APPLICATION NOTE

Distributed Temperature Sensing (DTS) for Transformers, Substations, and Battery Energy Storage Systems (BESS)

Electrical infrastructure such as transformers, substations, and battery energy storage systems (BESS) form the backbone of modern power networks. As grids become more complex with increased renewable integration, electrification, and decentralization ensuring the safety, reliability, and efficiency of these assets is more critical than ever.

Thermal behaviour is a key indicator of asset health. Overheating due to electrical faults, aging components, or operational stress can lead to reduced performance, accelerated degradation, or catastrophic failure.

Distributed Temperature Sensing (DTS) using optical fiber technology enables continuous, real-time thermal monitoring across critical assets and infrastructure. By providing precise temperature profiles, DTS supports early fault detection, improved asset utilisation, and enhanced operational safety.

Key Applications

This document addresses three key applications:

Power Transformers
Monitoring of critical components and connections

Substations
Thermal monitoring of high-voltage equipment and cable systems

Battery Energy Storage Systems (BESS)
Early detection of thermal runaway and fire risk

DTS Technology Overview

Distributed Temperature Sensing (DTS) systems use optical fibers as continuous linear temperature sensors. A DTS interrogator sends laser pulses through the fiber and analyses backscattered light (typically Raman scattering) to determine temperature along the fiber.

Key Benefits

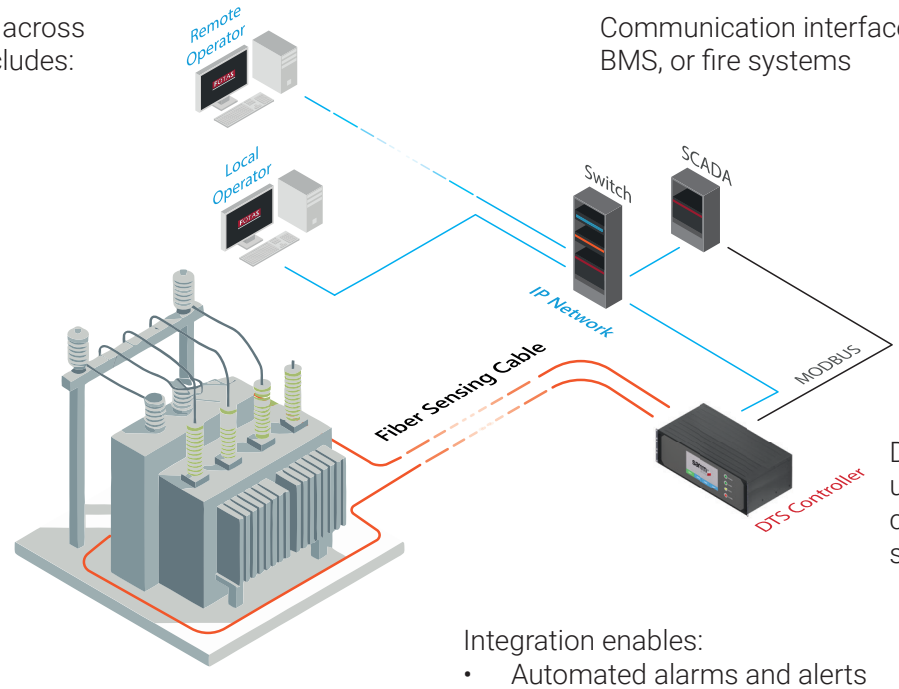
- Continuous monitoring over long distances
- Real-time temperature data
- Passive sensing element with no power required
- Immune to electromagnetic interference

System Architecture

A typical DTS system across these applications includes:

Fiber optic sensing cables installed near critical assets using newly installed or existing fiber cables typically used for SCADA

Redundant configurations for high-availability environments



Communication interfaces to SCADA, EMS, BMS, or fire systems

DTS control units located in control rooms or substations

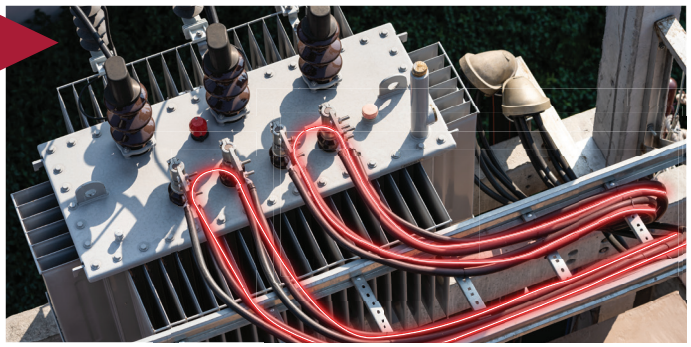
Integration enables:

- Automated alarms and alerts
- System shutdown or load reduction
- Activation of ventilation or suppression systems
- Data-driven maintenance and operational decisions
- Hard wired relay triggering of fire system and associated suppression

Key Factors for Successful Deployment

- **Thermal coupling:** Proper placement for accurate temperature sensing
- **Cable selection:** Resistant to environmental and mechanical stresses
- **Zoning strategy:** Logical segmentation for alarm management
- **Redundancy:** Loop or dual-ended configurations for critical assets
- **Integration planning:** Alignment with existing protection and control systems

DTS FOR POWER TRANSFORMERS



Challenges

- High thermal stress under varying load conditions
- Critical dependence on cooling performance
- Risk of insulation degradation and failure
- Limited visibility of external connection points

Applications

Hot Spot Detection
- Identification of overheated connections/components
- Early warning of insulation degradation

Cooling System Monitoring
- Detection of blocked or underperforming radiators
- Verification of cooling efficiency

Load Optimisation
- Correlation of temperature with load conditions
- Improved asset utilisation without exceeding thermal limits

Deployment

- Transformer bushings and connections
- Cable terminations and links
- Radiators and cooling systems
- On-load tap changers (OLTC) external monitoring

Key Benefits

- Enhanced transformer protection
- Reduced risk of failure and unplanned outages
- Improved maintenance planning
- Extended asset lifespan

DTS FOR POWER SUBSTATIONS

Challenges

- Complex infrastructure with multiple critical assets
- Exposure to environmental conditions
- High fault currents and associated thermal stress
- Need for reliable fire detection

Applications

Cable Trench and Tunnel Monitoring
- Continuous temperature monitoring along cables
- Early identification of overheating cables

Switchgear and Connection Monitoring
- Detection of hot spots at joints and terminations
- Prevention of equipment failure

Fire Detection and Protection
- Linear heat detection across substation areas
- Integration with fire alarm / suppression systems

Deployment

- Cable trenches and tunnels
- Busbars and switchgear
- Cable terminations and joints

Key Benefits

- Improved safety and fire prevention
- Reduced outage risk
- Enhanced situational awareness
- Lower maintenance requirements

DTS FOR BATTERY ENERGY STORAGE SYSTEMS (BESS)

Challenges

- Risk of thermal runaway in lithium-ion batteries
- High energy density and fire risk
- Need for early fault detection and rapid response
- Increasing deployment in both utility and commercial environments

Applications

- **Early Thermal Runaway Detection**
- Detection of abnormal temperature rise at cell/module level
- Early intervention before escalation

Rack and Container Monitoring
- Identification of localised hot spots
- Monitoring of temperature distribution within enclosures

Fire Detection and Safety Integration
- Activation of fire suppression systems
- Integration with battery management systems (BMS) and alarms

Cooling System Performance
- Verification of HVAC effectiveness
- Detection of airflow or cooling failures

Deployment

- Along battery racks or container rows
- Within cable connections and power interfaces
- Around HVAC and cooling systems
- Across container or enclosure perimeters

Key Benefits

- Enhanced safety and risk mitigation
- Early detection of critical events
- Reduced likelihood of fire incidents
- Improved operational reliability

Conclusion

Distributed Temperature Sensing provides a versatile and reliable solution for monitoring transformers, substations, and battery energy storage systems. By delivering continuous, real-time thermal insight, DTS enables early fault detection, enhances safety, and supports optimized asset performance.

As energy systems evolve toward greater complexity and higher performance demands, DTS is becoming an essential component of modern monitoring and protection strategies.