Islamic Republic of Iran
Vice Presidency for Strategic Planning and Supervision

General Technical Specification and Execution Procedures for Transmission and Subtransmission Networks Transmission Lines

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Technical Specification of Transmission Line Conductors

1- General requirements

This specification covers minimum requirement for the design, manufacturing, factory testing, marking and packing of overhead transmission lines conductors. Conductors shall be as specified in schedule (I).

Conductors shall be designed, manufactured and tested according to the latest edition of the following standards:

- ASTM A 938: Standard Test Method for Torsion Test of Wire
- ASTM B 230: Standard Specification for Aluminum 1350-H190 Wire for Electrical Purpose
- ASTM B 232/M: Standard Specification for Concentric–Lay–Stranded Aluminum Conductors, Coated – Steel Reinforced (ACSR)
- ASTM B 354: Standard Terminology Relating to Uninsulated Metallic Electrical Conductors
- ASTM B 498: Standard Specification for Zinc–Coated (Galvanized) Steel Core Wire for Aluminum Conductors, Steel Reinforced (ACSR)
- ASTM B 500: Standard Specification for Metallic Coated Stranded Steel Core for Aluminum Conductors, Steel Reinforced (ACSR)
- ASTM B 502: Standard Specification for Aluminum–Clad Steel Core Wire for Aluminum Conductors, Aluminum–Clad Steel Reinforced
- ASTM B 606: Standard Specification for High–Strength Zinc–Coated (Galvanized) Steel Core Wire for Aluminum And Aluminum–Alloy Conductors, Steel Reinforced
- ASTM B 609M: Standard Specification for Aluminum 1350 Round Wire, Annealed and Intermediacies Tempers, for Electrical Purposes
- ASTM B 682: Standard Specification for Standard Metric Sizes of Electrical Conductors
- IEC 61089: Round Wire Concentric Lay Overhead Electrical Stranded Conductors
- IEC 61395: Overhead Electrical Conductors-Creep Test Procedures for Stranded Conductors

2- Design and construction

Conductors should be so designed to be able to carry the specified current.

All wires shall be free of scratch and any agent that decrease conductor quality and increase corona losses and radio waves interference.

In nominal current carrying conditions, the final temperature of conductor with regard to ambient temperature should be reach to maximum 90 °C.

Conductors should be able to carry the defined fault current for duration of 1 second and don't face any problem. During the fault its final temperature of conductor shall be less than 180 °C. Initial conductor temperature before fault should be considered 90 °C. conductors should tolerate permanent thermal load current without any damages.

Conductor shall be stranded uniformly without any tear, scratch and erosion. All conductors shall not have any defect due to construction process.

Conductor shall be so designed, in addition of having specified electrical and mechanical requirements, to have necessary flexibility.

In the tension equal to 30 percent of it's ultimate tension strength, the decrease in area of cross section of conductors shall not be greater than 2 percent.

When conductor tension equal to 50 percent of it's ultimate tension strength, cylindrical shape of conductor shall be kept and should not be any relative motion between strands.

All aluminum wires and steel core wires should be conform to prenominate standards before stranding.

Cold – pressure welds and electric – butt welds, may be made in the finished individual aluminum wires during the stranding process.

The area of cross section of the aluminum wires of a conductor should not be less than 98% of the area specified.

The steel core of a ACSR conductor generally includes 7 to 19 zinc or aluminum coated steel wires. The steel wires shall be so stranded that when the stranded core is cut the individual wires can be readily regrouped and held in one hand.

There shall be no joints of any kind made in the finished zinc or aluminum coated steel wires.

The direction of lay of the aluminum and steel wires shall be reversed in successive layers and all lengths of stranded core shall be furnished to a length tolerance of ±2%.

The length of lay of the various layer of wires in a conductor shall conform to ASTM B232M.

The number and diameter of aluminum and steel wires and the area of cross section of aluminum wires shall conform to the requirements prescribed in ASTM B232M standard.

Grease must be used to prevent corrosion if necessary. The type and specification of grease should be so that it withstand the specified weather conditions and retrain it's qualification.

3- Using grease in conductors

3-1- Grease specifications

The conductor greases divided in two types:
One type is the grease that generally use coldly. Solid and semisolid greases are kinds of this grease that their major compositions are mineral and synthetic oil with densifying organic compounds.
The other type is the grease that generally use hotly. Semisolid and solid petroleum materials are kinds of this type that is made from microcrystal wax and mix with a little amount of natural (mineral) oil and other combinations.

3-2- General requirements for grease

Grease shall not have damage and leakage in shipping, warehousing, local installation and utilization in conditions of maximum allowable temperature of operation or normal fault current conditions.
Grease shall have good adherence to wire and adherence test should be done for certifying this characteristic.
Grease shall not be damaged in different steps of conductor greasing. Stability, longevity and oil isolation must be performed on grease to certify these characteristics.
Grease shall protect the conductor against corrosion and dose not cause corrosion itself. Also it shall not affect on specification of galvanized steel, steel with aluminum clad, aluminum and any alloy.
Corrosion test must be performed on grease for certifying its characteristics. Also grease shall not increase noise and corona.
Grease shall not have any risk for health and conform to all common sanitary standards.

4- Production delivery

The conductor shall be supplied wound on a drum. When packing, it is important the conductor does not come into contact with materials which can cause corrosion.
Unless otherwise agreed upon, the barrel of the drum shall have a diameter of at least 1000 mm. The drum shall have a center hole about 100 mm in diameter.
The drum shall be capable of withstanding all stresses due to breaking on stringing operations.
Each end of the conductor shall be equipped with a cap and fasten to the drum propely and securely.
The drum shall be of such design, construction and strength as to guarantee satisfactory delivery of the conductor to its destination without displacement, chafing, or other damage incurring during shipment or field handling.
Direction of rolling shall indicate with arrow shape on drum sidewall.

In addition to marks required for shipping purposes, each drum shall be marked to show name, serial number, order code, date of production, type of conductor, length of conductor with tolerance, arrow showing the end of the conductor and gross, tare and net weights. All marking shall be plainly legible and durable. This information shall be superscribed on aluminum plates and attached on both sides of drum. Pulley shall be ball bearing type and should be made from aluminum and shall be clean and oil before installation so that can move freely.

After installation of pulleys on tower and during the stringing, pulley shall be replaced with new pulley if any obstacle occurred. Groove of pulleys shall have resinoid semiconductor coating or similar materials to make electrical contact between stringing conductor and tower.

The minimum radius at the base of the groove shall be 1.1 times the radius of the conductor and the depth of groove should be minimum of 25% greater than the diameter of the conductor to facilitate the passage of conductor, grips and swivels. Also the sheaves diameter should be minimum 10 times the diameter of used conductor.

The axis of drum shall parallel with the direction of motion during drum shipping by carrying vehicle. In the drum lifting, a shaft shall be entered in the inner hole of the drum and then lift up by means of chain or similar equipments.

Conductor drums always shall be kept perpendicularly in shipping and warehousing and indicator sign of position shall be showed on it by a plate.

Drums shall roll in direction of arrow. Drum rolling shall not be done on rigid surfaces.

5- Tests

5-1- Conductor wires

- Aluminum wires before stranding shall comply in all respect with the latest revision of standard ASTM B230.
- Conductor with galvanized steel core before stranding shall comply in all respect with the latest revision of standard ASTM B498.
- Conductor with aluminum clad steel core before stranding shall comply in all respect with the latest revision of standard ASTM B341 and ASTM B502.

5-2- Completed conductor

a) Tests related to dimensions and ultimate strength

With purchaser request, a conductor specimen shall be tested by contractor in accordance with standard ASTM B232M. Ultimate strength test should be performed to calculate ultimate tensile strength. Cross section of the conductor shall be measured in 1000 kg intervals to 50 percent of its ultimate strength. This measurement perform to determine the variation of circumference of the conductor relative to the value of load.

b) Creep and strain – stress tests

Determination of strain – stress curves of the conductor and calculation of primary and final elasticity module shall be done in accordance with IEC 61089.

5-3- Factory tests

The following type and sample tests must be performed in accordance with IEC 61089.

a) Type tests:

- Joints in aluminum wires
- Stress – strain curves
- Breaking strength of conductor

b) Sample tests:

- Strain on aluminum and steel wires
- Aluminum wires twist
- Electrical resistance of aluminum wires
- Stress at 1 percent elongation on steel wires
- Wrapping for steel wire (winding a wire around a mandrel)
- Zinc coating in steel wires
- Cross – sectional area of conductor
- Overall diameter of conductor
- Mass per unit length of conductor (liner density)
- Breaking strength of aluminum and steel wires after stranding
- Surface condition of conductor
- Twist test
- Creep test

- Lay ratio and direction of lay of conductor

Selecting of appropriate conductor length for each of the tests should be performed according to IEC 61089.

5-4- Inspection

The manufacturer shall inform test location and date of type and sample testing to the purchaser at the time of purchase. The manufacturer shall afford the purchaser all necessary and sufficient testing facilities in order to satisfy him. Whether the test results are positive or not, the purchaser can reject factory productions if during of erection time, the conductor specifications have not adoption with necessary requirements or working not satisfiable in utilization and guarantee time.

6- Drawing and documents

6-1- Documents to be given by tender

- Filled conductor schedule (II)
- Catalog and technical pamphlets
- Summary of type test reports
- Detailed summary of exceptions to tender specification
- Packing, shipping, warehousing, erection and operating instruction manuals

6-2- Documents to be given by contractor / supplier

The design, fabrication, factory testing, packing, shipping, warehousing, erection, site tests and operation drawings, documents and manuals shall be submitted as the following:

- Packing, shipping and warehousing details.
- Test reports and certifications for success
- Erection, operating and maintenance instruction manuals
- Drawing that show dimensions and shape of shipping drums, their weights, types and other specifications.
- Complete descriptions of the cleaning method of the conductor
- Creep curves in intervals of one hour, 24 hours, 30 days, one year and ten years with consideration of the conductor creep.
- Description of present facilities for test performance by manufacturer.
- Manufacturers suggestion for minimum pulleys diameter

- Current curves in accordance with temperature increment from zero to 60 °C greater than ambient temperature (ambient temperature equal 40 °C) and propagation coefficient is equal 0.5.
- Fault current conductor curves
- Monthly work progress report
- Time schedules

7- Conductor installation

7-1- General requirements

Contractor shall perform stringing with tension method.
For stringing standard equipment, apparatus and machinery shall be used by contractor. Contractor in stringing procedure shall prevent of conductor dragging on the ground with choosing appropriate policy.
Conductor installation, connections and fastening to clamps shall be so perform that prevent from exertion of extra and unauthorized strength and any damage such as wires scratch, sqush, twist and swell.
Contractor shall have adequate attention to prevent from applying unauthorized load to towers and when if needed the towers shall be supported by anchors. After termination of stringing, anchors shall be picked up.
On the subject of passing from over the 20 kV or under 63, 132, 230 and 400 kV transmission lines, the contractor after final sagging shall measure the nearest points between the two lines and inform the result to the employer representative or consultant and continue stringing after achieving the verification.

7-2- Connections

In stringing, drums with longer length conductor shall be used to reduce the midpoint connection. For this reason, before stringing operation it is necessary that contactor inspect and consider the conductor length and location of midpoint connections.
Appropriate equipment shall be used for cutting the layer of conductor to prevent from wire damages on underneath layer. Connecting shall be so that to guarantee the specified mechanical strength and electrical resistance.
Making connection is not allowable in spans crossing road, railway, buildings and power transmission lines. Also in adjacent spans, not allowed to make midpoint connection.
Location of each midpoint connection shall preset for prevention from passing the conductor from the pulley after pressing operation.

Electrical resistance of each midpoint and endpoint connections shall be measured and recorded by contractor with four terminal microhmmeter and this value shall not be greater than minimum 105 percent of under testing conductor resistance with similar length. Mechanical strength of forenamed connections and clamps shall not be less than 95 percent of related conductor mechanical strength.
In the end of stringing operation, contractor should supply the report for each connection. This report should specify location, date of performance and measured electrical resistance.

7-3- Sagging

Contractor shall use appropriate dynamometer and special camera for sagging control. When sagging is performed on the ground a theodolite shall be used.
Sagging shall be performed according to submitted sag – tension tables.
Conductor temperature in sagging shall be measured by thermometer. This thermometer shall be placed inside the conductor. Conductor steel core shall be replaced with thermometer. Length of conductor specimen shall be approximately 50 to 60 centimeter. For exactly measuring conductor temperature the thermometer shall be placed on the point of conductor support to pulley with a period of 15 minute and sagging shall be performed according to measured temperature.
Conductors sag difference in a bundle shall not be greater than 50 mm and conductors sag in each phase with other phases shall not be greater than 15 cm so that in all phases, conductors have similar tolerance (positive or negative).
The selected spans for sagging in each section shall have length close to the equivalent span. Also two spans in adjacent dead end towers shall consider for sag measuring.

7-4- Stringing and configuration of equipments

Stringing operation shall be done in appropriate atmospheric conditions. While wind cause diversion in midpoint of span greater than 1.5 meter from normal state, and also in very cold or very hot weather that may cause damage to personnel and equipments, stringing operation shall be stopped.
For stringing following notices shall be considered:

- Appropriate site for installation of equipment and machinery shall be selected.
- Equipment must be so installed to be available from each sides for working group and necessary control.
- Stringing machinery and base of drums shall be fastened to the ground.

- Drums shall be set on related bases and far from brake vehicle approximately 10 to 15 meter. Drums shall so set that conductor easily pass from brake vehicle pulley and don't chafe to its groove wall.
- Brake vehicle pulleys shall have semicircle shape and proper coated grooves with plastic or similar materials. The number of pulley grooves shall be so that prevent from slipping conductor layers to each other.
- Direction of conductor entrance to brake vehicle pulley depends on the direction of outer layer wires so that conductor with right handed outer layer shall be enter from left side of the pulley and exit from right side of conductor pulling direction and conductor with left handed outer layer shall be enter from right side of the pulley and exit from left side of conductor pulling direction.
- Contractor shall not string more than 2 drum or approximately 6000 meter of conductor unless in cases of employer confirmation.

The followings items should be performed before stringing:

- Configuration control of all stringing necessaries, equipment and machinery and it safety and security.
- Control of condition and form of work groups.
- Control of security considerations that shall be controlled such as ground connecting and machinery support and bases of drums and anchors.
- Control of (wireless) communication equipment of different responsible persons and operators of brake and puller vehicle and trellis watchman on junctions with energized lines and roads.
- Joint installation is not allowable in crossing over railway, waterway, important communication lines and important transmission lines.
- Installing Proper and necessary earth connections in according to equipment configuration and type of performance
- Location of earth connections shall be so selected that prevent from hazardous potential in equipment that is connected to each other. In the cases that constructing transmission line is in parallel with a energized transmission line or crossing those lines or occurrence of thunder is forecasted it is necessary to install more earth connections in sensitive points.
- Before conductor stringing operation, the stringing and sagging of shield wires in two horizontal and vertical configuration of conductor wires shall be performed.

7-5- Control of grounding equipment and devices

All temporary grounding devices such as wires, grips and rods should be controlled and test and should tolerate the specified fault current.
Current carrying capability of copper or aluminum or aluminum or steel conductor with copper clad grounding conductors shall be conform to IEEE 524.

7-6- Operating with brake and puller vehicle

Operator shall watch out that the motion of vehicles and drums behind of brake vehicle perform smoothly. Each system should be readily controllable and capable of maintaining a constant conductor tension to prevent any sudden jerking or bouncing of the conductor which may cause scathes such as layer swelling or extreme elongation of aluminum wires.
Both brake and puller vehicle shall have dynamometer to show tension strength to facilitate the control of tension during sagging.
In stringing operation watchmen of pulleys shall prevent from pulley speed up on base with adequate brake adjustment.
While stringing is simultaneously done for three phases, coordination and necessary attention shall be applied to control brake and puller vehicle.

7-7- Necessary tension strength for stringing in tension method

Maximum tension strength in this method is so that to provide conductors secure distance between ground and its terrain.
Experimentally proved that most proper tension for this method will be about half of necessary tension during final sag adjustment.
Sag of each conductor shall be accurately according with sag – tension table and ambient temperature.

8- Commissioning tests

8-1- Line preparing for energization

After preparation of line for energization and commissioning, contractor shall inform employer or his representative and submit all documents drawing and verification of control board to employer.
After contractor announcement employer or his representative proceed to inspection and control of the line. If the line is proper for energizing and commissioning tests, contractor officially shall be announced to the employer.

8-2- Tests performance

In preset date, employer or his representative and contractor attend in one of the ends of the line substations and perform following test in presence of accountable persons.

- Line insulation test that carry on with 5 kV megger.
- Resistance measurement test of line conductors.

After tests are performed successfully the line is energized experimentally from one side and then perform test of equality of both side phases of the line. While do not occur any problem other side of the line is connected to the network and line loading perform to forecasted range.

It is clear that all consideration of protective systems (coordination of protective relays) shall be performed before the line energization.

CONDUCTOR SCHEDULE (I)
RATING AND CHARACTERISTIC OF CONDUCTOR

ITEM	DESCRIPTION		TECHNICAL SPECIFICATION FOR SYSTEMS WITH FOLLOWING NOMINAL VOLTAGES			
			63/66 KV	132 KV	230 KV	400 KV
1	**Particulars of systems**					
1-1	Nominal system voltage	kV	63/66	132	230	400
1-2	Highest system voltage	kV	72.5	145	245	420
1-3	Nominal system frequency	Hz	50	50	50	50
1-4	Max. time of fault current occurrence	Sec	1	1	1	1
2	**Service condition**					
2-1	Max. ambient temperature	°C	40/45/50/55	40/45/50/55	40/45/50/55	40/45/50/55
2-2	Min. ambient temperature	°C	-40/-35/-30/-25	-40/-35/-30/-25	-40/-35/-30/-25	-40/-35/-30/-25
2-3	Max. value of daily temperature	°C	*	*	*	*
2-4	Altitude above sea level	m	1000/1500/2000/2500	1000/1500/2000/2500	1000/1500/2000/2500	1000/1500/2000/2500
2-5	Pollution level		Low/medium/high/ very high/special	Low/medium/high/ very high/special	Low/medium/high/ very high/special	Low/medium/high/ very high/special
2-6	Max. wind velocity	m/s	30/40/45	30/40/45	30/40/45	30/40/45
2-7	Wind velocity in ice condition	m/s	20	20	20	20
2-8	Ice coating thickness	mm	5/10/20/25	5/10/20/25	5/10/20/25	5/10/20/25
2-9	Seismic acceleration	m/s^2	0/2-0/25-0/3-0/35	0/2-0/25-0/3-0/35	0/2-0/25-0/3-0/35	0/2-0/25-0/3-0/35
2-10	Relative humidity	%	90/95/greater than 95	90/95/greater than 95	90/95/greater than 95	90/95/greater than 95

CONDUCTOR SCHEDULE (I)
RATING AND CHARACTERISTIC OF CONDUCTOR

ITEM	DESCRIPTION		TECHNICAL SPECIFICATION FOR SYSTEMS WITH FOLLOWING NOMINAL VOLTAGES			
			63/66 KV	132 KV	230 KV	400 KV
3	**Conductor characteristic**					
3-1	Nominal transmission line current	A	*	*	*	*
3-2	Transmission line fault current	kA	*	*	*	*
3-3	Conductor name		Lynx/Hawk/squab/strling /canary/curlew/grakle	Lynx/Hawk/squab/strling /canary/curlew/grakle	Lynx/Hawk/squab/strling /canary/curlew/grakle	Lynx/Hawk/squab/strling /canary/curlew/grakle
3-4	Conductor cross – section (aluminum section)	mm^2	*	*	*	*
3-5	Steel core coating		GS/AS/AW/AZ	GS/AS/AW/AZ	GS/AS/AW/AZ	GS/AS/AW/AZ
3-6	Is grease necessary?	(Yes/No)	*	*	*	*
3-7	Grease type		*	*	*	*

* These will be specified by designer engineer.

CONDUCTOR SCHEDULE (II)
RATING AND CHARACTERISTIC OF CONDUCTOR

ITEM	DESCRIPTION		TECHNICAL SPECIFICATION FOR SYSTEMS WITH FOLLOWING NOMINAL VOLTAGES			
			63/66 KV	132 KV	230 KV	400 KV
1	Type of conductor					
2	Name of conductor					
3	Total cross section	mm^2				
4	Cross section of aluminum	mm^2				
5	Cross section of steel	mm^2				
6	Diameter of conductor	mm				
7	Number and diameter of aluminum wires	number /mm				
8	Number and diameter of steel wires	number /mm				
9	Number of aluminum layers					
10	Number of steel layers					
11	Ultimate breaking strength of conductor (guarantee)	N				
12	Equal temperature of creep	°C				
13	Aluminum wires (before stranding):					
13-1	Tension on breaking tensile	N/mm^2				
13-2	Elongation in 250 mm of conductor length in breaking moment	%				
13-3	Minimum conductivity					

CONDUCTOR SCHEDULE (II)
RATING AND CHARACTERISTIC OF CONDUCTOR

ITEM	DESCRIPTION		TECHNICAL SPECIFICATION FOR SYSTEMS WITH FOLLOWING NOMINAL VOLTAGES			
			63/66 KV	132 KV	230 KV	400 KV
13-4	Solidity according to ASTM 230					
14	Steel wires (before standing):					
14-1	Tension on breaking tensile	N/mm^2				
14-2	Elongation in 250 mm of conductor length in breaking moment	%				
14-3	Minimum tension in one percent elongation	N/mm^2				
15	Equal elasticity module (final and primary)	N/mm^2				
16	Equal length expansion coefficient	°C				
17	Max. dc resistance per kilometer in 20 °C	Ω				
18	Max. permanent load current:					
18-1	Min. ambient temperature, conductor temperature 90 °C	A				
18-2	Max. ambient temperature, conductor temperature 90 °C	A				
19	Weight of conductor per km	kg				
20	Length of conductor on drum	m				
21	Weight of drum without conductor	kg				

CONDUCTOR SCHEDULE (II)
RATING AND CHARACTERISTIC OF CONDUCTOR

ITEM	DESCRIPTION		TECHNICAL SPECIFICATION FOR SYSTEMS WITH FOLLOWING NOMINAL VOLTAGES			
			63/66 KV	132 KV	230 KV	400 KV
22	Weight of complete drum with conductor	kg				
23	Diameter of conductor on shipping drum	cm				
24	Drum type	metal /wood				
25	AC resistance of conductor in nominal frequency					
25-1	In 25 °C	Ω/km				
25-2	In 50 °C	Ω/km				
25-3	In 75 °C	Ω/km				
25-4	In 90 °C	Ω/km				
26	GMR in nominal frequency	cm				
27	Grease type applied in conductor					