Application Note

Remote monitoring of key transformer parameters using IIoT

PRESSURE GAUGE | SWITCH | TRANSMITTER | DATALOGGER

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Executive summary

Transformers are remote assets which are important for our day to day life, failures of which can cause sufficient inconvenience and loss to a large section of population. While there are several methods to monitor transformer health, most of them being time based, a ***condition based*** monitoring of transformers to predict failures is the need of the hour. A cost effective way is being suggested in this paper.

1. Introduction

Transformer is an important device in electric power transmission and distribution system. The preventive maintenance of transformer has become increasingly necessary to improve the reliability of the electrical power system. Transformers have problems caused from various reasons such as equipment damage, case leakage, overload and temperature.

The most important parameter of transformer monitoring is temperature that sees a rapid rise during over current condition. It causes rapid degradation of transformer insulation which results in many problems. The condition monitoring of a transformer uses a variety of tests and instruments to determine the healthiness of a transformer. Normally auxiliary protective devices installed on transformers do not provide log data of the transformer itself.

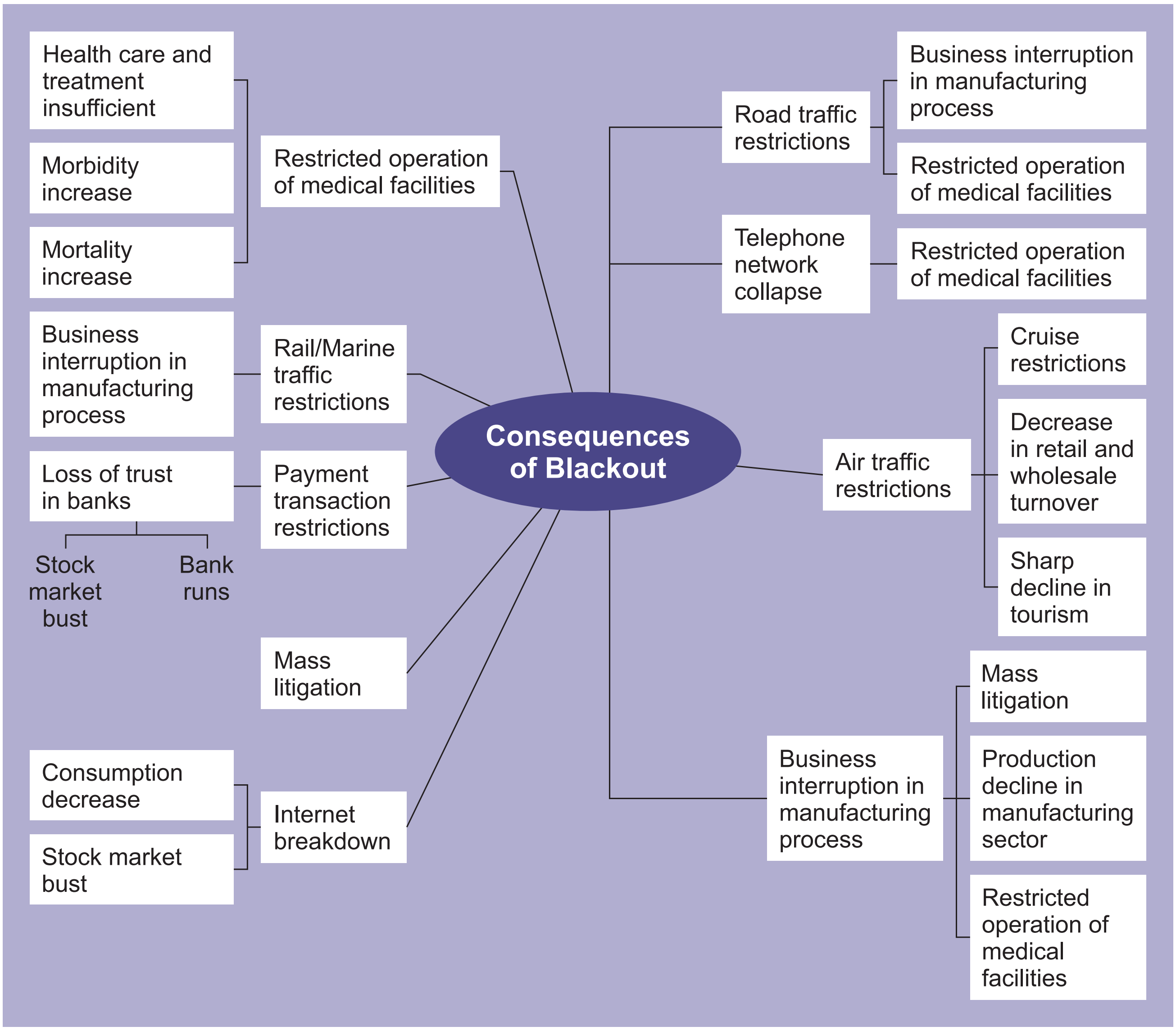
Internet of things (IoT) devices can be effectively used for online monitoring of different parameters of a transformer. Parameters to be monitored during an overload including under voltage, over current and under frequency have been discussed in various fora. Protection of power transformer from fault condition by using the wavelet transforms of magnetizing inrush currents and internal faults are another pointer. The quadrature method for calculating RMS voltage is used to efficiently detect power quality event by testing real time monitoring for voltage events. Also load monitoring of transformer is capable of measuring voltage, current and power. Amongst these, temperature and oil level are key pointers and monitoring them can serve as an early warning for failures of transformers.

Using a transformer monitoring and alert system helps to avert abnormal failure of transformers. In this system, all collected data are sent to a cloud based

application via wifi. In addition, the proposed functions are created based on failure modes and effects analysis (FMEA) to identify alarm and alert conditions. The collected data can be used effectively for diagnostics and performance/efficiency analysis . IoT can be applied to communicate with field devices for collecting the assigned parameters such as temperature, oil level, pressure, and electrical power (electrical power not in scope) and effectively act on them. This system will offer a method of measuring various parameters, record data locally and also transmit it to cloud and monitor system values in real-time via web application as shown on dashboard. The web application can notify via email fault and alert messages to the user. The advantage is that it can monitor status of the transformer 24 X 7 via internet. This, regardless of the location of the user. Additionally, the system offers data collection (diagnostics can be based on these) and alerts that guide users to solve initial problems when faults occur in transformers.

1.1 Power outages and effects

Electricity is the backbone of each industrialised society and economy. Modern countries are not used to having even short power blackouts. The increased dependency on continuous power supply related to electronics, industrial production, and daily life makes todays' society much more vulnerable concerning power supply interruptions. A brownout (reduced voltage) of some minutes or a similar blackout (complete failure of electricity supply) may cause some inconvenience at home such as having the lights turn off. But a blackout of a few hours or even several days would have a significant impact on our daily life and the entire economy. Critical infrastructure such as communication and transport would be hampered, the heating and water supply would stop and production processes and trading would cease. Emergency services like fire, police or ambulance could not be called due the breakdown of the telecommunication systems. Hospitals would only be able to work as long as the emergency power supply is supplied with fuel. Financial trading, cash machines and supermarkets would in turn have to close down, which would ultimately cause a catastrophic scenario. If the blackout were to spread across the border lines, which is more likely today due to the interconnection of power grids between different states, the impacts would escalate as a function of the duration of the interruption.



2. Condition monitoring of transformers

2.1. Temperature

Temperature is a key parameter that affects the dielectric strength of the transformer. The temperature will increase or decrease depending on pay load of transformer. Normally transformer has two temperature sensors and a contact to measure winding temperature and top oil temperature. Moreover, top oil temperature is compared with ambient temperature to then control the cooling unit. Normally, PT100 RTD are used as temperature sensors to measure temperature. In normal operation, winding temperature should not be more than 15°C of top oil temperature.

2.2. Oil level

Oil is used for insulation and cooling the coil inside transformer body. It has a breakdown voltage of more than 30 KV (IEC165). The normal function is to transfer heat away from coils to the radiator, and through radiator fins to the air around the transformer. This ensures that the coil wire and iron core of transformer is cooled off and also maintains the coil wire insulation. The oil should cool enough so as to not reach it's flash point. The insulation between the high and low voltage coil should be properly maintained.

The transformer oil has a very long life, but the level must be checked regularly. Normally transformer has oil level sensors and indicators. However, datalogging is usually not done.

2.3. Pressure

The pressure inside transformer can cause short circuit inside the transformer. If a short circuit occurs inside the transformer, caused by a large arc within the transformer, the transformer oil will produce gas vapor and will create continuous and rapid high pressure, called Dynamic Pressure Peak(DPP). Moreover, if the pressure rises quickly it indicates there is air in the transformer body.

The pressure in the transformer body should be not exceed 0.2 bar.

2.4. Power quantity

Power quantity parameters are usually monitored, including current (A), voltage (V), and electric power (kW, kVA, kVAR). A load consumption of not over 80% of rated current of the transformer should be allowed, and phase balancing should not differ more than 20% of the average.

Since these are regularly monitored, they are not included in the scope of this system.

Proposed architecture

3. IIoT system architecture consists of 3 layers

3.1. Physical layer

Sensors and instruments are installed inside / outside of transformer to measure the assigned parameters. Signals from physical devices that are discrete/ analog are converted to digital data. Alarms, signals are also configured here for local alerts and information.

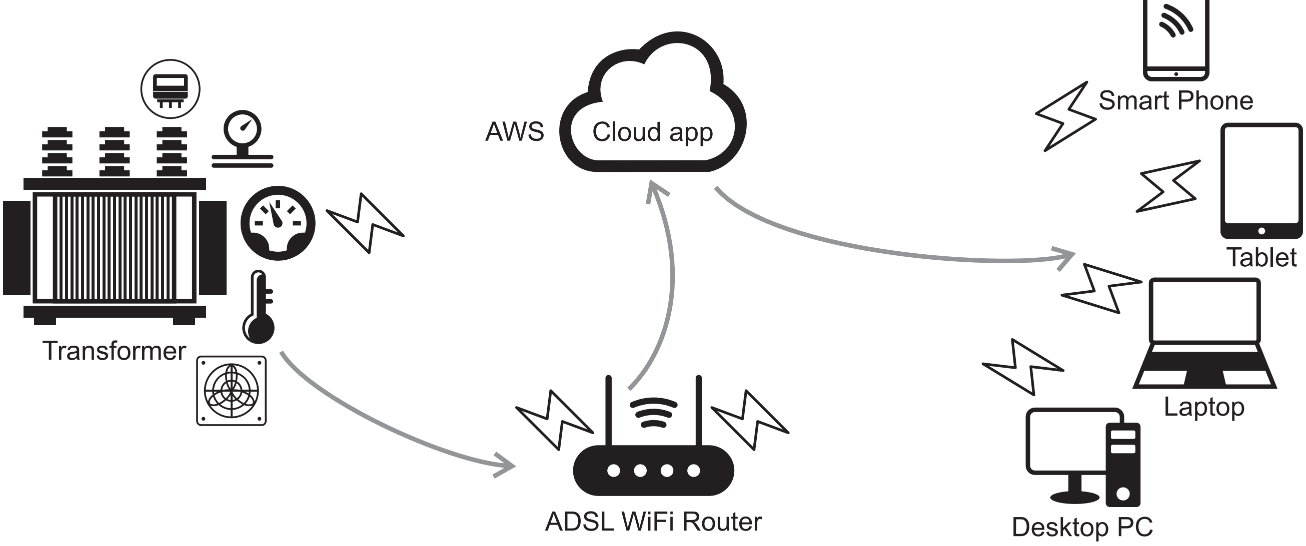
3.2. Network layer

The network layer uses devices / systems for collecting, and processing data. In addition, any wifi router is configured as gateway between the physical layer and Cloud server. Various protocols and signals from physical layer up to cloud like MQTT protocol, wifi or local bluetooth are used for transmitting this data to the cloud.

3.3. Application layer

A cloud server based application is used for delivering specific alarm and alert services to additional users or public at large. Users can remotely monitor by smart phone, tablet, laptop and PC the parameters being measured at the physical layer.

Sensors and Actuators Device



4. Determining key parameters using FMEA (Failure Modes and Effects Analysis)

FMEA is used to identify values of oil levels, typically oil level too low (low low), oil level low, oil level high, oil level too high (high high). Any of these conditions are notified to relevant users by email.

A sample for oil level is given below :

Name	Function	Mode	Cause	Effect	Criticality	Remarks
Oil level indicator	Oil level Checking	Oil level too low	Oil level less than set point, oil leak	Reduce electrical insulation and loss of cooling the winding coil inside. Transformer will overheat	Dangerous	Have to check tank of oil and add oil to correct value, Check leak
		Oil level too High	Overpressure when the oil expands	The oil pressure inside increase and trip occurs	Dangerous	Check level of oil and make to correct value
		Oil level incorrect	Malfunction of sensors and calibration value not corrected	False trip	Safe	Calibrate or replace oil level indicators

Normal range of oil level is 70%–95% of full scale.
Alarm range is <60% or >95% of full scale.

5. Conclusion

The proposed system is beneficial for preventive maintainence of transformer from any faults. This method can transform ***time-based maintenance*** to ***condition-based maintenance***. Monitoring only key parameters via devices / systems to collect and convert field data into information goes a long way to avoid transformer failures. The system can monitor in real time via web based application dashboard the key transformer values. Alarm and alert conditions that are developed based on FMEA, can support users to save time and solve problems predictively. The system can send alerts to the user via email.

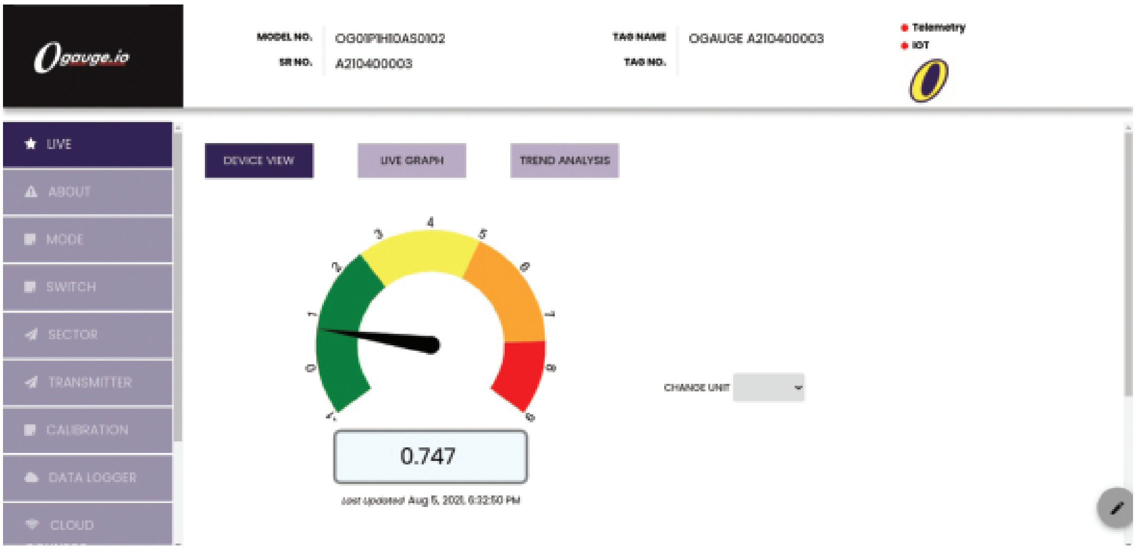
The diagnosis, based on the number of times the relay of temperature unit was triggered, will give a clear indication of frequent overloading, or faults within the transformer. Any oil leakage due to ageing, or faulty manufacturing, leading to tripping of oil level relay will serve as an early warning to look into the defects and repair them.

6. Proposed solution

An IIoT based device for transformer oil level and oil temperature will help condition based monitoring. Alarms generated will be on realtime events of oil leakage (oil level low) and / or temperature rise (overloading or leakage). All this data will be logged and available for analysis on the cloud to several executives (or even to public) for all transformers equipped with these devices.

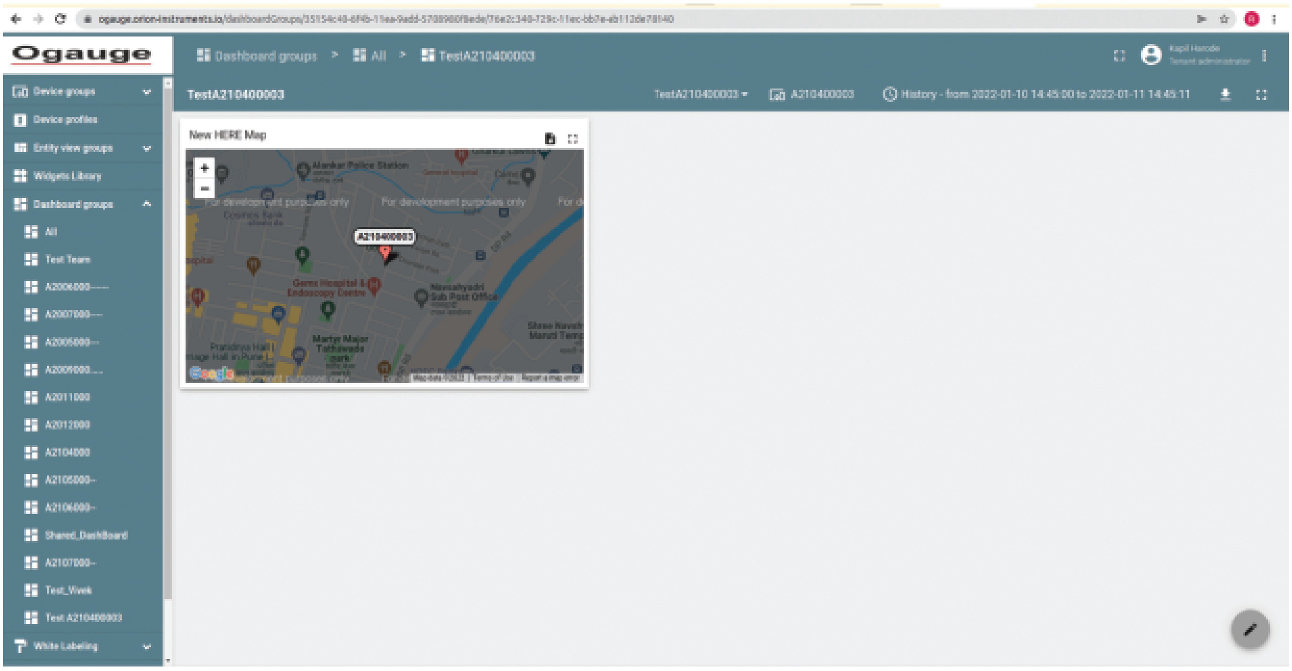
A typical IIoT device will look like this :

A cloud based dashboard will be provided where the parameters of individual transformers can be monitored.



6.1 Geotagging

All transformer assets can be geotagged to know the location. The cloud based application can give conditional access to users who wish to see the measured parameters.



7. Suggested specification

All oil filled transformers should be equipped with device(s) / system to monitor oil level and compensated temperature of top oil. The device(s) / system should have a three tier role based access to setting it's parameters, a local indication that also can be monitored within 15 feet of the transformer to ensure personnel safety, with analog outputs for remote indication of parameters within the control room. The following minimum attributes of the transformer asset should be transmitted to a cloud based application : the GPS coordinates, the measured parameters, the ambient temperature.

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