# Technical Specification for ERS

***NOTE****: Anywhere text is shown in blue on a yellow background indicates the actual requirements shall be inserted in place of that text at that location. All text in blue/yellow is provided as an example only. All such text is consistent with itself through the specification.*

## Scope of Specification

This specification describes the technical requirements for the supply of one set of an emergency restoration system (ERS). Each emergency restoration system will consist of all necessary parts, services, software, and all other equipment necessary to restore a damaged or destroyed permanent transmission tower in the event of an emergency.

Specifically this work will document the requirements necessary for the column sections, the foundations, the articulating gimbal joint, the guy plates, the anchors, the guy wire, the guy wire accessories, the insulators, the conductor hardware, construction tools, spare parts, computer software, and field training.

## Qualifying Requirements

The ERS manufacturer must have provided at least 3 sets of ERS anywhere in the world in strict conformance of IEEE 1070-2006, “IEEE Guide for the Design and Testing of Transmission Modular Restoration Structure Components”, including earlier or later versions. Strict conformance of IEEE 1070-2006 includes testing requirements, material requirements, fabrication requirements, and all other geometric and dimensional requirements listed in the IEEE 1070 standard, without exception. The manufacturer shall submit with his proposal, a certified copy of the Design Test Report as required in Section 4 of IEEE Standard 1070-2006.

If the manufacturer has never produced, or is incapable of producing, their ERS structures in accordance with the IEEE 1070 standard without exception, then they should explain their deficiency to the purchaser and explain why they are unwilling or unable to conform to common international requirements. The purchaser may decide, on a case by case basis, to accept a technical proposal from manufacturers who are unable to comply with this standard.

International standards that are not relevant to Emergency Restoration Systems are not suitable for substitution. For example, the IEC 60652 standard is pertinent to loading tests on overhead line structures and while it may be specified in addition to IEEE 1070-2006, as it makes no mention of emergency restoration structures it will not be considered a standard for emergency restoration structures.

## ERS Towers

The following restoration scenarios should be utilized: *[User to insert specific requirements here. The following section in blue is used as an example of a restoration scenario.]*

1. 12 Single Circuit, three vertical phase, 400 kV Tangent (0°-5° Line Angle) Suspension Structures.

OR

1. 4 Single Circuit, three vertical phase, 400 kV Angle (0°-30° line Angle) Tension Structures, and

8 Single Circuit, three vertical phase, 400 kV Tangent (0°-5° Line Angle) Suspension Structures.

OR

1. 3 Single phase 400 kV Large Angle (60°-90° Line Angle) Tension Structures, and

2 Single Circuit, three vertical phase, 400 kV Angle (0°-30° Line Angle) Tension Structures, and

7 Single Circuit, three vertical phase, 400 kV Tangent (0°-5° Line Angle) Suspension Structures.

The complete set of ERS should be capable of constructing any one of these failure scenarios. Towers to be used at 400 kV should also be suitable for use at lower voltages. The towers should have modular components which can be reconfigured into economical designs at different voltages.

One double circuit ERS tower is not sufficient to replace two single circuit ERS tower. When restoring a downed transmission line it can be assumed that the ERS towers will bypass the fallen towers off to the side. This ensures that the original line can be reconstructed. For this reason two single circuit towers cannot be replaced by a single double circuit tower. In general a transmission line using ERS will bypass to the side of a permanent line and it is envisioned that the ERS towers are only suitable for single circuit towers. ERS towers may replace double circuit towers by using two single-circuit ERS.

All towers must withstand the loading conditions specified in Section 6 of this document.

All towers must maintain clearances and support spans in accordance with Section 6 of this document.

The towers should use a configuration which is suitable for a vertical disposition of conductors. Additional columns to support a configuration with a horizontal disposition are not required.

# Structure Components – General

Each ERS will consist of modular components which can be used to construct a temporary transmission tower in a variety of different configurations. These components must be light-weight to allow for manual transportation if needed. Each major component of the ERS structure shall conform to all the dimensional and geometric requirements of IEEE Standard 1070-2006, “IEEE Guide for the Design and Testing of Transmission Modular Restoration Structure Components”, without exception.

In order to simplify construction, the ERS structures shall minimize the number of guy wires used to support the structure. Guy wires will only be attached at the same level as the insulator attachment points and only one additional intermediate guy location between the lowest insulator attachment point and the foundation shall be allowed.

The primary material used in the construction of the ERS and the fabrication and welding of that material shall be in complete compliance with Section 3 of IEEE Standard 1070.

The ERS structural components shall meet the testing requirements of IEEE Standard 1070-2006 “IEEE Guide for the Design and Testing of Transmission Modular Restoration Structure Components.” All ERS Components shall be identified and marked as required in Section 6.1 of IEEE Standard 1070-2006.

The ERS shall be suitable for a variety of internationally recognized standard fall arrest equipment. The tower shall be capable of attaching a lifeline fall arrest system. In addition the tower shall accommodate the use of standard locking rebar snap hooks with shock absorbing lanyards and individual harness.

Only one size and diameter of threaded fastener as specified in IEEE Standard 1070, shall be used to assemble the ERS structural elements. Different sizes of fasteners may be used for associated items such as construction tools, conductor hardware, or connections between insulators.

Any ferrous materials used must be galvanized as per ASTM A153. Any threaded parts can be galvanized as per ASTM A-123 which is the applicable standard. Throughout this document any mention of ASTM A153 will automatically imply the alternate standard ASTM A123 for threaded components. All materials must be protected from corrosion and capable of outdoor or warehouse storage for a period of 20 years with no required maintenance.

## Column Sections (Mast Components)

All components shall have the following characteristics:

All Column sections shall be made in accordance with Figures 1A and 1B in IEEE Standard 1070.

* Each column section shall be routinely tested in accordance with Section 5.1 and 5.2 of IEEE Standard 1070.
* A minimum of 20% extra connecting bolts, nuts and lock washers shall be supplied with each column section.

## Foundation Plates

The foundation plates shall be made in accordance with Figure 4 in IEEE Standard 1070.

## Gimbal Joint

The gimbal shall be made in accordance with Figure 3 in IEEE Standard 1070.

## Guy Plates

The Guy plates shall be made in accordance with Figure 2 in IEEE Standard 1070.

## Box Sections

The Box Sections shall be made in accordance with Figure 5 in IEEE Standard 1070.

## Insulators

Suspension insulators shall generally conform to all applicable electrical and mechanical tests as required by ANSI C29.11 and IEC 61109. All suspension insulators shall be given a routine test load (RTL) of111 kN and an ultimate mechanical load of 222 kN. Suspension insulators shall be capable of being linked together to form a two-part insulator or multi-part insulator. This allows modular construction for different voltages. (e.g. 200 kV insulators can be supplied for use at 220 kV or 400 kV if they are placed together in series.)

The individual post insulators shall have a minimum diameter of fiberglass reinforced resin rod of 3.5 inch (88 mm). Post insulators shall be capable of being linked together to form a two-part insulator or multi-part insulator. This allows modular construction for different voltages. (e.g. 220 kV insulators can be supplied for use at 220 kV or 400 kV if they are placed together in series.)

All 220 kV suspension and post insulators shall be designed to have the following characteristics:

* The minimum leakage distance shall be 20 mm/kV phase-phase.
* Standard Power Frequency Withstand Voltage of 460 kV
* Standard Lightning Impulse Withstand Voltage of 1050 kV

Two insulators rated at 220 kV may be connected in series to form a single 400 kV insulator as long as 400 kV grading rings are also provided. The suspension insulators or post insulators may be combined in this way. The compressive strength of the combined post insulator must be appropriately decreased to account for the reduced buckling and bending capacity caused by increasing the length. Appropriate testing shall have been performed to verify the buckling strength of any post insulator assembly under the loading conditions specified in section 6.

Five percent (5%) additional spare suspension insulators, and five percent (5%) additional post insulators and five percent (5%) additional of each size of grading shield shall be supplied.

## Anchors

Each anchor shall terminate with a triple eye nut suitable for attachment of preformed type guy wire grips.

Each anchor shall have a minimum strength of 150 kN. The actual holding strength of the anchor may be less than this depending on the soil. The anchor itself should be able to withstand 150 kN of load.

Each anchor shall be hot dip galvanized as per ASTM A153.

Installation tools for anchors must also be provided as described in section 3.1.

A quantity of Manta-Ray anchors or similar anchors are to be provided. These anchors should be capable of being installed with a hydraulic jack hammer as specified in section 3.1. The anchors should be self-locking when set in place with a hydraulic pulling device, (i.e. a load locker). The minimum bearing area of these anchors shall be 450 cm2. These anchors should be supplied with a 1 m extension rod and a 2 m extension rod. Extension rods with lengths of 3.5 ft and 7.0 ft are acceptable.

A quantity of cross-plate anchors shall be provided. These anchors should have a minimum bearing area of 2500 in2. The cross-plate anchors should come included with a 3 m extension rod that ends in a triple eye attachment. Extension rods with a length of 10 ft are acceptable.

Triple Helix anchors should be provided. The triple helix anchor should have a 38 mm square shaft with a minimum helix thickness of 10 mm. An anchor with a 1.5 inch square shaft with a helix thickness of at least 3/8 inch is acceptable. The three helices should have minimum diameters of at least 343 mm (13.5 in), 292 mm (11.5 in), and 241 mm (9.5 in). The triple helix anchor will include a 1.5 m extension rod and a 3 m extension rod. Extension rods with lengths of 5 ft and 10 ft are acceptable.

Rock anchors shall be provided. The rock anchors must be suitable for installation in solid rock. These anchors should be supplied with a 1 m extension rod. Extension rods with a length of 3.5 ft are acceptable.

Anchors with an extremely large bearing area are not required. These types of anchors are not practical especially for swampy areas as this type of soil has no shear strength. Large concrete anchors are a better solution for this type of soil. Concrete anchors with weights of 10 to 20 ton may be used with the guyed structures as an effective anchor. Large concrete anchors are not included in this specification and will be provided by local suppliers if deemed necessary.

## Guy Wire and Grips

The guy wire shall be 9/16”-19 strand EHS guy wire as specified by ASTM A475. All guy wire shall conform exactly to ASTM A475. The guy wire shall have a minimum breaking strength of 149kN. The guy wire shall have a 9/16” diameter. Guy wire shall have 19 strands for flexibility. Guy wire with 7 strands is not acceptable. All guy wire shall be supplied in spools of 2000 m or of 1000 m.

Preformed helical grips suitable for attachment with the above guy wire shall be provided. The strength of the preformed grip should be equal to the strength of the guy wire.

Guy wire thimbles shall be provided for effective attachment of guy wires to anchors or guy plates. The guy wire thimbles should be appropriately sized for attachment with the guy wire specified in this document.

Anchor attachments ending in a thimble eye do not require an additional guy wire thimble.

Thirty percent (30%) additional spare guy wire and fifty percent (50%) additional compatible helical preformed grips and guy wire thimbles shall be supplied beyond the minimum required to build any of the ERS Structures specified in Section 1.0.

## Conductor Hardware

Ultimate strength of each hardware component shall be greater than 134kN, except as noted below.

All ferrous materials shall be galvanized in accordance with the latest revision of ASTM A153. All materials shall be free from burr, sharp edges, lumps and dross and shall be smooth so that any connecting parts may be assembled or disassembled easily. All threaded parts shall be galvanized after threading and excessive zinc shall be removed from threads. Drilling shall be made before galvanizing. All nuts and lock nuts shall be re-tapped after galvanizing and shall be capable of being turned on the bolt threads easily without using a wrench. All cotter pins shall be made of stainless steel in order to avoid oxidation.

A minimum number of different types of hardware shall be provided in order to minimize confusion during emergencies. All insulator/hardware assemblies shall be designed to attach to the structure in 1.45 m increments to correspond to the column section lengths supplied in order to minimize confusion during emergencies.

Only one size of shackle shall be supplied. These shackles shall be capable of fitting all hardware and guy wire anchoring assemblies. These shackles shall have a minimum ultimate strength of 267 kN and be supplied with a bolt, nut and cotter.

Bolted tension clamp shall be supplied to fit the range of conductors specified.

The conductor and overhead shield wire suspension and tension clamps shall have a minimum ultimate strength of 111 kN, and shall be capable of allowing a minimum 150 line angle at the suspension clamp.

A quantity of 156 kN turnbuckles corresponding to at least one half the quantity of suspension insulators, shall be provided for take up of hardware assemblies. Minimum take up shall be 0.3 m.

Routine mechanical pull tests shall be applied to all hardware items in accordance with IEEE Standard C135.61-1997. All galvanized wire rope with swaged fittings shall be proof tested to one half (50%) their ultimate strength

Test reports shall be prepared in detail containing all the data, number of tested samples and other necessary information as required by IEEE Standard C135.61-1997.

A minimum of ten percent (10%) additional spare hardware shall be supplied beyond the minimum required to build any of the ERS Structures specified in Section 1.0.

## Guy Strain Insulators

An additional quantity of fiberglass guy strain insulators, having a minimum length of 2.5 m, shall be provided to provide electrical clearance for guy wires. These guy strain insulators shall have a minimum strength of 149 kN. These guy strain insulators shall be provided with sufficient hardware for connecting them together when a greater length is required.

The quantity of guy strain insulators should be sufficient to build the structures specified. However, since these guy strain insulators are typically installed due to field variables (e.g. adjacent energized lines, proximity of down guys to conductors on tension structures a minimum of 120 guy strain shall be supplied per ERS set. More may be supplied if required by the design.

Suspension insulators may be used instead of guy strain insulators.

# Tools

A quantity of all necessary construction hydraulic tools and hand tools shall be provided for assembly and erection of a complete emergency restoration structure.

## Anchor Installation Tools

Anchor installation kits shall be supplied. Each anchor installation kit shall have:

* An 18 HP gasoline hydraulic power unit, capable of delivering 5-8 gpm (20-35 lpm) at a maximum pressure of 2000 PSI (13790 kPa).
* A compatible hydraulic driving hammer (i.e. 90 pound class and above for 8 inch. 200 mm, concrete applications) for installing the anchors in soil,
* A compatible hydraulic rotary hammer for drilling holes in rocks for installing rock anchors
* A compatible hydraulic proof testing unit for locking and proof testing soil anchors and proof testing rock anchors,
* All necessary and compatible hydraulic hoses, rock drill bits (5 per rotary hammer), and torque installation tools for the rock anchors. Hydraulic hoses shall have quick disconnect type couplers.

## Construction Tools

Each set of construction tools shall consist of the following:

### One (1) gin poles made from aluminum alloy will be provided. The gin pole shall be supported on one corner of a column section and allow lifting of up to 200 kg to the top of the structure. The gin pole shall be suitable for simultaneous lifting a column section and a post insulator support section. All necessary snatch blocks and rigging ropes will be supplied with the gin pole. All ropes shall be polyester with a minimum diameter of 15 mm. The gin pole shall have a davit arm to keep loads clear of the structure while being raised by a capstan hydraulic power unit, and low friction bushings for rotation of the load. A slider shall clamp to the corner members of the emergency restoration structure and allow the gin pole to be raised on the structure using manpower or a pulley and the capstan winch.

### A ½ ton hydraulic capstan winch with foot pedals shall be provided with each gin pole for controlling the speed of the capstan. This capstan shall be capable of being powered by the same hydraulic power unit used to install the soil anchors (section 3.1). The capstan shall be mounted to a plate that can be anchored to the ground.

### A quantity of eight (8), high-quality 2-ton Tractel Tirfor-style grip hoists will be provided with 45 m of 7/16” (11.5 mm) wire rope. Forged safety hooks shall be provided on both ends for the grip hoist body and for the 7/16” wire rope.

### A quantity of twelve (12), reversible ratchet for hand installation of ERS bolts. The reversible ratchet shall be made of forged material and provided with a ½” square drive and socket to fit the ERS bolts used to join the tower sections. A quantity of twelve (12) forged closed box wrenches will also be provided as an assembly tool.

### A quantity of six (6), three (3) ton reversible chain hoists will be provided for tensioning of guy wires and conductor. Forged safety hooks shall be provided on the reversible chain hoist. The hook throat openings shall be a minimum of 35 mm and sufficient chain shall be provided to have a standard lift of 3m.

### A quantity of nine (9), pulling eyes that attach to the anchor rods and allow placement of safety hooks for either the 3 ton chain hoist or the 2 ton grip hoist shall be provided.

### A quantity of nine (9), automatic wire grips suitable for gripping the 9/16 x 19 strand guy wires shall be provided. They shall have a minimum safe working load of 65 kN. The grips shall be made of forged steel and have a bail suitable for attachment of the 3 ton chain hoist safety hook.

### A quantity of one (1) 3 m, 16 mm diameter double loop 6x37 steel wire rope slings shall be provided. These slings shall have a loop eye swaged at both ends and have an ultimate strength of 100 kN. A quantity of one (1) 3 m, 75 mm wide, two ply nylon slings shall be provide for lifting purposes. The slings shall have a twisted eye at both ends and have a rated capacity of 40 kN when loaded vertically. A quantity of eight (8) 1.8 m long, round endless slings, with a rated capacity of 24 kN when loaded vertically, shall be provided for temporary guying of this structure.

### One (1) self-contained 6 ton hydraulic wire cutter shall be provided. This self-contained hydraulic cutter shall be capable of not only cutting the 9/16 x 19 strand guy wire but also the ACSR conductor and the overhead static wire.

### For each foundation, four (4) foundation stakes of 25 mm diameter and 1.2 meters in length shall be provided for staking the foundations to the ground. The stakes shall have a pulling eye at the top for retracting the stakes after use.

### A quantity of six (6), aluminum conductor lifting hooks shall be provided. These lifting hooks shall be made from high strength aluminum alloy and shall a minimum ultimate strength of 45 kN.

### A quantity of 20 foot ocean cargo storage containers shall be provided. These containers shall be outfitted for holding all of the hardware, insulators, guy plates, guy and anchor accessories, tools (including the gin pole) and nuts and bolts. The insulators shall be held in individual racks or PVC tubes in order to protect them. All hardware and nuts and bolts shall be stored in ferrous containers. There shall be easy access to the containers and easy access to the parts in the containers. The 20 foot ocean cargo storage container shall be lockable to prevent loss. All ERS components shall be stored in these 20 foot containers.

# Field Training

The Supplier shall be required to impart training to utility field and engineering personnel at a mutually agreed upon site for a minimum period of five (5) working days. The training shall include actual field training imparting firsthand knowledge about the assembly of modular structures, fixing of foundation plates, erecting of structures on the foundation, guying the tower with anchoring arrangement and stringing of conductor. Specific instructions shall be given for installation of ERS using cranes, gin pole and hydraulic hoisting equipment. The training shall also include classroom lectures, including training in computer analysis programs described in section 5 in order to assist the purchaser’s personnel in determining the capabilities of the structures. The class room training may also include explanation/demonstration of actual scenario. Special stress shall be given so as to ensure that the trained personnel acquire proficiency in restoring of failed structures so that they can take up this work independently.

Any additional construction equipment not supplied in the ERS proposal (e.g. cranes, helicopters, etc.) or material (e.g. conductor) and all construction personnel (except for the field trainer) shall be supplied by the purchaser.

# Computer Software

Computer software capable of being run on personal computers using Microsoft Windows shall be provided.

The computer program shall be able to be copied as many times as deemed necessary by the purchaser for multiple users employed by the purchaser without incurring additional or recurring licensing fees or requiring a special hardware (e.g., USB) key.

The program calculations shall show if loads are acceptable with the various structure components used, and they shall also show the foundation and anchoring forces. Applicable computer calculations shall take into account the flexibility of structures and possible displacement of anchoring or foundations.

The same computer programs shall also calculate and show construction loads. The program shall calculate the total weight of the structure and provide lifting loads for the tilt up gin pole method of erection, crane erection, and helicopter erection.

The computer program should be specially developed in order to analyze emergency restoration structures. The computer program should not require any additional software in order to run or analyze emergency restoration structures. The supplier shall guarantee that the computer software will provide accurate and true predictions of the structure capability and component (i.e. insulator and anchor) loading.

The computer programs and calculations shall use the following typical input data:

* Emergency restoration structure geometry.
* Conductor specifications.
* Overhead shield wire specifications.
* Wind loading on conductor and structure.
* Overload safety factors.
* Guy slopes.
* Wind and weight spans.

The computer program and calculations shall have the following typical output data:

* Allowable conductor height and span.
* Insulator loads.
* Guy and anchor loads.
* Right-of-Way requirements.
* Graphic representations of the structures to be built.

The computer software shall allow easy analysis of 220 kV and 400 kV restoration structures. The programs shall be accompanied by a detailed instruction manual that explains the theory used and gives examples for each type of structure. The programs shall come ready to analyzing the following types of structures:

* Angle or Suspension Chainette
* Angle or Suspension Four Pole
* Single or Double Circuit Herringbone
* Angle or Suspension Horizontal Vee
* Delta Horizontal Vee
* Running Angle
* Single phase Tension
* Three phase Tension

The computer program should be easy to learn. A qualified engineer should be capable of learning to use this software within one day. Any software program that requires a week or more of training is strictly disallowed as this creates an additional burden at a time of emergency. Software programs must be user friendly.

The program must give clear and failsafe outputs. If a tower is not sufficient to meet the necessary loading conditions then the program should immediately display a failure message or it should neglect to provide a printout. A computer program that analyzes a failing tower design and still outputs a printout of the tower is strictly disallowed. For emergency use there is no time to analyze outputs and therefore all outputs should be limited to only passing results.

PLS-CADD is not included in this specification since it is not a software program used for emergency towers. PLS-CADD may be purchased directly from Power Line Systems, Inc. or their authorized representatives. PLS-CADD is not allowed as a substitute for ERS software.

# Loading Conditions

The following loading and assumptions shall be incorporated into the design and analysis of the ERS structures specified in Section 1.0. Computer printouts showing the results of each analysis shall be supplied, clearly showing the results. The quantity of anchors and guy wire shall be determined from the maximum required from this analysis and the required spare quantity requirements specified throughout this document.

## CONDUCTOR AND OVERHEAD SHIELD WIRE DATA

The following values shall be used in the design of the ERS:

220kV Requirements

|  |  |
| --- | --- |
| Conductor: | ACSR Zebra |
| Conductors per phase: | 1 |
| Conductor diameter: | 28.6 mm |
| Conductor weight/length: | 1.62 kg/m |
| Conductor tension (Initial construction): | 15.0 kN |
| Conductor Tension (High wind condition): | 25.0 kN |
| Conductor Tension (Heavy ice condition): | 28.0 kN |
| Overhead Shield Wire diameter: | 11 mm |
| Overhead Shield Wire weight/length: | 0.58 kg/m |
| Overhead Shield Wire tension (Initial construction): | 8 kN |
| Overhead Shield Wire Tension (High wind condition): | 13 kN |
| Overhead Shield Wire (Heavy ice condition): | 18 kN |

400kV Requirements

|  |  |
| --- | --- |
| Conductor: | ACSR Moose |
| Conductors per phase: | 2 |
| Conductor diameter: | 31.8 mm |
| Conductor weight/length: | 2.00 kg/m |
| Conductor tension (Initial construction): | 18.5 kN |
| Conductor Tension (High wind condition): | 30.9 kN |
| Conductor Tension (Heavy ice condition): | 33.5 kN |
| Overhead Shield Wire diameter: | 11 mm |
| Overhead Shield Wire weight/length: | 0.45 kg/m |
| Overhead Shield Wire tension (Initial construction): | 8 kN |
| Overhead Shield Wire Tension (High wind condition): | 13 kN |
| Overhead Shield Wire (Heavy ice condition): | 18 kN |

## HIGH WIND LOADING DATA FOR 220kV AND 400kV

The following values shall be used in the design of the ERS:

High Wind Loading Requirements

|  |  |
| --- | --- |
| Maximum Wind Pressure on Conductor: | 934 Pa |
| Maximum Wind Pressure on one face of the Structure: | 1073 Pa |
| Vertical overload safety factor (conductor): | 1.1 |
| Wind overload safety factor (structure and conductor): | 1.1 |
| Tension overload safety factor (conductor): | 1.1 |

NOTE: The horizontal forces caused by wind on the emergency restoration structure shall be calculated by the following equation:

in which:

F: horizontal force caused by wind

: wind pressure

A: projected area of one face of the structure or conductor

C: drag coefficient = 1.0 for conductor only

C: drag coefficient based on structure solidity ratio and selected from the table below:

|  |  |
| --- | --- |
| Solidity Ratio | Drag Coefficient |
| 0.1 | 3.4 |
| 0.2 | 2.9 |
| 0.3 | 2.5 |
| 0.4 | 2.2 |
| 0.5 | 2.0 |

Source: IEC 60826

## HEAVY ICE LOADING DATA FOR 220kV AND 400kV

The following values shall be used in the design of the ERS:

Heavy Ice Loading Requirements

|  |  |
| --- | --- |
| Maximum Radial Ice (913kg/m density) on Conductor: | 12 mm |
| Maximum Wind Pressure on Conductor: | 172 Pa |
| Maximum Wind Pressure on Structure: | 172 Pa |
| Vertical overload safety factor (conductor): | 1.3 |
| Wind overload safety factor (structure and conductor): | 1.3 |
| Tension overload safety factor (conductor): | 1.3 |

## CONSTRUCTION LOADING DATA FOR 220kV AND 400kV

The following values shall be used in the design of the ERS:

Construction Loading Requirements

|  |  |
| --- | --- |
| Maximum Radial Ice on Conductor: | 0 mm |
| Maximum Wind Pressure on Conductor: | 76 Pa |
| Maximum Wind Pressure on Structure: | 76 Pa |
| Vertical overload safety factor (conductor): | 3.0 |
| Wind overload safety factor (structure and conductor): | 3.0 |
| Tension overload safety factor (conductor): | 2.0 |

## REQUIRED SPANS FOR 220 kV AND 400 kV TOWERS

The design of ERS towers must be suitable for the spans listed below. An equal wind and weight span shall be assumed. Broken wire condition is not required for emergency towers.

Wind and Weight Span Requirements

|  |  |
| --- | --- |
| 400 kV Suspension ERS with 25 m conductor height at tower 0°-5° Line Angle: | 400 m |
| 400 kV Tension ERS with 25 m conductor height at tower, 0°-30° Line Angle: | 350 m |
| 400 kV Tension ERS with 25 m conductor height at tower, 60°-90° Line Angle: | 330 m |
| 220 kV Suspension ERS with 19 m conductor height at tower, 0°-5° Line Angle: | 300 m |
| 220 kV Tension ERS with 19 m conductor height at tower, 0°-30° Line Angle: | 300 m |
| 220 kV Tension ERS with 19 m conductor height at tower, 0°-60° Line Angle: | 300 m |

## REQUIRED ELECTRICAL CLEARANCES.

The ERS towers must be designed to meet the clearances listed below.

Electrical Clearances for 220 kV

|  |  |
| --- | --- |
| Minimum height of bottom conductor at tower: | 19 m |
| Minimum clearance to live metal/ground: | 1.58 m |
| Minimum phase-to-phase clearance: | 2.77 m |
| Minimum vertical distance from phase to earthwire: | 1.58 m |
| Minimum distance to guy strain insulating rods: | 1.0 m |

Electrical Clearances for 400 kV

|  |  |
| --- | --- |
| Minimum height of bottom conductor at tower: | 25 m |
| Minimum clearance to live metal/ground: | 3.15 m |
| Minimum phase-to-phase clearance: | 5.37 m |
| Minimum vertical distance from phase to earthwire: | 3.15 m |
| Minimum distance to guy strain insulating rods: | 1.5 m |