Distributed Temperature Monitoring of Energy Transmission Systems

Meeting the Demands of a Modern Power Management
Coordinated Control for your Assets

In times where power utilities face growing need of energy - forcing operators to stress the power cables to the physical limit - safety and efficiency becomes more and more important.

Undoubtedly, knowledge in real time of cable temperature and thermal behaviour of the cable installation are key to control safety and efficiency of a power distribution network. Regardless of cable design, operational limits or installation practice, the fact is that unforeseeable adverse thermal conditions can and do cause system capacity degradations and service interruptions - especially with fatigue. The monitoring systems by LIOS Technology enable the user to locate any cable hotspot before failure, to dynamically optimize the power load and ensure reliable supplies of electricity.

Systems of the OTS product series measure temperatures by means of optical fibres functioning as linear sensors. Temperatures are recorded along the sensor cable, thus not at points, but as a continuous profile. A high accuracy of temperature determination is achieved over great distances or large surfaces, whilst measuring times are short.

- Real time temperature profile measurement.
- Increased performance and an extended measurement range up to 10 kilometres at a single end multimode fibre.
- Precise localisation of hotspots at early stages due to an appealing spatial measurement resolutions even at most remote distances.
- Multiple alert parameter freely configurable for each zone.
- Integrated fibre switch for monitoring different cables respectively phases simultaneously.
- Trend analysis and online interface to accurate thermal rating systems.

Our impressive track record in various market segments demonstrates high reliability and industrial strength. The LIOS’ OTS technology has been successfully proven in critical applications like fire detection in road and rail tunnels and special hazard buildings, power cable and transmission line monitoring, in oil & gas exploration for permanent downhole monitoring and for industrial induction furnaces surveillance, where these systems have been equipped in worldwide projects with more than 1000 permanent installations since 1997.
Power Cable System Monitoring

- Localised areas of high native soil thermal resistivity
- Mutual heating effects from parallel or crossing distribution or transmission circuits
- Elevated ambient temperatures from cables located under asphalt

The actual distributed cable temperature along the entire length of the cable route provides the answer to questions regarding:

- Load capacity adaptation at crossings with district-heating conduits or cable bundling
- Load capacity adaptation when conduits are laid for particular route sections
- Utilisation of reserves in extreme situations without having to exceed permissible conductor temperature
- Reduction of outages and improvement of operating efficiency
- Location of cable “hot-spots”

Maximising power transfer and minimising costs of existing as well as designed cable routes are key goals of modern power management and utilities. With extensive assets of underground cables, this means knowing the “hot spot” along a cable circuit. Calculation is based on the permitted conductor temperature of the cable type used and the assumed heat dissipation which may result from one or more of several conditions:

Distributed temperature sensing is a powerful tool that allows to accurately rate the cables based on actual field conditions. It is especially valuable for dynamic rating, since the accuracy of the temperature modelling can be coupled with the monitoring and the predictive functions of the dynamic rating system.

LIOS Technology provides expert knowledge on monitoring techniques and methods for all types of power cable systems. With optical fibres located in the shield area of the MV, HV and EHV power cables, it is possible to measure temperature profiles of the entire cable length with a high degree of accuracy.

LIOS TECHNOLOGY

Courtesy of NKT Cables GmbH
Monitoring Overhead Line Conductors

Providing sufficient electrical power reliably requires ongoing monitoring of temperatures within overhead transmission lines. The LIOS monitoring system is an inexpensive and highly reliable method that enables real-time monitoring of an entire network or of selected critical spans.

LIOS Technology introduces a sophisticated monitoring system for overhead transmission lines, which enables the utility to activate previously unused resources in existing power lines and to respond quickly and dynamically to transmission requests or overload conditions.

The easy-to-install, low-maintenance system offers a multitude of advantages. By enabling dynamic analysis of network structure, it increases the overall safety and reliability of the grid. It facilitates dynamic reactions to transmission requests, resulting in more flexible capacity and revenue management in both the short and long term. And the potential for cost-savings is enormous: Downtimes and blackouts can be avoided, and the need for new lines and upgrades (e.g. increasing the height of overhead transmission lines) can be greatly reduced.

Operating benefits:

- Increase earnings by activating previously unused resources in existing power lines
- Respond quickly and dynamically to transmission requests by online metering of the grid capacity
- Conduct precisely and in real-time load predictions as new sources of energy are added to the grid
- React quickly to overload conditions
- Distributed temperature data provides real time information on critical sag, load and thermal line conditions
- Utilisation of reserves in extreme situations without having to exceed permissible conductor temperature
The so-called Raman effect is particularly well established to measure temperatures with optical fibres made of Quartz glass. The light in the glass-fibre scatters at microscopically small density fluctuations which are smaller than the wave lengths. Apart from the elastic part of the dispersion (Rayleigh scattering) found in the back-scattering on the same wave length as the incoming light, there are also additional components on other wave lengths caused by the molecular oscillations, and thus the local temperature.

By detecting the back-scattered Raman light from the sensor cable it is possible, reliably and without interference, to indicate changes in temperatures of a few degrees centigrade per minute.
Highly Advanced Technology...

System Design
The OTS systems consist of an evaluation unit to which the fibre-optic sensor cable is connected. Both components can be individually adapted to the respective conditions of deployment, both with regard to their fittings and to the technical specifications. However, there are evaluation units with different ranges, local resolutions and measuring time intervals. LIOS offers the right sensor cable for every application. The type is in particular determined by the expected ambient temperature and the required mechanical stability. The sensor cable can be either integrated into the power cable resp. transmission line or attached closely on its sheathing. The temperature profiles themselves, or the results deriving from these, can be transmitted via standard interfaces from the evaluation unit as required, and be either displayed or further processed by PC, PLC or SCADA systems.

As a result of the increasing demands placed on the ability to network and integrate measuring systems into management systems, LIOS offers network components which summarise OTS data from several evaluation units and transport or convert it to the required network standards and protocols like DNP3, IEC60870-5 or XML based data interfaces (e.g. POSC).

This unique technique allows an evaluation of the Stokes- and Antistokes line which yields distributed data on temperatures with high accuracy from the entire length of the sensor cable.
The fibre optic sensor element is a purely passive optical cable, no-maintenance and immune to:

- Electromagnetic interference
- Mechanical influences
- Atmospheric conditions
- Extreme temperatures
- Aggressive chemicals, fluid or solid
- Dust and dirt

The optical fibres are the most important components in the sensor cable. The optical fibres are typically encased in a stainless steel tube which increases the mechanical stability of the cable significantly. In addition, the inside of the pipe is lined with gel to ensure that the sensor cable remains permanently water-proof. There are various options for the outside jacketing of the stainless steel tube, so that the sensor cable can be optimally adapted to every application.

The fact that temperatures are measured purely optically produces two major advantages for this technology. Firstly, the high electromagnetic tolerance means that fields of disturbance, such as high voltage cables, electric motors or any kind of transmitter (e.g. mobile phones), do not disturb the measurement. Secondly, the sensor cable is practically maintenance free. All maintenance work can be performed from the evaluation unit.

No electronic elements need to be installed along the cable. The measuring system is fully passive in the actual measuring area. Fibre optic temperature measurement systems from LIOS Technology can therefore also be deployed in areas with high safety risk, such as places endangered by potential explosions.
The applied OFDR light source is a modern and durable semiconductor laser diode, instead of a rather complex solid state laser, which powers typically Raman OTDR systems. The semiconductor laser diode has been critically type tested according the Telcordia GR-468 standard and is fulfilling telecom standards with a medium lifetime of > 25 year.

### Product Concept and Specifications

Increase your grid security and prolong the working life of your facilities by a complete network monitoring solution based on distributed temperature measurement.

- The multi channel capability of the OTS is perfectly suited for the entire surveillance of a 3 phase cable system or a 2 x 3 phase double cable system.

- The powerful Ethernet TCP/IP interface simplifies links to network structures significantly.

- A direct link to SCADA and other overall management systems is ensured by proven protocol conversion to industry standard protocols, like DNP3 or IEC 60870-5.

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<td>4 km OTS40P</td>
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<tr>
<td>6 km OTS60P</td>
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<tr>
<td>8 km OTS80P</td>
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<tr>
<td>10 km OTS100P</td>
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<tr>
<td><strong>Measurement Channels</strong></td>
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<tr>
<td>(Standard: 1 Channel)</td>
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<tr>
<td>2, 3, 4, 6 or 8</td>
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<td><strong>Spatial Resolution</strong></td>
</tr>
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<td>3 m / 1.5 m</td>
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<tr>
<td>1 m</td>
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<td>0.5 m</td>
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<tr>
<td>20 Relay Outputs</td>
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- Feature implemented
- Feature available as an option
- Only in combination with Ethernet interface
- Additional software package, customized for a particular project, engineering effort applies
The OTS distributed temperature sensing product series, front and rear of the evaluation unit, here an eight channel version. The product series OTS60P, OTS80P and OTS100P delivers increased performance and an extended measurement range up to 10 kilometres at a single end multimode fibre.

Technical Data

- **Performance**
  - Range: up to 10 km (at a multimode GI 50/125 or 62.5/125 fibre single end measurement)
  - Number of measurement channels: 1, 2, 3, 4, 6, 8
  - Spatial resolution: down to 0.5 m
  - Temperature resolution better than 1.0 K

- **Power supply**
  - DC power supply 20 .. 30 V DC,
  - power consumption typ. 33W max. 39W@24V DC
  - Socket SUB-D 3WK3, 3 pin
  - AC power supply 85 – 264 V AC, 47 – 63 Hz
  - Input current
    - @230V AC; max. 0.3 A
    - @115V AC; max. 0.6 A

- **Communication**
  - Interface RS232, socket SUB-D 9 pin male
  - Interface Ethernet, TCP/IP, socket RJ45
  - 4 programmable inputs, socket SUB-D 9 pin female
  - Up to 20 programmable outputs,
  - socket SUB-D 25 pin female, resp. SUB-HD 44

- **Operation conditions**
  - Laser classification Class 1M Product
  - Temperature 0°C to 40°C
  - Relative humidity up to 95 % (non condensing)
  - Cable deployable in areas endangered by explosions (EX up to zone 0)

- **Mounting**
  - Recess mounting in 19" cabinet, mounting heights: 3U
  - Size H x W x D 13.5 cm x 44.9 cm x 31.5 cm
  - Cabinet depth 60 cm, width 60 cm (swing frame: width 80 cm)
  - Weight 10.2 kg
Convincing Features

Improved spatial resolution
Apart from the standard spatial resolution of 3 m, a more exact scanning of the sensor cable is necessary for other applications. The latest system makes spatial resolutions up to 50 cm possible and is thereby applicable for cable monitoring in order to protect a cable circuit from overheating and at the same time maximise its load.

The applied Optical Frequency Domain Reflectometry (OFDR) principle ensures a temperature survey even over long distances at an appealing spatial resolution of 1 m or even 50 cm, which suits the needs of the electrical asset operators. The OFDR technology provides an almost invariant spatial resolution along the entire sensor length, which ensures to identify and clearly measure atypical hotspots (e.g. at cable joints) at early stages, even at most remote distances of currently up to 10 km.

This is in contrast to other measurement principles (e.g. laser pulse principle, OTDR), which are sensitive to dispersion effects and therefore affected by a broadened spatial resolution at longer measurement distances; in other words, the hot spot sensitivity of pulse type measurements degrade with a function of distance.

Real Time Thermal Rating
LIOS provides an integrated Real Time Thermal Rating (RTTR) evaluation via a well defined interface between its OTS data visualisation software and a commercialised – the industry’s de facto standard - cable ampacity program based on IEC standardised methods.

Extended communication capabilities
The OTS systems are configured by an attached PC or Notebook. In normal operation the OTS works independently and can communicate events in the simplest case using relay outputs. The number of integrated outputs amounts to 10 and can be extended up to 20. The OTS system is basically equipped with an RS232 interface, through which status, alarm or temperature data can be transferred to PC or PLC systems. If requested, the OTS controller can be equipped with an Ethernet interface. Hereby, the evaluation unit communicates assigned as a TCP/IP server with several clients.
A powerful and reliable tool is the result of our continuous development of the commissioning and visualisation software CHARON_02. Its structures are efficient and highly loadable ensuring pleasant working.

- Ethernet access: several controller signals can be reliably summarised and processed on one PC system
- Well thought-out database design: capable and efficient
- Boundless visualisation capabilities: customised for cable system surveillance
- Embedded storage and visualisation of external point-type data, like conductor current or partial discharge

CHARON_02 provides a database built storage of all measurement and configuration data which enables the following new features:

- Synchronised measurement browsing
- Simplified import and export of configuration sets
- Embedded configuration within all measurement data files
- Ring buffer storage functionality which allows permanent data storage or event (alarm) triggered storage of measurement data
- Clearly arranged measurement data explorer: Easy tracing of requested measurement data by time period, event, OTS number or title/description
- Detailed reports in order to file configurations of commissioned projects
- Automated DVD or remote network data export services in order to manage properly huge measurement data amounts
Due to the high local resolution sampling of temperature, long sensor lengths and short measuring cycles, efficient preparation and compression of the volume of measuring data is of great importance. The CHARON_02 parameterisation and visualisation software associated with the OTS systems was developed for just this purpose. It can be adapted to specific requirements and offers numerous options for displaying and processing the recorded measuring data. This software makes it possible to create zone views, which allow a freely configurable division of the sensor stretches into zones and the configuration of zone-related alarm generation with event handling.

Two versions of the visualisation software are offered:

- CHARON_02 standard visualisation with basic zone view and temperature profile display
- CHARON_02 enhanced visualisation with additional schematic drawing of the application

Enhanced visualisation offers a customized embedded schematic drawing of the application to provide the overall project status at first sight. The drawing with individually shaped zone outlines can easily be added and can cover data from multiple OTS.
Better Communication

Complex problems or situations cannot be solved by isolated measurement value transmitters. Requirements are constantly shifting – systems which can be easily integrated and flexibly adapted to the most varied network and protocol standards fulfil the demands of today and as well as tomorrow.

That is why communication capabilities are a major consideration with the OTS systems: They have RS232 and Ethernet (TCP/IP) interfaces, via which configuration parameters can be set during commissioning. For simple communication tasks, the serial interface is usually adequate for transmitting the required data and displaying it on a PC monitor.

More complex structures can be implemented with the provided network components, which help to bridge distances, summarise signals from several evaluation units or convert protocols into industry standards like DNP3 or IEC60870-5 or according to specific customer requirements.

The online measured, distributed temperature information of the monitored cable system is especially valuable for dynamic rating. LIOS provides an integrated Real Time Thermal Rating (RTTR) evaluation via a well defined interface between its data visualisation software and a commercialised cable ampacity program. These two technologies are efficiently combined to produce a system capable of computing the future cable ampacity based on real-time temperature measurements. The actual maximum temperature reading of each configured cable section and the actual electrical current reading are evaluated for dynamic cable rating based on IEC standardised methods. When the geometry of the installation is not included in the IEC standards, the RTTR evaluation uses finite element methodologies to complement the IEC calculations.

LIOS provides an integrated Real Time Thermal Rating (RTTR) evaluation via a well defined interface between its data visualisation software and a commercialised cable ampacity program.
Highlights

The sensor
- Passive sensor cable neutral to the surroundings, no influence on the temperature field
- Small volume with low weight, flexible and simple to install
- Can also be integrated in power cables and wires and other places which cannot be accessed after installation
- Not sensitive to electro-magnetic disturbances
- Deployable in applications with an explosion risk (up to zone 0)
- Individually adaptable to the specific requirements: high mechanical protection, deployable under high pressure, temperatures up to 350°C

Evaluation
- Precise measurement of temperature profiles along several kilometres of sensor cable
- Variable ranges and spatial resolutions
- Division of the sensor route into zones and sub-zones using software as required
- Flexible adaptation of alarm criteria per zone to the specific demands of the application
- Extensive visualisation options for displaying temperature profiles, event lists as well as integrating system images
- Communication via RS232/Ethernet (TCP/IP)/USB interfaces or switch contacts
- Integrated and reliable solutions for protocol conversion, data storage management including automated DVD or server backups and both-way interfaces with RTTR software packages
- Passive sensor cable neutral to the surroundings, no influence on the temperature field
- Small volume with low weight, flexible and simple to install
- Can also be integrated in power cables and wires and other places which cannot be accessed after installation
- Not sensitive to electro-magnetic disturbances
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About Us

LIOS Technology GmbH is a dynamic company based in Cologne, Germany, with an international outlook – it is a member of the Danish NKT group, which operates throughout the world. Building on an innovative development in the field of fibre optic sensor engineering, our cooperation strategy has enabled us to become the global leader in supplying the most up-to-date fire alarm technology for use in road and rail tunnels and in underground transport systems.

Our strengths as a company concerned with the development and production of hardware and software for linear sensor engineering lie in our ability to turn advanced technology into robust and flexibly deployable products, the properties of which are precisely tailored to the requirements of each area of application. In conscious of the strong requirements being made in the safety market, we provide a highly proofed product based on the compliance with international quality standards recognised by impartial and competent partners for type testing our products like the VdS (Association of German Property Insurers) and is furthermore reflected in our implemented quality management system, certified according DIN ISO 9001 / Edition 12/2000. In this context, we focus not only on the pure sensor technology itself, but also on the application-related downstream processing of the recorded measuring data and on linking up data communications between systems.

Our expert advice for smooth and efficient deployment of the products manufactured under high quality standards ensures that your assets, whether these concern power cable networks, transformers, generators or associated equipment, are offered optimum protection by constant thermal monitoring on the basis of linear fibre optic sensors.

Further information about our products and services can be obtained at our internet sites
www.lios-tech.com
www.thermal-rating.com

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