The Evolution / Revolution of Overhead Conductors… *and why it matters*

BRIEF BACKGROUND:

In the early 1900's Aluminum Conductor Steel Reinforced (ACSR) conductor was developed to replace copper wires, due to the war effort when copper was needed for munitions. In the 1970's growing demand for electricity inspired the development of higher capacity Aluminum Conductor Steel Reinforced (ACSS) conductor. The ACSS conductor became known as the first "High-Temperature, Low-Sag" (HTLS) conductor. The design used the same steel core as ACSR (with improved galvanized coatings) and fully annealed aluminum so it could operate at higher temperatures and allow the delivery of more electric energy. While fully annealed aluminum is slightly more conductive than non-annealed aluminum, it is somewhat weaker, so overall conductor strength was slightly decreased. In the 1990's a number of conductor manufacturers began using higher strength steel to make up the difference. Comparative data can be found in the chart below.

SOMETHING NEW:

In the early 2000's, a handful of manufacturers introduced composite core conductors such as Aluminum Conductor Composite Reinforced (ACCR)[1] and Aluminum Conductor Composite Core (ACCC)[2]. The ACCR conductor replaced the steel core wires with aluminum wires reinforced with ceramic fibers. The improved conductivity of the core compared to steel and ability to operate at higher temperatures due to the utilization of anneal-resistant aluminum-zirconium alloy, enabled the ACCR conductor to carry twice the twice the current of ACSR conductors, with decreased thermal sag.

While ACSS conductors (and other HTLS conductors shown in the adjacent sag graph) can also carry twice the current of ACSR conductors, the coefficient of thermal expansion of various conductor cores differs and, in some cases, could cause the conductor to sag below safe clearances at higher temperatures depending upon structure height, initial tension and so forth.

Data provided in the Sag Comparison chart was compiled by Hydro One during testing at Kinectrics Lab in Toronto, Ontario, Canada. A Drake size ACSR conductor was installed on a 215 foot test span inside the lab. Each of the "novel" conductors were subsequently installed at equal tension, and a 1,600 amp load was applied (in series) to compare conductor sag.

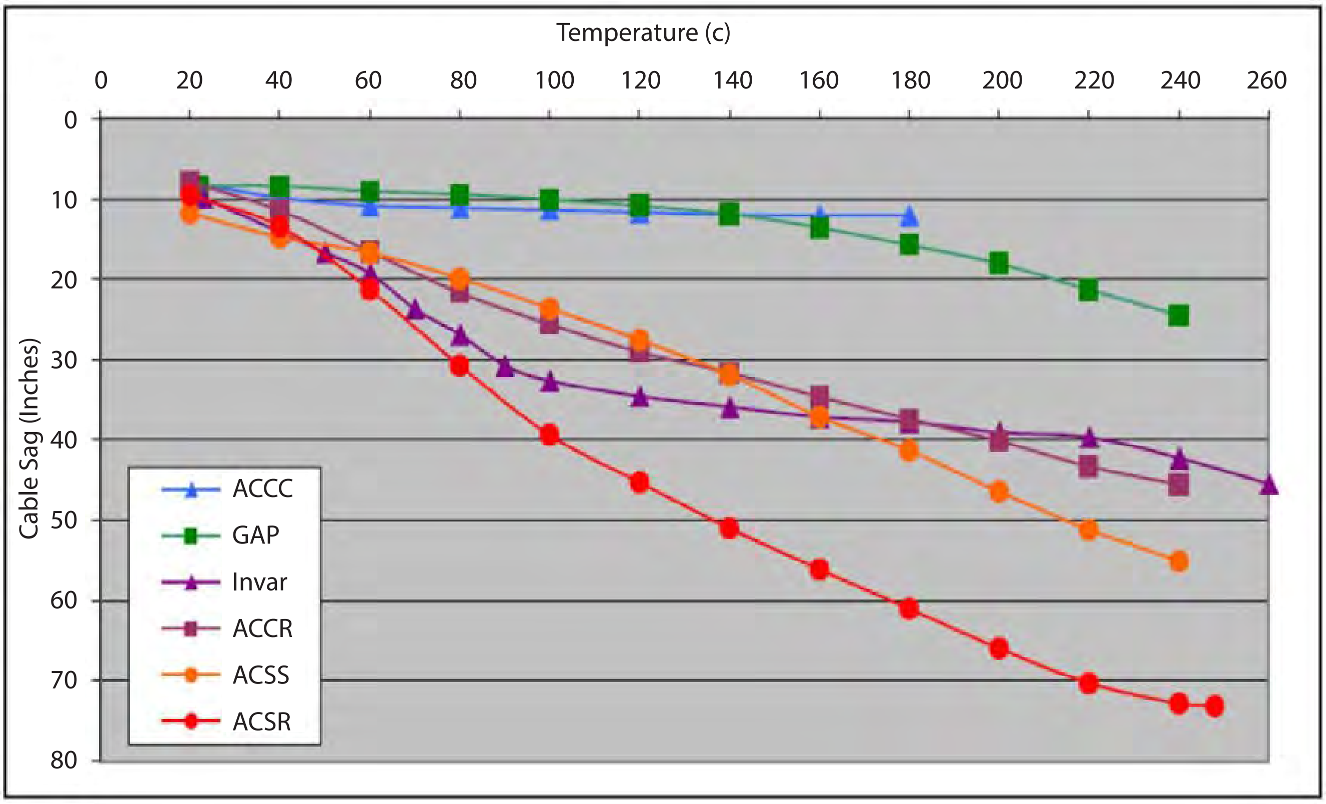
While the ACSR conductor was only designed to operate at ~75° C, due to the fact that the aluminum will begin to anneal at 93° C, the other conductors depicted in the graph were designed to operate at higher temperatures without degradation or weakening due to annealing.

One of the most interesting aspects about this comparison of HTLS conductors is the fact that the ACCC Conductor carried equal current at substantially cooler temperatures compared to the other conductors tested.

Conductor Comparison Chart

Conductor Comparison		Conductive Strands			Core Strands			
Code Name	Conductor Description	aluminum type	tensile strength	conductivity (%IACS)	type	tensile strength	modulus	CTE (x10-^6/deg C)
AAC	All Aluminum Conductor	1350-H19	24-28 ksi	61.2	1350-H19	24-28 ksi	10 msi	23
AAAC	All Aluminum Alloy Conductor	6201-T81	46-48 ksi	52.5	6201-T81	46-48 ksi	10 msi	23
ACAR	Aluminum Conductor Al Alloy Reinforced	1350-H19	24-28 ksi	61.2	6201-T81	46-48 ksi	10 msi	23
ASCR	Aluminum Conductor Steel Reinforced	1350-H19	24-28 ksi	61.2	coated steel	210-230 ksi	29 msi	11.5
AACSR	Aluminum Alloy Conductor Steel Reinforced	6201-T81	46-48 ksi	52.5	coated steel	210-230 ksi	29 msi	11.5
ACSS	Aluminum Conductor Steel Supported	1350-O	~8.5 ksi	63	coated steel	210-285 ksi	29 msi	11.5
ACIR	Aluminum Conductor Invar Reinforced	Al-Zr alloy	23-26 ksi	60	invar steel	175-185 ksi	22 msi	3.7
ACCR	Aluminum Conductor Composite Reinforced	Al-Zr alloy	23-26 ksi	60	metal matrix	200 ksi	32 msi	6
ACCC®	Aluminum Conductor Composite Core	1350-O	~8.5 ksi	63	carbon hybrid	310 ksi	16 msi	1.6
ACCC ULS	ACCC Conductor with Higher Strength Core	1350-O	~8.5 ksi	63	carbon hybrid	375 ksi	19 msi	0.75
ACCC AZR	ACCC Conductor with Aluminum Zirconium	Al-Zr alloy	23-26 ksi	60	carbon hybrid	310-375 ksi	16-19 msi	0.75-1.6

Sag Comparison



ACCC® CONDUCTOR DESIGN:

The ACCC® Conductor replaced the steel core (or aluminum core strands) with a single non-conductive carbon and glass fiber composite core. This design, coupled with the use of compact trapezoidal aluminum strands, allows a 2X increase in capacity with greatly reduced thermal sag. The standard ACCC Core has a coefficient of thermal expansion of 1.6 x 10^{-6} per degree C, which is about ten times less than steel (11.5 x 10^{-6} per degree C), and nearly twenty times less than aluminum (23.0 x 10^{-6} per degree C). The ACCC Conductor is also available in a higher strength - higher modulus ("ULS") version that further reduces the coefficient of thermal expansion to 0.75 x 10^{-6} per degree C. The ULS version also increases tensile strength from 310 ksi to 375 ksi. For comparison, high strength steel is generally rated at 285 ksi.

While the ACCC Composite core is fully elastic and will not plastically (and permanently) deform like steel or aluminum when subjected to severe wind or ice loads, it can exhibit greater ice load sag compared to steel reinforced conductors. To combat extreme ice load conditions the base or ULS versions can be used with stronger aluminum-zirconium alloy strands, as shown is the comparison chart above.

ACCC CONDUCTOR BENEFITS:

While increased capacity and reduced thermal and ice sag are primary conductor attributes, the ACCC Conductor's composite core offers additional benefits. Unlike steel, the composite core will not rust or corrode. It is also highly resistant to cyclic load fatigue. Legacy conductors such as ACSR and ACSS generally use round core wires and round conductive strands. When subjected to vibration and/or galloping, the small contact area where the helically wound strands cross over each other can lead to fretting fatigue, micro-fracture propagation and broken strands. Broken strands can cause hot spots on the conductor which can also damage galvanized coatings and accelerate corrosion. The ACCC Conductor uses a single, smooth-surface composite core and smooth-surface trapezoidal shaped strands the dissipate vibration much more effectively, while also mitigating fretting fatigue.

Legacy ACSR/ACSS Conductor and Modern ACCC® Conductor

EFFICIENCY ATTRIBUTES:

As depicted in the graph above, the ACCC Conductor is able to carry high levels of current at relatively cooler temperatures compared to other conductor types of the same diameter and weight. This is because the carbon fiber core is about 70 percent lighter than the steel core it replaced. The lighter weight core allows the incorporation of nearly 30 percent more conductive aluminum in any given conductor size. The added aluminum content reduces the conductor's electrical resistance. Reduced electrical resistance reduces transmission and distribution line losses by approximately 30 percent.

WHY IT MATTERS:

According to a researchers[3], nearly one-billion metric tons of CO2 equivalents can be attributed to transmission and distribution line losses. While substantial efforts are ongoing to reduce Greenhouse Gas (GHG) emissions by improving the efficiency of generation assets and demand side applicance, build more renewable sources of generation and convert vehicles and other equipment to electric power, very little is being done to improve *the efficiency of the grid itself* that is expected to deliver as much as 60 percent more electricity by 2045[4].

The ability of the ACCC Conductor to deliver more power, *more efficiently*, is so remarkable that the technology is now being recognized by multilateral banks and has become a tool in their kit to combat climate change. While dozens of new lines and reconductor projects are being funded based on the desire to support economic development *and* combat climate change in developing countries, the situation in North America is somewhat different, but equally urgent.

In the United States it has become extremely obvious that climate change has led to more frequent and severe weather events. In 2019 and 2020, drought conditions, sagging power lines and flying debris caused firestorms that had devastating consequences. Earlier this year (2021), unusual freezing temperatures in normally very warm states caused severe blackouts when generation assets and inadequate transmission could not support peak load conditions. The economic consequences and loss of life were severe.

TIME TO ACT:

While FERC is studying a new "consumer benefits" approach to offering incentives to inspire more investment in transmission and determine ROI's, and the new administration seems keen to build a more robust infrastructure, at this point in the U.S., we may be stuck in a holding pattern as it relates to considering the importance of building a higher capacity, *more efficient* grid. But as we all know, there are already many projects in the queue, and it can take years to get new projects approved.

When contemplating project alternatives and conductor selection, please consider using modern conductors such as ACCC. The technology has been proven at nearly 1,000 projects in 60 countries; has a demonstrated track record of success; and provides an excellent means of future-proofing our transmission system for things that our planners may have not yet envisioned. The return on investment is tremendous and the opportunity huge.

1. ACCR was developed by the 3M Corporation.
2. ACCC® is a registered trademark and developed by CTC Global Corporation.
3. The Climate Mitigation Opportunity Behind Global Power Transmission & Distribution – Kavita Surana and Sarah M. Jordaan; Nature Climate Change, Volume 9, September 2019, 660-665
4. Southern California Edison – "Pathway 2045"

ACCC® Conductor
High-Capacity, Low-Sag Conductor
Lowest Cost Solution to:
Mitigate Sag Violations
Increase Line Capacity
Resolve Project Challenges
Over 110,000 Kilometers at over 900 projects in 60 countries
Now available with the InfoCore™ System
For More Information please contact:
CTC GLOBAL
www.ctcglobal.com