimum no. of twists in a gauge length equal to 100 times diameter of wire which the strands can withstand in the torsion test		
	a) Before stranding	Nos.	
	b) After stranding	Nos.	
	c) Minimum elongation of strand for a gauge length of 250 mm	%	
	d) Resistance of 1m length of strand at 20 deg. C	Ohm	
5.8	**Galvanizing/ Misch Metal coating (if applicable)**		
	a) Minimum mass of zinc coating per sqm. of uncoated wire surface.	gm	
	b) Minimum mass of Misch metal coating per sqm. of uncoated wire surface (if applicable).	Nos.	
	c) Min. no. of twists which a single strand shall withstand during torsion test for a length equal to 100times dia of wire after stranding.	Nos.	
	d) Minimum elongation of strand for a gauge length of 250 mm	%	
6	**FILLER (if applicable)**		
6.1	Type & Designation of Filler		
6.2	Chemical composition of Filler		

6.3	Mass of Filler	Kg/km		
7	**COMPLETE HTLS CONDUCTOR**			
7.1	Cross section drawing of the offered conductor enclosed	Yes/No		
7.2	Diameter of conductor a) Nominal b) Maximum c) Minimum	 mm mm mm		
7.3	UTS (minimum) of Conductor	kN		
7.4	Lay ratio of conductor a) 1st layer from centre (excluding central wire) b) 2nd Layer c) 3rd Layer d)4th Layer		Maximum	Minimum
7.5	DC resistance of conductor at 20°C	Ohm/km		
7.6	Final Modulus of elasticity			
	a) Upto transition temperature	Kg/sq. mm		
	b) Above transition temperature	Kg/sq. mm		
7.7	Coefficient of linear expansion			
	a) Upto transition temperature	Per deg C		
	b) Above transition temperature	Per deg C		
7.8	Calculation for transition temperature enclosed	Yes/No		
7.9	Transition temperature (corresponding to ---m ruling span and tension at ruling condition as per 7.19)	Deg C		
7.10	Minimum Corona Extinction Voltage (line to ground) under Dry condition [for 400kV lines]	kV(rms)		
7.11	RIV at 1MHz and 305 kV (rms) under dry conditions [for 400kV lines]	Micro-volts		
7.12	Maximum permissible conductor temperature for continuous operation	Deg C		
7.13	Maximum permissible conductor temperature for short term operation	Deg C		

7.14	Permissible duration of above short term operation	Minutes	
7.15	Steady state conductor temperature at specified conductor current of -----A and under Ambient conditions detailed in Clause 1.2.1 of Section-IV of the Technical Specification for HTLS conductor		
7.16	AC resistance at maximum continuous operating temperature corresponding to specified maximum operating current (---A under ambient condition enclosed as per Clause 1.2.1 of Section-IV of the Technical Specification for HTLS conductor)	Ohm/km	
7.17	AC resistance at continuous operating temperature corresponding to specified operating current of ---A (under ambient condition enclosed as per Clause 1.2.1 of Section-IV of the Technical Specification for HTLS conductor)	Ohm/km	
7.18	Details of Creep characteristic for HTLS conductor enclosed (as per Clause 1.4.3 of Section-IV of the Technical Specification for HTLS conductor)	Yes/No	
7.19	**Sag Tension Calculation**		
7.19.1	Sag Tension Calculation enclosed (clause 1.4.1 of Section-IV of the Technical Specification for HTLS conductor)	Yes/No	
7.19.2	Tension at 32 deg. C & no wind	Kg	
7.19.3	Sag & tension at maximum continuous operating temperature (corresponding to current of 1574 A and Ambient conditions detailed in Clause 1.4.1 of Section-IV of the Technical Specification for HTLS conductor)	Meters & Kgs	
i)	Tension for following conditions:		
a.	32 deg. C & full wind condition	kg	
b.	32 deg. C & Nil wind condition	kg	
c.	Minimum tempt. & Nil wind condition	kg	

d.	Minimum tempt. & 36% of full wind condition		
e.	32 deg. C & 75% of full wind condition		
7.19.4	Tension at transition temperature	kg	
7.20	Direction of lay for outside layer		
7.21	Linear mass of the Conductor a) Standard b) Minimum c) Maximum	 Kg/km Kg/km Kg/km	
7.22	Standard length of conductor	M	
7.23	Maximum length of conductor that can be offered as single length	M	
7.24	Tolerance on standard length of conductor	%	
7.25	Drum is as per specification	Yes/No	
7.26	No. of cold pressure butt welding equipment available at works	Nos.	

GUARANTEED TECHNICAL PARTICULARS OF SUSPENSION HARDWARE FITTINGS

Sl. No.	Description	Unit	Value guaranteed by the Bidder
1.	Name & address of Manufacturer		
2.	Address of Manufacturer		
3.	Drawing enclosed	Yes/No	
4.	Maximum magnetic power loss of suspension clamp at conductor / sub-conductor current of ---- amperes (at steady state conductor temperature)	Watt	
5.	Slipping strength of suspension assembly (c!amp torque Vs slip curve shall be enclosed)	kN	
6.	Particulars of standard/AGS Standard / AGS preformed armour rod set for suspension assembly		
	a) No. of rods per set	No.	
	b) Direction of lay		
	c) Overall length after fitting on conductor	mm	
	d) Actual length of each rod along its helix	mm	
	e) Diameter of each rod	mm	
	f) Tolerance in		
	i) Diameter of each rod	±mm	
	ii) Length of each rod	±mm	
	iii) Difference of length between the longest and shortest rod in a set	±mm	

	g) Type of Aluminium alloy used for manufacture of PA rod set		
	h) UTS of each rod	Kg/mm^2	
7.	Particulars of Elastomer (For AGS Clamp only)		
	a) Supplier of elastomer		
	b) Type of elastomer		
	c) Shore hardness of elastomer		
	d) Temperature range for which elastomer is designed		
	e) Moulded on insert		
8.	UTS of suspension clamp		
9.	Purity of Zinc used for galvanizing	%	
11.	Minimum corona extinction voltage under dry condition [for 400kV lines]	kV (rms)	
12.	Radio interference voltage at 1 Mhz for phase to earth voltage of 305 kV (dry condition) [for 400kV lines]	µV	
13.	Maximum permissible continuous operating temperature of		
	i) Clamp body	Deg. C	
	ii) Standard/AGS preformed rods	Deg. C	

GUARANTEED TECHNICAL PARTICULARS OF TENSION HARDWARE FITTINGS

Sl. No.	Description	Unit	Value guaranteed by the Bidder	
1.	Name of Manufacturer			
2.	Address of Manufacturer			
3.	Drawing enclosed	Yes/ No		
4.	Purity of aluminum used for aluminum sleeve	%		
5.	Material for steel sleeve			
	(i) Type of material with chemical composition			
	(ii) Range of Hardness of material (Brinnel Hardness)	BHN	From …….to ……..	
	(iii) Weight of zinc coating	gm/m^2		
			Aluminium / Alloy	Steel
6.	Outside diameter of sleeve before compression	mm		
7.	Inside diameter of sleeve before compression	mm		
8.	Length of sleeve before compression			
9.	Dimensions of sleeve after compression			
	(a) Corner to Corner			
	(b) Surface to Surface			
10.	Length of sleeve after compression			
11.	Weight of sleeve			
	(a) Aluminium/ aluminum Alloy	kg		

	(b) Steel	kg	
	(c) Total	kg	
12.	Electrical resistance of dead end assembly as a percentage of equivalent length of Conductor	%	
13.	Slip strength of dead end assembly	kN	
14.	UTS of dead end assembly	kN	
15.	Purity of Zinc used for galvanizing	%	
16.	Design calculation of yoke plates and sag adjustment plate enclosed.	Yes / No	
17.	Minimum corona extinction voltage under dry condition [for 400kV lines]	kV (rms)	
18.	Radio interference voltage at 1 Mhz for phase to earth voltage of 305 kV (dry condition) [for 400kV lines]	µV	
19.	Maximum permissible continuous operating temperature of dead end assembly	Deg. C	

GUARANTEED TECHNICAL PARTICULARS OF MID SPAN COMPRESSION JOINT FOR HT/HTLS CONDUCTOR

Sl. No.	Description	Unit	Value guaranteed by the Bidder	
1.	Name of Manufacturer			
2.	Address of Manufacturer			
3.	Drawing enclosed		Yes/No	
4.	Suitable for conductor size	mm		
5.	Purity of aluminium used for aluminium sleeve	%		
6.	Material for steel sleeve			
	(i) Type of material with chemical composition			
	(ii) Range of Hardness of material (Brinnel Hardness)	BHN	From …….to ……..	
	(iii) Weight of zinc coating	gm/m^2		
			Aluminium / alloy	Steel
7.	Outside diameter of sleeve before compression	mm		
8.	Inside diameter of sleeve before compression	mm		
9.	Length of sleeve before compression			
10.	Dimensions of sleeve after compression			
	(a) Corner to Corner			
	(b) Surface to Surface			
11.	Length of sleeve after compression			
12.	Weight of sleeve			
	(a) Aluminium	kg		

	(b) Steel	kg	
	(c) Total	kg	
13.	Slip strength	kN	
14.	Resistance of the compressed unit expressed, as percentage of the resistivity of equivalent length of bare conductor.	%	
15.	Minimum Corona extinction voltage under dry condition [for 400kV lines]	kV (rms)	
16.	Radio interference voltage at 1 MHz for phase to earth voltage of 305 kV under dry condition[for 400kV lines]	µV	
17.	Maximum permissible continuous operating temperature of mid span compression joint	Deg. C	

GUARANTEED TECHNICAL PARTICULARS OF REPAIR SLEEVE FOR HT/HTLS CONDUCTOR

Sl. No.	Description	Unit	Value guaranteed by the Bidder
1.	Name of Manufacturer		
2.	Address of Manufacturer		
3.	Drawing enclosed	Yes/No	
4.	Suitable for conductor size	mm	
5.	Purity of Aluminium / Al Alloy type	%	
6.	Dimension of sleeve before compression		
	i) Inside diameter of sleeve	mm	
	ii) Outside dimensions of sleeve	mm	
	iii) Length of sleeve	mm	
7.	Dimension of sleeve after compression		
	i) Corner to Corner	mm	
	ii) Surface to Surface	mm	
	iii) Length of sleeve	mm	
8.	Weight of sleeve	Kg	
9.	Minimum Corona extinction voltage under dry condition [for 400kV lines]	kV (rms)	
10.	Radio interference voltage at 1 MHz for phase to earth voltage of 305 kV dry condition) [for 400kV lines]	μV	
11.	Maximum permissible continuous operating temperature of Repair Sleeve	Deg. C	

NOTE: Tolerances, wherever applicable, shall also be specified.

GUARANTEED TECHNICAL PARTICULARS OF VIBRATION DAMPER FOR HT/HTLS CONDUCTOR (IF APPLICABLE)

Sl. No.	Description	Unit	Value guaranteed by the Bidder	
1.	Name of Manufacturer			
2.	Address of Manufacturer			
3	Drawing enclosed			
	(a) Design Drawing	YES / NO		
	(b) Placement Chart	YES / NO		
4.	Suitable for conductor size	mm		
5.	Total weight of one damper	kg		
			Right	Left
6.	Diameter of each damper mass	mm		
7.	Length of each damper mass	mm		
8.	Weight of each damper mass	kg		
9.	Material of damper masses			
10.	Material of clamp			
11.	Material of the stranded messenger cable			
12.	Number of strands in stranded messenger cable			
13.	Lay ratio of stranded messenger cable			
14.	Minimum ultimate tensile strength of stranded messenger cable	Kg/mm^2		

15.	Slip strength of stranded messenger cable (mass pull off)	kN		
			Right	Left
16.	Resonance frequencies			
	(a) First frequency	Hz		
	(b) Second frequency	Hz		
17	Designed clamping torque	Kg-m		
18.	Slipping strength of damper clamp			
	(a) Before fatigue test	kN		
	(b) After fatigue test	kN		
19.	Magnetic power loss per vibration damper watts for ---Amps, 50 Hz Alternating Current [average continuous operating current]	watts		
20.	Minimum corona Extinction voltage kV (rms) under dry condition [for 400kV lines]	kV		
21.	Radio Interference Voltage at 1 MHz for phase to earth voltage of 305 kV (rms) Microvolts under dry condition [for 400kV lines]	µV		
22.	Maximum permissible continuous operating temperature of Vibration Damper	Deg. C		
23.	Percentage variation in reactance after fatigue test in comparison with that . before fatigue test	%		
24.	Percentage variation in power dissipation after fatigue test in comparison with that before fatigue test	%		

NOTE: Tolerances, wherever applicable, shall also be specified.

GUARANTEED TECHNICAL PARTICULARS OF BUNDLE SPACER FOR HT/HTLS CONDUCTOR (IF APPLICABLE)

Sl. No.	Description	Unit	Value guaranteed by the Bidder	
1.	Name of Manufacturer			
2.	Address of Manufacturer			
3.	Drawing enclosed			
	(a) Design Drawing		YES / NO	
	(b) Placement Chart		YES / NO	
4	Suitable for conductor size	mm		
5.	Material / Manufacturing process of component parts			
			Material	Manufacturing Process
	(a) Insert			
	(b) Main body			
	(c) Retaining rods (if any)			
6.	Retaining rods (if used)			
	(a) Type of alloy used			
	(b) Number of retaining rods used for each spacer	no.		
	(c) Diameter	mm		
	(d) Length	mm		
	(e) Weight	kg		
7.	Elastomer			

	(a) Contractor			
	(b) Type			
	(c) Moulded on insert			
	(d) Shore hardness			
	(e) Thickness on insert	mm		
	(f) Temp. range for which designed	°C		
8.	Minimum ultimate tensile strength of spacer			
	(a) Compressive load	kN		
	(b) Tensile load	kN		
9.	Weight of Spacer	kg		
10.	Designed clamping torque(if applicable)	kg. m		
			Before Vibration	After Vibration
11.	Slipping strength of spacer clamp	kN		
12.	Magnetic power loss per spacer for ---- A, 50 Hz Alternating Current (at steady state conductor temperature)	Watt s		
			Maximum	Minimum
13.	Electrical resistance of elastomer cushioned spacer	oh m		
14.	Minimum corona Extinction voltage kV (rms) under dry condition [for 400kV lines]	kV		
15.	Radio Interference Voltage at 1 MHz for phase to earth voltage of 305 kV (rms) Microvolts under dry condition [for 400kV lines]	µV		
16.	Maximum permissible continuous operating temperature of Bundle spacer	Deg. C		

NOTE: Tolerances, wherever applicable, shall also be specified.

GUARANTEED TECHNICAL PARTICULARS OF RIGID SPACER FOR JUMPER FOR HTLS CONDUCTOR

Sl. No.	Description	Unit	Value guaranteed by the Bidder
1.	Name of Manufacturer		
2.	Address of Manufacturer		
3.	Drawing enclosed		
	(a) Design Drawing	YES / NO	
	(b) Placement Chart	YES / NO	
4	Suitable for conductor size	mm	
5.	Material of component parts		
	(a) Clamp		
	(b) Main body		
6.	Manufacturing process for		
	(a) Clamp		
	(b) Main body		
	(e) Weight	kg	
7.	Elastomer		
	(a) Contractor		
	(b) Type		
	(c) Moulded on insert		
	(d) Shore hardness		
	(e) Thickness on insert	mm	
	(f) Temp. range for which designed	°C	

8.	Minimum ultimate tensile strength of spacer			
	(a) Compressive load	kN		
	(b) Tensile load	kN		
9.	Weight of Spacer	kg		
10.	Designed clamping torque(if applicable)	kg.m		
11.	Slipping strength of spacer clamp	kN		
12.	Magnetic power loss per spacer for Watts ---Amps, 50 Hz Alternating Current (at steady state conductor temperature)	watt		
			Maximum	Minimum
12.	Electrical resistance of elastomer cushioned spacer	ohm		………
13.	Minimum corona Extinction voltage kV (rms) under dry condition [for 400kV lines]	kV (rms)		
14.	Radio Interference Voltage at 1 MHz for phase to earth voltage of 305 kV (rms) Microvolts under dry condition [for 400kV lines]	μV		
15.	Maximum permissible continuous operating temperature of rigid spacer	Deg. C		

NOTE: Tolerances, wherever applicable, shall also be specified.

GUARANTEED TECHNICAL PARTICULARS OF SPACER DAMPER FOR HTLS CONDUCTOR (IF APPLICABLE)

Sl. No.	Description	Unit	Value guaranteed by the Bidder
1.	Name of Manufacturer		
2.	Address of Manufacturer		
3.	Drawing enclosed		
	(a) Design Drawing	YES / NO	
	(b) Placement Chart	YES / NO	
4	Suitable for conductor size	mm	
5.	Material of component parts		
	(a) Clamp		
	(b) Main body		
6.	Type of Clamps		
7.	Type of Damping element		
8.	Manufacturing process for		
	(a) Clamp		
	(b) Main body		
	(e) Weight	kg	
9.	Elastomer		
	(a) Contractor		
	(b) Type		
	(c) Moulded on insert		

	(d) Shore hardness			
	(e) Thickness on insert	mm		
	(f) Temp. range for which designed	°C		
10.	Minimum ultimate tensile strength of spacer			
	(a) Compressive load	kN		
	(b) Tensile load	kN		
11.	Weight of Spacer	kg		
12.	Designed clamping torque(if applicable)	kg. m		
13.	Slipping strength of spacer clamp	kN		
14.	Magnetic power loss per spacer for Watts 1574 Amps, 50 Hz Alternating Current	watt		
			Maxi mum	Minim um
15.	Electrical resistance of elastomer cushioned spacer	ohm		
16.	Minimum corona Extinction voltage kV (rms) under dry condition [for 400kV lines]	kV (rms)		
17.	Radio Interference Voltage at 1 MHz for phase to earth voltage of 305 kV (rms) Microvolts under dry condition [for 400kV lines]	µV		
18.	Maximum permissible continuous operating temperature of spacer damper	Deg. C		

NOTE: Tolerances, wherever applicable, shall also be specified.

ANNEXURE-V

OFFICE ORDER FOR CONSTITUTION OF THE COMMITTEE

Govt. of India
Ministry of Power
Central Electricity Authority
Office of Secretary.
Sewa Bhawan, R.K. Puram,New Delhi – 110066
Website: www.cea.nic.in
Phone: 011-26105619 Tel Fax: 011-26108476

ISO : 9001-2000

No.CEA/SETD/ 323/2016/23 January 18 , 2016

Sub: Constitution of Technical Committee to "Discuss and rationalize the effective use of new generation High Performance Conductor (HPC) [High Temperature / High Temperature Low Sag (HTLS) Conductor] in Indian Transmission & Distribution System

In India, ACSR and AAAC are commonly used conductors for transmission of Power on over head lines for transmission and distribution system. The enhancement in power transmission capacity in existing corridor, reduction in losses and optimization of Right of Way (RoW) etc. of electric network is the need of the hour. New technologies are emerging out globally and there is need to adopt them rationally to suit India's Transmission and Distribution Sector. New generation HPC is one of the emerging technologies on the horizon that could help electric power delivery system for efficient transmission of energy. New generation Conductors can reduce losses and at the same time enhance power flow per unit (or meter) of Right of Way (RoW) under normal as well as under emergency condition and can address issues like growing congestion in existing corridor of transmission / distribution network and Right of Way (RoW) problems.

1) In view of above, it has been decided to constitute a Technical committee comprising of representatives from IEEMA/few manufacturers, users of new generation conductors, CPRI and CEA to discuss various aspects of new generation conductor to rationalize the effective use of such conductors. The composition of Committee shall be as follows:

1	Chief Engineer (PSE&TD), CEA	Chairman
2	A Representative from (PSP&A-I & PSP&A-II), CEA	Member
3	A representative from (DP&ED), CEA	Member
4	Two nominees from IEEMA(Manufacturers of HPC conductors)	Members
5	A representative from CPRI	Member
6	A representative from PGCIL and CTU	Member
7	Representatives from State/Pvt. Power Utilities • UPPTCL (UP) • MSETCL (Maharashtra) • WBSETCL (West Bengal) • OPTCL (Odisha) • RRVPNL (Rajasthan) • GETCO (Gujrat) • M/s. Tata Power • M/s. Torrento Power • CESC	Members
8	Director(PSE&TD), CEA	Member Secretary /Convener

2) The Terms of Reference (ToR) of the committee will be as follows:

a) Rationalize effective use of New Generation High Performance Conductor (HPC) [High Temperature conductor / High Temperature Low Sag (HTLS) conductors] in Transmission & Distribution Sector
b) Compare the pros and cons of various types of new generation conductors in use / commercially available and cost benefit analysis taking into account LCC.
c) Assess the Indigenous manufacturing facility and capability to supply New Generation HPC and associated accessories
d) Decide Broad Technical parameters required to be specified for different types of New Generation HPC for bidding process
e) Decide criteria for Technical Evaluation of Bids for different types of New Generation HPC
f) Discuss about the Testing of New Generation HPC [Type testing and Routine testing etc.] and assess the testing facility available in the Country
g) Discuss about Performance, erection & commission, and Operation & Maintenance issues pertaining to various types of New Generation HPC in India and abroad

3) The TA/DA and other expenses shall be borne by the respective organizations of the members of the Committee.

4) The committee will submit its recommendation within three (3) months from the date of constitution of the committee.

Committee may Co-opt any other Member.

14/11/16

(P.D. Siwal)
Secretary, CEA

To:

1. Chief Engineer(PSE&TD), CEA
2. Chief Engineer (PSP&A-I & II), CEA
3. Chief Engineer (DP&ED), CEA
4. Director General, Central Power Research Institute, Professor Sir C.V.Raman Road, P.O.Box-8066, Banglore-560080
5. Director (Projects), PGCIL
6. MD/CMD of following state utility & Pvt. Utilities.
   a. UPPTCL
   b. MSETCl
   c. WBSETCL
   d. OPTCL
   e. RRVPNL
   f. GETCO
   g. M/s. Tata Power
   h. M/s. Torrento Power
   i. CESC
7. Director General, IEEMA

With a request to nominate their representative as Member of Committee (not below the rank of GM/Chief Engineer /equivalent) along with an alternate member(not below the rank of AGM/SE/equivalent)

8. Director(PSE&TD), CEA

REFERENCES

1. CIGRE 695 WG: B2.48: Experience with the mechanical performance of non-conventional conductors, August 2017

2. EPRI's report 1017448: Demonstration of Advanced Conductors for Overhead Transmission Lines, July 2008

3. CIGRE 426 WG: B2.26: Guide for Qualifying High Temperature Conductors for Use on Overhead Transmission Lines, August 2010

4. International Journal of Advance Engineering and Research Development, Volume 2, Issue 5, May 2015, Re-conductoring scenario and payback calculations of ACSR Moose and its equivalent conductors for 400 kV transmission line [Thermal Uprating]

5. PGCIL's specifications of High Performance Conductors and Accessories

CENTRAL ELECTRICITY AUTHORITY

Central Electricity Authority (CEA) is a statutory organization, originally constituted under Section 3(1) of the replaced Electricity (Supply) Act, 1948, since substituted by section 70 of the Electricity Act, 2003. It was established as a part-time body in 1951 and made a full-time body in 1975. The functions and duties of CEA are delineated under Section 73 of the Electricity Act, 2003. The 'Office of CEA' is an Attached Office of the Ministry of Power.

CEA is an apex technical body facilitating overall development of the power sector in the country with the vision to provide quality Power for all at an affordable price. CEA advises Central Government on the matters related to National Electricity Policy, formulates short-term and perspective plans for development of electricity systems, specify various technical standards for construction of the electric plans & electric lines, grid connectivity, safety requirement for construction and O&M of electrical plants & electric lines, installation & operation of electricity meters, promotes & assists in timely completion of schemes & projects, promotes measure for upgrading skills of human resource in the power sector, collects & utilization of industry, promotes research in matters affecting power sector, and advise the central Government, State Governments, Electricity Regulatory Commissions & licensees on all such matter of power Sector on which its advise is sought.

CENTRAL ELECTRICITY AUTHORITY

MINISTRY OF POWER, GOVERNMENT OF INDIA

POWER SYSTEM ENGINEERING & TECHNOLOGY DEVELOPMENT DIVISION

SEWA BHAWAN, R. K. PURAM, NEW DELHI - 110 066