Design and Implementation of High Precision Automated Online Monitoring of Distribution Transformer (OMDT) Device

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ABSTRACT: This paper presents a system which works on a wireless, real time, multi object monitoring system of distribution transformer. The device is known as OMDT (Online Monitoring of Distribution Transformer) device. A design based PIC (16f877A) microcontroller is developed for monitoring the key parameters of distribution transformer. An algorithm for monitoring the voltage, current, temperature, oil level, power factor and frequency is developed and programmed to the microcontroller. The system can be installed at the distribution transformer and by measuring above parameters, it will help the utilities to optimally utilize the transformers and identify problems before any catastrophic failure

Keywords: Distribution Transformer, Microcontroller, catastrophic failure

I. INTRODUCTION

In recent years, increased emphasis has been placed on power reliability and economy. In particular, major changes in the utility industry have caused increased interest in more economical and reliable methods to generate and transmit and distribute electric power. In this regard monitoring the health of equipment constituting the system is critical to assure that the supply of power can meet the demand [1]. Distribution Transformer is critical equipment in power system, so it is necessary to ensure its safe and stable operation. Therefore, monitoring of key parameters are necessary for evaluating the performance of the distribution transformer and also helpful to avoid or reduce disruption due to sudden unexpected failure. "Monitoring" is here defined as online collection of data and includes sensor development, measurement techniques for online applications [3].

The present method for monitoring of distribution transformer has the following drawbacks
a) Operation in case of equipment failure are done manual
b) Time consuming
c) Demand a lot of labour work
d) Production process also gets affected at the outmost [2].
The reliable operation of distribution networks can be improved by implementing centralized monitoring. Centralized monitoring realizes the overwhelming advantage of wireless communicating technology such as convenient, fast and low transmission cost [4].

II. TRANSFORMER FAULT ANALYSIS

A transformer consists of a set of windings around a magnetic core. The windings are insulated from each other and the core. Operational stresses can cause failure of the transformer winding, insulation, and core. The transformer windings and magnetic core are subject to a number of different forces during operation. Transformer faults such as over load, over temperature, oil level fault etc. produce physical forces that cause insulation wear. These effects are cumulative and should be considered over the life of the transformer.

A. Over Load

Over current is the current flowing through the transformer resulting from faults on the power system. Fault currents that do not include ground are generally in excess of four times full load current fault currents, that include ground can be below the full-load current depending on the system grounding method. Over current conditions are typically short in duration (less than two seconds) because protection relays usually operate to isolate the faults from the power system.

B. Over Temperature

Excessive load current alone may not result in damage to the transformer if the absolute temperature of the windings and transformer oil remains within specified limits. Transformer ratings are based on a 24hour average ambient temperature of 30°C (86°F). Due to over voltage and over current, temperature of oil increases which causes failure of insulation of transformer winding

C. Oil Level Fault

Oil mainly used in transformer for two purposes one is for cooling of transformer and another use is for insulation purpose. When temperature of transformer goes high, oil level in transformer tank decreases due to heating effect. For normal operation of transformer oil level should maintain at required level. If oil level decreases beyond required level, it affect cooling and insulation of the transformer.

III. BLOCK DIAGRAM

The proposed system is based on microcontroller (PIC) that monitors the voltage, current, frequency, power factor, temperature and oil level of a distribution transformer. The device is fixed on the secondary of the distribution transformer and the monitored output will be display on a LCD on the device and at the same time it is send to the monitoring station through wireless communication. The monitored output values are compared with the rated values of the transformer and the microcontroller is programmed in such a way that if the monitored values are exceeds a certain set value then the relay become active and cut the supply and thereby allows the transformer to free from faults such as over loading. Also at the time fault occurs it shows a warning message on the monitoring station. The microcontroller continuously scans the transformer and updates the parameters in the monitoring station.

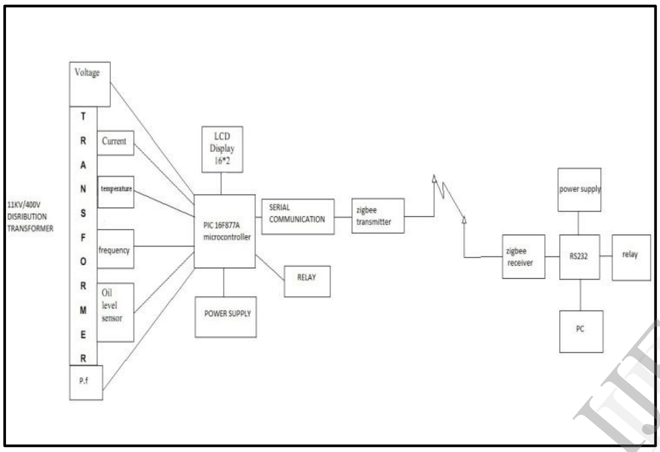

Fig.1. Block Diagram

A. Voltage Monitoring

The main feature of the voltage monitoring ensures rated consumer voltage by providing proper communication with the control station. During the line to earth fault, as per the existing distribution line protection system the fault current flows through the faulty area and distribution side protection fuses gets tripped depending upon the rate of fault current. During line to earth fault the voltage reduces from its rated value. The threshold value of voltage stored at the Microcontroller instantly acts for the Relay cutoff and avoids electric shock hazards. Thus the corresponding phase will get disconnected and provides efficient protection instantly

B. Current Monitoring:

The current monitoring aims for the protection of consumers and distribution transformer from fault current and avoid electrical shock hazards. When the fault occurs at the distribution line, the fault current flows through the distribution line and the fuses connected to the distribution lines get cut-off. If the fuse wires are not connected upon the current rating standards that is with the increased thickness it will take some more time to get cut-off during the occurrence of fault or overloading. Thus for efficient operation of transformer the secondary rated current is set as the maximum threshold value of current at the microcontroller of the Online Monitoring Device and above which results in the supply to cut off.

C. Power Factor Monitoring

The PF can be thought of as a measure of electrical efficiency in a power system. Utilities have several different rate structures that may be used for billing.

kVA Billing – straight charges for all apparent power consumed.

kVAr Billing – additional charges for reactive power.

Power Factor Penalty – charges based on the customer's actual power factor.

Adjusted kW Demand – the real power demands is adjusted by a formula and is based on the customer's actual power factor.

Therefore in all cases, the power factor of a customer will become a direct or indirect factor in the utility bill.The online monitoring of power factor provides a gate way for power factor correction in Distribution System. Capacitor banks or step up boosters can be used for power factor correction. Thus by improving power factor the benefits such as improved voltage levels, reduced line losses etc. can be achieved.

D. Frequency Monitoring

Frequency is an important parameter of distribution line parameters.At lower frequencies, the magnetizing currents to transformers and motors will increase as their inductive impedances fall (2.pi.f.L). The excitation currents to synchronous machines have to be increased to maintain voltage levels. These increases would ultimately result in overheating of the machines. So Online Monitoring device provides efficient monitoring of frequency by limiting the supply, if the frequencies are not in the safe limit.

E. Oil level Monitoring

Transformer windings are insulated with cellulose and surrounded by oil to ensure proper insulation and cooling. Poor oil level can lead to a low dielectric strength and even to a system failure. For normal operation the oil level should maintained at a particular level failing which causes damage to the winding. So it is necessary to monitor the oil level of transformer and if it is not in the appropriate level the device will cut off the supply from transformer.

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F. Temperature Monitoring

For proper operation of transformer the temperature should be within the maximum allowable value. During a fault, the current may increase and hence, the temperature also, and may leads to the formation of bubbles in the oil. These bubbles will trap between the windings and results in spark between the windings. So it is important to monitor the temperature of the transformer to ensure safe operation.

IV. COMPONENTS

A. PIC Microcontroller

PIC16F877A is a small piece of semiconductor integrated circuits. PIC16F877A IC can be reprogrammed and erased up to 10,000 times. Therefore it is very good for new product development phase. It is very popular because PIC 16F877A is very cheap and it is also very easy to be assembled.

B. Current Transformer

Instrument transformers are used for measuring current in electrical power systems and for power system protection and control. A current transformer isolates the measuring instruments from what may be very high voltage in the monitored circuit.

C. Temperature Sensor

The LM35 series are precision integrated circuit temperature sensors, whose output voltage is linearly proportional to the temperature. The LM35 thus has an advantage over linear temperature sensors calibrated in Kelvin, as the user is not required to subtract a large constant voltage from its output to obtain convenient centigrade scaling.
Features of LM35

- Calibrated directly in ºCelsius
- Linear +10 mv/ºC scale factor
- Operates from 4 to 30 V
- Low self-heat heating

D. Zigbee

Zigbee is a specification for a suite of high level communication protocols used to create personal area networks built from small, low-power digital radios. Zigbee is based on an IEEE 802.15 standard.Zigbee networks are secured by 128 bit symmetric encryption keys.

E. LCD

LCD (Liquid Crystal Display) screen is an electronic display module and find a wide range of applications. A 16x2 LCD display is very basic module and is very commonly used in various devices and circuits. These modules are preferred over seven segments and other multi segment LEDs.

F. MAX 232

The MAX232 is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. Each receiver converts EIA-232 inputs to 5-V TTL/CMOS levels.

V. WORKING

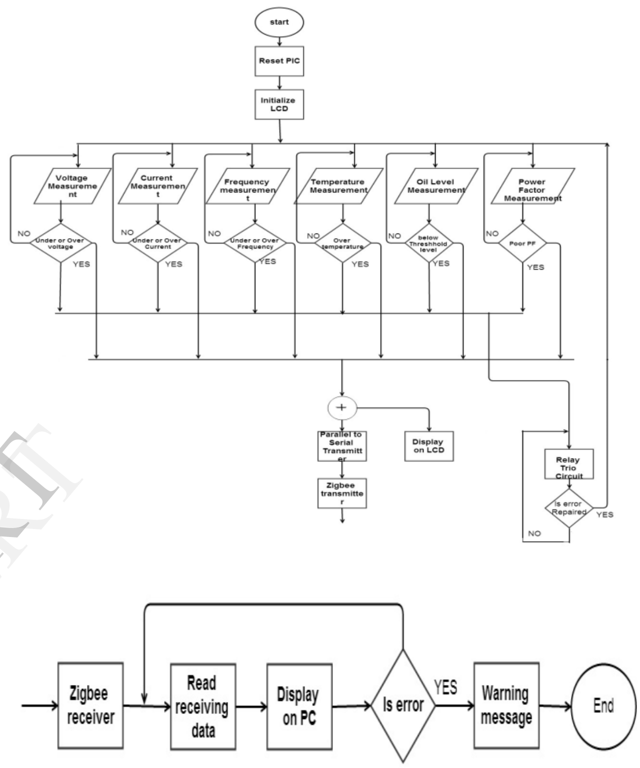


Fig.2. Flow Chart of OMDT

The circuit is divided in to different parts such as input section, control section, transmitting section and receiver section. The input section consists of distribution transformer, current transformer, relay, transistor, rectifier circuit, filter circuit etc. The control section consistsof PIC microcontroller which is the main part of the circuit powered by a 5V external dc supply. The parameters which are to be measure or monitor is given to the various pins of microcontroller that is, the inputs to the controller are currenttransformer output, the rectified and filtered output from the secondary of the distribution transformer and also the outputs of temperature sensor and oil level sensor. The measured values are displayed on a LCD fixed in the transformer side and also at the same time the values are given to the transmitting section which consists of a zigbee module. Also one pin of the controller is used to turn on and off the relay. The receiver section consists of azigbee receiver, RS 232 etc.

Since the input voltage to the microcontroller is 5V the voltage in the secondary of the distribution transformer is step down and rectified by a voltage transformer and it is measure by the controller. Similarly the current is measured with the help of current transformer .The output voltage of the temperature sensor and oil sensor varies with their corresponding changes in the temperature and oil level. All these inputs are given to the controller through analog channels which is then converted in to digital and then measured. The measured values are send to the LCD and also to the zigbeetransmitter and are received by the zigbee receiver and displayed on a user interface screen created usingvisual basic. During the continuous monitoring process, if the parameter values are not in the specified limits due to any faults such as overloading, then the controller will send a pulse to the base of the relay driving transistor. As a result the relay cut off the supply from transformer and at the same time a warning message will appears in the monitoring station thereby ensure that transformer is safe.

VI. SIMULATIONMODEL AND RESULTS

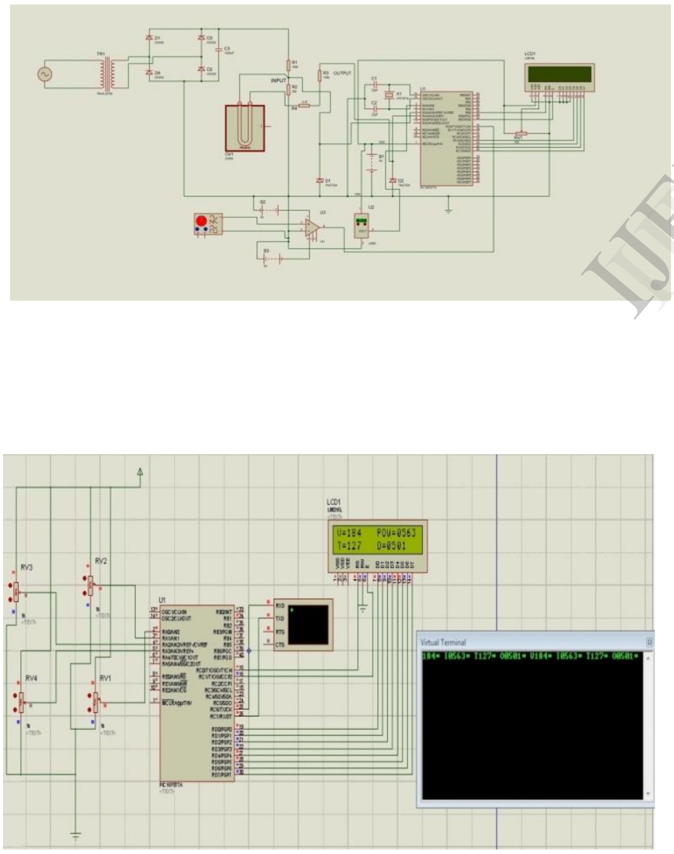
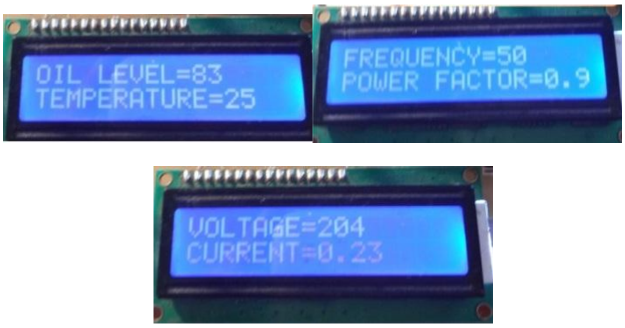


Fig.3. Simulation Circuits

The simulation circuits are divided in to two. In the first part the various parameters are measured and displayed simultaneously in the 16*2 LCD. The voltage is stepped down and found by the voltage division principle and similarly the current also. To measure large current, an impedance coil is fed as load. The frequency is made variable by feeding it from signal generator. The variation in quantities is achieved by varying the settings in the simulator platform. In Proteus designer software, there is no facility to design a wireless communication and hence the second simulation circuit is used. Serial transmission is used to transmit the measured details in a particular pattern. V<value> * I<value> * T<value> * O<value> **



VII. PROTOTYPE MODEL AND TESTING

Fig.4. OMDT device

The prototype model of microcontroller based Distribution transformer monitoring system can be done for each distribution transformer in a particular zone and the input data to the PIC microcontroller can be transmitted to the PC using wireless communication technology. The program for microcontroller is done using mplab in C. For testing purpose instead of oil level sensor we are using a potentiometer and fictitious loads are used for current measuring. Usually frequency and power factor has no considerable amount of change and hence they are not compared in this model and only voltage, current, oil level and temperature are compared with in the set values. By varying the voltage across the potentiometer, different levels can be indicated which indirectly implies the oil level. By varying each parameter within and out of the set values the proper working of device is ensured.

TABLE I. TEST RESULTS

Voltage	Current	Temperature	Oil level	Relay status	Lamp status
204	0.23	24	86	OPEN	ON
285	0	27	75	CLOSED	OFF
230	0.7	30	60	OPEN	ON
237	0	47	67	CLOSED	OFF
220	0	27	25	CLOSED	OFF
225	0	48	24	CLOSED	OFF
220	0.7	28	48	OPEN	ON

VIII. CONCLUSION

The OMDT device, used to protect the distribution transformer is setup and successfully tested in the lab. For the designed system, it is observed that the supply is interrupted for the following conditions. Voltage greater than 280V and less than 160V, current greater than 7A, oil level below 30 and temperature above 45̊C. By taking the advantage of transducers, we can install the system in the distribution transformer, so as to increase the health of transformer.

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