Continuous Thermal Monitoring
Peace of mind thanks to condition-based monitoring of MV & LV switchgear

Ken Box, P.E.
Thermal Monitoring is a timely and relevant topic

Enabling Predictive Maintenance Using Condition Monitoring Course Launch
- 10:00am CT
Live Q&A following the presentation

Fundamentals of Vibration-Based Condition Monitoring Course Launch -
12:00pm CT Live Q&A following the presentation

Using Wireless Sensors and Real-Time Data to Improve Maintenance Practices Course Launch - 2:00pm CT
Live Q&A following the presentation

Outstanding applications in maintenance and quality 4.0 Course Launch -
3:00pm CT
Live discussion forum following the presentation
We know there was a failure in the switchgear that caused the fire that absolutely created the issue," said Paul Bowers, president and CEO of Georgia Power, speaking on ABC's Good Morning-America Monday morning.
Would Periodic IR Scanning Have Prevented the HJIA Cable Fire?
Georgia Power said visual inspections of the underground cables and switches was last conducted a month before the incident. The underground system was installed between 1985 and 1988 and the company said it conducts visual and infrared inspections on the equipment at the tunnel every 12 to 18 months.

The fire which occurred in an underground tunnel that runs cables that supply power to the main terminal, concourses and the plane train disrupted operations during the busiest travel season. Power delivery to the Control Tower and the North Airfield Lighting vault was also affected.
Faulty connections are a major cause of electrical equipment failures

**Critical connections in the field:**
- Cable connections
- Withdrawable breaker connections
- Bus bar connections
- Transformer connection

**Continuous thermal monitoring** for early detection
- 24/7/365 monitoring
- Prevent unscheduled downtime
- Increase operator and equipment safety
- Optimize maintenance: from **time** based to **condition** based maintenance
- no more need for periodic thermography
Local and remote alarming based on wireless and battery less sensors

Remote connection to
• SCADA, BMS
• Enable advanced services

Switchgear Monitoring Device :
• In busway, switchgear, transformers, MCCs
• Algorithm => Local alarming

Thermal sensors :
• Measurement of critical point
What’s in it for your client?

- Wireless sensor
- Self powered sensor
- Small size sensor
- In contact of measured point
- Algorithms based on cubicle characteristics
- Dedicated HMI
- Ethernet communication
- SMS (texting)

- **Easy installation** for new and retrofit
- **No battery**
- Monitoring of all **critical points**
- **Accurate** monitoring
- **Early detection**
- **Easy identification** of bad connections
- **Remote monitoring** and **alarming**
- Simple **7x24 alarming**
Thermal monitoring – Stand alone system with SMS alarming

Thermal Monitoring System

Nearby HMI

Local HMI

PLC

GSM

SMS messaging

Zigbee Concentrator

Local signaling

Thermal monitoring sensors
Thermal Monitoring System
Connected to Remote HMI/SCADA

- Local HMI
- Nearby HMI
- Remote HMI/SCADA
- PLC
- Zigbee Concentrator
- SMD
- LAN – Modbus/TCP-IP
- Thermal monitoring sensors
- ZigBee

Local signaling:
- Red
- Yellow
- Green
Thermal monitoring
Connected to *Cloud Based Performance Management Platform*

- **SMD**
- **Nearby HMI**
- **Local HMI**
- **PLC**
- **LAN – Modbus/TCP-IP**
- **Gateway**

**Thermal monitoring sensors**
- **TH110**

**Connectivity**
- **ZigBee Concentrator**
- **ZigBee**
- **Wifi**
Thermal Monitoring
Connected to SCADA & Cloud PMP

Remote HMI/SCADA - BMS

LAN – Modbus/TCP-IP

Cloud PMP

SE gateway

Thermal monitoring sensors TH110

Nearby HMI

Local HMI

Zigbee Concentrator

PLC

SMD

LAN – Modbus/TCP-IP

SE gateway

Thermal Monitoring sensors TH110

Remote HMI/SCADA - BMS

LAN – Modbus/TCP-IP

Cloud PMP

SE gateway
“Asset Advisory” Software in the Cloud – “Your Built in Doctor”

End-to-end service supported by experts and platform to provide actionable maintenance recommendations up to action on site
Modern infrastructure for modern times – IoT 4.0
Connected Medium Voltage Electrical Distribution Equipment Choices

- Busbar connections
- Busbar at power cable connections

Air Insulated MV Switchgear

Gas Insulated MV Switchgear

Shielded Solid Insulated Switchgear

Low Voltage Draw Out Switchgear

Busway

Filed Installed Offer only
Thermal Monitoring – Example of 10 MV Switchgear Cubicles

- temperature sensors (inside MV compartments)
- 2 concentrators (inside LV cabinet)
- 1 PLC (inside LV cabinet)
- 1 HMI (front face of main LV cabinet)
- nearby monitoring (on any smart phone, tablet)

(1 concentrator for 60 sensors)
# Battery free and wireless thermal sensor

## Characteristics

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Power supply</strong></td>
<td>Energy harvested from power circuit by magneto-generator based on solenoid coil and ferromagnetic core</td>
</tr>
<tr>
<td><strong>Minimum activation current</strong></td>
<td>5A</td>
</tr>
<tr>
<td><strong>Metering principle</strong></td>
<td>Thermistor</td>
</tr>
<tr>
<td><strong>Accuracy</strong></td>
<td>+/- 2°C</td>
</tr>
<tr>
<td><strong>Temperature Range</strong></td>
<td>-25°C to +150°C (5X at max T)</td>
</tr>
<tr>
<td><strong>Transmission period</strong></td>
<td>60 s</td>
</tr>
<tr>
<td><strong>Wireless Communication</strong></td>
<td>ZigBee Green Power 2.4GHz</td>
</tr>
<tr>
<td><strong>Emission power</strong></td>
<td>0 dBm</td>
</tr>
<tr>
<td><strong>Dimension</strong></td>
<td>31x31x13 mm (1.23 x 1.23 x .52 inches)</td>
</tr>
</tbody>
</table>
## Substation Monitoring Device Characteristics

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>Functions</td>
<td>Thermal monitoring of connections</td>
</tr>
<tr>
<td></td>
<td>Local and remote alarming</td>
</tr>
<tr>
<td>Power Supply</td>
<td>24Vdc</td>
</tr>
<tr>
<td>Inputs/outputs</td>
<td>3 Digital outputs for local signaling</td>
</tr>
<tr>
<td>Communication</td>
<td>Modbus TCP/IP for remote interface (*)</td>
</tr>
<tr>
<td></td>
<td>Modbus serial line for relays communication (*)</td>
</tr>
<tr>
<td></td>
<td>GSM for SMS transmission (*)</td>
</tr>
<tr>
<td></td>
<td>Wi-Fi for nearby HMI (*)</td>
</tr>
<tr>
<td></td>
<td>Zigbee Green Power for sensors</td>
</tr>
<tr>
<td>HMI</td>
<td>Local color display (on cubicle)</td>
</tr>
</tbody>
</table>

*Plc:

*Local HMI:*
Thermal monitoring algorithms

Tracking faulty electrical connection (cable, bus bar, CB)

- **Absolute temperature threshold**
  - Detection of hot point
  - Threshold is based on installation characteristic

- **Phase comparison**
  - Detection of one phase evolution

- **Predictive threshold**
  - Detection even at low load before any trouble
  - Threshold adapted in regards of load (I)
HMI for Local Alarming

- **HMI Color display**
  - Synthetic temperature value presented on single line diagram
  - Detailed information for each cubicle, transformer
  - Navigation thanks to touchscreen
  - Warning (Yellow) and Alarm (Red) notification
  - Nearby HMI on mobile or tablet as an option

- **Red / Yellow / Green digital outputs**
  - Give a synthetic level of alarm
  - Interface to local lights, RTU, Alarm display panel,…
Interface for Remote Alarming

• Alarming thanks to “SMART” mobile application
  • It is a digitized maintenance log-book
  • Alarm notification on a mobile device or emails to maintenance team

• Alarming through SMS
  • Alarm and warning generate SMS to one number

• Remote connection for SCADA or service
  • All temperature and alarms
  • Modbus/TCP-IP protocol
LV Switchgear ANSI C37.20.1/UL-1558
Factory Assembled Solution

Providing info that was hidden before
Up to 60 sensors per Server/Concentrator to monitor Field Connections

1. Incoming Phase Connections of Main Breaker(s)
2. Outgoing Phase Connections of Feeder Breakers

Note:
- Not available on Busduct or Close Coupled Transformer connections nor bus splices or joints since they aren’t cables and are considered maintenance free joints when torqued with spring loaded washers
- Must reserve space to prevent Concentrator from being farther away than 2 sections from farthest sensor. Zigbee Concentrator can be in A-D cell but can be no farther away from sensors than 2 sections. (i.e. Section 1 for 1-3 section lineup, section 3 for 4-5 section lineup, section 3 and 6 for 1-8 sections, sections 3 and 8 for 9-10 section lineup.)
Sensor Placement

LV Switchgear ANSI C37.20.1/UL-1558

Mains Section

Feeder Section

TH110

CL110

TH110

CL110
Digital Local Thermal Monitoring
Enabling your Connected Equipment

Local HMI

- Door mounted HMI and local Pilot Lights
  - Green = No Alarms
  - Amber = Pre-alarm
  - Red = Alarm
  - Contact output available
- Local, cost-effective real-time monitoring and Alarming.
- Single Line Diagram representation with temperature values and journal of alarm on color display
Conventional IR Window Cost

CTM vs. IR is about $3,500 more.

- Each vertical section gets (2)-IR windows in the rear.
- A double with section gets 4 windows.
- $1,600 installed cost per window.
- $16,000 installed cost.
- Add cost of professional service to scan and prepare a written report. ~ $2,500.
- CTM pays for itself in year 2 or the next time you would have conducted IR scanning.
Price for LVDO Continuous Thermal Monitoring

- Price for Continuous Thermal Monitoring Pretested: Local HMI, SMD, Zigbee Concentrator, Sensors
  - +Thermal Sensor Adder per Breaker = $850 net
  - +Adder per 5 Sections (accounts for SMD/Concentrator) = $8,500
  - +Moisture Sensor Adder per Section = $850 Net
  - +Adder for Local HMI = $3000 Net

- Optional Price for Cloud Gateway Adder per Lineup = $2000 net to allow connection to APMaaS in the Cloud, otherwise you get one Ethernet (Modbus TCP/IP) connection

- Optional Price for an Ethernet Switch if lineup has comms already for Breaker/Meters network

- Total $21,700, w/o moisture sensors, $25,100 with moisture sensors. Add $2000 for the APMaaS Cloud package.
What About UL 891 Switchboards?

- Not practical for group mounted feeder breakers.
- (9) feeder breakers will require (27) – thermal sensors assuming one conductor per phase.
- Add neutral connections and your total is now 54 sensors.
- It’s gets expensive quickly.
Busway Thermal Monitoring

Wireless Sensors for 24/7 Busway Monitoring
Risk Control Bulletin-Low Voltage Busway Systems

CNA Insurance Companies

- Lack of a formal Electrical Preventive Maintenance program.
- Excessive ambient temperature accelerates the rate of insulation degradation.
- Excessive internal temperatures due to high resistance at loose connections.
- Contamination by water or condensation causing corrosion and high resistance at connection points ultimately damaging insulation.
- Dirt and/or dust leading to arc flashover

- Improper or inadequately supported busway
- Misalignment; improper installation, such as loosening of bolts; improper vertical support, creating permanent deformation of the busway due to bowing.
- Uneven pressure or expansion forces cause the busway to bend at “weak points.”
- Thermal expansion
- Increased loads from original design.

https://www.cna.com/web/wcm/connect/fab67ce0-bffe-49f2-b2a4-ea6e9e733d76/RC_Bul_Prop_EB_LowVoltageBusway_CNA.pdf?MOD=AJPERES&ContentCache=NONE&CACHEID=fab67ce0-bffe-49f2-b2a4-ea6e9e733d76
Busway Thermal Monitoring
Providing Valuable Insight

- Become more proactive in managing Busway systems
- Ensures proper torque on connections
- Monitors bus joints 24/7
- Eliminate Infrared Scans in hard-to-reach areas
- Can be used within existing systems to provide early notification of changes
- Establish baseline based on utilization (loads)
- Can be combined with load profile, ambient temp and humidity to provide context in the analysis

• Bus Joints
• Bus Plugs
Busway Thermal Monitoring

What impacts the price?

- Access to Busway
- Number of Bus Plugs
- Length of Busway
- Scope of Project
  - Number of Zigbee Concentrators required
    - Each Zigbee can accommodate (60) Sensors
- On-site installation support
- Cloud / Edge Control / Local Monitoring

Customer to Supply:

- Network Drop
- Control Power
- Any programming to an existing system (if connected to Edge Control)
Motor Control Center Thermal Monitoring

MCC Bucket

11 Section MCC

1. MCC Data Card
2. MCC Sensor Loom
3. MCC LED Unit
Evolution of Thermal Monitoring
Resolving Industry Challenges

Factors that put critical MCC applications at risk

- The impact of constant thermal cycling on the joints
- Weakening of spring-type connectors (jaws)
- The high number of site made terminations
- Difficult to monitor thermal data at multiple locations
- Limited Thermography Tests or other measurement procedures
- Addition of IR windows are costly and require periodic manual use

<table>
<thead>
<tr>
<th>Traditional Thermal Imaging</th>
<th>Thermal Monitoring Solution</th>
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<tbody>
<tr>
<td>Inspection</td>
<td>Inspection</td>
</tr>
<tr>
<td>Low Load</td>
<td>Low Load</td>
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<tr>
<td>Position/View</td>
<td>Position/View</td>
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<tr>
<td>Maintenance</td>
<td>Maintenance</td>
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<tr>
<td>Reliability</td>
<td>Reliability</td>
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<tr>
<td>Availability</td>
<td>Availability</td>
</tr>
<tr>
<td>Safety</td>
<td>Safety</td>
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<tr>
<td></td>
<td>Permanent monitoring 365/365</td>
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<td></td>
<td>Dynamic fault detection even at low load</td>
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<td></td>
<td>Internal / Unlimited</td>
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<td></td>
<td>Fit &amp; forget</td>
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<td></td>
<td>No human involvement/ Continuous &amp; accurate data</td>
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<td></td>
<td>Real-time data integrated into SCADA/BMS</td>
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<tr>
<td></td>
<td>Increases facility / operator safety</td>
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</tbody>
</table>
Motor Control Center Thermal Monitoring

• Quick and Easy fit to any MCC
• ‘In-drawer’ solution disconnects & removes with drawer
• Warning and Critical thermal alarms
• Temp imbalance alarm for phases.
• Front mounted LED provides local visual condition status
• Networking capability via Ethernet/IP
• Increased operator and facility safety
• Increased operational uptime
Design Features
Stand Alone – Unit Only

- Continuous 24X7 monitoring
- All factory made connections available
- Configured To Order using product selectors
- Available in all unit sizes
- Retrofits units available for all models made in 1992 & later
Low Voltage Distribution Transformers with Continuous Thermal Monitoring

UNIQUE 24X7 TEMPERATURE MONITORING OF TRANSFORMER CONNECTIONS:

The Modbus Transformer Solution (MTS) provides the ability to permanently install thermal Sensors, which continuously monitor the Primary, Secondary, and tap connections within the transformer housing. The output from the Sensors is analyzed by Modbus Transformer Data cards (MTDs) which are mounted in box connected to top side of the transformer housing and provide a high level alarm.

ALARMS
For compromised terminations, a high level alarm is generated. This alarm is visible via an external LED status light situated on the front/side of the enclosure. The LED provides system status, alarm type and location. The alarm is also available via a relay contact (remote alarm)

All status information in MTS can be monitored 24/7 via a Modbus RS485 connection.
Continuous Thermal Monitoring Summary

- **Safety**: Eliminate unsafe activities for your client’s maintenance staff
- **Reliability**: Predict & prevent electrical equipment failures
- **Cost Savings**: Optimize your client's maintenance budget. 7x24 monitoring—it’s always on.
Life Is On | Schneider Electric