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Simulation of Standalone Hybrid Solar-Battery Fed Water Pumping System

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Abstract

A hybrid battery-based solar (Photovoltaic) water pumping system for agriculture applications has been presented in this research. The battery hybrid power generation is utilized as an energy source to accomplish full-scale continuous water delivery, regardless of climatic conditions. The solar photovoltaic (PV) battery system is used as the primary source, with the battery acting as a backup. With that, when the photovoltaic cluster is insufficient to handle water pumping due to weather conditions or around night time, the battery supplies power. Moreover, it is charged by the solar cluster when the water conveyance isn't needed. As a result, no external inventory is used to charge the batteries. A bidirectional charging control allows to change the battery's activity mode by using a buck-boost converter. Artificial neural network is proposed as the controller for switching the pulse of the bidirectional converter. MATLAB/SIMULINK software is used for analysing performance of the proposed system.

Keywords: Photovoltaic, Battery, bidirectional DC-DC converter, Artificial Neural Network

1. Introduction

Sustainable energy sources use solar, wind, biomass, tsunamis, and other natural phenomena to provide clean electricity. Because of concerns about climate change and rising oil prices, the age of sustainable electricity has become enormously important [1]. Recently, environmentally friendly power in the form of sunlight-powered storage has become a promising option for water pumping applications due to the fact that sun-powered extorting frameworks have a few strong qualities: they are eco-friendly, simple to set up, free, and do

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not require tedious maintenance [2]. The water flow obtained by a pumping system rises in accordance with the increase of solar irradiance owing to the inhomogeneity of Photovoltaic cell and the dynamic variation in solar irradiance during the day, however the PV modules cannot provide the peak power. As a result, various researches have presented a wide range of maximum power point tracking (MPPT) methodologies. The most well-known MPPT method is perturbed and observed (P&O) [3]. In this article, the solar energy framework for independent irrigation using the induction motor was offered, specifically tailored to a segregated area, to ensure the demand for water, particularly for domestic usage and small networks [4].

As climatic conditions change, the capacity of renewable energy generation also changes, resulting in a constant variation in DC-bus voltage [5]. An external energy storage device with a bidirectional DC-DC converter (BDC) is required to enable energy exchange between the battery and the DC-bus[6]. In any case, once the most extreme power point (MPP) is reached, the Perturb and Observe algorithm calculation with a fixed step size is unable to stop the oscillation, resulting in significant power losses.

Solar water pumping system application frequently uses BLDC motors due to its advantages over brushed DC motors and induction motors. BLDC motor have high speed versus torque characteristics, greater dynamic response, good efficiency, pro long operating life, less noise at operating condition, excellent speed ranges, rugged construction, and etc. In any event, when the most extreme power point (MPP) is accomplished, the P& O calculation with a fixed step size can't stop the perturbation, bringing about serious power misfortunes [7]. The tracking speed, on the other hand, is somewhat slow [8]. Some academics have proposed updated versions of P&O to address the flaws of fixed step size algorithms. The Incremental Conductance method is a step forward from the Perturb and Observe Algorithm. This method offers greater precision and efficiency, particularly in the presence of fluctuating atmospheric circumstances. The size of stator current of BLDC engine at starting condition is controlled by working the VSI in PWM (Pulse Width Modulation) mode for a pre-characterized span. In any case; when the engine is started; the VSI is worked with the fundamental frequency resulting in a limited exchanging misfortune and upgraded conversion efficiency [9].Advance Multilevel inverter is used in recent days [10] but in this work voltage source inverter is used for its simplicity and efficiency.

A bidirectional DC-DC converter is a key feature of isolated solar photovoltaic systems for integrating the battery storage system. The main objective of this proposed work implementing an artificial neural network for battery charging and discharging according to the solar power generation and load.

The work is divided into two parts: section II comprises of the circuit configuration and some technical requirements. In section III, the control techniques for each level of the system are explored. The numerical simulation and analysis of the data are presented in Section IV. Finally, some conclusions are presented in the final section.

2. Model Configuration

The hybrid PV water pumping system circuit is shown in Fig 1. Combination of solar array and storage system forms a common DC bus through VSI.Two stage of operation will perform in this proposed system first one is DC-DC converter along with MPPT and second one is buck- boost converter act as charge controller with storage system. Bidirectional converter acts as step-up converter when it discharged and step-down converter when it is charged. A VSI plays out an electronic start-up of BLDC motor. A water pump is mechanically coupled to the BLDC engine, which has three Hall Effect sensors integrated into it to provide compensating signals. Figure 1 shows a block schematic of a hybrid water pumping system.

Table 1. System Specification

S.No	Parameter	Value
Solar PV array	Short –circuit Currrent Isc	10.6A
	OpenCircuit Voltage Voc	462V
	Current at Maximum Power Imp	8.84A
	Voltage at Maximum Power Vmp	374V
DC-DC boost converter	Input Capacitor	2000 μF
	Inductance(L)	3mH
	Dc link Capacitor	3000 μF
Brushless DC Motor		Number of Poles = 6, Rated speed = 3000rpm, Stator resistance = 0.37ohms.
Battery	Nominal Voltage(Vb)	192V

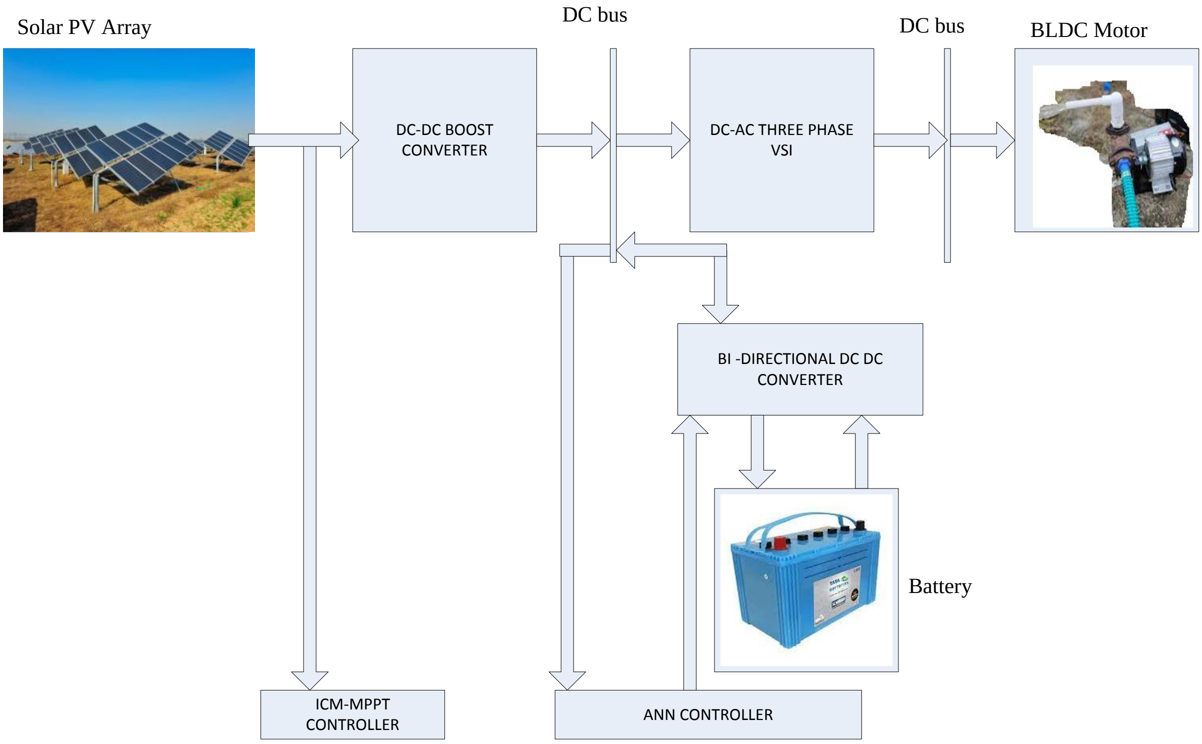

Figure 1. Block Diagram the proposed Hybrid method

3. Control Techniques

Maximum power generated is obtained by tracking the maximum power point from the solar array using the incremental conductance technique (ICM-MPPT). An ANN control method is applied to battery charging and discharging.

3.1 ICM-MPPT for solar array

Generally the efficiency of solar array is less when MPPT is absent which in turn reduces the power generation. Hence MPPT is recommended to use in any solar application. Many MPPT technique is used in market but in this work ICM-MPPT algorithm is used for its advantage of tracking abilities under dynamic conditions [1-8].

In ICM-MPPT perturbing will stop after reaching the maximum operating point. If maximum point is not reached perturbed can be obtained by the equation (1) and equation (2)

$$\frac{dP}{dV} > 0 \tag{1}$$

$$\frac{-dP}{dV} < 0 \tag{2}$$

which is derived by $\frac{Dp}{dv}$ is negative when operating point is at right of MPPT and positive when it is left of Maximum power point as shown in Fig 2. Tracking capacity of ICM-MPPT algorithm is rapidly increase and decrease according to radiation of solar array.

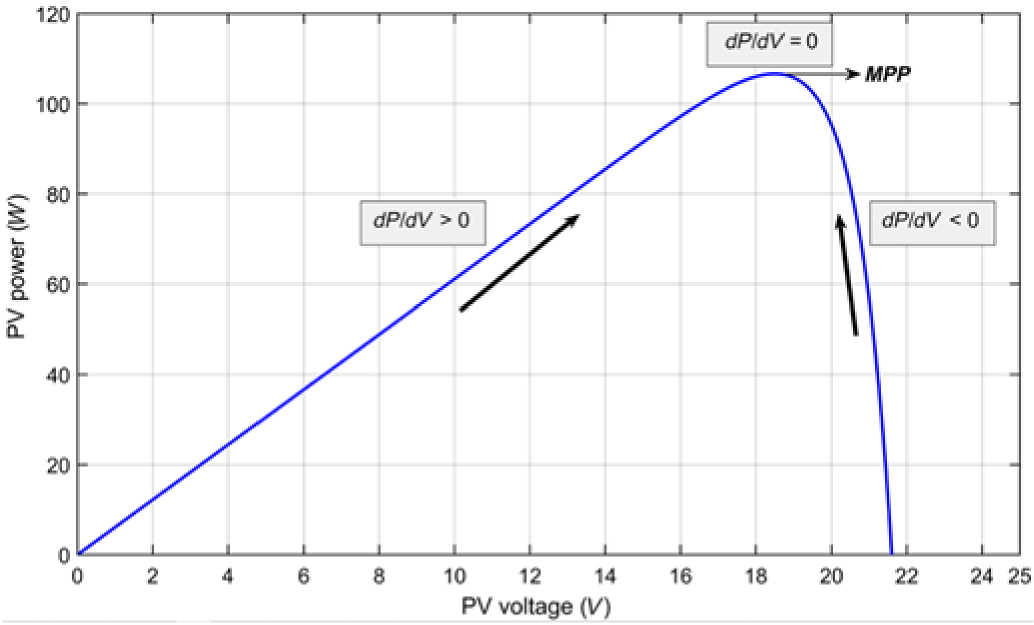

Figure 2. ICM-MPPT Tracking

3.2 Battery Control Algorithm

Power transfer between DC coupling and storage system is done by bidirectional power converter. Mode of operation of Battery control is shown in Fig. 3. Flow chart of battery control Algorithm. Depending upon the SoC (State of Charge) of battery the proposed technique of estimation is briefly described:

Step 1: Create the database for battery discharge, including terminal voltage, discharge current, temperature and SoC.

Step 2: Normalized all data on discharge batteries.

Step 3: Prepare the Artificial neural network training set.

Step 4: Select number of neurons in the hidden layer of the artificial neural network (ANN)

Step 5: Use the L-M training to develop the ANN SoC estimation neural network.

Step 6: End the training process.

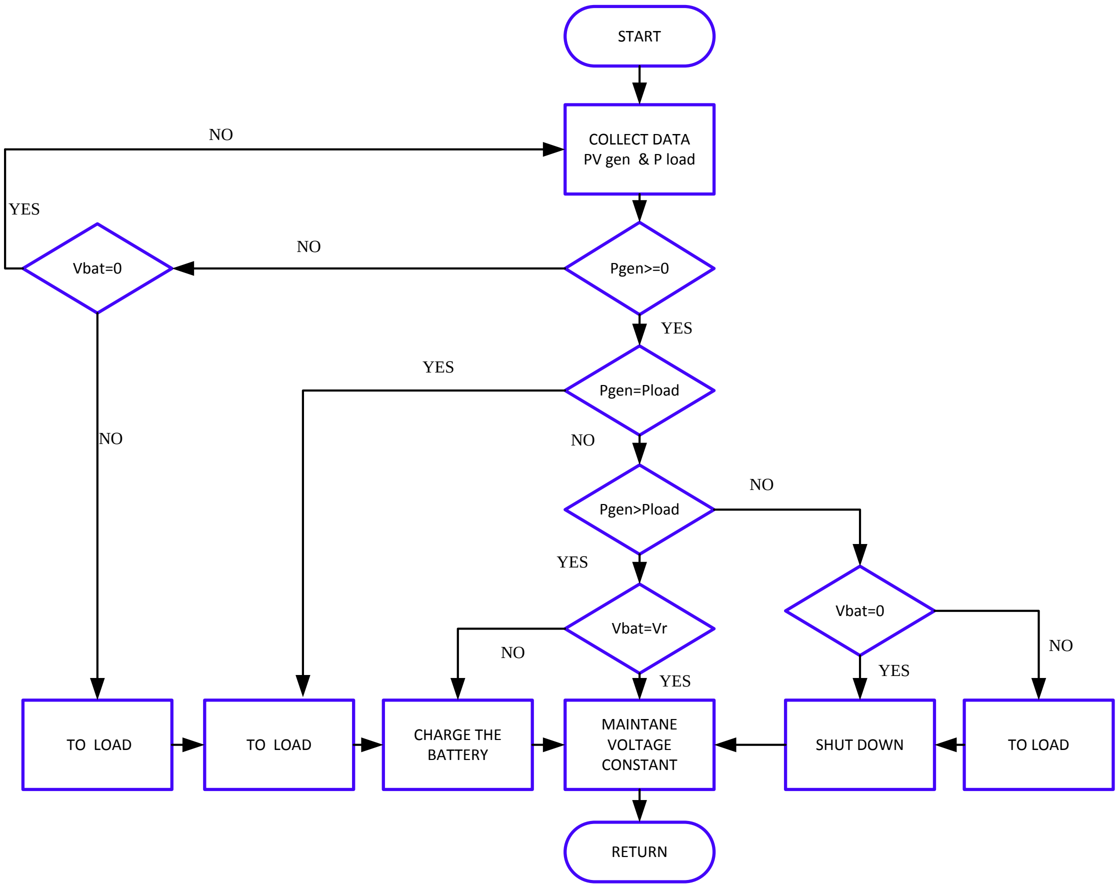

Figure 3. Flow chart of Bi-directional DC –AC converter control.

3.3 BLDC Motor Commutation

The Hall sensor produces hall signals with respect to rotor position. With help of Decoder circuit hall signals are converted into pulse for VSI.

4. Results and Discussion

MATLAB -Simulink toolkits are used to investigate the performance of the proposed water pumping framework under various operating conditions. This study assesses a unique way of behaving of the framework under poor sunlight based radiation. At the point when a low radiation is noticed; the battery is naturally placed into impact. This case is represented in Fig. 4. The sun-powered radiation; S is diminished from 1000 W/m2 to 500 W/m2 bringing about a decrease in power result to almost half. Until 500 W/m2; the water pumping is taken care of by the SPV exhibit simply as it is adequate to run the pumping at full limit at initial state of battery. No current is drawn from the battery and it stays at 50% of SOC.

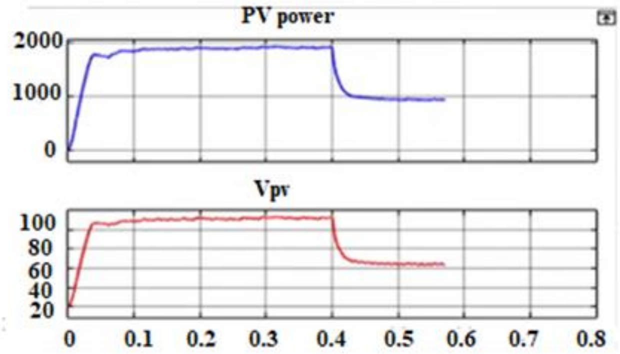

Figure 4(a). Output of PV power and PV voltage at dynamic condition of irradiance

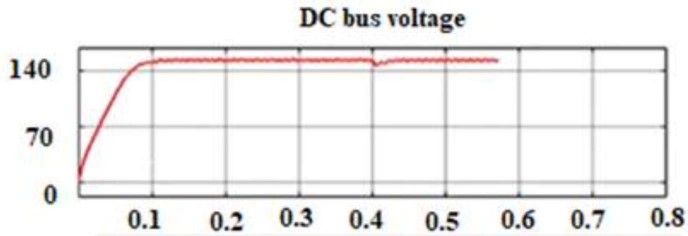

Figure 4(b). Output of DC bus voltage at dynamic condition of irradiance

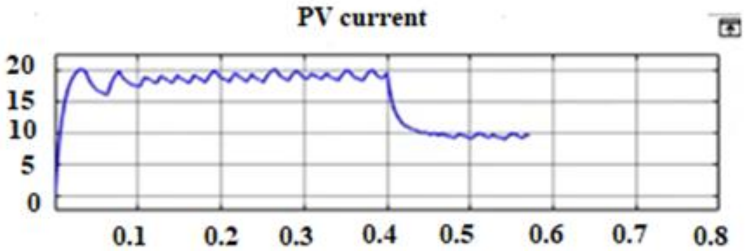

Figure 4(c). Output of PV current at dynamic condition of irradiance

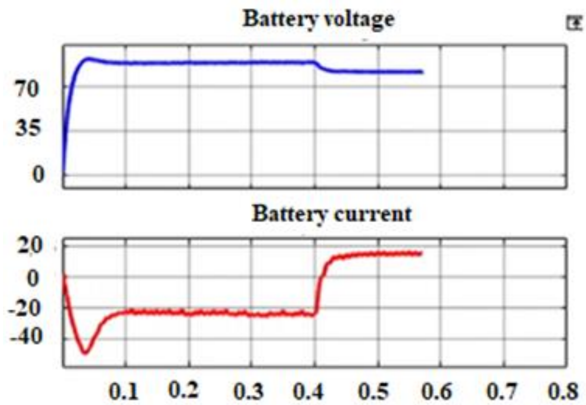

Figure 4(d). Output of Battery Voltage and Battery Current at dynamic condition of irradiance

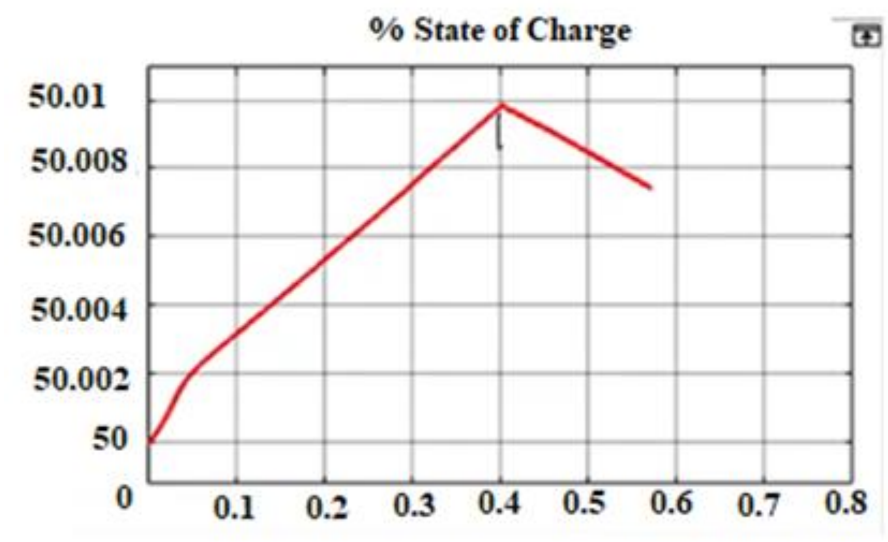

Figure 4(e). Output of % State of Charge

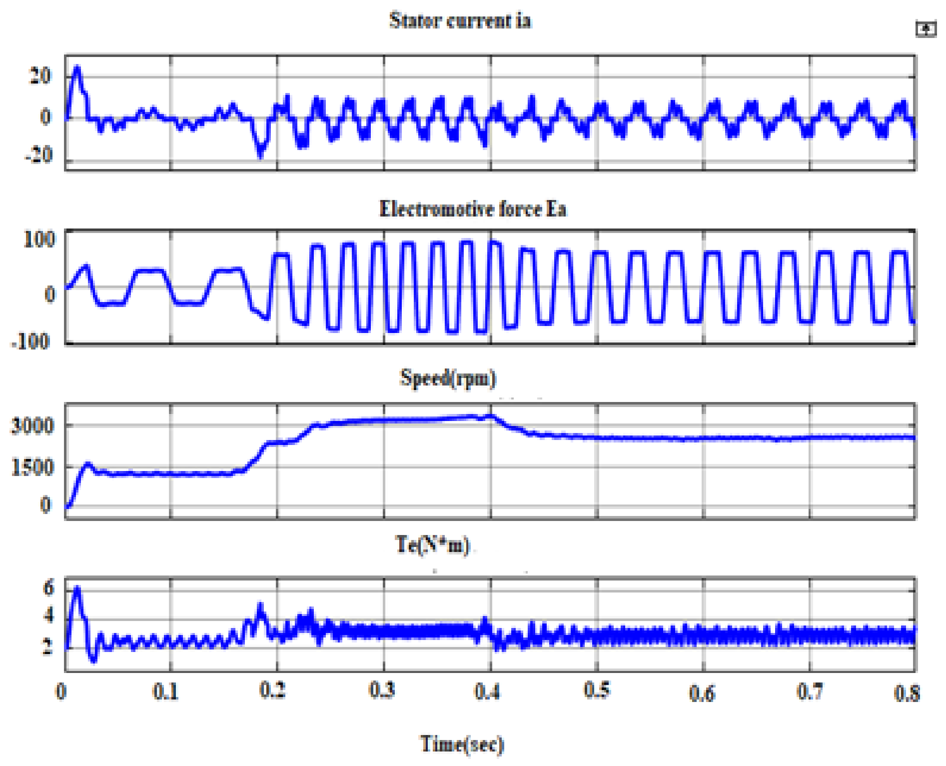

Figure 4(f). BLDC motor variable response at irradiance

Figure 4. Output Results of the proposed hybrid battery-solar framework

5. Conclusion

Solar photovoltaic battery based standalone water pumping system has been proposed and its various performances have been analysed under dynamic conditions. A full utilization of the SPV array and pumping system has been made possible. A power flow control using ANN has been applied to enable a power transfer between the DC link bus and battery storage through a bidirectional buck boost converter. This grid independent system has been found more useful for remote and isolated region.

References

[1] S. S. Chandel, M. Nagaraju Naik, and R. Chandel, “Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies,” Renewable and Sustainable Energy Reviews, vol. 49, pp. 1084–1099, Sep. 2015.

[2] S. S. Patil and R. M. Zende, “Solar powered water pumping system,” in 2017 Third International Conference on Sensing, Signal Processing and Security (ICSSS), Chennai, India, 2017, pp. 186–190.

[3] D. Sera, L. Mathe, T. Kerekes, S. V. Spataru, and R. Teodorescu, “On the Perturb-and-Observe and Incremental Conductance MPPT methods for PV systems,” IEEE J. Photovoltaics, vol. 3, no. 3, pp. 1070–1078, Jul. 2013.

[4] Atarsia Loubna, Toufouti Riad, “Standalone photovoltaic array fed induction motor driven water pumping system ,” in International Journal of Electrical and Computer Engineering (IJECE) Vol. 10, No. 5 2020.

[5] H. R., H. Daneshpajooh, A. Safaee, P. Jain, and A. Bakhshai,“Bidirectional DC - DC converters for energy storage systems,” inEnergy Storage in the Emerging Era of Smart Grids, R. Carbone, Ed. InTech, 2011.

[6] B. Y. Li, C. Xu, C. Li, and Z. Guan, “Working principle analysis and control algorithm for bidirectional DC/DC converter,” p. 9, 2017.

[7] M. A. Elgendy, B. Zahawi, and D. J. Atkinson, “Evaluation of perturband observe MPPT algorithm implementation techniques,” in 6th IET International Conference on Power Electronics, Machines and Drives (PEMD 2012), Bristol, UK, 2012, pp. P110–P110.

[8] J. Macaulay and Z. Zhou, “A fuzzy logical-based variable step size P&O MPPT algorithm for photovoltaic system,” Energies, vol. 11, no. 6, p. 1340, May 2018.

[9] Rajan Kumar , Bhim Singh, “Solar PV-Battery based Hybrid Water Pumping System using BLDC Motor Drive ,” in 1st IEEE International Conference on Power Electronics. Intelligent Control and Energy Systems (ICPEICES-2016) p. 9, 2016.

[10] Ramasamy, Suganthi, and Maruthupandi Perumal. "CNN based deep learning technique for improved H7 TLI with grid connected photovoltaic systems." International Journal of Energy Research 45.14 (2021): 19851-19868.

Author's biography

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