Smart Grid

The Role of Distributed Temperature Sensing (DTS) in Smart Grid Implementation

Smart Grid and DTS

As electric utilities across North America, Europe, and the world begin to implement Smart Grid technologies, there is a growing need for complementary monitoring tools. Initial Smart Grid efforts are focused on the "nodes" of the system - primarily the management of power generation and storage elements. However, with the shift from distant to localized renewable power generation and the need for the grid to accept power injections from all energy resources, the reliability, efficiency, and capacity of the cables connecting the nodes is core to realizing the benefits of Smart Grid. The retooling of the electricity infrastructure in major markets is likely to occur over a span of 20 – 30 years. Such a large changeover comes with a unique set of challenges such as standardization of technologies and protocols, synchronization of cross-border regulations, and major decisions regarding interfaces between old and new systems. Continuous, cost-effective monitoring of these interfaces within the new grid structure are essential to the successful implementation of Smart Grid.

The Smart Grid initiative is a major undertaking that the European Commission Directorate-General for Research has compared to the leap the Internet has made into the Web 2.0 age. In a similar manner that Web 2.0 features user-generated content, Smart Grid features user-generated power. As power begins to move throughout the grid in bi-directional flows, it becomes more important to actively monitor all the power cables – not just the EHV transmission lines at the core of the traditional grid system. DTS technology is perfectly suited for power cable monitoring, as it enables continuous, precise, and accurate temperature measurements to be rapidly and dynamically collected across distances typically in the range of 1 to 15km with 0.5m sampling resolution, 0.1°C temperature resolution, and accuracy within +/-1°C.

For power cable monitoring, DTS offers two levels of load characterization when combined with real-time Cable Ampacity Analysis Software (CAAS) – one showing actual (real-time) conditions and the other predicting future conditions (based on possible loads).

First, by continuously monitoring the cables themselves, temperature events (hot spots, cable damage, over current conditions, etc.) are easily identified – reducing the risk of failures associated with operating above the cable's specified maximum temperature (e.g. 70°C). Because the temperature is measured directly, rather than estimated based on load and environmental conditions, the usable capacity in monitored lines is maximized. Utilities today use conservative mathematical models to estimate the cable temperature for given load conditions – building in a "factor of safety" to ensure the cable does not overheat. While these models are effective at protecting the cables from failure, they are ineffective at maximizing the usable capacity of the circuit. As a result of deploying DTS-based, real-time dynamic monitoring, the cable's temperature is empirically, rather than theoretically, obtained, allowing for operation of the cable closer to its maximum capacity. Maximum capacity results in maximum flexibility – which is key to realization of Smart Grid.

The second level uses DTS to make predictions of future conditions based on various load scenarios. This is accomplished by using dense temperature data collected over short measurement times to estimate the heat transfer characteristics of the cable.

What DTS Means to the Grid

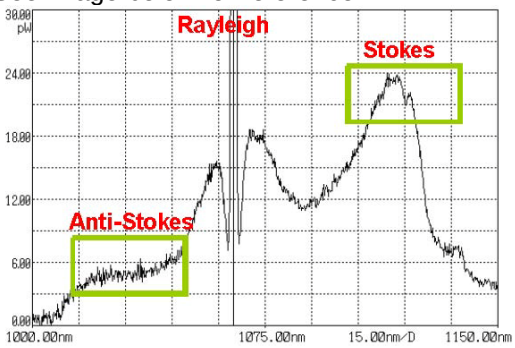
In summary, DTS is a key Smart Grid infrastructure technology that enables:

- Maximization of usable capacity of the circuit

- Ability to cost-effectively monitor all power cables from EHV down to LV
- Active management of loads with little risk of over-temperature failures
- Predictive Ampacity estimation using actual temperature data inputs with CAAS

How DTS Works

Single laser DTS systems use the light source from a single laser to record temperature traces, deriving the temperature information from two backscattered signals that operate at two different wavelengths. One of those wavelengths represents the Raman Stokes signal, and the other represents the Raman anti-Stokes signal. See image below for reference.



Given that the intensity of the optical signal exponentially decays as a function of distance, single laser DTS systems are calibrated utilizing an exponent called Differential Attenuation Factor (DAF). DAF is the difference in attenuation between Stokes and anti-Stokes wavelengths, and it is typically determined by the fiber material. When multiplied by the Stokes, DAF serves as a correction factor to match the attenuation profile to that of the anti-Stokes signal. Temperature is then derived by taking the ratio of the two signals.

Early installations of DTS for power cable monitoring have been focused on the identification of problem areas and hot spots. With Smart Grid implementations however, DTS serves a critical infrastructure role in load management. With the ability to implement DTS monitoring solutions for as low as $10/meter, it is now possible for utilities to obtain and use real-time dynamic temperature measurements across all circuits. With the injection of renewable energy and consumer-generated surplus power into the system, it is critical to control variable bi-directional flows of current in order to ensure efficient, failure-free Smart Grid operation. Using DTS, utilities will be able to closely manage load balancing using actual rather than calculated temperature data.

DTS Software

Data integration and communications functionality are other important components of Smart Grid implementations. SensorTran DTS systems are available with a comprehensive Software Suite comprised of three main applications:

- SensorTran DTS Commander for setting up, calibrating, and managing the DTS system
- SensorTran AssetViewer for advanced graphical asset visualizations
- SensorTran Cable Ampacity Analysis Software (CAAS) for cable ampacity calculations and on-line query tools

This advanced suite of software tools enables users to collect, display, interpret, analyze, manage, and integrate DTS data from multiple units

DTS Installation

Recent technological advances in DTS technology have greatly reduced the time, energy, and expertise required to successfully deploy advanced fiber optic-based monitoring systems. These advances are based on three SensorTran proprietary components: PERFECTVISION®, Calibration Modules, and DTS Commander.
These components combine to provide DTS systems which are easy to calibrate, and periodically verify that calibration is accurate based on installed conditions of the fiber and its surroundings/environment change. This has greatly simplified management of DTS, enabling field crews to set up and operate the system without needing to involve highly skilled technicians. Operators of the system can define zones and set alarms through the control panel on the SensorTran DTS Commander. After configuration, the system will alert the operator immediately when pre-specified temperature thresholds are approached and/or crossed.

PERFECTVISION® technology is a proprietary dual laser solution developed by SensorTran which accounts for non-uniform optical losses in fiber probes, enabling calibration and viewing of backscattered light even in damaged or stress-darkened fiber.

The SensorTran AssetViewer (example shown above) provides the ability to view temperature and alarm information mapped to the actual asset being monitored – enabling both quick and intuitive data interpretation. In addition to an extensive library of existing assets, SensorTran delivers custom builds for unique or complex solutions. The example above illustrates a system-wide view of a substation, including satellite imagery as well as a CAD/CAM representation of the actual facility.

Fiber Deployment for DTS

SensorTran has hands-on experience deploying fiber for new construction and for retrofit applications – where fiber is added to existing infrastructure and circuits.

To date, the majority of fiber deployments for power cables have been during new construction projects. In this situation, the fiber is typically placed inside the cable itself or externally bound/banded to the cable. If properly planned for by both the utility and installer, this type of deployment is straightforward and easily accomplished.

Existing Infrastructure

For situations where existing infrastructure is to be monitored, the fiber optic probe must be retrofit onto the cable or into the cable duct bank. SensorTran has proven through practical demonstration that fiber probes can be successfully retrofit into existing facilities without damaging the power cables, even in situations with sharp angles of up to 90 degrees.

This ability to effectively retrofit DTS monitoring solutions is one of the key elements that makes DTS a unique, cost-effective piece of the Smart Grid infrastructure.

DTS Costs

As previously mentioned, DTS monitoring can be implemented in dense urban conditions for as low as $10/meter. This low-cost is possible because SensorTran DTS systems are designed with the highest optical budget on the market – delivering a best-in-class signal-to-noise ratio & industry-leading temperature resolution. Given the outstanding performance of these systems, a single DTS can be deployed with up to 50 channels, enabling a single DTS to monitor a multitude of discrete assets. Depending on distance and specific monitoring conditions, a single probe may be used to monitor one cable using one channel or run serially along multiple cables, enabling one channel to monitor more than one asset.

Cable Ampacity Analysis Software

In addition to providing real-time distributed temperature data, Cable Ampacity Analysis Software is now available to provide real-time temperature rating (RTTR) capabilities. CAAS uses the dense DTS temperature measurements made over time and real-time load as inputs to improve the accuracy of ampacity calculations.

CAAS computes the cable conductor core temperature in-real time and provides various query-based tools for the computation of cable thermal ratings as below:

- derive ampacity from time and temperature
- derive temperature from load and time
- derive time from load and target temperature

This capability is available without requiring any additional hardware, further enhancing the value of DTS deployment.

The ability to use one cost-effective DTS system to monitor circuits for immediate and future capacity-related events is clearly in line with the goals of efficient Smart Grid implementation – making it a key infrastructure technology.

The SensorTran Advantage

SensorTran, a NASA technology spin-off, is the technology leader in distributed temperature sensing and is committed to supplying its customers with smart, cost-effective distributed monitoring solutions. The company employs the largest fully DTS-focused team in the industry and is leading the charge in pushing the boundaries of the existing technology while making DTS easier to use. The SensorTran team is dedicated to providing “best-in-industry” customer care from project conception to the development of specifications, through installation, training, and beyond.

SensorTran is ISO-9001 certified and UL registered.