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Bulk Power Carrying Conductors

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***Abstract*— With the ever growing urbanization and industrialization; the need of power is increasing alarmingly. At the same time the generated power should be transmitted to distant locations efficiently. So, we should have such a transmission network of conductors which can handle the bulk power so that the transmission losses, sag, land requirement etc. are minimal and ampacity of conductors are maximum. One better way is to replace the conventional conductors with new breed of conductors i.e. ACCC, ACSS, ACCR, etc. in the existing network. Our paper will compare the performance of these new conductors with respect to sag and ampacity.**

***Index Terms*— Sag, Ampacity, Conductors.**

I. INTRODUCTION

The design of a transmission line has to be satisfactory from electrical as well as mechanical considerations. The line should have sufficient current carrying capacity so that the required power transfer can take place without excessive voltage drop or overheating. Careful selection of conductors is very important so as to meet near all design requirements.

II. TYPES OF CONDUCTORS

Aluminium Conductor Steel Reinforced (ACSR):

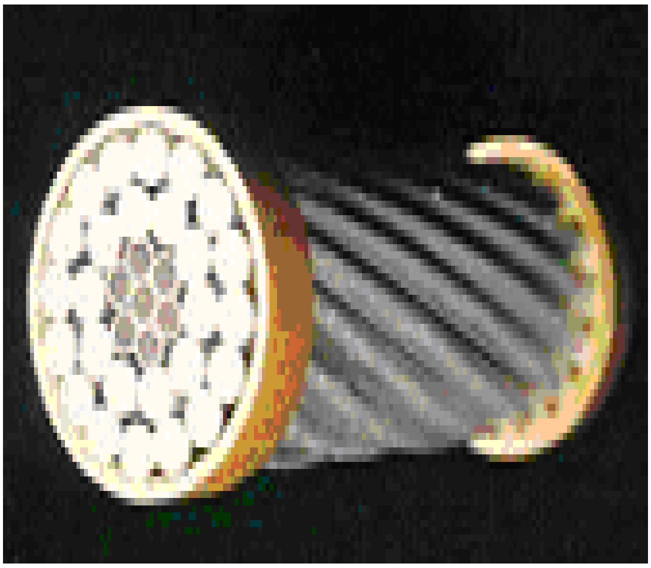

Fig. 1.1 ACSR Conductor.

This conductor consists of a solid or stranded steel core surrounded by strands of aluminium. ACSR conductor is available in a wide range of steel varying from as low as 6% to as high as 40%. The principal advantages of these conductors are high tensile strength and light weight with longer spans as well as with lesser supports.

All Aluminium Conductor (AAC): It is also known as aluminium stranded conductor or all aluminium conductor cable. It is manufactured from electrolytically refined aluminium of EC grade, and the range has 99.5% purity which in other words implies that it contains a minimum of 99.5% aluminium by weight.

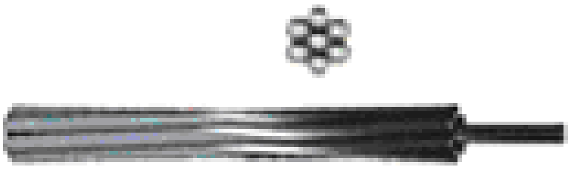

Fig. 1.2 All Aluminium Conductor.

It is available in wide range of various specifications of stranding and wire diameters, mass, resistance, breaking load, etc. It has a minimum conductivity of 61%.These are mainly used in urban areas where the supports are placed closer to each other. Due to the corrosion resistance of AAC conductors, they are widely used in coastal areas also. It has a high conductivity.

All Aluminium Alloy Conductors (AAAC): It is made from Aluminium-Magnesium-Silicon alloy containing magnesium (0.6-0.9%) & Si (0.5 - 0.9%) of high electrical conductivity containing enough magnesium silicide to give it better mechanical properties after heat treatment. It has a better corrosion resistance & better strength to weight ratio & improved electrical conductivity than ACSR.

Fig.1.3 All Aluminium Alloy Conductor.

Aluminium Conductor Composite Reinforced (ACCR): ACCR is a light weight, thermal expansion product that ensures low sag at high ampacities. ACCR is a unique amalgamation of aluminium matrix core and heat resistant

Al-Zr at the outer strands, assuring a strong advantage over other conductors. This material has a strength similar to steel, but with less than half the weight and half the thermal expansion. Its advantages are:

Fig.1.4 Aluminium Conductor Composite Reinforced.

a) Consistent performance at high temperatures, 210°C continuous and 240°C emergency, up to 1,000 hours cumulative.

b) Corrosion resistance without coatings or barriers between the core and the outer wire, required for steel or carbon core conductors.

c) Superior durability and performance, with life expectancy of 40 years or more, even when operated at high temperatures.

d) More amps on the same size conductor and less sag due to heat from high energy loads.

Aluminium Conductor Steel Supported (ACSS):

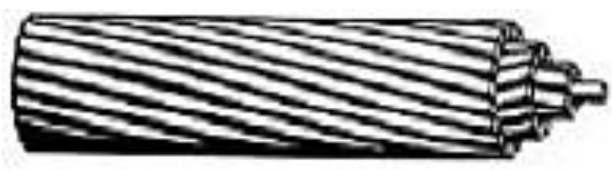

Fig.1.5 Aluminium Conductor Steel Supported.

ACSS is a composite concentric-lay stranded conductor. Steel strands form the central core of the conductor with one or more layers of aluminium 1350-0 wire stranded around it. The fully annealed aluminium wires are softer and have higher ductility than hard drawn aluminium wires and are more susceptible to damage during installation and handling.

ACSS is useful where conductors are added for increased current with existing tensions and clearances, new line applications where structures can be economized because of reduced conductor sag and new line applications requiring high emergency loadings.

Aluminium Composite Core Cable (ACCC):

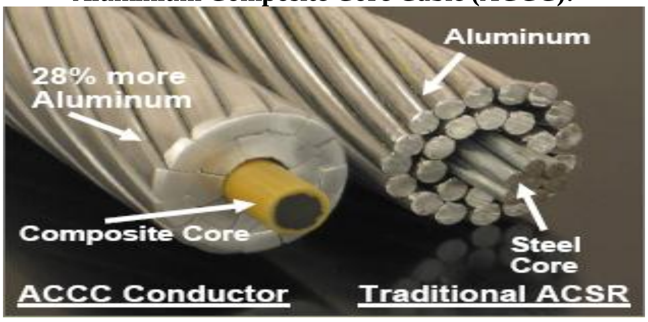

Fig.1.6 Aluminium Composite Core Cable

The cable (ACCC, Aluminium composite core cable) was tested in Kansas (United States) that has a core made of carbon fibre, glass and epoxy. The composite expands very little when heated, and in fact gets stronger. The result is that the cable stretches only about a tenth as much as standard cable. That eliminates sag as a factor that will limit the amount of current that can be sent through a line.

Comparison of Power Handling Capacity and Sag Production.

As the conductors attempt to carry large currents their conductor temperature rise; their metal cores expand and the lines sag. So the conductor with high thermal capacity will transmit more power with less sag.

Comparison between ACCR and ACSR

The figure clearly suggests the higher ampacities of the ACCR conductor as they can withstand the higher conductor temperature of 210°C. The ACCR 795 kcmil (Aluminium area unit) conductor can carry the current which even an ACSR 1590 kcmil can't.

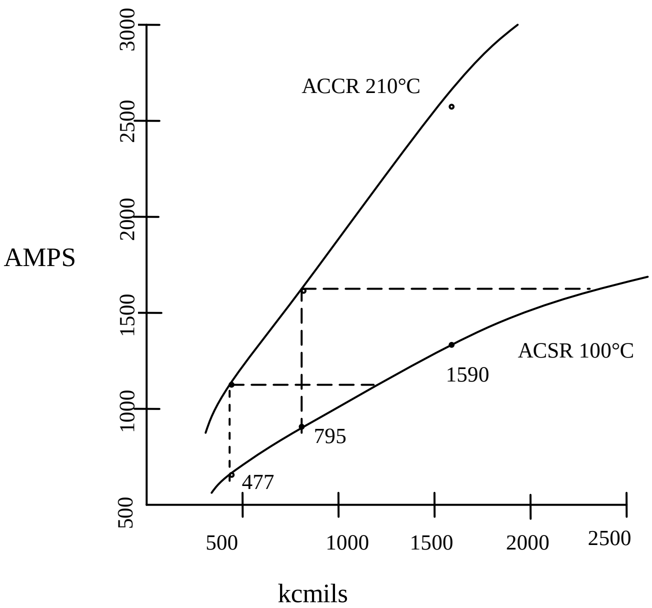

Fig. 1.7 Comparison of ACCR and ACSR Ampacities:

Consider a power system which is designed for the conductor whose Al area is 795 kcmil (402.9mm^2), from the Figure it is clear that for ACCR when the conductor temperature is 50°C, sag is 8.6868m but for the same temperature the sag produced by the ACSR conductor is 9.9669m although the safe limit is 11.7957m.

Therefore comparing on those lines for ACCR when the conductor temperature is 100°C, sag is 9.6012m but ACSR reach safe limit of 11.7957m at this temperature. ACCR is found to work satisfactorily and continuously up to 210°C (and up to 240°C for short duration during emergency) for which the sag produced is only 10.9118m. The safe temperature limit of the Aluminium is 75°C although in few literatures we find it up to 100°C.

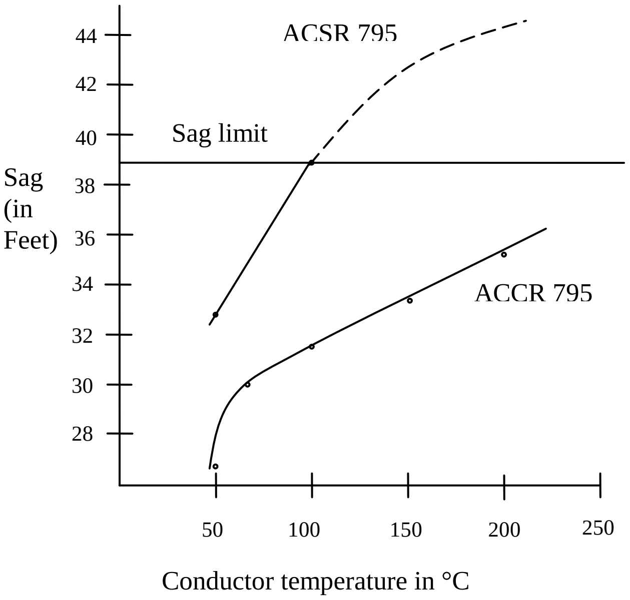

Fig. 1.8 Sag- temperature chart showing ACCR provides larger ampacity by operating at higher temperatures also exhibiting reduced sag.

Comparison between ACSS and ACSR:

Consider ACSS / TW 795 kcmil (402.9mm^2) fully annealed aluminium wires formed into trapezoidal shape. It creates a more compact conductor with same metal but smaller diameter; it results in smaller ice and wind loading on the conductor.

Also consider a 795 kcmil 26/7 ACSR "Drake". Now if the ampacities are calculated assuming the ambient temperature of 40°C, 0.61m/sec wind, sun, 0.5 coefficient of emissivity and absorptivity, then we get the following results as shown in table:

Table: 1

Conductor Temperature (in °C)	Standard 795 ACSR. (Ampacities in Amps)	ACSS/TW Equal area. (Ampacities in Amps)
75	730	720
100	990	980
150	-----	1320
200	-----	1560
250	-----	1740

Again we have observed that ACSS due to its higher thermal capacity can have high ampacities than ACSR of same area and will also have less sag generated.

Comparison between ACSS and ACCR:

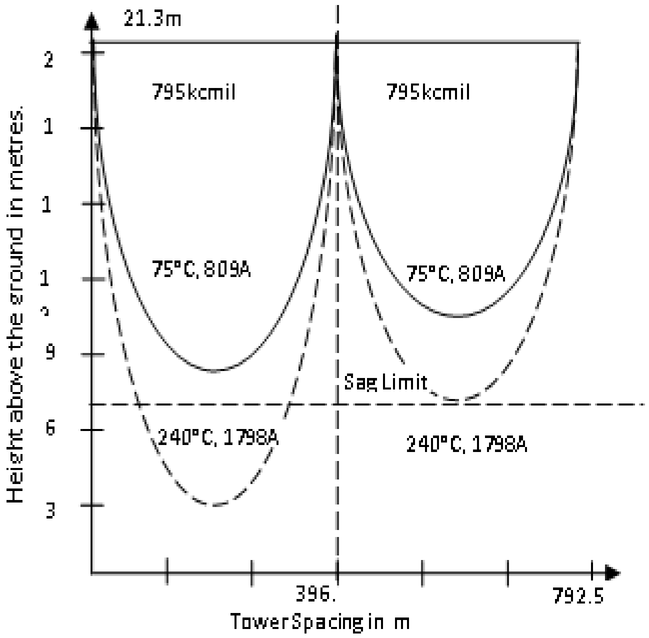

Fig. 1.9 Sag comparisons of ACSS and ACCR conductors.

The above results shown in graphical manner assumes ACSS and ACCR at 1,300 feet (396m) ruling span, initial tension: 6,557 lbs (2,974 kg) maximum loading at -1°C), no ice, 5.4 kg wind load; 0.6 m/sec wind speed, perpendicular wind direction, 0.5 emissivity and solar absorption.

Based on the above figure we can compare the ACSS and ACCR conductors. If we take ACSS and ACCR conductors of equal area say 795kcmil then it is found that the current carrying capacity of ACCR at 210°C is 1692A while that of ACSS at same conductor temperature is approximately 1610A, hence ACCR can be considered superior in terms of ampacity. Again if we compare the sags produced by both the conductors based on 305m span and 150°C; it is found that the sag produced by ACSS is 37.8 feet whereas that of ACCR is 33.4 feet.

Comparison between ACCC and ACSR:

A little drawback when we compare the ACCC conductors with the others is from the point of view of uniformity; size of the aluminium area used by the ACCC conductors is different from the others. Still if we compare the ACCC conductor and

ACSR conductor we find that till the ACSR conductor is operating in its temperature region; it is a bit superior to ACCC conductor. Take an example of an ACSR 636 kcmil conductor whose ampacity at 75°C is found to be 790A and on similar grounds if we take ACCC 611kcmil conductor; its ampacity at 75°C is 745A. On the other hand ACCC conductors can satisfactorily and continuously operate at 180°C for its entire range and in emergency or short duration can also operate at 200°C. Hence the biggest conductor ACCC 2727 kcmil can carry the current up to 3233A at 180°C. Therefore it is helpful in carrying bulk power at low sag.

Comparison between ACCC and ACSS:

Consider an ACSS 795 kcmil conductor whose ampacity at 180°C is found to be 1573A and on similar grounds if we take ACCC 816 kcmil conductor; its ampacity at 180°C is 1527A. Hence despite taking a close and higher aluminium area conductor for ACCC conductor with respect to ACSS, the ACCC conductor has delivered less. Therefore ACSS conductors are more superior to the ACCC conductor.

Comparison between AAC, AAAC and ACSR:

AAC and AAAC are both stable up to 90°C against ACSR conductors which are stable up to 75°C. Hence AAC can carry at least 10-15% extra current as compared to ACSR of equal size and similarly AAAC can carry at least 15-20% extra current as compared to ACSR of equal size. Therefore both the AAC and AAAC are superior to ACSR of same size.

Comparison between ACSR and Other Conductors:

There are few other lesser known conductors which discussed here in brief: a) ZTACIR (Zirconium Alloy Aluminium Conductor Invar Steel Reinforced): It has high-temperature aluminium strands over a low-thermal elongation steel core. It can operate up to 210°C satisfactorily. b) GTACSR (Gap Type heat resistant Aluminium alloy Conductor Steel Reinforced): It has high temperature aluminium, grease-filled gap between core/inner layers. It gives satisfactory operation till 150°C. GZTACSR (Gap Type Super Heat Resistant Aluminium Alloy Conductor Steel Reinforced), it has inferior properties than GTACSR in terms of area of cross section used for similar ampacity but it is superior to ACSR for sag comparison.

c) CRAC (Composite Reinforced Aluminium Conductor): It has annealed aluminium over fibreglass/thermoplastic composite segmented core. It has the probable satisfactory operation up to 150°C.

d) ACCFR (Aluminium Conductor Composite Carbon Fibre Reinforced). It is an annealed or high-temperature aluminium alloy over a core of strands with carbon fibre material in a matrix of aluminium. It has the probable satisfactory operation up to 210°C.

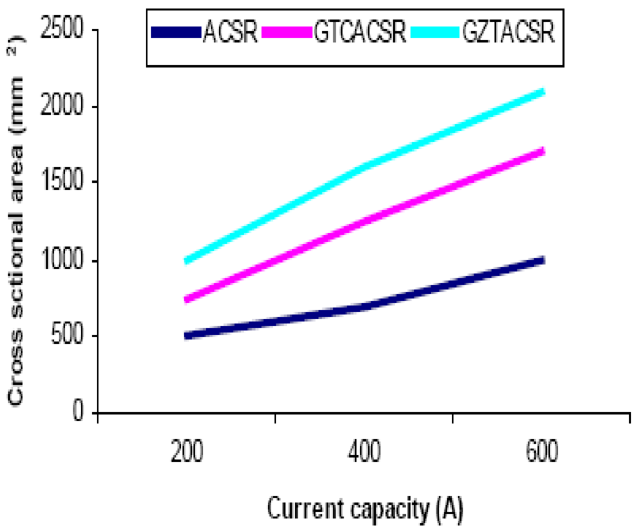

Fig.1.11 Comparison of Current carrying capacities of ACSR, GTACSR and GZTACSR.

From the figure we can clearly observe that the ACSR conductors require less cross sectional area for the same current carrying capacity than GTACSR or GZTACSR.

III. Conclusions

This paper emphasizes the role of thermal capacity (temperature bearing capacity) of various conductors which can be used in the transmission line because during loading condition the temperature of the conductor rises, its core expands and sags. For years we were using ACSR conductors but it has safe limit of only 75°C as a conductor temperature or 100°C for emergency or short duration. It proved to be insufficient; hence the invention of new conductors took place such as ACCR, ACSS, ACCC, AAAC, AAC etc. These conductors were more thermally stable hence could bear the temperature from 90°C (in case of AAC) to 210°C (in case of ACCR) depending upon which conductor is chosen. Hence the ampacity of the various conductors in increasing order is AAC, AAAC, ACCC, ACSS, and ACCR. Similarly the sag produced by various conductors of same size in decreasing order is AAC, AAAC, ACCC, ACSS, and ACCR.

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