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Transformer Health Condition Monitoring Through GSM Technology

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Abstract—. Transformers are a vital part of the transmission and distribution system. Monitoring transformers for problems before they occur can prevent faults that are costly to repair and result in a loss of service. Current systems can provide information about the state of a transformer, but are either offline or very expensive to implement. Transformers being the essential part of power transmission system are expensive, as is the cost of power interruptions. Because of the cost of scheduled and unscheduled maintenance, especially at remote sites, the utility industry has begun investing in instrumentation and monitoring of transformer. On-line transformer diagnostics using conventional technologies like carrier power line communication, Radio frequency based control system, and Supervisory control and data acquiring systems, Distributed control systems and Internet based communications are having their own limitations. GSM is an open, digital cellular technology used for transmitting mobile voice and data services.

This project objective is to develop low cost solution for monitoring health condition of remotely located distribution transformers using GSM technology to preent premature failure of distribution transformers and improving reliability of services to the customers. An Embedded based hardware design is developed to acquire data from electrical sensing system. It consists of a sensing system, signal conditioning electronic circuits, advanced embedded hardware for middle level computing, a powerful computer network for further transmission of data to various places. A powerful GSM networking is designed to send data from a network to other network for proper corrective action at the earliest. Any change in parameters of transmission is sensed to protect the entire transmission and distribution. The performance of prototype model developed is tested at laboratory for monitoring various parameters like transformer over load, voltage fluctuations, over temperature, oil quality and level etc.

Index Terms. Power system faults, transformer health monitoring, GSM technology, micro controller

1 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. As has been seen recently in northern grid failure on 30th and 31st July 2012 due to inefficient load management functions lead to wider blackout, leaving almost 700 million people without electricity in six northern states of our country.

The main concern with transformer protection is protecting the transformer against internal faults and ensuring security of the protection scheme for external faults[2]. System conditions that indirectly affect transformers often receive less emphasis when transformer protection is specified. Overloading power transformers beyond the nameplate rating can cause a rise in temperature of both transformer oil and windings. If the winding temperature rise exceeds the transformer limits, the insulation will deteriorate and may fail prematurely. Prolonged thermal heating weakens the insulation over time, resulting in accelerated transformer loss-of-life. Power system faults external to the transformer zone can cause high levels of current flowing through the transformer. Through-fault currents create forces within the transformer that can eventually weaken the winding integrity. A comprehensive transformer protection scheme needs to include protection against transformer overload, through-fault, and over excitation, as well as protection for internal faults.

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This paper focuses on liquid-immersed transformers because the majority of medium and high-voltage transformers are of this type.Transformer fault analysis is discussed in section-II, while section III describes about designing of microcontroller for monitoring of transformer health. The prototype model development is discussed in section IV. While programme execution and testing is discussed in section V.

2 TRANSFORMER FAULT ANLYIS

A power 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 power transformer windings and magnetic core are subject to a number of different forces during operation:[3]

1. Expansion and contraction caused by thermal cycling
2. Vibration caused by flux in the core changing direction
3. Localized heating caused by eddy currents in parts of the winding, induced by magnetic flux
4. Impact forces caused by fault currents.
5. Thermal heating caused by overloading.

These operating limits only considered the thermal effects of transformer overload. Later, the capability limit was changed to include the mechanical effect of higher fault currents through the transformer. Power transformer faults produce physical forces that cause insulation wear. These effects are cumulative and should be considered over the life of the transformer.[2]. The following discussion highlights on different capability limits of transformer

2.1 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. Overload, by contrast, is current drawn by load, a load current in excess of the transformer name-plate rating. In summary, loading large power transformers beyond nameplate ratings can result in reduced dielectric integrity, thermal runaway condition (extreme case) of the contacts of the tap changer, and reduced mechanical strength in insulation of conductors and the transformer structure. Three factors, namely water, oxygen, and heat, determine the insulation life of a transformer. Filters and other oil preservation systems control the water and oxygen content in the insulation, but heat is essentially a function of the ambient temperature and the load current. Current increases the hottest-spot temperature (and the oil temperature), and thereby decreases the insulation life span.[2]

2.2 Over Temeperature

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 24-hour average ambient temperature of 30°C (86°F). Due to over voltage and over current, temp. of oil increases which causes failure of insulation of transformer winding.[2]

2.3 Over Excitation

The flux in the transformer core is directly proportional to the applied voltage and inversely proportional to the frequency. Over excitation can occur when the per-unit ratio of voltage to frequency (Volts/Hz) exceeds 1.05 p.u. at full load and 1.10 p.u. at no load. An increase in transformer terminal voltage or a decrease in frequency will result in an increase in the flux. Over excitation results in excess flux, which causes transformer heating and increases exciting current, noise, and vibration.[2]

2.4 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.

3 DESIGN OF MICROCONTROLLER BASED TRANSFORMER HEALTH CONDITION MONITORING KIT

fig.1. It consist of current transformer, power transformer, thermister, oil sensor, micro-controller (89S51), converter (ADC0808), LCD display, GSM modem and relay. Normally in transformer, failure occurs due to voltage and current fluctuation, overheating, change in oil level etc. In this project, to sense these fault we have used current and power transformer, temperature sensor, oil sensor respectively.

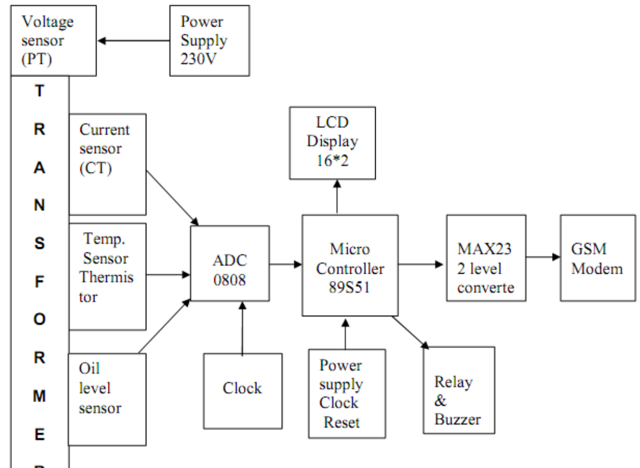

Fig.1 Block Diagram

Fig.1. Basic block diagram.

All these sensors are connected to converter (ADC0808) and digital output from converter is given to micro-controller 89S51. MC89S51 has four ports viz. P1, P2, P3 and P0 to which we will be connected to address lines, GSM model and LCD respectively. When fault occurs due to above any reason then change in ratings will be shown on LCD and quick SMS will go to control room via GSM modem. A brief discussion about components used is as given below

Sensors play a vital role in effective implementation of the project. As we are interested in monitoring over current , over temperature and oil level following sensors are selected and suitable designed with respect to prevailing conditions of power system and rating of transformer to be protected.

3.1.Current and Voltage Transformer

Current or voltage instrument transformer are necessary for isolating the protection & control. The behavior of current and voltage transformer during and after the occurrence of fault is critical in electrical protection since error in signal from transformer can cause mal operation of the relays.

3.2. Thermistor

Thermistors are special solid temperature sensors that behave like temperature-sensitive electrical resistors. No surprise then that their name is a contraction of "thermal" and "resistor". There are basically two broad types, NTC-Negative Temperature used mostly in temperature sensing and PTC-Positive Temperature Coefficient, used mostly in electric current control.

Features :

• Low cost solid state sensor • Standard resistance tolerances down to ±2% • High sensitivity to changes in temperature• Suitable for temperature measurement, control and compensation • Excellent mechanical strength.

3.3 Oil Level Sensor

Oil level sensor is float connected angular potentiometer. Float is immersed in oil and its mechanical output is given to angular potentiometer. When there is any mechanical movement of float, there is voltage generation corresponding to mechanical movement of float. That voltage is used for oil level monitoring.

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3. 4. Analog to Digital Converter

The heart of this single chip data acquisition system is its 8-bit analog-to-digital converter. The pin diagram and block diagram of ADC 0808 is s as shown in fig.2 and 3 respectively[4]. The converter is designed to give fast, accurate, and repeatable conversions over a wide range of temperatures. The converter is partitioned into 3 major sections: the 256R ladder network, the successive approximation register, and the comparator. The converter's digital outputs are positive true.

The ADC0808, ADC0809 offers high speed, high accuracy, minimal temperature dependence, excellent long-term accuracy and repeatability, and consumes minimal power[6].

Features :

1. Easy interface to all microprocessors operates ratio metrically or with 5 VDC or analog span adjusted voltage reference;
2. No zero or full-scale adjust required 8-channel multiplexer with address logic.

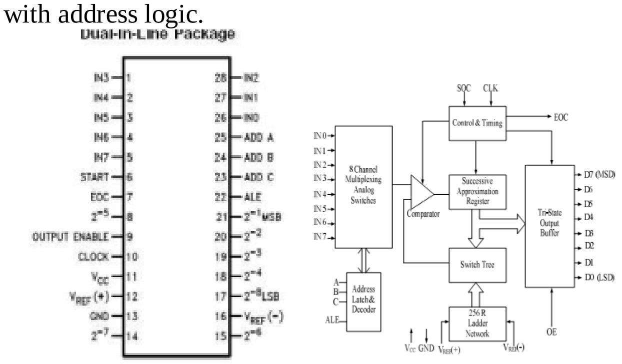

Fig. 2Pin and block diagram of ADC0808

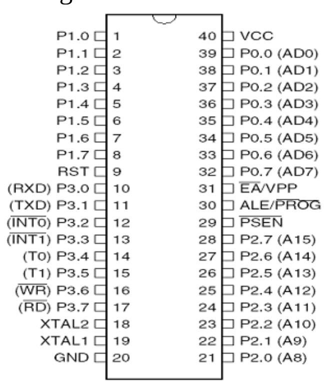

Fig.3.Pin diagram of AT89S51 μ Controller

3.5. Micro Controller

In this project a low power, high performance8 bit microcontroller (AT 89S51) is used. The pin diagram of AT89S51 is as shown in fig.3. The AT89S51[5] is a low-power, high-performance CMOS 8-bit μC with 4K bytes of In System Programmable Flash memory. The on-chip Flash allows the program memory to be reprogrammed in-system or by a conventional nonvolatile memory programmer. It has following features:

• Compatible with MCS®-51 Products
• K Bytes of In-System Programmable (ISP) Flash Memory
• 4.0V to 5.5V Operating Range
• 128 x 8-bit Internal RAM
• 32 Programmable I/O Lines
• Dual Data Pointer

3.6. GSM Modem

A GSM modem is a specialized type of modem which accepts a SIM card, and operates over a subscription to a mobile operator, just like a mobile phone.

Fig.4. GSM Modem

We are using the FARGO MAESTRO 20 GSM as shown in fig.4. This is a powerful GSM/GPRS Terminal with compact and self-contained unit. This has standard connector interfaces and has an integral SIM card reader. The modem has a DB9 connector through which a speaker and microphone can be connected allowing audio calls being established, but this feature is not utilized in this project as only data transfer is needed.

Features & Specification

• Cellular frequency 900/1800MHz
• Easy to use
• Serial port DB9 connector
• Antenna length is 120mm

3.7. MAX 232

The MAX232 device is a dual driver/receiver that includes a capacitive voltage generator to supply EIA-232 voltage levels from a single 5-V supply. The MAX232 was the first IC which in one package contains the necessary drivers (two) and receivers (also two), to adapt the RS-232 signal voltage levels to TTL logic. It became popular, because it just needs one voltage (+5V) and generates the necessary RS-232 voltage levels (approx. -10V and +10V) internally. This greatly simplified the design of circuitry. The pin configuration of MAX 232 is as shown in fig.5.

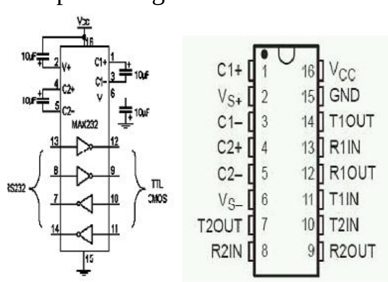

Fig.5. Pin configuration of MAX 232

It has features like operating from a Single 5-V Power Supply, operates up to 120 kbit/s Two Drivers and Two Receivers 30-V Input Levels Low Supply Current 8 mA Typical..

4. PROTOTYPE MODEL DEVELOPMENT

As shown in the fig.6 microcontroller 89S51 is the main controlling element to which PT on input side, CT on load side, thermister and float sensor are connected. These four sensors are

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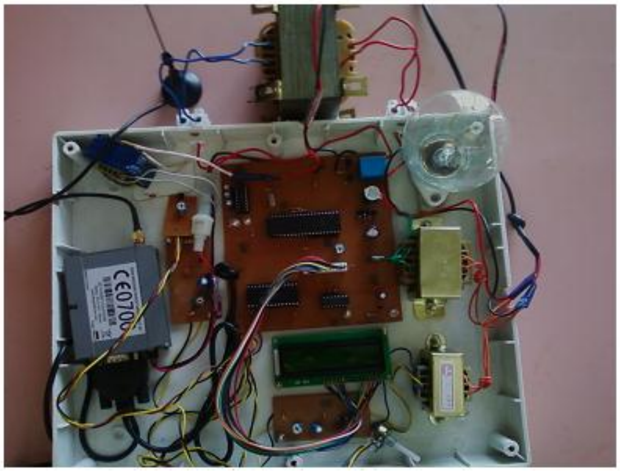

Fig.6. Prototype model of microcontroller based transformer health condition monitoring kit.

used to monitoring transformer parameters (voltage, current, temperature & oil level) Initially input from mains lines to load is monitored by CT current transformer. This CT gives the current level based on load used by costumer. Output of the CT is current and ac which is rectified and made voltage by signal conditioner circuit consisting of 10 ohm resistor; diode and capacitor. The output of the CT is fed to the ADC0808 for converting analog voltage to digital voltage. ADC0808 does conversion of analog signal into digital by successive approximation method and with the help of clock pulses, which is generated by NOT gate IC, this NOT gate produces 50kHz clock and give it to ADC. The output of the ADC is 8 bit which is fed to the microprocessor for further processing of the data. When power supply is switched on, microcontroller starts program execution from zero memory location. The microcontroller has four input parts, which are contains 8 lines for input or output. In our project 4 lines of microcontroller are used for giving address selection input and ALE signal to ADC for selecting sensor line, after this microcontroller receives 8 bit output from ADC. This output is digital equivalent of power consumption. Microcontroller gets another I/p from maximum limit setting switches, which are connected on pin 10,11,12,13. This gives maximum limit of power which consumer can use during peak time. The peak time pulse are received from real time clock, which is connected on pin no 16&17.This all information is displayed on LCD which is connected on pin 32 to40.The functions of microcontroller is continuously check power consumption of customer by means of CT, ADC and get digital I/p. This I/p is compare with maximum limit setting. Display both those data on LCD. If the I/p ie power consumption exceeds the maximum limit then initially an alarm is sent telling consumer to reduce power consumption. This alarm is given by microcontroller through pin 14, and a transistor amplifier giving signal to a buzzer. After some time delay, microcontroller again check power consumption by customer, if it decreases then alarm stops or else microcontroller gives another trigger signal on pin 15, which signal is amplified by transistor & fed to relay. This relay switches off the supply to consumer for predetermined time limit. After this time limit completion again the supply resumes to consumer & microcontroller check the power consumption again. If consumer exceeds his maximum limit setting again then he gets alarm & cycle is continuous.

5. PROGRAM EXECUTION AND TESTING

The project is based on microcontroller programming. The program for microcontroller in embedded C language. program written burned into microcontroller and saved as Hex file. For AT89S51 controller Atmel programmer is used. Program hex file is compiled in µcontroller flash compiler. This compiler converts program into machine language code as well as check program for error if any error found notifies and these errors are corrected manually. Then it successfully executed in compiler. After compiling program in µcontroller flash compiler, it is burned into AT89S51 microcontroller with the help of universal program burner kit FP8903 programmer which is connected to computer. After successful program burning, microcontroller becomes ready for use.

In testing, after successful program burning, microcontroller is mounted on its base and kit becomes ready for testing. For testing In program kit has provided with following four parameter of transformer:

1. 180 >Voltage > 260 -- Voltage Fault
2. Temperature > 40^0C--- Temperature fault
3. Power > 125W -- Over load
4. Oil level < 10 ml --- Oil level fault

Therefore any change occurred in above rating during running of project model, these changes is shown in LCD and same data obtained in SMS and at the same time transformer gets disconnected from supply with the help of relay. Results obtained during testing as per given input and fault conditions on LCD are as follows:

6. CONCLUSION

Transformers are among the most generic and expensive piece of equipment of the transmission and distribution system. Regular monitoring health condition of transformer not only is economical also adds to increased reliability. In the past, maintenance of transformers was done based on a pre-determined schedule. With the advancement of communication technology now it is possible to receive fault information of transformer through GSM technology remotely to the operator and authorities so one can able to take possible solution before converting fault in to fatal situation. Depending upon fault analysis a prototype model of microcontroller based transformer health monitoring kit is developed in laboratory. Using digital controller analysis results are regularly updated. During abnormal conditions exceeding specified limits information is immediately communicated through GSM technology to the operator and also to concerned authority for possible remedial action. This type of remote observation of health condition of transformer not only increases the life of transformer increases mean down time of transformer there by increased reliability and decreased cost of power system operations.

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