Operation and Monitoring of Substations by using IoT

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Abstract:

With the vast scale of transformation possibilities throughInternet of things (IoT), which changed everything about the way everyone lives and work. Even electric power substations operations are brought under IoT for superior efficiency and automation. In this work, double bus bar single bay (Demy) has been operated, which is a part of the substation operated by using IoT mechanism,The idea behind the work is for operation of a substation in real-time to monitor the situation of the substation by using IoT. The operation of the breaker, isolator, and earth switch symbolically with the help of IoT has been performed. The single-bay interlock between the breaker isolator and the earth switch system has been developed and operated using Internet of Things. The entire work is based on the concept and its applications of IoT, which is the advent of a new age of power industries has changed our nation and the world. India's Power and New & Renewable Energy Minister Shri. Raj Kumar Singh said that India will achieve 175GW of renewable energy targets by 2022. India has huge potential because the energy demand is here and demand will grow at the ratio of 7 to 9 percent. By using IoT technology, better predictive electricity grid load management and maintenance can be achieved for renewable sources which is shown via experimental setup.

Key Words: IoT, VNC,Raspberry pi,Substation.

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1. Introduction:

Today due to increase in complexity of the power system including substation, automation of the substation indeed become need of the hour to improve its efficiency and deliver quality of power to the consumer. It is known that India has huge potential because the energy demand is here and demand will grow at the ratio of 7 to 9 percent. Still many power outages and blackouts are seen in this modern era also, reason of occurrence is still unknown in many cases, this is due to lack of automation of power system and substation. By bringing IoT technology into the operation of power system, better predictive electricity grid load management and maintenance can be achieved for renewable sources. In today's era, digital platforms or devices had made the life of human being better and comfortable. In India, lots of unmanned substations have been developed to increase the productivity and reduce manpower. In 2013, all power grid unmanned substations were managed remotely. These unmanned substations are already linked through the Supervisory Control and Data Acquisition (SCADA) and Programmable Logic Controllers (PLC).

With availability of technology as more flexibility in today's world we connect to the entire world just by using Smartphones and Cloud. With the help of new technologies, lot of time can be saved by collecting the information and securing the data in a cloud. IoT and devices required for IoT are very small, inexpensive,abundant research work and easy to deploy. It has an ease of installation, reduced cost, and increased data accuracy as well as we can control and monitor at our fingertips. This work aims to show a practical development in power systems with the help of digital era technology such as IoT. IoT devices are unusual computer devices that connect wirelessly to the network and have the ability to transmit data via online devices. IoT involves extending internet connectivity beyond standard devices, such as desktops, laptops, cell phones and tablets, to any range of "dumb" or offline Internet and everyday objects. Embedded in technology, these devices can communicate and interact online.

The Internet of Things (IoT) technologies related to the infrastructure of the electricity industry have undergone several research and made significant development during the past ten years. In this section, a number of important studies on IoT technology are provided. [10] suggested an IoT-based solution for remotely managing and watching over the functioning of the University of Mosul power plant. Power Factor, supply voltage, and total load current are all monitored for each sub-station inside the university area. In order to monitor the zero crossing of current and voltage during low and high voltage, as well as fault protection, fault detection, and fault avoidance, [11] designed a monitoring system on the intended substation utilizing an Ethernet LAN.Additionally, the system enables Internet of Things-based remote administration of the distribution transformer, helping the client prevent frequent power outages and guaranteeing that consumers receive reliable, high-quality electricity. Unified Modeling Language (UML), formal modelling approaches, and the Internet of Things (IoT) were used to create a systematic model of a distribution management system made up of substations, distribution lines, and smart meters [12]. In order to demonstrate the development and application of WSN-based communication systems in the power grid for intelligent monitoring and automated control, [13] proposed a system. Grid sharing may be enhanced with the help of this invention to ensure power quality. The dynamic controller managed both the voltage increases and the power quality issues. On an INTEL GALILEO 2ndgeneration development board, [14] demonstrated the design and building of an Ethernet-based Smart Home intelligent system for monitoring electrical energy use based on real-time device tracking that may be used in homes and communities. [15] proposed a technique for smart home automation that makes use of the Raspberry Pi and the Internet of Things and that is performed by integrating cameras and motion sensors into a web application.This may be used to manage home appliances that are connected to the internet through a monitor. [16] proposed a smart control system based on IoT technologies to address the challenge of effectively and conveniently managing and regulating a variety of appliances at home to provide a more comfortable, secure, and healthy environment. The smart home control system configures a 433 MHz wireless sensor and actuator network(WSAN). using a smart central controller Switch modules and radio frequency control modules are only a couple of the control modules the WSAN has developed that may be used to directly control various home appliances. For the most efficient use of time and resources, [17] suggested an IoT-based network architecture for monitoring and managing substation equipment. A system based on the Internet of Things enables objects to be sensed or controlled remotely over the existing network infrastructure, allowing for a more direct integration of the physical world into computer-based systems, increasing efficiency, accuracy, and economic benefit while requiring little human involvement. [18] proposed a paradigm in which the substation is managed by the required components so that it may be monitored and managed remotely, lessening the severity of infiltration.Depending on the sensors that are installed at the substation, the microcontroller may combine and perform multiple functions. To avoid further harm to the power delivery system and control transformer from overload, short trip deficiency, surge voltage, and outpourings, electrical parameters such as current, voltage, and the rated value may be compared consistently. Using an Arduino platform as a microcontroller to read voltage and current from sensors and then wirelessly transmit the measured data to a new Android application for monitoring the outcomes, [19] proposed a new smart voltage and current monitoring system (SVCMS) technique for monitoring a single-phase electrical system.The integrated SVCMS design uses an Arduino Uno as the microcontroller to measure the output from voltage and current sensors, and after calculation, to transmit the data to a user's Android smartphone device through Wi-Fi. [20] provided a user-friendly, low-cost system that runs in autonomous mode to save labour and energy waste. To guarantee that the system's parameters are monitored and controlled by various persons for safety and security concerns, the system's findings are shown in several ways. This approach is unique in that it simultaneously shows findings on a PC and a mobile device.[21] shown how to utilize LoRa (Long-range) technology to monitor and diagnose distribution transformer status utilizing various sensors and devices. Important operational parameters like as voltage, load current, winding temperatures, oil temperatures, oil level in conservator, and breather silica gel condition of each distribution transformer may be monitored across a 10-kilometer radius using LoRa modules. [22] proposed a remote real-time temperature and humidity sensor system based on the Raspberry Pi and Java programming language for enhancing temperature and humidity monitoring at substations.

2. Implementation of IoT based operation inthe substation:

This work is aimed to design a double bus-bar single-bay substation prototype that can operate or control and monitor the substation by using IoT or in other words, wireless technology is being used, which can be handled by laptop / mobile phones to operate entire substation. The real-time operation of isolator earth switch interlock, etc. can also be operated. Figure.1 is the line diagram of the substation where IoT technology will be implemented for operation.

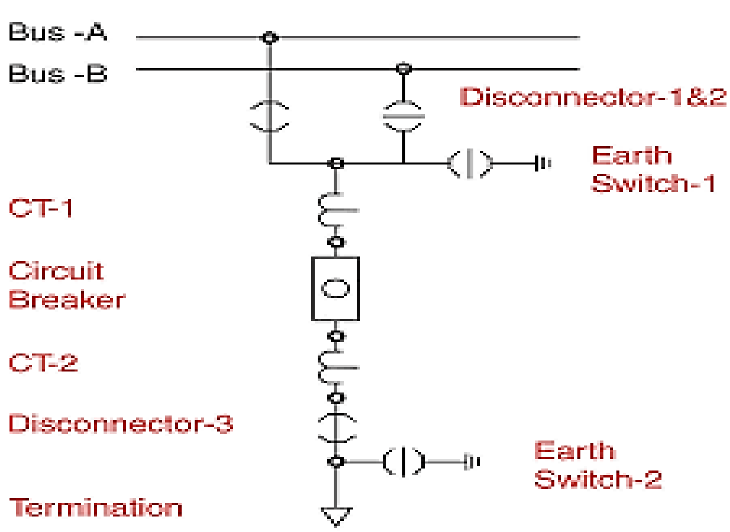

Figure 1: Substation line diagram

IoT module provides the communication interface. By using IoT techniques, quality of power transferred equipment can be enhanced, an uninterrupted power supply can be given.

3. Proposed Method for Substation Monitoring and Operation:

This work involves both hardware and software which are required to develop the prototype and operate using IoT. A substation prototype depicted in figure 2 is developed using Power transformer, Relay, LED lights for indication, SD card, Raspberry Pi GPIO which is core and heart of the system, Jumper wire, sensors, resistors, capacitors, inductors, connector which are all integrated to the computer system using a Raspberry Pi software for automation of the entire hardware system.

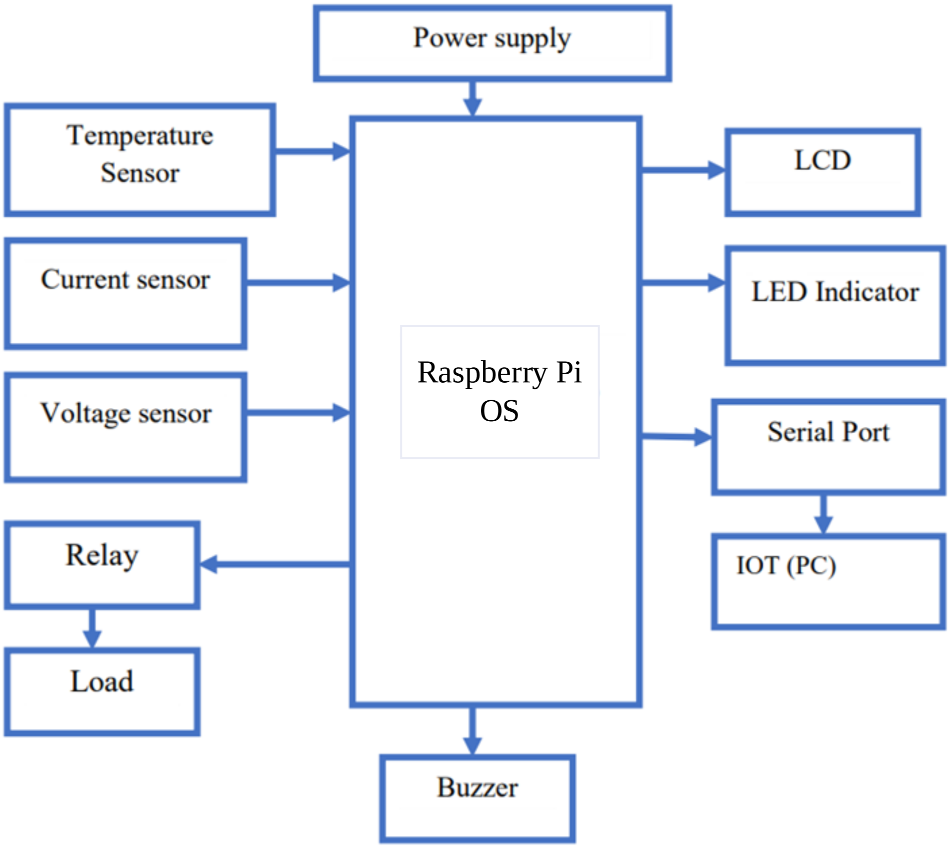

Figure 2: Block Diagram of Proposed System

3.1. Software Description

3.1.1. Raspberry pi software

Raspberry pi software is used to operate the hardware i.e., substation with the help of IoT, which needs to be installed on an SD card. Raspberry Pi OS is a free, open-source Debian Linux application built for use on Pi boards. Additionally, several computers on one ARM board use the Raspberry Pi OS. The first version, then known as the Raspbian, was released in 2013, and from 2015 onwards the Raspberry Pi Foundation provided it as an official Pi distro. Engineers Peter Green and Mike Thompson have a responsibility to create a Raspbian, initially independent effort. It is very cheap and that runs Linux. It also provides a set of general-purpose input/ output (GPIO) pins.

3.1.2.VNC

For controlling another computer over network connections, a remote-control software is needed, for this purpose Virtual Network Computing (VNC) has been used. Virtual

Network Computing, or VNC, is an open-source application that provides screen sharing services and is available on almost all operating systems such as Windows, Linux, and OS X.

3.1.3. PuTTy:

Putty is a free and open terminal template, serial console and network file transfer application. It supports several network protocols, including SCP, SSH, Telnet, rlogin, and green socket connections. It can also connect to a serial port. PuTTY was originally written for Microsoft Windows, but has been shipped to various applications.

3.2. Hardware Description:

3.2.1. Raspberry Pi GPIO:

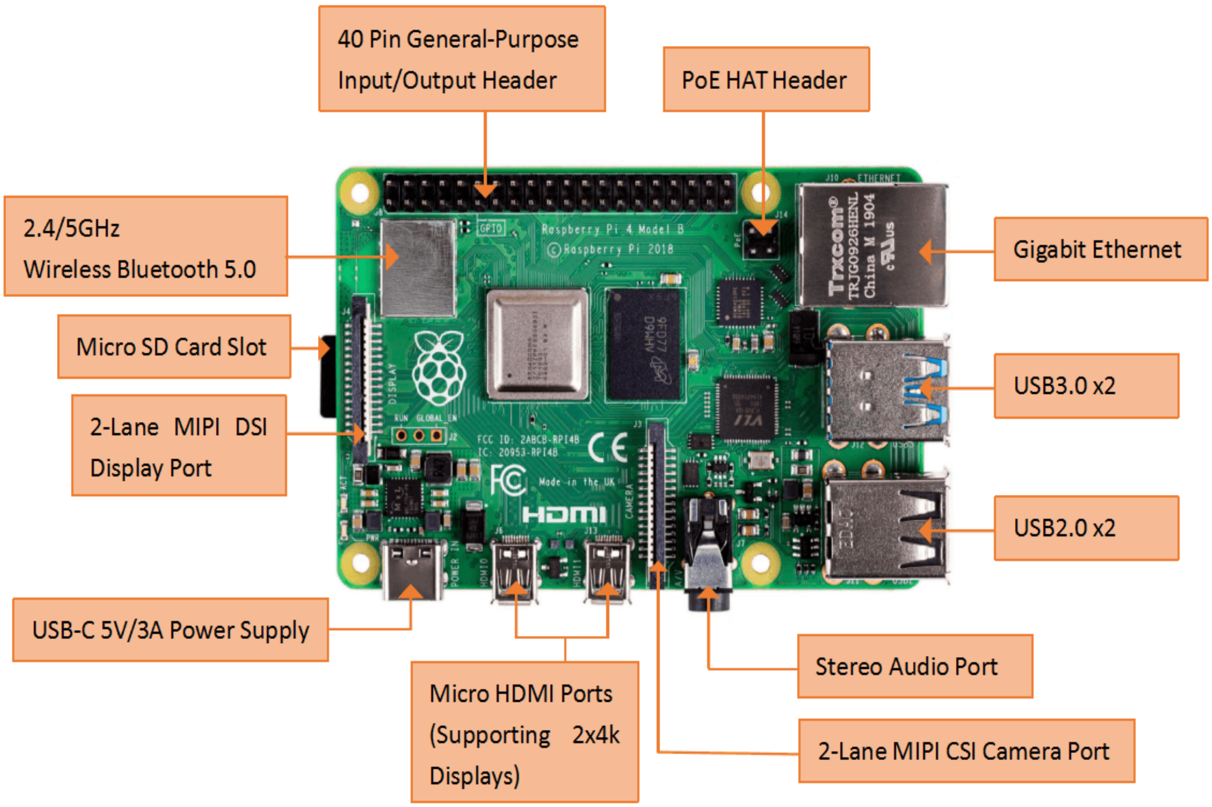

Figure 3: Hardware Equipment Raspberry Pi Board Top View

- **Power Pins:**Starting with power pins, which incorporate both 3.3V and 5V. These pins communicate power as result to drive connected peripherals.
- **Ground**:Also, on the off chance that will fix up electrical circuits here with power, aground will be required. A lot of grounds can be tracked inside the pins too.
- **Standard GPIO Pins:** Take out the power and ground pine pins will be remaining, that are devoted to sending yield and getting input. These can be utilized for direct info/yield undertakings!
- **Chatty Cathy Pins:** A portion of the standard GPIO pins are utilized for correspondence purposes. Here is a fast outline of these correspondence conventions.
- **SPI pins:** The Serial Peripheral Interface (SPI) is a correspondence convention used to move information between miniature PCs like the Raspberry Pi and fringe gadgets. The MISO pin gets information, and the MOSI pin sends information from the Raspberry Pi.

Besides, the sequential clock pin sends beats at a customary recurrence between the Raspberry Pi and the SPI gadget at a similar speed in which the gadgets move information to one another.

- **UART pins:** UART represents a general nonconcurrent beneficiary transmitter, which is an actual circuit intended to send and receive information.
- **PWM pins:** PWM signifies "beat width adjustment," which is a correspondence convention best utilized with stuff that moves and lights up: engines, LEDs, etc.
- **I2C pins:** I2C is short for between coordinated circuits (two "entombs" or I"squared" C). It works in basically the same manner as SPI, yet it doesn't drive you to utilize almost such countless pins.

4.Working Methodology System Setup

Step1: The Raspberry Pi OS image ought to be introduced on the micro-SD card. Assuming thata clear micro-SD card is being used, for that visiting the Raspberry Pi Foundation is needed to install the appropriate image.

Step2: To operate Raspberry pi with internet, configurations of ID and password is required to Raspberry pi with the help of 16GB SD card. For which, make a blank notepad file and name it to “ssh” and second note pad **file name -wpa_supplicant.conf**with following codes.

```
file name -wpa_supplicant.conf
ctrl_interface=DIR=/var/run/wpa_supplicant
GROUP=netdev
update_config=1
country=IN
network={
ssid="Hanu"
psk="Hitarth@081017"
}
```

Both files are saved in micro SD card with the Raspberry Pi OS image.

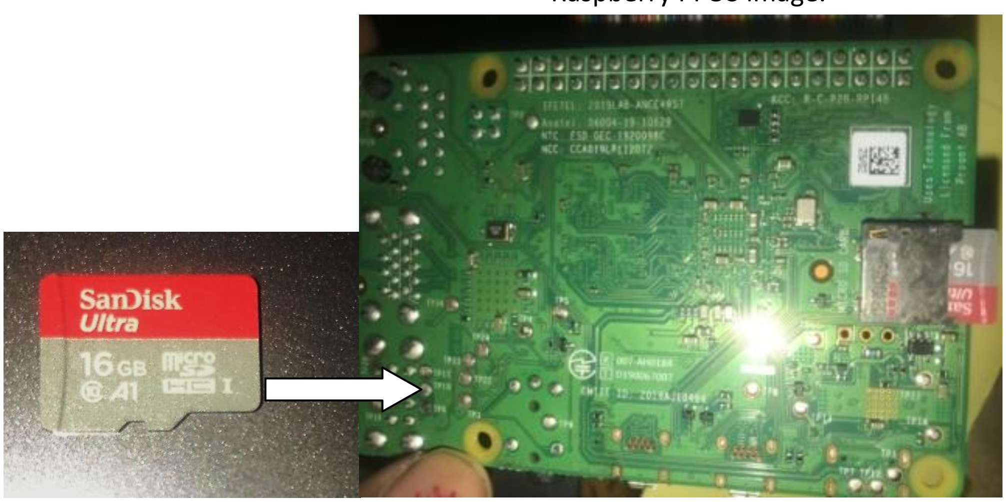

Figure 4: Micro-SD card with the Raspberry Pi OS image

It can be seen in the configurations that, insertion has been done with some information regarding net connection such as user country, ID, and password. SD Card, is been inserted into Raspberry pi which is connected to the same wifi automatically. By using the IP scanner IP address of the pi can be found. With the help of this IP address and PuTTY which is a free implementation of SSH for PCs running Microsoft Windows, laptop can be connected to pi. After that raspberry uses that wifi to be ready to operate and control a prototype substation with somecommands.

Step 3: By using Python program, system of a prototype substation can be operated and monitored. Assignment of assign each and every pin of GPIO with directly Equipment has been done.

5. Python program for the operation

For the proper run the program one folder named template inside the project folder is created. In project folder, python code file name python code .py is created, code is mentioned in the following:

1-

```
import RPi.GPIO as GPIO
from flask import Flask, render_template,
request
app = Flask(__name__)
GPIO.setmode(GPIO.BCM)
GPIO.setwarnings(False)
# define actuators GPIOs
Q1 = 12
Q2 = 16
Q0 = 20
Q51 = 13
Q3 = 26
Q8 = 19
# initialize GPIO status variables
Q1Sts = 0
Q2Sts = 0
Q0Sts = 0
Q51Sts = 0
Q3Sts = 0
Q8Sts = 0
# Define led pins as output
GPIO.setup(Q1, GPIO.OUT)
GPIO.setup(Q2, GPIO.OUT)
GPIO.setup(Q0, GPIO.OUT)
GPIO.setup(Q51, GPIO.OUT)
GPIO.setup(Q3, GPIO.OUT)
GPIO.setup(Q8, GPIO.OUT)
# turn leds OFF
GPIO.output(Q1, GPIO.LOW)
GPIO.output(Q2, GPIO.LOW)
GPIO.output(Q0, GPIO.LOW)
GPIO.output(Q51, GPIO.LOW)
GPIO.output(Q3, GPIO.LOW)
GPIO.output(Q8, GPIO.LOW)
Q3Sts = GPIO.input(Q3)
 Q8Sts = GPIO.input(Q8)
 templateData = {
 'Q1': Q1Sts,
 'Q2': Q2Sts,
 'Q0': Q0Sts,
 'Q51': Q51Sts,
 'Q3': Q3Sts,
 'Q8': Q8Sts,
 }
 return render_template('index.html',
**templateData)
if __name__ == "__main__":
 app.run()
```

In templates we make a html file name index with following codes

```
<!DOCTYPE html>
<head>
<title>GPIO Control</title>
<link rel="stylesheet" href='../static/style.css'/>
</head>
<h1>Operation And Monitoring Of
Substation</h1>
<h2> Status </h2>
<h2> INTERLOCK OPERATED == 0 </h2>
<h3> Q1 BUS-1 ISOLATER ==> {{ Q1 }}</h3>
<h3> Q2 BUS-2 ISOLATER ==> {{ Q2 }}</h3>
<h3> Q0 CIRCUITE BREAKER ==> {{ Q0 }}</h3>
<h3> Q51 EARTH SWITCH ==> {{ Q51 }}</h3>
<h3> Q3 LINE ISOLATER ==> {{ Q3 }}</h3>
<h3> Q8 LINE EARTH SWITCH ==> {{ Q8 }}</h3>
<br>
<h2> Commands </h2>
<h3>
```

```
@app.route("/")
def index():
 # Read Sensors Status
 Q1Sts = GPIO.input(Q1)
 Q2Sts = GPIO.input(Q2)
 Q0Sts = GPIO.input(Q0)
 Q51Sts = GPIO.input(Q51)
 Q3Sts = GPIO.input(Q3)
 Q8Sts = GPIO.input(Q8)
 templateData = {
 'title': 'GPIO output Status!',
 'Q1': Q1Sts,
 'Q2': Q2Sts,
 'Q0': Q0Sts,
 'Q51': Q51Sts,
 'Q3': Q3Sts,
 'Q8': Q8Sts,
 }
 return render_template('index.html',
**templateData)
@app.route("/<deviceName>/<action>")
def action(deviceName, action):
 if deviceName == 'Q1':
 actuator = Q1
 if deviceName == 'Q2':
 actuator = Q2
 if deviceName == 'Q0':
 actuator = Q0
 if deviceName == 'Q51':
 actuator = Q51
 if deviceName == 'Q3':
 actuator = Q3
 if deviceName == 'Q8':
 actuator = Q8
 if action == "on":
 GPIO.output(actuator, GPIO.HIGH)
 if action == "off":
 GPIO.output(actuator, GPIO.LOW)
 Q1Sts = GPIO.input(Q1)
 Q2Sts = GPIO.input(Q2)
 Q0Sts = GPIO.input(Q0)
 Q51Sts = GPIO.input(Q51)
```

```
 Q1 BUS-1 ISOLATER Ctrl ==>
<a href="/Q1/on" class="button">TURN
ON</a>
<a href="/Q1/off"
 class="button">TURN OFF</a>
</h3>
<h3>
 Q2 BUS-2 ISOLATER Ctrl ==>
<a href="/Q2/on" class="button">TURN
ON</a>
<a href="/Q2/off"
 class="button">TURN OFF</a>
</h3>
<h3>
 Q0 CIRCUITE BREAKER Ctrl ==>
<a href="/Q0/on" class="button">TURN
ON</a>
<a href="/Q0/off"
 class="button">TURN OFF</a>
</h3>
<h3>
 Q51 EARTH SWITCH Ctrl ==>
<a href="/Q51/on" class="button">TURN
ON</a>
<a href="/Q51/off"
 class="button">TURN OFF</a>
</h3>
<h3>
 Q3 LINE ISOLATER Ctrl ==>
<a href="/Q3/on" class="button">TURN
ON</a>
<a href="/Q3/off"
 class="button">TURN OFF</a>
</h3>
<h3>
 Q8 LINE EARTH SWITCH Ctrl ==>
<a href="/Q8/on" class="button">TURN
ON</a>
<a href="/Q8/off"
 class="button">TURN OFF</a>
</h3>
</body>
</html>
```

6. Results & Discussion

It can be operated from anywhere and further operations and monitoring can be performed on any equipment. This is the phenomenon, which can make a conventional product into smart or digital products.

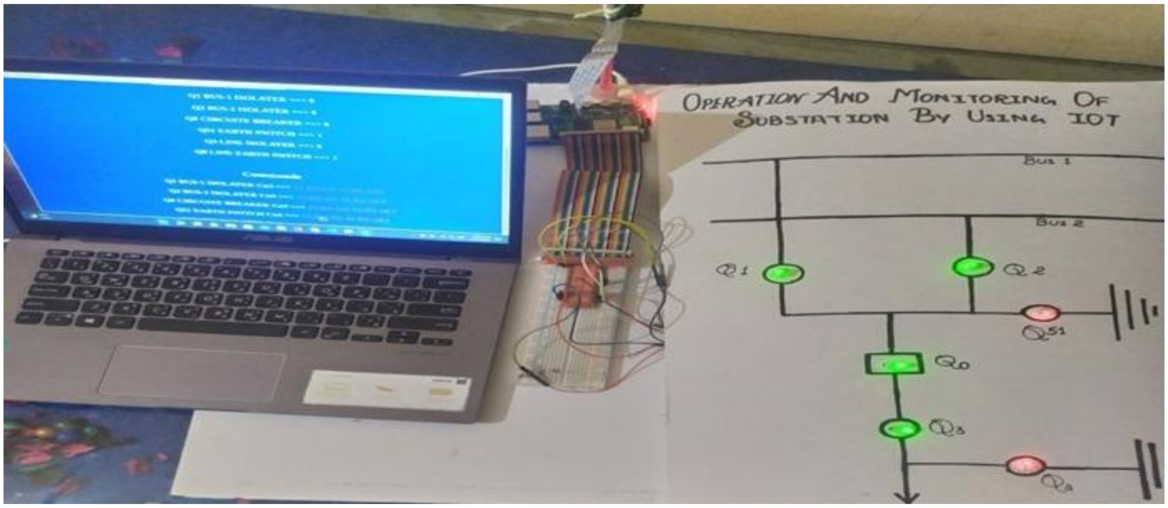

Figure 5: Overall view of prototype

It can be seen in the given figure 5:–
Q1 represent Bus 1- Isolator
Q2 represent Bus 2- Isolator
Q53 represents – Earth switch
Q0 represents - Circuit breaker
Q3 represent – line Isolator
Q8 represents – line earth switch

The glow of the red LED shows the equipment is in close condition and the green LED shows the equipment is in open condition.

Figure 6: Command Screen

With this developed setup, command can be given to the equipment and also can be identified, which equipment is closed and which is open. The status of equipment is also being showed. A camera can also be used for monitoring the substation. This camera always monitors the substation, feeds data to the control center by which analysis the condition of the substation.

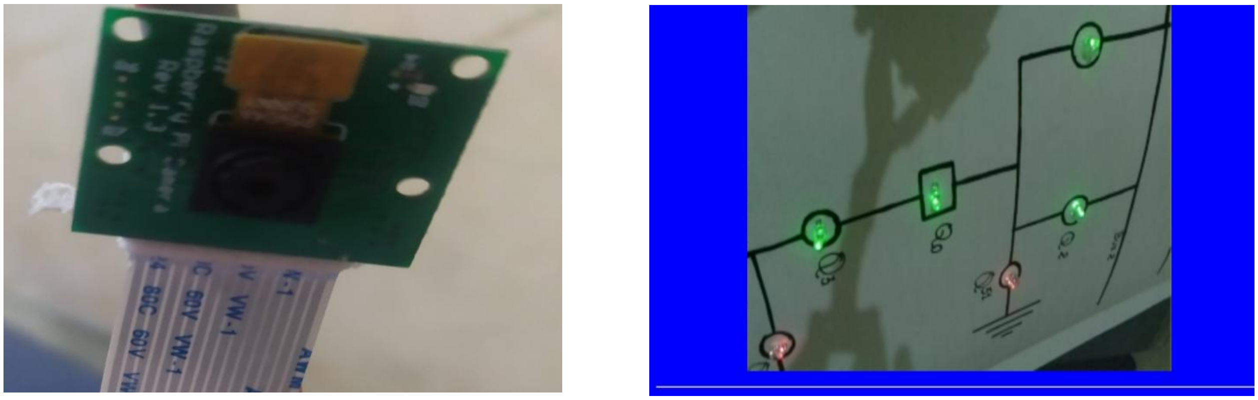

Figure 7: Hardware Response to Command Operation

7.Conclusion:

The prototype work that has been developed of IoT based monitoring and controlling of electric power substation is a simple approach to make the substation smart automated with quality of power delivered to the consumers is ensured by incorporation of Raspberry pi based IoT system.It is seen that any abnormalities in the substation can be quickly isolated even from remote location.Therefore, the system is automated and the real time values of the important line parameters are continuously monitored through IOT and cloud server. This provides the complete data of the systems operating conditions for the entire time of its operation. The operator can start or stop the system remotely with the help of IOT. It will reduce the human contact for maintenance purpose and becomes self-operating system. Overall cost and maintenance burden is reduced in long term.

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