POWERSIDE®

White Paper

Cost-Effective Transformer & Distribution Monitoring

We describe a value-based approach to transformer health monitoring based on Powerside's PQube 3e® power analyzer. This is an economical solution for combined asset management *and* operational monitoring of power distribution networks.

Background

The conventional approaches to power distribution operational monitoring and transformer health monitoring are: i) a SCADA system, and ii) periodic inspection and test of the transformer throughout its 25+ year lifetime. The goal of the latter is to detect signs of compromised physical structure, and of progressive electrical degradation, through spot tests of coolant chemistry and contamination, operating temperatures, and sometimes parametric electrical tests.

An alternative approach to periodic inspection is to persistently monitor the condition and performance of the transformer in-service and at-load, using direct electrical measurements, combined with measurement of other leading indicator sensors. In-service monitoring has dual benefits: i) it provides real-time and trend monitoring of transformer condition, and of stress, and ii) it is a cost-effective means of simultaneously monitoring multi-circuit distribution power flow and power quality. This combined capability is particularly valuable in the case of remote installations operating on a tight budget.

Figure 1: Typical distribution transformer

This white paper illustrates the new approach, leveraging the advanced power and sensor monitoring capabilities of Powerside's PQube 3e power analyzer.

System hardware for remote substation monitoring

Figure 2 shows schematically the typical sensor arrangement for remote substation monitoring using Powerside's PQube 3e, the capabilities of which are outlined in the Appendix. PQube 3e monitors and meters voltage and current on the output of the transformer, and on the grid side as well if Potential and Current Transformers are available.

Additional sensors are provided for transformer health and facility monitoring. According to the transformer type and customer requirements; these may include:

- A) Coolant pressure
- B) Top and C) bottom coolant temperature
- D) Coolant conductivity
- E) Vibration & Coolant Level
- F) Ambient temperature, humidity

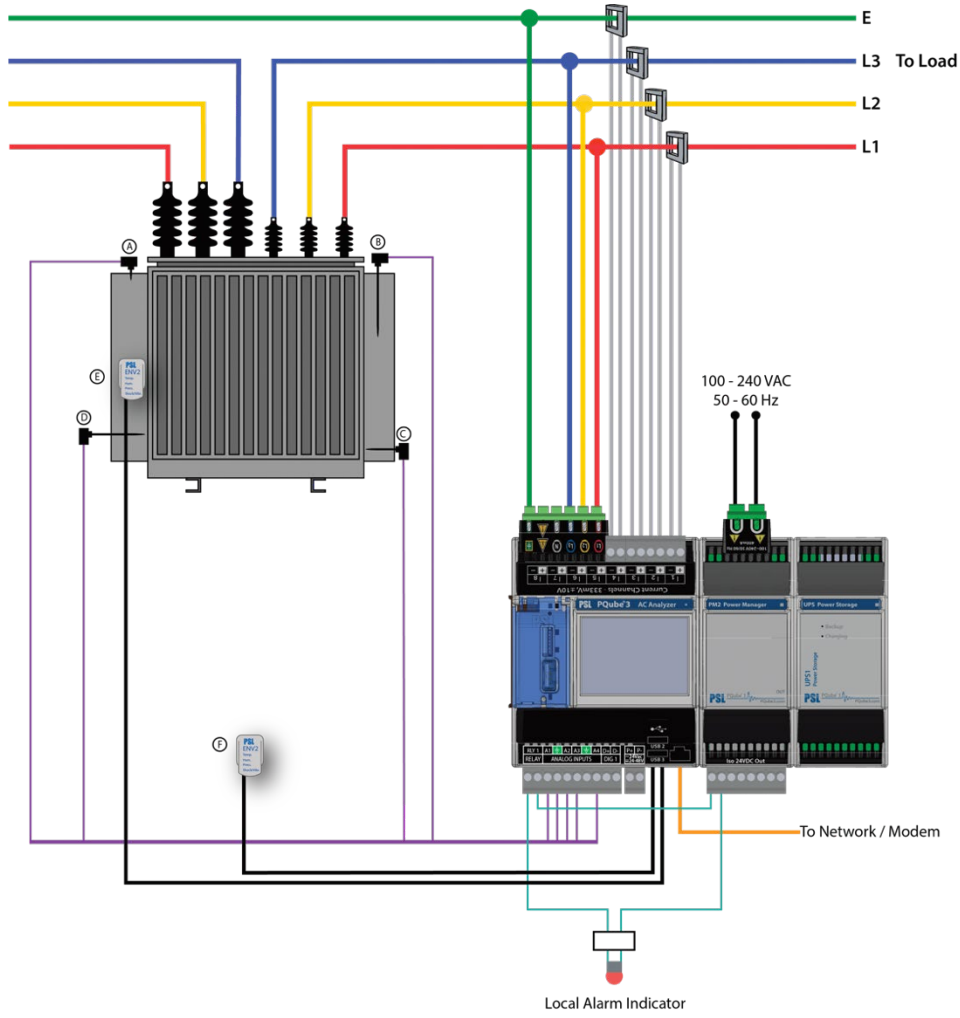

Figure 2: Sensors for remote distribution transformer monitoring

In a remote monitoring application, PQube 3e is normally equipped with a short-term UPS module, so that critical snapshot data from outages is transmitted following the event to enable immediate root cause analysis and corrective action planning.

Data backhaul is via a network connection, or through a cellular modem, according to the location. Trend and event data are transmitted directly via a range of protocols, including email, SNMP, DNP 3.0, Modbus, using 128-bit signed encryption. PQube 3e supports a range of reporting options including: i) streamed continuous data reporting, and ii) immediate transmission of alerts, but less frequent transmission of trend data, in order to limit the cost of cellular backhaul.

Transformer Health Monitoring

Some transformer failure modes are listed in Table 1 mapped to the relevant data used for condition monitoring. Trend data is used to establish baseline and seasonal sensor readings according to load level and time of day, such that divergences in the trends can be used to identify impending or actual fault conditions.

Failure mode	Data							
	Power, imbalance	Harmonics, transients, HF emissions	Coolant Temperature	Vibration	Ambient temperature	Coolant contamination	Coolant pressure	Coolant level
Overload	x	x	x	x	x		x	
Electrical breakdown	x	x						
Tampering				x				
Coolant insufficiency	x		x				x	x
Coolant contamination						x		
Corrosion						x		

Table 1: Transformer failure modes and applicable sensor data

Electrical stress and overload are assessed through a combination of factors which are directly measured and reported by PQube 3e:

- Instantaneous load and operating temperature
- Phase imbalance, which results in transformer derating and elevated thermal stress
- Harmonics, which increase heat dissipation
- Transients, which create additional stress (e.g. lightning strikes, grid noise)

Wear on the transformer is assessed by observing lifetime operating time at power, and temperature. High frequency current emissions can also provide indications of leakage current.

Efficiency of the transformer can be calculated in the case that grid-side CT/PT are also available, operating the PQube 3e in dual-voltage mode. In this case, voltage harmonics can be calculated on both sides of the transformer, providing information about the transformers harmonic load, and the source of harmonic energy.

Tampering is a not uncommon source of transformer failure, which can in some cases be detected by a vibration sensor.

Coolant health is assessed first by a conductivity sensor, to assess any water ingress, and by top and bottom temperature sensors to determine cooling efficiency versus load and ambient temperature. Coolant sufficiency can be assessed by both coolant pressure and tank level sensors.

PQube 3e can be programmed to generate device-specific alerts with snapshot data when electrical stress levels, and other critical sensor readings, are exceeded.

Table 2 contrasts the capabilities of the Preventative Maintenance (PM) and remote monitoring approaches to transformer asset management.

Use case	On Site PM	Persistent Remote Monitoring
Physical inspection, repair, coolant inspection / replenishment	x	
Continuous health monitoring		x
Real time fault detection & root cause analysis		x
Fault avoidance		x
Smart Preventive Maintenance timing		x
Smart parts replacement intervals		x

Table 2: Transformer monitoring use case for On-site PM, and for persistent remote monitoring

Obviously, there is no substitute for on-site presence when physical inspection and repair is required, but this is costly for remote installations. Remote condition monitoring enables expert event and trend analysis at headquarters from which to set optimized on-site maintenance visits. For example, critical sensor readings such as coolant contamination, and coolant temperature as a function of load and of ambient temperature, can be baselined when the transformer is in a known-good state, and then tracked to determine when an on-site intervention is required, rather than relying on a time-based maintenance schedule. Likewise, transformer efficiency degradation, indicated by rising coolant temperatures for a given power level and ambient temperature, can anticipate the need for maintenance.

Overall, remote asset monitoring provides the confidence to optimize maintenance intervals without jeopardy to system reliability and uptime. In case of failure, rich trend and time of event sensor data accelerates accurate root cause analysis, and durable recovery planning.

Grid and Distribution Monitoring

PQube 3e, Figure 3, has been selected and deployed by major global utilities for all kinds of substation, distribution, and facility monitoring applications. A single PQube 3e combines high performance synchronized load metering and power quality monitoring for up to four 3-phase circuits simultaneously, making it a cost-effective solution for substation operations monitoring. Consumption as well as load-induced conditions such as poor power factor, imbalance, high harmonic levels and resonances, and other power pathologies can all be detected, reported, and trended in real time. Likewise, grid transients are also captured and reported.

PQube 3e data can be viewed through Powerside's IOT Cloud software, QubeScan, PQView, or integrated with other SCADA via DNP3, SNMP, Modbus or other protocols.

Conclusion

Headquarters monitoring of remote substations and transformers has the benefit of serving both the utilities asset management and their operational monitoring missions, at lower cost and with higher certainty than conventional approaches.

A single PQube 3e can monitor key transformer health indicators at load and in real time, enabling optimized on-site maintenance timing, fewer surprise failures, and faster failure recovery. A small team of headquarters engineers is leveraged across the entire fleet of assets, without the need for travel. Real-time data supports confident asset management with the minimum expenditure.

That same single PQube 3e supports distribution operational monitoring, with real-time load and power quality analytics for up to four circuits, as well as trends and alerts.

PQube 3e is field proven by major global utilities in diverse Transmission and Distribution monitoring and metering applications. Versions of the unit are available in DIN rail mount, packaged, and pole-mount configurations.

Appendix: Outline capabilities of Powerside's PQube 3e Power Analyzer

PQube 3e, figure 3, is a versatile monitoring solution for power quality, load metering, and sensor telemetry, whose key characteristics include:

- Up to 14 AC source/load channels monitored by a single device
- Synchronized data capture across channels for unambiguous cause and effect determination
- Comprehensive power quality analysis per IEC 61000-4-30 Ed3 Class A
- Optional application-specific sensor modules: multi-axis vibration, pressure, temperature, humidity, fluid level, facility intrusion
- 4 AC or DC custom sensor channels per unit, with options for more
- Event triggers with programmable thresholds
- Immediate alert transmission and actionable data: e.g. waveforms, switching transients, power instability
- Daily, weekly and monthly trend reports on key power indicators, and on alerts: e.g. power, voltage, current, transients, outages, harmonics, emissions, imbalance etc.
- Multi-channel load metering per ANSI C 12.20 0.2%
- A range of backhaul solutions and protocols: ethernet/modem, DNP 3, Modbus, SNMP, email, IOT
- Robust data security protocols
- Optional UPS modules to ensure critical data is captured and transmitted post-outage

Figure 3: Powerside PQube 3e Power Analyzer module

Powerside customers have deployed 50,000+ PQube family of products in a wide range of global monitoring applications.

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