iJRASET
International Journal For Research in
Applied Science and Engineering Technology

INTERNATIONAL JOURNAL
FOR RESEARCH
IN APPLIED SCIENCE & ENGINEERING TECHNOLOGY

Volume: 8 **Issue:** V **Month of publication:** May 2020

DOI: http://doi.org/10.22214/ijraset.2020.5499

International Journal for Research in Applied Science & Engineering Technology (IJRASET)
ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 7.429
Volume 8 Issue V May 2020- Available at www.ijraset.com

Substation Automation Operation and Protection

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Abstract: Substation Automation is a key concept in Smart Grid Technology. The present work proposes an Internet of Things (IoT) based system for the monitoring, visualization, storage and analysis of sensor data in an easy, cost effective and reliable manner. MQ Telemetry Transport (MQTT) protocol is used to communicate and transfer data between different sensor nodes using Raspberry Pi 3 as the MQTT broker. The sensor nodes are capable of wirelessly transferring the sensor data using an arduino Uno and ESP8266. The sensor data can be conveniently accessed by any device on the network from the MQTT broker by subscribing to it. The given sensing system intends to complement and enhance the capabilities of the present substation automation environment. It incorporates the possibility of remote accessibility and better data analysis of the sensor data in the Substation environment. An arduino a part of the ongoing implementation of the system which will be described in further works.
Keywords: Protection, Operation, Power System, Smart Grid, etc.

I. INTRODUCTION

Electricity is an extremely handy and useful form of energy. It plays an ever-growing role in our modern industrialized society. The electrical power systems are highly non-linear, extremely huge and complex networks. Such electric power systems are unified for economic benefits, increased reliability and operational advantages. They are one of the most significant elements of both national and global infrastructure, and when these systems collapse it leads to major direct and indirect impacts on the economy and national security. A power system consists of components such as generators, lines, transformers, loads, switches and compensators. However, a widely dispersed power sources and loads are the general configuration of modern power systems. Electric power systems can be divided into two sub - systems, namely, transmission systems and distribution systems. The main process of a transmission system is to transfer electric power from electric generators to customer area, whereas a distribution system provides an ultimate link between high voltage transmission systems and consumer services. In other words, the power is distributed to different customers from the distribution system through feeders, distributors and service mains. Supplying electricity to consumers necessitates power generation, transmission, and distribution. Initially electric power is generated by using electric generators such as: nuclear power generators, thermal power generators and hydraulic power generators and then transmitted through transmission systems using high voltage. Such assets comprise:

A. Power plants,
B. Transmission lines,
C. Transformers,
D. Protection Equipment.

Electric utility substations are used in both the transmission and distribution system and operate independently to generate the electricity. It plays an ever-growing role in our modern industrialized society.

II. TOOLS

A. Raspberry PI

Fig 1. Raspberry Pi module

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The Raspberry Pi 3 Model B+ is the latest product in the Raspberry Pi 3 range, boasting a 64-bit quad core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT The dual-band wireless LAN comes with modular compliance certification, allowing the board to be designed into end products with significantly reduced wireless LAN compliance testing, improving both cost and time to market. The Raspberry Pi 3 Model B+ maintains the same mechanical footprint as both the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B.

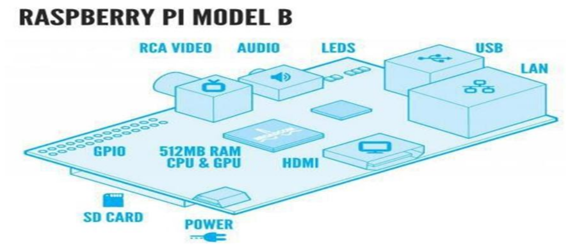

Fig.1 Rapberry Pi model B

B. Current Sensor

Accurate sensor to measure AC/DC current up to 20A. The sensor can even measure high AC mains current and is still isolated from the measuring part due to integrated hall sensor. The board operates on 5V. ACS712 current sensor operates from 5V and outputs analog voltage proportional to current measured on the sensing terminals. You can simple use a microcontroller ADC to read values.

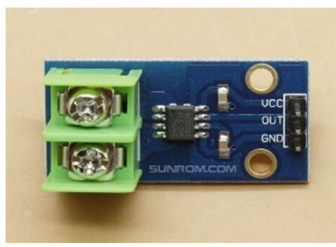

Fig 2 Current sensor

C. Voltage Sensor

Fig 3 Voltage sensor

This module is based on resistance points pressure principle, and it can make the input voltage of red terminal reduce 5 times of original voltage. The max Adriano analog input voltage is 5 V, so the input voltage of this module should be not more than 5 V x 5 = 25 V.Because the arduino AVR chip have 10 bit AD, so this module simulation resolution is 0.00489 V (5 V / 1023), and the input voltage of this module should be more than 0.00489 V x 5 = 0.02445 V.

D. IOT Module

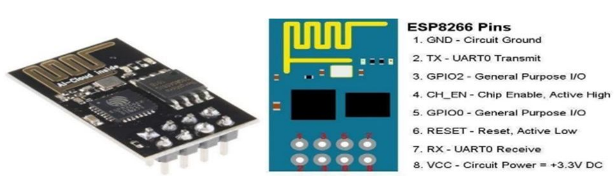

Fig 4 IOT Module

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The ESP8266 is a low-cost Wi-Fi microchip with full TCP/IP stack and micro controller capability produced by manufacturer Express if Systems in Shanghai, China. The chip first came to the attention of western makers in August 2014 with the ESP-01 module, made by a third-party manufacturer Ai Thinker. This small module allows micro-controllers to connect to a Wi-Fi network and make simple TCP/IP connections using Hayes-style commands. However, at first there was almost no English-language documentation on the chip and the commands it accepted. ESP8266EX offers a complete and self-contained WIFI networking solution; it can be used to host the application or to offload WIFI networking functions from another application processor. When ESP8266EX hosts the application, it boots up directly from an external flash. In has integrated cache to improve the performance of the system in such applications.

E. Temperature Sensor

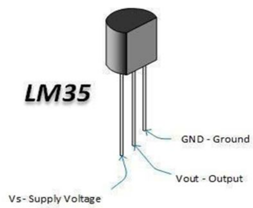

Fig 5 Temperature sensor

The LM35 can be connected easily in the same way as other integrated circuit temperature sensors. It can be stuck or established to a surface and its temperature will be within around the range of 0.01˚C of the surface temperature. This presumes that the ambient air temperature is just about the same as the surface temperature; if the air temperature were much higher or lower than the surface temperature, the actual temperature of the LM35 die would be at an intermediate temperature between the surface temperature and the air temperature. The temperature sensors have well known applications in environmental and process control and also in test, measurement and communications. A digital temperature is a sensor, which provides 9-bit temperature readings. Digital temperature sensors offer excellent precise accuracy, these are designed to read from 0°C to 70°C and it is possible to achieve ±0.5°C accuracy. These sensors completely aligned with digital temperature readings in degree Celsius.

F. Relays

A relay is an electrically operated switch. Many relays use an electromagnet to mechanically operate a switch, but other operating principles are also used, such as solid state relays. Relays are used where it is necessary to control a circuit by a separate low power signal, or where several circuits must be controlled by one signal. The first relays were used in long distance telegraph circuits as amplifiers: they repeated the signal coming in from one circuit and re-transmitted it on another circuit. relays were used extensively in telephone exchanges and early computers to perform logical operations.

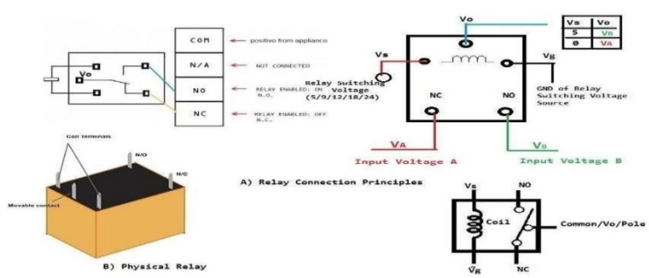

Fig 6 Types of relays

With circuit breaker From the symbolic diagram we can see from the source line Electric power is coming through the CB to the Bus Bar. Now if a fault _F_ i through the line. Now we can see before CB a CT is there for protection. CT ratio is designed to detect the fault current ie; if the current is more than the CT ratio then it is treat as fault current. When such type of current is flow through line then CT secondary energized .The relay coil, this relay coil close the path of trip circuit, trip circuit get power by the DC source which energized the trip coil, this trip coil give the trip pulse to the CB, and CB is operate to open so the switchgear equipments stay safe.

III. OPERATION

Substation Automation System (SAS) provides protection, control, automation, monitoring, and communication capabilities as a part of a comprehensive substation control and monitoring solution. Substation automation is the act of automatically controlling the substation via instrumentation and control devices. Substation automation refers to using data from Intelligent Electronic Devices (IED's), control and automation capabilities within the substation, and control commands from remote users using SCADA to control power-system (switchyard) devices. Substation automation system is commonly used to control, protect and monitor a substation. However, over the years advances in electronics, information and communications technology have brought about sweeping changes in the way substations are operated. The advent of software-based substation automation systems connected by serial links rather than rigid parallel copper wiring gradually became the norm rather than the exception. To operate a grid substation there are some operation engineers under the supervision of the grid in charge. In grid substation there are eight operation engineers, & 4 technical staff. Shutdown work: In the electrical system for any kinds of maintenance work on any section, the must prerequisite is to assure the proper shutdown for that section For this the maintenance engineer will submit written request to the authority for shutdown of the specific part of the electrical system where maintenance is required. After that the authority will take necessary steps to assure the proper shutdown of the specific part of the system. All load feeders CB must be open which belongs to that transformer.

A. Main Equipment's Of Control Room

It is a room from where all the switch gear equipment's are controlled. Here all the equipment's are connected through grounding wire or underground cable. When any operation is done , the associated operation is done by motor control. This room is equipped with high tension panels (H.T)and low tension panels (L.T) whose are connected with the associated switchgear equipments. The line voltage , line current, phase voltage , power factor etc. values are monitored in this room. These values are recorded in a note book. It has also a battery backup section which works when is fail. There is also a battery charger. These batteries arrangement supplies about 110 V and high ampere. So the main equipments installed in control room are listed below.

1) High Tension Panel
2) Low Tension Panel,
3) Bus Bar Coupling,
4) Power Factor Improvement Panel
5) Back Up Battery,
6) Battery Charger,
7) Relay panel.

B. DC System OF the Sub-Station Storage Battery.

Fig. 7 Battery Storage room

A cell is a device in which an electrical difference of potential is established between the two electrodes as a result of chemical reaction between the electrode & electrolyte. There are two types of cell:-

1) Primary cell
2) Secondary or storage cell.

The batteries are connected to the circuit breaker for tripping the circuit breaker .Here trip is used through type relays.

IV.PROTECTION

Electricity is an extremely handy and useful form of energy. It plays an ever-growing role in our modern industrialized society. The electrical power systems are highly non-linear, extremely huge and complex networks. Such electric power systems are unified for economic benefits, increased reliability and operational advantages. They are one of the most significant elements of both national and global infrastructure, and when these systems collapse it leads to major direct and indirect impacts on the economy and national security. A power system consists of components such as generators, lines, transformers, loads, switches and compensators. However, a widely dispersed power sources and loads are the general configuration of modern power systems. Electric power systems can be divided into two sub- systems, namely, transmission systems and distribution systems. The main process of a transmission system is to transfer electric power from electric generators to customer area, whereas a distribution system provides an ultimate link between high voltage transmission systems and consumer services. In other words, the power is distributed to different customers from the distribution system through feeders, distributors and service mains. Supplying electricity to consumers necessitates power generation, transmission, and distribution. Initially electric power is generated by using electric generators such as: nuclear power generators, thermal power generators and hydraulic power generators and then transmitted through transmission systems using high voltage. Such assets comprise:

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3) Transformers,
4) Protection equipment.

Electric utility substations are used in both the transmission and distribution system and operate independently to generate the electricity. It plays an ever-growing role in our modern industrialized society. The electrical power systems are the highly non-linear, extremely huge and complex network. In the present scenario electricity still suffers from low power quality and blackouts so the present work recommends a well-planned design approach for sensor management in substation using IOT.

A. Protection System Failure Modes

It is imperative that instrument transformer secondary circuit integrity be tested on a regular basis. PTs and CTs provide information to protective relays and are subject to several possible failures:

1) Failed instrument transformer (shorted or open turns)
2) Blown fuse in the secondary (PTs only)
3) Open secondary circuit wiring
4) Short circuited CT secondary (e.g., shorted at the shorting blocks at the generator, transformer, exciter, etc., or accidentally shorted in the wiring)
5) Incorrect polarities or phasing ¬ Incorrect wiring ¬ Insulation failure
6) Spurious grounds or loose grounds, multiple grounds
7) Loose connections

Every important component of power system such as a power transformer or a transmission line needs to be protected against faults in order to minimize the damage caused by the fault. Nature of faults on various power system components vary. As a result different types of protective relays have been developed to provide efficient and reliable protection against various power system faults. Protective relays can be broadly classified into five basic classes

a) Magnitude relays,
b) Differential relays
c) Directional relays
d) Distance relays.
e) Pilot relays.

B. Ground protection

Power transformers with impedance grounded or solidly grounded neutral, can be equipped with different types of ground fault relays to protect the grounded winding. Low- impedance residual over current relays or harmonic restraint over current relays can be connected according to A or B in Fig. When the transformer neutral in Fig is effectively grounded and the transformer is ted from either side H or side Lo a fault at F1 or F2 is detected by a relay at point A. The relay at point B may Also operate depending on the

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distribution of the zero sequence impedance in the network. A fault at F3 is detected by the relays at point A and B. Consider the transformer ted from either side H or side L and that the transformer neutral is impedance grounded. With only one point in the network grounded. a fault at F1 or F2 is detected by a relay at point A. Fault F3 is detected by the relays at point A and B. These types of over current relays must therefore be delayed. or else they will operate for faults which should be taken care of by other ground fault relays in the network. The relays also have a back up function regarding the ground fault protection of the lines. They are also a slow back up for transformer differential relays in solidly grounded networks

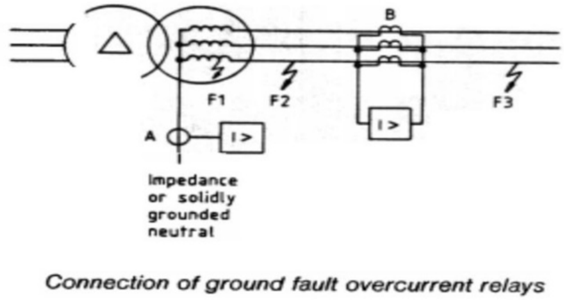
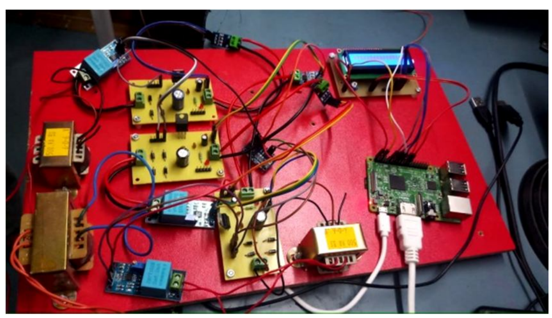


Fig 8 Ground protection.

C. Over current protection

This type of ground fault relay can be connected either to a current transformer in the neutral or to residually connected phase current transformers, see fig The relay should be released by a residual voltage relay to prevent operation due to saturation of any CT during a short-circuit or due to a magnetizing inrush current. The relay can operate for ground faults in the network and also for magnetizing inrush current containing a zero sequence component. The relay must therefore be delayed longer than the duration of the inrush current or Longer than the delay of other ground fault relays in the network.

Actual Photo



V. CONCLUSION

We used Raspberry pi as the heart of the project to control all the work involved. Transformers being the essential part of power transmission system are expensive, as is the cost of power interruptions. Because of the cost of scheduled and unscheduled maintenance, especially at remote sites, the utility industry has begun investing in instrumentation and monitoring of transformer. This project is developed low cost solution for monitoring health condition of remotely located distribution transformers.

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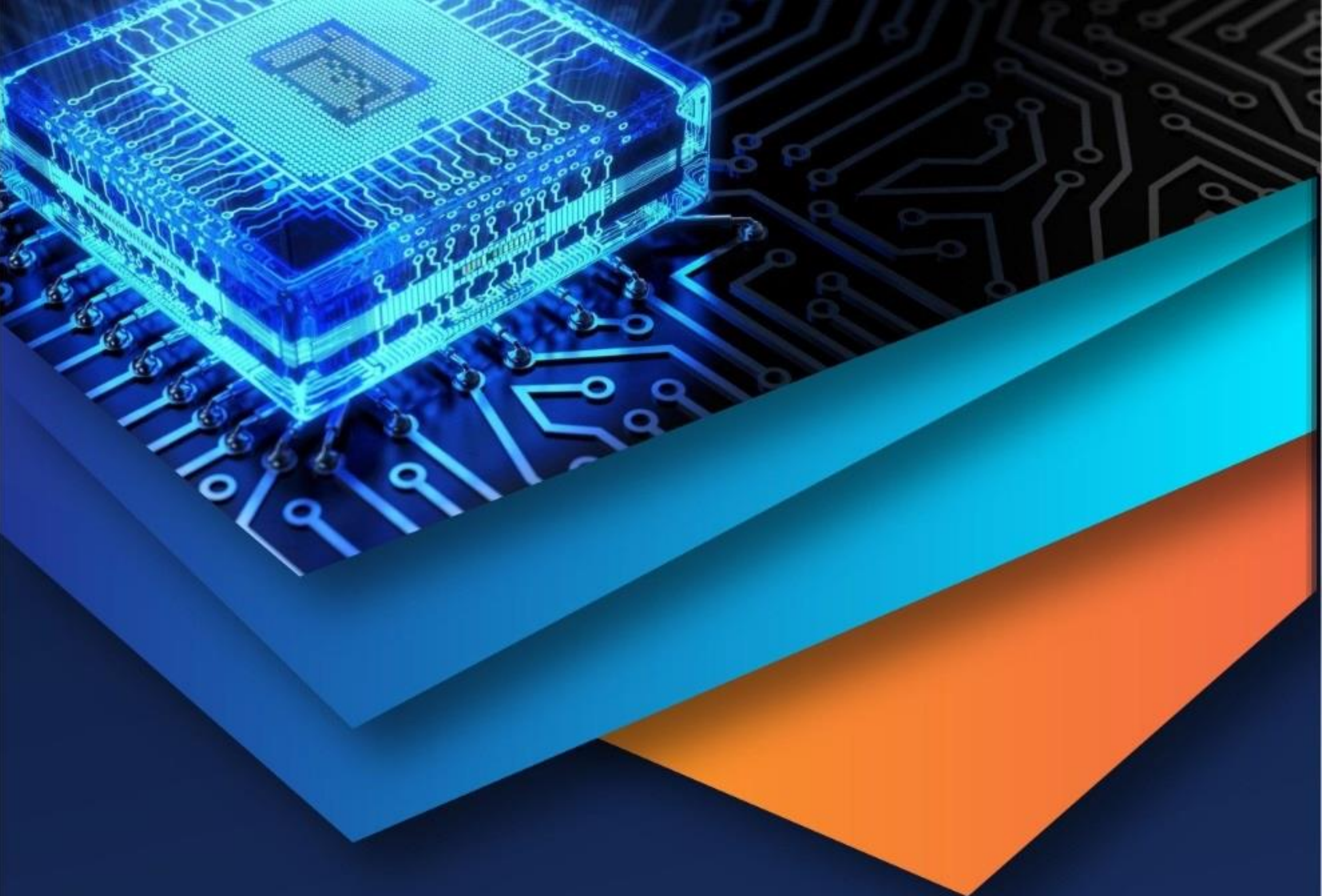

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