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Original Article

IOT - Powered Smart Photovoltaic Charge Controller

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Abstract *- Renewable energy sources are proven to be reliable and accepted as one of the best ways to meet our growing energy needs. Solar energy is an innovative and emerging technology that does not emit zero carbon in today's world. Thus, it becomes really vital to pay close consideration to its monitoring and application for using solar energy creation. An IoT-centered photovoltaic monitoring framework is proposed to collect and analyze solar energy parameters to predict performance to ensure sustainable energy production. Our framework's main advantage is knowing the optimal solar storage efficiency. The basic use of the charge controller is to monitor the system to provide a price-friendly solution, which constantly demonstrates remote power Product and their functionality on a desktop or mobile device. The proposed system is a tested solar module to monitor power supply, current, voltage, load and mode. This solar monitoring project is made up of a small WiFi Module (ESP32) controller with an embedded Arduino Nano that connects and uploads data via dweet.io. Also, the wireless monitoring system increases the operational reliability of the solar system with low system costs.*

Keywords *- Arduino nano, MOSFET driver, Buck convertor, Solar panel, Sensors.*

1. Introduction

The Internet of Things foresaw the internet pervading each component of our regular lives, with web gadgets playing a crucial role. The Technology allows aspects to be sensed and remotely operated utilizing the existing network, leading to higher productivity, preciseness, and monetary benefit, as well as reduced human involvement. Photovoltaic urban areas, savvy countryside, substations, and photovoltaic street lighting are just a few of the applications of this technology. As This has been the most notable achievement in renewable energy history, with a much significantly faster rate than previously. [1] Energy sources are rapidly changing all over the world. Increasing electricity usage, environmental problems, and a force for green technology are driving the transition to renewable energy sources. Whilst fossil fuels might very well continue to satisfy almost 80 percent of the total electricity generation by 2040, renewable power is predicted to supply over 50 percent of the total supply after that, with a current annual growth rate of 2.5%. [2] This concept demonstrates a distinct curiosity inside and prospects for sustainable power for future energy demand. Sunlight has already soared to be among the upper three most powerful alternative energy sources (RESs) among potential RESs such as solar and wind, biofuels, hydropower, geothermal heat, oceanic energy, and so on. Renewable energies generated an estimated 6586 terawatt hours of energy in 2018, as per the Global Wind Energy Council (IRENA). Wind energy accounted for 1261 Terawatt Hours (19%), solar radiation accounted for 562 Terawatt Hours (9%), biofuel accounted for 522 Terawatt Hours (8%), whereas geothermal energy accounted for 88 Terawatt Hours (1%), and maritime energy accounted for 1 Terawatt Hour [3]. Contempt to the rapid growth of photovoltaic applications, the nonlinearity (NV) of solar cells presents a major obstacle in obtaining the most power from solar energy. A solar pv (PV) system ‘s (current to voltage) and electricity (power to voltage) curves, in specific, have a variational estate that is strongly dependent on the sun's solar insolation, temp, and load [4]. The current and voltage continuously differ from the predicted absolute maximum power formed by the PV system based on temperature and irradiance fluctuations. The PV panel's nonlinearity reduces the energy and shows improvement while growing system installation costs. To overcome the nonlinearity, PV modules must function at their maximum point of power (MPP) under various conditions [5-10]. Many mpp telematics (MPPT) methods for the pv system (SCC) have been developed to monitor the MPP of the solar cell. For example, perturb and watch [11-26], step-by-step thermal conductivity (IC) [27-30], biological, neurological evaluation, and fuzzy control (FLC) are being researched as methodologies for functioning the Photovoltaic solar panel at MPP more efficiently. In contrast, the P&O algorithm is renowned for its clarity and good efficiency. SCC with MPPT generates modulation of pulse width (PWM) message that controls the boost converter output from the Photovoltaic panel's output (voltage and current). The PV panel can achieve MPPT without the use of a controller circuit, but an efficient energy transmission isn't always assured, resulting in greater energy losses, while a Maximum power point can convert upwards of 90 percent of both the Photovoltaic power to the battery. Though the MPPT- SCC are uncomfortable, costly, and out of date. Its function is typically complicated, especially for city dwellers and non-technical individuals. Furthermore, these controllers do not include any data monitoring features. An effective technique for post-harvest and dispersion is critical to meeting the current energy demand. Charge or change is sometimes necessary for modern societies to preserve an equilibrium of supply and demand. A self-contained solar photovoltaic system with replacement power storage, like a power supply, can generate enough power to power the loads. Batteries are widely considered the most efficient origin of home power generation in rural and remote areas. Furthermore, because of the trend of smart cities, building automation, and home automation, the efficient use of power generation without sacrificing comfortability, a device which really can leverage and disseminate fuel from the Photovoltaic in a computational manner is essential. As a consequence, the necessity for effective MPPT-SCC is greater than ever. As a result, this paper created an adaptable, simple, reduced-price, and long charging control system that may be fitted in remote locations for less than the cost of a standard charging control algorithm. PWM energizes the charger controller described in this paper from Arduino. Before comparing the outcomes current and current to the voltage level evaluated by the battery-powered and current sensors, the solar power system evaluates the dc output and current. Consequently, a large power output power will have an LCD screen and transfer files to online application offerings, enabling users to track data output from any location on the planet.[31,32]

2. Methodology

2.1. Block Diagram and Explanation

The solar charge controller implementation includes a solar array, DC-to-DC converter, voltmeter, photodiode, Arduino, load and battery. Fig.1 depicts the framework of an envisaged Arduino-based solar array system with internal blocks.

A rechargeable and current solar array detector and an electric battery sensor provide system input. The current and voltage sensors measure the solar panel's output current and output voltage and are sent to the Arduino nano through an analogue-to-digital converter. A tiny control system reads the ADC data to determine the battery's open, sealed mass, absorption, and floating states. The output system comprises a DC-to-DC converter, an LCD, an LED display, and a load. The Arduino nano generated PWM signals to control MOSFET swapping from the DC-to-DC converter and an altered task loop to regulate the outcome of a DC-to-DC converter to charge the battery. An operational amplifier capable of supplying the rated current drive setup is considered necessary for the MOSFET from the low-power IC controller, which powers the MOSFET gateway circuit operator. The solar array, current, rated power, voltage level, power supply %, charging circumstance, and Pulse width modulation operating cycle will also be displayed on the LCD panels.

The wi-fi module is linked to a mobile device, specifically dweet.io, a cloud service. The LCD is connected to an I2C circuit, and a fuse of 300 Amp is connected from the solar input to the current sensor, the system's input, and three resistors form a voltage divider. The solar voltage will pass through the capacitor and into the buck converter. The MOSFET is used for switching, while the PNP transistor performs the correct ON and OFF functions. When the power supply is turned off, current flows between the inductor, capacitor, and freewheeling diode. The freewheeling diode directs current to the battery when the solar panel is turned on. The voltage regulator for 5V is 7804. A relay is used to turn a on and off a load. The PWM charge controller functions as an electric switch between the two batteries. MPPT is a technique for monitoring and controlling energy flow from the solar panel to the batteries.

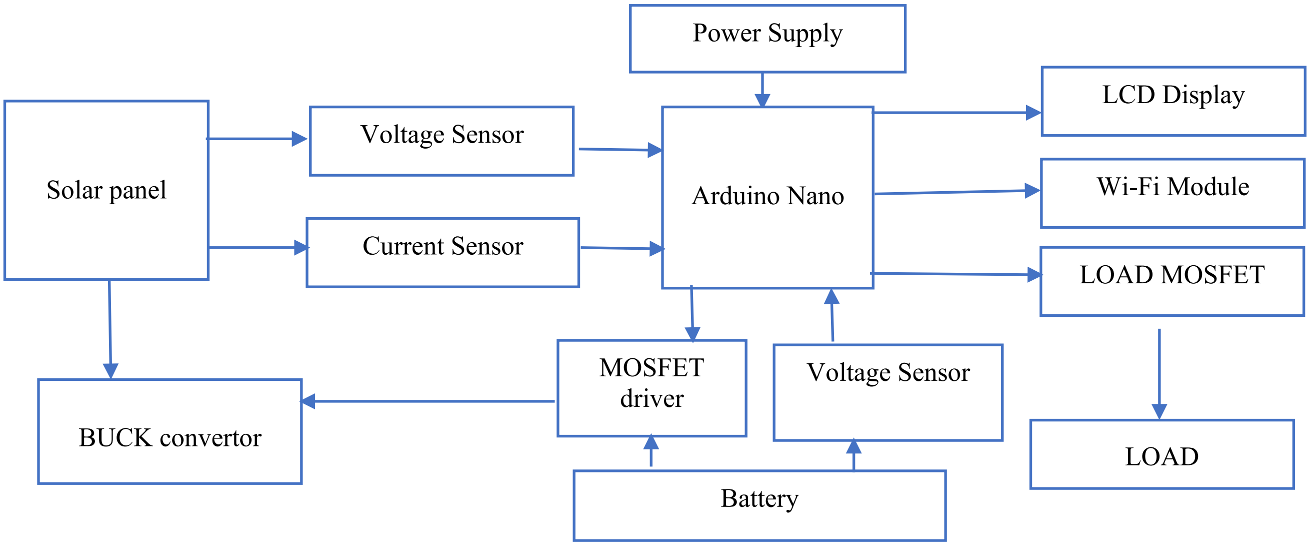


Fig. 1 Block Diagram of Photo-Voltic Charge Controller

2.2. Circuit Diagram and Layout

The circuit diagram for the photovoltaic system is shown in fig. 2 and fig. 3, representing the interconnection of different modules and blocks with detailed circuit and layout representation. It was designed and simulated using proteus.

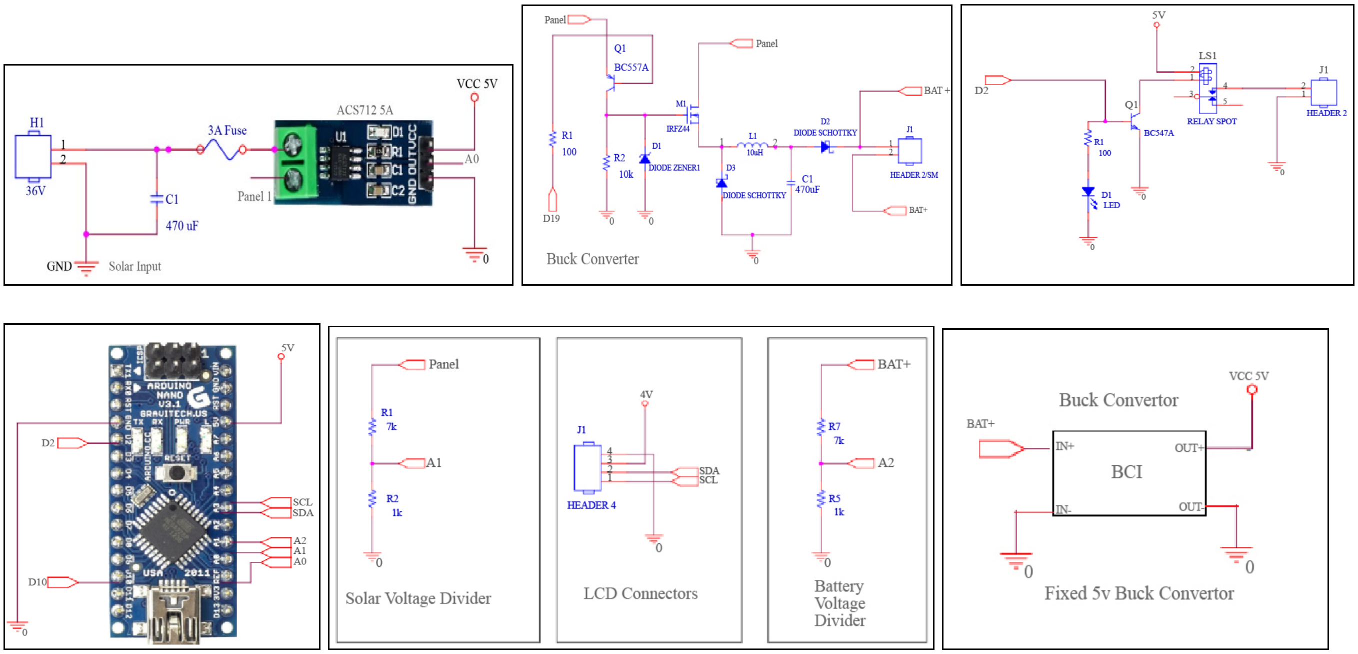


Fig. 2 Circuit diagram of the photovoltaic charge controller

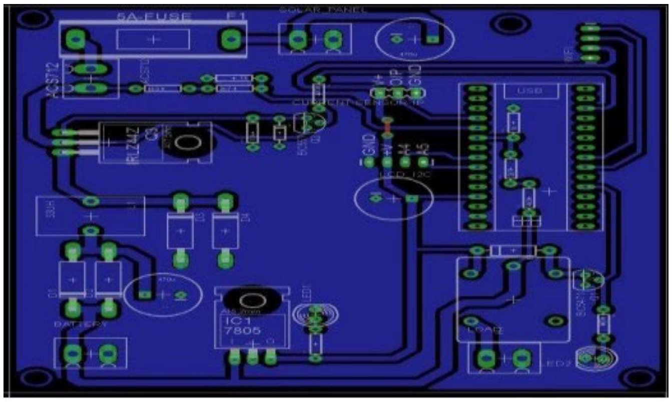


Fig. 3 Layout of the photovoltaic charge controller

Table 1. Modes and the description of the modes

Modes	Description
Bulk mode	When the battery is less than 80% charged, this stage occurs.
Absorption	The battery is said to be in absorption mode if the voltage is between 14.4 and 14.8 volts.
Float	When a battery is fully charged, it reaches the float condition.

Fig. 4 shows the workflow of the implemented project, which involves the various stages starting from designing the circuit diagram to the final development of code and testing as well as troubleshooting of the same, followed by the final assembly of hardware, including testing to checking the working of the project.

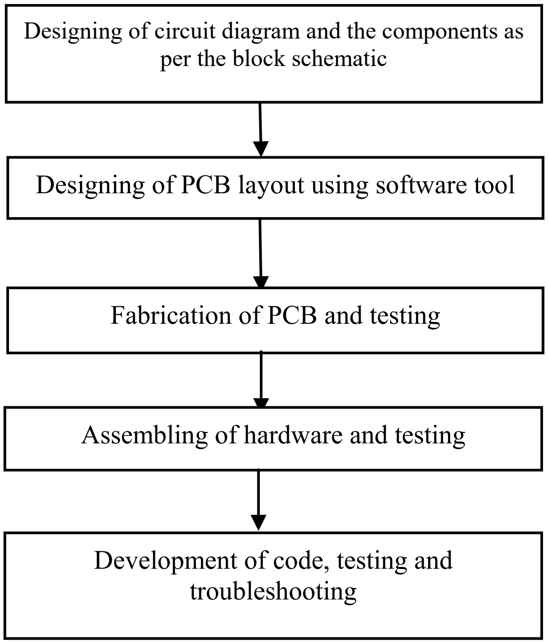


Fig. 4 Workflow of the implemented project

2.3. Dc-Dc buck Converter

A drop/buck converter is a DC-to-DC converter that reduces the voltage from input to output. The power supply phase typically comprises a minimum of two semiconductors and only one energy storage element, such as a capacitor, inductor, or both. To reduce ripple voltage, capacitors produced of capacitors are frequently added to the converter's output and inputs. Switch converters produce a lot of power. Direct controls, simple circuits that decrease power output such as heat but don't increase output, are more effective as DC-to-DC converters.

Table 2. Pin connections details of Arduino nano

Arduino Nano Analog Pins	Pin Connection Description
A0	Solar Panel with Current Sensor
A1	Solar Voltage Divider
A2	Battery Voltage Divider
SDA	LCD connection
SCL	LCD connection
D2	Load Enable/Disable
D10	Buck Converter

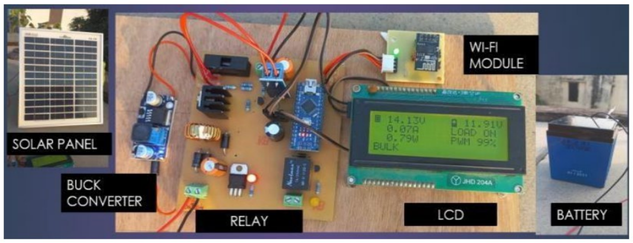


Fig. 5 Hardware Design of Photovoltaic Charge Controller

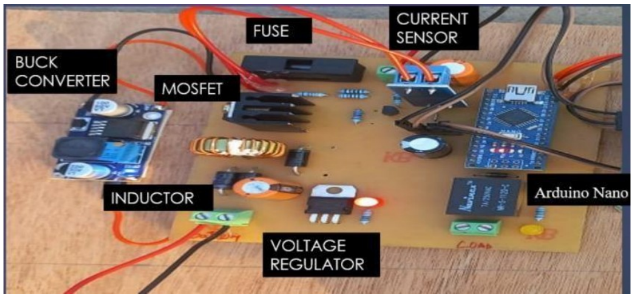


Fig. 6 Major Components of Photovoltaic Charge Controller

2.4. Software Implementation

2.4.1. EAGLE

EAGLE is a computer-aided design automation (EDA) operating system that enables PCB printers to seamlessly connect system drawings, element layouts, PCB routes, and full library contents.

2.4.2. ARDUINO IDE

The Arduino Software Development Model is a cross-platform (Windows, macOS, and Linux) application written in C and C++.

2.4.3. Dweet.io

It is simple to publish and adhere to computers, detectors, gadgets, robots, and gadgets on Dweet.io. Dweet.io makes device and detector information easily accessible via a Restful API-based web, allowing you to create applications or simply share data quickly.

Fig. 7 shows the flowchart for implementation steps for software simulation, where it specifies the level from placement of components and devices to connecting them and troubleshooting.

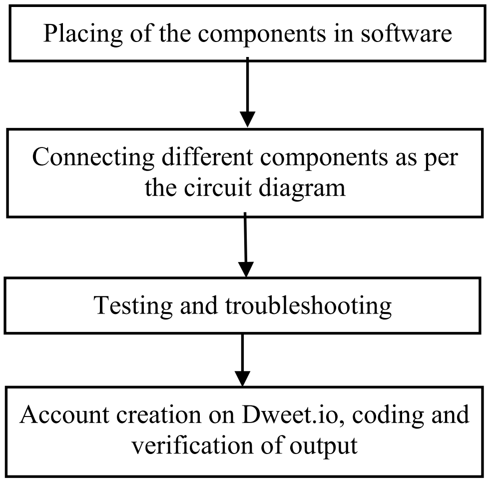


Fig. 7 Flowchart for implementation steps for software simulation

Table 3. Iot cloud service and their use

Software	Purpose of the use
Arduino IDE	Write the code and upload it to the board.
EAGLE	To develop a circuit layout
Proteus	To develop a circuit diagram

Table 4. Software and its description

Iot cloud service	Uses
Dweet.io	IOT cloud service

3. Observations and Results

Current voltage and detector interpretation data can be viewed online in real-time. Data.io allows it to be showcased on mobile devices. The experiment intends to display the recharging voltage information from the solar array to the battery. Table 5 shows the results that the designed charge controller works properly. The system efficiency ranges from 83% to 98%, depending on the power input from the board and the decline of I2R (copper) in the Power converter. Furthermore, the interaction charge controller is linked to an LCD and dweet.io, which will display some variables as shown in table V below and also shown in fig. 8 and fig. 9 in the result section.

Table 5. Photo-Voltic charge controller performance test

Modes	Solar Panel			Battery		
	Solar Panel Voltage (V)	Solar Panel Current (A)	Solar Panel Power (W)	Load	PWM	Battery Input Power (W)
Bulk	0.00V	0.01A	0.11W	ON	99%	11.82V
Absorption	17.88V	0.16A	0.11W	ON	99%	15.00V
Float	When the battery is fully charged, it reaches float condition.					

3.1. Modes in Solar Charge Controller

There are three stages for battery charging as follows:

3.1.1. Bulk

The first step/stage of charging begins when the sun shows up, or the generator is turned on. This phase comes when batteries are only slightly charged, usually less than 80%. The frequency band enables a solar cell or power source to charge batteries with as much amperage as possible. The voltage of the batteries will gradually increase over time as they collect electricity.

3.1.2. Absorption

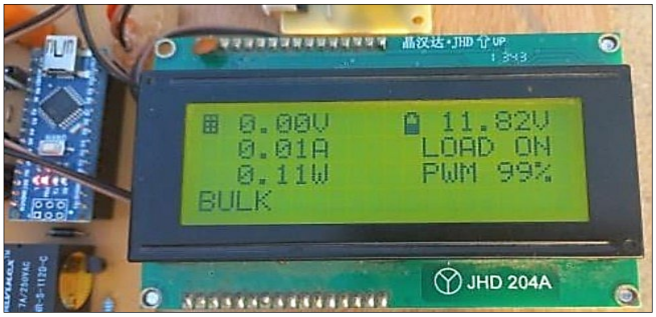
Once batteries attain a fixed "Absorb Voltage," which is usually between 14.4 and 14.8 volts, they enter into Absorb phase. Whenever the power supply reaches this stage, it is usually charged at around 80-90%, relying on the charging level. The battery packs are preserved at a constant voltage during this phase, and the cranking amps to the battery packs decrease as the batteries charge completely. This stage concludes when a scheduled stage is reached or even a count of amps trying to enter the charger drops below the threshold.

3.1.3. Float

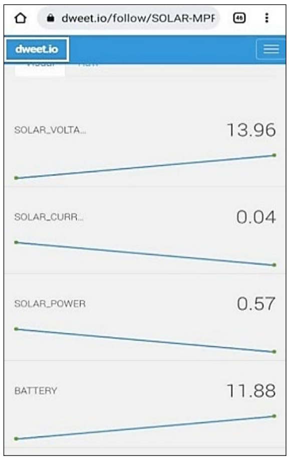
After the Absorption stage, the charging control system will reduce the voltage to the specified value and start the Float phase. When fully charged, battery packs reach a floating point. Remember that it is critical to configure your controller or charger properly.

3.2. Results

3.2.1. Bulk Mode


```
 0.00V    11.82V
 0.01A    LOAD ON
 0.11W    PWM 99%
BULK
```

(a)


dweet.io/follow/SOLAR-MPF

dweet.io

SOLAR_VOLTA... 13.96

SOLAR_CURR... 0.04

SOLAR_POWER 0.57

BATTERY 11.88

(b)

Fig. 8 Results shown for Bulk mode (a) LCD display output and (b) Dweet.io output

3.2.2. Absorption Mode


```
 17.88V    15.00V
 0.16A     LOAD ON
 2.42W     PWM 99%
ABSORPTION
```

(a)


dweet.io/follow/SOLAR-MPF

SOLAR_VOLTA... 14.05

SOLAR_CURR... 0.09

SOLAR_POWER 1.08

BATTERY 11.77

dweet.io is brought to you by Bug Labs, Inc.
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hello@dweet.io

(b)

Fig. 9 Results shown for Absorption mode (a) LCD display output and (b) Dweet.io output

4. Conclusion

In this paper, we have designed, implemented, and tested an intelligent IoT-based solar charger. The suggested hardware was first modelled on the Proteus system to verify the results before being developed and tested as a model device. The design specification was then validated using modelling & test results. The suggested charging controller includes an IoT port, allowing us to track system status remotely easily. We can turn the on and off the circuit while attempting to access and monitor data with our electronic devices. As a result, we can continue operating the controller without any manual process, even if the controller is not present. The 12-volt power supply can be updated to a 48-volt battery. Photovoltaic grid systems can be implemented to electrify remote, isolated areas where traditional electricity is difficult to reach. After charging the battery, excess energy generated can be sent to the national grid, helping to meet the world's growing energy demand.

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