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Improving the Efficiency, Capacity and Reliability of the Smart Grid Using ACCC Conductor

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SUMMARY

The U.S. Department of Energy defines Smart Grid as "an electrical grid that uses computers and other technology to gather and act on information, such as information about the behaviors of suppliers and consumers, in an automated fashion to improve the efficiency, reliability, economics, and sustainability of the production and distribution of electricity."

While efficiency and reliability are clearly established goals of the U.S. Department of Energy's Smart Grid, by definition, the means by which they strive to achieve these goals, via information gathering and behavior monitoring, may add layers of complexity to an already complex system.

Surprisingly absent from the Smart Grid definition is the term "capacity." The US Energy Policy Act of 2005 clearly stated and provided several incentives for the utilization of new technologies that can improve the "efficiency, capacity and reliability of the grid." This included advanced conductors such as Aluminum Conductor Composite Core "ACCC."

This paper discusses the importance of increased capacity as a component of Smart Grid objectives and also explores a less complex method of improving the efficiency and reliability of the grid using advanced ACCC® conductor versus electronic monitoring alternatives. Is adding complexity to an already complex grid really that smart? An "efficient grid" that uses high-capacity, low-sag and low-loss conductors may be smarter, less expensive, more reliable and potentially less prone to disruption due to telemetry or computer failures.

KEYWORDS

Smart Grid; Advanced Conductors; HTLS Conductors; Transmission Efficiency; ACCC

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On August 14th, 2003, the Northeast United States and Ontario Canada experienced the second most widespread blackout on record at that time (after Brazil in 1999) affecting 55 million people. Six weeks later, on September 28th, 2003, a similar outage occurred in Europe which affected 56 million people. According to the final NERC report [1], the US/Canada blackout of August, 2003, was caused by a number of factors. This included incorrect telemetry data used to operate the Midwest Independent Transmission System Operator (MISO) "State Estimator" (and subsequent re-boot failure); a "race condition" computer bug in FirstEnergy's Energy Management System; and three 345kV transmission line trips (outages) due to excessive conductor sag, which led to a cascading of similar sag-trip outages on their 138kV system. These events and lack of effective communication between other utilities ultimately shut down 508 generating units at 265 power plants.

On July 30th and 31st of this year (2012), a series of blackouts in India affected more than 670 million people. At the time of this writing it is not known what sequence of events caused these blackouts, but initial reports suggested a shortage of generation and grid limitations [2].

As we strive to modernize our transmission infrastructure, globally, we need to consider the importance of capacity, efficiency and reliability of conductors used in the Smart Grid, and recall lessons from the past that remind us of the limitations of computers and telemetry devices to offer effective capacity alternatives during peak demand periods, N-1 conditions, or more serious emergency events.

In 2005, a new conductor was introduced to electric utilities worldwide that offered increased capacity and reduced thermal sag due to the low coefficient of thermal expansion of its carbon fiber composite core. The Aluminum Conductor Composite Core "ACCC" conductor was initially developed to help alleviate congested transmission lines that were driving costs of electricity up, as less expensive sources of energy could no longer be imported due to transmission line thermal constraints. Though it took several years of testing and validation by a number of utilities, worldwide, ACCC has redefined the "High-Temperature, Low-Sag" HTLS acronym. ACCC conductor is now known as a High-Capacity, Low-Sag "HCLS" conductor.

While the ACCC conductor is among a number of other conductors capable of being operated at temperatures up to or above 200°C during emergency operating conditions, the ACCC conductor's added aluminium content and decreased electrical resistance (compared to other conductors of the same diameter and weight), offers reduced line losses under normal and extreme conditions. Figure 1 depicts the sag and operating temperatures of several conductors tested at a maximum load of 1,600 amps [3]. While the ACCC conductor offered the lowest thermal sag compared to the other conductors tested, it also operated 60 to 80 degrees C cooler under the same 1,600 amp load. The significantly reduced operating temperature reflects a substantial reduction in line losses under this extreme condition. However, even under normal operating conditions, the ACCC conductor's decreased electrical resistance still offers a substantial reduction in line losses as described in more detail below.

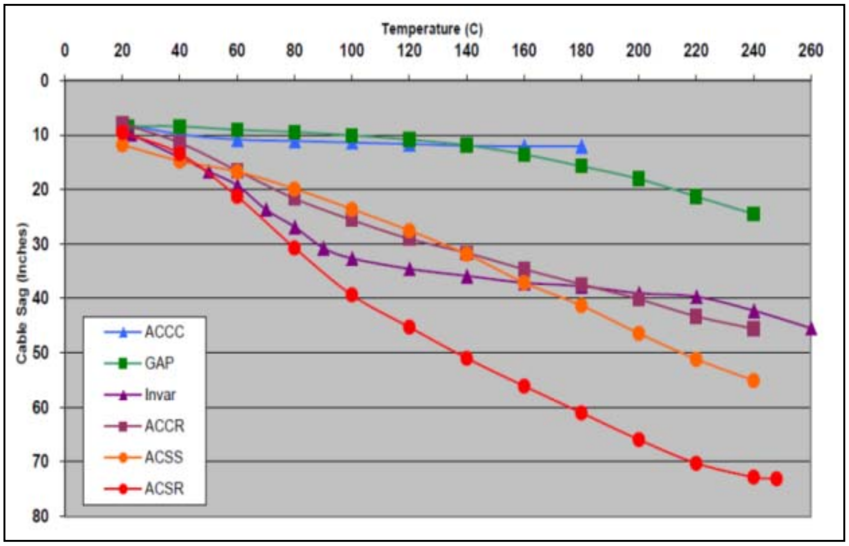

Figure 1 - Sag and Temperature Comparison of several Drake size conductors at a peak of 1,600 Amps.

While increased line capacity is major element of grid reliability, improved efficiency through reduced line losses should also be considered an important Smart Grid objective. According to the United States Energy Information Administration, more than 1.4 trillion kWh hours are lost during the transmission of electricity every year, globally. If that number could be reduced by one-third using more efficient high-capacity low-sag overhead conductors such as ACCC, 466,620,000 MWh could potentially be saved every year. This is the energy equivalent of 53,267 MW, which is the generation required to power nearly 48 million homes (not taking capacity factor into consideration).

From an oil-energy perspective, at a Btu conversion rate of 42 percent, a one-third reduction in line losses would save the energy equivalent of 1.9 billion barrels of oil annually. That's a potential energy savings of over 5.2 million barrels of oil per day, just by replacing a conventional steel reinforced overhead conductor with a more efficient composite core conductor of the same diameter and weight (meaning no expensive structural modifications would be required to perform the upgrade). This potential energy savings could have a profound impact on society, our resources and the environment.

As it relates to line loss reductions and CO_2 emissions, using the combined US national average CO_2 generation of 1.372 lbs per kWh (for all sources of energy including coal, natural gas, nuclear, wind, solar, geothermal, etc., combined) [4], a one-third reduction in line losses offered by the ACCC conductor would equate to a reduction of 1.2 trillion metric tons of CO_2 annually, which is comparable to removing 55.8 million cars from the road. Additional reductions in NOx and SO_2 could also be realized depending upon fuel source.

Looking at things on a project-level scale, as AEP, PacifiCorp, OG&E, NV Energy and several other utilities have, a 62 mile, 230 kV transmission line operating at a relatively low load factor of 53 percent with a peak ampacity of 1,000 amps was considered. Using common operating assumptions and a conventional steel reinforced ACSR Drake size conductor, line losses would amount to nearly 77,000 MWh annually. By upgrading to a higher capacity, more efficient composite core conductor of the same diameter and weight, a reduction in line losses would save over 20,000 MWh every year. Simply stated, the new conductor would save the equivalent of about $1.00 per linear conductor foot in reduced line losses, each year (at $50/MWh assuming a three phase 62 mile AC line).

The generation capacity savings offered by the reduction in line losses in the 1,000 peak amp scenario described above, would also save the equivalent of 8 MW of generation. That equates to over $8.00 per linear conductor foot, which in most cases would be higher than the cost of the conductor, *installed.*

Increasing the peak ampacity in the scenario above from 1,000 to 1,600 amps (at the same 53 percent load factor) the line loss reduction *savings* jump from 20,000 MWh per year to 73,000 MWh per year, with a generation capacity savings of 29 MW. Converting these values into $/linear conductor foot, you would realize a line loss reduction savings of $3.71 per foot, per year, and a generation capacity savings of $29.26 per linear conductor foot.

In this scenario the line loss reduction savings would nearly pay for the cost of the conductor in the first year, while creating an attractive revenue stream over the life of the asset. Conversely, spending ~$5 million on a conductor that saved approximately $29 million on generation investment (assuming a generation cost of $1 million/MW), offers additional advantages. Keep in mind that special permits are generally not required to replace conductor, as this is generally performed under maintenance programs.

To date, approximately 10,000 miles of ACCC conductor has been installed at over 220 project sites, worldwide. Here in the U.S., AEP is preparing to install over 1,650 miles of ACCC on their 345kV "Valley" reconductoring project while the line remains energized. This will be the largest deployment of ACCC conductor in the U.S.

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