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# Review and Study Paper of Conductors Used In Transmission, Distribution and High Power Appliances

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***Abstract***: **-- Electrical energy forms a key factor in the development of a nation. Electricity cannot be stored and needs to be transmitted to the load center from the generation site. For transmission and distribution of electricity, conductors play a major role. This paper deals with the study of different types of conductors and underground cables used in transmission and distribution systems along with electrical cables used in high power appliances. The paper reviews aluminium conductors and cables, important electrical and mechanical parameters and properties are discussed.**

***Keywords*— Transmission conductor, Distribution conductors Underground cable, High power appliances.**

## I. INTRODUCTION

This overview contains information about conductors used in electrical transmission lines, distribution and high power application. Transmission and distribution conductors have different technical requirements than that of conductors used in high power application. In overhead power transmission lines which are suspended by towers, the bare conductor is generally made by using aluminium materials. The various types of conductors used in transmission line are aluminium alloy conductors and they are AAC, AAAC, ACSR, ACCC etc. AAC and ACSR are the most common type of conductors which are used in transmission line. Conductors used in high power application includes a conductor and insulation, and is suitable for run underground or underwater. This is a contrast to the overhead line, which does not have any insulation. High voltage power cable have a metallic shield layer over the insulation which is connected to the ground and is designed to equalize the dielectric stress on the insulation layer. High-voltage cables can be of any length having comparatively shorter cables used in apparatus, longer cables run within buidings or as buried cables in the industrial plants or for power distribution, and the longest cables often used as submarine cables under the ocean for power transmission.

## II. OVERHEAD TRANSMISSION AND DISTRIBUTION CONDUCTORS

Overhead transmission and distribution conductors mainly include All Aluminium Conductor(AAC), All Aluminium Alloy Conductors(AAAC), Aluminium Conductor Steel Reinforced (ACSR) and Aluminium Conductor Composite Core(ACCC).

### 1. AAC

AAC conductor also known as aluminum stranded conductor. This conductor is manufactured from aluminium which is electrolytically pure which have purity of minimum 99.5% of aluminium (with minimum Conductivity of 61%). AAC conductor is used mainly in urban areas because the spacing is short and the supports are close. All aluminium conductors are made up of one or more strands of aluminum wire depending on the end usage. AAC conductors are also used extensively in coastal areas because they have a very high degree of corrosion resistance. Key features of AAC conductor are as follows

- Excellent resistance to corrosion
- Ideal for use in coastal area
- Suitable for low voltage line & medium voltage lines in urban area

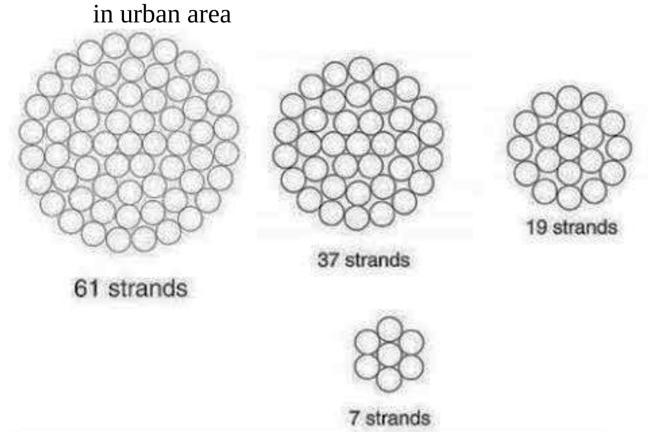


***Fig 1:-Stranding of AAC***

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*Table 1: Properties of AAC*

| Code Word | No./Standing Wire Dia. | Approximate Weight Kg/km | Maximum DC Resistance at 20$^{0}$ C | Braking Load | Current rating | | Voltage Drop |
|---|---|---|---|---|---|---|---|
| | | | | | T | Tr | |
| | x/mm | Kg/mm | Ω/km | kN | A | A | mV/A/m |
| Midge | 7/2.06 | 64 | 1.227 | 4.00 | 114 | 72 | 3.056 |
| Gnat | 7/2.21 | 73 | 1.086 | 4.59 | 124 | 78 | 2.808 |
| Mosquito | 7/2.59 | 101 | 0.7731 | 6.17 | 144 | 93 | 2.079 |
| Ant | 7/3.10 | 145 | 0.5419 | 8.30 | 181 | 112 | 1.590 |
| Fly | 7/3.40 | 174 | 0.4505 | 9.90 | 199 | 124 | 1.390 |
| Blue bottle | 7/3.66 | 202 | 0.3884 | 11.34 | 219 | 132 | 1.154 |
| Wasp | 7/4.39 | 290 | 0.2702 | 16.00 | 271 | 158 | 0,884 |
| Bee | 7/4.90 | 391 | 0.2169 | 19.90 | 308 | 175 | 0.784 |

Where,
T:- Temperate
Tr :- Tropica

## 2. AAAC

This conductor mainly consist of Al Mg Si alloy having high electrical conductivity which contain Magnesium 0.6-0.9% & Silicon 0.5-0.9% , to give it better mechanical properties after treatment. These conductor has a better corrosion resistance and better strength to weight ratio and improved electrical conductivity than ACSR Conductor on equal diameter basis. AAAC conductors are generally made out of aluminum alloy 6201 (Minimum Conductivity is 54%). AAAC also exhibits substantially better electrical loss characteristics than there equivalent single layer ACSR constructions. However the thermal coefficient of expansion is greater than that of ACSR. The maximum short circuit temperature of AAAC must be below 340 to prevent dangerous conductor annealing.

*Fig 2:- Stranding of AAAC*

The key features of AAAC are as follows

- Better sag characteristics
- Improved electrical properties
- Excellent corrosion resistance
- Lighter than ACSR
- Reduced losses

*Table 2: Properties of AAAC*

| Code Word | Strands Strands /Diameter of wire(mm) | Weight Weight (kg) | Breaking Load (KN) | Calculated Resistance at 20 C Max (omh/km) | Breaking Length(km) |
|---|---|---|---|---|---|
| Box | 7/1.85 | 51 | 5.27 | 1.7490 | 10.63 |
| Acacia | 7/2.08 | 65 | 6.67 | 1.3840 | 10.46 |
| Almond | 7/2.34 | 82 | 8.45 | 1.0930 | 10.50 |
| Cedar | 7/2.54 | 97 | 9.95 | 0.9281 | 10.45 |
| Fir | 40 | 131 | 13.41 | 0.6881 | 10.44 |
| Hazel | 50 | 164 | 16.78 | 0.5498 | 10.43 |
| Pine | 60 | 196 | 20.09 | 0.4594 | 10.45 |

## 3. ACSR

ACSR consists of steel core with concentrically stranded EC grade aluminium wires. The core may consists of single earth stranded galvanised steel wires imparting high mechanical strength to the conductor , with class A, class B or class C zinc coating to offer corrosion protection this make it suitable for installations with extra long spans & river crossing etc. It combines the high tensile strength and rigidness of steel with light weight and conductivity of EC grade aluminium The inner core wires of ACSR may be of zinc coated (galvanized) steel, available in standard weight class A coating or heavier coating of class B or class C. Class B coatings are about twice the thickness of class A, and class C coatings are three times thicker than class A. The inner cores may be of aluminium coated (aluminized) steel or aluminium clad steel.

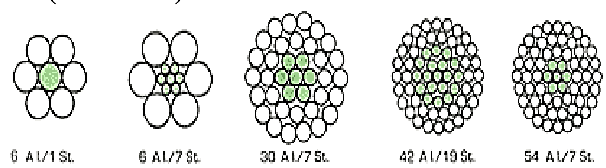


*Fig 3:- Stranding of ACSR*

The key features of ACSR conductor are as fo;;ows

- High tensile strength and High mechanical strength to weight ratio
- Low corona effect
- Better sag properties
- Economic and best suited for transmission lines with long spans.

***Design criteria & construction:-***

(Materials for ACSR Conductor):-

i) Aluminium: The aluminium strands of the steel core aluminium conductor shall be hard drawn electrolytic aluminium rods of E.C. Grade having purity not less than 99.5%.

ii) Steel: The steel wire strand shall be drawn from High carbon steel wire rods produced by either the acid or the basic open hearth process, or, the electric furnace process of the basic oxygen process and shall conform to the following requirements as to the chemical composition. Element % Composition Manganese 0.40 to 1.10 Carbon 0.50 to 0.85 Phosphorus 0.05 max.Sulphur0.05 max. Silicon 0.15 to 0.35

iii) Zinc: The zinc used for galvanizing shall be electrolytic High Grade (HG) quality of 99.95% purity. It shall conform to the requirements of IS: 209.

Table 3: Properties of ACSR

| Code word | Nominal Al. area(mm2) | Approximate weight(kg/km) | Breaking load (kN) | Calculated resistance at 20$^0$C max.(ohm/km) | Current rating | |
|---|---|---|---|---|---|---|
| | | | | | T | Tr |
| Gopher | 25 | 106 | 9.60 | 1.093 | 126 | 77 |
| Weasel | 30 | 128 | 11.40 | 0.9077 | 134 | 84 |
| Ferret | 40 | 172 | 15.20 | 0.6766 | 161 | 98 |
| Rabbit | 50 | 214 | 18.40 | 0.5426 | 185 | 112 |
| Horse | 70 | 538 | 61.20 | 0.3936 | 268 | 148 |
| Racoon | 80 | 320 | 27.20 | 0.3623 | 231 | 131 |
| Dog | 100 | 394 | 32.70 | 0.2733 | 278 | 153 |
| Wolf | 150 | 726 | 69.20 | 0.1828 | 355 | 162 |
| Dingo | 150 | 506 | 35.70 | 0.1815 | 349 | 179 |

**4. ACCC**

In 2002, CTC Global started the development of the 'High-Capacity Low-Sag' ACCC® ("Aluminium Conductor Composite Core") conductor. After considerable testing, this conductor was commercially establish in 2005. The new conductor achieved its high capacity objective while offering a substantial reduction in thermal sag compared to any other commercially available conductor, due to its very low coefficient of thermal expansion. More importantly, due to decreased weight of composite core compared to steel, an ACCC® Drake size conductor, for instance, could incorporate 28% more aluminum using compact trapezoidal shaped strands, with a slight overall reduction in weight.

The key features of ACCC conductors are as follows

- Consists of a hybrid carbon and glass fiber composite core
- Free of metallurgical corrosion associated with steel core
- Excellent self-damping characteristics;
- extreme ice load survivability due to the high strength and elasticity of the composite core
- The conductive strands are generally fully annealed aluminum and trapezoidal in shape to provide the greatest conductivity and lowest possible electrical resistance for any given conductor diameter.
- The central carbon fiber core is surrounded by high-grade boron-free glass fibers to improve flexibility and toughness while preventing galvanic corrosion between the carbon fibers and the aluminum strands
- Has a lowest-in-the-industry coefficient of thermal expansion which reduces conductor sag under high electrical load / high temperature conditions.

*Fig 4:- Stranding of ACCC*

 

*Table 4: Properties of ACCC conductor*

| Code word | Daimatre | Weight | Core Rated Srtrength | Conduct or rated strength | Max Dc Resisance |
|---|---|---|---|---|---|
| ATSM Size | (in) | (lb/kft) | (kips) | (kips) | (ohm/ mile) |
| Pasadena | 0.616 | 321 | 13.6 | 15.5 | 0.2942 |
| Linnet | 0.720 | 440 | 13.6 | 16.3 | 0.2096 |
| Oriole | 0.741 | 463 | 19.3 | 22.1 | 0.2059 |
| Waco | 0.770 | 485 | 22.9 | 25.8 | 0.1990 |
| Laredo | 0.807 | 548 | 19.3 | 22.7 | 0.1704 |
| Irving | 0.882 | 649 | 29.3 | 33.2 | 0.1483 |
| Hawk | 0.852 | 625 | 19.3 | 23.2 | 0.1477 |
| Dove | 0.927 | 728 | 22.9 | 27.5 | 0.1265 |
| Grosbeak | 0.990 | 837 | 25.2 | 30.4 | 0.1103 |
| Lubbock | 1.040 | 924 | 29.3 | 35.1 | 0.09990 |

## III. CONDUCTORS USED IN HIGH POWER APPLICATIONS

### *A. Industrial Cables*

Industrial cables cover a wide range of applications including industrial plants, buildings, ordinary houses, railway rolling stocks ,ships and industrial machinery, so that varieties of electrical wires and cables are developed and supplied in response to the service condition and required performance. Industrial Cable is used in tough, demanding applications. This type of cable works in high temperature environments as well as high-voltage uses. It can withstand harsh treatment such as abrasion and contact with flames

**1. EPR/HYP Unshielded Power Cable (2400 V)**

- ➢ EPR/HYP Unshielded Power Cable (2400 V) Construction:
  - o Conductor:

1000 kcmil annealed bare copper Class B strand
  - o Extended Strand Shield (ESS):

Extruded Thermoset Semi-Conducting Stress Control Layer over conductor
  - o Insulation:

Ethylene Propylene Rubber (EPR) colored to contrast with black jacket material
  - o Jacket: Low-Lead Chlorosulfonated Polyethylene (CSPE) /Elastomer blend
- ➢ EPR/HYP Unshielded Power Cable (2400 V) Applications:
  - o For use in industrial and utility applications, where ease of installation is a major concern because of limited space and exposure to personnel is minimal
  - o For use in wet or dry locations, when installed in accordance with NEC
  - o For use in aerial, conduit, open tray and underground duct installations
- ➢ EPR/HYP Unshielded Power Cable (2400 V) Features:
  - o Rated at 90°C
  - o Excellent heat and moisture resistance
  - o Flexibility for easy handling
  - o High dielectric strength
  - o Low moisture absorption
  - o Electrical stability under stress
  - o Low dielectric loss
  - o Chemical and radiation resistant
  - o Simplifies splicing and termination because there is no need to handle the cable shield
  - o Extra-tough, mechanically rugged composite insulation and jacket construction
  - o Meets cold bend test at -35°C

*Table 5:Properties of EPR/HYP Unshielded Power Cable*

| Part no. | Nom. O.D. (in) | Approx .LSB/ MFT | Nom. Insul. Thick.(in) | Nom. Dia. Of cond. | Min. Insul. Dia.(in) |
|---|---|---|---|---|---|
| 74505.205400-18 | 0.5800 | 196 | 0.125 | 0.14 | 0.41 |
| 74505.205300-18 | 0.6200 | 241 | 0.125 | 0.17 | 0.44 |
| 74505.205200-18 | 0.6600 | 308 | 0.125 | 0.22 | 0.49 |

**2. 35kV EPR/AIA/PVC Shielded Armored PowerCable Construction**

- o Conductor:

1/0 AWG thru 750 kcmil bare, compact copper Class B strand
- o Extended Strand Shield (ESS):

Thermoset Semi-Conducting Extruded Stress Control Layer over conductor
- o Insulation:

Ethylene Propylene Rubber (EPR) colored to contrast with black conducting layer
- o Extruded Insulation Shield (EIS):

 

Thermoset Semi-Conducting Polymeric Layer free stripping from insulation

- Shield:

5 mil annealed copper tape with a minimum 25% overlap

- Ground:

Annealed bare copper Class B stranding per ASTM B8

- Armor:

Aluminum Interlocked Armor (AIA)

- Jacket:

Flame retardant, moisture and sunlight resistant Polyvinyl Chloride (PVC) - Red

➢ 35kV EPR/AIA/PVC Shielded Armored Power Cable Applications:

- Ideally suited for use in a broad range of commercial, industrial and utility applications where reliability is the major concern, maximum performance is demanded, space is limited, ease of installation is critical and fire resistance is necessary
- May be installed in wet or dry locations, indoors or outdoors and in exposed or concealed work
- May be used in cable trays or on approved supports in protected areas
- Permitted for use in Class I, Class II Division 2, and Class III Divisions 1 and 2 per NEC Article 334

➢ 35kV EPR/AIA/PVC Shielded Armored Power Cable Features:

- Rated at 105°C wet or dry
- Excellent heat and moisture resistance
- Outstanding corona resistance
- Flexibility for easy handling
- High dielectric strength
- Low moisture absorption
- Electrical stability under stress
- Low dielectric loss
- Chemical and radiation resistant
- Excellent crush resistance
- Cost-effective alternative to installations in conduit
- Meets cold bend test at -25°C

***Table 6: Properties of 35kV EPR/AIA/PVC Shielded Armored Power Cable***

| Part no. | Jacket thick | Nom. O.D. cable (in) | Nom. Dia. Of cond. | Armour(in) | Min. insul. Dia (in) | Approx LSB/MFT |
|---|---|---|---|---|---|---|
| 8740.267550-18 | 0.075 | 2.93 | 0.34 | 2.77 | 1.02 | 4063 |
| 8740.267600-18 | 0.075 | 3.02 | 0.38 | 2.86 | 1.06 | 4441 |

**B) Marine Cable**

GPTM Tinned Copper marine wire and GPTM Bare Copper marine cable can be used for general circuit wiring in marine applications within environments up to 105 degrees Celsius. Our Flat Multi-conductor Marine Cable may be used for both marine cable and brake cable

**1. Tinned Copper Marine Wire Features**

Tinned copper marine wire can be used in 105°C marine applications and general circuit wiring.

***Table 7: Properties of Tinned copper marine wire***

| Part number | size | Conductor stranding | Nom. Insl. Thickness(in) | Nom. O. D. (in) | Approx LBS /MFT |
|---|---|---|---|---|---|
| GPTM 18 16T | 18 | 16/30 | 0.023 | 0.0920 | 8.35 |
| GPTM 16 19T | 16 | 19/29 | 0.023 | 0.1030 | 11.1 |
| GPTM14 19T | 14 | 19/27 | 0.023 | 0.1170 | 16.2 |
| GPTM 12 19T | 12 | 19/25 | 0.026 | 0.1410 | 24.5 |
| GPTM 10 19T | 10 | 19/23 | 0.031 | 0.1730 | 37.4 |
| GPTM 8 19T | 8 | 19/21 | 0.037 | 0.2150 | 58.6 |

 

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2. Bare Copper GPTM Marine Wire

- ➢ GPTM Bare Copper Marine Wire Construction:
- ○ Conductor: Stranded Copper, Bare
- ○ Insulation: Polyvinylchloride (PVC)
- ➢ GPTM Bare Copper Marine Wire Applications:
- ○ This GPTM marine wire can be used for general circuit wiring in marine applications with temperatures not exceeding 105°C.

***Table 8: Properties of GPTM Bare Copper Marine Wire***

| Part number | Size | Conductor stranding | Nom. Insl. Thickness(in) | Nom. O. D. (in) | Approx LBS/MFT |
|---|---|---|---|---|---|
| GPTM 18 | 18 | 16/30 | 0.023 | 0.0930 | 8.35 |
| GPTM 16 | 16 | 19/29 | 0.023 | 0.1020 | 11.1 |
| GPTM 14 | 14 | 19/27 | 0.023 | 0.1180 | 16.2 |
| GPTM 12 | 12 | 19/25 | 0.026 | 0.1410 | 24.5 |
| GPTM 10 | 10 | 19/23 | 0.031 | 0.1780 | 37.4 |
| GPTM 8 | 8 | 19/21 | 0.033 | 0.2150 | 58.6 |

3. Flat Multi-Conductor Marine Cable

- ➢ Marine Cable Features:
- ○ Boat Cable Polyvinylchloride(PVC) 105°C Dry/75°C Wet; 600 Volts
- ○ Flat boat cable can be used for marine and brake cable.
- ○ Meets UL Style BC-5W2 for boat cable. (UL 1426 rating available upon request)
- ➢ Flat Boat Cable Construction:
- ○ Conductor: Stranded Tinned Copper
- ○ Jacket: Polyvinylchloride (PVC), White or Gray
- ○ Insulation: Polyvinylchloride (PVC)

***Table 9: Properties of Flat Multi-Conductor Marine Cable***

| Part number | Size | No. of cond. | Conductor stranding | Nom. Insl. Thickness(in) | Approx Dimension | Jacket Thick | Approx LBS/M Ft |
|---|---|---|---|---|---|---|---|
| Boat 18/2 | 18 | 2 | 16/30 | 0.032 | 0.17* 0.280 | 0.030 | 33 |
| Boat 16/2 | 16 | 2 | 26/30 | 0.032 | 0.18* 0.322 | 0.030 | 42 |
| Boat 16/3 | 16 | 3 | 26/30 | 0.032 | 0.18* 0.448 | 0.030 | 59 |
| Boat 14/2 | 14 | 2 | 41/30 | 0.032 | 0.20* 0.356 | 0.030 | 55 |

## IV. CONCLUSION

More recently, many innovative conductor designs have been developed to address changing needs of the electrical utility industry. New alloys have been developed to provide thermal stability increased conductivity, vibration resistance and other specific characteristics. Conductor design or selection for transmission, distribution and high power application has become a science. The selection of the optimum conductor type and size for a given line design requires a complete understanding of the characteristics of all the available conductor types. This understanding must encompass more just the current carrying capability or thermal performance of a conductor. There is no unique process by which all transmission, distribution and high power lines are designed. It is clear that all major cost components of line design depends on the electrical and mechanical parameters of conductor

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