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An Efficient Phase Fault Monitoring System for Distribution Transformers

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Abstract: This paper present a system of monitoring the phase of distribution transformers to determine if the Johnson & Phillips (J&P) fuse is blown or not. Blown fuses are common with distribution transformers to protect the transformer itself from being faulty. When a phase is overloaded the fuse gives way to protect the transformer. However, this fault should be promptly reported and localized so that power can be quickly restored to the phase. It was against this backdrop that this system was developed. It checks the phase of the transformer, with particular reference to the fuse of each phase to determine whether it is open or closed. If the system detects a blown fuse, the PIC18F4585 microcontroller will activate the buzzer and the SIM900A GSM module, to send a pre-programmed message indicating the location of the fault to the utility provider. The state of the blown fuse detector circuit will also be displayed on the LCD. Thus reducing the downtime that is associated with such faults from the manual system of reporting currently practised in Nigeria. The circuit was constructed and tested by putting OFF the switch used to represent each phase of the distribution transformer feeder-pillar. When the switch was in the OFF state, the buzzer came up and an SMS was sent to the electricity distribution company to notify them of a failed phase in the distribution transformer feeder-pillar.
Keywords: Blown Fuse, Distribution Transformer, Feeder-pillar, GSM Module, LCD

1. Introduction

Uninterruptible power supply still remains a mirage in Nigeria. It is grossly inadequate for a population of over 190 million [1] to depend on less than 5000 Megawatt of electricity supply. Electricity from the national grid cannot provide the minimum acceptable international standards for electricity availability and stability [2]. Apart from inadequate generation, there are other issues that affects the availability of stable power supply in Nigeria, ranging from transmission line faults [3, 4] to faults in the distribution system [5, 6].

There are several types of faults in the distribution system. However, faults associated with the distribution transformer are a major source of downtime in power supply. Some of these faults are phase fault such as single phase to ground fault, two phase to ground fault, phase to phase fault, three phase fault [5, 7, 8]. In order to guarantee stable power supply, distribution transformer should be monitored continuously. Some of the parameters that can be monitored are load currents, under-voltage, overvoltage, oil level, oil aging, overload, frequency, winding temperature and ambient temperature [9, 10, 11].

Currently in Nigeria, distribution transformer monitoring system is done offline, mainly by inspection or by the residents in the area reporting a fault to the utility provider [12, 13, 14]. This often leads to power outage for a long time, since detection is not automated and response may be slow. However, with current technologies especially in the area of telecommunications, it is possible to monitor distribution transformers on real time basis using any of the available technologies, reporting incidences immediately and protecting the transformer from further damage. There are various types of technologies/systems used for online transformer diagnosis such as Supervisory control and data acquiring (SCADA) systems [14], Radio frequency (RF) based control system [11], Distributed control systems [15], Internet based communications [10, 11], WCDMA [16], GSM [9, 13], ZIGBEE [14, 17] and wireless sensor networks (WSN) [4].

Several works have been done in the area of monitoring distribution transformers for the purpose of increasing the lifespan of the transformer and ensuring stable power supply. One of such system is Desai and Hasabe where voltage, current and temperature sensors were installed on the distribution transformers to monitor the coresponding parameters. The system sends an SMS to a designated number if an abnormality is detected

[18]. Similar approach have been used by other authors [9, 10, 19]. Surekha et al. uses temperature sensor and viscosity module to measure the temperature and viscosity of transformer oil and report its status through SMS [20]. Omondi developed a system that monitors the current in the transformer and isolates it from the power system using a relay or contactor, if the current exceeds normal level [21].

In this paper, we present a means of detecting phase failure in a distribution transformer as a result of an open fuse. Fuses are used to protect the phases in distribution transformer to prevent overloading. If the load on a phase exceed the set limit, the fuse will blow to protect the transformer, knocking off consumers from the supply. A phase failure may result in overload on the remaining phases, further creating problem for the distribution transformer. This will lead to power outage for a while until the local residence makes a formal complain to the utility provider in most cases. However, with the system developed in this work, prompt reporting can be done through GSM technology indicating the location of the transformer and the phase that failed, so as to facilitate quick response from the electricity providers.

2. Materials and Methods

The block diagram of the system is shown in figure 1. It consists of the detector unit, processing unit, display/transmission unit and the power supply unit.

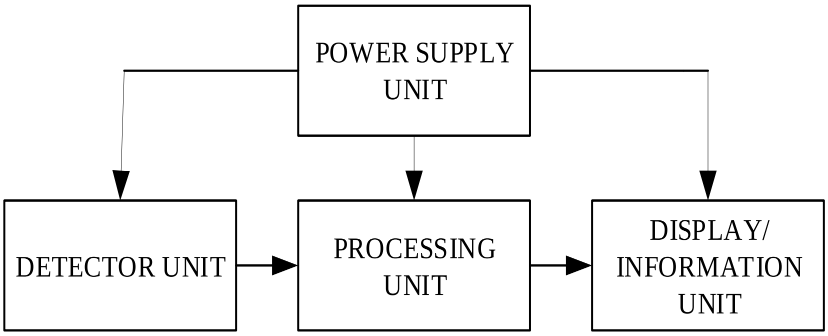

Figure 1: Block diagram of the system

2.1. Detector Unit

The blown fuse detector circuit as shown in figure 2, constantly check for blown fuse at the output of the feeder pillar of the distribution transformer. The active components that make up this unit are the transformer, bridge rectifier, optocoupler and a pull down resistor which connects the detector circuit to ground when there is a failed phase.

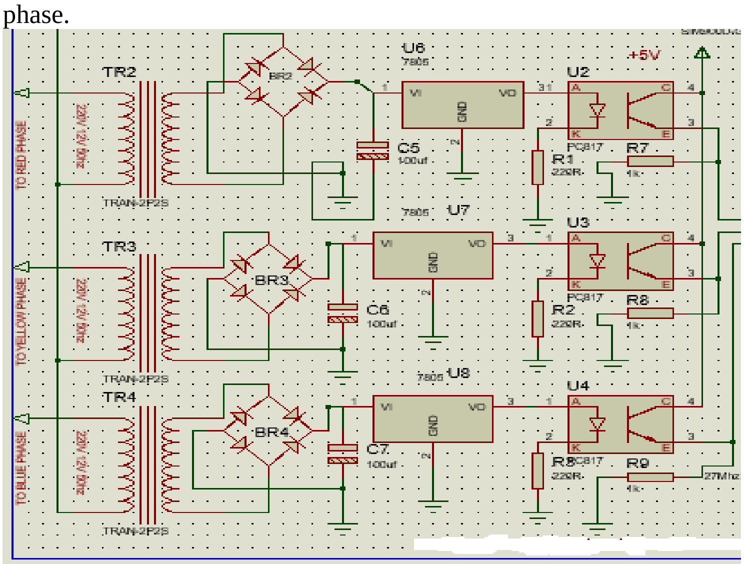

Figure 2: Blown fuse detector circuit

2.2. Processing Unit

The microcontroller used in the system was PIC18F4585. It has four I/O ports. Ports C and D were configured as output ports while port B was configured as input port. The PIC18F4585 is a 40 pin, 8-bit microcontroller which does all the processing required by the device. It processes the input signals it receives from the detector circuit and takes appropriate action depending on the state of the signal it receives. It has all the computational capability needed for the work. Embedded C programming language was used to program the microcontroller.

2.3. Display/Information Unit

This unit gives the output information by displaying it and sending it to a predefined phone number. It displays the state of the various detector circuit. It comprises of a liquid display (LCD) which is interfaced with the microcontroller. 16 x 2 LCD was used. Three Pilot lights were also used to indicate the phases available. A variable voltage regulator was connected across pin 2 and 7 to control the brightness of the LCD.
By means of the SIM900A GSM module interfaced with the microcontroller. The GSM module requires a SIM card to operate. Some of the features of the SIM-900A GSM module which made it indispensable in this work are its tiny configuration of 24mm x 24mm x 3 mm, a complete Quad-band GSM/GPRS, it delivers GSM/GPRS 900/1800MHz performance for voice, SMS, Data, and Fax with low power consumption. A preprogrammed SMS can be sent to the utility providers indicating the location of the transformer and the faulty phase.

2.4. Power Supply Unit

The power supply unit provides the desired 5 VDC to run the circuit. A step-down transformer is used to step the voltage from 230VAC to 12VAC. Using a bridge rectifier the 12VAC is rectified to 19.81VDC and a.c ripples are removed by the filter capacitor. Finally, a voltage regulator regulates the rectified voltage to the desired 5VDC.
The input voltage to the power supply circuit from the national grid is 230VAC, 50 Hz. The transformer steps down the voltage from 230VAC to 12VAC.
The bridge rectifier is made up of four diodes. For efficiency, the peak inverse voltage was determined. Assuming the AC signal is a pure sine wave, equation 1 was used to determine the peak inverse voltage.

$$PIV = V_m \times 2 \quad \ldots\ldots\ldots \; \ldots\ldots\ldots\ldots\ldots.. \; (1)$$

But $V_m = V_{rms} \times\sqrt{2}$
$V_m = 12 \times\sqrt{2}$
$V_m = 16.97\text{V}$
$PIV = 16.97\times2 = 33.94\text{V}$
Diode IN4001 was chosen since it has a peak inverse voltage rating of 50V.
After rectification, the next stage is filtering. The capacitance of the capacitor needed to filter the ripples is given in equation 2.

$$C = \frac{I\times t}{V} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots.. \; (2)$$

Where I = maximum current
t = time for full wave rectification

$$V = V_{peak} - V_{regulated} \ldots\ldots\ldots\ldots \; (3)$$

$V_{peak} = 16.97V$

Now 1.4V will be dropped in two diodes (0.7V per diode) as two will be forward biased for half wave.
$V = 16.97 - 1.4 = 15.57V$
When the capacitor discharges into the load circuit it must provide 7V to 7805 IC.
$V = 15.57 - 7 = 8.57V$
Therefore,

$$C = \frac{500mA \times 10ms}{8.5V}$$

$C = 588\mu f$
Therefore the value of capacitor needed for $C4, C5, C6, C7 = 1000\mu f$.
Finally, an LM7805 IC is used to regulate the voltage to 5 VDC.

2.5. Mode of Operation

The system operates following the sequence shown in the flowchart in figure 3.

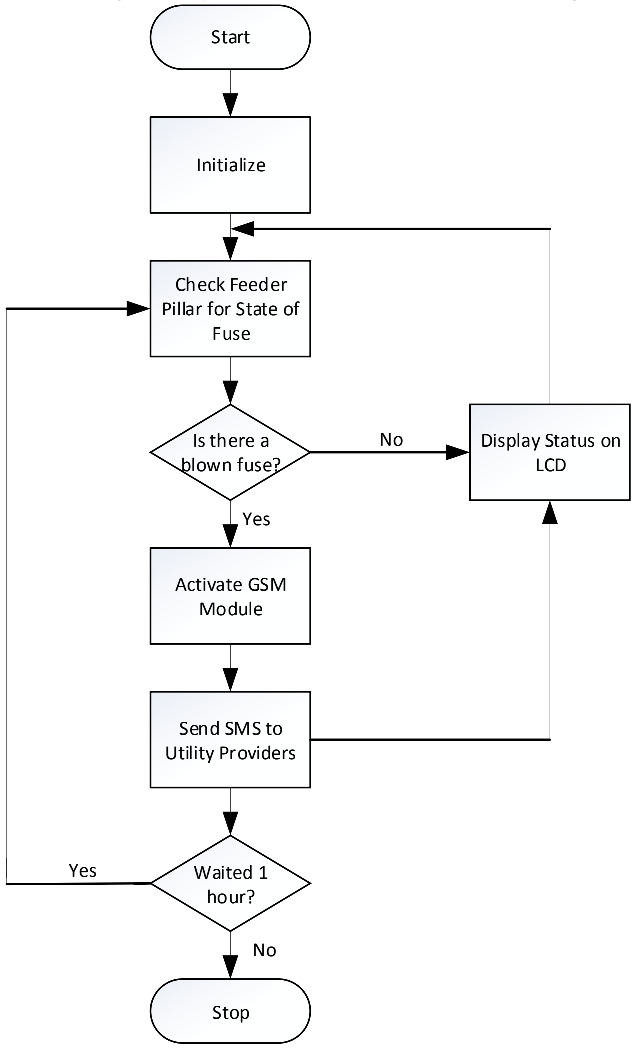

Figure 3: Flowchart of the distribution transformer phase monitor

When the system is connected to a power supply of 240VAC, the 240VAC is stepped down to 12VAC by the step down transformer TR1, TR2, TR3 and TR4, the 12V AC is rectified by the bridge rectifier to 12VDC, filtered to remove ripples by capacitor C4, C5, C6, and C7 and regulated by the voltage regulator U5, U6, U7and U8 to produce a fixed value of 5VDC which is used to power the entire system as shown in figure 4. Assuming all the phases are in good condition, the voltage regulator U6, U7, and U8 produces a 5V DC output which is supplied to the optocoupler making each of the output to produce a high(1) which is fed to pin 33, 34 and 35 of the microcontroller (PIC18F4585). The microcontroller then sends an output which is displayed on the LCD indicating that the system is okay.

Assuming any of the phase is faulty (red phase), there will be no input to transformer. TR2(red phase), voltage regulator U6 will produce 0V at the output making optocoupler U6 to produce a low(0) which is fed to pin 33 of the microcontroller. Since one of the input to the microcontroller is low, it will initiate the GSM module (SIM-900D) and an SMS will be sent to the utility providers informing them of the failed phase and the location of the transformer. The buzzer is activated and the status is displayed on an LCD. The microcontroller is programmed to wait for one hour after which it checks the input ports to which the detector circuit is connect. If the fault has not been corrected it sends another SMS. If the faulty phase has been corrected the status is simply displayed on an LCD.

Note that TR2 represents the red phase, TR3 represents the yellow phase, and TR4 represents the blue phase. The implemented work is shown in figure 5.

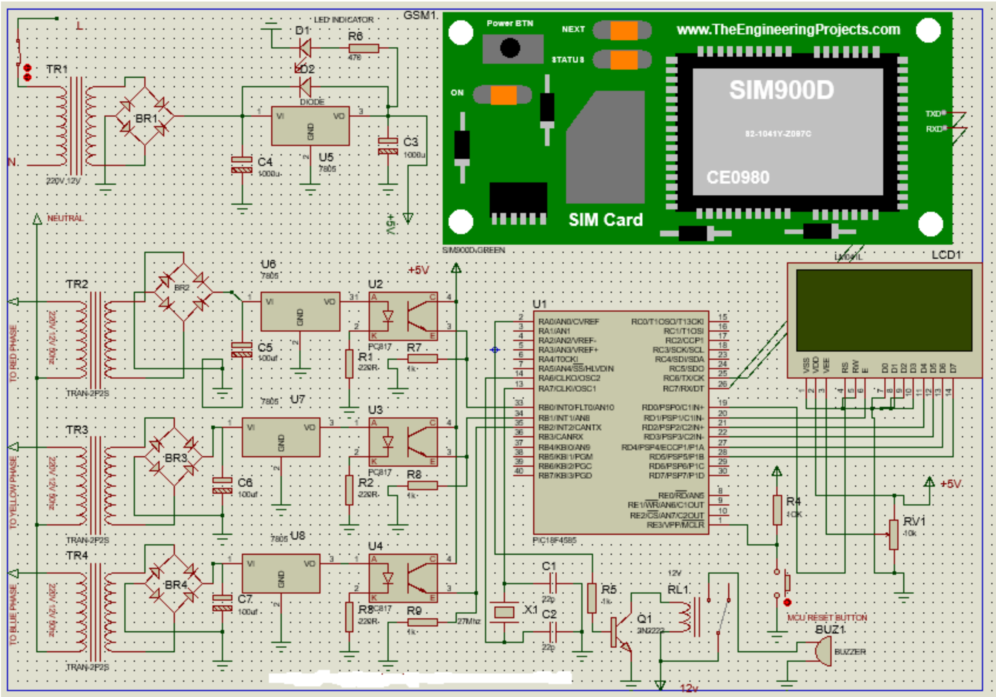

Figure 4: Complete circuit diagram of the system

Figure 5: Picture of the phase monitor system

3. Test/Results

In the constructed work switches were used to represent the three phases of the distribution transformer feeder-pillar and pilot lamps were used to indicate the state of the phase. Test was carried out by switching OFF/ON to see how the system responds. When a particular switch was put OFF, the corresponding pilot lamp went off, the buzzer came up and an SMS was sent to the pre-programmed number representing the utility providers to notify them of a failed phase in the distribution transformer feeder-pillar. Figure 6 shows the SMS sent indicating clearly the location of the fault while Table 1 shows the test result.

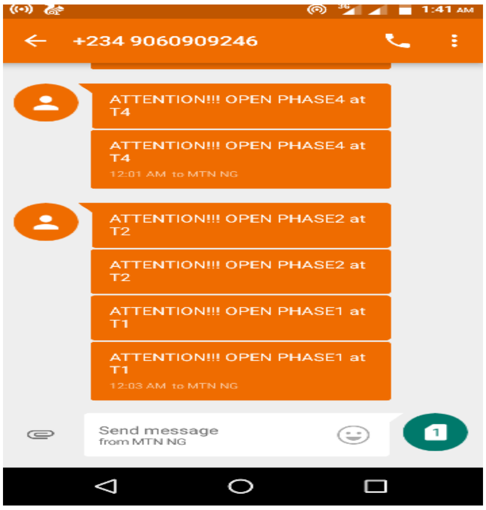

Figure 6: Screenshot of communication test

Table 1: Test result for the operation of the system

S/N	STATE OF PHASE			OUTPUT OF OPTOCOUPLER IN VOLTS			SMS RECEIVED (IN SECONDS)
	RED(TR1)	YELLOW(TR2)	BLUE(TR3)	U6	U7	U8	
1	OFF	OFF	OFF	0	0	0	29.40
2	OFF	OFF	ON	0	0	1	28.99
3	OFF	ON	OFF	0	1	0	26.76
4	OFF	ON	ON	0	1	1	27.50
5	ON	OFF	OFF	1	0	0	27.48
6	ON	OFF	ON	1	0	1	27.51
7	ON	ON	OFF	1	1	0	29.20
8	ON	ON	ON	1	1	1	0

4. Conclusion

In this work we developed a low cost system that can automatically monitor the phase of a distribution transformer, detect a blown fuse, and promptly report the location of the fault to the electricity distribution company. This system will definitely reduce the downtime associated with the frequent blown fuses in the distribution transformers' phases in Nigeria since it gives instant notification and indicates the location of the fault.

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