

Design and Implementation of a GSM-based Monitoring System for a Distribution Transformer

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Abstract — Maintaining the distribution power substation's health and reliability has been an issue for many years. A typical transformer measurement device detects only one transformer characteristic, such as power, current, voltage, or phase. While some methods can detect several factors, the acquisition time and operation parameters are too long, and the testing speed is insufficient. However, a monitoring system that can check the temperature level of the transformer continuously and predict faults such as overheating, overcurrent, after which the fault diagnosis is relayed to the base station through a GSM modem is developed in this paper. After receiving the message of any abnormality remedial action can be taken immediately to prevent any catastrophic failures of distribution transformers. Key components used in this development are the ATmega328 microcontroller, the GSM modem, the LM35 temperature sensor, ACS712 current sensor, and so on. The GSM-based monitoring of the distribution transformer is preferable to manual monitoring since it is not always possible to monitor the ambient temperature rise, load current manually.

Keywords — Transformer, GSM, monitoring system, overload, temperature.

I. INTRODUCTION

Sustaining the distribution power substation's health and dependability has been an issue for many years. As a result, maintenance staff would occasionally turn off transformers and circuit breakers to see if they were functioning properly. There are still catastrophic failures with this strategy, not to mention unnecessary maintenance. The introduction of online monitoring and artificial intelligence analysis techniques has been used to the electrical distribution power substation in response to a rising need for lower cost and more efficient diagnostic tools. In this research, an intelligent monitoring system that can check the temperature level of the transformer continuously and predict faults such as overheating, overcurrent, after which the fault diagnosis is relayed to the base station through the Global System for Mobile Communications (GSM) modem will be developed.

As a result, maintenance may be done as needed rather than regularly. The ATmega Microcontroller-based system has been created to continually monitor the temperature during its operation. When the Microcontroller detects that the temperature has beyond the setpoint, the programmed

controlling unit shuts down the entire device. In addition, the systems show the values all through the operation for the user's reference and provide further information about the transformer's present state. As a result, the technology improves the transformer's security, intelligence, and robustness.

There are some flaws and concerns with the monitoring equipment or systems that are currently employed to monitor distribution transformers. The following are a handful of them [10]-[15]:

(a) A typical transformer measurement system detects only one transformer parameter, such as power, current, voltage, or phase. While some methods can detect several factors, the acquisition time and operation parameters are too long, and the testing speed is insufficient.

(b) Several monitoring systems convey data using "power carrier communication", but this method has some drawbacks, including serious frequency interference, signal attenuation as distance increases, and large electrical noise caused by load variations. As a result, if data is sent through "power carrier communication, real-time data" transfer and reliability may be compromised [10]-[13].

Based on the given specifications, we need a distribution transformer real-time monitoring system to detect all system parameters and report them to the monitoring centre promptly. It allows for real-time tracking of important operating characteristics of the transformer, which can give valuable data on transformer health. This will allow utilities to make the most of existing transformers and keep them in service for longer. This will aid in the early detection of issues, resulting in considerable cost reductions and increased reliability. The extensive application of mobile networks and GSM equipment such as GSM modems, as well as their lower costs, have rendered them an appealing alternative not only for voice media but also for other large network applications [10]-[13].

An embedded system, GSM modem, mobile users, cellular networks, and sensors deployed at the transformer's location make up the online tracking system. On the transformer, sensors measure the physical quantity from the distribution transformer before converting it to an analogue signal. The transformer's location houses the integrated module. The

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integrated module is for collecting, processing, displaying, sending, and receiving parameters from and to the GSM modem. The GSM module is the second. It connects the embedded system with the public GSM network. The third is a utility module, which is controlled by a PC-based server at the utility control centre. The server is connected to a GSM modem and receives and sends SMS to and from the transformer [1]-[3], [10]-[13].

Li *et al.* in [12] developed an electromagnetic environment multi-parameter monitoring system for distribution transformers capable of relaying the health status of the transformer in real-time to an observer. The system, which used GSM, ensured a safe and reliable power grid. Srivastava and Tripathi [4] and Pawar *et al.* [22] proposed the implementation of this notion using the internet of things (IoT) to obtain the real-time state of the distribution transformer. The proposed health monitoring system incorporates a temperature sensor, a potential transformer, and a current transformer to monitor the temperature, voltage, and current of the distribution transformer and send this information to a remote server where it can be monitored, and necessary action taken to avoid a power outage. The authors in [22] observed that transformers decrease the primary voltage to the usage voltage for customer use in energy distribution and transmission. The study of Pawar and co offered a system which monitor different parameters of the distribution transformer. The system consisted of both the remote terminal unit (RTU) and the monitoring unit. Remote terminal unit includes of evaluating factors such as current, temperature, rise and fall in oil level, vibration and humidity with the help of PIC 18F4550. All monitoring parameters are evaluated and if any irregularity happens, the system sends alert messages to the mobile phones and recorded in system memory through the analogue to digital converter. General Packet Radio Service (GPRS) was used to deliver all parameter values to the monitoring node. If an emergency situation arises, a message will be sent to the corresponding engineer by GSM, and we will be notified via GPRS on our webpage. A buzzer will sound near the remote terminal device, and an LCD will display information regarding the emergency situation. Because an engineer at a transformer cannot keep a constant check on the transformer, the suggested solution used a GSM/GPRS module to communicate with us in the event of a distribution transformer emergency.

Bhavarkar *et al.* [1], Kadam *et al.* [2] and Kepa *et al.* [3] suggested a remote mobile embedded system that combines a GSM/GPRS module with an Arduino microcontroller board as well as sensor packages.

Mahesar *et al.* [5] designed and implemented mobile interfaced systems to monitor and record critical characteristics of a 500 KVA Distribution Transformer, such as load current, voltage, oil level, transformer vibration, and temperature. This monitoring system combined a GSM modem with a standalone single-chip Raspberry PI3 controller, functions as a mini-computer and interfaces with numerous sensors. This system was situated at the distribution transformer position, and the above-mentioned parameters were recorded by an embedded system's analogue to digital converter (ADC). The parameter received is then processed and stored in the system memory. When an

abnormal or emergency state occurs, the system sends a short message to the mobile phone via a GSM-based mobile network. In addition, Fahim *et al.* [6] noted the prevalence of the theft of small transformers in their locality in southeast Asia and consequently devised a GSM-based transformer theft protection and monitoring system. A transformer's health parameters can also be monitored by the system. The system proposed in the study utilises many sensors, including a magnetic sensor, infrared sensors, and weight sensors, to detect nearby people who want to steal or vandalize the transformer and contact the authorities via GSM technology's SMS service. Furthermore, the authorities can keep track of transformer health indicators like temperature and oil level.

Shetty and Co [10] sought to prevent the distribution transformer from overload damage by devising a method that continually monitors the transformer's load and transmits that information to a smartphone. An observer can see the continuous information about the transformer on the display. The information reported include why the transformer failed, when the electricity was restored, and so on. The department's maintenance personnel can keep a constant eye on the transformer with the aid of this type of technology. Therefore, this study develops a monitoring system that can continually check the temperature level of the transformer and predict defects such as overheating and overcurrent, after which the fault diagnosis is transmitted to the base station through a GSM modem. Hassan developed and built a mobile system to monitor and record important distribution transformer data like load current, oil level, and ambient temperature in [11]. Before any disaster, an online monitoring system includes a worldwide service mobile (GSM) modem, a freestanding single-chip microprocessor, and other sensors. It is installed at the distribution transformer site and records the above parameters using the system's ADC. The parameters acquired are processed and stored in the system memory. If an abnormality or an emergency scenario arises, the system sends an SMS to the phone with information about the anomaly, based on predetermined instructions encoded in the microcontroller. This transportable device will assist transformers in running smoothly and detecting failures.

Chavan and Co [13] noted accurately that monitoring of a transformer's physical properties presents a number of difficulties. Currently, distribution transformers require the creation of a data collection system that can be utilized for condition monitoring. This in turn will aid in fault identification and prevention. Subsequently, the authors used GSM to remotely monitor the transformer's characteristics, which saves time and effort. To monitor characteristics such as voltages, currents, and temperatures, we developed an embedded system architecture. This system reads sensors, analyses data, and provides remote monitoring. An ATMEGA2560 Arduino was utilized to operate, process, and communicate between modules.

A. Sensors Used in Transformer Monitoring System

In the authors in [20] recognised that power transformers are critical components in power transmission networks that transport energy from a source to a consumer. And that in situ diagnostics of power transformer performance offers a number of advantages for ensuring dependable energy transmission. Its immunity to electromagnetic interference,

high sensitivity, good insulation, and tiny optical sensing dimensions makes it ideal for power transformer monitoring applications. Therefore, partially discharge, dissolved gases, temperature and other essential sensing, and optical detection were all discussed in the authors work as diagnostic procedures for power transformers. The benefits and drawbacks of various monitoring strategies were thoroughly addressed and weighed. Finally, the current technical barriers to optical monitoring systems for power transformers were discussed, as well as their future potential.

Another area of concern is transformer insulation. The insulating state of a transformer often determines its life span. The authors in [21] noted that partial discharge is the most common cause of insulation failure. Partial discharges (PDs) are electrical discharges that occur in the transformer insulation system. The presence of PDs causes the transformer insulation system to deteriorate. To avoid catastrophic transformer breakdown, it is vital to measure and detect the PD at an early stage. For PD monitoring in power transformers, different PD detection and measurement technologies, such as electrical, chemical, acoustic, UHF, and optical methods, are being used. Traditional PD monitoring methods, such as electrical or chemical, have certain drawbacks. To address these challenges, the optical Fiber Bragg Grating (FBG) Sensor was employed as a PD sensor for PD monitoring in the power transformer. The authors work examined the use of FBG sensors as a PD monitoring sensor in an oil-filled power transformer.

II. SYSTEM DESCRIPTION

The block and circuit diagram of the proposed GSM-based transformer monitoring system is shown in Fig. 1 and 2 respectively.

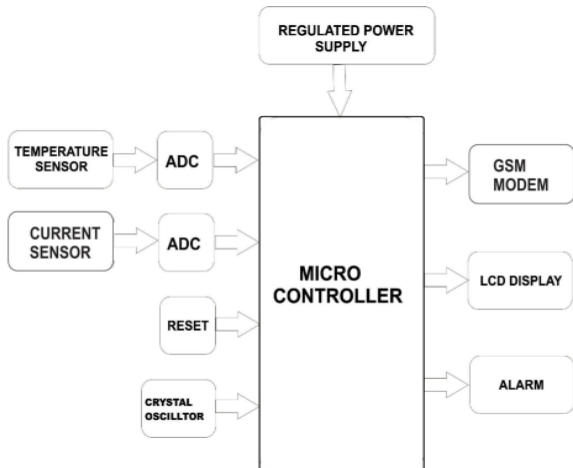


Fig. 1. The block diagram of the system.

From Fig. 1, it will be noticed that the key components of the proposed system include a microcontroller, temperature and current sensor, GSM modem, liquid crystal display (LCD) and an ADC.

A. Component Description

1) Microcontroller

In this study, the ATmega328 was used. It has the following characteristics: 8 Kbytes of Read-While-Write In-System Programmable Flash, 512 bytes of EEPROM, 1

Kbyte of SRAM, 18 general-purpose I/O lines, configurable timer/counters with comparison modes, interrupts, and a 6-channel ADC with 10-bit accuracy. The CPU is turned off in idle mode, while the SRAM, timer/counters, SPI port, and interrupt system continue to work [16], [17].

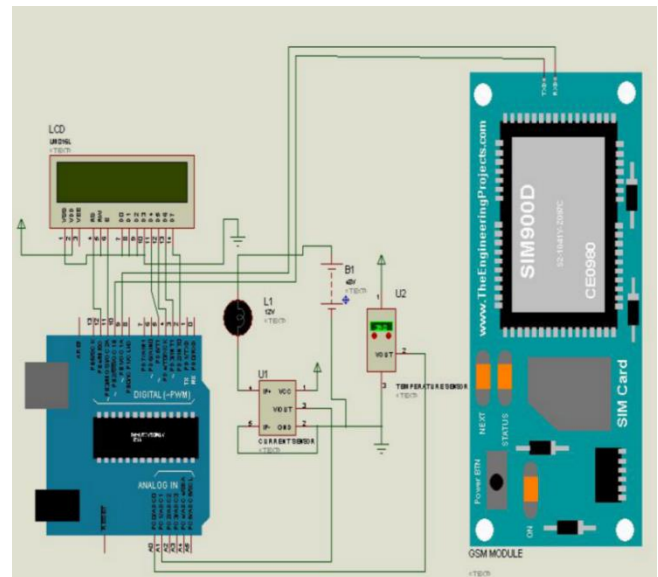


Fig. 2. Circuit diagram of the monitoring system.

2) Sensors

Within the transformer premises, sensors are used to read and measure the physical quantity from the distribution transformer before converting it to an analogue signal. The load current, ambient temperature, winding temperature, oil temperature, and oil level are all monitored via sensors. When the sensor is triggered, it receives and responds to a signal. For real-time tracking, a variety of different quantifiable variables can be gathered. However, using the complete spectrum is rarely necessary. As a result, the sensor must be tailored to the individual needs of a transformer based on its overall condition. The two sensors used are discussed next.

2.1) LM 35-a Temperature Sensor

The LM35 is a temperature sensor that can measure temperatures from 0 to 150 degrees Celsius. It's a three-terminal gadget that outputs an analogue voltage proportional to temperature. The output voltage increases as the temperature rises. The output analogue voltage can be converted to digital form using an ADC and then processed by a microcontroller. Commercially available temperature and current sensors are shown in Fig. 3 (a) and (b) respectively.

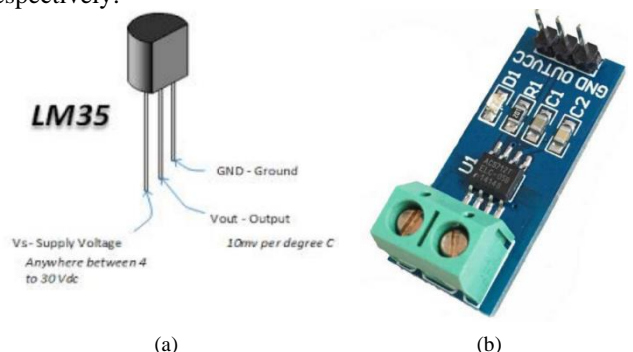


Fig. 3. Sensors (a) LM 35- temperature sensor (b) ACS712 current sensor [8].

2.2) ACS712 Current Sensor

Full-scale readings of 30A are available for this current sensor. This sensor is based on the Allegro ACS712ELC chip, which works on the Hall-effect concept. The concept is defined as when a current-carrying conductor is put in a magnetic field, a voltage is formed across its edges that is perpendicular to both the current and the magnetic field directions.

2.3) LM35 Temperature Sensor Interfacing with ATmega323

The LM35 temperature sensor has three terminals, the VCC, out and the ground, the VCC is connected to the 5v dc supply of the regulated power supply, and the out terminal is connected to Pin 40 of the ATmega328 then the third terminal is connected to the ground. The connection is shown in Fig. 4.

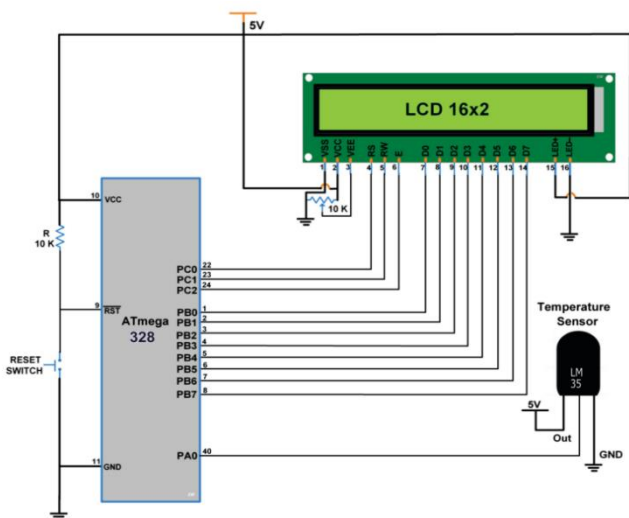


Fig. 4. LM35 temperature sensor interfacing with ATmega328 [7]

2.4) ACS712 current sensor interfacing with ATmega328

The ACS712 current sensor has VCC, out, ground and the two outputs going to the load. The connections with the microcontroller and with load are shown in Fig. 5 and 6.

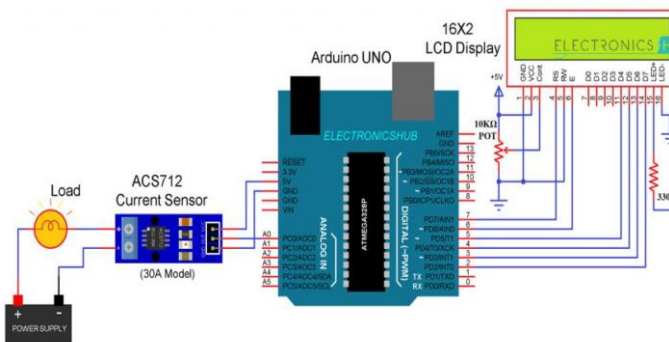


Fig. 5. ACS712 Current Sensor Interfacing with Atmega328 [8].

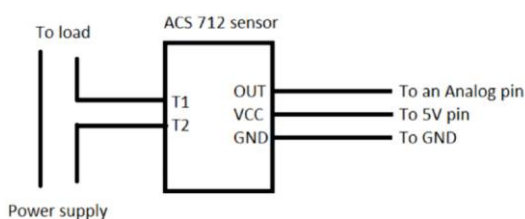


Fig. 6. Connection of ACS712 current sensor with the load.

B. Power Supply

After programming the microcontroller, it needs to be powered to standalone, so there is a need for a power supply system. The power supply provides the required dc voltage for the other circuits to operate. Although we receive 220 V AC from the mains, the remaining components of our circuit demand 5 V DC. This is achieved by employing a step-down transformer and a bridge rectifier. The step-down transformer is employed to provide 12 V AC, which is then rectified to 12 V DC. The rectifier's output still has some ripples, which are eliminated by means of a capacitor serving as a filter circuit. A positive voltage regulator chip, 7805, reduces the 12 V DC to 5 V.

C. The GSM Modem and Interfacing with LCD and Atmega328

A GSM modem is a type of wireless modem that connects to a GSM network. A wireless modem functions similarly to a dial-up modem. The main distinction is that a dial-up modem sends and receives data through a fixed telephone line, whereas a wireless modem sends and receives data via radio frequency (GSM 900/1800 bands). A GSM modem needs a SIM card from an operator to function [14], [15]. Fig. 7 shows a commercially available GSM modem.



Fig. 7. GSM modem. (<https://www.indiamart.com/>).

Serial connections between the modem and the microcontroller are accomplished in the system by connecting Txd and Rxd pins to the modem Rxd and Txd pins, respectively. The modem's third pin is also grounded. We have an interface modem to microcontroller directly without the usage of Max232 or RS232 in our hardware architecture, and we are getting good results with good communication. Logic converters such as Max232 and RS232 are also utilized [15].

They may both operate at the CMOS and TTL logic levels. If the microcontroller is TTL and the GSM modem is CMOS, a logic converter such as RS232 is used to bring the two logic levels together. However, because both the Microcontroller and the GSM Modem in our model operate at the TTL logic level, we have not used Max232 or RS232. The modem and the microcontroller are connected directly [15]. The connection is depicted in Fig. 8.

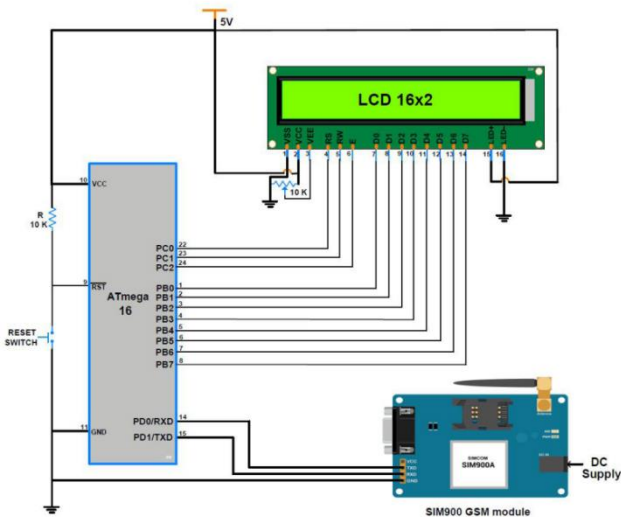


Fig. 8. GSM modem interfacing with ATmega328 [9].

D. The Relay and Its Interfacing with ATmega328

Relays are switches that open and close circuits electromechanically or electronically.

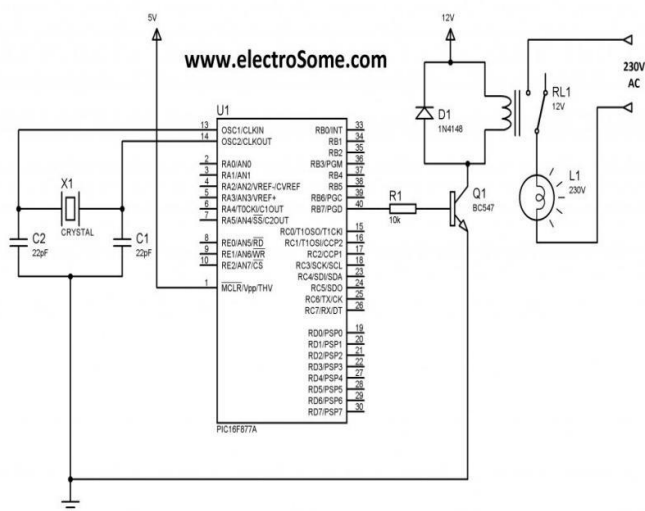


Fig. 9. Relay interfacing with ATmega328.

Relays control one electrical circuit by opening and closing contacts in another circuit. As relay diagrams show, when a relay contact is normally open (NO), there is an open contact when the relay is not energized. When a relay contact is Normally Closed (NC), there is a closed contact when the relay is not energized. In either case, applying electrical current to the contacts will change their state. The connection is shown in Fig. 9.

E. Liquid Crystal Display

The display is a 16x2 Liquid Crystal Display (LCD), which means there are 16 characters per line and two lines. The HD44780U standard refers to the controller chip that accepts data from an external source (in this case, the ATmega328) and communicates directly with the LCD. The LCD is set to its 8-bit mode, which means it uses an 8-bit data bus. EN, RS, and RW are the three control lines. "Enable" is the name of the EN line. This control line is used to inform the LCD that data is being sent. The application should first set the other

two control lines or put data on the data bus before delivering data to the LCD.

Bring EN high and wait for the minimum amount of time specified by the LCD datasheet before bringing it low again.

The RS line stands for "Register Select." The data is handled as a command or special instruction when RS is low (0) (such as clear screen, position cursor, etc.). The data delivered when the RS is high (1) is text data that is displayed on the screen. Set RS high, for example, to display the letter "B" on the screen. The "Read/Write" control line is the RW line. The information on the data bus is written to the LCD when RW is low (0). The software successfully questions (or reads) the LCD when RW is high (1). The read command consists of only one instruction ("Get LCD status"). All of the other instructions are written commands, so RW will always be below [18,19].

The lines of an 8-bit data bus are designated as DB0, DB1, DB2, DB3, DB4, DB5, DB6, and DB7.

III. PROCEDURE FOR HARDWARE IMPLEMENTATION

The sequence of methodologies followed in the monitoring of distribution transformer via GSM technology are highlighted as follows [15]:

- First, sensors positioned at the transformer site sense various transformer properties and convert them into analogue signals that may be processed in signal conditioning circuits.
- The SCC, which is made up of op-amps and resistors, then converts the analogue signal to a value that can be read by the embedded system.
- A microcontroller is then used to process the signal. The ADC is utilized to read the parameters, and the embedded software program that handles parameter acquisition, processing, displaying, transmitting, and receiving is housed in the built-in EEPROM. The observed parameters well as the hourly and daily averages are saved in the onboard EEPROM.
- The microcontroller is connected to the GSM modem through a RS 232 adaptor, which allows it to post and retrieve SMS messages containing information on the transformer's characteristics and status.
- The modem then delivers a short message service to mobile users with information on the transformers' settings and values.

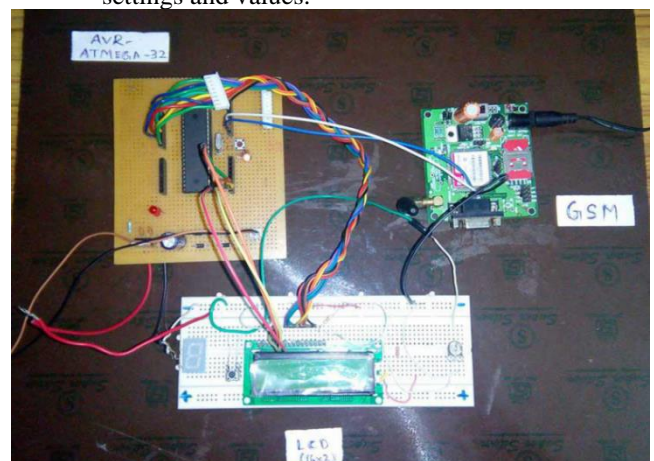


Fig. 10. Snapshot of the developed transformer monitoring system.

To make the construction, testing, and maintenance easier, the system was built in modules as intended and then connected after completion. A prototype of the system depicted in Fig. 10 was built on a breadboard first, then moved to Veroboard once it was proven to be functional. The whole system circuit was meticulously planned out to reduce error and simplify troubleshooting.

IV. TESTING AND RESULTS

During the development of the overall system, the hardware and software components were split into units. Smaller components of the system were built and tested, making it more manageable and efficient. The power supply unit was initially tested to confirm that it could provide the circuit with the necessary power. Before connecting with the microcontroller, the temperature sensing device was also tested, and it was discovered to be capable of generating an accurate output signal corresponding to varying temperatures. The current sensor was then verified before being connected to the microcontroller. The outputs from the module were conditioned and supplied to the microcontroller once it was determined that the temperature sensing unit and current sensing unit gave accurate data.

The GSM modem was tested with a DC 9V battery before interfacing with the microcontroller. After the final testing and coupling of the modules, the device was found to be working. The snapshot of the device observing transformer status is shown in Fig. 11(a)-(d).

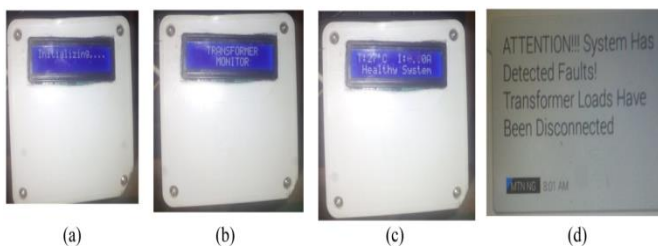


Fig. 11. Results of the testing of the GSM modem.

V. CONCLUSION

GSM-based transformer monitoring is more convenient and more reliable than manual monitoring since it is impossible to manually monitor environmental temperature rise and load current all of the time. We may take prompt action after getting a notice of any irregularity to avert disastrous system breakdowns. There are numerous distribution transformers in a distribution network, and by identifying each transformer with a system, we can quickly determine which transformer is experiencing a problem based on the message provided to mobile. We don't need to inspect all transformers and their phase currents and voltages, so the system may be recovered in less time. Although the time it takes to receive messages may vary owing to public GSM network traffic, it is still more effective than manual monitoring.

This system can contain a server module that receives and stores transformer parameter information from all of a utility's distribution transformers in a database application regularly. This database will be a valuable resource for utility

transformer information. Analyses of the recorded data will assist the utility in monitoring the functioning of its distribution transformers and identifying issues before they become catastrophic, resulting in considerable cost savings and improved system dependability.

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