Progress in Engineering Application and Technology Vol. 3 No. 1 (2022) 383-390
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PEAT

Homepage: http://publisher.uthm.edu.my/periodicals/index.php/peat
e-ISSN : 2773-5303

Development of Solar Photovoltaic Monitoring System For Maximum Power Point Tracking Solar Charge Controller

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DOI: https://doi.org/10.30880/peat.2022.03.01.039
Received 17 January 2022; Accepted 11 April 2022; Available online 25 June 2022

Abstract: Renewable energy is very important these days because it contributes significantly to the improvement of our climate. Renewable energy created very little environmental damage because it was derived from natural resources that replenished themselves in less than a human lifetime without depleting the planet's resources. The proposed system refers to the online display of solar energy power usage as a renewable energy. For this study, the monitoring system is carried out on a Raspberry Pi with the Flask framework. The goals of this study are to observe the power extraction from the solar panel and to develop a monitoring system for the MPPT charge controller. As a result, this smart monitoring are going to display the daily usage of power extracted by the MPPT. This study will aid in the introduction of a concept of monitoring utilizing the online platform technique for improved display for the charge controller.

Keywords: Renewable Energy, Raspberry Pi, Monitoring System, MPPT

1. Introduction

The Internet of Things (IoT) is a network that connects computing devices, digital and mechanical equipment, items, individuals with unique identities, and the ability for data transfer without human-to-human or human-to-computer contact. Physical items that are no longer detached from the virtual world can be controlled remotely over the internet [1]. Photovoltaic power plant is a complete photovoltaic system generating and supplying electricity that is connected to some local electricity network or to a distribution network [2]. Solar energy (photovoltaic) is gaining more attention for electricity supply around the world [3]. Solar is one of the most popular renewable energy utilized today. With its popularity, the efficiency of modern solar systems has become a vital issue [4]. As the world's population grows, so does the world's demand for energy. As a result, governments across the world are increasingly focused on the development of renewable energy. The most promising and trustworthy

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renewable energy source is solar energy [5]. Solar energy also known as solar photovoltaic (PV), is not a new technology. It has been the subject of extensive research for more than a century. Alexandre Edmond Becquerel, a French physicist, discovered the photovoltaic phenomenon in 1839, and the first solar cell was created in 1877 using selenium. The device was later developed, and in 1941, the first monocrystalline silicon solar cell was introduced [6]. PV modules' energy conversion efficiency has significantly improved. By utilizing modern technologies, it has now risen to 40.00 %. Multi-junction solar cells are one example of such technology. As a result, PV systems have become an important source of energy in the generation of electrical energy all over the world [7]. In the literature, several PV monitoring systems have been created and developed. These systems commonly use wireless public networks like GSM or other wireless communication networks to transfer data. High operating and maintenance expenses, as previously indicated, limit the growth of monitoring systems and, as a result, obstruct the process of effective real-time monitoring.

Stand-alone or grid-tied photovoltaic (PV) systems have been used traditionally in buildings [8]. Several researchers has made researches regarding PV monitoring system which monitor the activities of the solar panel performances [9] Tracking the maximum power point (MPP) of a photovoltaic (PV) array is usually an essential part of a PV system [10]. The technique of getting the most power out of PV modules/arrays may be separated into two types. The first is the best PV module/array configuration. The second is the creation of efficient Maximum Power Point Tracking (MPPT) algorithms. In this work, the second technique is adopted, and the algorithm allows us to monitor Maximum Power Point (MPP) under different climatic circumstances [4]. When temperature and/or irradiance change, the MPPT controller's job is to follow a new modified maximum power point in its corresponding non-linear curve, as illustrated in Figure 1.1. Perturb and observe (P&O) Algorithms have been proposed in the literature to accomplish this, and they work on various concepts such as considering voltage, current, and power [11]. This paper discusses design and implementation of microcontroller based wireless PV monitoring system of the MPPT solar charge controller [12]. The goal of this work is to use a serial communication on a Raspberry Pi for data collecting system to create an MPPT controller monitoring system.

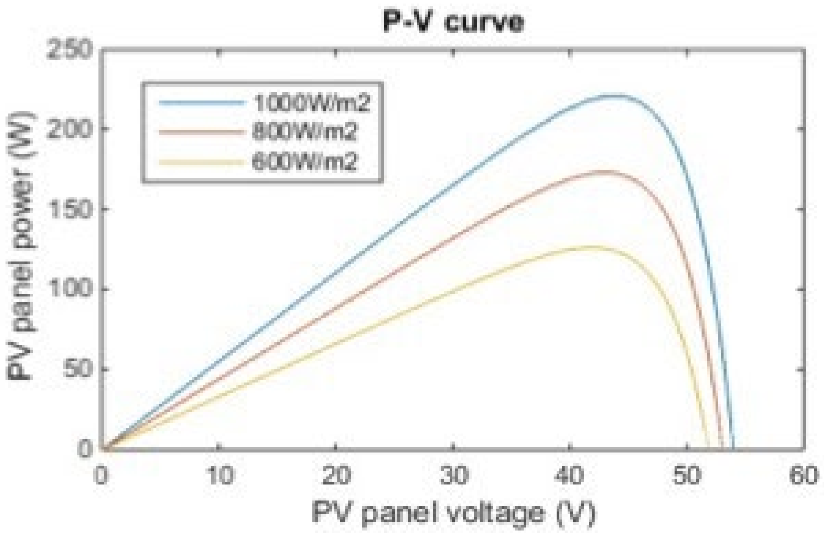


Figure 1: Power vs. Voltages Characteristics of Solar Cell at Different Irradiances [1]

2. Materials and Methods

A maximum power point tracker or (MPPT) is a high efficiency DC to DC converter that provides an optimal electrical load to a solar panel or array and generates a voltage appropriate for the load [13]. Main component of the hardware development are the solar panel, MPPT charge controller, lithium ion battery, voltage converter and the Raspberry Pi which works as the medium for serial communication between the MPPT and smart device.

2.1 Main components

The main components for this project are shown in Figure 2 where the Raspberry Pi (RPi) is connected to the MPPT solar charge controller using the RJ45 connector. The RPi ground used is on pin 6. The serial transmit TX is pin 8 and serial receive RX is pin 10. For the communicating process between the RPi and the MPPT charge controller, the pins connected must be the TX and RX pin only along with one of the ground pins. The RJ45 pin 4 which is the ground is connected to the respective ground pin on RPi which is the pin 6. The TX pin 5 is connected to GPIO 15 which is the RX on the RPi while the RX pin 6 is connected to GPIO 14 on the RPi which is the TX. So, transmit go to receive and receive goes to transmit.

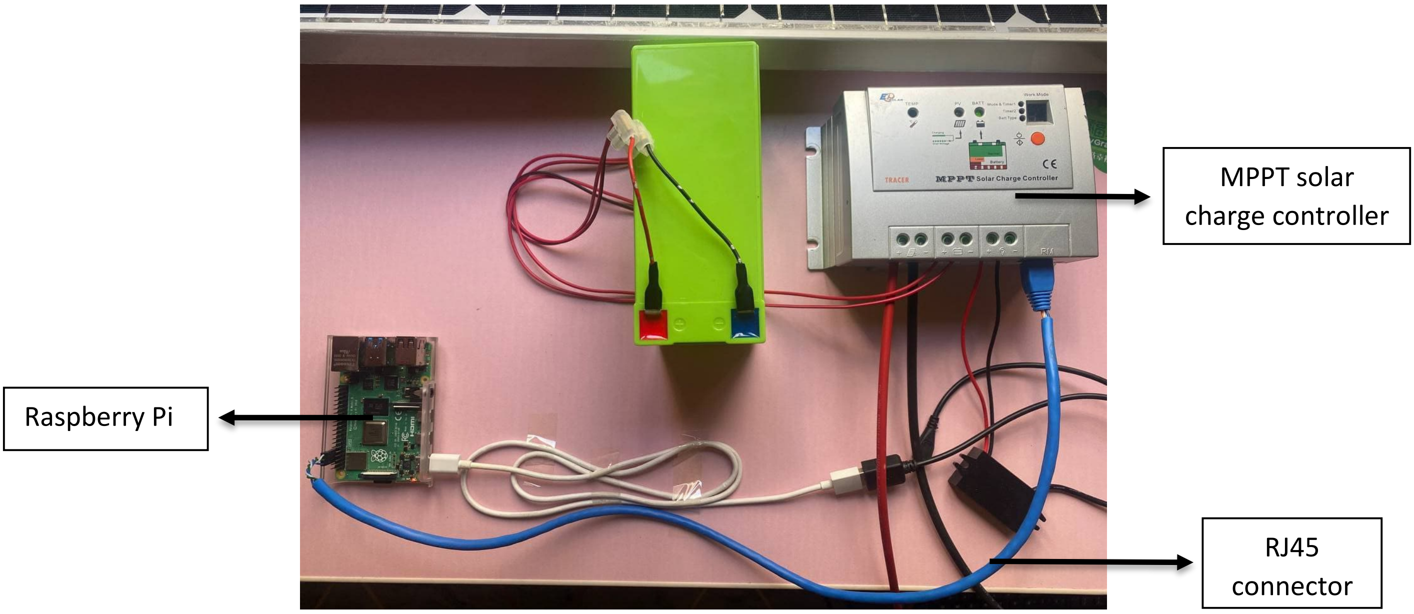


Figure 2: Raspberry Pi Connection with The RJ45 Connector

2.2 Overview of the system and operating principle

Figure 3 shows the process and works flow of this project from the start to the end. The MPPT charge controller will select the optimal area to absorb the most voltage possible from the PV panel as it absorbs sunlight. The MPPT charge controller will charge the battery until it is fully charged after the greatest power has been consumed. After that, the serial communication cabling between the MPPT and the Raspberry Pi is linked. To lower the output voltage from 12 V to 5 V, a 12 V voltage regulator is linked to the MPPT. The goal is to charge the Raspberry Pi, which requires 5 V to function. When there is no sunlight throughout the night, the Raspberry Pi will be powered by the battery that was charged earlier. Following that, a REST API will be created using a lightweight Python web framework called Flask, which is a very basic web server that can be used to receive or transmit data to a program, a mobile app, a web page, or any device with web access. With the current version of Raspbian, Flask is pre-installed. After then, Ngrok is used to show all of the desired info on the internet. In response to web queries to the solar route, the battery voltage, panel voltage, charging current, and load current are responded.

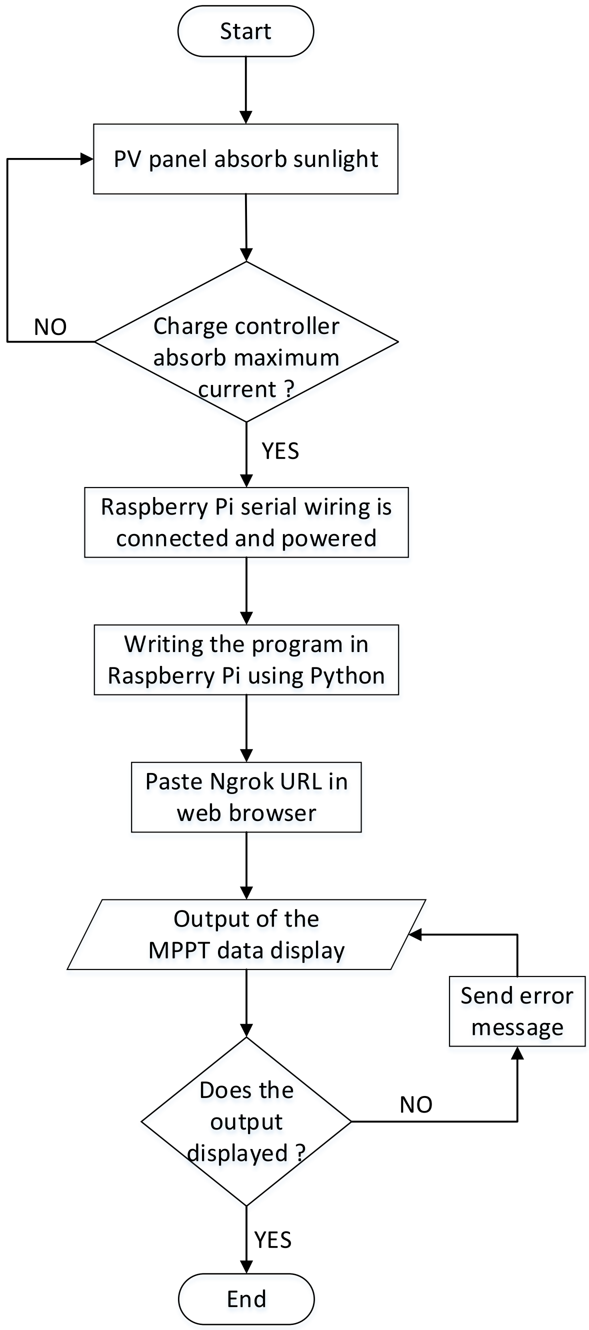


Figure 3: Flowchart of The Project

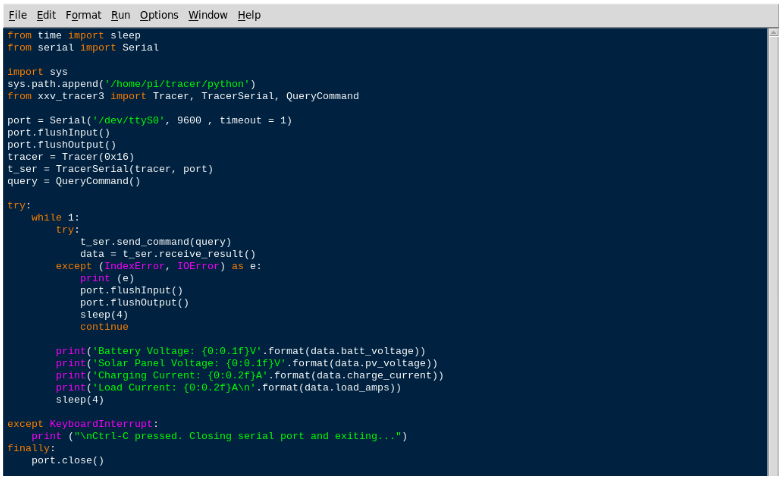
2.3 Hardware development

The hardware for this project is depicted in Figure 4. By using 12 gauge wire and MC4 connectors, the negative and positive outputs of the panel are linked to the controller's respective terminals. The Pi is powered at night using a 12 V battery linked to the controller's cell connections. When a step-down converter is placed in series to lower the 12 V to 5 V, the controller has 12 Vdc load terminals, which can operate the Raspberry Pi. The regulator's inputs are fed by the controller's 12 V load outputs. After that, the Pi's power input is linked to the 5 V output. The step-down regulator came with a USB-C connector that is compatible with the Raspberry Pi.

Figure 4: Complete Hardware Set Up of The Project

2.4 Software development

The python programs for serial communication data transmission between the MPPT solar charge controller and the Raspberry Pi are shown in Figure 5. The MPPT solar charge controller's real-time data is then obtained by running the program codes. The python code below shows few outputs displayed when the program is running. For every new data point, the panel voltage, battery voltage, charging current and load current are presented at a 4 second interval.



```
File Edit Format Run Options Window Help
from time import sleep
from serial import Serial

import sys
sys.path.append('/home/pi/tracer/python')
from xxv_tracer3 import Tracer, TracerSerial, QueryCommand

port = Serial('/dev/ttyS0', 9600 , timeout = 1)
port.flushInput()
port.flushOutput()
tracer = Tracer(0x16)
t_ser = TracerSerial(tracer, port)
query = QueryCommand()

try:
    while 1:
        try:
            t_ser.send_command(query)
            data = t_ser.receive_result()
        except (IndexError, IOError) as e:
            print (e)
            port.flushInput()
            port.flushOutput()
            sleep(4)
            continue

        print('Battery Voltage: {0:0.1f}V'.format(data.batt_voltage))
        print('Solar Panel Voltage: {0:0.1f}V'.format(data.pv_voltage))
        print('Charging Current: {0:0.2f}A'.format(data.charge_current))
        print('Load Current: {0:0.2f}A\n'.format(data.load_amps))
        sleep(4)

except KeyboardInterrupt:
    print ("\nCtrl-C pressed. Closing serial port and exiting...")
finally:
    port.close()
```

Figure 5: Python Code for Serial Communication Data Transferred

3. Results and Discussion

This section presents the result and discussion of the study. Figure 6 shows the connection of the Raspberry Pi to the power supply with their respective GPIO port for serial communication. Raspberry Pi is chosen for better performance and stability. The Raspberry Pi is powered up using the supply from the battery connected in line with the voltage regulator in order to only supply 5 V to the Pi. After the connection is completed, the connection is tested by running the Python program code.

Figure 6: Raspberry Pi GPIO Port Connection

Figure 7 shows the output of the MPPT solar charge controller, with the values of the output presented alternating every 4 seconds. The battery voltage is 13.3 V, the solar panels are 17.2 V, and the battery is being charged at 0.11 A. The Raspberry Pi uses only 0.54 A for load current. After 4 seconds, the current charging the battery and the current required by the Pi both increased to 0.15 A and 0.57 A, respectively. The battery should simply stay charged during the day as long as there is sunlight. The battery used in this project is a 10 Ah battery which definitely suitable to provide power overnight. Simple calculation can be made to determine the estimated hour to power up the Pi during the sun sets.

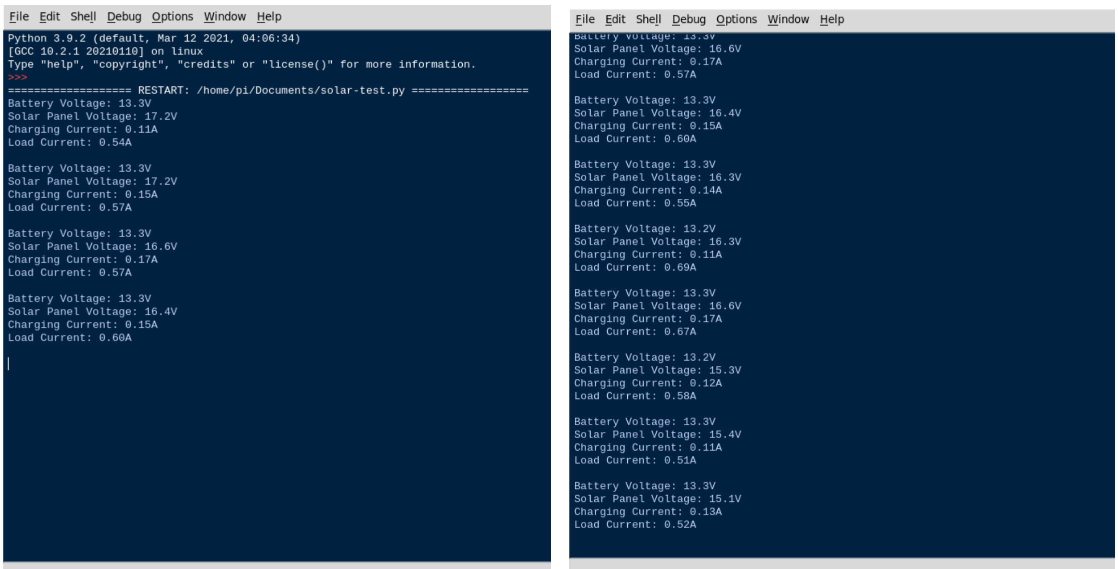


Figure 7: Output Displayed by The MPPT Solar Charge Controller

The output of the MPPT solar charge controller may be accessed publically through the forwarding URL indicated in Figure 8 from any web-enabled device. The data transmission from the MPPT to the Raspberry Pi may now be accessed using the address provided from any web-enabled device.

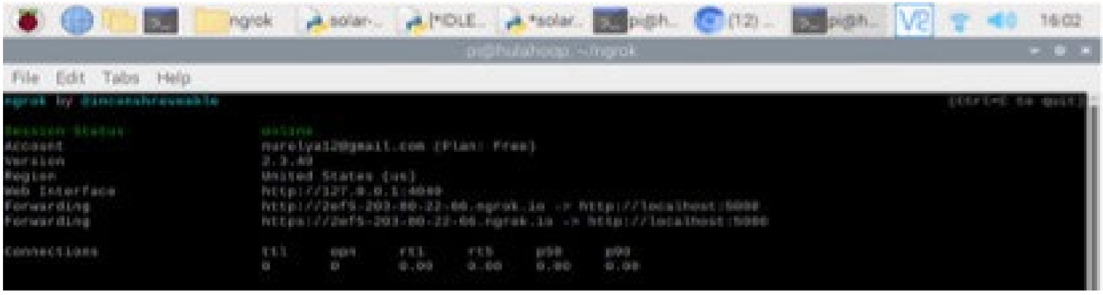


Figure 8: Raspberry Pi's Public Web Address

In terms of security, the https forwarding address is preferable than the http address. Copy the URL to the clipboard after selecting it. Open a new browser on a PC or any other web-enabled device, paste the URL, and then attach the solar route to the address. As demonstrated in Figure 9, the MPPT solar charge controller's most recent data is now shown. The information is now freely accessible to anybody with a web browser.

Figure 9: Return Data of The MPPT Solar Charge Controller

The final outcome of this project is determined by two factors: first, the project's hardware connection. The MPPT solar charge controller comes with a built connector for connecting the solar panel, battery, and load. Because the Raspberry Pi requires a power supply to operate, it is linked as a load in this project. The Raspberry Pi is also linked to an in-line step down voltage regulator, which reduces the voltage from 12.00 V to 5.00 V. The web development for data display via smart devices comes next. The serial communication between the MPPT and the Raspberry Pi is used to retrieve data from the MPPT solar charge controller. To show real-time data acquired by the MPPT solar charge controller, a Python software was built. The data is sent to any device with internet connectivity using the Flask framework. The web server is then hosted on the public internet via Ngrok.

4. Conclusion

One of the strategy for mitigating the worst environmental consequences is to use renewable energy technology. Due to the frequent of power outages, which are usually caused by severe weather, it is critical to use renewable energy and to monitor it. This study proposed a monitoring method for maximum power tracking in a solar module. A web development building is used to monitor data such as solar panel voltage, battery voltage, charging current, and load current in real time on any smart device application. This technology, in particular, allows for better monitoring, maintenance, and performance of photovoltaic generators. The system designed is capable of analyzing and monitoring the state of the parameters of a solar system that are being measured. Its main role is to regulate the evolution of the line's maximum output power.

Acknowledgement

The authors would like to thank the Faculty of Engineering Technology, Universiti Tun Hussein Onn Malaysia for its support.

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