Comparative Analysis of ACSR and HTLS Conductor

Manish Kumar
ME Student, EEE Dept. SSTC,
Bhilai, Chhattisgarh,India
e-mail: manishrathore786@yahoo.co.in

Mrs. Roshni Rahangdale
Asst.Professor EEE Dept. SSTC,
Bhilai, Chhattisgarh,India
e-mail: roshnibobby@gmail.com

***Abstract*—**In India, ACSR (Aluminum Conductor Steel Reinforced) and AAAC (All Aluminum Alloy Conductor) are most commonly used conductors for transmission lines. To transfer bulk power from long distance and to meet the increased load demand either we have to construct the new UHV or EHV transmission lines or to uprate the existing transmission line. Uprating of transmission lines i.e. modifications in the existing transmission line to enable the increased current flow limits. Making a new transmission lines also have few constraints: ROW constraints (Lack of availability of corridors for construction of new transmission lines due to High Population Density, Forest/ Ecology conservation) and Time constraints

Keywords- *Ampacity,ACSR,HTLS,INVAR,ACCC.*

*****

I. Introduction

A rapid increase in electric power consumption is witnessed which results the increase in demand of the uninterrupted power supply .The new generation units are being built with increased installed capacity, but the existing transmission lines are reaching their critical limits of ampacity and there is shortage of corridors particularly in dense populated cities to construct the new overhead lines specially in country like india. Most of the times it becomes impossible to obtain a right of way for the new transmission lines and hence present circumstances demands the use of available lines with cheaper solution than going in for an underground transmission [(1] Dae-Dong Leea, 2011)

The constructions of new line have several disadvantages. In addition, there is a large limitation of construction space, ROW issues and construction costs are very high when rebuilding the towers, hence the best suited method is to increase the operating temperature by adopting heat resistant aluminum alloy conductors .The purpose of developing a new type ACSR conductor was to double the current capacity by restringing conductors on existing steel towers Thus it is unnecessary to either rebuild or construct tower with longer in height, the steel towers to enlarge the capabilities of overhead transmission lines. New HTLS requires lower construction costs, has a shorter construction period and does not need larger towers, larger conductors, or bundled conductors. The structure, fittings, and construction methods of HTLS are designed to be the same as those of ordinary ACSR [(4]S. Sakabe N. Mori, 1981)4].

During last few decades the world is going through a phase of rapid industrialization. A the time the electrification in developing countries in being carried out at a high rate and due this cumulative effect the power demand is increasing day by day. In response government and private projects fare involved to increase the power generation, subsequently the transmission and distribution of increased required power is becoming a great challenging for the utilities in terms of cost and capacity, where the existing lines have reached their maximum limits. Hence on the solution to build new lines parallel with existing one but this is not an economical solution. One of most cost effective solution is to adopting high temperature low sag (HTLS) conductor for transmission and distribution. These are different from the conventional ACSR conductor in terms of material but same in size. It can carry approximately 2 to 2.5 times the current that of conventional ACSR conductors of same size and can withstand higher temperature (>200 °C),due to high current carrying capability the elongation of conductor is less, so the sag is very less. One of the major advantages of HTLS over conventional ACSR conductor is to re-conduct ring the existing double circuit line with HTLS without disturbing the another circuit. The possibility of replacing conventional overhead conductors with new generation high performance conductor is called high-temperature low-sag (HTLS) conductors, it is attractive choice particularly in those corridors which are thermally limited and it can operate upto temperatures as high as 210 C, almost doubling the ampacity of existing ACSR conductors. [(5] Subba Reddy B and Diptendu Chatterjee., 2016)5], [(6] Antonio Gómez Expósito, 2007)6].

CHARACTERISTICS OF HTLS (HIGH TEMPERATURE LOW SAG CONDUCTORS):

- G (Z)TACSR (Gap Thermal Alloy Conductor Steel Reinforced)
- ZTACIR (Thermal Alloy Conductor Conductor Invar Reinforced)
- ACSS (Aluminum Conductor Steel Supported)
- ACCC (Aluminum Conductor Composite Core)

ISSN: 2454-4248
29 – 35

Here G refers to Gap between steel and aluminum conductor and Z refers to trapezoidal same of aluminum conductor. HTLS conductors are similar to conventional ACSR conductor in terms of electrical conductivity and geometrically. The main difference is, it offers the low coefficient of heat expansion and as results HTLS can operate at a higher temperature with an increased CCC (current carrying capacity) maintaining same sag that of traditional ACSR conductors.

A. G(Z)TACSR

In G (Z) TACSR type conductor is known as Thermal Resistance Aluminum Alloy conductor Steel Reinforcement as shown in Figure 1, where inner core is composed of galvanized steel and outer layers are composed of thermal resistant aluminum conductor. A small gap is maintained between the steel core and the innermost aluminum layer, and the gap is filled with heat-resistant grease to reduce friction between the steel core and the aluminum layer and to prevent ingress of water and hence its improves corrosion resistance.

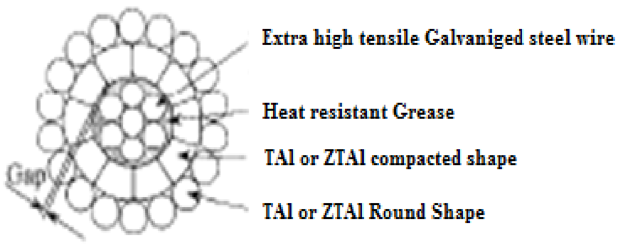

Fig.1 Cross sectional view of G(Z) TACSR Conductor

B. ZTACIR

Super thermal alloy (STAL) is made from Al-Zr (Aluminum Zirconium) alloy. The conductor comprises of an inner core of Aluminum clad Invar (36%Ni in steel) and outer layer are made of STAL wires.

Here the Figure 2 shows the cross sectional view of (Z) TACIR conductor.

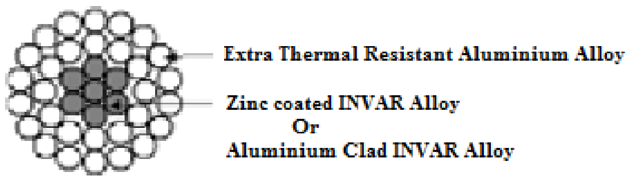

Fig.2 Cross sectional view of ZTACIR Conductor

Instead of using conventional steel in conventional ACSR conductor, in ZTACIR conductor, INVAR is used which is made of an alloy of steel and 36% nickel and as a results the coefficient of expansion practically become linear and it is invariable with application of heat and that's why the name was given as INVAR.

Super thermal alloy contains Zr which deposits over the grain boundary of Aluminum, thus increasing the recrystalisation temperature of Aluminum which enables STAL to operate at high temperature without any loss in strength.

C. ***ACSS***

ACSS is known as Aluminum Conductor Steel supported as shown in Figure.3.

In ACSS the core is made of round steel and aluminum strands are made of trapezoidal shape. The steel wires may either galvanized wires or aluminum clad (aluminum coating). In ACSS conductors the aluminum wires can be the standard round strand or it may be trapezoidal aluminum strand.

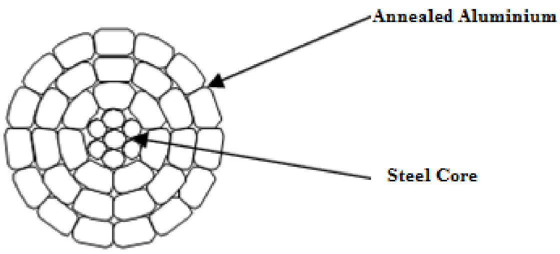

Fig.3 Cross section of ACSS Trapezoidal Conductor

IN HTLS conductor the main modification is done on aluminum strands which are completely annealed wires and steel core which is made of INVAR strand and conductivity of core is enhanced by 14%, where in ACSR conductor the conductivity of core is almost zero. During stringing when tension is applied on the HTLS conductors, the permanent elongation takes place quickly in aluminum wires, since the core is made of INVAR strands, where the coefficient of linear expansion is invariable with temperature and as a results the sag of the conductor will be greatly reduced. In operating conditions, the coefficient of expansion of conductors is close to the value provided by the steel core, in the order of (10to $13x10^{-6}$°C),which is quite low as compared to conventional ACSR conductors i.e. order of (18 to $22{\cdot}x10^{-6}$°C) and results of this reduction in overall sag and therefore an increase in the ground clearance.[7-8]

D. ACCC

ACCC refers to Aluminum Conductor Composite Core, as shown in figure 4 and composition used carbon, glasss fiber and trapezoidal shaped aluminum that are resistant to environment degradation.

 ISSN: 2454-4248
29 – 35

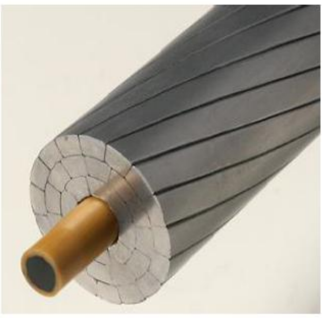

Fig.4 Cross sectional view of ACCC Conductor

The conventional ACSR and AAAC are designed to operate continuously at temperature of 85°C and 95 °C respectively. High Temperature Low Sag (HTLS) conductors are designed to operate continuously at temperature of at least 180 °C. Some HTLS conductors can be operated as high as 240 °C. The new material used in HTLS conductor differs from conventional steel reinforced ACSR.

The new material includes INVAR steel (Fe-Ni alloy), temperature resistant Aluminum-Zirconium (Al-Zr) alloys, annealed aluminum, high strength steel and both metal & polymer composites. A conductor in general is a simple combination of core and aluminum and aluminum alloy. HTLS conductor is stranded with combination of
Aluminum alloy wires for better conductivity and reinforced by steel core.

There is two different way of upraitng of transmission line,firstly the uprating can be done by constructing a new transmisison line with traditional ACSR conductor,by extra HV lines or with bundling of transmission line or making bigger size conductor diameters.Secondan way to change the conductor with advanced material by increaing therir thermal raing.

Different type of HTLS conductors are ZTACIR (with INVAR steel core), GZTACSR (with specified gap between steel core and inner layer of aluminum wires), ZTACSR (with steel core), ACSS (with steel core)
The TACSR, GZTACSR, ACSS and ACCR are available with both round wire and trapezoidal Al-Zr alloy wires in the outermost layer. ACCC uses only trapezoidal annealed aluminum wires. GZTACSR, commonly known as Gap type conductor, the Gap is filled with heat resistant grease (filler material) to prevent water ingress and improves the corrosive resistance, such type of conductors are mainly required in coastal areas.

Materials used

STAL wire containing Zr (Zirconium) element has highly improved the annealing property without loss of tensile strength at high temperature. HTLS using Al clad invar has low thermal coefficient of expansion (approx 1/3 rd) of steel at Temp 210 °C.

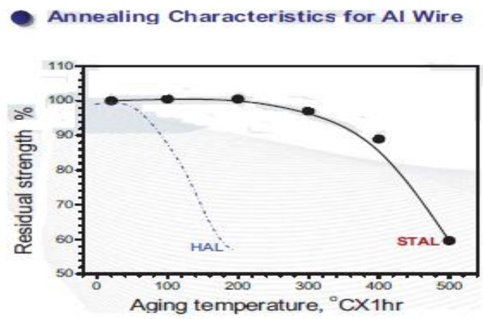

Fig.5 Annealing characteristic of STAL wires

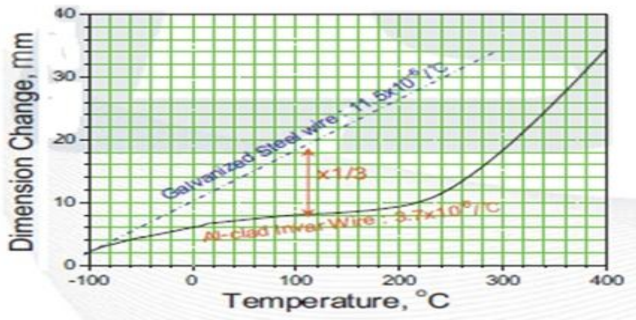

Fig.6 Coefficient of thermal expansion of steel and STACIR

The ordinary hard drawn aluminum wires used in conventional ACSR, start losing tensile strength at 90°C and therefore it is not suitable for long term use at temperature above this. Al-Zr aluminum alloys wires have the same conductivity and same tensile strength as ordinary EC Grade aluminum wire but it can operate at higher temperature range upto 150 to 200°C.

In India since last few years, the need for use of HTLS conductors in some corridors has been felt. The power flow in those corridors has increased and congestion has been reduced by using such conductors. Such conductor would be required where the power transfer over the line is constrained due to consideration of thermal loading.
InIntra-state transmission system, requirement of such conductor is expected at 220kV, 132kV and 66kV level. The requirement of such conductor may not be much in ISTS, which is dominated by 400kV and 765kV network. In case of ISTS lines, the HT/ HTLS conductor would be a good substitute to Quad bundle ACSR and AAAC conductor, particularly at 400kV level when line length is short. Therefore the HTLS conductor can be considered for

II. METHODOLOGY:

Power Line System –Computer Aided Design and Drafting (PLS-CADD)is the most powerful and comprehensive

 ISSN: 2454-4248
29 – 35

program/tools for the structural and geometric design of overhead lines. It covers all environment aspects of transmission line design, including terrain modelling, route selection, manual or automatic minimum cost spotting, sag-tension, clearance and strength checks, plan & profile drafting and much more.

For new transmission lines projects **PLS-CADD** will significantly increase capabilities and productivity of line. reconductoring of existing lines and can also be used in new lines. The cost of such conductor is about 2 to 3 times the cost of conventional ACSR conductor.

By placing six numbers of 400 KV tower structure in plain terrain placed approx 400 meter apart in by using PLS CADD Tools as shown in Fig.7

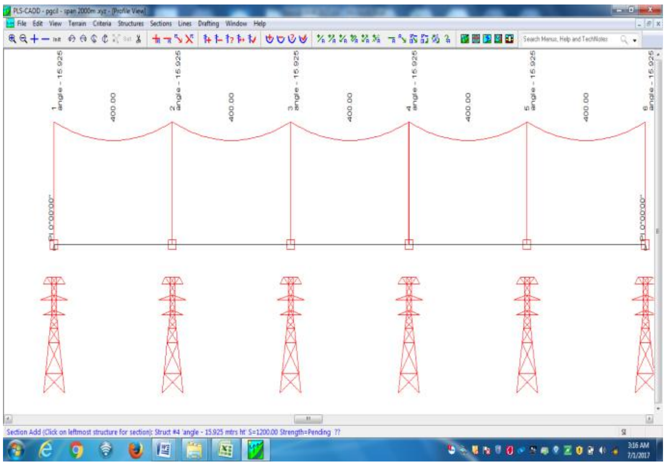

Fig.7 Model of 400KV Transmission line using PLS Cadd

III. CASE STUDIES:

For comparative analysis we have compare ACSR Moose conductor to ACCC-Budapest (a type of HTLS conductor)

Case 1: Comparison when maintaining same Current and their operating temperature:

Table 1

Description	MOOSE (ACSR)	ACCC-Budapest (HTLS)
Calculations are carried out at temp degree	85	77.40
Current to be maintained:	902	902
AC Resistance (ohms/km)	0.070644	0.05313
Line losses in kW/ckt	172	130
Power Factor	0.85	0.85
Power Transferred in MW/ckt	531	531
Price Loss (in Lacs Rs/KW)	263	198

Case (2): ACCC Budapest (Type of HTLS conductor) operated at its maximum operating temperature i.e. 210 degree.

Given a maximum conductor temperature of 210.0 (deg C), The steady-state thermal rating is 2114.0 amperes.

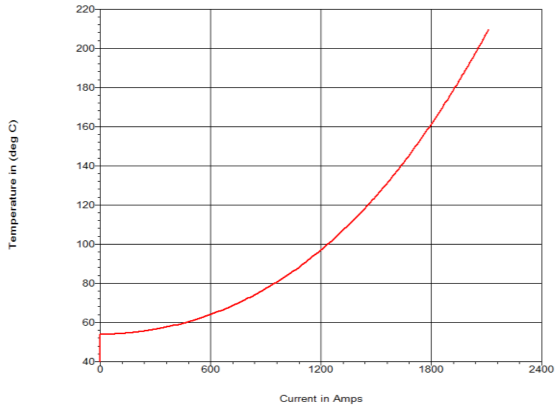

Fig.8 Temperature verses Current graph of ACCC Budapest conductor when operated at its maximum temperature i.e. 210^0C

Case (3): ACCC Budapest (Type of HTLS conductor) operated at 85^0C temperature

Given a maximum conductor temperature of 85.0 (deg C), The steady-state thermal rating is 1030.6 amperes.

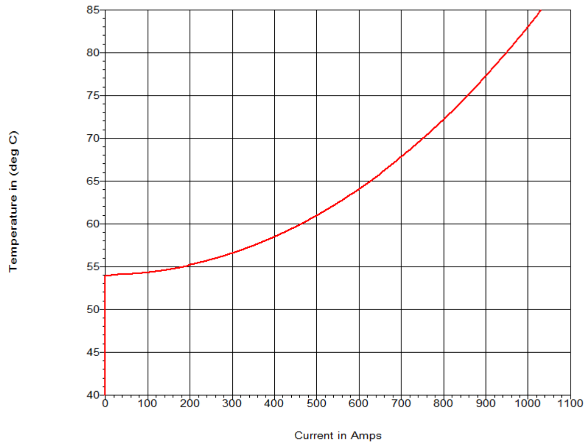

Fig.9 Temperature verses Current graph of ACCC Budapest conductor when operated at its maximum temperature i.e. 85^0C

Conclusion of Case 1: The maximum operating temperature of ACSR Moose conductor is 85^0C and maximum current carrying capacity is 902 amps in specified working condition, therefore the comparison is done at 902 Amps between ACCC-Budapest (a type of HTLS conductor)conductor and

ACSR conductor and all the calculation is done based this ampere rating.

ACSR Moose conductor reaches 902 Amps at 85^0 C (operated at maximum operating temperature level) and while ACCC-B achieved this current rating at reduced temperature level i.e. 77.4^0 C (well below the maximum operating temperature level i.e. 210^0C).

For ACSR conductor the ac resistance is 0.0.070644 ohm/kms whereas for ACCC-B conductor the ac resistance is only 0.05313 ohm/kms which is quite lower as compared to ACSR Moose conductor,as a results of this the line losses will be lower side i.e. 130 kw/ckt which is approximately 43 % lower than the ACSR Moose conductor.

For ACCC-Budapest the price losses will be only 198 (Lacs Rs/kw/ckt) as compared to 263 (Lacs Rs/kw/ckt) of ACSR Moose conductor.

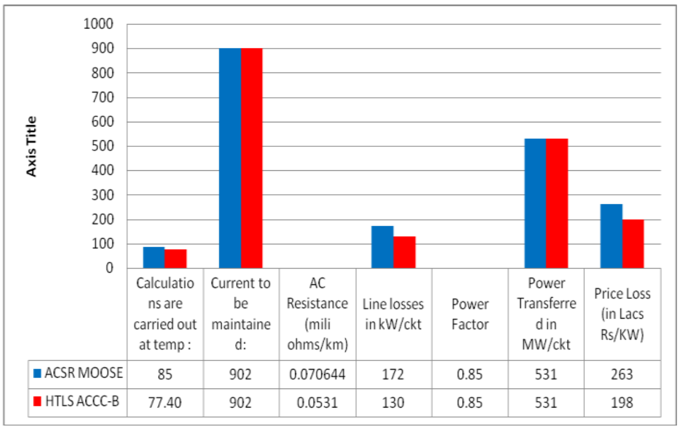

Fig. 10 Comparison chart of ACSR Moose and ACCC-B (HTLS) conductor when operated with maintaining same current rating i.e.902 Amps

Case-2: Comparison when maintaining maximum current in amps at maximum continuous operating temperature:

Table 2

Description	MOOSE (ACSR)	ACCC-Budapest (HTLS)
Calculations are carried out at temp degree	85	210
Current to be maintained:	902	2114
AC Resistance (ohms/km)	0.070644	0.0706
Line losses in kW/ckt	172	947
Power Factor	0.85	0.85
Power Transferred in MW/ckt	531	1245
Price Loss (in Lacs Rs/KW)	263	1444

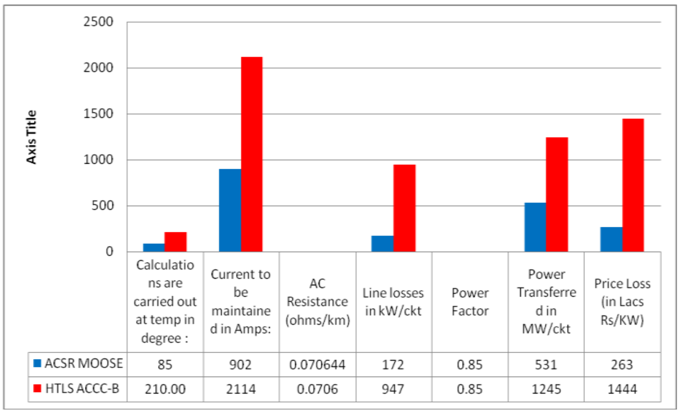

Fig. 11 Comparison chart of ACSR Moose and ACCC Budapest (HTLS) conductor when operated at maximum thermal limit

Conclusion of Case 2: In this case both the conductors are operated at their maximum operating temperature and maximum current carrying capacity. The maximum operating temperature of ACSR Moose conductor is 85^0C and maximum current carrying capacity is 902 Amps in specified working condition, whereas the maximum operating temperature of ACCC-Budapest conductor is 210^0C and maximum current carrying capacity is 2114 amps and all the comparisons were done based their maximum operating levels.

- ACSR Moose conductor is limited to operate upto 85^0 C maximum while ACCC-B can be operated upto much higher temperature level i.e. 210^0 C .

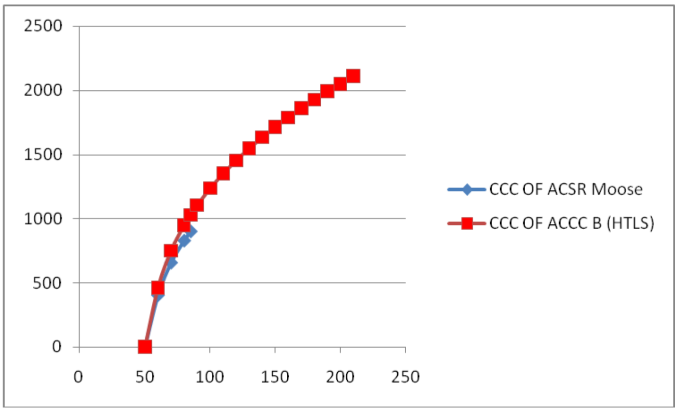

Fig. 12 Current V/s Temperature curve for ACSR-Moose and HTLS ACCC-Budapest conductor

Here Fig. 12 represents the Current V/s Temperature curve, curve shows that ACCC-Budapest (HTLS) can be easily operated upto 210 ^{0}C, but the maximum operating temperature of ACSR Moose conductor is 85 ^{0}C only (Thermal limit).

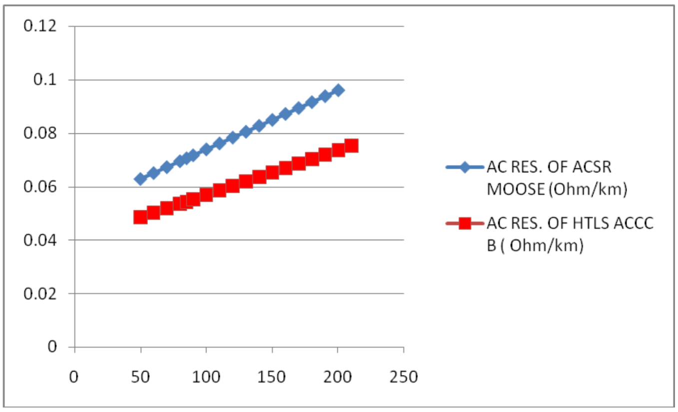

Fig. 13 Resistance V/s Temperature curve for ACSR Moose and HTLS ACCC-Budapest conductor

Here Fig.13 represents the Resistance V/s Temperature curve, curve shows that ACCC-Budapest (HTLS Conductor) can be easily operated upto 210 ^{0}C with minimum resistance but the maximum operating temperature of ACSR Moose conductor is 85 ^{0}C only (Thermal limit) and because of less resistance as compared to ACSR conductor, HTLS conductor offers less (I^2R loss).

When both conductors were operated at 902amps then power loss i.e ((I^2R loss), is 130 Kw/ckt figure taken from table no 1,which is 25% lesser than the equivalent ACSR conductor.

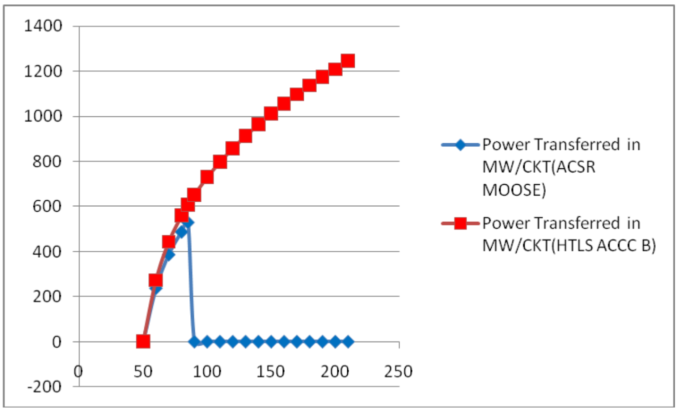

Fig. 14 Temperature V/s Power Transfer Capability curve

Here Fig. 14 shows the Temperature V/s Power Transfer Capability curve, which shows that ACCC-Budapest (HTLS Conductor) can be easily operated up to 210 ^{0}C. The power transfer capability of ACCC-B is 1245 (MW/ckt) which is almost 2.3times than the power transfer capability of ACSR conductor i.e.531(MW/ckt), it means for transferring same amount of power by using ACSR conductor, we have to construct two another transmission line, that will become another time consuming and costly as well.

IV. Conclusion

In present scenario the major difficulties are getting new right of way (ROW) approval from public and local administrations. For this squeezing more power into existing corridors in becoming quite crucial and for which the HTLS constitutes a attractive and cheaper solution. These conductors being capable of working at over 200 °C, double the ampacity as compared to conventional ACSR conductor with approx. same impedance.

In growing congestion in existing corridor of transmission / distribution network,the enhancement of power flow per unit (or meter) of Right of Way (RoW) and reduction inlosses under normal as well as under emergency condition. High Temperature Low Sag (HTLS) conductors should be considered in those corridors where the power transfer over the line is constrained due to consideration of thermal loading of conductor. In Intra-state transmission system, requirement of such conductor is expected at 220kV, 132kV and 66kV level. In case of ISTS lines, the HTLS conductor would be a good substitute to Quad bundle ACSR and AAAC conductor, particularly at 400kV level when line length is short. Application of HTLS conductor may not be cost effective for HVDC system and for 765kV and above voltage system used in new lines. The terminal equipment rating at substations needs to be examined for enhancement of power flow in a line. However, for new lines, proper system studies need to be carried out to identify the specific corridor for use of such costly conductors. HTLS conductor may be considered for use in distribution system where utility can get more benefits in terms of technical loss although initial investment cost will be high. The HTLS conductor with composite cores needs careful handling. Composite materials are highly anisotropic, i.e., they have good tensile strength but lower shear, transverse and tensional strength. Thus composite materials require careful handling to prevent failure or overstressing.

References

[1] Dae-Dong Leea, Jae-Myung Shimb, Young-Dal Kimb, Keun-Seok Parkb, and Dong-Seok Hyuna (2011), Mechanical and electrical characteristics analysis of the ACSR affected byhigh temperature.Vol. 30, Spec. Issue, Mar 2011, pp. 311-315.

[2] Dae-Dong Leea, Jae-Myung Shimb, Keun-Seok Parkb, and Young-Dal Kimb (2011),Deterioration inference according to mechanical characteristics analysis of ACSR due to an artificial flame and a forest fire.Vol. 30, Spec. Issue, Mar 2011, pp. 305-310.

[3] Konstantinos K., C.T.-ChakontaandCarlos Cruzat,(2016), Power Network Reliability Evaluation FrameworkConsidering OHL Electro-Thermal Design, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 31, NO. 3, MAY 2016,pp 2463-2471.

[4] S. SakabeN. Mori, K. Satoand Y. Miyake, A. Tanaka, Development of Extremely-Low-Sag,INVAR Reinforced ACSR (XTACIR), April 1981, p 1505.

[5] Subba Reddy B and Diptendu Chatterjee,IISC,Banglore,Performance Evaluation of High Temperature and High current conductors.IEEE Transactions on Dielectrics and Electrical Insulation Vol. 23, No. 3; June 2016,pp 1570 -1579.

[6] Antonio Gómez Expósito, Jesús Riquelme Santos, and Pedro Cruz Romero, Planning and Operational Issues Arising From the Widespread Use of HTLS Conductors, IEEE TRANSACTIONS ON POWER SYSTEMS, VOL. 22, NO. 4, NOVEMBER 2007,pp 1446-1455.

[7] Konstantinos Kopsidas , Boudjemaa Boumecid, Ian P. Cooper, Overhead line design considerations for conductor creep mitigation,IET Gener. Transm. Distrib., 2016, Vol. 10, Iss. 10, pp. 2424–2432.

[8] G.Filippone , M.G. Ippolito, F. Massaro, A.Puccio, On the roadmap to Supergrid in Sicily: LIDAR technology and HTLS conductors for uprating the 150 kV lines, 2014 5th IEEE PES Innovative Smart Grid Technologies Europe (ISGT Europe), October 12-15, Istanbul.

[9] Jonghwan Kwon ✉, Kory W. Hedman, Transmission expansion planning model considering conductor thermal dynamics and high temperature low sag conductors, IET Gener. Transm. Distrib., 2015, Vol. 9, Iss. 15, pp. 2311–2318

[10] Subba Reddy B and Diptendu Chatterjee, Analysis of High Temperature Low Sag Conductors used for High Voltage Transmission,Energy Procedia 90 (2016) 179 – 184.