A HYBRID MPPT ALGORITHM FOR SOLAR PV WITH BATTERY CONNECTED SYSTEM

Harrini R[1], Dr. V. Gopalakrishnan[2]

[1]PG Scholar, Power Systems Engineering, Government College of Technology, Coimbatore, India
[2]Electrical & Electronics Engineering, Government College of Technology, Coimbatore, India

Email: [1]harrini662000@gmail.com, [2]gopalakrishnan.v@gct.ac.in

Abstract

Electricity generation using renewable energy resources rather than fossil fuels reduces gobar gas emissions from the power sector and prevents pollution. The best alternative to conventional energy sources is solar photovoltaic (PV) generation; however, it has some significant disadvantages, including high initial costs, poor photoconversion efficiency, and climatic dependencies. In order to overcome this, PPT techniques are used. The projected work provides a solar power system which tracks the maximum power point using Artificial Neural Network and Perturb and Observe algorithm. Additionally, it adds a new setup for the system that links the photovoltaic array as well as the battery to the system inverter's DC-link through a single DC-DC converter that can act as both charge controller and Maximum Power Point Tracking (MPPT) device at the same time. When solar energy production exceeds demand, the excess energy is stored in batteries and provided during periods of very low irradiance. The DC voltage is converted into AC voltage using an inverter. The benefit of this technique is that it has greater tracking accuracy. For validation, the proposed model has been analyzed by using MATLAB/Simulink.

Keywords: Photovoltaic, MPPT, Artificial Neural Network Perturb and Observe, Single DC-DC converter.

1. Introduction

The best alternative to traditional energy sources is renewable energy-based solar photovoltaic (PV) generation, however there are several key downsides, including high initial costs, poor photoconversion efficiency, and dependence on the climate. The projected work presents a solar power system that tracks the Maximum Power Point (MPP). When solar

energy production exceeds demand, the excess energy is stored in batteries and provided during periods of very low irradiance. Unlike conventional energy sources like fossil fuels, natural gas, and nuclear energy, solar cells deliver clean, pollution-free energy. Its low efficiency when associated to other conventional energy sources is one of its drawbacks. Currently, the process of converting solar energy into electricity is expensive and uses photovoltaic systems that have a low efficiency. A variety of controllers, including DSP processors, are used to implement digital methods worldwide.

Under typical working settings, a solar array's efficiency is extremely low, and it further drops with changing loads and climatic factors. Today, sophisticated control algorithms known as Maximum Power Point Tracking (MPPT) are utilised to boost the efficiency of solar arrays. For the array to be able to offer the highest power possible, each of these algorithms aims to synchronise the source and load impedances. As radiation increases, power (Ppeak) decreases. So, the temperature and level of irradiation have a major role in power fluctuation. Using the MPPT algorithm, maximum power may therefore be monitored.

Between the load and the solar array, DC-to-DC converters with pulse width modulation are utilised to achieve this impedance matching. Both the analogue and digital domains use this MPPT approach. While the digital method is easier to implement and adapt, the analogue method is faster. A variety of controllers, including DSP processors, are used to implement digital methods worldwide.

The MPPT algorithm is expressed as a coded programme for microprocessors, microcontrollers, etc. Graphical programming, however, is easier to comprehend, use, and alter. Data from the outside world is gathered, processed, and output is either displayed or delivered to an output port as a control signal using software like MATLAB/Simulink and Lab VIEW. The SIMPOWER SYSTEM block set from MATLAB programme is used to implement the model, which is based on computer simulation. The design, analysis, and evaluation of power electronic converters and their controller heavily rely on computer simulation.

2. Existing System

In conventional system, a separate DC-DC converter is used for PV array and for battery as shown in Fig.1. Conventional Photovoltaic system utilizes separate DC-DC

converters (MPPT) to establish connections between the DC-link, array, and the energy storage. The battery charge control provides MPP monitoring. In order to make it cost effective, single bidirectional DC-DC bidirectional converter is used.
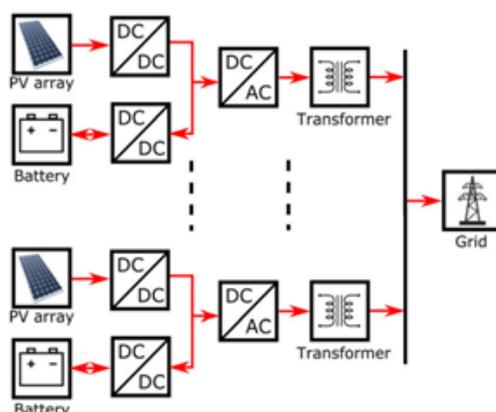

Figure 1. Existing method with multiple DC-DC converters

An electronic tool called the MPP tracker is made to get the most power possible out of renewable energy sources. Different MPP tracking (MPPT) strategies have a significant impact on how efficiently energy is converted from a PV system. According to thorough comparative literature evaluations, numerous MPPT approaches have been presented up to this point. These techniques largely consist of traditional optimization algorithms, AI MPPT algorithms, and other techniques. The Perturb and Observe (P&O) and (Inc Cond) approaches are two of the conventional MPPT techniques that are currently in use. To increase the tracking efficiency and precision, some variable variations of these two techniques are also being researched.

Two additional DC-DC converters are frequently added to configurations that use PV systems with Battery Energy Storage (BESS), which increases system complexity and decreases total system efficiency as a result of losses in the auxiliary components. In these setups, a separate DC-DC converter is used for connection establishment between the inverter DC-link, photovoltaic array, and the battery pack. The DC-DC converter battery acts as a charge controller and controls the DC-link voltage of the inverter, while the DC-DC converter photovoltaic array guarantees that the photovoltaic array voltage complies with its MPP. Most battery-integrated PV system topologies are described by using a single

converter. In the current setup, a two-stage converter's DC bus is directly connected to the battery. According to recent study, the BESS might be connected to the grid using its own inverter.

In this research, an MPPT charge controller is suggested in order to excerpt the most power possible from the solar panel. The indirect approaches and direct procedures are the two important MPPT techniques. Simple assumptions and periodic MPPT estimation are made using straightforward measurements in this type of tracking. For instance, the fixed voltage technique just modifies the nominal voltage of the solar module rendering to the expectation that the MPP voltages will be greater in winter and lower in summer. This system is inaccurate since temperature and irradiation levels can change over the same season.

The OCV method is another widely used indirect MPPT method. This technique makes the assumption that k is a constant, with crystalline silicon typically having a value of between 0.7 and 0.8. Compared to other strategies, this one is simpler and simpler to apply. However, the constant k is only a rough estimate. Consequently, efficiency is decreased, and each time the illumination state changes, the system must determine the new open circuit voltage (Vout). Every time, the load attached to the PV module must be unplugged in order to determine the new open circuit voltage; this results in power loss. In comparison to indirect approaches, direct MPPT systems, which measure the voltage, current or power, are more accurate and responsive. One of the direct MPPT approaches, P&O, is employed in this context with a few modifications. Instead of using P&O algorithm alone, this project combines P&O and ANN, and the average of the duty cycle is given as final duty cycle value to the bidirectional buck- boost converter.

3. PROPOSED SOLAR PV SYSTEM

For optimal solar energy usage, the solar PV array should be run at its highest power setting. Under various irradiance and temperature conditions, the photovoltaic arrays could still draw the same output fast and effective. This work provides a hybrid MPPT method that tracks the MPP using an ANN and a perturb and observe methodology. Instead of using only P&O algorithm to track the MPP, this hybrid algorithm reduces the oscillation around MPP and provides better results. When the PV system's available power surpasses its maximum AC capacity, conventional solar inverters cut off the extra power. A battery and a solar panel are each connected to a separate DC-DC converter in conventional procedures.

The block diagram of the projected system is depicted in Fig.2. The bidirectional DC-DC buck-boost converter receives input from the PV panel. The MPPT uses the solar panel's temperature and irradiance as inputs [1]. The ANN and P&O algorithm process the input data and produce an output that serves as the gate input for the MOSFET. The primary goal of the suggested bidirectional DC-DC buck boost converter is to boost the stored energy during periods of low irradiance by bucking excess solar PV power, storing it in batteries, and powering the load. The output of the converter is fed to the battery. The output from the battery is fed to an inverter, where it converts the DC supply into AC supply. The output of the inverter is given to the load.

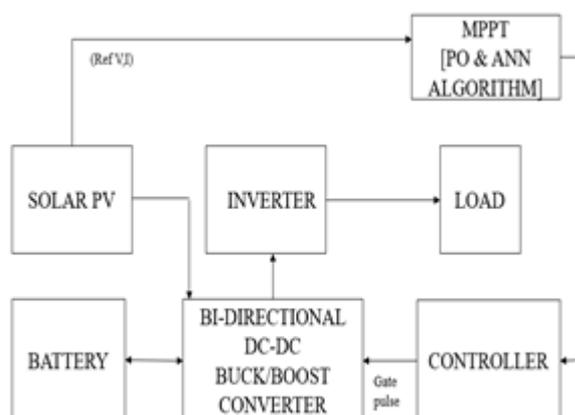### 3.1 Block Diagram of Proposed Solar Photovoltaic System

Figure 2. Block diagram of proposed solar photovoltaic system

By keeping the output voltage of the PV array at its MPP reference, the proposed bidirectional converter assures MPPT stability. The load side demand and the amount of solar PV electricity available determine how switches S1 and S2 operate. When the PV array and the inverter reference power are not in synchrony switch (S1) in the buck mode charges battery and the switch (S2) in boost mode discharges the battery to satisfy the load requirement across the photovoltaic array and the reference of the maximum power point [1].

3.2   Proposed Bidirectional DC-DC Buck Boost Converter

The Buck /Boost bidirectional DC-DC converter for the suggested layout is made up of dual switch, a capacitor as well as inductor [2]. When the array's available power is greater than the reference power of the inverter or when it is greater than the power available in array, [3] in normal photovoltaic system (single stage), there are chances of voltage (terminal) deviation from maximum power point and has a propensity to short circuit [1]. Whenever a discrepancy occurs amid the reference power of the inverter and the photovoltaic array, the suggested arrangement ensures MPPT stability by maintaining the maximum power point reference and the terminal voltage of the photovoltaic array [4]. When terminal voltage (photovoltaic array) exceeds the reference of maximum power point, switch Q1 is actuated, and the battery is charged in buck mode along the extra power required to ensure the maximum power point stability [5]. During lower terminal voltage of photovoltaic array, Q2 is switched on and the battery is discharged to ensure the stability and rectify the shortfall [6]. A bidirectional converter, which uses switches Q1 and Q2 to control the battery charge and discharge currents, connects the inverter and the photovoltaic array with the battery via DC-link [1].
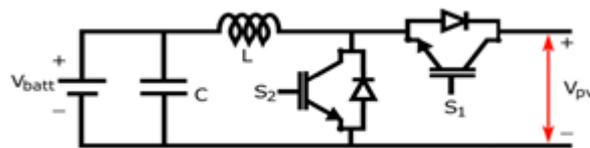
Figure 3. Proposed bidirectional Converter

3.3   MPPT Technique

Maximum Power Point Tracking, or MPPT, is a technique used by charge controllers to draw the most power possible from PV modules under specific circumstances [2]. The voltage at which a PV module produces the greatest power is known as its MPP (or peak power voltage). Sunlight intensity, surrounding temperature, and solar cell temperature all have an impact on maximum power. The PV module is connected with the load via DC-DC boost converter. The duty cycle can be changed to alter the load impedance. At the peak of the power, this variable impedance is matched. MPPT is done for maximum power output [5].

The MPPT is classified into the following types:

- Classic

- Intelligent

- Optimization

- Hybrid

For the projected system, a combination of intelligent and classic MPPT which comprised of ANN (Artificial Neural Network) and P&O method of MPPT is used for the solar PV system.

3.4   Artificial Neural Network

The three levels of an ANN controller are the input layer, hidden layer, and output layer [2]. The neural network receives a lot of inputs, and depending on the inputs, it produces some typical outputs; hence, the neural network is trained based on the given input and trained output. Here, temperature and irradiance are given as input. In the pre-activation function the inputs get collected and it is processed in the activation function and the output is Vmpp.
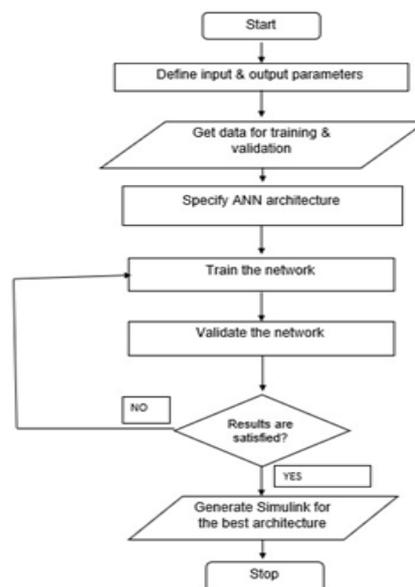

Figure 4. Flowchart for ANN

The flowchart of Artificial Neural Network is shown in Fig.4, where the inputs data is collected and it is used to train and validate the ANN architecture which are depicted in Fig.5 and Fig.6.
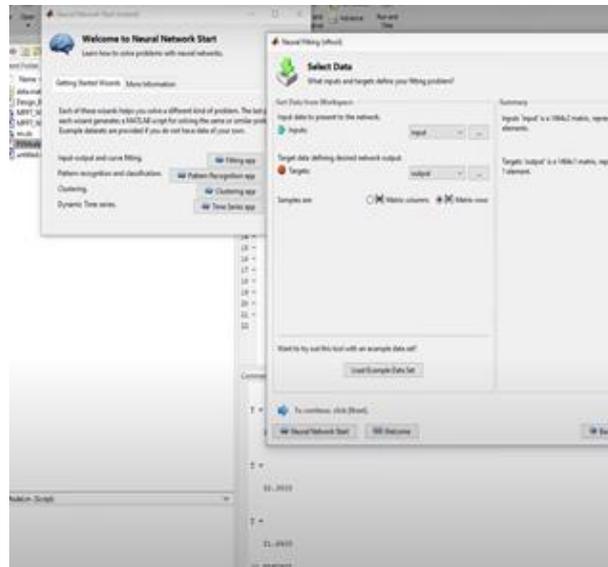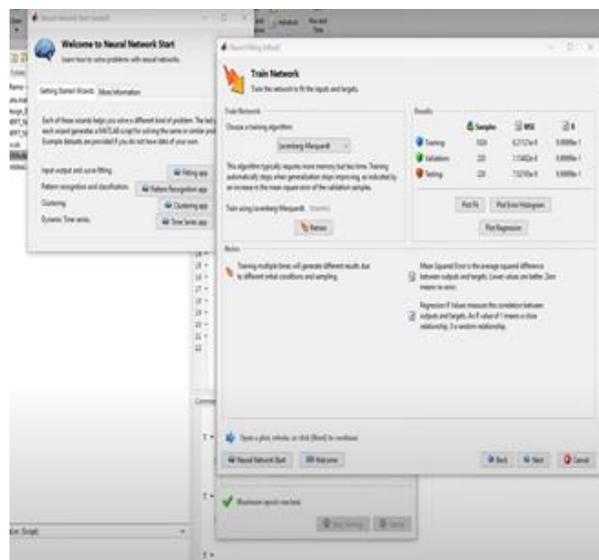

Figure 5. ANN Tool box

Figure 6. ANN Training

The activation function in hidden layer is given by, z (1) = W(1)X + b(1) a(1)

Here, layer 1's vectorized output, or z (1), is shown [1].

• Let W(1) represent the vectorized weights assigned to the hidden layer's neurons. The vectorized input is X.

• In the hidden layer, neurons are given a vectorized bias

 (b). a(1) is the vectorized form of any linear function.

In this proposed system, the irradiation and panel temperature are used as inputs for the ANN controller in the first step. These data are used for training the ANN Network. There are two input layers, one output layer, and two hidden layers, each of which has 10 hidden neurons.

3.5   Perturb and Observe Algorithm

This method makes use of a simple feedback system with few measurable parameters. With this technique, the module voltage is regularly perturbed, and the output power that results is compared to that from prior perturbing cycles. This algorithm causes a small amount of system perturbation. The power of the solar module changes as a result of this disruption [2].

If the perturbation increases in power, it will remain to move in the similar direction. When the peak power is reached, the perturbation then reverses because the power at the MPP is zero and then decreases in the next moment. Once the stable condition has been established, the algorithm begins to oscillate around the peak power point. The perturbation size must stay very tiny in order to keep the power variation low.
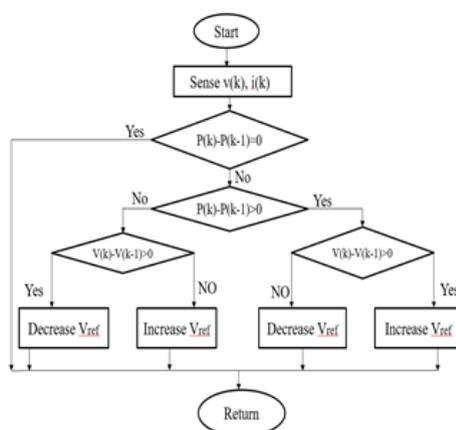

Figure 7. Flowchart for PO

A PV system operates differently due to changes in load and the weather. To guarantee that the solar arrays produce their maximum power, a dynamic tracking technique is crucial. The most basic MPPT algorithms can be created using microcontrollers, and they are as follows. The MPPT algorithm is founded on the observation that the derivative of output power (P) with respect to panel voltage (V) is zero at the maximum power point [4].

Various MPP methods are available in the literature to enhance solar system performance by successfully tracking the MPP. Flowchart for PO is depicted in Fig. 7. The duty cycle from the ANN and Perturb and Observe algorithm is taken as an average duty cycle and this duty cycle is given to the pulse width modulator and this gate pulse generated is given as input pulse for converter.

3.6   Inverter

By varying the duty cycle and pulse duration, the Pulse Width Modulation (PWM) method produces pulses with a constant amplitude [7]. The production of reference and carrier signals is necessary for analogue PWM control because they are fed into the comparator, which generates the final output based on some logical input. The carrier signal is either a sawtooth or triangular wave at a frequency much higher than the reference signal. The reference signal is the desired signal output, which may be sinusoidal or square wave. Schematic diagram shown in Fig.8. displays the PWM inverter's circuit diagram.

IGBTs are properly turned on to deliver AC output voltage to the output. The circuit functions are as shown in the following description. IGBTs are activated appropriately such that the output receives AC output voltage. The circuit operates in the manner described below. IGBT S1 and S4 are first turned on by triggering the IGBT gate. The current flows from the positive supply, through S1, S2, the load, and to the supply's negative. IGBT S2 and S3 are turned on during the next phase or cycle by sending a trigger pulse to the IGBT gate. The input voltage is applied to the output during this time, but in the opposite direction. Conduction of the current begins at the supply, S2.
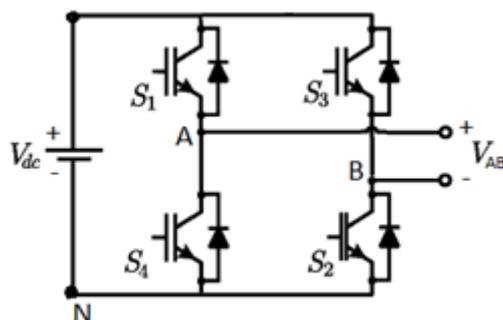
Figure 8. Schematic diagram of PWM inverter circuit

4. Results and Discussion

The Simulink library is used in MATLAB to model the entire suggested system design. The PV panel acts as an input source for the proposed Buck Boost converter. The temperature and irradiance of the solar panel are taken as the input for the MPPT. Later these values are processed according to the ANN and P&O algorithm, which gives out an output which acts as the gate input for the MOSFET. The main purpose of the proposed bidirectional converter is to buck the excess voltage and store it in battery and boost it whenever it is needed [1]. The output of the converter is fed to the battery. The battery output is fed to an inverter, where it converts the DC supply into AC supply [2]. The output of the inverter is given to the Load [3].

4.1 I-V, P-V Characteristics of Solar Array

A photovoltaic system is one that turns solar energy into electricity using one or more solar panels. The photovoltaic modules, mechanical and electrical connections and mountings, as well as devices for controlling and/or altering the electrical output, are some of the parts that make up this system. The core power conversion component of a PV generating system is the PV module. The solar insulation, cell temperature, and voltage output of the PV module all affect the output characteristics [6]. Due to their nonlinear features, PV modules must be modelled in order to be used in the design and modelling of PV system applications for maximum power point tracking [6].

In the forty years, mathematical PV models that are employed in computer simulation have been developed. The output parameters that are primarily influenced by solar insulation, cell temperature, and load voltage are described by almost all well-developed PV models.
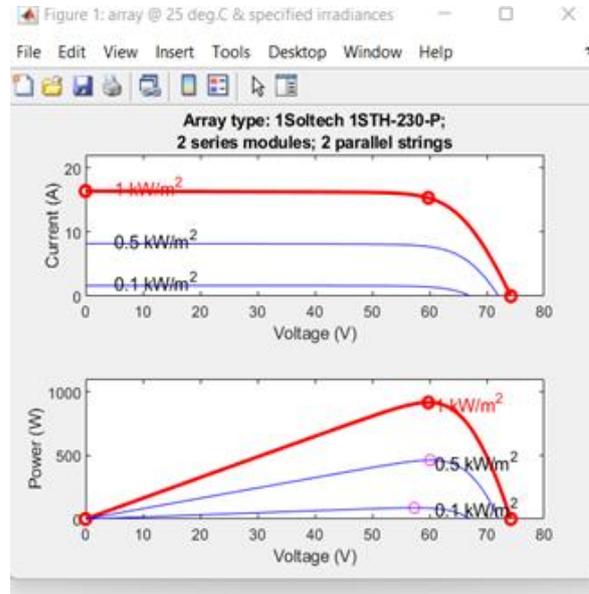

Figure 9. I-V P-V characteristics under various irradiance

A 228W panel draws various I-V P-V characteristics of solar array [1] under a constant temperature of 25 degree Celsius at various irradiance, which is depicted in Fig. 9.
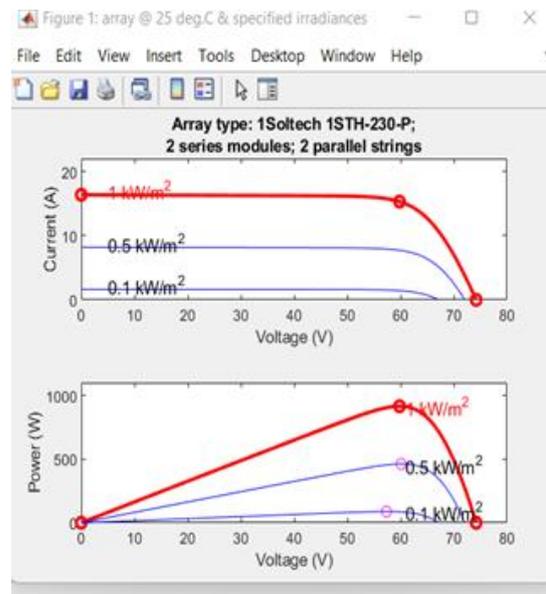

Figure 10. I-V P-V characteristics under various temperature

A 228W panel draws various I-V, P-V characteristics of solar array [1] under a constant temperature of 25 degree Celsius at various temperature which is depicted in Fig.10.

Panel parameters of the PV array is given in Table 1.

Table 1. Solar Array Parameters

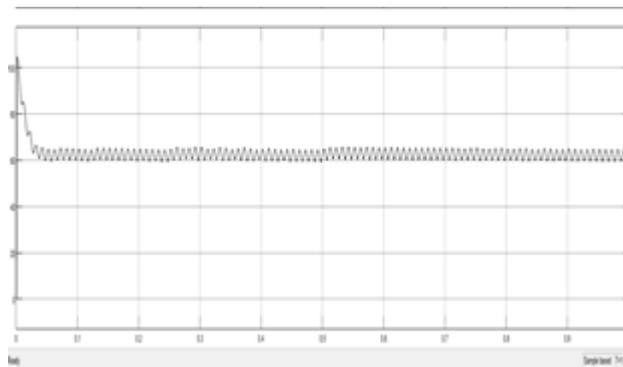| PARAMATER	SPECIFICATION
OPEN CIRCUIT VOLTAGE (V_{OC})	37.1 V
SHORT CIRCUIT CURRENT (I_{SC})	8.18 A
MAXIMUM OUTPUT POWER	228.7 W
VOLTAGE AT MAXIMUM POWER POINT	29.9 V
CURRENT AT MAXIMUM POWER POINT	7.65 A

4.2 Boost converter output

Figure 11. Voltage output of boost converter

In Fig. 11, the simulation result of the boost converter's voltage output when the battery is being discharged to the system's load is displayed.
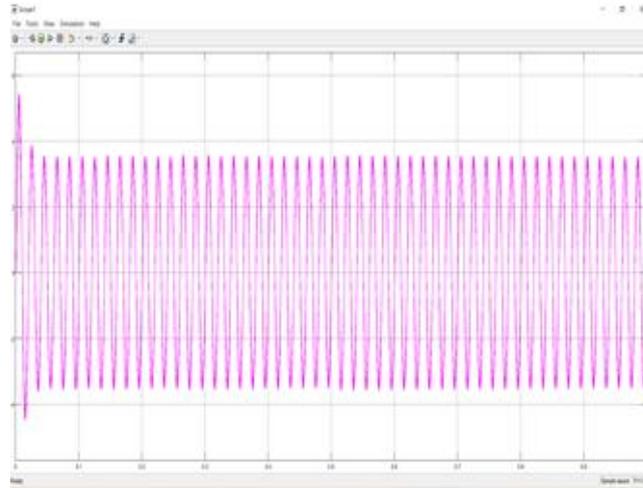
Figure 12. Current output of boost converter

The current output of boost converter during the discharge of battery to the load of the projected system is depicted in the Fig.12.
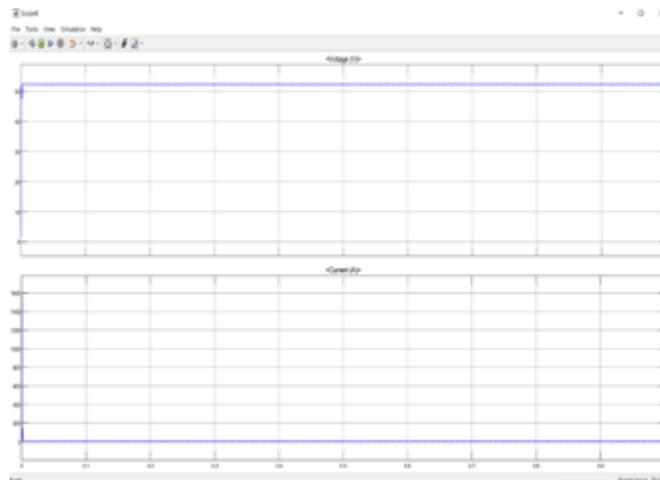

Figure 13. Voltage and Current Output of battery during battery discharge

The simulation result of the battery output during discharge with the nominal voltage of 50V and current above zero is depicted in fig.13.

Figure 14. Battery SOC output
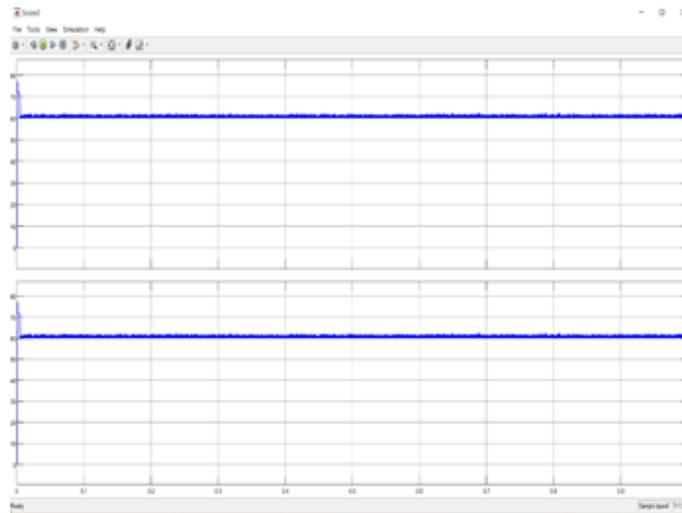
4.3 Buck Converter Output

Figure 15. Voltage output of solar and buck converter

When solar power exceeds the demand, the excess power is buck, and it is stored in the battery. Figure 15 displays the voltage output of the solar panel and buck converter. The simulation result of output current of buck converter is depicted in Fig.16. The battery output during charging is depicted in Fig .17.
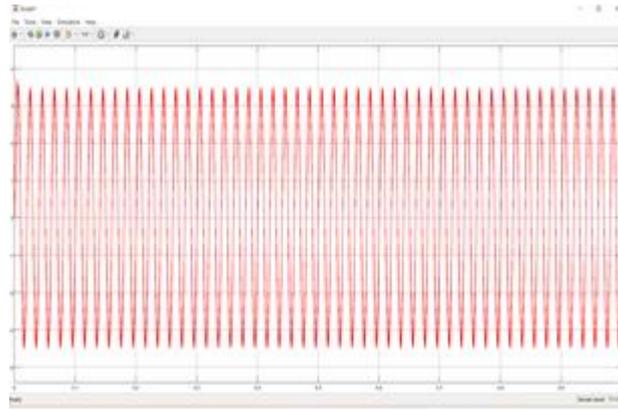
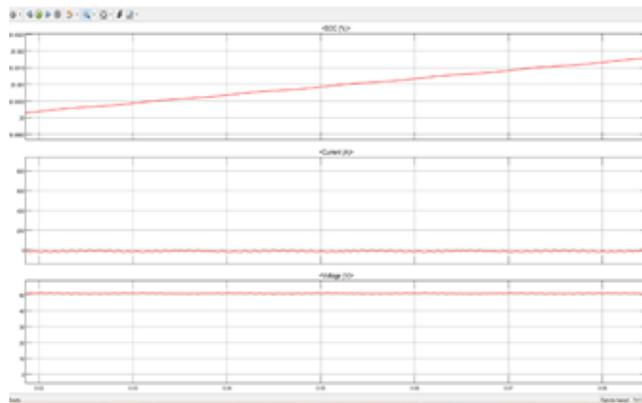**Figure 16.** Current Output of Buck Converter

Figure 17. Battery output during charging

The battery's nominal voltage is 48V and the state of charge is 20% which is the battery parameter. Here, it tracks around 50V and current in negative direction, which shows that it is getting charged.

Table 2. Panel and Converter Output

PANEL PARAMTER	ACTUAL VALUE	OBSERVED VALUE
VOLTAGE	59.8 V	60 V
POWER	457 W	450 W

Table 2 displays the converter output and panel output for the suggested setup. Also, the new technique offers relatively low cost for battery integrated PV systems with MPPT optimal control since no additional DC-DC converter is necessary.

5. Conclusion

In recent years, the electrical power demand is amplified due to the increase in the number of industries. Using an artificial neural network and the Perturb and Observe method, the maximum power point is monitored. The study and analysis of the solar array's output characteristics have been elaborated. Solar arrays are operated at their maximum power point regardless of solar irradiation by employing the MPPT algorithm and a bidirectional DC-DC buck boost converter. Under both typical and erratic weather circumstances, the MPPT algorithm can quickly monitor the solar array's maximum power point. The findings demonstrate that the hybrid MPPT proposal can follow the global MPP with a quick convergence rate. The primary goal of this research is to provide compensation towards the energy demand by the use of a system which consists of MPPT controlled solar system where the energy is stored in battery for energy saving purpose. This work suggests an approach for PV systems that makes use of battery unit for solar PV arrays and a bidirectional DC-DC converter that can function as both a charge controlling device and an MPPT tracking device at the same time. The benefits of this system include improved system performance, improved control of the PV system's DC-link voltage during power outages and increased overall energy output.

References

[1] Wei Zhang, Guopeng Zhou , Haoni , and Yunlia sun, 2019, "A Modified Hybrid Maximum Power Point Tracking Method for Photovoltaic Arrays Under Partially Shading Condition", Journal Article, IEEE access ,volume 4, pp. 181-188

[2] T. Esram, P.L. Chapman, "Comparison of photovoltaic array maximum power point tracking techniques," IEEE Transactions on Energy Conversion, vol. 22, no. 2, pp. 439-449, 2007.

[3] K. Ishaque , Z. Salam, "A review of maximum power point tracking techniques of PV system for uniform insolation and partial shading condition," Renewable and Sustainable Energy Reviews, vol. 19, pp. 475-488, 2013.

[4] L.L. Buciarelli, B.L. Grossman, E.F. Lyon, N.E. Rasmussen, "The energy balance associated with the use of a MPPT in a 100 kW peak power system," IEEE Photovoltaic Specialists Conference, pp. 523-527, 1980.

[5] K.H. Hussein, I. Muta, T. Hoshino, Osakada M, "Maximum photovoltaic power tracking: an algorithm for rapidly changing atmospheric conditions," IEE Proceedings of Generation, Transmission and Distribution, vol. 142, no. 1, pp. 1350-2360, 1995.

[6] H. Patel, V. Agarwal, "Maximum power point tracking scheme for PV systems operating under partially shaded conditions," IEEE Transactions on Industrial Electronics, vol. 55, no. 4, pp. 1689-1698, 2008.

[7] Y.H. Ji, D.Y. Jung, J.G. Kim et al, "A real maximum power point tracking method for mismatching compensation in PV array under partially shaded conditions," IEEE Transactions on Power Electronics, vol. 26, no. 4, pp. 1001-1009, 2010.

[8] K. Kobayashi, I. Takano, Y. Sawada, "A study of a two stage maximum power point tracking control of a photovoltaic system under partially shaded insolation conditions," Solar Energy Materials and Solar Cells, vol. 90, no. 18-19, pp. 2975-2988, 2006.

[9] N. Kumar, H. Ikhlaq, B. Singh, and B. K. Panigrahi, May 2017, "Rapid MPPT for uniformly and partial shaded PV system by using JayaDE algorithm in highly fluctuating atmospheric conditions," IEEE Trans. on Ind. Informatics., vol. 13, no. 5 pp. 2406- 2416.

[10] S. Chandel, M. N. Naik, and R. Chandel, May 2015,"Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies," in Renewable and Sustainable Energy Reviews, Vol.49, no.9,pp.1084-1099.

[11] "Solar PV array fed water pumping system using SEPIC converter based BLDC motor drive," in Proc. Eighteenth National Power Systems Conf., Guwahati, Dec 2014, pp. 1–5.

[12] "Buck-boost converter fed BLDC motor drive for solar PV array based water pumping," in Proc. IEEE Power Electronics, Drives and Energy Systems International Conf., Mumbai, Dec 2014, pp. 1–6.

[13] G. N. A. Maranho, A. U. Brito, J. T. Pinho, J. K. S. Fonseca, A. M. Leal, and W. N. Macłdo, "Experimental results of a fuzzy controlled variable speed drive for

photovoltaic pumping systems: A review," IEEE Sensors J., vol. 16, no. 9, pp. 2854–2864, May 2016.

[14] S. A. K. M. Niapoor, S. Danyali, and M. B. B. Sharifian, "PV power system based MPPT Z-source inverter to supply a sensorless BLDC motor," in Proc. 1st Power Electronic Drive Systems Technologies Conf., Tehran, Feb 2010, pp. 111–116.

[15] S. Jain, A. K. Thopukara, R. Karampuri, and V. T. Somasekhar, "A single-stage photovoltaic system for a dual-inverter-fed open-end winding induction motor drive for pumping applications," IEEE Trans. Power Electron., vol. 30, no. 9, pp. 4809–4818, Sept 2015.

[16] S. Jain, R. Karampuri, and V. T. Somasekhar, "An integrated control algorithm for a single-stage pv pumping system using an open-end winding induction motor," IEEE Trans. Ind. Electron., vol. 63, no. 2, pp. 956–965, Feb 2016.

[17] S. Sashidhar and B. G. Fernandes, "A novel ferrite SMDS spoke-type BLDC motor for PV bore-well submersible water pumps," IEEE Trans. Ind. Electron., vol. 64, no. 1, pp. 104–114, Jan 2017

[18] P. Damodharan and K. Vasudevan, "Sensorless brushless DC motor drive based on the zero-crossing detection of back electromotive force (EMF) from the line voltage difference," IEEE Trans. Energy Convers., vol. 25, no. 3, pp. 661–668, Sept 2010.

[19] P. Damodharan, R. Sandeep, and K. Vasudevan, "Simple position sensorless starting method for brushless DC motor," IET Electr. Power Appl., vol. 2, no. 1, pp. 49–55, Jan 2008.

[20] K. H. Ahmed, M. S. Hamad, S. J. Finney, and B. W. Williams, "DC-side shunt active power filter for line commutated rectifiers to mitigate the output voltage harmonics," in Proc. IEEE Energy Conversion Congress and Exposition International Conf., Atlanta, Sept 2010, pp. 151–157.

[21] R. Kumar and B. Singh, "BLDC motor-driven solar PV array-fed water pumping system employing zeta converter," IEEE Trans. Ind. Appl., vol. 52, no. 3, pp. 2315–2322, May 2016.

[22] P. Bhatnagar, R.K. Nema, "Maximum power point tracking control techniques: State-of-the-art in photovoltaic applications," Renewable and Sustainable Energy Reviews, vol. 23, pp. 224-241, 2013.