# UPGRADATION OF EXISITING 66 KV TRANSMISSION LINE WITH SUITABLE HTLS CONDUCTOR TECHNOLOGY IN NEPAL

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## SYNOPSIS

Utilities in almost all parts of the world face a common obstacle in the construction of new overhead transmission line - obtaining land for their clearway (ROW). Moreover, due to the ever increasing power demand and pressing needs of integrating renewable energy sources into the grid, increasing the power transfer capacity of existing transmission line, seems to be the one of the viable solution. The present condition of the existing transmission corridor may be completely different from the one designed years ago. Hence, the selection of suitable HTLS conductor technology considering ruling span and existing tower loadings may not meet the ground clearance requirements. So, evaluating with respect to present conditions like actual ground clearance of the complete transmission corridor, current tower loadings, spotting and weather conditions is more important and would bring cost effective and reliable solution. This paper elaborates the advantages of selecting technology, considering the present conditions of the transmission corridor over the ruling span methodology, in one such case in Nepal. The surveyed data of the existing line has been used in PLS CADD for the selection of suitable HTLS conductor technology to double the power evacuation capacity considering optimum cost and reliability.

## KEYWORDS

Reconductoring, Uprating, transmission line, High Temperature Low Sag (HTLS) Conductor, ground clearance.

# 1. INTRODUCTION

In many countries of the world, new power lines have not been built from many years as obtaining right of way is difficult. Nevertheless, over the same period of the time, the world experienced an increase in power consumption. But most of the transmission lines are strung with conventional conductors like ACSR, AAC, AAAC, ACAR etc., and by using the same lines it is difficult to draw more power. It has thus become necessary to uprate the thermal power transfer capacity. Uprating of overhead line is possible by increasing current carrying capacity of transmission line, but that may lead to increase in sag value by considering ruling span with same towers/poles, which may not meet the ground clearance of existing line. So, evacuating more power with present conditions such as existing ground clearance and towers/poles, there is an optimal technique for Uprating the transmission line with high temperature low sag conductors (HTLS).

HTLS has been used across the world to uprate the existing transmission line. The investigation of different techniques to improve the transmission system capacity in power network shows that HTLS conductor was useful in uprating by increasing current rating. More than double increase in power capacity was obtained by replacing conventional conductor with HTLS Conductor, which was evaluated to be the best solution from both technical and economic aspects. This paper elaborates the advantages of selecting suitable HTLS technology, with respect to the existing tower, weather and ground clearance conditions of the transmission corridor over the ruling span methodology, in one such case in Nepal to enhance the power transfer capacity.

# 2. HIGH TEMPERATURE LOW SAG CONDUCTORS

"High Temperature Conductor" is defined as a conductor that is designed for applications where continuous operating temperature is higher than the traditional conductors which is about $75^0$C to $85^0$C.

"Low Sag" is defined on the basis of at that particular operating temperature sag should matches with 'traditional conductors' sag value.

HTLS Conductors are made by thermal-resistance aluminium/super thermal-resistance aluminium/annealed aluminium layers stranded around a core of material with low coefficient of thermal expansion.

Note: The maximum permissible duration of emergency operating temperature of HTLS Conductor shouldn't be more than 400 hours for total life of the conductor.

## 2.1. Conductive Layer – Aluminium

Generally, the conventional aluminium and its alloy has limitation of operating temperature from $75^0$C to $100^0$C throughout its life span. The conventional aluminium and aluminium alloy (1350,1370,6201,6101, Al59,1120, etc) will lose its strength at higher temperature because of annealing.

The challenge of increasing the operating temperature of the aluminium and its alloy without loss of its electrical conductivity was addressed with the following high temperature electrical conductivity aluminium and its alloy:

a) High temperature EC grade – 1350 – Annealed Aluminium

b) Thermal resistant aluminium alloy – Al-Zr alloy (Aluminium-Zirconium)

TABLE:1 Comparison of different aluminium alloys

**TABLE: 1**

| Properties | ACSR (Hard drawn 1350 Al) | Annealed Aluminium – 1350 | TAL (Thermal Alloy Al Zr) | STAL (Super Thermal Alloy Al Zr) |
|---|---|---|---|---|
| Tensile Strength in MPa | 160 | 60 | 160 | 160 |
| Conductivity %IACS | 61 | 63 | 60 | 60 |
| Continuous Operating Temperature | 85 | 250 | 150 | 210 |

## 2.2. Core – Strength Member

Aluminium has good electrical conductivity and lesser density but the challenge is tensile strength and endurance limit. So ACSR uses steel core as strength member for reinforcement. Steel has higher strength, lower linear expansion than aluminium but the constraint is lower electrical conductivity and higher density.

The core material for HTLS conductors should have:

- High strength
- Less density
- Less linear expansion
- Good modulus of elasticity

In the past, development in core materials were made to increase the strength of steel or to reduce the linear expansion with alloy steel etc. But in the year 2002, composite materials were introduced. The composite materials have higher tensile strength, less density, less linear expansion but the challenges are compressive strength, modulus of elasticity.

Commercially available core materials are listed below

Steel →

- Ultra High Strength Steel (UHS)
- Extra High Strength Steel (EHS)
- High Strength Steel (HS)

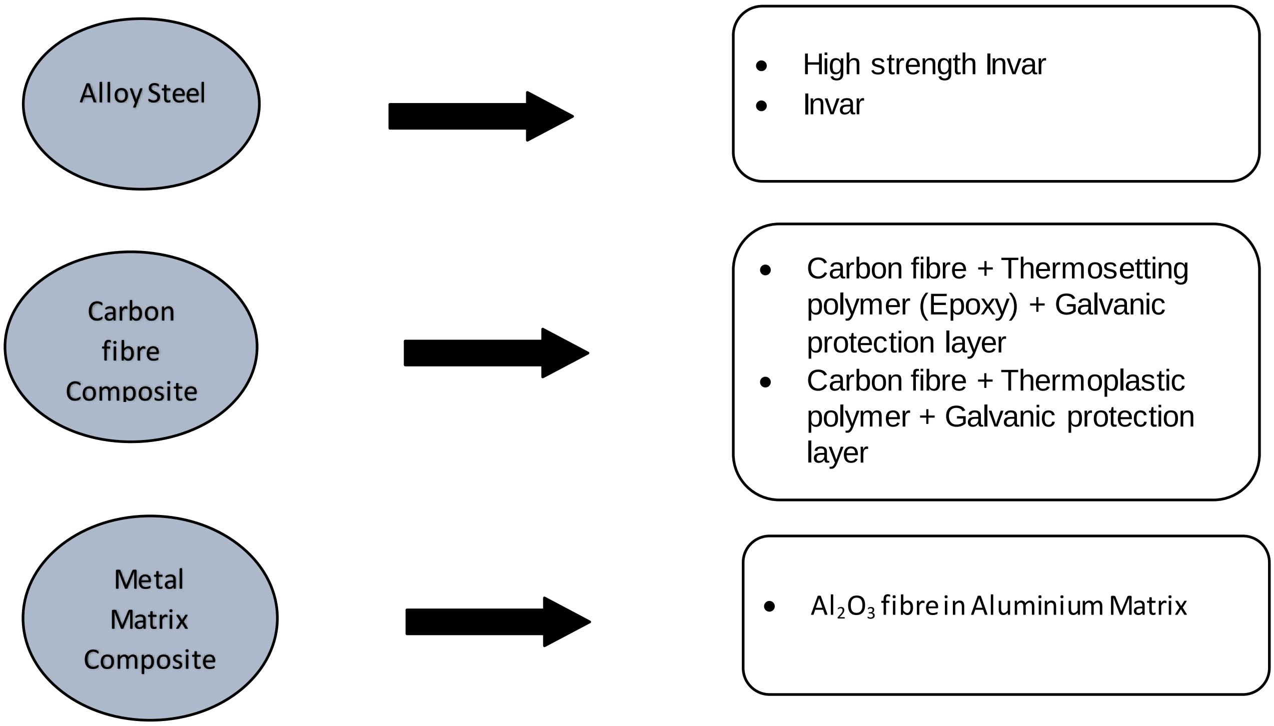
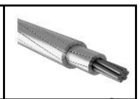
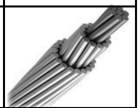



TABLE: 2 The list of commercially available HTLS technologies are as follows:

**TABLE: 2**

| | | |
|---|---|---|
| ACSS | Aluminium Conductor Steel Supported |  |
| TACSR | Thermal Resistant Aluminium Alloy Conductor Steel Reinforced |  |
| GTACSR / GZTACSR | Gap Type Ultra Thermal Resistant Aluminium Alloy Conductor Steel Reinforced |  |
| STACIR | Super Thermal Aluminium Alloy Conductor Invar Reinforced |  |
| ACCC | Aluminium Conductor Composite Core |  |
| ACFR | Aluminium Conductor Faber Reinforced |  |
| ACCR | Aluminium Conductor Composite Reinforced |  |

## 3. NEPAL 66 KV LINE TECHNICAL CONSEQUENCES

### 3.1 Scope of the Project:

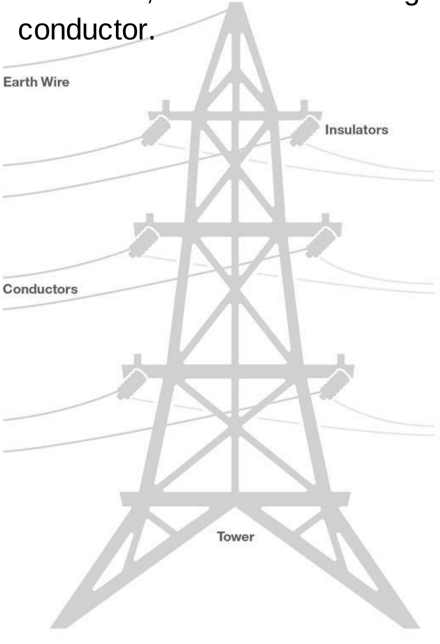
The overhead transmission lines, having voltage level of 66 kv are mostly equipped with ACSR 150 mm2 & ACSR 120 mm2 conductors.
To enhance the power transfer capacity, the first solution considered, was to install new overhead line. For the new transmission lines increasing power transfer capacity is easy, as it can be performed by increasing portion of aluminium or by increasing the number of conductors in bundle.
However, this solution has several inconveniencies. First, land saturation that generates difficulty to get right of way to install a new overhead line. Also, the period of time when the need of a new line is identified, until the line is finally installed can be a decade or longer. Another problem is that a new overhead line produces an increment of visual and environmental impact. These factors make a sector of the society refuse the installation of new overhead lines.
Taking into account the difficulties to install new line, second solution is to improve the current rating of existing line by replacing traditional conductor with HTLS Conductor. Reconductoring the line with HTLS conductors without any tower reinforcements with short time execution and a reasonable cost. With two times the current carrying capacity, HTLS Conductors maintaining the existing ground clearances.

### 3.2 Existing Tower Loadings:

Tower loading is the most vital input for designing any transmission line. The existing towers in the 66 KV transmission line has been designed with various types of loads. In the load calculation, wind plays a major role.

In this case the existing component of tower like insulator string, ground wire will remain the same but the existing conductor will be replaced with new HTLS conductor. So, the only change in component is overhead conductor.

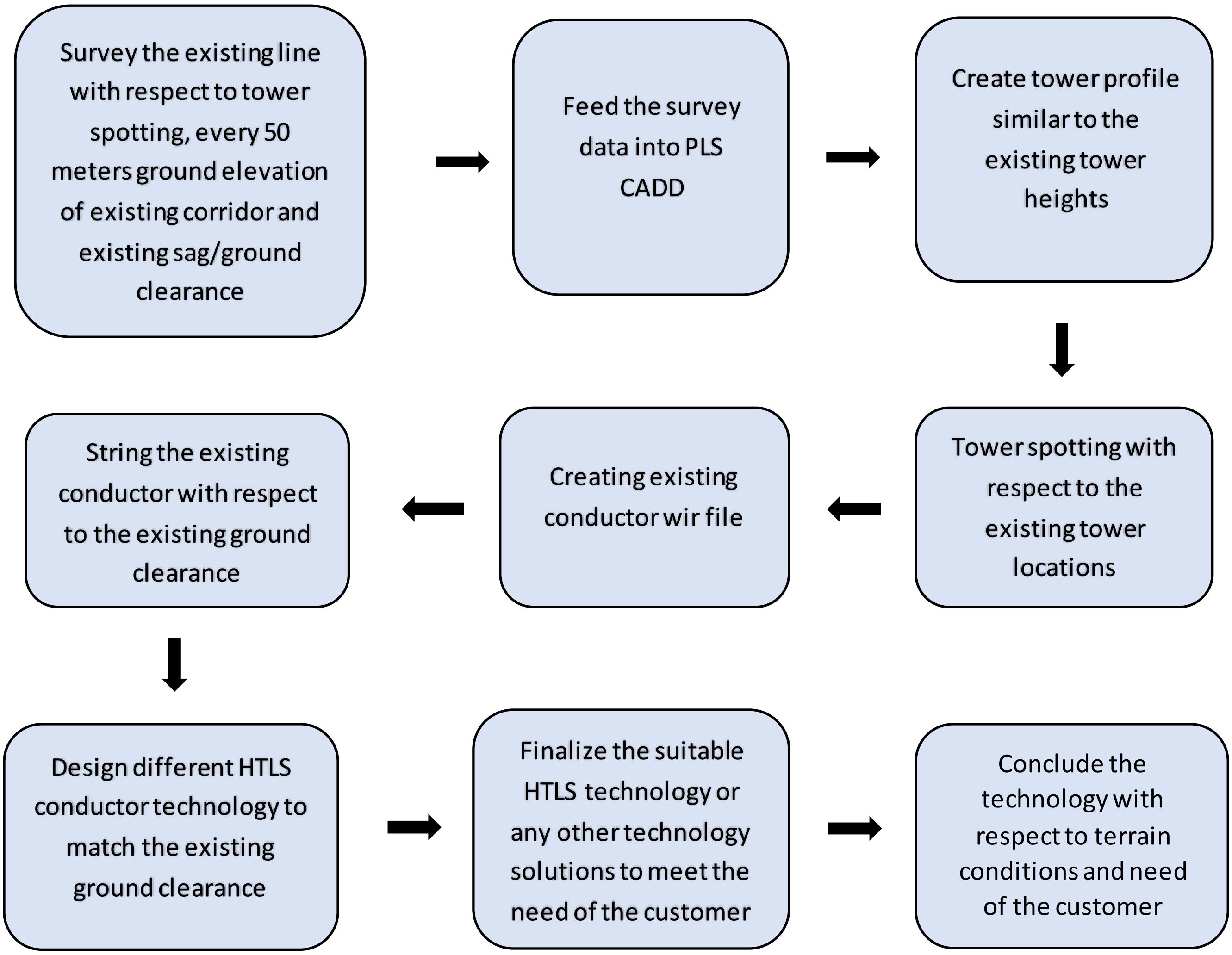
The existing tower was designed with ruling span and wind conditions depending on the weather condition of the corridors. So, the proposed HTLS conductor should have equal or lesser loading conditions of the existing ACSR conductor under the designed conditions of tower. So, the data of existing tower design plays a vital role in designing a suitable HTLS conductor.




The conductor loading condition:

1) **Transverse Load**
   Wind load on conductor
   Mechanical tension of conductor
2) **Vertical load**
   Loads due to weight of conductor
3) **Longitudinal Load**
   Unbalanced horizontal load due to mechanical tension of conductor

## 4. OUR APPROACH FOR RECONDUCTORING OF EXISTING LINE WITH SUITABLE HTLS TECHNOLOGY




## 6. TECHNICAL ANALYSIS

To maintain the line's safety in operation, for example to conserve the towers and the insulating strings when using HTLS conductors, the following restrictions have to be fulfilled:

**TABLE: 3**

The HTLS conductor shall meet the following minimum requirements:

| Description | Unit | Value |
|---|---|---|
| Overall diameter of complete Conductor | mm | Not exceeding 15.74 |
| Approx. mass of complete conductor | Kg/km | Less than or equal to 528 |
| Direction of lay of outer layer | - | Right Hand |

For maintaining the ground clearance of existing line, the HTLS Conductor should meet the following sag tension requirements as specified in table: 4

**TABLE: 4**

Sag -Tension Requirements

| Description | Value |
|---|---|
| Tension at everyday condition (28 deg C, no wind) | Not exceeding 25% of UTS of proposed conductor |
| Tension at 20 deg C, full wind (53 kg/m2) | not exceeding 50% of UTS of proposed conductor |
| Tension at minimum temperature -5 deg C, 37.7 % of full wind (20 kg/ m2) | not exceeding 50% of UTS of proposed conductor |
| Maximum working stress allowed for conductor | 1323 Kg |

Table: 5 shows the comparison of technical characteristics that will have an impact on the existing tower while replacing with different HTLS technologies.

**TABLE: 5**

ACSR vs HTLS reconductoring Comparison Considering Ruling Span 298 meters

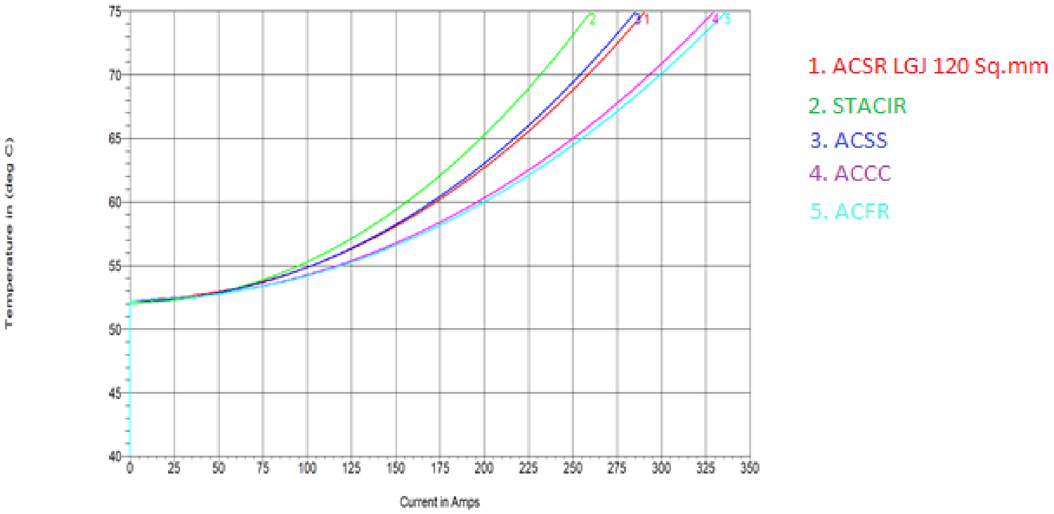
| Description | Unit | ACSR | ACSS | STACIR | ACCC | ACFR |
|---|---|---|---|---|---|---|
| Conductor Diameter | Mm | 15.74 | 15.4 | 15.02 | 15.65 | 15.7 |
| DC resistance at 20 deg C | Ohm/km | 0.2398 | 0.2465 | 0.2943 | 0.1859 | 0.1792 |
| Min UTS of conductor | KN | 47.6 | 45.3 | 51 | 69 | 46 |
| Weight | Kg/km | 528 | 525 | 522 | 470 | 457 |
| Modulus of Elasticity | Kg/mm2 | 7885 | 8134 | 8165 | 6779 | 6265 |
| Co-efficient of linear expansion | $X\ 10^{-6}$ /°C | 18.33 | 17.86 | 14.4 | 17.36 | 18.76 |
| Maximum allowable continuous operating temperature | DegC | 75 | 250 | 210 | 180 | 180 |
| Emergency operating temperature | DegC | 100 | 280 | 240 | 200 | 200 |
| Ampacity at 75 Deg C | A | 290 | 283 | 256 | 325 | 335 |
| AC resistance at 75 Deg C | Ohm/km | 0.2935 | 0.3018 | 0.3602 | 0.2277 | 0.2188 |
| Sag at 75 Deg C | Meters | 9.15 | 8.28 | 8.52 | 7.22 | 8.16 |
| Maximum ampacity that can pump per conductor without exceeding the ACSR Sag | A | N/A | 483 | 580 | 707 | 724 |
| Temperature at above ampacity | Deg C | N/A | 125 | 195 | 180 | 180 |
| Ruling span | Meters | 298 | 298 | 298 | 298 | 298 |
| Tension 28 Deg C, no wind | Kg & % | 758 & 16 | 832 & 18 | 792 & 15 | 762 & 11 | 885 & 19 |
| Tension at 20 Deg C, Full wind pressure (53 kg/mm2) | Kg & % | 1323 & 27 | 1308 & 28 | 1323 & 25 | 1314 & 19 | 1265 & 27 |
| Tension at -5 Deg C, wind pressure (20 kg/mm2) | Kg & % | 1021 & 21 | 1021 & 22 | 1015 & 20 | 1021 & 15 | 1021 & 22 |
| Losses at 290 A per CKM (Loss load factor 0.53, circuit - single, Route Length - 1 Km) | Kw | 39.2 | 40.4 | 48.2 | 30.4 | 29.3 |

The calculations of steady-state thermal rating, given a maximum allowable conductor temperature, weather conditions, and conductor characteristics were performed by the computer using PLS CADD based on the IEEE Std 738 - 2006. For steady – state thermal rating, the following parameters were adopted:

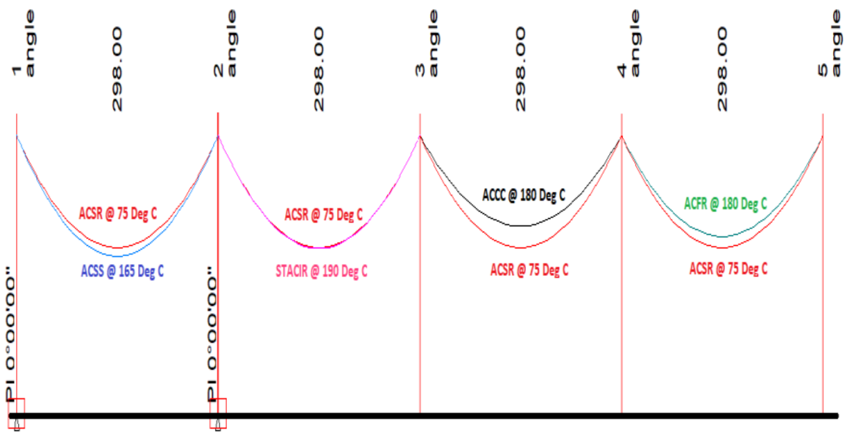
- Wind speed: 0.56 m/s;
- The angle between wind and conductors: $90^0$;
- Emissivity: 0.45;

- solar absorptivity: 0.8;
- Air temperature: $40^0$C
- Solar radiation:1045 watt/sq.m;
- Elevation above sea level:1300 meters;

**Current carrying capacity comparison graph at 75 Deg C for Different Conductors**




**HTLS Conductors Sag comparison at ≥ double current carrying capacity**




**Graphical representation is based on below assumptions**

Ruling span: 298 meters
Everyday temperature: 28 deg C
Operating temperature at double current capacity of each HTLS conductor

*The above graphical representation showing the results of sag value for different type of HTLS technology at after creep condition.

## Conclusion:

The replacement of existing conductor should improve the mechanical reliability of the line conductor. To uprate the 66 KV line in Nepal by using high temperature conductors is considered as a feasible desideratum from the technical point of view. All the selected conductors can be strung to accomplish equal or smaller sag than the initial one, but at higher temperature.

Finally, from techno – commercial point of view, the detailed analysis of the suitable conductor technology can be considered on the basis of techno commercial evaluation of different HTLS technology by the customer. From the detailed technical analysis considering maximum power transfer capacity without violating the ground clearance of existing line, the most attractive solutions are Invar & Composite core technologies. The utility can reconductoring the line either with Invar or composite core conductors if cost will be accepted.

## REFERENCES

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Working Group SC 22-12 Cigre (Chairman R. Stephen). “The thermal behaviour of overhead conductors Section 1 and 2 Mathematical model for evaluation of conductor temperature in the steady state and the application there of” (Electra number 144 October 1992 pages 107-125).

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**Standards:**

IEEE Std. 738-2006 IEEE Standard for calculating the Current-Temperature relationship of bare Overhead conductors.