An Approach to Remote Condition monitoring of Electrical Machines based on IOT

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Abstract. With the progress and development of national economy, the power system reliability and safety issues of power system is also to be considered important. Predictive maintenance is preferred in many of the systems as it reduces the downtime, increase efficiency and reliability. Condition monitoring is important to identify the fault early in distribution transformer and generator. If any fault occurs in the generator or transformer it may affect the entire process of the generating and distributing system. And it results in unexpected shut down of power supply and expenses. Therefore real-time monitoring of transformer/generator is mandatory for supplying the constant supply to the consumers. IOT based monitoring of transformer and generator system is proposed in this paper, which could monitor the most important parameters such as temperature, current and voltage in transformer & fuel level, oil level, temperature in generator with help of sensors and the information is also updated to server via Wi-Fi module. If any abnormal conditions is detected it will automatically result in tripping off of the system and the information is send to the server via Wi-Fi. Therefore remote condition monitoring protection becomes possible with the proposed technology.

1. Introduction

The electrical power systems are highly non-linear, extremely huge and complex networks. On the other hand, the developed countries also do not have sufficient power supply to meet the growing demand. Transformer is one of the important electrical equipment as a simple fault at the distributing end can cause black-out of power to the whole area. The fault can also be very dangerous as the transformers contain large quantity of oil in direct contact with high voltage components. This increases the risk of fire and explosions due to failures. Continuous monitoring of transformer can reduce the fault occurrence. The main objective of the system is to protect the transformer by continuous monitoring and acquire real-time data of transformer remotely over the internet falling
under the category of internet of things (IOT). The real time data’s of the temperature, current and voltages of the remote located transformers are collected with temperature sensor, current transformer and potential transformer and the data’s are sent to the control room using internet. These three analog values are taken in multiplexing mode and connected to a programmable microcontroller (Ardino). They are then sent directly to a Wi-Fi module. The real-time data is also send & seen at the ending end LCD display interfaced with the microcontroller. The power failure will be detected by relay, and it can be communicated to microcontroller to alerts the authorized person via Wi-Fi. In addition to that, parameters like Fuel level, oil level and temperature of the generators are monitored and communicate to authorized person. The acquired parameters are processed and recorded in the system or server.

![Fig 1. Block diagram of monitoring system](image-url)

**1.1 Input Unit**

The parameters to be monitored in transformers are voltage, current and temperature and the parameters to be monitored in generators are fuel level, oil level and temperature. In this project, the fault conditions of the transformers are created artificially to create a situation which is similar to the fault occurrence condition.

**1.1.1 For Transformer.** The input unit consists of 2 transformers with the ratings 230/9V and 230/12V. Two transformers are provided to produce the situation of healthy condition & faulty conditions. The operation of the transformer with the rating of 230V/9V is healthy condition and 230V/12V is taken to be the faulty condition.

- **Fault 1.** For analysis purpose the healthy condition is said to be the value below or equal to the 9V and the faulty condition is said to be the value exceeding the 12V.
- **Fault 2.** For analysis purpose the healthy condition is said to be the value below or equal to the 100mA and the short circuit faulty condition is said to be the value exceeding 500mA.
- **Fault 3.** The healthy condition is said to be the value of temperature between -55°C to 150°C .If it exceeds this values then it’s defined as a faulty condition.

**1.1.2 For generator.** The oil level and fuel level is monitored for protection purpose, this monitoring is done by taking oil and fuel in two different bowls and then it is monitored separately.
Creation of faulty condition. These two faults are considered in the following method. 

**Fault1.** For analysis purpose the healthy condition is said to be the value of oil level equal to the (4-20MA liquid ultrasonic) and the faulty condition is said to be the value that reduces below this value. 

**Fault2.** For analysis purpose the healthy condition is said to be the value of fuel level equal to the (0-40ppm) and the faulty condition is said to be the value that reduces below this value.

1.2 Sensing Unit

Sensing unit consists of four types of sensors for monitoring voltage, current and temperature of the transformer and oil & fuel level of the generator. In this system, potential sensor, current transformer, temperature sensor and ultrasonic sensors are used to monitor the voltage, current, temperature, oil level and fuel level.

1.2.1 Current sensor. Current sensing circuit is used to sense the current in the transformer and the output of transformer is connected to microcontroller. The current sensing transformer is used to sense the over load current or short circuit current to protect the load from the impact of the fault occurrence. Current sensing is measured at transformer side.

A current transformer (CT) is a type of transformer that is used to measure alternating current (AC). It produces a current in its secondary side which is proportional to the current in its primary side. A current sensor is a device that detects and converts current to an easily measured output voltage, which is proportional to the current through the measured path. When a current flows through a wire or in a circuit, voltage drop occurs. Also, a magnetic field is generated across the current carrying conductor. Both of these phenomena are made in the design of current sensors.

1.2.2. Voltage sensor. The voltage transformer is used to sense voltage level. Here output of transformer is connected to microcontroller. The microcontroller receives the voltage level. If in case the value crosses threshold level, micro controller will automatically cut off the single phase supply to protect the system.

Potential transformer is a device that steps down the line voltage. This voltage is sensed by low rating relays & if the voltage levels are found to be abnormal then protective devices comes into operation. Potential transformer is a voltage step-down transformer which reduces the voltage of a high voltage supply to a lower level for the purpose of measurement. These are connected across or parallel to the line which is to be monitored.

1.2.3 Temperature sensor. The temperature sensor is used to sense temperature level of generator and transformer. LM 35 sensor is used to monitor temperature value in transformer and generator. The operating temperature range is from -55°C to 150°C. The output voltage varies by 10mV in Response to every °C rise/fall in ambient temperature, i.e., its scale factor is 0.01V/°C. If any abnormal is detected relay will automatically trip off to protect the load.

1.2.4 Fuel level sensor. The fuel level sensing unit is located in the generator. The end of the rod is mounted to a variable resistor. If there is more resistance, the less current will flow. In a fuel tank, the variable resistor consists of a strip of resistive material connected on one side to the ground. When fuel level is low, the fuel sensor will intimate to microcontroller and automatically buzzer will alert and status of generator is displaying in LCD.

1.2.5 Oil level sensor. The Generator oil level is sensed by oil level sensor. When oil level is decreased, the information will be send to power station & it alerts the buzzer and display faulty condition in LCD. The fault information is sent to the server in each case discussed above, via Wi-Fi, so as to know complete information in WEBPAGE. If in case the output value crosses threshold level, micro controller will automatically alert the buzzer and update the values in server via Wi-Fi.
1.3 Signal conditioning unit

The signal conditioning gets input from current and voltage sensing unit. The sensing device output is AC. Current sensing and voltage sensing also done in transformer side and that output is connected to signal conditioning. Signal conditioning can include amplification, filtering, converting, range matching, isolation and any other processes required to make sensor output suitable for processing after conditioning.

1.3.1 Filtering. Filtering is the most common signal conditioning function, as usually not all the signal frequency spectrum contains valid data. The common examples are 60 Hz AC power lines, present in most environments, which will produce noise if amplified.

1.3.2 Amplifying. Signal amplification performs two important functions: increases in the resolution of the inputted signal, and increases its signal-to-noise ratio. For example, the output of an electronic temperature sensor, which is probably in the milli volts range, is probably too low for an Analog-to-digital converter (ADC) to process directly. In this case it is necessary to bring the voltage level up to that required by the ADC. Commonly used amplifiers on signal conditioning include Sample and hold amplifiers, Peak Detectors, Log amplifiers, Antilog amplifiers, Instrumentation amplifiers or programmable gain amplifiers.

1.3.3 Isolation. Signal isolation must be used in order to pass the signal from the source to the measurement device without a physical connection: it is often used to isolate possible sources of signal perturbations. Also notable is that it is important to isolate the potentially expensive equipment used to process the signal after conditioning from the sensor. Magnetic or optic isolation can be used. Magnetic isolation transforms the signal from voltage to a magnetic field, allowing the signal to be transmitted without a physical connection (for example, using a transformer). Optic isolation takes an electronic signal and modulates it to a signal coded by light transmission (optical encoding), which is then used for input for the next stage of processing.

1.4 Control unit

This controlling unit consists of Ardino, relay driver and relay.

1.4.1 Arduino. Arduino is a single-board microcontroller to make using electronics in multidisciplinary projects more accessible. The hardware consists of a simple open source hardware board designed around an 8-bit Atmel AVR microcontroller, or a 32-bit Atmel ARM. The software consists of a standard programming language compiler and a boot loader that executes on the microcontroller.

1.4.2 Relay driver. The circuit used for driving a relay can be termed as a relay driver circuit and it can be designed using various integrated circuits. These relays are needed to be driven for activating or to turn ON. So, relays require some driver circuitry to turn ON or OFF (based on the requirement).

1.4.3 Relay. Relays are most commonly used switching device in electronics. The relay is mostly used to switch from low power device to high power device. When sensing device detect above threshold level, automatically the relay will trip of the supply.

1.5 Display and Communication Unit. These four sensors sense the value and microcontroller will convert the analog values to digital value and display it on LCD at the same time the data send to the server via Wi-Fi module. If we get any unsecure data about transformer/generator we can protect the device before damage.
1.5.1 Wi-Fi Module. ESP8266 is an impressive, low cost WIFI module suitable for adding WIFI functionality to an existing microcontroller project via a UART serial connection. The module can even be reprogrammed to act as a standalone WIFI connected device. The ESP8266 requires 3.3V power—do not power it with 5 volts. The ESP8266 needs to communicate via serial at 3.3V and does not have 5V tolerant inputs. ESP8266 on-board processing and storage capabilities allow it to be integrated with the sensors and other application specific devices through its GPIOs with minimal development up-front and minimal loading during runtime. With its high degree of on-chip integration, which includes the antenna switch power management converters, it requires minimal external circuitry, and the entire solution, including front-end module, is designed to occupy minimal PCB area.

2. Circuit Diagram

Figure 2 shows the simulated module of the circuit diagram of the monitoring system proposed. The simulation tool used is Proteus 7.0 which is a Virtual System Modeling (VSM) that combines circuit simulation, animated components and microprocessor models to co-simulate the complete microcontroller based designs.

2.1 Simulation. The input voltage 12V, 1A regulated input voltage is converted to 5V.

2.1.1 Current and voltage sensing circuit. In electrical engineering, a current transformer (CT) is used for measurement of electric currents. When it detects over voltage or current, Microcontroller will automatically trip of the load.

2.1.2 Relay and driver. The relay is used to turn ON/OFF the load when it detect over voltage and current in circuit. It is connected to LOAD Input.

2.1.3 Temperature sensor. The temperature sensor is used to sense the temperature level in transformer and generator. It provides only analog output. So here we are connected to analog pin in atmega328. Here we are using 10 bit ADC.

2.1.4 Ultrasonic sensor. The ultrasonic sensor is connected with PIC microcontroller. The sensor output is given to controller in analog 25 and 24. The ultrasonic sensor senses the oil level and fuel level in generator and given corresponding voltage will be give to microcontroller.

2.1.5 Wi-Fi. The Wi-Fi is used to transmit and receive data from server. It will connect to Wi-Fi TX and RX pin. Here, the sensing data will be transmitted to server via Wi-Fi.

![Fig 2. Circuit Diagram](image-url)
3. Simulation Results for Transformer

The analysis was carried out under healthy and faulty conditions for transformers. Figure 3 and 4 shows the simulation model of healthy and faulty conditions of the transformers respectively. Voltage, current and temperature of the transformer is measured and sent as input signal to arduino board. The board compares the input values which are received from the transformer and microcontroller will compare it with the Set value, and the display shows the values and Lamp (ON) is used to indicator.

Faulty conditions of the transformer is shown, voltage current and temperature of the transformer is measure and sent as input signal to the arduino board. The board compares the input value which is received from the transformer and it is compared with set value. Now if the input value is more than the set value, the display shows “FAULT” and lamp is turned off to indicates that it has fault.

Fig 3. Healthy condition of the transformer

Fig 4. Faulty condition of the transformer
4. Simulation Results for Generator

The analysis was carried out under healthy and faulty conditions for the generators. Figure 5 and 6 shows the simulation model of healthy and faulty conditions of the transformers respectively.

Fuel level, oil level and temperature of the generator is measured and sent as input signal to the arduino board. The board compares the input value which is received from the generator and it is compared with set value. Now if the input value is more than the set value, the display shows “FAULT” and lamp is turned off to indicates the fault occurrence.

![Fig 5. Healthy condition of the generator](image)

Fuel level, oil level and temperature of the Generator is measured and sent as input signal to arduino board. The board compares the input values which is received from the transformer and its compared with the Set value, and the display shows the values and Lamp(ON) is used to indicator.

![Fig 6. Faulty condition of the generator](image)

5. Hardware Kit

Figure 7 shows the hardware setup of the condition monitoring system. The input voltage 12V, 1A regulated input voltage is converted to 5V. The current and voltage sensing circuit will sense the load current and load voltage. A current transformer (CT) is used for measuring the electric currents. When it detects over voltage or current, automatically load will be OFF. The relay is used to ON/OFF
the load when over voltage and current is detected in circuit. The temperature sensor is used to sense the temperature level in transformer and generator. It provides only analog output. And it should be connected to analog pin in atmega328. 10 bit ADC is used in this project. The ultrasonic sensor is connected with arduino microcontroller. The ultrasonic sensor senses the oil level and fuel level in generator and gives the corresponding voltage to microcontroller. The Wi-Fi is used to transmit and receive data from server. It is connected to the Wi-Fi TX and RX pin. Here, the sensing data will be transmitted to server via Wi-Fi.

![Fig 7. Hardware kit of the condition monitoring system](image)

6. Hardware Results

Figure 8 shows the hardware results of the condition monitoring system with healthy and faulty conditions of the transformers and the generators.

![Hardware Results](image)
Fig8. Hardware results of the condition monitoring system (a) Healthy condition of the transformer (b) Faulty condition of the transformer (c) Healthy condition of the generator (d) Faulty condition of the generator

Figure 8a shows the result displayed during normal conditions of the transformer and the displayed result is “NOR”, which indicates the normal condition. Figure 8b shows the result of the abnormal conditions of the transformer. Since the input value is more than the set value, the result shown is “ABN”, which indicates the abnormal condition. Figure 8c shows the result of the normal condition of the generator. The result indicated as “NOR” indicates the normal condition of the transformer. Figure 8d shows the result of the abnormal condition of the generator. The result shown is “ABN” which indicates the abnormal condition of the generator.

7. Data Storage

Figure 9 shows the data storage of the transformer and the generator.

| Date Received On | Generator Temperature | Transformer Temperature | Load Voltage | Load Current | Fuel Level | Oil Level | Mode | Load Status |
|------------------|------------------------|-------------------------|-------------|-------------|-----------|----------|------|-------------|
| 23-03-2019 09:47:31 | 28                     | 22                      | 300         | 0           | 330       | 310      | Manual | ON          |
| 23-03-2019 09:47:42 | 28                     | 22                      | 300         | 0           | 330       | 310      | Manual | ON          |
| 23-03-2019 09:47:25 | 28                     | 22                      | 300         | 0           | 330       | 310      | Manual | ON          |
| 23-03-2019 09:47:25 | 28                     | 22                      | 300         | 0           | 330       | 310      | Manual | ON          |
| 23-03-2019 09:47:25 | 28                     | 22                      | 300         | 0           | 330       | 310      | Manual | ON          |

Fig 9. Data storage of the transformer and the generator.

Voltage, current, temperature, oil level and fuel level of the transformer and generator is measured and sent as input signal to the ARDUINO board. And the values will be displayed in the LCD board at the same time the information is also sent to the Wi-Fi via server and the data is stored the WEBPAGE. The displayed data in fig 9 shows the sample data stored on a single day.

8. Graphical Representation

In this project data can be analyzed from the microcontroller and updated to the wifi through (ESP8266). The ESP8266 can be controlled from your local wifi network or from the internet. Wi-Fi technology may be used to provide Internet access to devices that are within the range of a wireless network that is connected to the Internet. All the analyzed data will be stored in the cloud storage and it can be accessed by logging in to the ip address. we can analysis the data in the form of graph. Graph can be plotted in different types depends on our requirement i.e. we can plotted a graph for hours and weekly and monthly.

Figure 10, 11 and 12 shows the hourly report, weekly report and the monthly report of the data stored. The data stored are the temperature, load voltage, load current, fuel level and oil level.
9. Conclusion

The wireless based monitoring of distribution transformer and generator receives high priority as it reduces the downtime, increases efficiency and reliability. The IOT can realise the intelligent identification, localisation, tracking, monitoring and management of things through
connecting them with the internet for information exchange and communication. The abnormal condition of the transformer can be prevented immediately without causing severity to the systems. The proposed system is able to monitor, control and display the fault occurrence from remote place. Also it helps to record the data in the cloud and to retrieve the data at any time. The data is made available easily to the user through mobile communication. This system will maximize the system efficiency and accuracy in the power system.

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