International Journal of Reconfigurable and Embedded Systems (IJRES)
Vol. 11, No. 3, November 2022, pp. 275~283
ISSN: 2089-4864, DOI: 10.11591/ijres.v11.i3.pp275-283

Monitoring and control of single-phase electrical systems using IoT based microcontrollers

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Article Info

Article history:

Received Jul 9, 2022
Revised Aug 7, 2022
Accepted Sep 11, 2022

Keywords:

Arduino
Current sensor
Grid
Internet of things
Voltage sensor

ABSTRACT

The internet of things (IoT) has a significant impact on increasing the efficiency and quality of electricity in large power systems. Smart voltage and current monitoring systems (SVCMS) have been developed using a novel method. Using an Arduino Uno microcontroller and a Wi-Fi module, the integrated SVCMS design measures voltage and current sensor findings and sends the processed data to an Android phone. In order to communicate, the global systems for mobile communication (GSM) module is required. When anything goes wrong, an Android app may be used to notify users by text message or email and help them take the right action. It is possible to remotely monitor and control the operation of a gadget using logical programming techniques in Arduino which results easy load control.

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1. INTRODUCTION

The 'Monitoring and controlling of substations using internet of things (IoT)' project proposes a revolutionary architecture for constructing a microcontroller-based system. A single-phase system's voltage, current, and temperature are all monitored and protected by this device. Overloading, overheating, and high input voltage can all lead to equipment failure if they aren't properly monitored and controlled. In the event that any of these values surpass the limit, an electromagnetic relay [1] is activated to shut down the whole unit. When the parameters surpass the preset threshold values, this relay is triggered. The relay also functions as a circuit breaker, shutting down the main power source.

The global systems for mobile communication (GSM) module are used to communicate real-time electrical parameters through the short message service (SMS). When the parameters (voltage, current, and temperature) surpass the specified limitations, the system sends SMS notifications to the authorised individual [2]. The voltage is lowered via transformers, and the electricity is then distributed to end customers via distribution networks.

Distribution substations receive power from the transmission grid and scale it down to less than 10kV before distributing it to commercial, residential, and industrial customers through smaller distribution lines. System monitoring and control help to ensure that clients receive safe power [3], [4]. The system is made up of various electronic components such as transformers, circuit breakers, relays, and so on. Overheating is caused by transformer fluid leaks or internal insulation degradation, which leads to failures [5]. A time-consuming and inaccurate method of system verification still in use today calls for routine human inspection. Additional time is required to take corrective action for remote substations because of the difficulty of physically monitoring them. Automation of single phase systems is the solution to all of these issues [6].

Various characteristics such as current, temperature, and voltage are constantly evaluated using sensor module [7]. The microcontroller receives the outputs of these sensors as input. The microcontroller is preconfigured in such a way that if any of the parameters surpass a specified threshold value, it will notify the authorised person via wireless communication technologies such as GSM [8]. The internet of things (IoT) plays a key role in boosting efficiency in complicated power systems [9], [10]. The current system uses an Arduino platform as a microcontroller to read voltage, current, temperature, and frequency from sensors, then transmits the measured data and monitors the results for a single-phase electrical system.

2. BLOCK DIAGRAM

A 230V AC voltage is given as input to the transformer which convert 12-14V AC then, the voltage is given to the rectifier circuit that convert AC voltage to DC voltage, hence rectifier output will be 12V DC. Therefore, an input Voltage of 12V is supplied for the relay and buzzer. A 5V DC constant supply given to the Arduino. IC-7812 and 7805 gives constant 12V DC and 5V DC and filter circuit is used for the removing ripples from the output. In this project, digital humidity and temperature (DHT)-sensor is used for the temperature measurement, it gives temperature value, if temperature exceeds above certain level, then it sends SMS to authorized person using GSM and other parameters like voltage, current and frequency are displayed on the LCD. To measure the voltage, a rotational potentiometer by which voltage can be increased or decreased. When voltage is increased above certain level then its ends SMS to authorized person using GSM. Current sensor is used for current measurement if load is 60 W then current is small but if load will be increase then it sends SMS. To vary frequency LM358 and 555 IC are used. 555 IC generates square wave and it gives constant frequency so we are using pot for changing the frequency and also LM358 is used for giving constant 50 Hz frequency. LM358 using one zero crossing circuit is used that gives constant 50 Hz frequency. If any of the parameter increases beyond threshold level then buzzer will be on and relay will be off and the state of the system is sent through SMS using GSM [11], [12]. Figure 1 shows the block diagram of monitoring system using IoT.

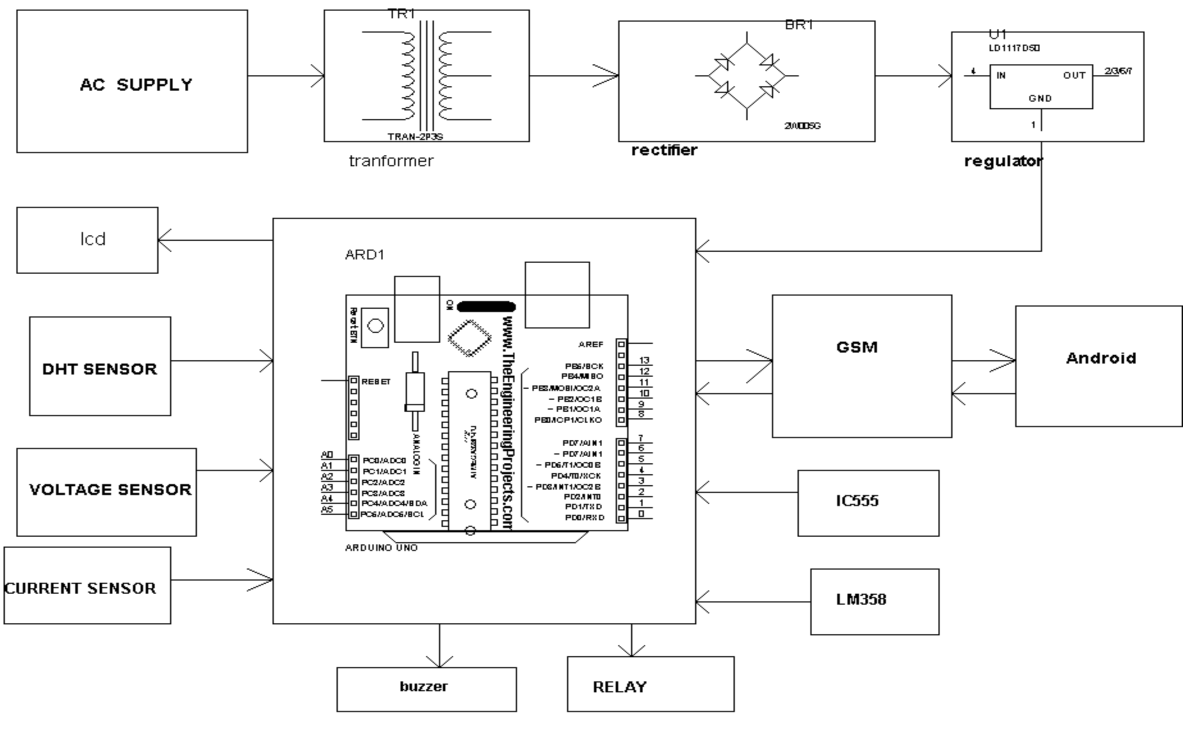

Figure 1. Block diagram of single-phase monitoring system using IoT

Microcontroller is very important in this research work. All hardware components must connect according to block diagram. According to user requirement, the programming also will be change. Basic operation of block diagram Figure 1under several load ON/ OFF conditions are discussed as follows: i) if Load ON, SMS sent to GSM-module then relay will be on and SMS is sent to particular person that SMS is turned ON; ii) if Load OFF, SMS sent to GSM then relay will be off and SMS is sent to particular person that SMS is turned OFF; and iii) if 'STATE' SMS sent to GSM-module, it sends all the values of parameters the temperature Voltage current and frequency along with its present state.

2.1. Hardware requirements

Hardware componentsforobtaining the actual output from research work of single-phase monitoring system using IoT in order to implement hardware setup, we need components Arduino Uno, Potentiometer, DHT sensor, IC 555, LM358 IC, GSM, transformer, diodes, voltage regulator, resistors, capacitors, LCD, relay, buzzer, and LEDs. Due to these valuable components work become quicker and more convenient. Based on block diagram, hardware components connected and perform a good response. This research work used lower weight components to develop actual model. Hence it will be portable and easy to repair or replace. While chosing hardware components must include quality, cost and size of components.

2.2. Arduino

Free and open-source electronic project creation software is available through Arduino shown in Figure 2. With the help of an integrated development environment (IDE) that runs on your computer, you may write and upload computer code to the physical board. Arduino boards are able to read inputs- light on sensor, a finger on button or message and turn it in to output-activating a motor or turning ON LED. It will enable user to create interactive electronic objects. Based on wiring Arduino programming language used. And based on processing Arduino software used. You can tell your board what to do by sending a set of instructions to the microcontroller on the board. It is easy to use and relatively inexpensive.

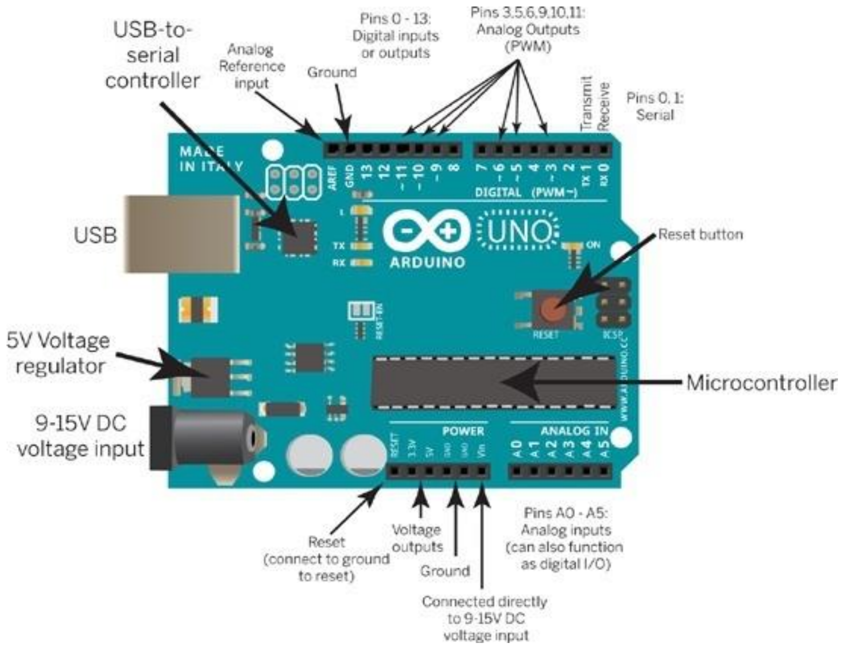

Figure 2. Arduino Uno module

2.3. GSM module

A wireless network technology based on TDMA called GSM (global system for mobile communications, formerly group special mobile) has been around since it was created and various components in GSM module appear in Figure 3. Using a SIM card to identify a user's account on a GSM phone is mandatory. Customers of GSM networks may easily move their phone numbers from one GSM phone to another by simply swapping out the SIM card. The 850 MHz, 900 MHz, 1,800 MHz, and 1,900 MHz frequency bands are now used by GSM networks. Quad-band devices support all four bands, while tri-band and dual-band devices only support three or two bands, respectively.

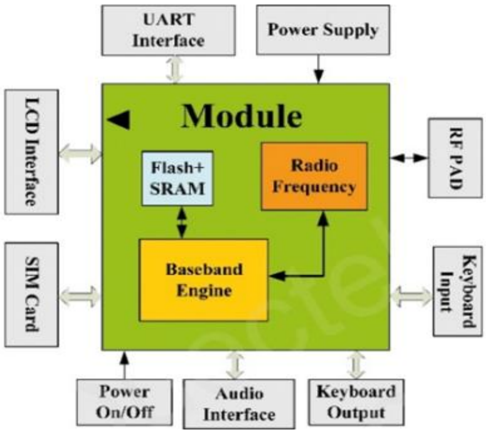

Figure 3. GSM module

2.4. Relay

Wire coils wrapped around a soft iron core, a low-resistance path for magnetic flux, a moving iron armature, and one or more contact sets are the essential components of an electromagnetic relay. The armature is attached to the yoke by a hinge and is mechanically connected to one or more sets of moveable contact points. An air gap forms in the magnetic circuit when the relay is deactivated due to the spring holding it there. When the relay is in this state, the first set of contacts is closed and the second set is open. Other relays may have more or fewer connections depending on their purpose. In the example, a wire links the armature to the relay's yoke. This ensures that the armature's moving contacts and the circuit track on the printed circuit board (PCB) are connected through the yoke, which is attached to the PCB. Coil current activates the armature and generates a magnetic field, which in turn activates the movable contacts and either makes or breaks a connection with a permanent contact (depending on design) [13], [14]. Relay de-energizing the contacts causes them to open and disconnect, and if the contacts were open when the relay was de-energizing, it causes them to close. In order for the armature to return to its relaxed condition, the coil's current must be turned off for a period of time. However, gravity is also commonly employed in industrial motor starters to provide this force. It is common for relays to operate quickly. This reduces arcing in high-voltage or current applications and minimises noise in low-voltage applications. If a diode is placed across the coil while it is charged with direct current, it acts as a dielectric to dissipate any resulting voltage spike that may otherwise injure semiconductor circuit components when the coil is deactivated. Prior to the widespread usage of transistors as relay drivers, such diodes were rarely used, but as early germanium transistors were easily destroyed by this surge, their use swiftly spread [15].

2.5. DHT sensor

As water vapour in the air increases, the humidity of the air decreases. Physical, chemical, and biological processes are all affected by the amount of humidity in the air. With regards to product pricing and health and safety of employees, humidity may have a significant influence in industrial settings. Humidity measurement is used to estimate the amount of moisture in the gas, which can be water vapour, nitrogen, argon, or pure gas. DHT11 is a sensor that measures both humidity and temperature [16]. An inexpensive digital temperature and humidity sensor, the DHT11, may be found on eBay. Humidity and temperature may be monitored in real time by connecting this sensor to a microcontroller such as the Arduino or Raspberry Pi, as shown in Figure 4.

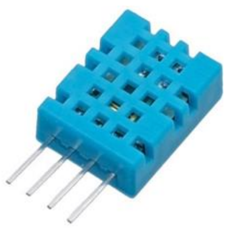

Figure 4. DHT sensor

Sensor and module versions of the DHT11 humidity and temperature sensors are available. This sensor may be distinguished from the module by a pull-up resistor and a power-on LED. Relative humidity is measured via the DHT11 sensor. This sensor measures the humidity in the air using a thermistor and a capacitive humidity sensor. Using a capacitive humidity sensor and a thermistor, the DHT11 sensor is able to measure both humidity and temperature. A moisture-holding substrate serves as a dielectric between the humidity sensor capacitor's two electrodes [17]. Humidity has an effect on capacitance values. Analog resistance measurements are digitised using the integrated circuit (IC).

3. PROTOTYPE MODEL

Prototype model is developed to monitor the parameters continuously and perform suitable control action (turn ON and OFF relay and buzzer) under various conditions as shown in Figure 5. A quality equipment must need to develop the model of single-phase monitoring system using IoT. The prototyping model is a systems development method in which a prototype is built, tested and then reworked as necessary until an acceptable outcome is achieved from which the complete system or product can be developed. As per end user requirement the prototype model will change: i) Arduino microcontroller, ii) GSM-module, iii) DHT-sensor, iv) potentiometer, v) step-down transformer, vi) current transformer, vii) LCD, viii) buzzer, ix) relay, x) lamp holders, xi) lamps, xii) diodes, resistors and transistor, and xii) miscellaneous items (push button, nuts, screws, plastic board).

Figure 5. Hardware kit to monitor and Control single phase system using IoT

Maximum values of parameters beyond which system enters into abnormal condition [18], [19]:

a. Under frequency: less than 45 Hz (<45 Hz)
b. Over frequency: greater than 55 Hz (> 55 Hz)
c. Over voltage: greater than 250 V (>250 V)
d. Under voltage: less than 210 V (<210 V)
e. Over current: greater than 1A (>1A)
f. Over temperature: greater than 40 ^{o}C (>40 ^{o}C)

4. RESULTS AND DISCUSSION

The simulation model as shown in Figure 6 is designed to monitor the parameters and to turn ON and OFF D1 (Relay) and D2 (buzzer) under normal and abnormal conditions. The main aim of the simulation model is to control the operation of D1 (Relay) and D2 (buzzer) under normal and abnormal conditions. It consists of four sensors which are connected to Analog pins (A0, A2, A4, and A5) of Arduino module. Transmitter (TX) and receiver (RX) pins of Arduino module are connected to receiver (RXD) and transmitter (TXD) pins of virtual terminal. It also consists of reset button which is used to restart the simulation model, when value of current is greater than threshold value. It also displays a message current overload and press reset in LCD. D1 (Relay) and D2 (buzzer) are connected to digital pins 10 and 12 of Arduino module.

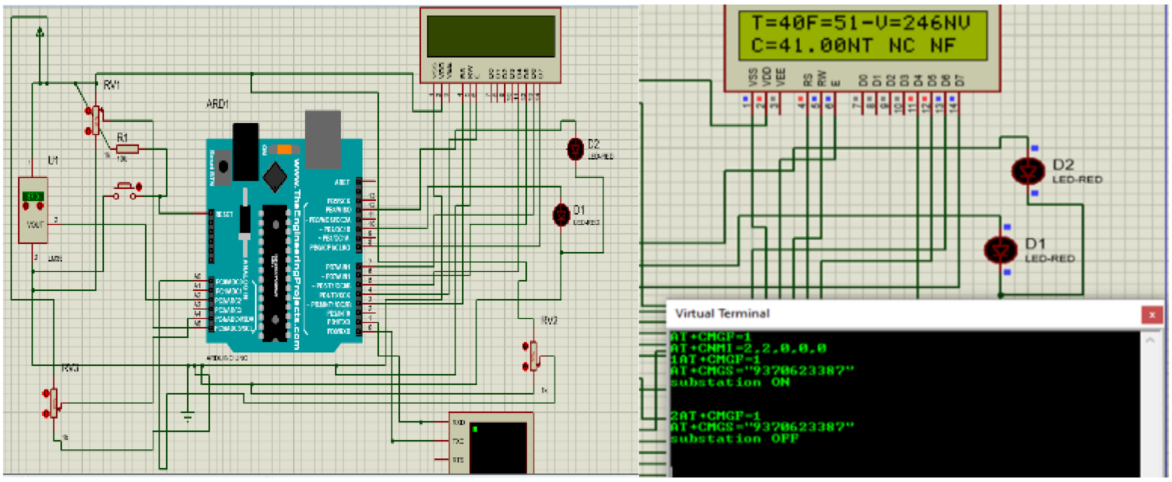

Figure 6. Simulation diagram to monitor parameters (voltage, current, temperature, and frequency) by PROTEUS software and manual mode: Input: ‘2’ Substation Off: Relay off and buzzer off under normal condition

4.1. Mode of operation: manual mode

In the developed simulation model as shown in Figure 6, upper LED-RED (D1) is analysed as relay and lower LED-GREEN (D2) is analysed as buzzer. In manual mode of operation, when all the parameters are below threshold values or system is in healthy condition, relay is turned on and buzzer is turned OFF. In manual mode of operation when the system parameters are in abnormal condition, the system is turned OFF and is indicated by turning OFF the upper and lower LED. In the above figure the system received input as ‘2’ from the user. It will enter into manual mode of operation. Under this condition the system is turned OFF. It is identified by observing the state of upper LED (Relay), in this condition it is turned OFF which is analysed as relay is turned OFF. The system is in healthy condition because all the parameters are below threshold value, so buzzer is turned off. It is identified by observing the state of lower LED-RED. The status messages that are displayed by system to the user [20], [21].

4.2. Mode of operation: auto mode

Input from user: 3. In this case, the system received input ‘3’ from the user which is displayed through virtual terminal. When the system receives input 3, it will enter into automatic mode of operation [22]–[24].

Case (i): under normal conditions. In this mode of operation, when all the parameters are below threshold value or the system is in healthy condition, the system turns on relay and turns OFF the buzzer automatically. When lower LED-RED (buzzer) is turned OFF it indicates the system is in healthy condition. Under this condition relay is turned ON and buzzer is turned OFF which is represented as: D1 (Relay): turn ON and D2 (buzzer): turn OFF.

Case (ii): under abnormal conditions. In this mode of operation, when the parameters are above threshold value or the system is in abnormal condition, the microcontroller turns OFF relay and turns ON the buzzer automatically. When lower LED-RED (buzzer) is turned ON, it indicates the system is in abnormal condition. Under this condition relay is turned OFF and buzzer is turned ON, which is represented as: D1 (Relay): turned OFF, and D2 (buzzer): turned ON. Therefore, by observing the state of buzzer the condition of the system can be determined as shown:
D2 (buzzer) OFF: system is in healthy condition (NV, NC, NT, NF),
D2 (buzzer) ON: system entered into abnormal condition (UV or OV, UF or OF, OC, OT).

4.3. Test cases

The Figure 7 describes the condition of the system when ‘Load on’ command is passed as an input to the user. It is also confirmed by indicating to the end user with text message ‘system ON’ which is transmitted through GSM-module. In this prototype model, lamps are used as load [25]. Whether the system is turned on or off, it can be identified by status of lamp. In this case the light is turned ON which indicates system is turned ON and also indicated to the end user via text message as shown in Figure 7.

Figure 7. System turned ON under normal conditions using input command

The Figure 8 describes the state of the system, in which the system sends the values of parameters (voltage, current, temperature and frequency) to the end user when it receives input command 'STATE' from user. Since, in this condition all parameters are below threshold and the system is turned ON which is indicated by the status of the lamp [26], [27]. The system is turned off when it receives input from the user in manual mode of operation, because when the system is operated in 'AUTO MODE' it does not require any input from the user to turn ON and OFF the system. It is indicated by observing the status of lamp which are used as load and also indicated to the end user via text message using GSM-module as shown in Figure 9.

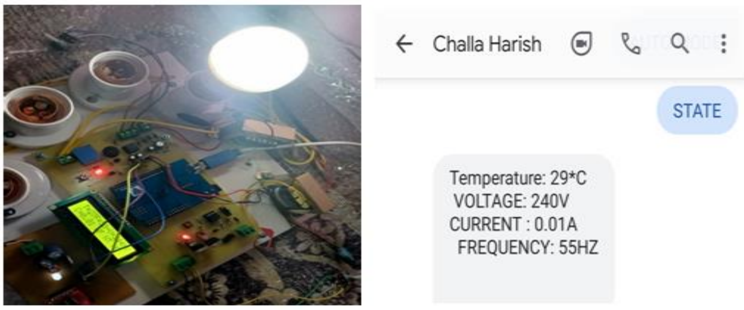

Figure 8. Operation of system under normal conditions and describing the state of system

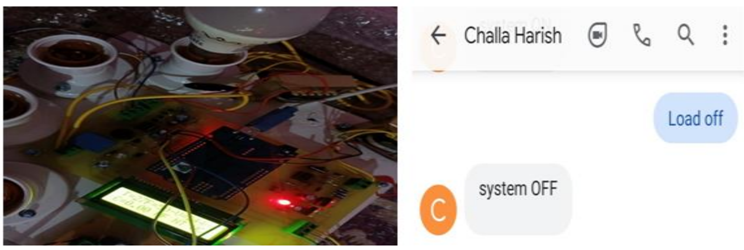

Figure 9. System turned off under normal condition using input command

When the frequency of the system is beyond threshold (UF or LF), the system is turned off and buzzer produces an alarm signal to indicate the system entered into abnormal condition. It is also intimated to the end user via text-message by displaying abnormal condition along with its value at that instant as shown in Figure 10. In this case the prototype model is tested with under frequency condition which is displayed as UF in LCD as shown in Figure 10. Similarly, the prototype model is tested under various abnormal conditions.

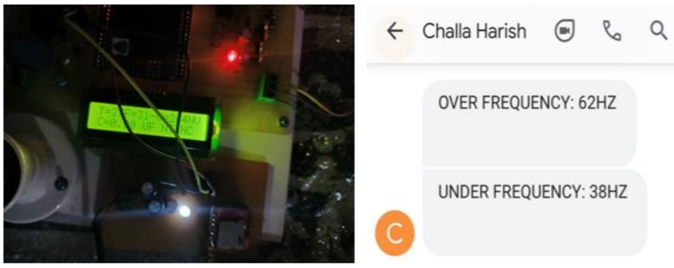

Figure 10. System turned off when parameters are beyond threshold

5. CONCLUSION

Hence, a monitoring system using GSM communication was developed and tested under various conditions (over voltage, under voltage, over frequency, under frequency, over current, over temperature) successfully and provides an intimation to end-user when parameters increase beyond threshold value. The prototype-model is developed and tested under various abnormal conditions such as (over voltage, under voltage, over frequency, normal temperature and over temperature) and provides intimation to end user via GSM-module. A Simulation model has been developed using ‘PROTEUS-software’ to monitor the various parameters such as voltage, current, frequency, temperature of substation which can be operated in manual and automatic mode and provides intimation to the user through virtual terminal.

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