TSOs Advance Dynamic Rating

A revolutionary line monitoring system is having a positive impact on Belgian and French transmission systems.

By **Eric Cloet**, *Elia, and* **Jean-Luc Dos Santos**, *RTE*

The rapidly increasing volume of renewable energy sources, especially large coastal and off-shore wind farms, has triggered the need for additional transmission capacity. However, transmission system operators (TSOs) face a huge power-delivery problem: increased resistance to the construction of new transmission lines. In such an environment, TSOs have no choice but to explore new ideas to increase the capacity of existing transmission lines.

Faced with this very problem, Elia, the Belgian TSO, decided to participate in a project launched by the Université of Liège in Belgium called Ampacimon, which is short for ampacity monitoring. Elia was quickly joined by RTE, the French TSO. The development and field trials, which extended over a period of two years, were successfully completed in 2010.

Real-Time Monitoring

The primary concern with the electrical loading of high-voltage overhead lines is ground clearance, which depends on several factors, including constantly varying weather parameters. This means the conductor sag is continuously changing, affecting vertical clearances and, ultimately, the permissible thermal rating of the line. In the past, the difficulty of predicting weather parameters has resulted in conservative assumptions to ensure public safety and power-system security.

A Fabricom Gdf Suez lineman in Belgium installs an Ampacimon sensor on one of Elia's 150-kV lines.

If TSOs are to increase the use of the overhead line circuits' load-transfer capacity while ensuring the regulatory clearances above ground are maintained, they need a system that determines the available real-time load-transfer capacity and conductor sag by direct measurement, without the need to factor in unreliable parameters based on theoretical models.

Smart Sensor Ampacimon

Ampacimon is a smart sensor attached directly to an overhead line conductor. It can evaluate the real-time sag without the need for any supplementary data, such as load, topological data, conductor data and weather data. The Ampacimon system does this by analyzing the conductor's vibrations, detecting the span's fundamental frequencies.

The fundamental frequencies form the exact signature of the span's sag. A larger sag means lower frequencies and vice versa. Exterior conditions such as load, weather, topology, suspension movement, creep and the presence of snow and ice affect the sag, and, therefore, are automatically incorporated into the frequency readings. Thus, this method is a direct sag evaluator compared to other methods that determine the sag based on conductor temperature measurements and inferences about other parameters.

Modules can be installed anywhere along the conductor suspended between two supports. Using accelerometers, even a slight movement of 1 mm (0.04 inches) can be detected at the lowest frequency for a typical span (at a nominal requency of 0.15 Hz), with even smaller movements detectable at higher frequencies. Data is initially processed by a data signal processor (DSP) before being sent by global system for mobile communications/general packet radio service (GSM/GPRS) to a remote server, where it is collated and analyzed to give the appropriate readings.

Once the Ampacimon unit is installed on the conductor, it is powered by the local electromagnetic field and is, thus, autonomous. Furthermore, it does not need to be calibrated, as the sag is deduced from the detected frequencies and not from signal amplitude. Modules measure around 400 mm (15.75 inches) in length and weigh approximately 8 kg (17.6 lb). They are fixed to the high-voltage conductors and can be installed using live-line techniques.

Principle

The sag is well known by definition; sag represents the largest vertical distance between the catenary and its imaginary chord (between the two attachment points). Measuring sag is time-consuming and usually done by land surveyors. However, cable dynamics also can solve the problem and determine the sag easily. The only parameter that must be known is the fundamental frequency because there is a relationship between that frequency and the sag. It is important to note this relationship does not make use of any data apart from the gravitational constant.

It is comparable to the pendulum. If a pendulum is oscillating, its swinging frequency is independent of its mass; the swinging frequency is just related to its length. Thus, by using a system to detect the movement of the span that is able to deduce from that movement the fundamental frequency, the sag can be found immediately without the need for other data, such as span length, mass of conductor, tension and so forth.

Practical Experience

Several Ampacimon modules have been fitted to Elia's and RTE's high-voltage transmission lines, and a whole system has been developed that includes the transmission links with the two TSOs' national control centers.

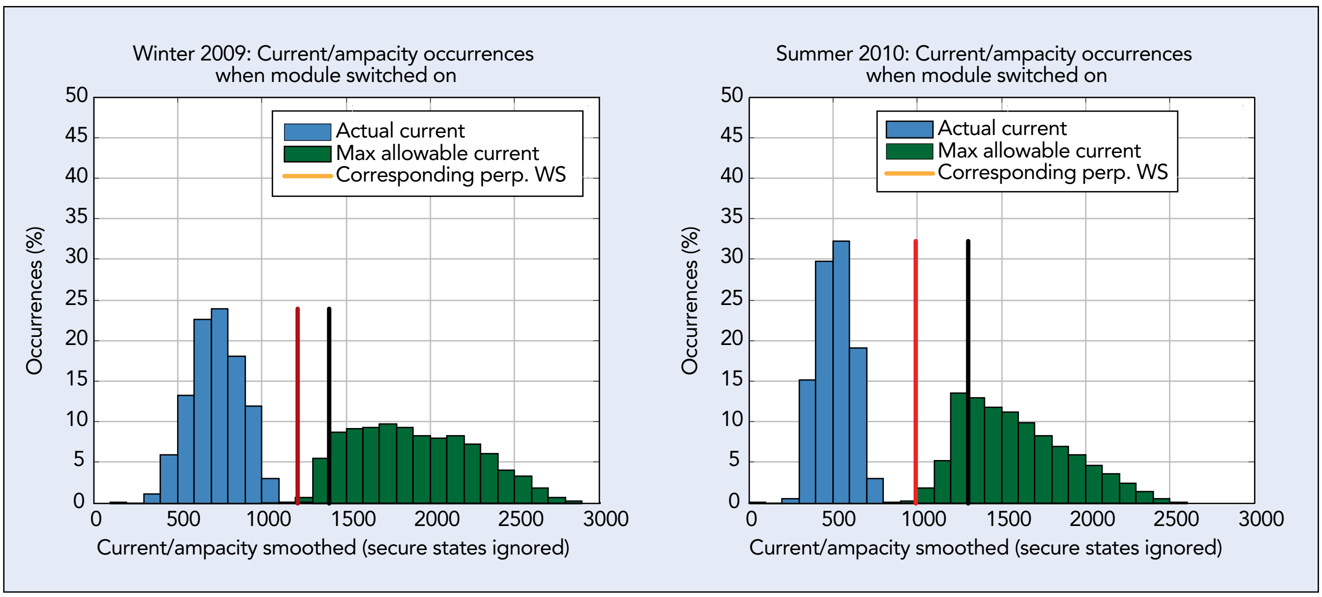
Completed field tests have confirmed the free choice of location along the span, and the simple clamp-on attachment makes installation a trouble-free process. In areas with especially high system loads, the possibility to install modules without the need for a system outage also has facilitated planning and accelerated the project. During the commissioning phase, the frequency signature of the span is determined. This critical phase has required substantial attention.

An RTE lineman installs an Ampacimon sensor (inset) using live-line techniques on a 245-kV line.

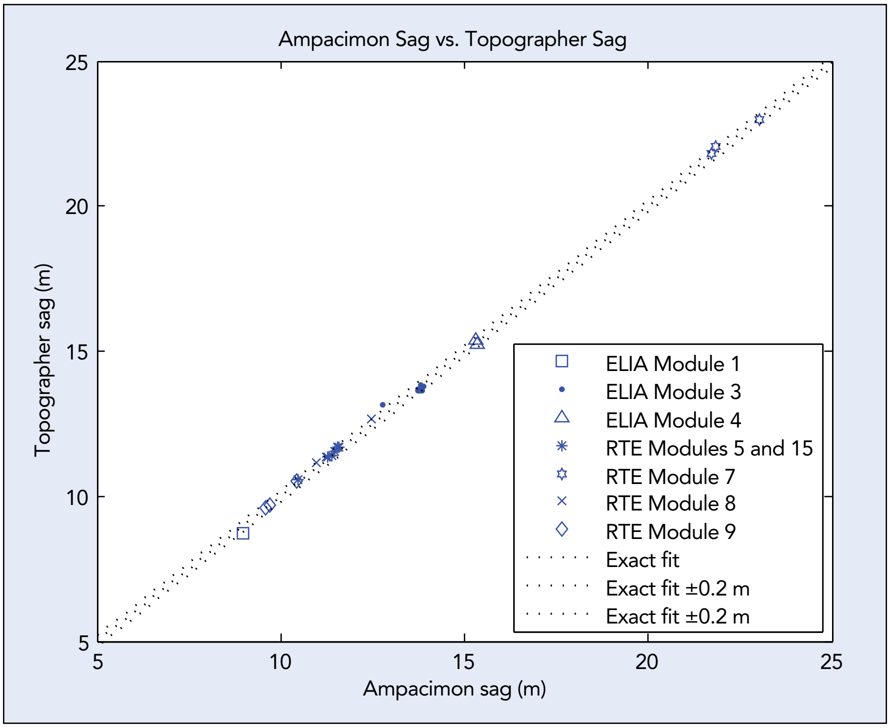
Sag Evaluation

To verify the system, independent land surveyors measured the sag at a given point over a period of several days and on many different spans and on circuits with different conductors and span lengths, including suspension spans and dead-end spans. Comparison of the results showed the margin of error to be some 200 mm (7.87 inches), which is sufficiently accurate enough to predict ampacity.

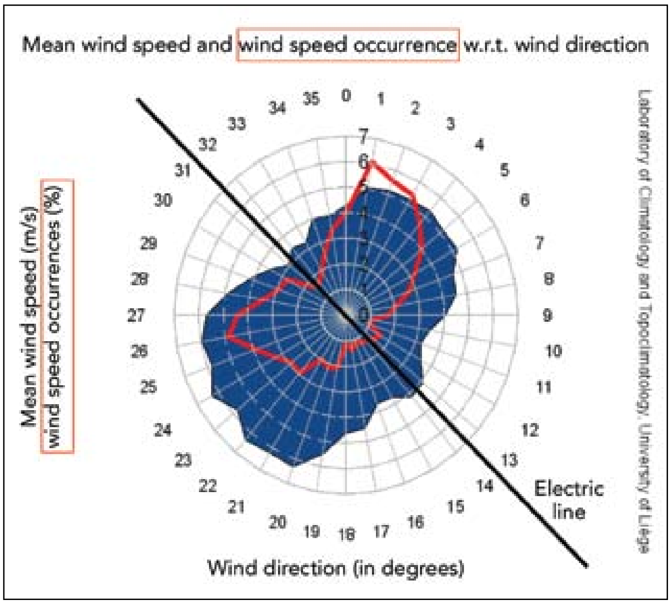
Based on this comparison of readings, it is possible to confirm Ampacimon gives appropriate and highly accurate sag



Histograms of the occurrences of actual loads and allowable dynamic load ratings. The vertical red line represents the 1,200-A static rating, and the black line is the operator target maximum of 1,400 A. It is obvious that this line has considerable capacity that is both unused and available.



Comparisons of sag as verified by surveyors and the sag as determined by Ampacimon show that there is very little difference.



Distribution of the wind direction for a year, showing percentage time in each direction at St. Nazaire, France.

measurements across the whole range, from 0 m to 25 m (0 ft to 82 ft), with less than a 200-mm margin of error. The Ampacimon system has proven to be accurate within a sag error margin of ±2%.

According to observations, sag changes are not only impacted by load changes, but are, as one might expect, drastically affected by the weather.

Ampacity

The main end objective of dynamic line rating is to increase the load-transfer capacity of the transmission system. Therefore, it was a critical goal of the evaluation to quantify the potential increase with an improved understanding of the parameters that influence this increase. Observations from more than a year confirmed the permissible ampacity was far higher than static ampacity, by at least 20% in most cases.

To a large extent, ampacity depends on the prevailing weather conditions and is particularly sensitive to wind speed and direction. In Bretagne, France, the conditions are favorable as the line is roughly perpendicular to the dominant wind direction in this coastal region that experiences above-average wind speeds.

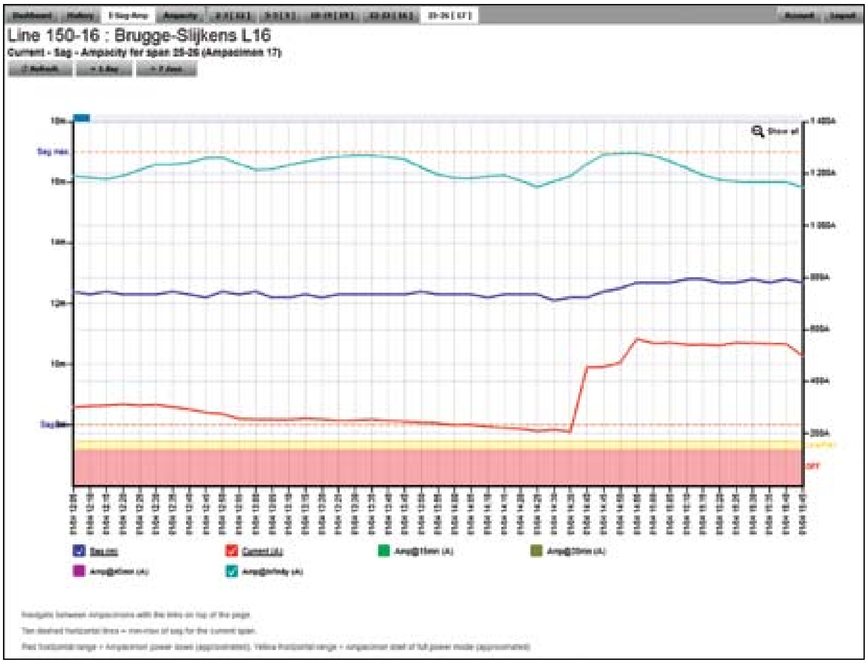
It is important to note relatively low wind speeds are enough to have a significant impact on the line rating and a perpendicular wind speed of 2.4 m/sec (7.87 ft/sec) is sufficient to increase the ampacity by more than 50% above the usual static rating. This is because the wind speed varies significantly both in time and direction; hence, wind measurements are misleading and can lead to an overestimation of the line rating. Direct sag measurements are proven to be a safe method to quantify the additional ampacity available, as all the local effects on the complete line are taken into account.

During a recent experiment in Belgium, a transmission line was loaded to near the nominal capacity of the circuit by isolating the parallel circuit. During the test period, with a conductor temperature of 150°C (302°F) and a wind speed of 8 m/sec (26.2 ft/sec), the sag remained well above the minimum ground clearance and an ampacity of almost 200% remained available for several hours. The final stage was to load the line to the calculated real-time ampacity to confirm the sag remained below the allowable maximum.

Forecasting Model

Real-time ampacity is already very useful, but the availability of a reliable forecast is the key to give the TSO sufficient lead time to use the extra capacity. The Ampacimon system is able to determine, for a given site for which historical observations are available, a four-hour ampacity forecast. For example, with the real-time current being 800 A, the Ampacimon system will predict, in real time, that it is possible to uprate the transmission line to a minimum of 1,400 A for the next four hours. This forecast model was validated in 2010 and will be tried in live operations by RTE and Elia in 2012.

At the Bretagne site, the forecast over a full year indicated it was possible to use the line at 1400 A for more than 50% of the time. The forecast was inaccurate for 0.56% of the time, and even on these isolated occasions, the control center operator had sufficient warning to take action and reduce the load on the line to a new threshold.



Evolution of sag and ampacity during tests in Belgium (150-kV Brugge-Slijkens line). Static rating is 613 A.

A Step Toward the Future

Power systems are at the dawn of a new era as a result of smart sensors and related systems. Success will require fully reliable systems with appropriate autonomy, easy communication and full data integration. During the past two years, the Ampacimon system was tested on 150-kV, 245-kV and 400-kV transmission lines with great success. The innovative approach and success of the Ampacimon system convinced everyone of the technology, even linemen, who appreciated how simple it is to install the units.

To take advantage of real-time monitoring and dynamic ratings, TSOs must be prepared to adapt their conventional working methods by operating the transmission system in accordance with dynamic data received from the system. This is a difficult step to take for the TSOs, but it may prove necessary to cope with the challenges of large-scale integration of renewable and distributed energy sources.

The Ampacimon system is ready for real-time applications (the Belgian company Ampacimon S.A. launched in 2010 to commercialize Ampacimon sensor worldwide). It will be an even more attractive investment, both technically and economically, when day-ahead predictions based on weather forecasts and historical analysis are achieved and fully validated. TDW

Eric Cloet (eric.cloet@elia.be) obtained a diploma in electrical and mechanical engineering as well as a master's degree in informatics from the University of Brussels and a master's degree in management from the Vlerick Management School. He joined the electricity supply industry, starting his career in distribution. With more than 20 years experience in the electricity sector, he held several positions, such as in planning and investment studies, operational audit, replacement studies and maintenance methods. Cloet is active in several national and international associations. Currently, he has a position with Elia, the Belgian transmission system operator, in the customer relations department, where he is responsible for Codes, Contracts and Quality Connection.

Jean-Luc Dos-Santos (jean-luc.dos-santos@rte-france.com) received a diploma in electrotechnical and automatical engineering from the ENSEEIHT of Toulouse in France and joined EDF. Following the liberalization of the electricity market, he moved to RTE, the French transmission system operator. Dos-Santos has spent his career with the operational aspects of the transmission system, and he is currently a senior staff advisor in RTE's transmission department.

Companies mentioned:
Ampacimon S.A. **www.ampacimon.com**
Elia **www.elia.be**
Fabricom GTI **www.fabricom-gdfsuez.com**
RTE **www.RTE-france.com**