Intelligent IOT Based Changeover for Hybrid Domestic Solar Power System

U.I.K. Perera[1], Y.A.A. Kumarayapa[1*]

[1]*Department of Electronics, Wayamba University of Sri Lanka, Kuliyapitiya, Sri Lanka*

Abstract: The integration of renewable energy sources into home power networks has gained substantial popularity in recent years, particularly in the form of hybrid solar power systems. The seamless transition between the solar power system and grid power source, known as changeover, has traditionally been a manual procedure. This can lead to inefficiencies, continuous focusing/ human attention, energy wastage, and significant disruptions to the power supply. To address these difficulties, an intelligent IoT-based navel switching system for hybrid household solar power systems is presented. This system utilizes real-time monitoring of the battery voltage of the solar system, weather conditions, and household energy demand to automate the two way switching procedure. The system integrates a combination of sensors and actuators using a microprocessor based processing on the data was used to build the cloud-based monitor platform to gather data and make decisions regarding the optimal power source for the household at any given time. All the procedures were based on the Raspberry Pi 3 Model B and it was programmed using Python. The voltage of the battery was measured using the Voltage Detection Sensor module and the power usage in the household was measured using the SCT013 60A/1V Sensor module. Weather forecasts for a specific area are monitored using the 'openweathermap.org' application programming interface. Updated all the parameters such as weather conditions, mode of the changeover (auto/manual), power source use at the moment, battery voltage level, power usage of household, and internet access availability for the system were displayed using a 1.8-inch 128×160 TFT LCD Color Display at the station. With the help of the Web site created in this research study, all the parameters mentioned above can be monitored remotely.

Keywords: Automated Changeover, Hybrid solar energy harvesting systems, Internet of Things (IOT), Weather Forecast based Intelligent Control

1. INTRODUCTION

Transitioning to a sustainable and ecologically friendly energy harvesting and efficient utilization of power has become a global priority. In this environment, the integration of renewable energy sources, notably solar power electricity, into domestic power systems has gained substantial popularity. Two major challenges with photovoltaic (PV) generation systems are the conversion efficiency of electric power generation is exceptionally low (9–17%), especially under low irradiation conditions, and the amount of electricity generated by solar arrays varies constantly with weather conditions. Photovoltaic (PV) systems are primarily used in two configurations: stand-alone (household, street lighting, recreational vehicles (RVs) and camping, electric cars, boating, and marine applications) or grid-connected (residential and commercial PV hybrid systems) [1].

Grid-connected photovoltaic systems, are composed of PV arrays that are linked to the grid via a power conditioning unit and are intended to run in parallel with the utility grid [2]. The cost of an all-in-one power conditioning unit is expensive (about LKR 110, 000- LKR 280, 000) due to their integrated design and additional features [3]. A more economical setup can be obtained by combining separate units of charge controllers, inverters, and changeover switches.

A changeover switch is utilized in the above system, alternate between the PV system and grid power. Such a system provides an uninterrupted and consistent flow of electricity to the devices of home appliances connected to it.

The main objective of design and construction of an IoT based changeover to switch automatically between the grid and PV system based on the weather forecast, load power consumption, and battery voltage level. The IoT platform allows for real-time monitoring of the system [4].

The diagram in figure 1.Shows the Changeover system design, incorporating relevant theories, techniques, and components.

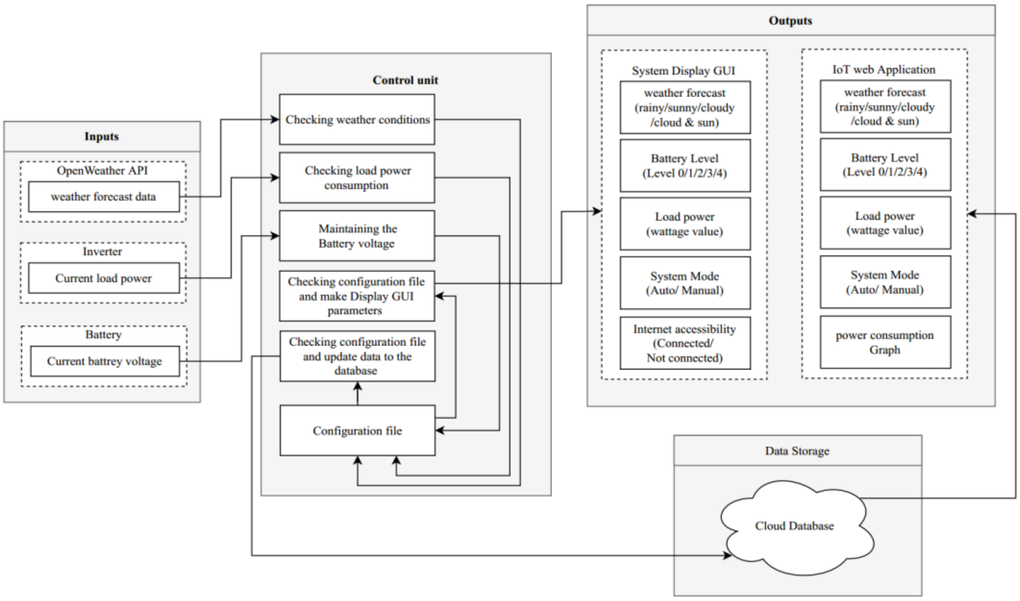


Fig.1: Block diagram of the designed Changeover system.

2. EXPERIMENTAL PROCEDURE

There are three primary processes in the implemented system: Weather Forecasting Data Monitoring, Load Power Measuring, and Battery Voltage Measuring then switching and displaying according to the measured parameters.

2.1 WEATHER FORECASTING DATA MONITORING.

All the weather forecasting data for the Kuliyapitiya area (latitude=7.4688 and longitude=80.0401) were obtained through the JSON file by sending the following 'GET' request to the 'OpenWeather' API and saved it into a configuration file.

GETRequest:
https://api.openweathermap.org/data/2.5/forecast?lat=7.4688&lon=80.0401&units=metric&appid=8422dff2e16 55bb932f888f2e5eXXXXX

2.2 POWER MEASURING OF THE LOAD.

The current drawn by the load was measured using the SCT013 Current Transformer sensor. It was connected to the Raspberry Pi board via ADS1115 16-bit 4-channel ADC. Power consumption was calculated by measuring the Root mean square (RMS) current through the inverter, using the equation 2.2.1. It is necessary to apply the RMS formula and capture instantaneous current values across the whole cycle of the waveform to obtain the RMS current [5].

$$I_{rms} = \sqrt{\frac{i_1^2 + i_2^2 + i_3^2 + \cdots + i_n^2}{n}} \quad [2.2.1]$$

Where; I_{rms} = root mean square (rms) current
i_1^2 = Instantaneous currents
n= Number of samples

The voltage of an AC inverter is typically fixed and can be found in the inverter manufacture's specifications or by measuring it directly with a voltmeter. Power can be calculated using IRMS and measured voltage values using equation 2.2.2.

$$P_{rms} = V \times I_{rms} \quad [2.2.2]$$

Where; P_{rms} = Root mean square (RMS) power
V = Output voltage of the inverter
I_{rms} = Root mean square (RMS) current
Calculated power values were saved into a configuration file for later use.

2.3 MEASURING OF THE BATTERY VOLTAGE.

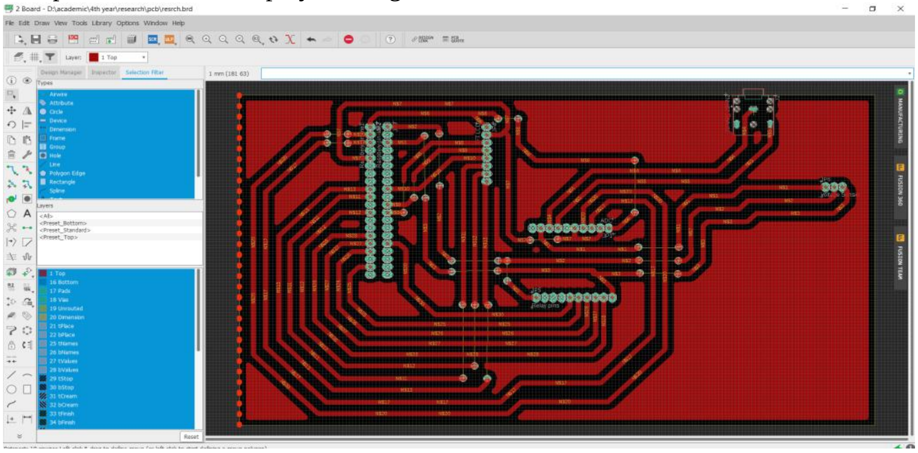
The voltage of the battery was measured using the voltage sensor. It was connected to the Raspberry Pi board via ADS1115 16-bit 4-channel ADC. Calculated voltage values were saved into a configuration file.

2.4 DISPLAYING ON TFT LCD.

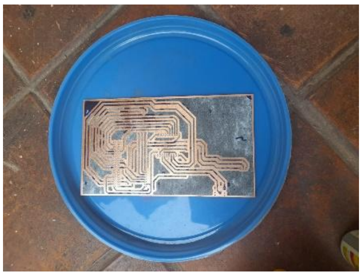
The 1.8-inch 128*160 TFT SPI serial LCD color display was used to show the parameters with a GUI.

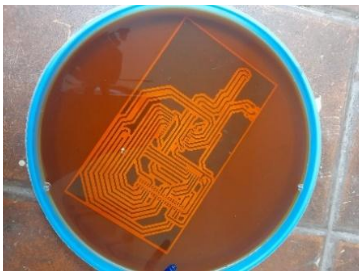
2.5 IOT MONITORING

All the parameters saved into the configuration file were uploaded to the MongoDB database using POST requests via JSON files. All the parameters in the MongoDB database were read using GET requests via JSON files. Those parameters were displayed using the web interface.



(a)





(b) (c)

Fig. 2: Designed and fabricated PCB for the navel changeover.

3. RESULTS AND DISCUSSION

The prototype of the proposed changeover is implemented design is shown in figure 3.

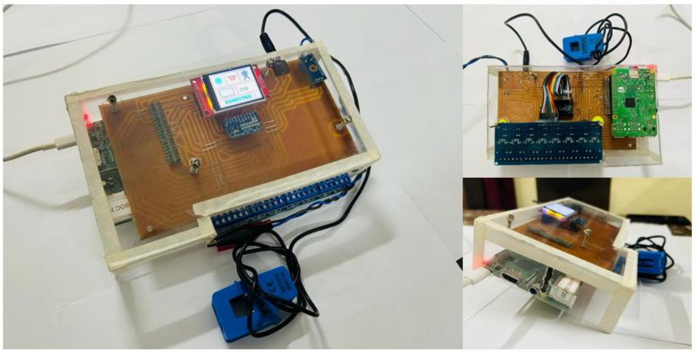


Fig. 3: Prototype of the Automatic changeover

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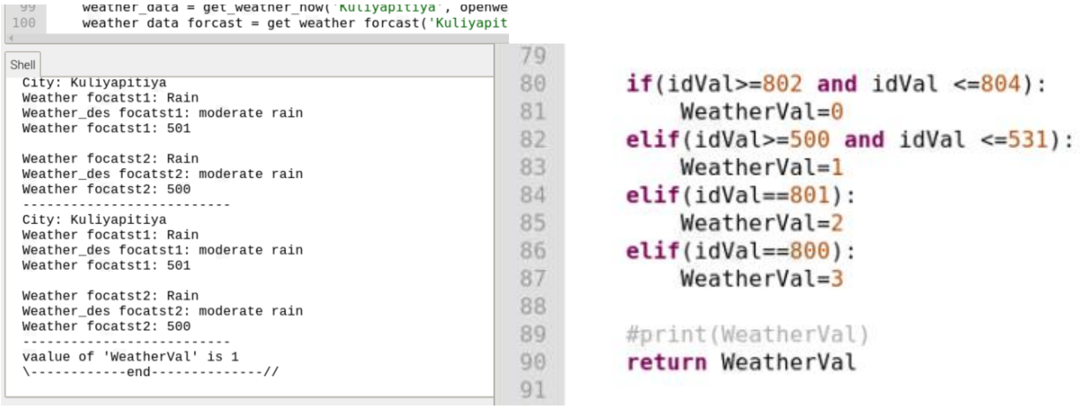
3.1 SWITCHING PROCESS ACCORDING TO WEATHER FORECASTING.

The weather forecast monitoring program retrieves the weather forecast data from a JSON file, as shown in Figure 4.a. It then sets the variable 'WeatherVal' according to the given instructions, as shown in Figure 4.b.



```
99      weather_data = get_weather_now('Kuliyapitiya', openwe
100     weather data forcast = get weather forcast('Kuliyapit
```

```
City: Kuliyapitiya
Weather focatst1: Rain
Weather_des focatst1: moderate rain
Weather focatst1: 501

Weather focatst2: Rain
Weather_des focatst2: moderate rain
Weather focatst2: 500
--------------------------
City: Kuliyapitiya
Weather focatst1: Rain
Weather_des focatst1: moderate rain
Weather focatst1: 501

Weather focatst2: Rain
Weather_des focatst2: moderate rain
Weather focatst2: 500
--------------------------
vaalue of 'WeatherVal' is 1
\------------end-------------//
```

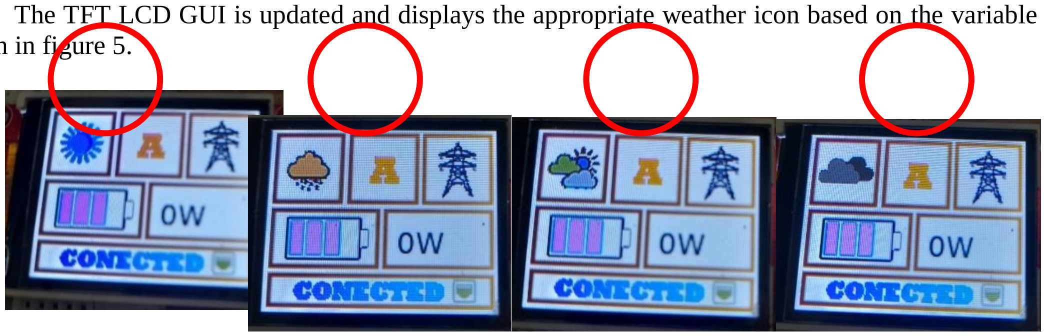
```
if(idVal>=802 and idVal <=804):
    WeatherVal=0
elif(idVal>=500 and idVal <=531):
    WeatherVal=1
elif(idVal==801):
    WeatherVal=2
elif(idVal==800):
    WeatherVal=3

#print(WeatherVal)
return WeatherVal
```

(a) (b)

Fig. 4: (a) Given instructions and (b) Display of the weather forecast data that was read by the weather forecast monitoring program.

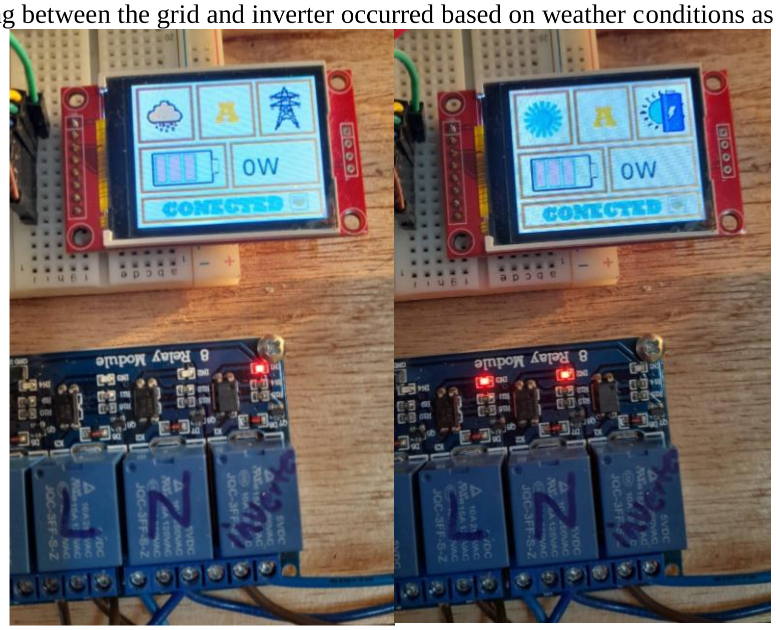
The TFT LCD GUI is updated and displays the appropriate weather icon based on the variable values as shown in figure 5.



(a) (b) (c) (d)

Fig 5: Display updates based on (a) sunny, (b) rainy, (c) sun with cloud, (d) cloudy weather condition

The switching between the grid and inverter occurred based on weather conditions as shown in figure 6.



(a) (b)

Fig. 6: power supply switched between the grid and inverter based on weather condition

As shown in Figure 6.a, when the weather condition is ‘rainy’, the changeover was switched to the grid, and the inverter is switched OFF (Red LED on the last relay module is turned ON for such indication). As shown in Figure 6.b, when the weather condition is ‘sunny, the changeover was switched to the PV system, and the inverter was switched ON.

Simultaneously the IoT web interface is updated and displays the appropriate weather icon and power source based on the variable values as shown in figure 7.

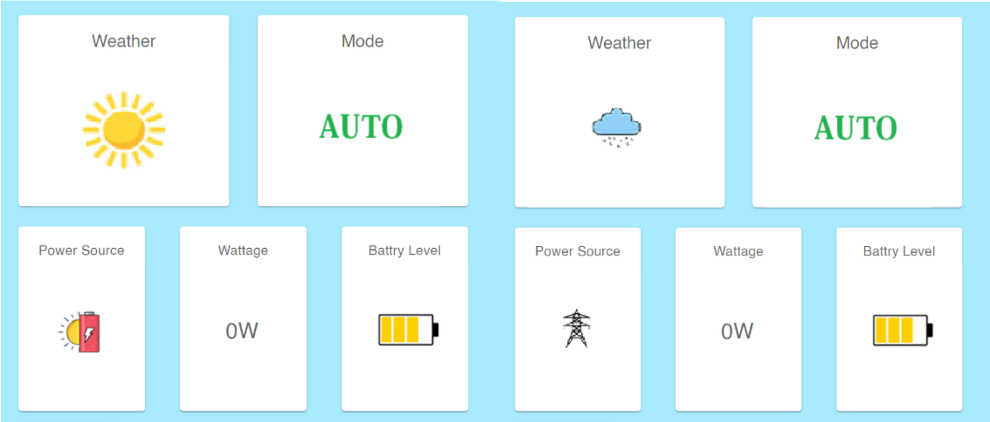
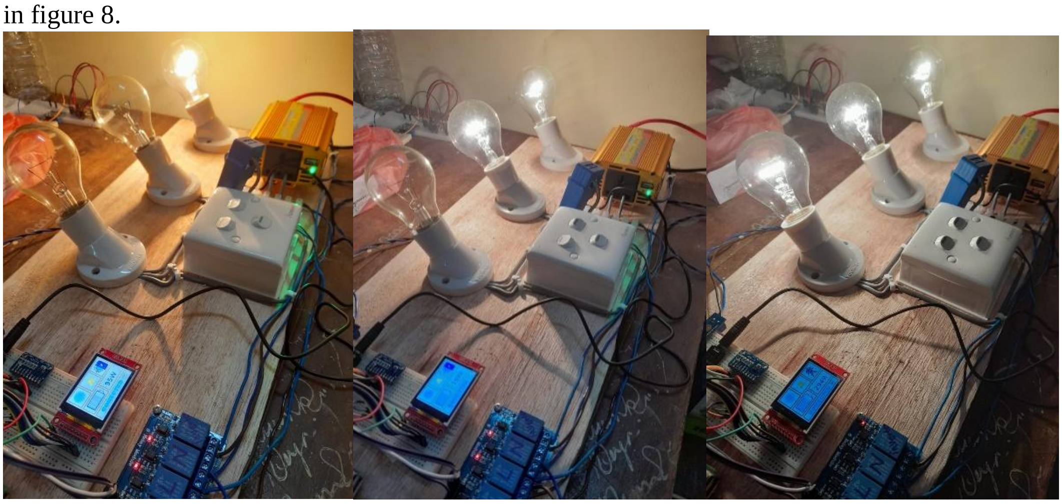


Fig. 7: web interface updates based on weather conditions and power source data

3.2 SWITCHING PROCESS ACCORDING TO POWER CONSUMPTION.

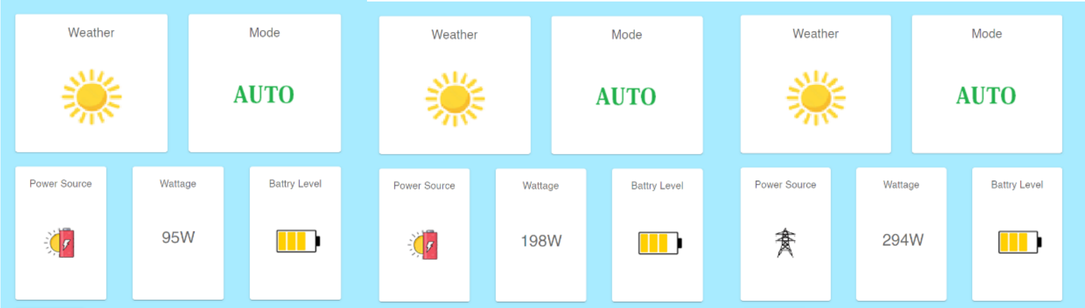
The switching between the grid and inverter occurred based on the power consumption of the load as shown in figure 8.



(a) (b) (c)

Figure 8: power source is switched between the grid and inverter based on load power consumption

As shown in Figures 8.a and 8.b, when the power consumption is below the reference power value (250W in this demonstration), the changeover was switched to the inverter, and the inverter was switched ON (Red LED on the last relay module was turned ON for indication). Also, it showed in the TFT LCD. As shown in Figure 8.c, when the power consumption is above the reference- power, the changeover is switched to the grid, and the inverter is switched OFF and indicated it on the LCD. Simultaneously the IoT web interface is updated as shown in figure 9.

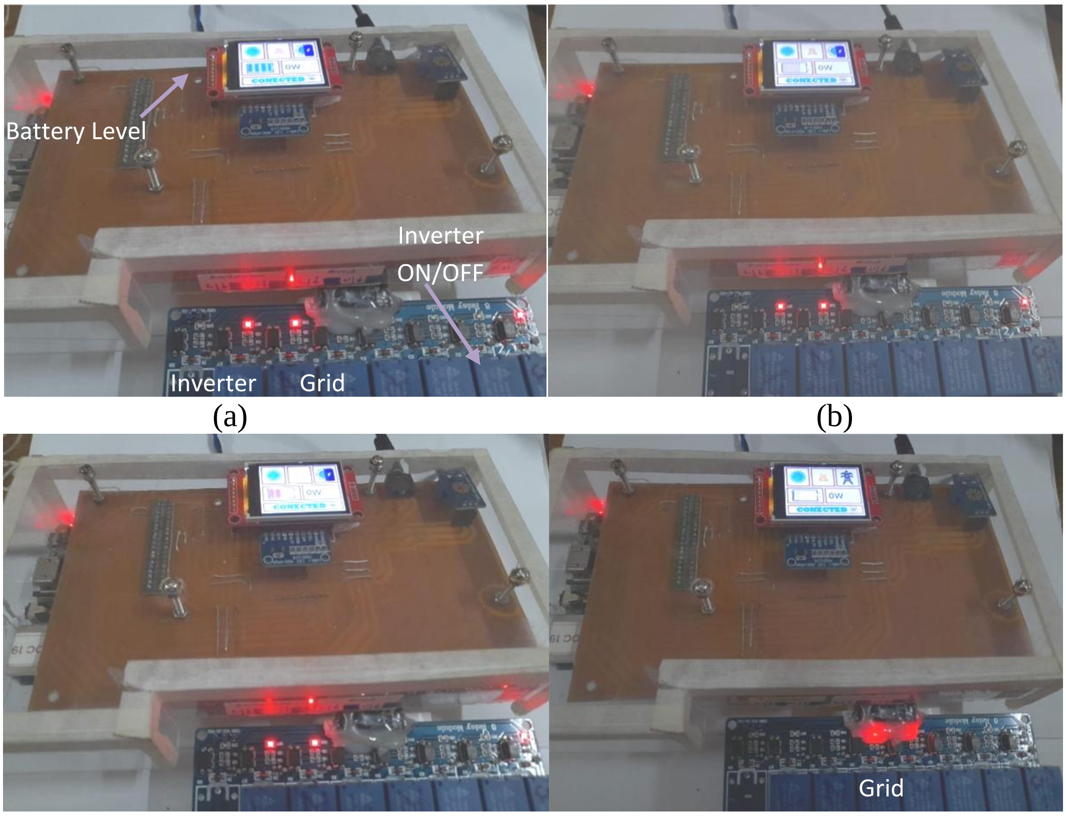


(a) (b) (c)

Fig. 9: IoT web interface was updated according to load power consumption

3.3 SWITCHING PROCESS ACCORDING TO BATTERY VOLTAGE LEVEL.

The switching between the grid and inverter occurred based on the voltage level of the battery as shown in figure 10.



(a) (b) (c) (d)

Figure 10: power source is switched between the grid and inverter based on voltage level of the battery

As shown in Figures 10.a 10.b and 10.c, when the voltage level is above the minimum voltage of the battery, the changeover is switched to the inverter, and the inverter is switched ON (Red LED on the last relay module is turned ON for indication). Also, it showed in the TFT LCD. As shown in Figure 10.d, when the voltage level is below the minimum voltage, the changeover is switched to the grid, and the inverter is switched OFF and indicated on the LCD. Simultaneously the IoT web interface is updated as shown in figure 11.

(a) (b) (c) (d)

Figure 11: IoT web interface is updated according to voltage level of the battery

The design and implementation of our system effectively demonstrated its capability to alternate between the grid and the inverter based on power demand and weather conditions. The system was equipped with a TFT LCD GUI and an IoT web interface that could be updated using weather forecast data from a JSON file. By monitoring the power consumption of the load, the system was able to switch between using the grid and the inverter as a power source. The system's performance was impressive and it proved to be efficient in controlling power consumption.The switching is occurred as shown in table 3.1

Table 3.1: Selecting power source according to Weather condition, Power consumption and Battery Voltage

Weather condition	Power consumption	Battery Voltage	Power Source
Sunny	above reference power	12.6 to 12.8 volts	Grid
Sunny	above reference power	12.4 to 12.5 volts	Grid
Sunny	above reference power	12.2 to 12.3 volts	Grid
Sunny	above reference power	12 to 12.1 volts	Grid
Sunny	above reference power	10.5 to 11.5 volts	Grid
Sunny	below reference power	12.6 to 12.8 volts	Solar
Sunny	below reference power	12.4 to 12.5 volts	Solar

Sunny	below reference power	12.2 to 12.3 volts	Solar
Sunny	below reference power	12 to 12.1 volts	Solar
Sunny	below reference power	10.5 to 11.5 volts	Grid
Rainy	above reference power	12.6 to 12.8 volts	Grid
Rainy	above reference power	12.4 to 12.5 volts	Grid
Rainy	above reference power	12.2 to 12.3 volts	Grid
Rainy	above reference power	12 to 12.1 volts	Grid
Rainy	above reference power	10.5 to 11.5 volts	Grid
Rainy	below reference power	12.6 to 12.8 volts	Grid
Rainy	below reference power	12.4 to 12.5 volts	Grid
Rainy	below reference power	12.2 to 12.3 volts	Grid
Rainy	below reference power	12 to 12.1 volts	Grid
Rainy	below reference power	10.5 to 11.5 volts	Grid
Sun with cloud	above reference power	12.6 to 12.8 volts	Grid
Sun with cloud	above reference power	12.4 to 12.5 volts	Grid
Sun with cloud	above reference power	12.2 to 12.3 volts	Grid
Sun with cloud	above reference power	12 to 12.1 volts	Grid
Sun with cloud	above reference power	10.5 to 11.5 volts	Grid
Sun with cloud	below reference power	12.6 to 12.8 volts	Solar
Sun with cloud	below reference power	12.4 to 12.5 volts	Solar
Sun with cloud	below reference power	12.2 to 12.3 volts	Solar
Sun with cloud	below reference power	12 to 12.1 volts	Solar
Sun with cloud	below reference power	10.5 to 11.5 volts	Grid
cloudy	above reference power	12.6 to 12.8 volts	Grid
cloudy	above reference power	12.4 to 12.5 volts	Grid
cloudy	above reference power	12.2 to 12.3 volts	Grid
cloudy	above reference power	12 to 12.1 volts	Grid
cloudy	above reference power	10.5 to 11.5 volts	Grid
cloudy	below reference power	12.6 to 12.8 volts	Grid
cloudy	below reference power	12.4 to 12.5 volts	Grid
cloudy	below reference power	12.2 to 12.3 volts	Grid
cloudy	below reference power	12 to 12.1 volts	Grid
cloudy	below reference power	10.5 to 11.5 volts	Grid

Table 3.1 can be shown as following graph ;Figure 12 for further understating.

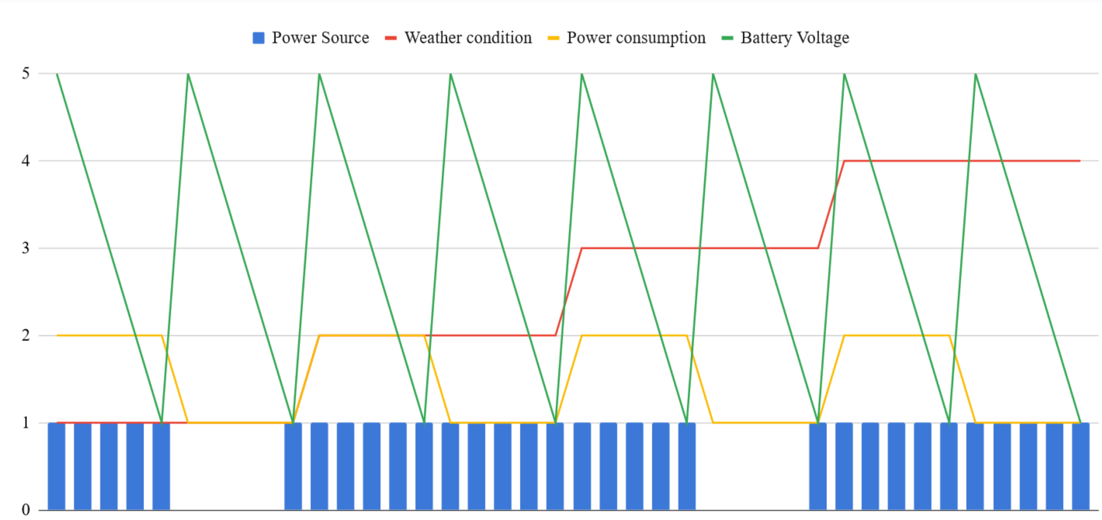


Fig.12 The Graph for illustrating the power source change according to all the combination of weather condition, power consumption and battry voltage

Where;

Weather condition	cloudy	4
	Sun with cloud	3
	Rainy	2
	Sunny	1
Power consumption	above reference power	2
	below reference power	1
Battery Voltage	12.6 to 12.8 volts	5
	12.4 to 12.5 volts	4
	12.2 to 12.3 volts	2
	12 to 12.1 volts	3
	10.5 to 11.5 volts	1
Power Source	Solar	0
	Grid	1

4. CONCLUSION

The need of switching to a sustainable energy system is growing more important as the Earth's resources get more limited and the world's energy consumption keeps rising. With its availability and advantages for the environment, solar energy is the promising energy replacement for traditional energy sources. One way to optimize energy use and reduce reliance on the grid is to develop a solar system changeover switch that switches based on weather forecasting data. The prepared switch can smoothly switch between solar and grid power, guaranteeing a dependable and economical energy source, by integrating weather forecast data.

The primary objective of this project is to develop an IoT-based automatic changeover switch for domestic purposes, switching between the grid and PV system, based on weather forecasting data. Accurate weather forecasting data was obtained by accessing the 'OpenWeather' API, which was used to develop the changeover system. Additionally, this system collects data on the power consumption of the load and the level of voltage in the battery. These data are uploaded to a MongoDB database in Real-time. The IoT web interface allows for device monitoring by retrieving data from the database.

Hence this system can be used to enhance the efficiency and reduce the maintenance cost of the PV system. In future studies, data can be collected about solar energy generation from panels to develop an analysis model for forecasting switching patterns without third-party platforms.

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