ONLINE CONDITION MONITORING OF POWER TRANSFORMER

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Abstract: *Conventional methods such as dissolve gas analysis, partial discharge method may be used for conditional monitoring but they are OFF-LINE methods and involve high cost and laborious process. Low cost ON-LINE monitoring of power transformer is very helpful and crucial to assess condition of the power transformer. By employing appropriate ON-LINE monitoring system it is always convenient to monitor the changes in the temperature, currents and voltages, so that the information is useful to prevent catastrophic unplanned failures. In order to achieve the scenario of ON-LINE monitoring potential transformer GPRS systems can be preferred which can employ digital systems along with microcontrollers. Real time monitoring of power transformer requires ability of data handling and data processing for a better assessment of diagnosis of power transformer. In this work a new GPRS system integrated with programmable measuring meters is proposed to collect the transformer parameters in terms of voltage, temperature and current through Voltage monitoring circuit, Temperature sensing circuit and Load monitoring circuit. A prototype model is developed and interfaced with GPRS system with PIC 16F876A. The proposed model monitors with temperature SL100 sensors and the temperature measuring circuit is designed with two OPAMPS one is configured as differential amplifier and the other as the voltage amplifier. The collected data from prototype model is quite useful to ascertain the condition of power transformer.*

Keywords: *Power transformer, GPRS system, voltage monitoring circuit, digital system, sensors, PIC Microcontroller.*

1. INTRODUCTION

Insulation system of the transformer is one of the most important parts of the system. But the dielectric strength of the insulation system deteriorates due to overloading, ageing, incipient faults and partial discharges and contributes to failure of transformer. Conventional methods such as dissolve gas analysis, partial discharge method may be used for conditional monitoring but they are OFF-LINE methods and involve high cost and laborious process. The OFF-LINE methods refer to checking of the transformer periodically, by the concerned personal in terms of temperature, gas, currents and voltages. These OFF-LINE methods are time consuming and may not provide dynamic condition monitoring of the transformer, essentially to monitor incipient faults involving with the changes in temperature of oil, changes in temperature of winding due to disturbances across the transformer. Therefore low cost ON-LINE monitoring of power transformer is very helpful and crucial to assess condition of the power transformer to prevent catastrophic losses by providing early warnings to electrical failures. The simplest and most effective means of monitoring of the transformer can be done by temperature sensors, current and voltage [1].

Abnormal temperature raises always indicate certain type of failures in a transformer. By employing appropriate ON-LINE monitoring system it is always convenient to monitor the changes in the temperature, currents and voltages, so that the information is useful to prevent catastrophic unplanned failures. In order to achieve the scenario of ON-LINE monitoring potential transformer GPRS systems can be preferred which can employ digital systems along with microcontrollers [2]. Due to the abnormal conditions, the changes in currents, voltages must be monitored (by using transformer and receiver) automatically for real time monitoring of transformer parameters. Real time monitoring of power transformer requires ability of data handling and data processing for a better assessment of diagnosis of power transformer.

In this work GPRS system is employed to collect the transformer parameters in terms of current, voltage and temperature. The work is divided in to the following sections. Section 2 describes about GPRS Network, Section 3 gives the details of data management, Section 4 describes the proposed prototype model interfacing for collecting the data in-terms of current, voltage and temperature for 9 consecutive days is quite useful to ascertain the condition of power transformer and section 5 concludes the work.

2. GPRS Network system

GPRS system consists of master system, GPRS acquisition terminal and Static meter. The architecture of GPRS is shown in Fig. 1.

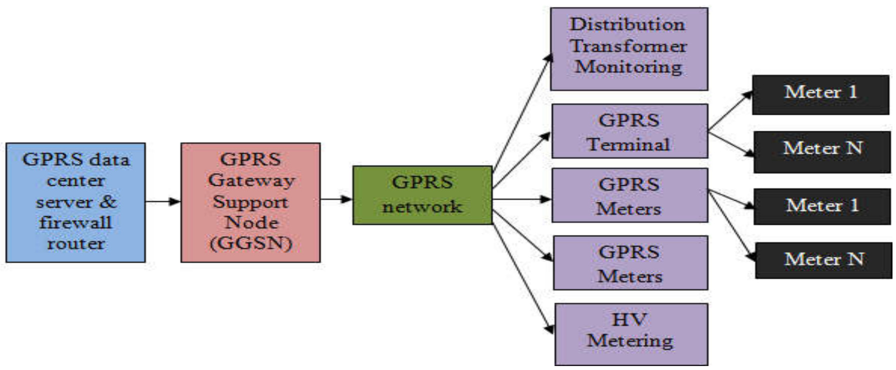

Fig. 1 Architecture of General GPRS system.

2.1 GPRS Network

GPRS wireless communication network end-user data terminal, data transmission channel and GPRS data center. As far as electrical consumers are concerned, the system GPRS data acquisition network can be in the following manner.

The GPRS communication data server applies for public dynamic IP via connecting to INTERNET by ADSL or dialing from the domain name certification server, communicating with terminals via the public network IP across Internet, GPRS network, whose configuration is simple [3].

This kind of network is applicable to the system with few terminals at its early stage, and reporting the data. The data quality will be slightly compromised because of communications across networks. The architecture of public dynamic IP is shown in Fig. 2.

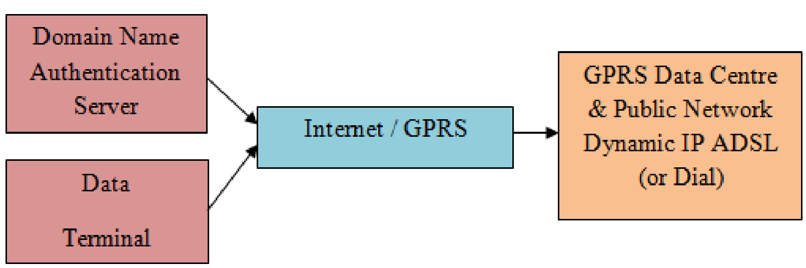

Fig. 2 Architecture of public dynamic IP.

Via the Internet server NAT port mapping of the public network IP, data channels are established between the data terminal and data centre. This kind of network is applicable to the system with few terminals at its early stage, and data reporting without being polled. The architecture of public network fixed IP is shown in Fig. 3.

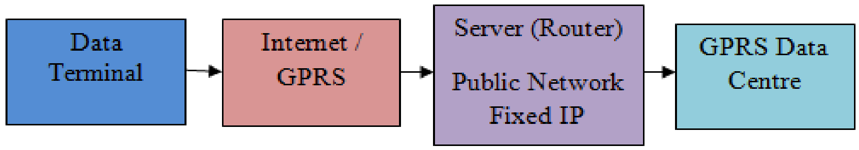

Fig. 3 Architecture of Public network fixed IP.

2.2 GPRS Data Center

GPRS communication data server provides the GPRS data center. In general data communication is carried out between the data center and GPRS terminal, manages the receiving of the data [4]. By using GPRS network for ON-LINE monitoring always ensures 99.9% of transmission of data packets.

3. Data management Terminal-GPRS

This unit is mainly to collect, store the data and supervise peripheral devices, transmission data to master station via GPRS network. The main feature of GPRS module is reliable data connection especially for ON-LINE monitoring. This module offers powerful configuration and supports local/remote parameterization. The functionality of GPRS module includes not only data acquisition with respect to temperature, current, voltage of the transformer but also there is a provision or transmission and receiving of demand data. The GPRS configuration offers instantaneous and reliable data storage with configurability and re-configurability options[5].

3.1 Hardware description

The tested hardware consists of the following components. The general block diagram of GPRS is as shown in Fig. 4.

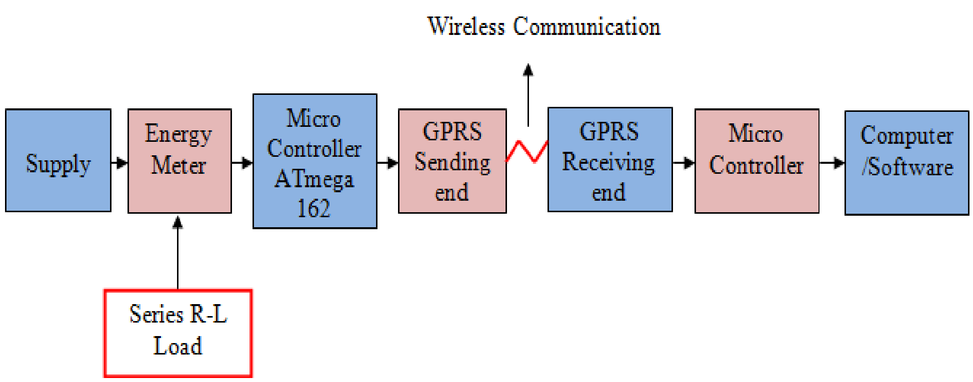

Fig. 4: Block Diagram representation of a GPRS based system.

3.2GPRS Modules

3.2.1 GPRS sending end module

In the process of online energy monitoring using GPRS, the GPRS system consists two modules. One is GPRS sending end module and another one is GPRS receiving end module.

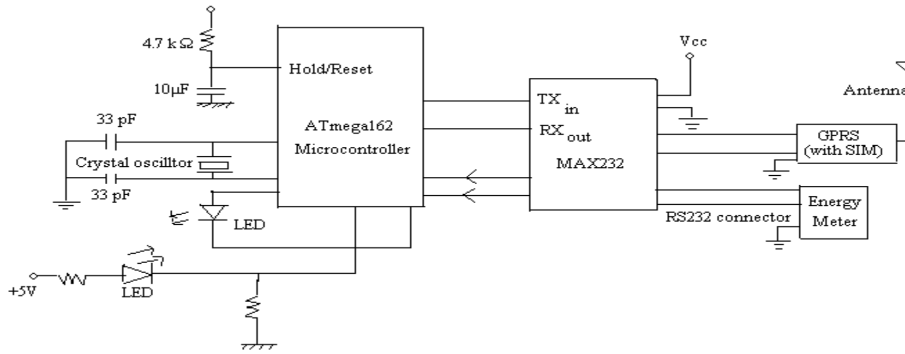

Fig.5 Circuit diagram of GPRS sending end module.

The parameters which are measured by the meter from load variations will be received by the microcontroller through MAX232 serial port and RS232 serial connector. The received parameters are transmitted from microcontroller to the GPRS based SIM card service through MAX232 serial port. GPRS SIM card send the parameters to the receiver side SIM card in the form of Short Message Service (SMS). In the Fig.5, the crystal oscillator provides a frequency of 10 MHz for the microcontroller operation and the microcontroller operates on voltage of 5V which is produced by the voltage regulator. Two LED's have been used in the circuit; one is for indication of supply and another one for indicating signal transmission.

3.2.2 GPRS receiving end module

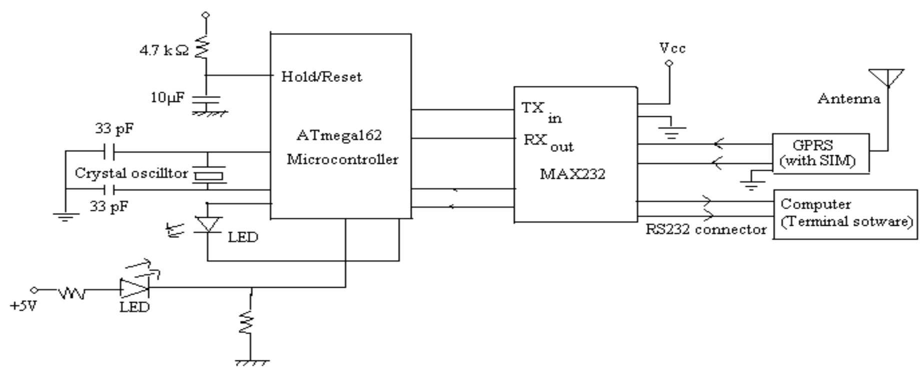

Fig. 6 Circuit diagram of GPRS receiving end module.

The signals (parameters) in the form of SMS received by the receiving side SIM card which are send from the sending end side SIM card are transmitted to microcontroller through MAX232 serial port. To display the measured parameters computer is used with terminal software. The computer and MAX232 serial port are connected with RS232 connector. In the Fig. 6, the crystal oscillator provides a frequency of 10 MHz for the microcontroller operation and the microcontroller operates on voltage of 5V which is produced by the voltage regulator. Two LED's have been used in the circuit, one is for indication of supply and another one for indicating signal receiving.

The operation of the architecture of GPRS system consists of two identical units one at sending end and the other at receiving end. The receiving end and sending end of entire system will have similar characteristics while carrying out data communication (temperature, current, voltage). At sending end (at transformer end) the changes in temperature, current, voltage will be send to programmable at 162 microcontrollers (as a meter) and is given to GPRS modem where the data in terms of temperature, current, voltage will be stored as per the program. As and when the disturbance occurs, the transformer parameters in terms of current, voltage and temperature will be identified by at MEGA 162 micro controller (programmable and re programmable) and these values will be given to GPRS modemthrough an interface. In the GPRS programming is developed to store the data corresponding to temperature, current and voltage. Since at transformer end, GPRS modem is SIM based, whatever the values that are been identified the GPRS modem will be transmitted from this end (transformer end) to receiving end where similar identical GPRS modem with SIM based is located. The values that have been received at the GPRS modem is again connected to again the programmable digitalized meters and in turn is connected to a PC for further analysis.

Thus at sending end and receiving end are configured for sending and receiving of temperature, current and voltage.

3.3 Schematic diagram of proposed system

Due to the electrical characteristics of the winding during disturbances the winding can be treated as the combination of R, L and C. But whenever there is a disturbance on the system the frequency associated with the signal (disturbance) consists of low frequency and high frequency and thus transformer winding model could be the combination of reactive elements. The schematic diagram is as shown in Fig. 7.

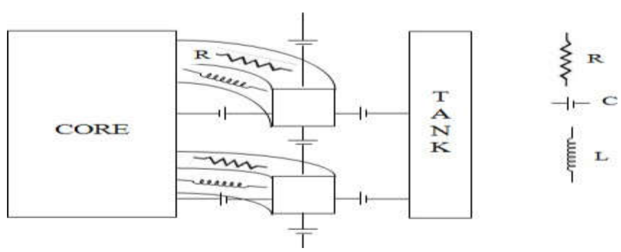

Fig. 7 Transformer Winding Model.

The micro controller based architecture is realized for ONLINE condition monitoring of potential transformer. Fig. 8 shows microcontroller based monitoring.

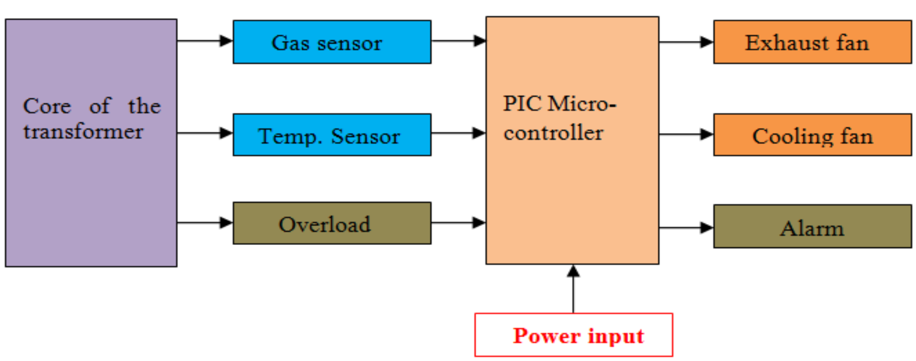

Fig. 8 Microcontroller Based Transformer Winding Model.

The rise in temperature is sensed by the processor and subsequently transformer will be disconnected from the supply by switching ON the cooling fan. Voltage divider circuits are implemented to determine the condition of overload of the transformer and send the information to the alarm for alerting the operator.

3.4 The digital model of monitoring Cum Control

The entire digital condition monitoring of the transformer is shown in Fig. 9 and is realized in three steps as (1) Voltage monitoring circuit (2) Temperature sensing circuit and (3) Load monitoring circuit.

For over voltage parameter monitoring input voltage to the transformer is fed from an auto transformer in the proposed prototype model 1:1 transformer is considered and is allowed to operate at 220V. The control circuit is programmed in such a way that, it disconnects the primary of the transformer from the supply if the voltage is greater than operating voltage is 220V. A relay contact is provided through which the supply to the primary is connected and micro controller is programmed such that relay will be energized which in turn disconnect the supply to the transformer. A Step-down transformer of 6V-0-6V center taped secondary is used as a line voltage sensor. As and when transformer primary voltage increases and the corresponding secondary voltage also rises and is rectified, filtered and with the help of another preset, set the value is fixed to the known required value. The output voltage sensing circuit is fed to the second channel of internal ADC for converting analog to digital. The relay is used in such a way that if abnormal conditions prevailed in the system then the relay energizes and subsequently supply to the primary of the transformer can be disconnected. At the same time the values corresponding to the abnormal conditions(current, voltage, temperature) is sensed by the microcontroller and in turn will be passed on to GPRS modem(SIM based) at the transformer end.

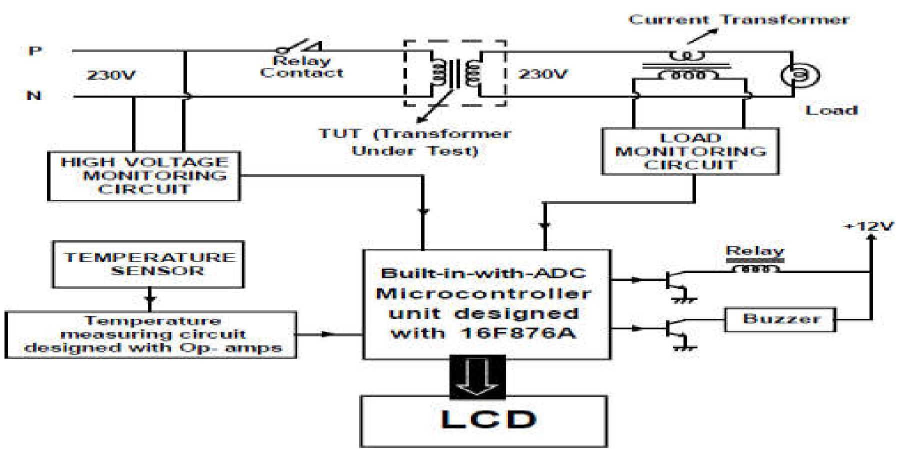

Fig. 9 Digital model of condition monitoring

Now the GPRS at the transformer end will send the information from transformer end to receiving end. Where similar kind of GPRS (SIM based) system receives the transmitted data (current, voltage, temperature). By using suitable interface system between GPRS and micro controller at receiving end which in turn connected to personal computer for further analysis and interpretation of received data using MATLAB. Thus ON-LINE monitoring is possible by using GPRS system which will facilitate condition monitoring of power transformer.

For monitoring the temperature SL100 sensors are used and the temperature measuring circuit is designed with two OPAMPS one is configured as differential amplifier and the other as the voltage amplifier. The advantages of using OPAMP based amplifier is that it can perform the functionality of signal conditioning, active filtering and regulating process. Thus by using GPRS network in combination with microcontroller it is possible to sense the abnormal conditions at sending end at the same information is received at receiving end because the GPRS modems are configured on the basis of mobile SIM.

4. Proposed GPRS Model

The GPRS system consists of master system, acquisition system and static meter. The monitoring system for the proposed model is suggested using hardware model for GPRS online monitoring shown in Fig. 10.

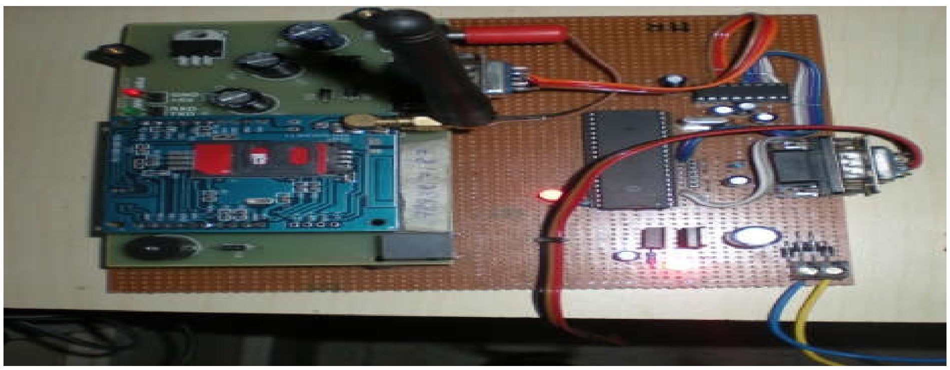

Fig.10 Developed hardware model for automated monitoring.

The automated monitoring system modeled using GPRS system is integrated with programmable measuring meters. The read data from the meter are transmitted from the measuring unit to the centralized monitoring unit using GPRS communication network.

Observations with respect to current, temperature and voltage is realized by using microcontroller and it identifies and transfers the observed data of transformer to GPRS at transformer end and the same is received by GPRS system at receiving end.

Fig. 11 (a) HardwareModel (b) Monitoring of Temperature

Fig. 11 (a), (b) Shows the hardware model and LCD display (for temperature, current and voltage) respectively. Table 1 is the observed data by the proposed GPRS system for monitoring the condition of potential transformer.

The proposed system for automated monitoring is modeled using GPRS modem integrated with energy meter interface. The read data from the meter are transferred from the measuring unit to the centralized monitoring unit using GPRS mode of communication. The data read from the meter are serialized and transferred to a mode of communication.

During the abnormal condition (overvoltage), the PIC microcontroller identifies the voltage level and gives the alarm for the transformer protection. In the case of the over temperature, the temperature sensor is activated and the transformer either disconnected or alarm circuit is activated. In extension to the existing hardware model, provision is available for transmitting the observed parameters through GPRS system such that online condition monitoring of the transformer is very much possible.

Table 1The observed parameters.

S. No	**Temperature (^{o}c)**	**Voltage (V)**	**Current (A)**
1	12	135	1.1
2	12.5	146	1.22
3	13	156	1.32
4	13.4	167	1.42
5	14.2	188	1.48
6	33	196	1.56
7	44	213	1.62
8	54	235	1.67
9	64	242	1.83
10	69 (alarm, circuit tripped)	249 (alarm, circuit tripped)	1.9 (alarm, circuit tripped)

The proposed and developed model is quite useful to transmit and receive the data from one location to another. At receiving end the collected data is interfaced to Personal Computer through RS 232 port so that the received data in terms of current, voltage and temperature is further analyzed using Signal Processing tools.

The data in-terms of current, voltage and temperature have been noted for nine consecutive days to monitor any changes in current, voltage and temperature. The transformer's monitored values along with their corresponding waveforms are listed below.In order to ascertain the condition of the power transformer, the power transformer parameters in terms of temperatures of winding and oil are shown graphically with x-axis in hours and y-axis in centigrade from Fig. 12 to Fig.29.

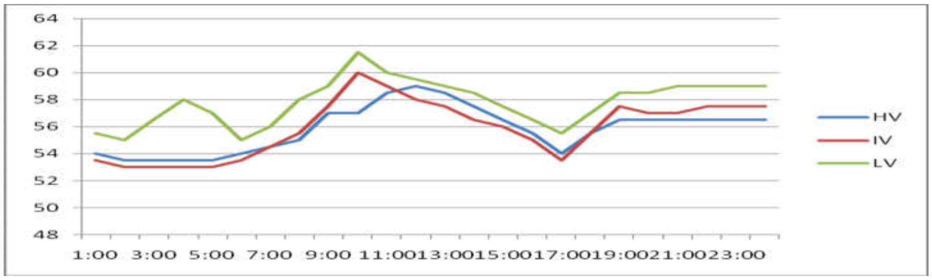

Fig.12 Waveforms of temperatures of winding insulation (Day 1)

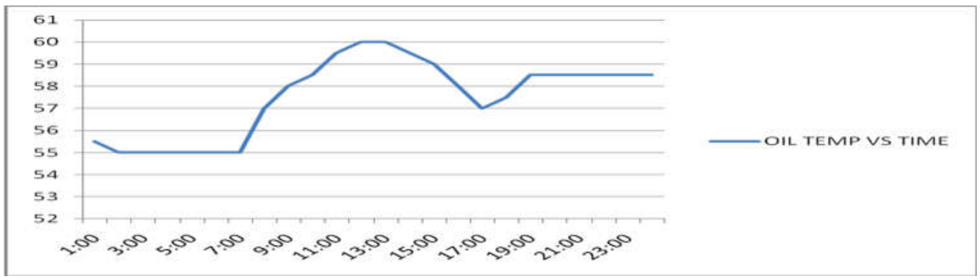

Fig. 13 Waveform of temperature of oil (Day 1)

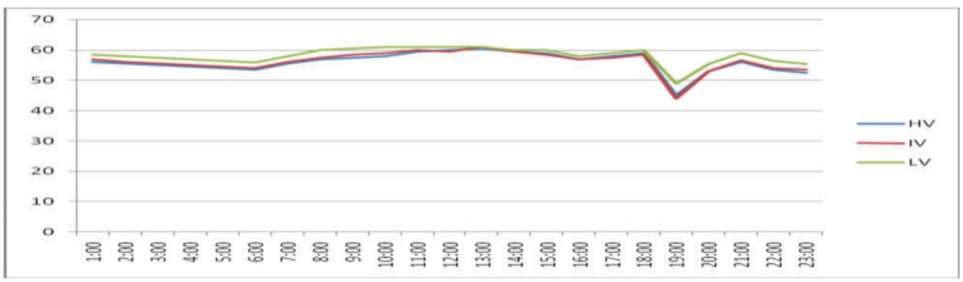

Fig. 14 Waveforms of temperatures of winding insulation (Day 2)

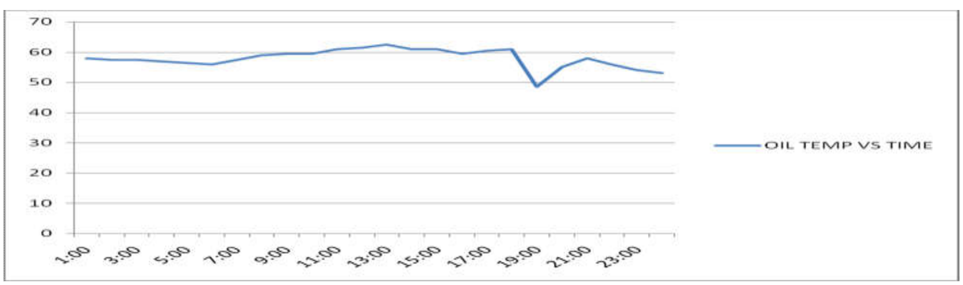

Fig. 15 Waveform of temperature of oil (Day 2)

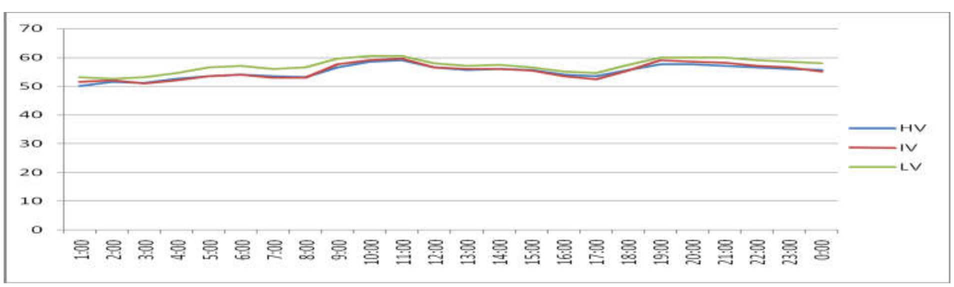

Fig. 16 Waveforms of temperatures of winding insulation (Day 3)

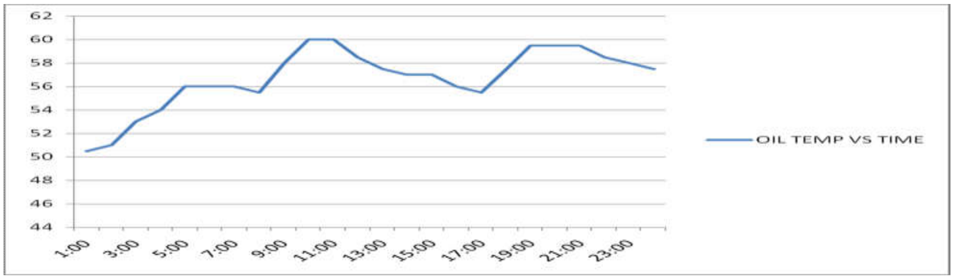

Fig. 17 Waveform of temperature of oil (Day 3)

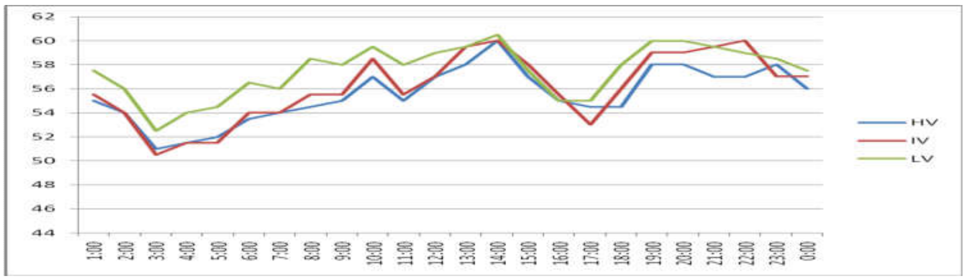

Fig. 18 Waveforms of temperatures of winding insulation (Day 4)

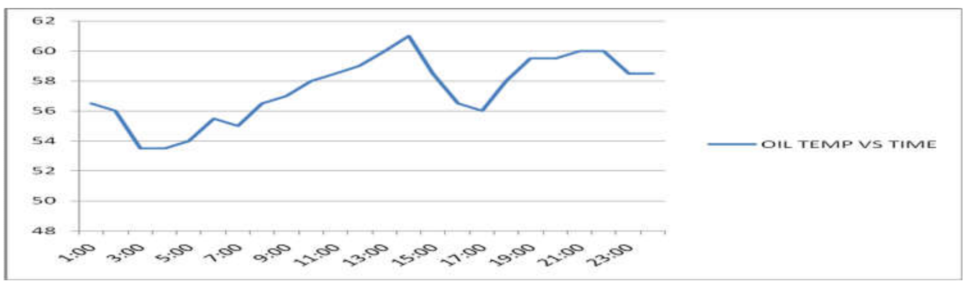

Fig. 19 Waveform of temperature of oil (Day 4)

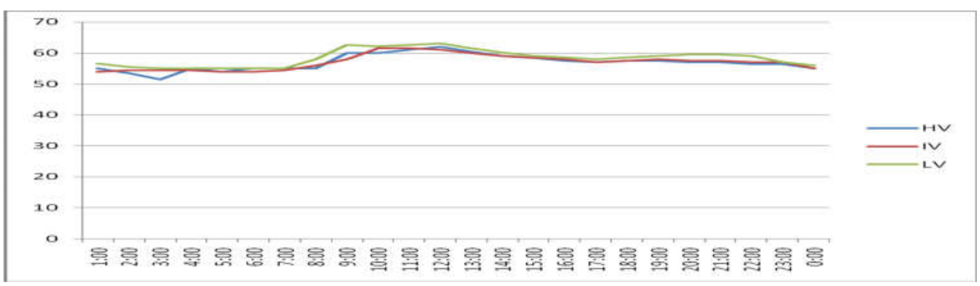

Fig. 20 Waveforms of temperatures of winding insulation (Day 5)

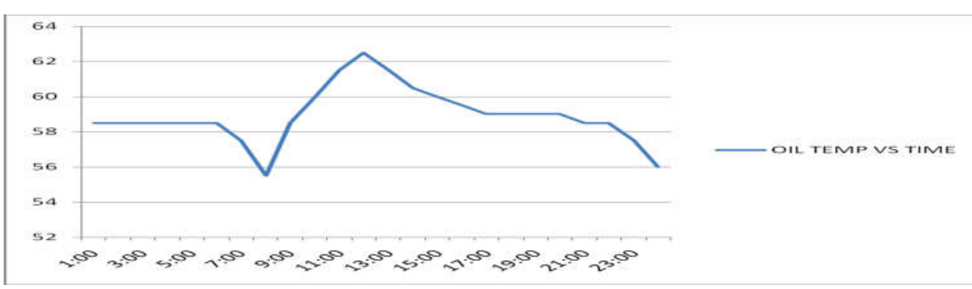

Fig.21 Waveform of temperature of oil (Day 5)

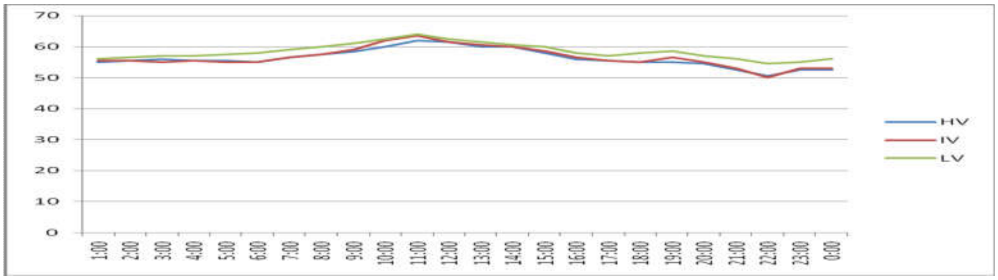

Fig.22 Waveforms of temperatures of winding insulation (Day 6)

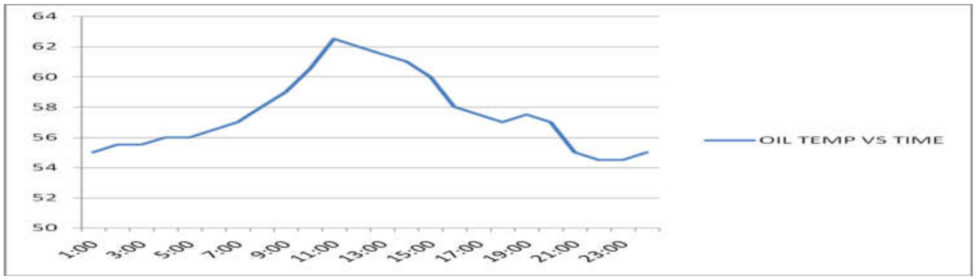

Fig. 23 Waveform of temperature of oil (Day 6)

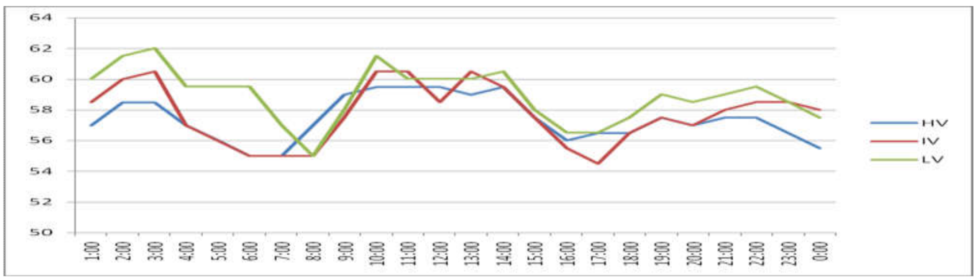

Fig. 24 Waveforms of temperatures of winding insulation (Day 7)

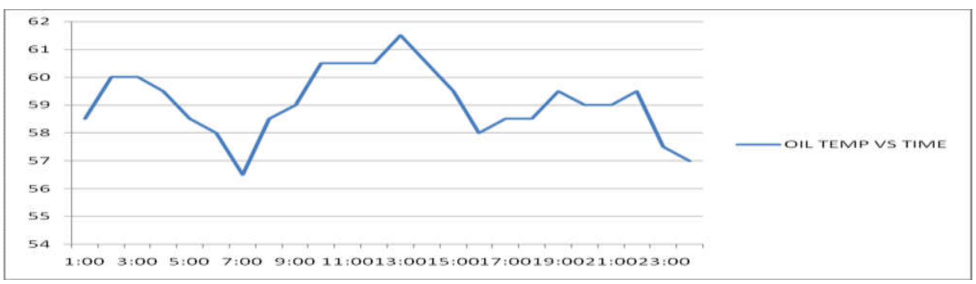

Fig. 25 Waveform of temperature of oil (Day 7)

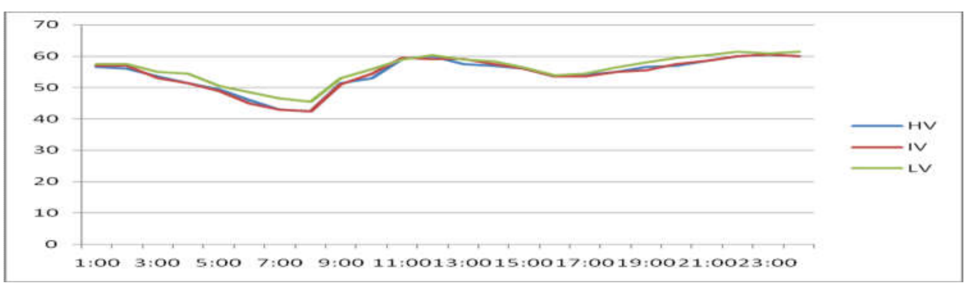

Fig. 26 Waveforms of temperatures of winding insulation (Day 8)

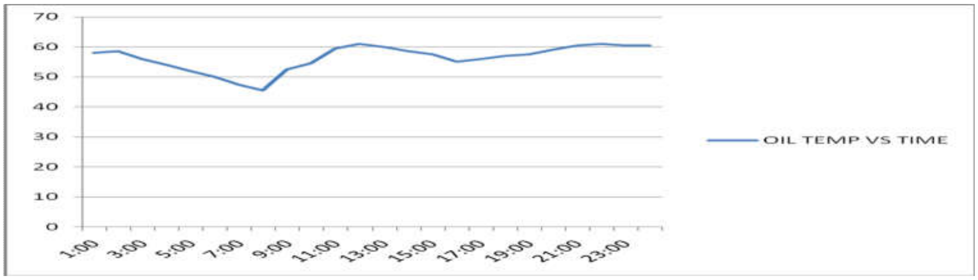

Fig.27 Waveform of temperature of oil (Day 8)

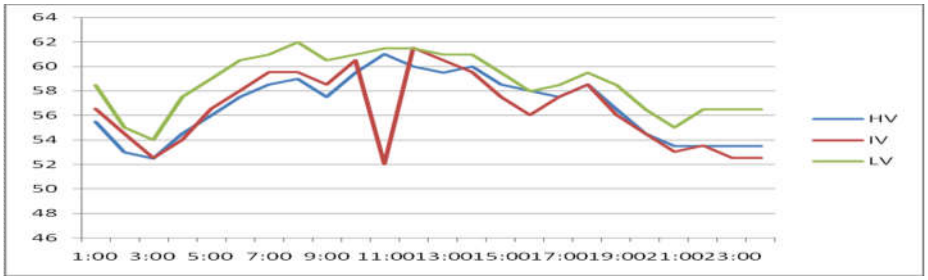

Fig. 28 Waveforms of temperatures of winding insulation (Day 9)

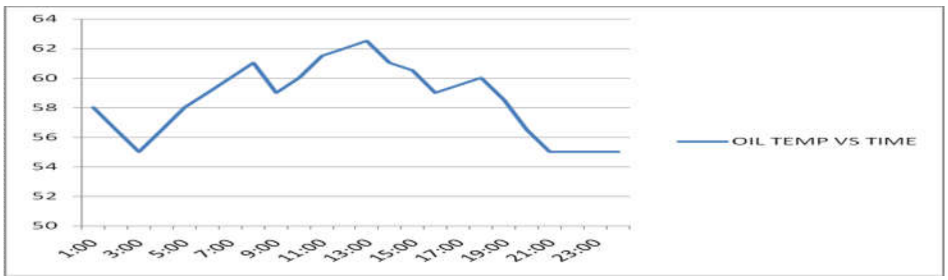

Fig. 29 Waveform of temperature of oil (Day 9)

In order to ascertain the condition of the power transformer, the power transformer parameters in terms of line currents are shown graphically with x-axis in hours and y-axis in amperes from Fig. 30 to Fig.32.

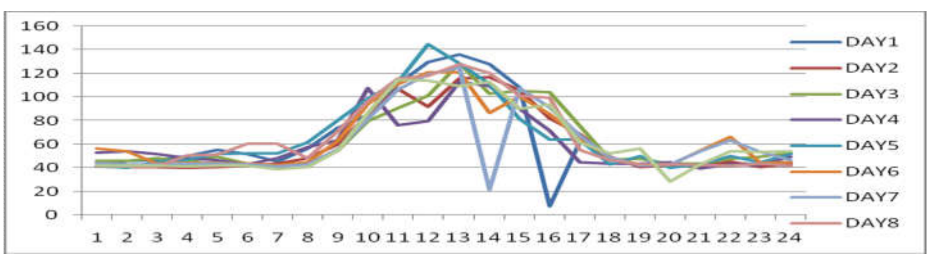

Fig. 30 Waveform of line current I_B (amp) of transformer from day 1 to day 9

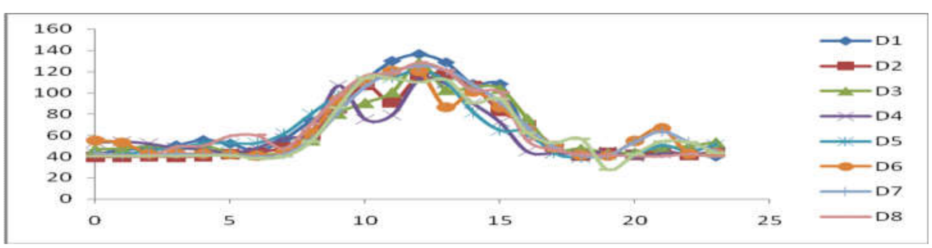

Fig..31 Waveform of line current I_R (amp) of transformer from day 1 to day 9

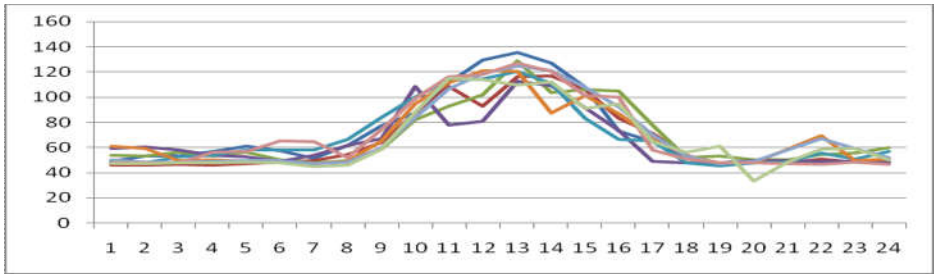

Fig. 32 Waveform of line current I_Y (amp) of transformer from day 1 to day 9

In order to ascertain the condition of the power transformer, the power transformer parameters in terms of line voltage are shown graphically with x-axis in hours and y-axis in volts from Fig. 33 to Fig.35.

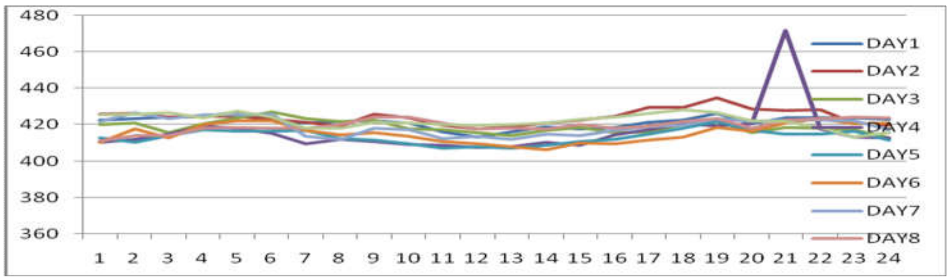

Fig. 33 Waveform of line voltage V_{RY} (volt) of transformer from day 1 to day 9

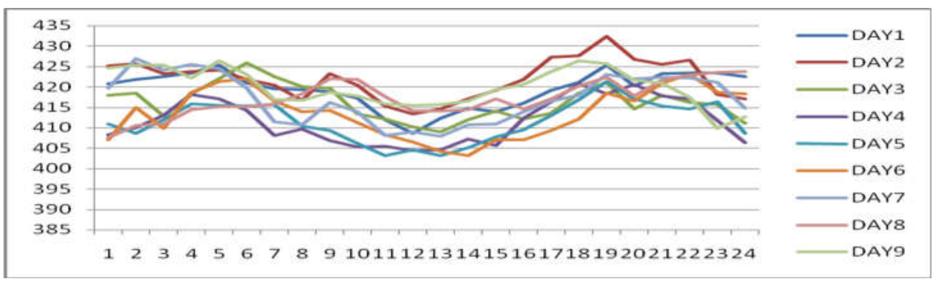

Fig. 34 Waveform of line voltage V_{YB} (volt) of transformer from day 1 to day 9

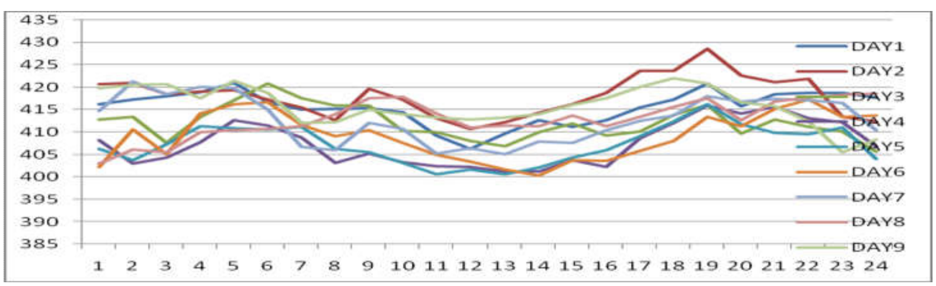

Fig. 35 Waveform of line voltage V_{BR} (volt) of transformer from day 1 to day 9

These graphs show the data of winding temperatures (HV, IV and LV) and oil temperatures. They have been recorded on hourly basis for 24 hours per day in order to have understanding of how temperatures of solid and oil insulation changes from day to day. These values are sensed by microcontroller at sending end and sent by GPRS from sending end to receiving end. These values are received by GPRS system at receiving end and passed to microcontroller at receiving end and in turn connected to personnel computer at receiving end. In personal computer by using MATLAB, abnormalities can be identified by using signal processing tool such as Wavelet transforms.

Similarly graphs are shown in Fig. 30 to Fig. 32 gives the details of I_B, I_R and I_Y and which have been recorded for consecutive nine days on hourly basis. The corresponding values of V_{RY}, V_{YB} and V_{BR} and corresponding graphs are shown Fig.33 to Fig. 35 respectively.

While collecting the data through GPRS, it is observed that the corresponding waveforms of temperature of the winding, oil, voltage, current shows indication of incipient faults .Therefore it is required to analyses the data by using signal processing tool such as wavelet transforms which identifies the hidden information in terms of any abnormalities. This information is quite useful in assessing the condition of the transformer.

5. Conclusion

Digital monitoring cum control of transformer is successfully designed and developed for implementation of transformer. The proposed prototype module effectively monitored and controlled when ever over load condition or over temperatures prevail on the single phase transformer. PIC 16F876A is selected, which avoids external devices like multiple channels ADC and clock signal generator. The developed proto type model is best suited to interface with the GPRS system to transmit the monitored parameters for further better analysis.

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