



## Experimental Study on MPPT Solar Charge Controller Using P and O Technique

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### Abstract

Solar panels transform solar energy into electrical power, it is stored in batteries during the day and used at night. Our aim is to maximise solar panel electricity to the load. A network principle called maximum power point transfer theorem helps us do this. The DC to DC converter adjusts the solar voltage output for the load in the circuit to raise or reduce voltage. The DC-to-DC converter's duty cycle is changed by an Arduino control board to reach the desired load voltage. The Arduino board uses Perturb and Observe to calculate the Maximum Power Point (MPP) from the load side signal. At full power, the battery charges and stores solar energy like a load. DC energy from the battery can be used directly or converted to AC via an inverter. We use the Perturb and Observe MPPT approach in this scenario. Photovoltaic panel performance depends on the MPPT algorithm. It tracks the maximum power point to improve solar module conversion efficiency. There are many tracking algorithms for this. Using P&O method, MPPT Solar charge controllers are more efficient than PWM controllers.

**Keywords:** Maximum Power Point (MPP), Perturb and Observe Technique Solar panels, electrical power

### 1 Introduction

Maximum Power Point Tracking (MPPT) is a technology used in solar power systems to optimize PV panels' efficiency [1]. Adjusting their operating point despite changing sunlight intensity and temperature conditions, requiring dynamic optimization for consistent energy harvesting [1-3]. MPPT ensures solar panels operate at the maximum power point, preventing fluctuations in output due to factors like sunlight intensity, temperature, and shading [5,6]. A 12V charging panel typically generates between 16 and 18 volts, influenced by various conditions, yet only around 14.6 volts is required to effectively charge the majority of 12V batteries. The majority of the voltage is lost. By utilising MPPT Charging Technology, we can transform the surplus voltage into current, thereby enhancing efficiency [7].

The main objectives of this paper are as follows:

- Simulate the performance of Smart Charge Controllers (SCCs) using PWM and MPPT techniques.
- Propose a prototype hardware model for IoT-enabled MPPT-SCCs.



- Compare the effectiveness of the suggested hardware model against the simulation outcomes.
- Monitor the real-time performance of the suggested prototype model through a smartphone.

In approaching years, solar energy adoption will increase. PV modules work in series and parallel to convert solar energy into electricity. Simple freestanding PV systems use PV arrays to convert sunlight into DC electricity [8]. An crucial part of our PV system, the charge controller, manages battery charging and discharging and guarantees the battery receives the right voltage. The Zulkifli group [9]. Photovoltaic systems and solar panels struggle to convert sunlight into electricity due to low energy conversion efficiency. Researchers found that the panel converts 35–45% of solar energy into electricity [10]. Thus, we must improve our solar panel's efficiency in converting sunlight into power. Storing energy and charging batteries efficiently requires a charging mechanism. A maximum power point tracking technique improves panel efficiency. Though solar PV works effectively at ambient temperature, output varies. This fluctuating solar output is captured using MPPT methods like P&O MPPT and soft computing algorithms. Although solar PV systems work effectively at room temperature, their output is uneven. MPPT methods like P&O MPPT and soft-computing algorithms are being researched to capture this variable solar electricity. Constant current, constant voltage, and reflex charging are typical. Constant charging can easily cause overcharging since constant voltage does not effect initial current charge. Reflex charging needs lots of electricity [11]. Methodologies, operational standards, proper parameters, and accurate measurements within a particular time window are the emphasis of [12]. Lead acid batteries are the major emphasis in these circumstances, so understanding the charging and discharging process is crucial before charging. It's also vital to choose the right charge controller from the three main types: basic voltage regulator-based, PWM-based, and MPPT-based. [13,14] SCC design can be investigated using MATLAB simulations, hardware prototypes, and a modified buck-boost converter and P&O algorithm. examined a two-phase MPPT charge controller that extends battery life and speeds charging. According to Rokonuzzaman et al. [15], the SCC with MPPT generation maximises electrical tracking and battery charging. These studies show that MPPT improves PV module efficiency. Further research compares MPPT methods [16], demonstrating that hardware optimisation can make the P&O MPPT approach more successful for commercial converters. The MPPT algorithm addresses monitoring speed, performance, cost, and complexity [17]. The authors estimated that the literature contains the latest and most essential solutions, highlighting their effectiveness in non-uniform shading situations. To maximise PV panel efficiency, they chose to supply fixed voltage to the main inverter circuit using a chopper. For solar cell controllers to determine the maximum power point (MPP), various MPPT algorithms have been developed. To improve MPP solar panel performance, P&O, IC, Genetics Neural algorithm, and FLC are being tested. P&O stands out for its simplicity and efficacy. The SCC and MPPT generate a PWM signal that controls the Boost converter's output based on panel voltage and current [18]. A PV panel can reach MPPT



without a controller, but power transfer may be inefficient and lead to power loss. In contrast, an MPPT-SCC may transmit 90% of panel power to batteries. Most MPPT-SCC models are big, expensive, and antiquated, making them problematic for urban inhabitants and non-technical users. Additionally, these controllers lack comprehensive data monitoring. Group Shakerie [19]. Energy extraction and distribution must be efficient to fulfil rising demand. When we go to smart cities, buildings, and houses, a smart device is needed to control and distribute PV energy. Devices must ensure power efficiency without sacrificing human comfort. Maximum power point tracking smart charge controllers are needed more. Internet of things (IOT) connects computers, gadgets, and people to transfer data without human participation [20]. IOT connectivity lets physical things be remotely controlled by the internet, integrating them into the digital world. MPPT-SCCs without IoT functionalities are expensive and difficult for urban and non-technical consumers. Features and efficiency are improved to increase energy collection and distribution. Thus, this study proposes a smart MPPT-SCC model with IoT to optimise battery charging and prevent against overvoltage and current, extending battery life.

## Methodology

As it is mentioned earlier that there are several techniques which can be used to track the Maximum Power Point and those techniques are as follows: Perturb and Observe (P&O), Incremental Conductance (INC), Fractional Open Circuit Voltage (FOCV), Hill Climbing (HC), Fuzzy Logic, Neural Network and many more among all these techniques [21]. It is impossible to find the proper and accurate technique which we need because every method has its own advantages and drawbacks. For example, the hill climbing and perturb and observe methods are broadly used as MPPT algorithm because of their easy implementation and requiring less sensors.

P&O method is one of the most widely used method for maximum power point tracking and the main objective of MPPT is to maximize the output power from a PV array which can vary based on some factors like sunlight intensity, temperature, and electrical characteristics of solar cell. The P&O method works by continuously adjusting the operating voltage of PV panel and observing the output power, it will then decide whether to increase the voltage or decrease the voltage to properly move toward the MPP.

There are some steps which is necessary to understand the function of P&O technique and those are:

1. **Initial Perturbation:** The process starts with perturbing i.e., change in the voltage of PV panel. That perturbation is generally very small change in voltage.
2. **Measurement of Voltage and Current:** After each perturbation the voltage and current of PV panel is measured and this measurement is further used to calculate the output power of the panel and the output power is calculated by using this formula: -



$$P = V * I$$

3. Comparison of Change in Power: After perturbing the voltage and measuring output power of PV panel the system compares the new output power with previous one:

- If the power increases ( $P_{NEW} > P_{OLD}$ ): if the power increases, then it indicates that the perturbation is closer to MPP so the voltage will increase to achieve the MPP.
- If the power decreases ( $P_{NEW} < P_{OLD}$ ): if the power decreases, then it indicates that the perturbation is far away from MPP so the voltage will decrease to achieve the MPP.

Let's take an example and understand it clearly,

Step 1: Measure initial parameter

- Initial Voltage: Let's assume the initial voltage of solar panel is 30V.
- Initial Current: Let's assume the initial current is 4A.
- Initial Power: Calculate the initial power

$$P_{OLD} = V_{OLD} * I_{OLD} = 30V * 4A = 120W$$

Step 2: Perturbation

- Perturbation ( $\Delta V$ ): Perform a small change in voltage and for this example increase the voltage by 0.5V.

$$V_{NEW} = V_{OLD} + \Delta V = 30V + 0.5V = 30.5V$$

Step 3: Measure New Parameters

- New Voltage ( $V_{NEW}$ ) = 30.5V (as calculated above)
- New Current ( $I_{NEW}$ ) = assume the new current is 3.95A.
- New Power ( $P_{NEW}$ ) = calculate the new power:

$$P_{NEW} = V_{NEW} * I_{NEW} = 30.5V * 3.95A = 120.475W$$

Step 4: Compare the Power Values

- Power Difference( $\Delta P$ ) = Change in power

$$\Delta P = P_{NEW} - P_{OLD} = 120.475W - 120W = 0.475W$$

Step 5: Decision making

- Here  $\Delta P > 0$

The Power increased with the increase in voltage.

- Action: Continue increasing the voltage in same direction.

Step 6: Update the Parameters



- $VOLD = VNEW = 30.5V$
- $POLD = PNEW = 120.475W$

Step 7: Repeat the Process

- **Continuously Monitoring:** Repeat the step 2 and 6 to continuously perturb the voltage and observe the change in power to operate on MPP.

### Proposed work:

This illustration, figure-2, presents a block schematic that outlines the fundamental design of the prototype hardware. To achieve maximum power output, the Solar PV panel must be operated with an MPPT controller utilizing P&O technology. The proposed rate controller has been confirmed as valid.

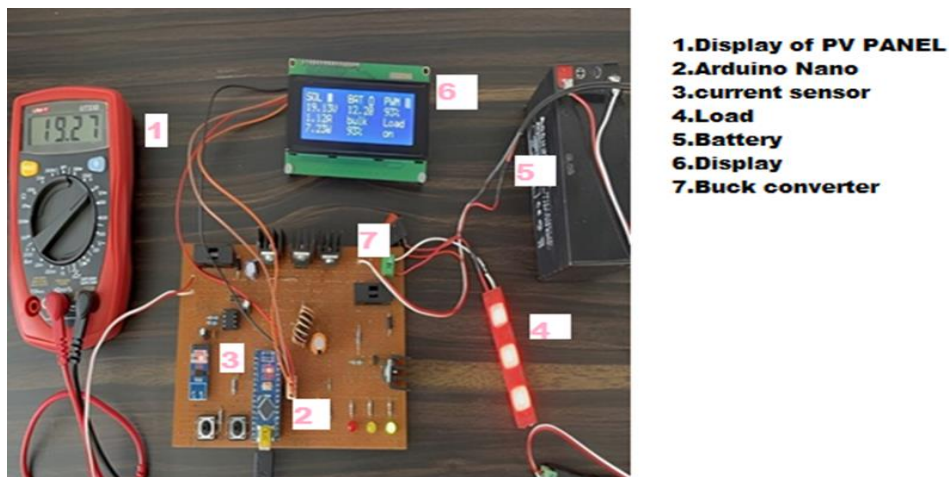


Figure 2: Complete Hardware type of MPPT Controller using P&O Technology

The Arduino NANO receives the input voltage and current via a current sensor and a voltage divider circuit connected through a fuse. The components of the prototype model include the Arduino NANO, relay, buck converter circuit, battery, display, and current sensor. a customised green back increases converter serves as an MPPT controller between the PV panel and the battery. Battery is to store energy in day time and converted it in AC in night. To show output parameters display is attached to the Arduino Nano. The various components utilised in the hardware model are presented in Table 1.

Table-1: elements featuring pricing and evaluations

S.No.	Item	Rating	Cost
1.	Solar PV panel	40 W	1200
2.	Arduino Nano	5 V	399



3.	Buck converter component	24V to 12V	55
4.	Fuse	5A	60
5.	Current Sensor	4.5 V - 5.5 V	249
6.	Battery	12 V	699-2999
7.	Display	5 V	700
8.	resistors	Different values	100
9.	capacitor	1000 $\mu$ F,etc	50

## 2 Result and Discussion:

This section presents the hardware results. Table-2 indicates that the efficiency of the SSC type solar charge controller is approximately 65.74% on average, taking into account varying solar insolation from 186 to 445 w/m<sup>2</sup> and temperatures ranging from 33 to 230°C [20] [13]. It can be observed from table-2 that the efficiency of the MPPT type is approximately 91.7% (on average).

Table-2: Efficiency of MPPT solar controller using P&O technology.

Time	Temperature	current	voltage	Power	Efficiency
8A.M	23 <sup>OC</sup>	1.8A	15.6V	22.08 W	91.2%
9A.M	25 <sup>OC</sup>	1.9A	16.3V	23.3W	92.1%
10A.M	27 <sup>OC</sup>	1.8A	16.9V	23.2W	91.9%
11A.M	29 <sup>OC</sup>	2.0A	17.1V	27.8W	92.9%
12P.M	31 <sup>OC</sup>	2.13A	17.0V	29.2W	93.1%
13PM	32 <sup>OC</sup>	2.23A	17.2V	30.4W	93.3%
14PM	33 <sup>OC</sup>	2.19A	17.5V	30.1W	93.0%

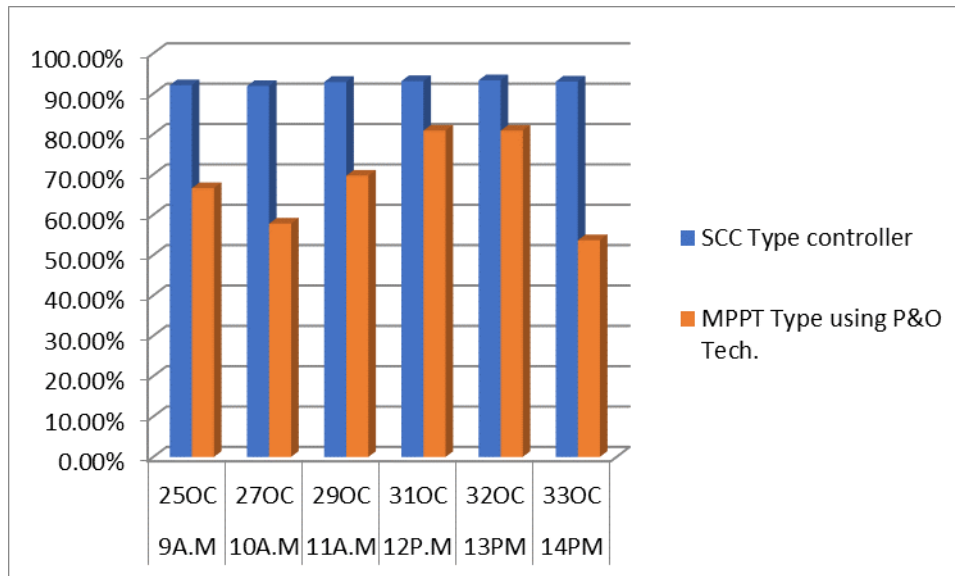


Figure 3: Comparison bar graphs the data from Proposed Hardware

### 3 Conclusion

In this research article a straightforward and effective MPPT solar charge controller model tailored for a PV system. The design effectively maximises power extraction from a PV cell through the use of the P&O algorithm. This model comprises various components, including the PV system, DC-DC converter, and load. The IV and PV curve from a single model and array, under constant temperature, constant irradiance, and specified temperature, has been observed. The MPPT algorithm is utilised to compare the ideal and actual power. The proposed method demonstrates greater efficiency and robustness when compared to traditional methods, particularly under varying radiation and temperature conditions.

### References

- [1] Tofoli, L. S., de Paula, W. J., Pereira, D. S., & Junior, L. A.: Comparative Study of Maximum Power Point Tracking Techniques for Photovoltaic Systems. International Journal of Photoenergy,(2015)DOI:doi.org/10.1155/2015/812582
- [2] Savaliya, S., & Ray, S. : A comparative study on different MPPT techniques applied on photovoltaic system. International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, 4(5), 4231–4236,(2015)
- [3] Kim, E., Warner, M., & Bhattacharya, I.: Adaptive Step Size Incremental Conductance Based Maximum Power Point Tracking (MPPT),(2020) DOI:arXiv:2011.07649
- [4] Airfoils: : Where the Turbine Meets the Wind.. Department of Energy, (2017)
- [5] Quadrillion: EIAprojects nearly 50% increase in world energy use by 2050. U.S. Energy Information Administration. (2021).



- [6] Sigrist, L., Lobato, E. and Rouco, L., 2013. Energy storage systems providing primary reserve and peak shaving in small isolated power systems: An economic assessment. *International Journal of Electrical Power & Energy Systems*, 53, pp.675-683. International Energy Agency. :World energy outlook 2024
- [7] Krishnaram, K., Sivamani, S., Alaas, Z., Ahmed, M.M.R., Senthilkumar, S. and Raj, S.A., 2024. Experimental design and analysis of advanced three phase converter for PV application with WCO-P&O MPPT controller. *Scientific Reports*, 14(1), p.10984.
- [8] Zulkifli, N.E.M., Mustafa, F., Zambri, N.A. and Yi, S.S., 2022. Development of solar photovoltaic monitoring system for maximum power point tracking solar charge controller. *Progress in Engineering Application and Technology*, 3(1), pp.383-390.
- [9] Ogunmodimu, O. and Okoroigwe, E.C., 2018. Concentrating solar power technologies for solar thermal grid electricity in Nigeria: A review. *Renewable and Sustainable Energy Reviews*, 90, pp.104-119.
- [10] Saravanan, S. and Babu, N.R., 2016. Maximum power point tracking algorithms for photovoltaic system—A review. *Renewable and Sustainable Energy Reviews*, 57, pp.192-204.
- [11] Liao, T.J. and Chen, C.L., 2008, November. Robust LED backlight driver with low output voltage drop and high output current accuracy. In *2008 IEEE International Conference on Sustainable Energy Technologies* (pp. 63-66). IEEE.
- [12] Samal, S., Barik, P.K. and Sahu, S.K., 2018, March. Extraction of maximum power from a solar PV system using fuzzy controller based MPPT technique. In *2018 Technologies for Smart-City Energy Security and Power (ICSESP)* (pp. 1-6). IEEE.
- [13] Kamath, R.H., Sharma, B.S.S.P.M. and Siva, B.R., 2018. PWM based solar charge controller using IoT. *International Journal of Engineering & Technology*, 7(2.7), pp.284-288.
- [14] Rokonzaman, M., Shakeri, M., Hamid, F.A., Mishu, M.K., Pasupuleti, J., Rahman, K.S., Tiong, S.K. and Amin, N., 2020. Iot-enabled high efficiency smart solar charge controller with maximum power point tracking—Design, hardware implementation and performance testing. *Electronics*, 9(8), p.1267.
- [15] Abuzairi, T., Ramadhan, W.W.A. and Devara, K., 2019. Solar charge controller with maximum power point tracking for low-power solar applications. *International journal of photoenergy*, 2019(1), p.5026464.
- [16] Baba, A.O., Liu, G. and Chen, X., 2020. Classification and evaluation review of maximum power point tracking methods. *Sustainable Futures*, 2, p.100020.



- [17] Singh, A.K., Hussain, I. and Singh, B., 2017. Double-stage three-phase grid-integrated solar PV system with fast zero attracting normalized least mean fourth based adaptive control. *IEEE Transactions on Industrial Electronics*, 65(5), pp.3921-3931.
- [18] Shakeri, M., Shayestegan, M., Reza, S.S., Yahya, I., Bais, B., Akhtaruzzaman, M., Sopian, K. and Amin, N., 2018. Implementation of a novel home energy management system (HEMS) architecture with solar photovoltaic system as supplementary source. *Renewable energy*, 125, pp.108-120.
- [19] Soni, R.K., Nayak, S., Samal, S., Barik, P.K., Sahoo, S. and Nanda, L., 2022. Efficiency enhancement of solar photovoltaic module based on different cooling arrangement. In *Innovation in Electrical Power Engineering, Communication, and Computing Technology: Proceedings of Second IEPCCT 2021* (pp. 31-39). Springer Singapore.
- [20] Samal, S., Barik, P.K., Soni, R.K. and Nayak, S., 2022. Simulation and experimental investigation of a smart MPPT based solar charge controller. *Energy Sources, Part A: Recovery, Utilization, and Environmental Effects*, 44(3), pp.7748-776