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Remote Substation Monitoring in a Distribution Power Grid

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Abstract- Monitoring and control of distribution transformers is desired by any distribution utility company in view of many reasons. Distribution transformers are located in remote places in order to supply power to few categories. In order to provide good and reliable power automation has become an essential part in the distribution network. Monitoring and controlling essentially require the data from the grid, analysis of the data and controlling the devices on the network on the basis of evaluated results. Objective of this paper is to design the cost effective model for monitoring the remote electrical parameters like voltage, current, temperature of a transformer and send these real time values over network to a remotely located substation or a device. This system can automatically update the real time electrical parameters periodically (based on time settings). This system can be designed to send alerts whenever the relay trips or whenever the voltage or current exceeds the predefined limits. This experimental setup is a prototype of the proposed project, for demonstration purpose we have used Arduino and Raspberry Pi here. The controller can efficiently communicate with the different sensors being used by detecting the abnormal operating conditions.

Keywords- Substation monitoring, transformer monitoring, IOT.

I. INTRODUCTION

Starting from the generation to transmission to distribution, the electrical networks and their controllers are highly non-linear, huge and complex. The complex power system is operated united for economic benefit, enhanced reliability and other operational advantages like automatic monitoring and control of various devices associated with the network.

As a whole, components of Generation, transmission and distribution systems, their operational strategies and controllers is one of the most significant elements in both national and global infrastructure. When any of these systems collapses it leads to major direct and indirect impacts on the economy and National security. In the broad spectrum a power system is considered to comprise of components such as generators, lines, transformers, loads, switches and compensators. Generally in the configuration of modern power systems sources and loads are widely dispersed along with localized generations. Today electricity still suffers from power outages and blackouts due to the lack of automated analysis and poor visibility of the utility over the grid.

The utility is not having the visibility of the loads at the remote places especially at the low voltage levels. A Wireless Sensor Network (WSN) may provide the utility a needed view by collecting information from different sub-systems of the grid.

The system designed and implemented can be considered as an embedded system as this performs the predefined tasks like monitoring, storing and controlling the parameters of the substation. The Embedded system includes two major sections,

- Hardware
- Software.

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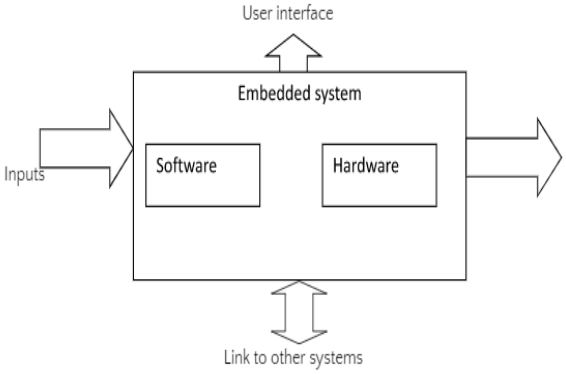

Fig 1. Layout of an embedded system.

This embedded system requires a hardware platform that is built with a microprocessor or microcontroller. The hardware has input output (I/O) interfaces, user interface, memory and the display. This system specifically needs power supply, appropriate processor, timers, memory, serial communication ports, application specific circuits, input and output circuits. Microcontrollers ae preferred as they are on chip computers with RAM,ROM and I/O ports, compact in size, available at low cost and can be used for specific purpose.

Software is developed to perform specific tasks. Required tasks are developed; software is written in a high level language format and then compiled. Compiling provides the code that can be lodged within a non-volatile memory of the hardware. For such embedded systems software is designed by keep in view of the availability of system memory and availability of processor's speed. When the system runs continuously, there is a need to limit power dissipation for certain events.

Following Figure 2 represents the general layout of the system with various hardware components. To make software to work for a specific task hardware and software are to be brought together to work synchronously. The source code is to be transferred to microcontroller which is a hardware component and which takes care of all operations to be done by embedded system according to the code. Generally source codes are in assembly language, but the processors run only executable files.

The process of converting the source code into an executable binary image involves the following three distinct steps.

- Each of the source files must be compiled or assembled into an object file.
- All of the object files that result from the first step must be linked together to produce a single object file, called the re-locatable program.
- Physical memory addresses must be assigned to the relative offsets within the re-locatable program in a process called relocation. The result of the final step is a file containing an executable binary image that is ready to run on the embedded system.

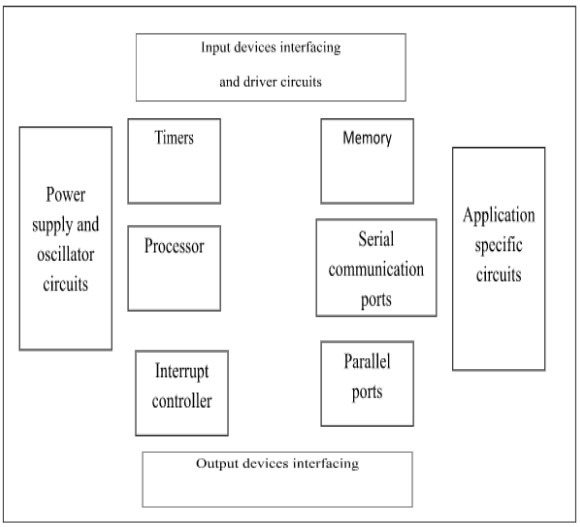

Fig 2. Components of embedded system.

II. LITERATURE REVIEW

Amol Ram Kate, in [1] developed a substation monitoring system which can monitor the substation by using a wireless technology called IOT. An IOT module provides the communication interface. Voltage, current, frequency and temperature are monitored. The project is designed in such a way that sensors are interfaced to the controller. This is implemented by using Arduino.

The purpose of the work done by Krupal Dhimar et. Al. in [2] is to acquire the remote electrical parameters like voltage, current and frequency and send these real time values over GSM network using GSM modem/phone along with temperature at power station. User can send commands in the form of sms messages to read the remote electrical parameters. This system also can automatically send the real time electrical parameters periodically (based on time settings) in the form of sms.

This system can be designed to send sms alerts whenever the relay trips or whenever the voltage or

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current exceeds the predefined limits. The controller is programmed using embedded c language. As complexity of distribution network has grown, automation of substation has become a need of every utility company to increase its efficiency and to improve quality of power being delivered.

Ghous Buksh Narejo [3] proposed a simulation model using protues in which a GSM cellular network-based controlling of substation is done. Authors in [4] developed mathematical models for Real-time condition monitoring of substation equipment using thermal cameras. A substation monitoring and control scheme is developed in [5] by 8051 micro controller. But this scheme did not employ any communication devices at the remote end.

A cost effective model is designed and implemented to reduce the manual reference and to monitor different parameters of transformers in a substation. Care is taken to trip the circuit under few predefined abnormal operating conditions. Designed system in this paper is helpful for managing the systems under abnormal conditions, remote access and monitoring. This system can find applications in substations, industries to monitor transformers or loads directly.

III. PROPOSED SYSTEM

An experimental setup is developed for monitoring and controlling of parameters in a substation using Raspberry Pi processor. Electrical parameters like voltage, current, temperature of a transformer are measured remotely and these real time values are communicated over network to a remotely located substation or a device. The current sensor measures the value of the bulb and it is interfaced with the Arduino.

The data of current sensor will be sent to the Raspberry Pi and the values are displayed on LCD. The voltage sensor checks the variation in voltage. If any deviation is seen from the preset values, an SMS will be sent to the registered mobile as an alert in the initial stage. The relay will operate to isolate the circuit during abnormal conditions.

As the sensors connected to raspberry pi are Analog these are connected to ADC module so that the values will be displayed on the LCD. The controlling of the loads can also be done by using Adafruit. The simple block diagram of the experimental setup is shown in Fig 3.

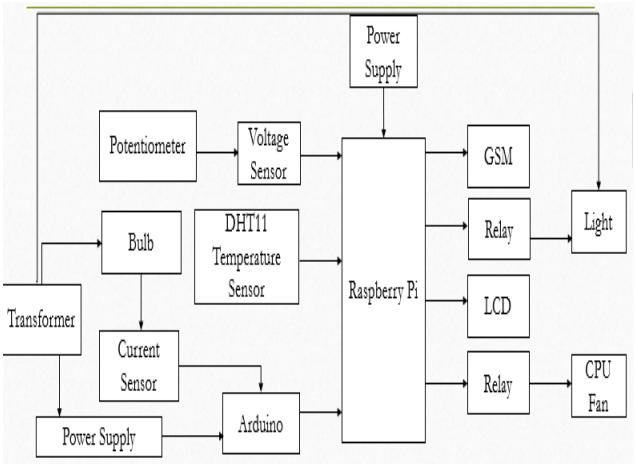

Fig 3. Interconnection of hardware components.

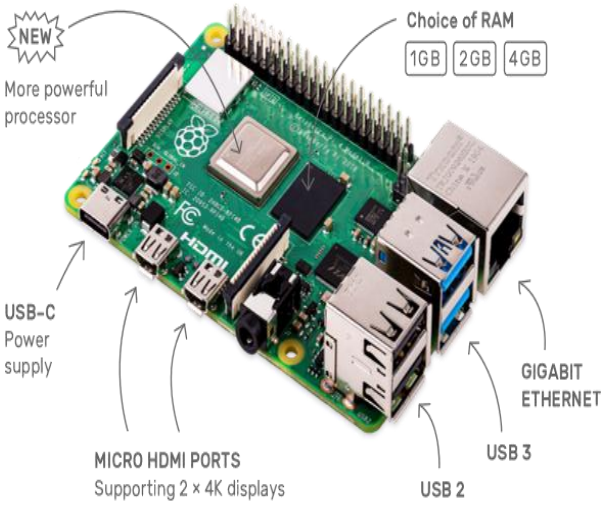

Fig 4. Raspberry Pi 4 Board.

1. Raspberry Pi 4 is the main processor where the on board:

Mini size computer used mostly to run larger and smart programs to achieve output quickly. Raspberry Pi 4 B+ (RP4) is one of the models developed by the company, which has all the required latest wired and wireless communications systems used in most of the smart projects. A single Raspberry Pi 4 comes to a Quad-Core processor but it has three different versions which give three different sizes of RAM. Pi 4 uses mini HDMI and it also has two ports for two 4K displays.

2. Modern Communication Support:

Raspberry Pi 4 has all modern communication systems. It has **internal Wi-Fi** and **Bluetooth** for wireless data communication. It can be used with internal at anywhere without any disturbance. The Pi

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can be moved easily within the same network due to fast Wi-Fi support. The device also has LAN support in case Wi-Fi is not available and the network is following the wired communication method to communicate.

- LAN – Gigabyte Ethernet
- Bluetooth – 5.0
- Wi-Fi – 2.4 with 5GHz speed

3. Rpi HDMI Interface Feature:

In previous Pi devices, there was only one HDMI port and it also has low graphics, but in the latest model there two mini HDMI ports that can be used at the same time for multiple desktop views. Both ports give a 4K ULTRA HD view to the user. It never feels that the user is viewing a mini-size computer.

- GPU SPECS – H264 (1080p60 decode, 1080p30 encode) OpenGL ES 3.0 graphics, H.265 (4kp60 decode)

4. SD Card:

It is the most required part of the Raspberry Pi. The OS of the Pi will be placed within the SD card and then the card will be used through the SD Card slot.

IV. ARDUINO NANO

The Arduino Nano is a small, complete, and breadboard-friendly board based on the ATmega328 (Arduino Nano 3.0) or ATmega168 (Arduino Nano 2.x). It has more or less the same functionality of the Arduino Duemilanove, but in a different package. It lacks only a DC power jack, and works with a Mini-B USB cable instead of a standard one. The Nano was designed and is being produced by Gravitech.

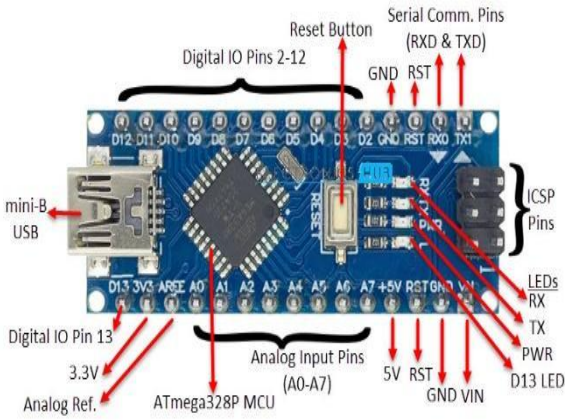

Fig 5. Arduino Nano Board.

ACS712 Current sensors, DHT11 temperature sensor, EC2173 voltage sensors are different components used in broader view. 16X2 LCD display is the output device on the board. The setup is made to communicate with the computer, VNC viewer software has enabled to do so. Advanced IP scanner will allow to detect the experimental setup kit and to access the kit from computer.

Circuit is designed and schematic is prepared primarily (Figure 6) with Proteus software tool. Then printed circuit board is organized (Figure7).

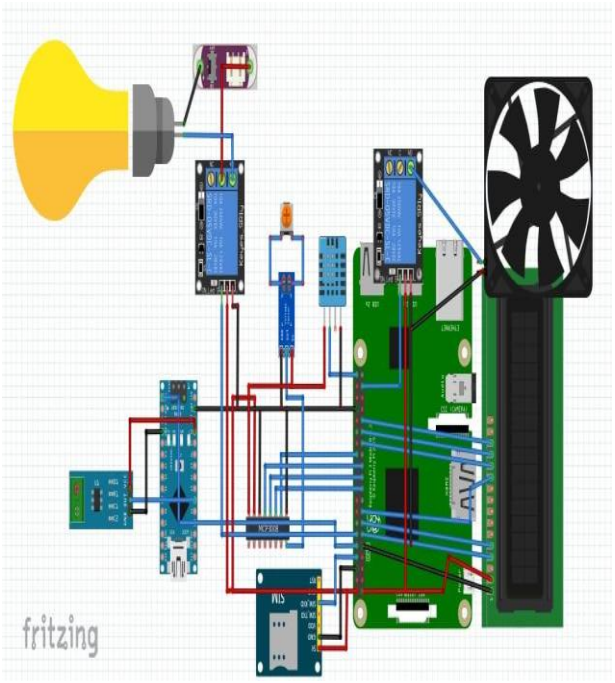

Fig 6. Schematic diagram.

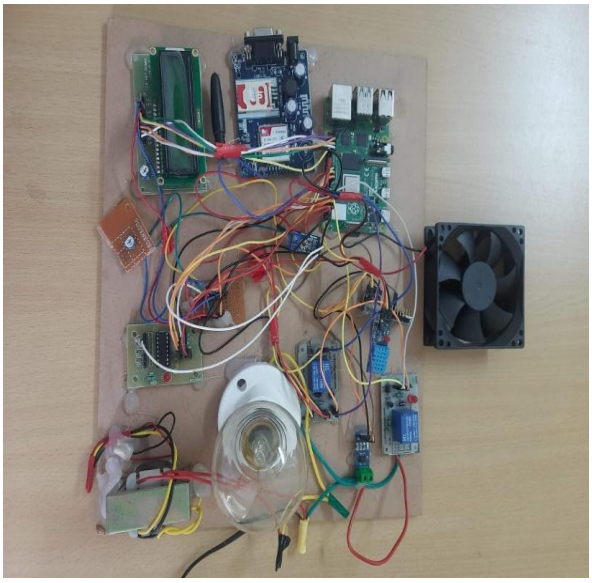

Fig 7. Hardware model indicating the components.

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V. EXPERIMENTATION AND RESULTS

Several case studies are performed to check the operation of the experimental setup. Three cases are presented (i) Normal Mode (ii) High voltage and (iii) High current.

Normal parameters are 50 degrees temperature, 250V and 2.0A.

1. Normal mode:

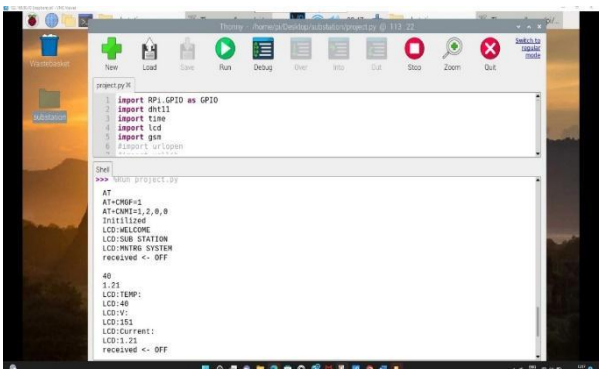

Fig 8. Normal mode output from VNC viewer.

Fig 9. Normal mode Output from LCD display.

2. High Voltage:

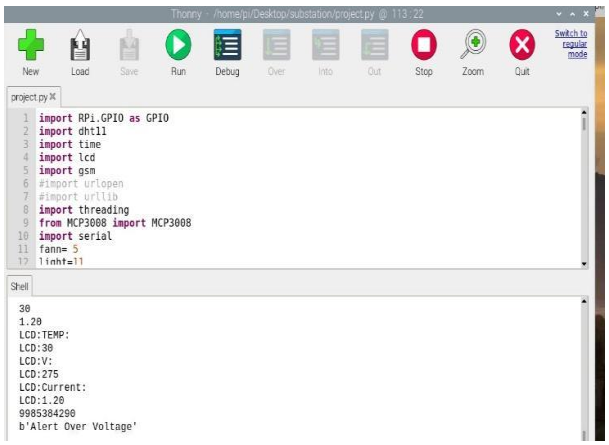

Fig 10. High voltage condition - Output from VNC Viewer.

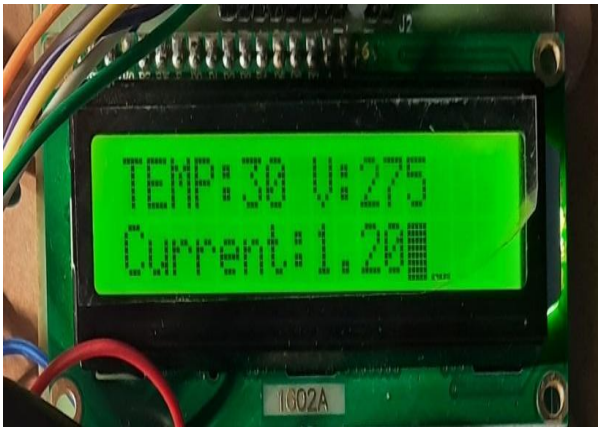

Fig 11. High voltage condition - Output from LCD screen.

3. High Current:

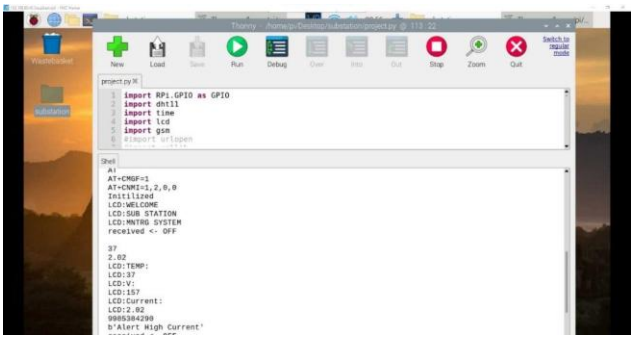

Fig 12. High current - Output from LCD screen

Fig 13. High current - Output viewed from VNC viewer.

VI. CONCLUSION

Monitoring means acquiring significant parameters from the sensors used. The acquired data is feasible to be used for analyses and identify the condition of the modules which is of great use for maintenance scheduling, failure management and controlling system and this method minimizes time contact between human and power devices.

The greatest issue is to have all the transformers data at a single sink when the data is collected manually.

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This proposed system is specially designed for monitoring the condition of substation transformers which are deployed at dispersed locations.

This system can automatically update the real time electrical parameters periodically (based on time settings). This system can be designed to send alerts whenever the relay trips or whenever the voltage or current exceeds the predefined limits. This experimental setup is a prototype of the proposed project, for demonstration purpose we have used Arduino and Raspberry Pi here. The controller can efficiently communicate with different sensors being used by detecting the abnormal operating conditions.

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