celduc® transfo

TECHNICAL NOTE

Expertise at the heart of every transformer

Transformer winding temperature monitoring:

3 solutions



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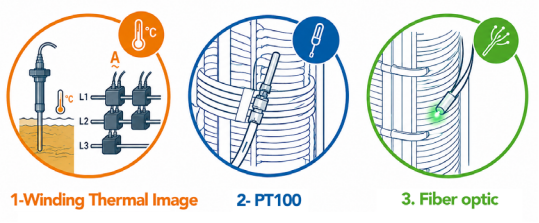
Made in France

Temperature is one of the key parameters to monitor during transformer operation. Excessive winding temperatures can accelerate the ageing of insulating materials and, over time, affect equipment reliability and service life.
Depending on the installation requirements, the required level of accuracy and the transformer characteristics, different technologies can be used to monitor winding temperature.

Three main solutions can be considered:

1. **Winding Temperature Indicator - Thermal Image (WTI):**
   An indirect temperature estimation.
2. **Pt100 sensor or Resistance Temperature Detector (RTD):**
   A local measurement requiring insulation precautions.
3. **Fibre optic:**
   Direct measurement within the winding.



1. Why monitor winding temperature?

When a transformer is in operation, electrical losses generate heat in the magnetic core and windings. Winding temperature varies in particular according to the transformer load and its cooling conditions. The presence of harmonics or load cycles are also parameters that must be taken into account when sizing the transformer. Temperature is not uniform throughout the winding, and thermal monitoring can therefore help to:

- protect the transformer against excessive temperature rise,
- generate alarm or trip thresholds,
- gain a better understanding of actual operating conditions,
- support transformer load optimization,
- help preserve the service life of the insulation system.

However, not all monitoring technologies measure the same thing.

2. Solution 1: Winding Temperature Indicator - Thermal Image (WTI)

Measurement level: INDIRECT

Principle

The WTI (Winding Temperature Indicator - Thermal Image) does not directly measure the temperature of the conductor forming the winding. It is a device that measures the oil temperature on the one hand and the current flowing through the windings on the other hand (via current transformers installed on the terminals of the windings whose temperature is to be monitored). The system uses these values to derive the theoretical winding temperatures. This is a theoretical measurement, but the system has the advantage of being relatively non-intrusive with regard to the windings. Generally, one or three phases are monitored, although additional phases could be monitored if required.

The displayed temperature therefore corresponds to a calculated or derived temperature, rather than a measurement taken directly within the winding.

Advantages

- Proven and widely used technology.
- Non-intrusive system with regard to the windings.
- No sensor needs to be integrated directly into the winding.
- Robust solution for general transformer monitoring.
- Possibility of combining the measurement with alarm and trip functions.

Limitations

The temperature obtained remains a theoretical representation of the winding temperature. It depends in particular on the thermal model used and does not provide a direct measurement of the actual conductor temperature at a specific location within the winding.

3. Solution 2: Pt100 or RTD

(Resistance Temperature Detector)



Measurement level: LOCAL, but subject to integration constraints

Principle

A Pt100 is a platinum resistance temperature sensor whose electrical resistance varies with temperature. It therefore provides a local temperature measurement at the point where it is installed. **However, using a Pt100 to monitor a winding requires particular attention:** since the Pt100 is electrically conductive, it must be electrically insulated from the winding conductor. This constraint becomes particularly important as the voltage level increases.

The insulation required between the Pt100 and the winding also introduces thermal resistance. Insulating materials, particularly dielectric-fluid-impregnated paper placed between the conductor and the sensor, create a difference between the temperature measured by the Pt100 and the actual conductor temperature.
The Pt100 therefore provides a local physical temperature measurement, but its integration into the windings must be assessed according to the transformer design and voltage level.

At **celduc® transfo**, we do not install Pt100 sensors in HV windings due to the associated dielectric constraints.

Advantages

- Physical temperature measurement.
- Proven industrial technology.
- Good accuracy under controlled installation conditions.
- Particularly suitable for monitoring dielectric fluid temperature.

Points to consider

- Electrically conductive sensor.
- Electrical insulation is required when the sensor is installed within a winding.
- Pt100 sensors can be installed in LV windings, but not in HV windings.
- Thermal resistance of the insulating materials between the conductor and the sensor: the insulation precautions required for Pt100 sensors introduce additional uncertainty between the value measured by the Pt100 and the actual winding conductor temperature, due to the thermal resistance of the oil-impregnated paper placed between the winding and the Pt100 sensor.
- Integration becomes more restrictive as the voltage level increases.

4. Solution 3: Fibre optic

Measurement level:
DIRECTLY WITHIN THE WINDING

Principle

Fibre-optic measurement goes one step further: the sensor can be integrated directly into the windings because, unlike a Pt100, the fibre used for measurement is electrically non-conductive. This characteristic makes it possible to position the measurement point as close as possible to the area where the temperature needs to be monitored, without introducing a conductive metallic sensor into the windings.
The measurement therefore provides a particularly representative indication of the local winding temperature.
During transformer design, the fibres can be positioned in specific areas to directly monitor the temperature within the windings. This approach is particularly valuable when the application requires accurate knowledge of the actual winding temperature.
The sensors are connected to an optoelectronic measurement unit, which converts the signal and makes it available to the monitoring system.
Depending on the selected architecture, the information can also be used to generate alarms or trip commands.

Advantages

- Measurement directly within the winding.
- Electrically non-conductive sensor.
- Highly representative measurement of the local winding temperature.
- No electromagnetic interference affecting the measurement, thanks to the optical measurement principle.
- Particularly suitable for applications requiring advanced thermal monitoring.

Points to consider

- More expensive solution.
- Integration must be planned from the transformer design and manufacturing stages.
- Measurement point locations must be determined according to the thermal design of the equipment.
- A dedicated acquisition unit is required.
- Fragile sensor, minimum bending radius must be respected.

5. Three technologies, three levels of information





	Winding Thermal Image	Pt100 (or RTD Resistance Temperature Detector)	Fibre optic
Principle	Thermal estimation	Resistive measurement	Optical measurement
Direct measurement within the winding	No	Possible under certain conditions	Yes
Conductive sensor	Not in the winding	Yes	No
Electrical insulation of the sensor within the winding	Not applicable	Required	No
Representativeness of local conductor temperature	Estimated	Not precise	Very precise
Integration	Standard	Possible in LV windings but not considered suitable for HV windings	To be planned at the design stage
Preferred use	General thermal monitoring	Local measurement. Mainly recommended for oil temperature measurement	Accurate winding monitoring
Cost	+	-	++

6. How to choose the right solution?

There is no single technology suitable for all transformers.
The choice of monitoring system depends in particular on:

- the winding voltage level,
- the transformer rating,
- the type of transformer and its cooling method,
- the required level of accuracy,
- operating constraints,
- the required protection and monitoring functions,
- the criticality of the installation,
- the budget allocated to the monitoring system.

For conventional thermal monitoring, a Winding Temperature Indicator - Thermal Image (WTI) can provide the information required for operation.
Pt100 sensors are a proven solution for directly measuring certain temperatures, particularly oil temperature. However, integrating them into the windings requires specific precautions due to their conductive nature.
When the objective is to obtain the most representative measurement possible of the local temperature within the windings, fibre optics are the most suitable solution among these three technologies.

7. The **celduc® transfo** approach

Thermal monitoring should be considered an integral part of transformer design.
At **celduc® transfo**, the selection and positioning of measurement devices can be studied according to the electrical, thermal and mechanical characteristics of each project.
Depending on the application requirements, different architectures can also be combined to provide several levels of monitoring or redundancy.
For example, an architecture can combine fibre-optic sensors for winding temperature measurement with Pt100 sensors as a complementary solution, where required by the project specifications. The objective is to adapt the level of monitoring to the actual criticality of the installation and provide the operator with relevant thermal information for transformer monitoring and protection.

KEY TAKEAWAYS

Winding Temperature Indicator - Thermal Image (WTI)	→ I derive the theoretical winding temperature from the oil temperature and an offset that depends on the current measured at the terminal connected to the relevant winding. This solution responds more quickly to load variations because it directly takes changes in current into account.
Pt100 or RTD (Resistance Temperature Detector)	→ I measure the temperature locally, with insulation constraints when the sensor is integrated into the winding because the sensor is electrically conductive.
Fibre optic	→ I measure the temperature directly within the windings. This is the most accurate, but also the most expensive solution, and it must be planned from the transformer design stage.

The closer the measurement is taken to the windings, the more accurately it reflects the actual thermal conditions of the winding.

Thanks for your attention



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