TELKOMNIKA Telecommunication Computing Electronics and Control
Vol. 22, No. 1, February 2024, pp. 202~210
ISSN: 1693-6930, DOI: 10.12928/TELKOMNIKA.v22i1.24865

Automatic detection, report, and alert of faults in 220 volts electric power distribution parts

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Article Info

Article history:

Received Dec 3, 2022
Revised Nov 3, 2023
Accepted Nov 15, 2023

Keywords:

Cable grid
Distribution transformer
Electric power grid
Fault detection
Global system for mobile modems
Global system for mobile network

ABSTRACT

The electrical power distribution parts include the distribution transformer responsible for reducing high voltage (HV) 11 Kv to low voltage (LV) 416/240 volts, and the power distribution lines (PDLs), which are the source of electrical power supply for residential neighborhoods. Any malfunction of these parts, result in a power outage. Currently, any faults are reported, detected, and alert in a primitive way, and this mechanism certainly takes a lot of time and effort. In this paper, an automatic approach for detection, report and alert has been suggested. This approach process is carried out by continuously checking the status of the three output feeders (power distribution lines), which is the low voltage side of the distribution transformer, when a malfunction occurs in any one or more of these feeders, it will generate an alert signal in the form of a text message using short message service (SMS). The maintenance center is notified by receiving this SMS via SIM900 modem through the global system for mobile (GSM) communications network. The SMS text message includes feeder number, fault type and location address (street number and distribution transformer number). In this design, time and effort are shortened and the maintenance center enables fully automatic monitoring of electric power distribution parts within the sector of responsibility.

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1. INTRODUCTION

In some countries, the weak point of the electrical power supply in the residential neighborhoods is the distribution lines and transformers. These two parts are always exposed to malfunctions leads to cutting the high or low tension cables or a malfunction within the transformer itself, which leads to the interruption of electrical energy for the citizen in residential neighborhoods. The process of fixing the faults of these parts usually depends of an uncivilized and slow process that requires time and effort. In a professional electrical power distribution system, distribution transformers and lines are one of the basic components and play an essential role in an electrical power distribution system [1]–[3]. A fault monitoring system based on three different approches, one to monitors nominal value of electric current in each line of electric grid, second monitor the value of electric power in each transformer station, thered to compares the value of current at the begin and end of each line, then checking if there is any discrepancy between them [4]. The fault type occurred in the power grid transmission line is detected and classified by the intelligent backup monitoring system. This process is based on spectral analysis of equivalent power factor angle (EPFA) variation to detect the occurrence of the fault anywhere in the network [5].

Automatic reclosing that is insearted into the fault line through a single phase AC voltage signal of the power electronic converter. This process can eliminate the influence of fault resistance for positioning the result. No communication line is required, because the measurement is performed only at the head end circuit. Fault information and the latching circuit breaker should be indicated when a permanent fault is found in the system. The circuit breaker must be switched when there is no fault notification [6]. A method that enables the detection of faults in the distribution transformer and its cooling system, by relying on two methods first: the thermography method, as this method is used with image processing to control transformer temperature distribution and obtaining the temperatures of the radiator and the top oil. The other way is to use a proposed advanced thermal model, where the radiator is considered as an additional thermal point which improves the accuracy of the thermal model [7].

Developing a system based on the internet of things (IoT) for protecting distribution transformers. This occure by control and monitoring of operating parameters such as current rating and oil level by using sensors. If it is any change in these parameters from the standard level, the device issues an alarm and an order to remove the transformer from the distribution line service. The use of this mechanism provides protection for the transformers from any abnormal conditions. The system is placed in the transformer base for the purpose of online monitoring the considered parameters in a regularly case and then transferring the data to a central web server [8]. As with any electrical device, defects in the electric power distribution transformers lead to a malfunction in its working function. Therefore, there is a need to monitor the status of the power transformer, and one of the approved methods is to use the failure modes and effect analysis (FMEA) technique [9].

The power transformer protects from over voltage states by allowing a limited volume of voltage to go to a transformer, and this is the surge protector function. Any failure at this protector leads to the passage of high voltage to the windings which causes to damage it [10]. Blown fuse detector for distributed transformer has been implemented for fault phase monitoring depend on using PIC18F4585 microcontroller, buzzer, SIM900A, and liquid crystal display (LCD) [11]. Provide comprehensive specifications of the distribution algorithm to find malfunctions and isolation and give an accurate characterization of the time from the point of occurrence of the fault to its location and then isolation using sensing, wireless networked and control [12]. PIC 16F877A microcontroller for fault detection and connection in assistance to global system for mobile (GSM) networks for distribution side has implemented to detect the changes in voltages and currents guidelines [13]. System for online monitoring the operational parameters of distribution transformer like oil level, voltage, oil temperature and load current using IoT, this system may can provide important and useful information about the transformer [14].

In this proposed design, a malfunction detection and alert mechanism has been implemented in an easy, inexpensive and automatic manner without human intervention. The process depends on continuous reading and analysis of the condition of the three programmable logic devices (PLDs). When a fault is detected in any of these lines, the maintenance center is notified by sending a short message service (SMS) via the GSM network. This SMS includes, the fault type with number of distribution line, and address of both distributed transformer and street. At the same time, the state of three PLDs will continuously display on the LCD and the light-emitting diode (LED) fault indicator will activated at the case when any fault occur at these PLDs. The study focused in this research on the low voltage aspect of the power distribution transformer because it is the source of electrical energy supply and the influencing factor that enters into people’s lives. On the other hand, this part is the output for the transformer and the high power transmission cables, so any defect in them also notifed by sending an alert message.

2. PROPOSED WORK METHOD

The architecture of the proposed system is described in Figure 1. The system elements are divided into a group of the following sub-units: automatic phase selector, AC to DC converter, multi DC power supply, Arduino Uno, 3-LED fault indicator, 16×2 LCD, and GSM modem. For the purpose of implemented the proposed system, the work method was divided into two parts, hardware and software. Everything related to hardware part is indicated in the schematic diagram of the circuit shown in Figure 2.

With regard to the hardware part, it was implemented in two mechanisms. Firstly, using a simulation program, which is Proteus 8 profesional, which was chosen for the reason for its widespread use due to its efficiency in simulating the operation of both analog and digital systems, gives simulation results similar to the results of tests in physical circuits, ease of use and it contains a large library that covers a wide range of applications [15], [16]. Secondly through the physical component as shown in the prototype circuit of Figure 3. The power supply unit represented by components C2, C3, RL3, R6, R7, R8, R9, R10, R14, U1, U3, U4, and B1 battery is used to supply all the design electronic circuit with the required voltages in the normal conditions of work, or via a 9-volt battery in an emergency, when missing the supply from all phases.

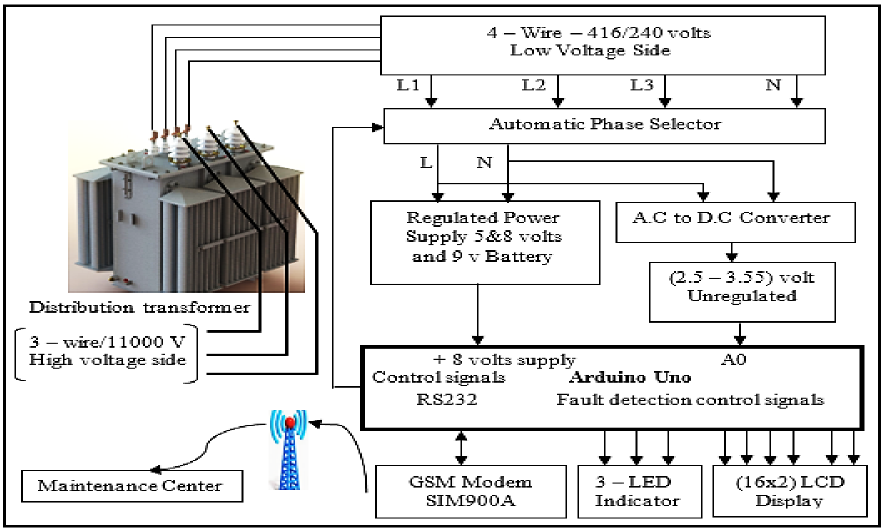

Figure 1. Proposed system functions block diagram

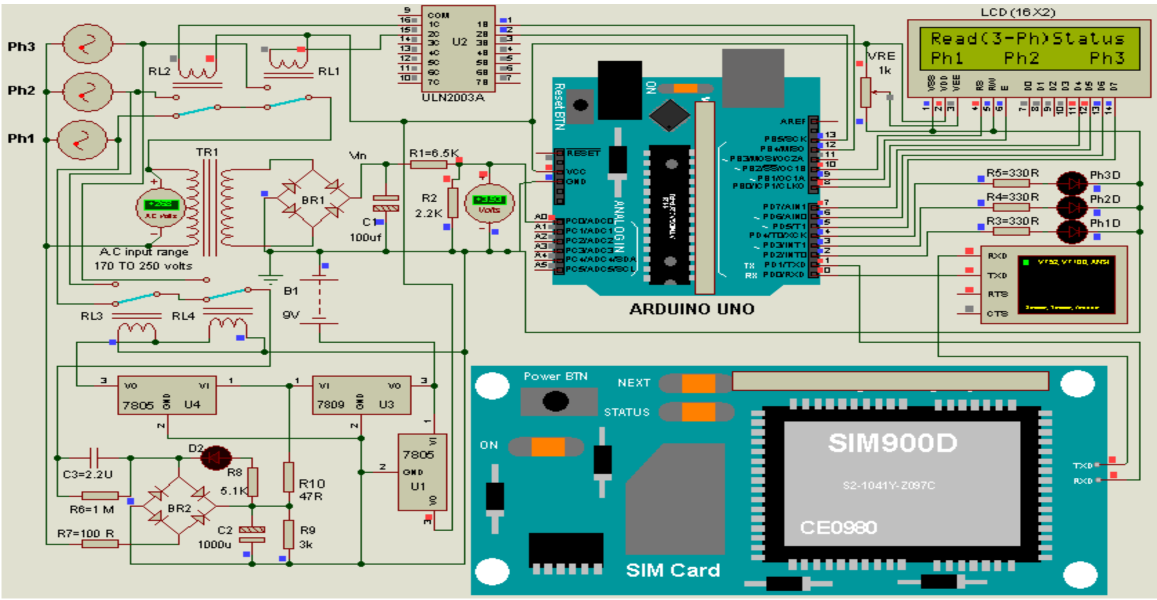

Figure 2. Hardware schematic diagram of proposed circuit

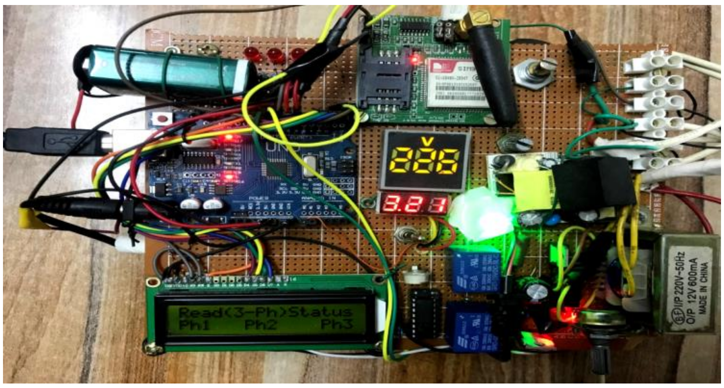

Figure 3. Prototype circuit of proposed work

As for the software part, the system algorithm response for the continuously reading and analysis the state of the three phases. This algorithm writing in the form of sketch code and download to Arduino control board. The integrated development environment (IDE) is the name of software required to develop the sketch in Arduino board [17], [18]. The steps of implementation of proposed system algorithm in Arduino IDE sketch are explained in the flow chart of Figure 4.

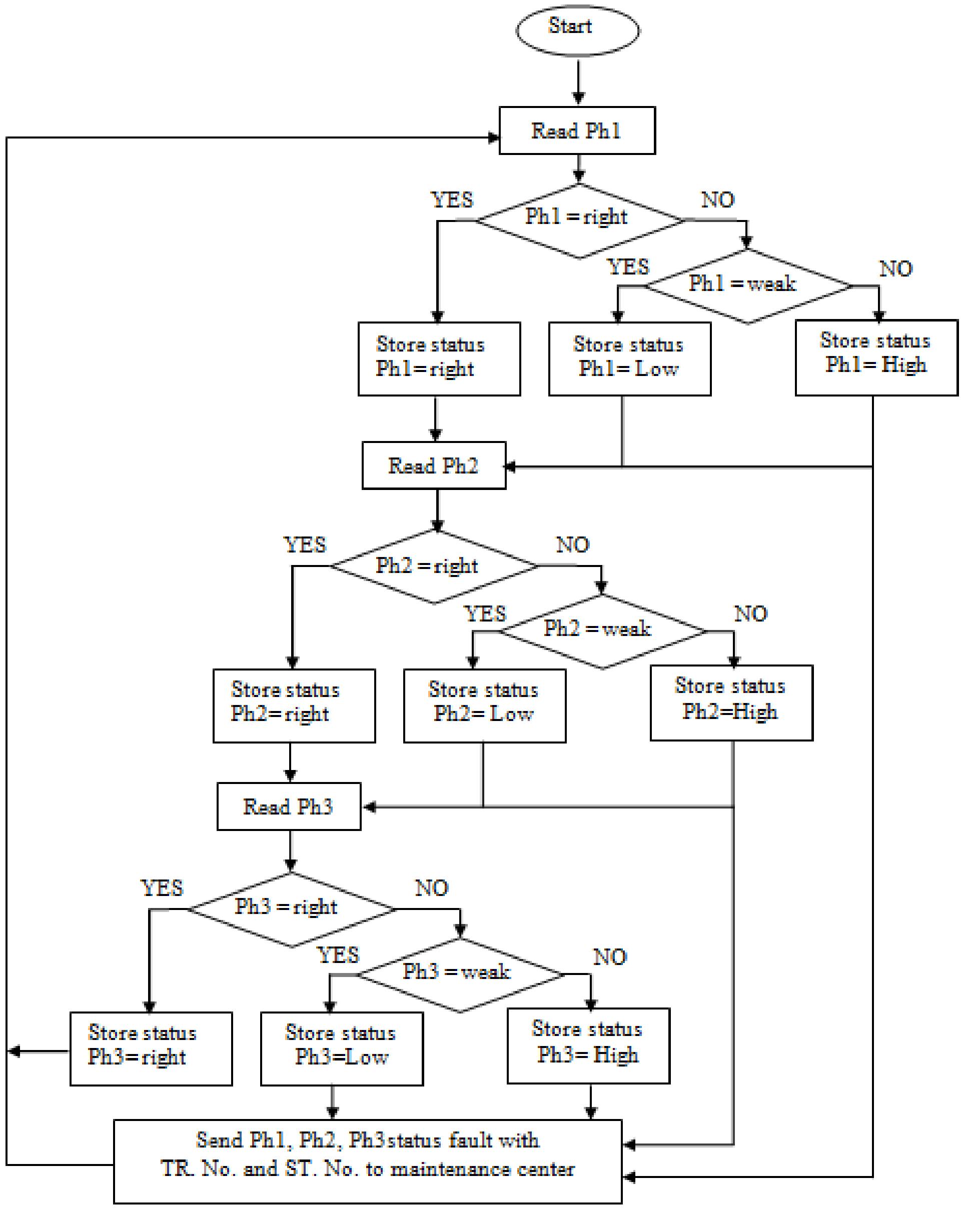

Figure 4. Flow chart for system algorithm

The unit response for sending alert messages from the proposed system to maintenance center is the GSM SIM900 modem. This modem shield specifically designed for connection with the Arduino Uno. This device is used to accomplish almost anything that can be accomplished with a regular cell phone, which means that it works anywhere in the world [19], [20]. SIM900 is a wireless modem work to sends and receives data through radio frequency (GSM 900/1800 bands). A GSM modem needs a subscriber identity module (SIM) card to connects to a GSM network for sending and receiving the data [21]. GSM modem needing a valid SIM card to connect with GSM network, while through the RS232 or I2C can interfacing with microcontroller's chip it's possible to control the modem by sending instruction to it and then to GSM network [22]. Using SMS service for data transmission as a tool for providing communication link between multi places such as power substations, power station and control rooms for the purpose of control and monitoring [23]. The proposed design in this paper employs the Arduino to control the GSM modem by using the AT commands. However fixed and extended set of AT commands are supported by the GSM modem. Depend on the AT commands, different SMS function can be enables [24].

3. DETAILS DESCRIPTION THE SYSTEM WORK

The key to the proposed system’s work begins with automatic phase selection unit. This unit consist of two relays RL1 and RL2, ULN2003 driver and two control signals UCON1 and UCON2 emanating from the pins (12,13) of Arduino board. The function of this circuit is to allow each phase, starting with phase one, to pass and connect it to the next unit (AC to DC converter) for a period of time of approximately 15 seconds, continuously and sequentially, and this period is subject to change according to demand.

The driver ULN2003 used for this unit is a monolithic high current and high voltage collection of seven NPN open collector Darlington pairs transistors connected in an array with common emitters. A Darlington pair is an arrangement of two bipolar transistors. ULN2003 is for 5 V transistor-transistor logic (TTL), complementary metal oxide semiconductor (CMOS) logic devices, used as relay driver, line driver and display driver [25]. The AC to DC converter represented by the components TR1, BR1, C1, R1, and R2 which are used for the purpose of reducing the phase’s voltage level from alternating voltage to unregulated DC voltage as shown in Figure 5. The unregulated DC voltage represent the output of the resistive voltage divider (RVD), which can be calculated by applying Kirchhoff’s voltage law (KVL) equation [26]. The RVD output is connected to pin A0 of the Arduino board for the purpose of reading and analyzing by the proposed algorithm to output the status of each phase and then determine the type of mu if found.

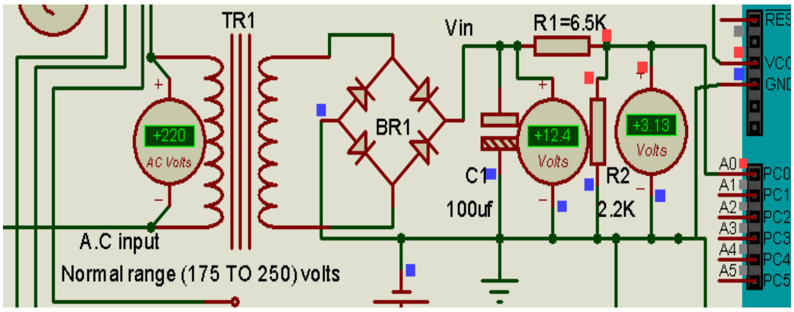

Figure 5. RVD circuit working

With a closer look at Figure 5 and for the purpose of applying KVL and RVD for the purpose of making mathematical calculations for the values shown in the voltage scales in the figure, the voltage across V_{R2} represent the voltage input to pin Ao (VAo)=V_{R2}=$V_{in}(R_2/(R_2+R_1))$. For AC input voltages=220 volts then VAo=V_{R2}=12.4(2200/(6500+2200))=3.13 volts DC and so on for all inputs. Relying on this equation, it is possible to determine the upper and lower value of the normal working voltage level for each phase which is (2.5 to 3.55) VDC, which corresponds to (175 to 250) VAC. As mentioned, because the three phases pass through the same unit for 15 seconds for each phase, therefore these readings apply to all three phases. Therefore, it is possible to indicate that the proposed system does not issue any alert message to the maintenance center when the voltage levels ranges are confined between the lower and upper levels, meaning that things are going correctly. But in readings that are higher or lower than these values, action is required to send alert message to maintenance center.

The components group R3, R4, R5, Ph1D, Ph2D, and Ph3D are used as fault indicators for the 3-phases, so that each LED specified to one phase. This meansif a malfunction occurs in one of the phases that leads to the glow of the LED related to that phase. Control of the glow of the three lamps occurs by issuing three signals from Arduino board pins (2, 3, and 4). The function of the (16×2) LCD is to continuously display the status of the three phases in all cases. SIM900 modem, it is used during the malfunction in one or more of the PLDs for the purpose of sending a text message written in AT command via one of the GSM to the maintenance center, where the message includes the information’s like the type of defect high or low, number of fault phase and address of the fault site which includes the street number and the distribution transformer number. Notification of the maintenance center is done only when there is a defect, and this process is one of the tasks of the algorithm.

The steps of implementation of proposed system algorithm in Arduino IDE sketch are explained in the flow chart of Figure 5. It's clear in this figure the algorithm starts first by reading the VDC level of three phases. This VDC is used continuously and sequentially by the system algorithm for the purpose of reading and analyzing in order to arriving to a decision based on the voltage level of the three phases. This decision is sent in the form of an alert text message to the maintenance center if fault is occurring. Starting from reading phase one VDC level, if its right, i.e., within the normal level (2.5 to 3.55) VDC, then change to check phase two if no there is a fault in the level voltage of phase one, in this case, the type of malfunction must be specify whether it is upper limit allowed is (3.55) volt, or less than the minimum allowed it (2.5) volt and stored as phase one status. By the same way, change to read the status level of others two phases. After checked the status of 3-phases, the one algorithm cycle has been ended, this means that the status of the three phases has become known, and this process takes approximately 45 seconds, with 15 seconds for each phase. After completing the reading of the three phases, if the level of these phases is within the normal level, the previous process is continuously repeated over and over; at this case the device will not send any alert message to maintenance, no LED fault indicator was turned on and display OK word for all three phases on LCD display. But when there is a malfunction in one or more phases the algorithm performs three operations: first, inform the maintenance center by SMS via SIM900 modem and through the GSM system, the SMS indicates the number and type of faulty feeder, street number, and transformer ID. Second generating a control signal to illumination, the LED fault indicator of specific phase, third, display the final status of three phases in the 16×2 LCD display.

4. TESTS AND RESULTS

For the purpose of conducting comprehensive tests and covering all expected conditions and to ensure that the proposed design works correctly and achieves the purpose for which it was designed. So, the best way to verify this is by feeding it with different voltage levels using Proteus simulation software, which leads to the investigation of several purposes which are as follows:

a) Check the functioning of the device components.
b) Measure the amount of the incoming voltage and the corresponding constant voltage as an output from the RVD.
c) Check whether the algorithm is working correctly and detecting the correctness of issuing the alert message to the maintenance center.
d) Test the turn on the phases fault LED indicator when there is a fault.
e) Ensure that the status of the three phases is continuously displayed on the LCD screen.
f) Verify that the system is working continuously without issuing any alert message to the maintenance center when there is no malfunction.

By feeding the device through the automatic phase selection circuit with different levels of input alternating voltages, the results obtained for working the RDV circuit are indicated in Table 1. As for the other tests that were conducted on the system and their results, the details are shown as follows:

Table 1. Different of AC and equivalent DC voltages

AC voltage for phase selector in volt	Equivalent DC voltage input for A0 in volt
160	2.25
170	2.35
175	2.5
190	2.7
205	2.9
220	3.13
230	3.29
240	3.4
250	3.55
260	3.7
275	3.92

4.1. Test one: two phases at normal state and one phase less than the normal level

In this test, when Ph1 and Ph2 at normal working condition between (175 and 250) volts, while the voltage level of the there'd feeder Ph3 is less than the minimum normal level (175) volts. In this case, the LED fault indicators for Ph3 is activated, the LCD screen will display the status of three phase (Ph1=OK, Ph2=OK, and Ph3=Low) to indicated that the there'd phase at low level, will others two phases at normal condition, this denoted by OK, and a text message (Ph3=Low, TR=2, and ST=5) clear shown in the virtual terminal window in Figure 6. This message informing the maintenance center, there is a fault in phase 3, the type of fault its low voltage with address which is transformer number 2 and street number 5.

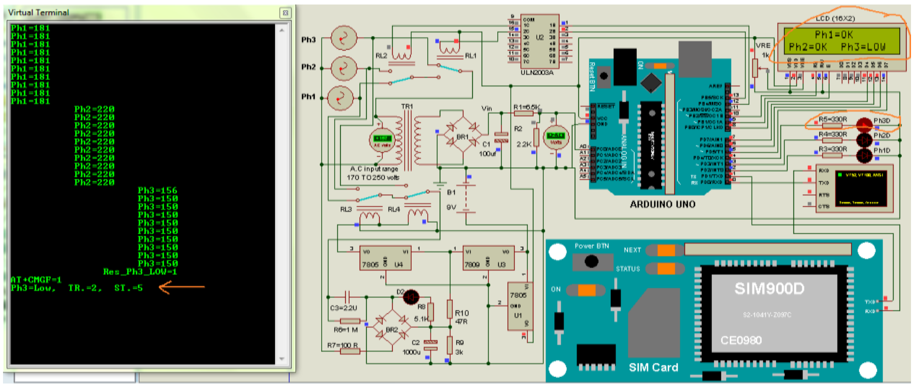

Figure 6. Circuit state at Ph1, Ph2 at normal and Ph3 at low level

4.2. Test two: two phases fault low and high and there'd phase normal level

In this case as shown in the Figure 7. Ph1 at voltage level more than upper limit, Ph2 at normal level and Ph3 less than lower level. At this case the system will generate the three activates, First lighting the LED fault indicators for Ph1 and Ph3, second display the word (Ph1=High, Ph2= OK, and Ph3=Low) at LCD screen, and there'd inform the maintenance center by the message (Ph1=High, Ph3=Low, TR=2, and ST=5).

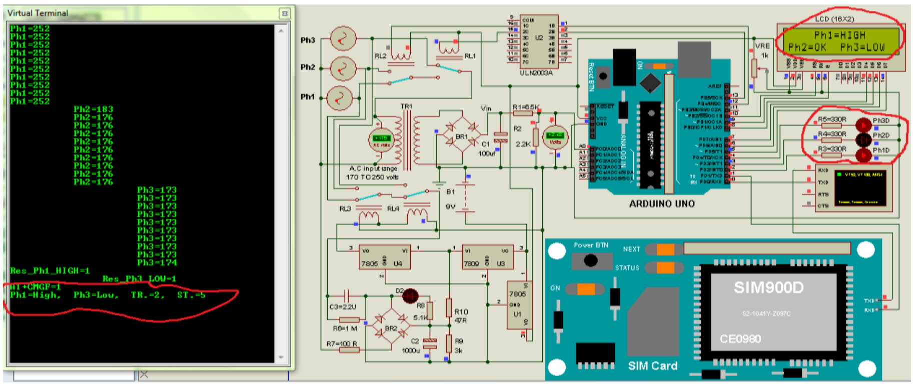

Figure 7. Circuit state when Ph2 at high, Ph2 normal and Ph3 at low level

4.3. Test three: fault in all three feeders

State of phases at this test are Ph1 and Ph2 at voltage level less than the lower level, Ph3 more than the upper level. At this case the system will generate the three activates, first activated all LED fault indicators, second display the word (Ph1=Low, Ph2= Low, and Ph3=High) at LCD screen, and there'd inform the maintenance center with message (Ph1=Low, Ph2=Low, Ph3=High TR=2, and ST=5). This test is shown in Figure 8.

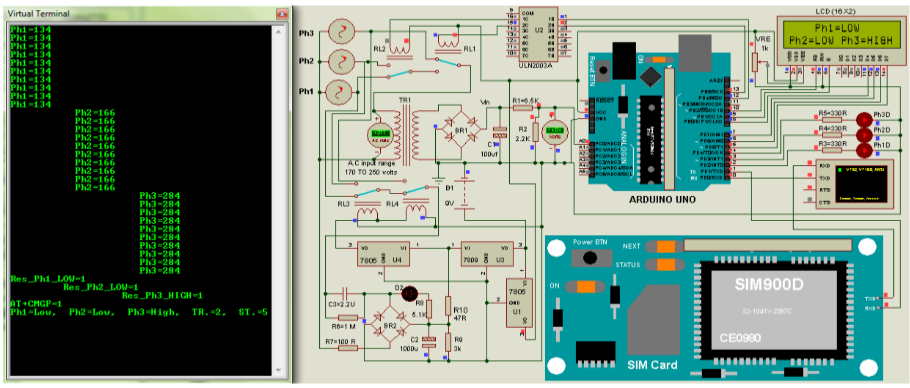

Figure 8. Circuit state when Ph1 and Ph2 at low, Ph3 at high

5. CONCLUSION

In this research, the design and implementation of a prototype of a system that automatically and continuously read and analysis the state of the three PLDs from distribution transformers to homes. The proposed system has the automatic ability to read and analyze the level of voltages of the three PLDs. When there is a malfunction in one or more of these feeders, the system sends a text message to the maintenance center using a GSM modem via the GSM network. The message contains the type of fault, the faulty feeder number, the distribution transformer number and the street number, which gives a complete address. At the same time, the system illuminates three LED fault indicators associated with the PLDs, as well as displaying the status of the three PLDs in the LCD screen. The design is done in two parts, hardware and software, then put together for output a required device. The goals achieved with this device can be summarized as follows: shorten the time and effort in the maintenance center notification, real-time knowledge of the fault with its full address, and thus the speed of its repair, canceling human intervention and preoccupation with the process of malfunctions.

The requirements for using this type of device cover all residential neighborhoods and as a result contribute to solving major problems in the electrical power distribution network for residential neighborhoods. The design of this device was based on simple elements, and therefore other features are added to it, such as ease of connection and repair, as well as small size, low cost and economical power consumption. A test and verification of the device's work was conducted to cover all the expected possibilities of faults in the electrical feed lines.

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