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A Prototype for Fault Analysis and Protection System of Distribution Transformer

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ABSTRACT: An innovative PIC based system is designed to monitor the current and temperature of a distribution transformer. Protection to the transformer is provided by shutting down the entire system using relay in case of fault currents and high temperatures. RF communication is used for remote monitoring of the above mentioned parameters of the transformer and relay circuitry is used to remotely shut down the entire transformer system. The communication system usually consists of two units, one is a transmitter and a display unit and the other is the receiving unit which is usually installed in a control room with a computer. The parameters are monitored continuously and whenever a fault such as open or short circuit, over temperature is detected, the microcontroller sends a signal to the relay circuitry to disconnect the incoming supply to the transformer. Whenever a fault occurs and the system is shut down, the transformer can be tested by using two simple methods- a) Voltage transformer ratio test and b) Step-up voltage ratio test. This is a low cost prototype for fault analysis with a quick response and high efficiency.

KEYWORDS: Microcontroller, Relays, Distribution transformer, RF transmission, Current sensor, Temperature sensor.

I.INTRODUCTION

Most of the utility customers are connected to a distribution transformer which steps down the voltage of the power lines. The most common faults occurring in a distribution transformer are- a) Over current fault due to over loads and external short circuits, b) Terminal faults, c) Winding faults and d) Incipient faults. This system deals with the short circuit faults and the rising of the temperature of the distribution transformer to excessive levels. The current and the temperature of the transformer are continuously sent to the processor which in turn sends these values to the client through RF transmission. A relay circuitry is used for switching whenever the current exceeds a predefined value. This system can help the utilities to optimally utilize the transformers. Whenever a fault is detected, the relay circuitry disconnects the transformer thus preventing it from failures. After a fault has occurred, the transformer can be tested to ensure that it is in good condition and not affected by the fault. Two simple methods can be used viz. voltage transformation ratio test and step up voltage ratio test. Both these tests are discussed in detail below. This system is relatively cheap and highly efficient for fault analysis as well as protection.

II.APPARATUS

1) Distribution Transformer: A three phase transformer is required. Instead, for this prototype, three single phase transformers are connected in Delta-Star and considered as a single three phase transformer. The primary winding is delta connected and the secondary winding is star connected. Polarity test of transformers is performed and the connections of the transformers are done accordingly. The transformers are of ROHITRA make, 230/15 V, 1 Ampere.

2) PIC 16F877A: The 16F877A is used to sense the conditions of the transformer and react as programmed.

3) Temperature sensor LM35: LM35 senses the temperature of the distribution transformer and sends the signal to the microcontroller. A threshold value is set with the microcontroller. If the value of the temperature sensed by the sensor exceeds the threshold value, the microcontroller sends a signal to the relay circuitry to shut down the supply to the transformer.

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4) Current sensor ACS709: ACS709, 37.5 amp senses the current at the output terminals and converts it to a corresponding voltage value (56mV per Ampere) to be sensed by the microcontroller. A threshold value is set and when the signal from the sensor exceeds the threshold value, the microcontroller sends a signal to the relay circuitry to disconnect the transformer from the supply.

5) Relay circuit: This circuit will trip and isolate the distribution transformer from the fault so as to prevent any sort of damage. This circuit basically works as a switching device to connect or disconnect the transformer as required. For this prototype, 3 relays are used working as a single relay circuitry.

6) LCD Display: LCD display is used to indicate the output of the different modules interfaced with the microcontroller. A 16*2 LCD by Optex Corporation is used.

7) RF module CC2550: A radio frequency wireless transmission and receiver module is used for the purpose of wireless data transmission from the microcontroller to a PC.

III.CONNECTIONS

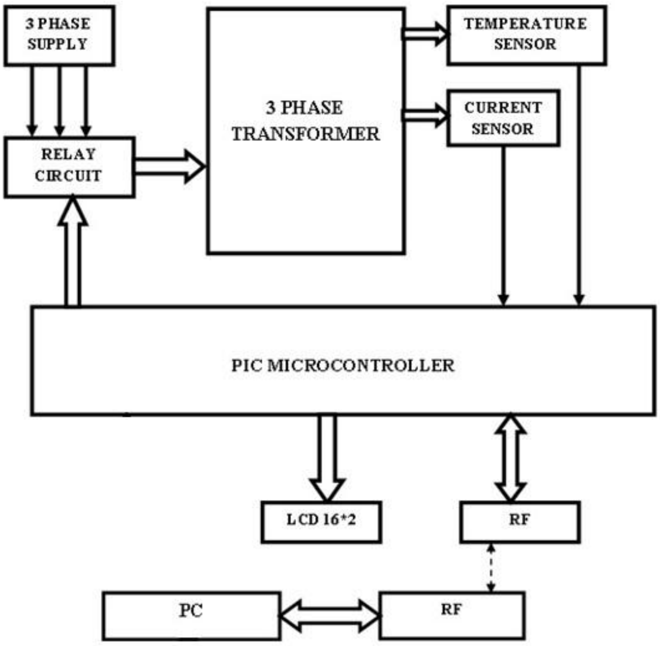

Fig. 1 Block Diagram of the fault analysis and protection system

Fig. 1 shows a block diagram of the connections in the fault analysis system. As shown in Fig 1, three phase supply is given to the transformer through a relay circuitry. The 3 phase supply is connected to the common of the relay and the NC of the relay is connected to the transformer primary. All the three phases have similar connections. The temperature sensor LM35 is placed in the vicinity of the distribution transformer to detect the temperature of the transformer. The V_{out} pin of the temperature sensor sends the signal to the microcontroller indicating the temperature. [5] For this prototype three temperature sensors are used and connected to pin 2(AN0), pin 3(AN1) and pin 4(AN3) of the microcontroller respectively. [1] The current sensor ACS709 is connected to the output of the transformer. Its pins IP+ and IP- are used to sense the current of the transformer. Its pin V_{IO} gives the corresponding output voltage and is connected to pin 5(AN3) of the microcontroller. [2][1] LCD display is interfaced with the PIC microcontroller to display the values of current and temperature on the LCD. [4] An RF transmitter module is interfaced with the microcontroller to send the data to the PC. A receiver module is connected to the PC through serial communication to receive the data sent by the RF transmitter. This receiver module is interfaced with the PC to display the parameters on the PC. The parameters are displayed on the PC using Visual Basics software. Wiegand protocol is used for serial communication.

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Since this is an interrupt based protocol, pin 33(INT0) and pin 37(INT1) of the PIC are connected to the RF transmission module. [1][3]

IV. METHODOLOGY AND OBSERVATIONS

For the purpose of testing the system, the transformer is connected to a short circuit connection through a 10 Ohm, 50W resistor and switches used for creating the fault across the resistor path. This acts as a path for the short circuit current. The output of this circuit is given to the current sensor through a bridge rectifier. The bridge rectifier is used to filter the output given to the current sensor. The current sensor senses the output and converts it to a corresponding voltage value and then feeds it to the ADC of the microcontroller. The microcontroller analyses this value and takes the necessary action. If a tripping command is needed, it is given to the relay circuitry in cases where the value received by the controller from the current sensor exceeds the limit. Once the circuit is tripped, the microcontroller is RESET after the fault is cleared. Depending upon the value received from the current sensor, the microcontroller distinguishes the fault as LG (Line to Ground) or LL (Line to Line) and displays on the LCD along with the RF transmission.

A short circuit between two lines and one line and ground is created across the resistor used for the prototype. The threshold values of the temperature and the voltage outputted by the current sensor are 50°C and 2.53V (at normal condition) respectively. The following table shows the observed values of fault current, voltage and its respective ADC count required by the microcontroller.

Condition	Fault Current	Output Voltage	ADC Count
Normal	0 A	2.53 V	-
LG Fault	0.71 A	2.57 V	526
LL Fault	1.25 A	2.60 V	532

Table 1 Readings of different faults on distribution transformer

The relay does not trip for the sensed temperature in this test as the temperature of the distribution transformer does not exceed 50°C. The relay trips when faults are deliberately created. When the switches are used to create_line to line or line to ground faults, the voltage obtained from the current sensor is sensed by the microcontroller through ADC. Since in this test this value of the voltage sensed by the controller exceeds the threshold value i.e. above 2.53V, the microcontroller sends a tripping signal to the relay circuitry which causes the relay to trip immediately. Thus the connection of the transformer from the supply is isolated and the transformer is prevented from any damage.

The RF transmission system is in place for remote monitoring of the transformers. The Wiegand protocol is a one way transmission protocol. Hence no supervisory action can be taken. But a signal can be generated by the controller to give to the PC indicating the occurrence of a fault. [3]

V.CALCULATIONS

$$\text{ADC Count} = (V/V_{ref})*1024 \quad (1)$$

Where,

V = Output Voltage

V_{ref} = Reference voltage to Current Sensor = 5V [2]

ADC being 10bit, 1024 is the multiplying factor [1]

VI.RESULTS

As per the connection diagram in Fig. 1, using the switching apparatus short circuit fault is created across the resistor. Once the fault is detected by the microcontroller, it successfully trips the Relay circuitry thus isolating the transformer. As observed from Table 1, when a fault is created between any line and ground, the fault current goes to 0.71A and

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between two lines it goes to 1.25A for the prototype. This states and proves that a Line-to-Line fault is severe as compared to Line-to Ground fault.

VII.DRAWBACK

A supervisory action from the control room is not possible because of the one way Wiegand protocol. [3] But a different protocol can be easily used which has two way communication for supervisory action. This system being a prototype only senses the current and the temperature. It fails to take into account other important things like the oil level in the transformer and other commonly occurring faults. This system is modular which means it can be easily expanded and modified to suit individual needs.

VIII.FUTURE PROSPECTS AND EXPANSION

Whenever an actual fault occurs, even if the system shuts down until the fault is cleared, until the transformer is closed, two important tests can be performed on the transformer. The first is the Voltage transformation ratio test. In this test RY, YB and RB are excited one by one using a generator and the voltages of RY, YB, RB- the primary side and ry, yb, rb- the secondary side of the transformer as well as rn, yn, bn of the secondary side are measured. Then by using the transformation ratio formula, the transformer is checked for its condition.

$$ry = (415/11000)*RY \qquad (2)$$

The second method is called as Step up voltage ratio test. In this method, single phase voltage is applied across phase and neutral bushing terminals of LV only at the time of measuring and reading.

The use of PIC microcontroller makes this system well known for the use in any industry. This system can also be expanded to analyse several transformers at once. Other sensors can also be added to make this system more comprehensive.

Since this system is very cheap and efficient, it has tremendous scope in the market. In every industry or a locality or even the utilities can find this system extremely useful and effective.

IX.CONCLUSION

A fast response to short circuit currents is observed for this system. The temperature sensor provides an additional protective layer to the transformer. Thus a cost effective and reliable system is developed for the fault analysis and protection of distribution transformer.

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