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ANN Based MPPT Applied To Solar Powered Water Pumping System Using BLDC Motor

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ABSTRACT: This paper introduces non-electrical input based artificial neural network (ANN) maximum power point tracking (MPPT) technique to the solar powered water pumping system using brushless DC (BLDC) motor. The objective is to model a step size independent MPPT using neural network for water pumping application. A DC-DC boost converter is being utilized which is driven by ANN based MPPT to extract maximum power out of solar photovoltaic (SPV) array and also responsible for soft starting of BLDC motor. Pulse width modulated (PWM) control of the voltage source inverter (VSI) using DC link voltage controller is used to control the speed of the BLDC motor. PWM signal is generated using the inbuilt encoder to perform the electronic commutation by hall signal sensing. Performance analysis of a BLDC motor driving pump system is carried out under the MATLAB/Simulink environment and efficiency of the overall system is calculated under various irradiance condition.

KEYWORDS: Artificial Neural Network (ANN), BLDC motor, Boost Converter, Maximum Power Point Tracking (MPPT), Solar photovoltaic (SPV) array.

I.INTRODUCTION

Due to increase in population, the requirement of the energy is increased rapidly which put the burden on the existing conventional source of the energy, results in the shifting focus from fossil fuel-based energy generation to clean and green source of energy generation. The solar photovoltaic technology can be connected on a bigger scale and it additionally shows a naturally ideal contrasting option to a non-renewable energy source (oil and coal-based power) controlled customary water pumps. A standalone solar photovoltaic water pumping system (SPVWPS) is one of the possible solutions to meet the water demand. This method widely receiving an appraisal for irrigation, household application and industrial automation. Introducing SPVWPS has numerous points of interest to the pumping locales, where the national electricity grid connection is not accessible, solar energy is accessible inexhaustibly, and transport facilities are sufficiently feeble. This paper is based on the work carried out in [1,2].

The DC link voltage varies with a change in solar irradiance [1] and speed control of BLDC motor is done by keeping DC link voltage at rated value [2]. In this paper second approach of the system modelling is considered. A DC-DC boost converter is utilized which is operate in continuous conduction mode (CCM) driven by ANN based MPPT to provided optimal duty cycle. Several MPPT techniques are discussed in the literature [3,4]. MPPT algorithms which widely receive acceptance are perturb and observe (P&O) [5,6] and incremental conductance (INC) [7,8] when the water pumping system is considered. But in a standalone SPVWPS, the step size of the MPPT method is an imperative factor that rules control qualities [9]. To avoid the negative effect of step size, ANN based MPPT technique is selected. It has been proposed for better dynamic performance, particularly under rapidly changing environmental condition. Several DC-DC conversion techniques are discussed in the literature boost, boost-buck, luo and landsman converter [1] [7] [8] [10]. But boost converter is selected because of its innate nature of least possible switching stress with high transformation effectiveness, very good switch utilization to reduce input ripple current because the input inductor itself behaves as a ripple filter and a fewer number of components required to design it [11].

A few researches in the field of SPV array driving water pumping utilizing induction motor, synchronous reluctance motor (SyRM) and switched reluctance motor (SRM) have been made in the literature [12-15]. It has been seen that the proficiency of an induction motor reduces under light loading as the excitation losses dominate, moreover an induction motor driven system has low power conversion efficiency. In case of SyRM can run satisfactorily for a

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restricted range of solar irradiance level. An SRM has not gotten much prominence due to a very high acoustic and torque ripple for SPVWPS [10]. So, BLDC motor selected for this purpose. BLDC motors don't utilize brushes, they have extended life, versatility and silent operation. BLDC motors have been utilized broadly in numerous applications that demand a reliable operation and optimum performance. BLDC motor has a permanent magnet, so it has high torque speed proportion than other motor of the same size and it is applicable for those operations where weight and space are crucial. It has extended speed ranges, preferable torque and speed than other motors. Enhances dynamic performance while shortening the operating cycle due to low rotor inertia 9140. Proposed SPVWPS uses two PI controller so, proper tuning is required for optimal performance of the model. MATLAB/Simulink environment is used to study the performance of the overall system and to evaluate efficiency at different solar irradiance value.

II.THE TOPOLOGY OF THE PROPOSED SYSTEM

Detailed schematic model SPVWPS using BLDC motor is given in Fig. 1. This system consists of 2.38 (3.2) kW (hp) BLDC motor coupled to a pump whose specification is given in Table 1. The system also has PV array, an ANN based MPPT driving DC-DC boost converter, DC link capacitor which is regulated by PWM signal generated by electronics commutation to control VSI and pump system. SPV array is selected carefully to ensure optimal and CCM operation of the DC-DC boost converter.

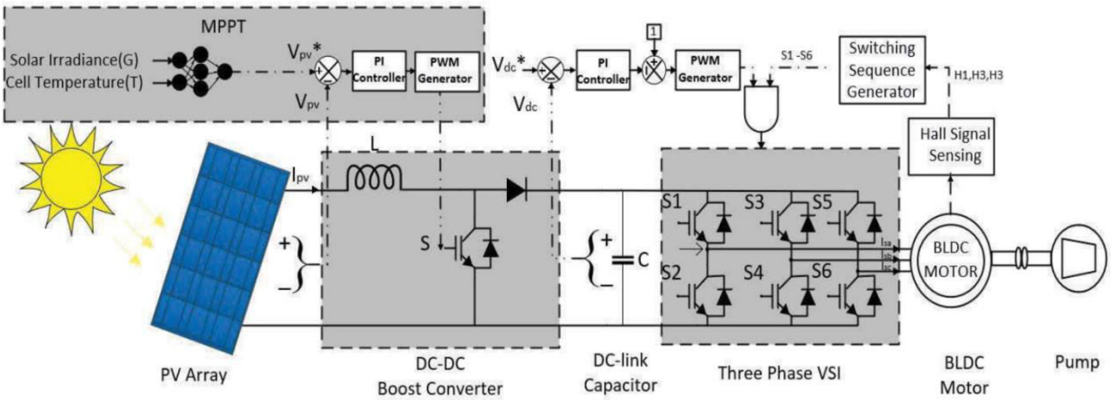

Fig. 1 Topology of SPVWPS using Boost converter and BLDC motor

A. Design of SPV Array

Trina Solar TSM-200DA01A.05 SPV module is selected which is available in the module section of PV array block in MATLAB/Simulink. SPV array of rating 2.81kW feeding 2.38 kW motor is selected. Excess power is required to overcome all the losses occur during various stages of the SPVWPS system. PV module specification is given in Table 2. I-V and P-V curve at various irradiance is given in Fig. 2. To generate 2.81kW, maximum voltage (V_{mpp}) selected as 267.4V.

Maximum current I_{mpp}which is required to get 2.81kW is estimated to be

$$\frac{Pmpp}{Vmpp} = \frac{2810}{267.4} = 10.50A \tag{1}$$

Number of modules connected in series $N_S = \frac{Vmpp}{Vm} = \frac{267.4}{38.2} = 7$ (2)

Number of modules connected in parallel $Np = \frac{Impp}{Im} = \frac{10.50}{5.26} = 2$ (3)

So, to generate maximum power of 2.81kW at standard test condition (STC) 7 module are connected in series and 2 modules are connected in parallel.

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Table 1. Nominal value and specifications of BLDC motor

BLDC Motor Specification	
Power, P (kW)	2.38
Speed, Nr (rpm)	2600
DC voltage, V_{dc}(V)	325
Current, I (A)	7.35
Poles, p	12
Inertia, J (kg cm^2)	7.05
Voltage constant, ke ($V_{peak\ L\text{-}L}/K_{rpm}$)	88.86
Torque constant, kt (Nm/A_{peak})	0.85
Phase to Phase resistance, Rs (Ohm)	0.957
Phase to Phase inductance, L_s(mH)	3.8

Table 2. SPV array specification

TSM-200DA01A.05 SPV module	
Maximum power (W)	200.932
Open circuit voltage V_{oc} (V)	46.2
Voltage at maximum power point V_m (V)	39.2
Short-circuit current I_{sc} (A)	5.62
Current at maximum power point I_m (A)	5.26
Cells per module (Ncell)	72
Parallel-connected modules per strings (N_S)	2
Series-connected modules per string (N_p)	7

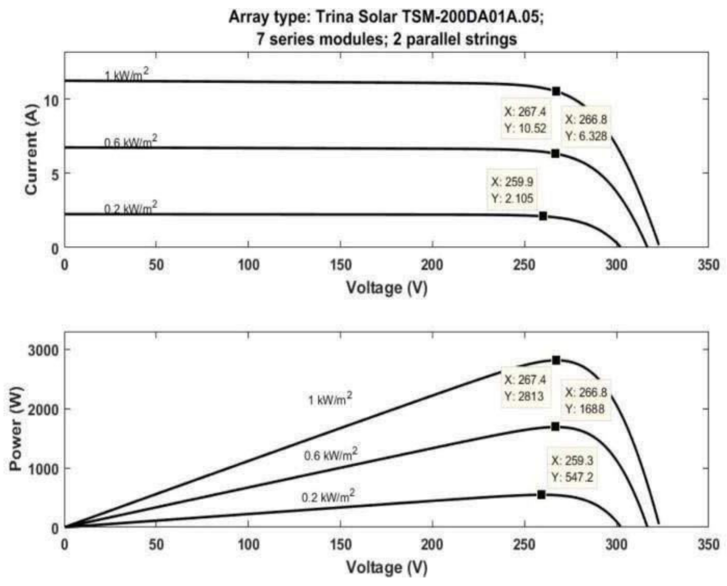

Fig.2 I~V and P~V curve of selected SPV array

B. Boost Converter Design

At STC, SPV array maximum output voltage is V_{mpp} = 267.4V and output of the boost converter maintained to be at 325V at DC link (V_{dc}) which is rated voltage of BLDC motor. So estimated Duty cycle (D) is given by

$$L = \frac{Vdc-Vpv}{Vdc} = \frac{325-267.4}{325} = 0.18 \qquad (4)$$

Switching frequency (F_{sw}) for the boost converter is selected to be 20,000 Hz. The motive behind selecting such a high value is to reduce ripples in the inductor current (i_L) and to improve the transient performance of the boost converter. At maximum powerpoint,I_{mpp}calculatedas10.52.Limitingthecurrentripple, ΔI_L in i_L at 8%, L is estimated as [9].

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$$L = \frac{Vpv \times D}{Fsw \times \Delta IL} = \frac{267.4 \times 0.18}{20000 \times 10.52 \times 0.08} = 3\text{mH} \tag{5}$$

Neglecting all converter losses, boost converter's average current at the output is given by Idc = Pmpp/Vdc = 2813/325 = 8.66A. Restricting the voltage ripple, ΔVdc in Vdc at 2%, C is estimated as is

$$\omega = 2\pi f = \frac{2 \times \pi \times Nr \times p}{120} = \frac{2 \times 3.14 \times 2600 \times 12}{120} = 1632.8 \text{ rad/sec} \tag{6}$$

$$C = \frac{Idc}{6 \times \omega \times \Delta Vdc} = \frac{8.66}{6 \times 1632.8 \times 0.02 \times 325} = 136 \text{ uF} \tag{7}$$

(sixth harmonic component of AC voltage is dominating on DC link of VSI which reflect from the input of the motor)

For simulation, C is taken as 200μF. A higher value of C reduces ripple at DC bus of VSI

III.MAXIMUM POWER POINT TRACKING

Several ANN based PV MPPT techniques are discussed [4]. In this paper non-electrical input-based ANN based MPPT is used which uses irradiance (G) and temperature (T) as input and give Vmpp as an output which is taken as reference Vpv*. This Vpv* is then compared with instantaneous Vpv and then an error is generated which will be feed to the PI controller. The PI controller's output will be provided to the PWM signal generator to generate the required duty cycle. Optimal tuning of PI controller should be performed for better performance.

IV.TRAINING OF NEURAL NETWORK

The training of neural network carried out after calculating the Vmpp value at different irradiance and temperature. For training 552 data points are generated. These data points are trained using 2 hidden neurons. Regression plot is given in Fig.3. which depicts the high accuracy of the trained model.

V.POSITION SENSOR

The position sensors placed in the motor can distinguish rotor position and change it into an electrical signal, provide the correct commutation information for the logic switch circuit.

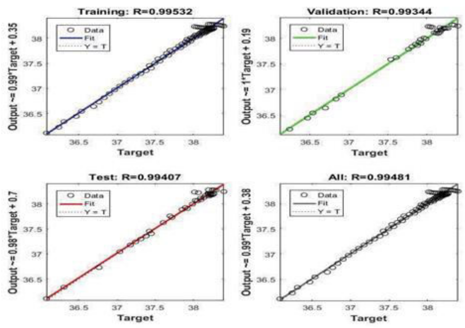

Fig.3 Regression plot of neural network MPPT model

Commutation for BLDC motor is a six-step process. All six switches of VSI turned ON/OFF to create six flow vectors. These vector makes BLDC motor points 60° to the next position. Hall effect position sensor is required for commutation process. The hall-effect position sensor senses the rotor position of the BLDC motor, 0 to 60o span and produces three hall signals which are decoded to create the suitable switching pulses for the switches of VSI. Fig.4 shows the switching state electronic commutator. The hall effect sensors are usually placed in such a way that the magnets change its values previously the rotor is entirely the following compensation position. This consider for the following commutation to be made before the rotor really winds up and stuck in one position.

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θ(°)	Hall Signals			Switching States					
	H_1	H_2	H_3	S_1'	S_2'	S_3'	S_4'	S_5'	S_6'
0-60	1	0	1	0	1	1	0	0	0
60-120	0	0	1	0	1	0	0	1	0
120-180	0	1	1	0	0	0	1	1	0
180-240	0	1	0	1	0	0	1	0	0
240-300	1	1	0	1	0	0	0	0	1
300-360	1	0	0	0	0	1	0	0	1

Fig.4 Control structure of the water pumping system.

VI.SIMULATION AND DISCUSSION

The simulation ran in the MATLAB/Simulink 2016a and performance curve of the overall system is shown in Fig.5-10. Fig. 5 shows the performance of the SPV array at STC condition. From the Fig. 5, it is observed that ANN based MPPT technique able to track maximum power of 2812 W with maximum voltage267.4 V and current 9.78 A. It is also observed that the proposed MPPT have excellent tracking efficiency. Fig. 6 shows the performance of the boost converter where inductor current iL is found to be 10.50 A and Vdc is maintained at 325 V. Duty cycles in Fig.6 desirable for CCM is shown. In Fig. 7 the BLDC motor builds up the rated speed and electromagnetic torque, (Te) at full load to drive the water pump. Due to present of ripples current at the DC link of the VSI, a minor fluctuation in Te is observed.Smooth starting of BLDC motor is also observed in speed~ time characteristics.

Dynamic characteristics of SPVWPS is shown in Fig. 8-10. Dynamic change in solar irradiance is applied; 1000 W/m2 form 0-0.4 s, 200 W/m2 from 0.4 to 0.7 s. and 600 W/m2 from 0.7-1 s. With respect to a dynamic change in solar irradiance, proposed MPPT successfully able to track maximum power in all the cases immediately as shown in Fig.8. In Fig.9 Vdc is maintained at 325 V and inductor current change in accordance with the solar irradiance. In Fig. 10 all variables of the BLDC motor i.e. speed, electromagnetic torque, pump load torque (TL), back emf of phase A (ea) and stator current of phase A (Isa) change in accordance with solar irradiance level. It is observed that the BLDC motor quickly able to reach steady-state value. At various irradiance pump load torque countered by the electromagnetic torque that depicts the steady performance of the motor. The efficiency of the SPVWPS is given in Table 3 at various irradiance level.

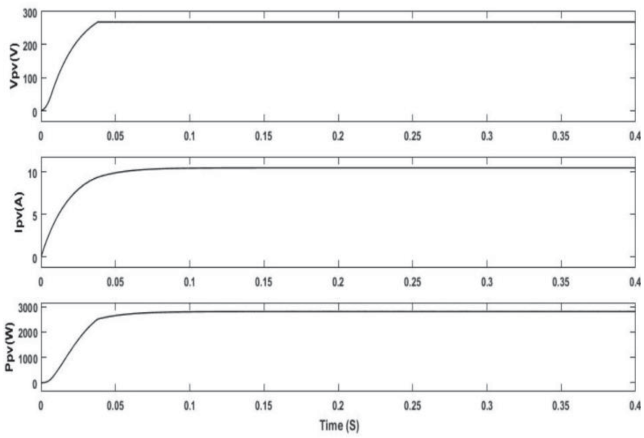

Fig.5 Performances of SPV array under STC.

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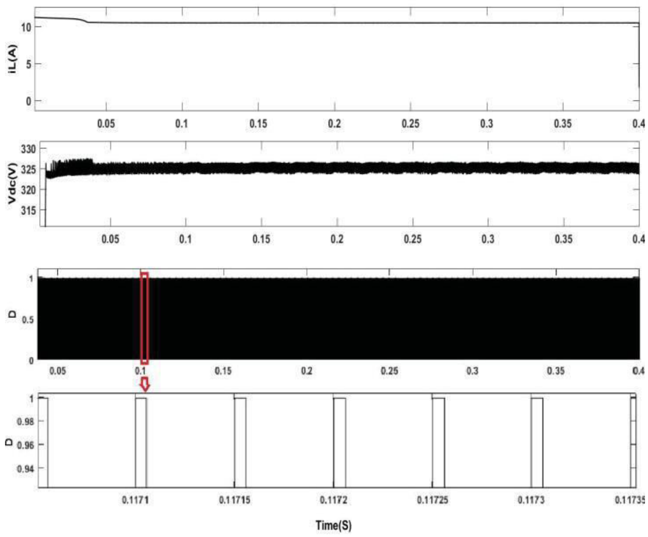

Fig.6 Performances of DC-DC Boost converter under STC of SPV array.

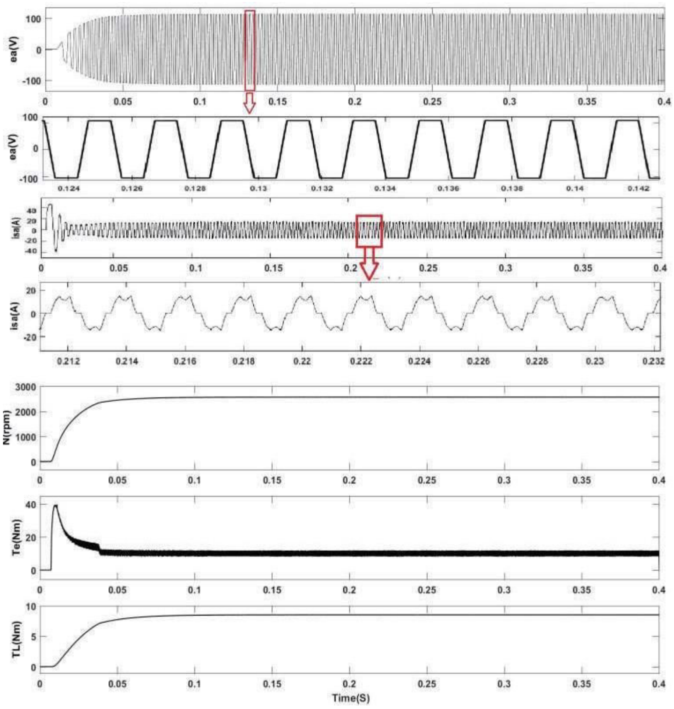

Fig.7 Performances of BLDC motor under STC of SPV array.

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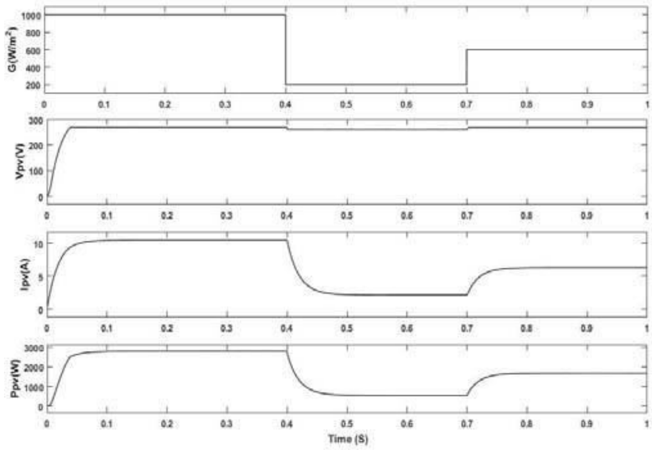

Fig.8 Dynamic performances of SPV array.

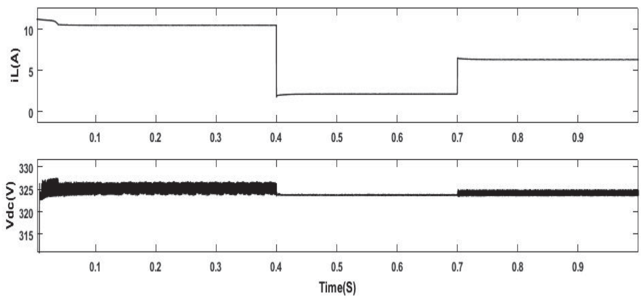

Fig.9 Dynamic performances of DC-DC Boost Converter.

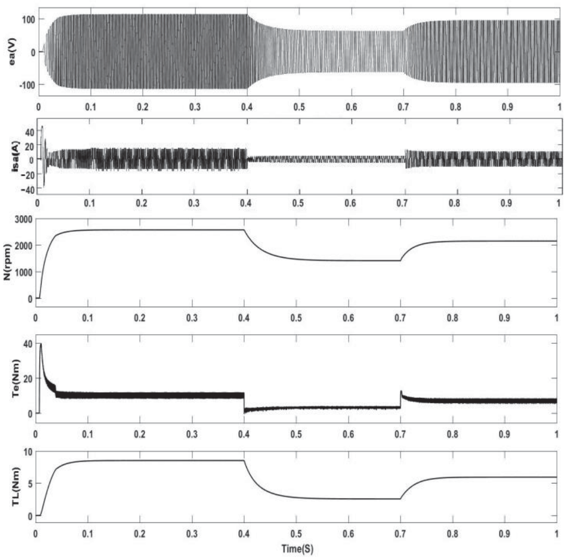

Fig.10 Dynamic performances of BLDC motor

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Table 3. Efficiency of the overall system at various irradiance.

G (W/m^2)	P_{pv}(W)	P_m(W)	4 (%)
200	547.2	377.78	69.03
300	831.9	614.02	73.80
400	1118	854	76.39
500	1403	1094.48	78.01
600	1688	1336.38	79.17
700	1972	1577	79.97
800	2254	1817.42	80.63
900	2534	2055.58	81.12
1000	2813	2294	81.55

VII.CONCLUSION AND FUTURE SCOPE

In this paper, a non-electrical input-based ANN MPPT is introduced for solar power water pumping system using BLDC motor. The objective was to introduce a step size independent MPPT technique and optimal modeling of the system. The outcomes have demonstrated that usage of ANN-based MPPT is one of conceivable option design step size independent operation of PV array driving water pumping system using BLDC motor. It has been observed that the system has excellent transient and steady-state performance over a wide range of irradiance. Results have proven the optimal performance of the system with the highest efficiency of 81.55% and maintain a continuous flow of water even at the lowest irradiance with an efficiency of 69.03%. Soft starting of BLDC motor is also achieved using a proposed method which is desirable for smooth operation of the motor pump set.

The output voltage THD values are not improved much so that the research should be carried out in this area; a filter circuits configuration should be improved. For the inverter circuits, the grid tied inverters are having the problem that if the grid fails, the customer will not get any supply even though there is power generation from the PV system. The BLDC motor can be used for electric vehicle applications. This should be considered as a serious problem and the research should be carried out in these areas.

REFERENCES

[1] Rajan Kumar and BhimSingh , "BLDC motor driven water pump fed by solar photovoltaic array using boost converter," in Annual IEEE India Conf. (INDICON), New Delhi, 2015.
[2] Bhim Singh and Ranjan Kumar, "Solar PV Array Fed Brushless DC Motor Driven water pump," in IEEE 6th International Conference on Power Systems (ICPS), New Delhi, 2016.
[3] B. Subudhi and R. Pradhan,, "A comparative study on maximum powerpoint tracking techniques for photovoltaic power systems," IEEE Trans. Sustain. Energy,, vol. 4, no. 1, pp. 89-98, jan 2013.
[4] Lina M. Elobaid, Ahmed K. Abdelsalam and Ezeldin E. Zakzouk, "Artificial neural network-based photovoltaic maximum power point tracking techniques: a survey," IET Renewable Power Generation, vol. 9, no. 8, pp. 1043-63, 2015.
[5] NajetRebei, RabiaaGammoudi , Ali hmidet and Othman Hasnaoui, "Experimental Implementation Techniques of P&O MPPT Algorithm for PV Pumping System," in IEEE 11th International Multi-Conference on Systems, Signals & Devices, Barcelona, Spain, 2014.
[6] S.G. Malla, C.N. Bhende and S. Mishra, "Photovoltaic based water pumping system," in International Conference on Energy, Automation and Signal, Bhubaneswar, Odisha, India, 2011.
[7] B. Singh and R. Kumar, "Solar PV array fed water pump driven by BLDC motor using Landsman converter," IET Renew. Power. Gener., vol. 10, no. 4, pp. 474-484, 2016.
[8] Rajan Kumar and Bhim Singh, "Solar Photovoltaic Array Fed Luo Converter Based BLDC Motor Driven Water Pumping System," in 9th International Conference on Industrial and Information Systems, Gwalior, India, 2014.
[9] Songbai Zhang, Zheng Xu, Youchun Li, and Yixin Ni, "Optimization of MPPT Step Size in Stand-alone Solar Pumping Systems," in IEEE Power Engineering Society General Meeting, Montreal, Que., Canada, 2006.

| e-ISSN: 2278 – 8875, p-ISSN: 2320 – 3765| www.ijareeie.com | Impact Factor: 7.282|

|| Volume 10, Issue 9, September 2021 ||

DOI:10.15662/IJAREEIE.2021.1009014 |

[10] Rajan Kumar, Bhim Singh, Ambrish Chandra and Kamal Al-Haddad, "Solar PV array fed water pumping using BLDC motor drive with boost-buck converter," in IEEE Energy Conversion Congress and Exposition (ECCE), Montreal, QC, Canada, 2015.

[11] N. Mohan, T. M. Undeland and W. P. Robbins, Power Electronics Converters,Applications and Design 3rd ed., New Delhi: John Wiley & Sons Inc., 2010.

[12] Utkarsh Sharma,Shailendra Kumar and Bhim Singh, "Solar array fed water pumping system using induction motor drive," in IEEE 1st International Conference on Power Electronics, Intelligent Control and Energy Systems, Delhi, India, 2016.

[13] Bhim Singh, Anjanee Kumar Mishra and Rajan Kumar, "Solar Powered Water Pumping System Employing Switched Relucatance Motor Drive," IEEE Transaction On Industrial Application , vol. 52, no. 5, pp. 3949-3957, Sep-Oct 2016.

[14] Si Young Yun ,Ho Joon Lee, Jung Ho Han and Ju Lee, "Position Control of Low Cost Brushless DC Motor Using Hall Sensor," in Sixth International Conference on Electromagnetic Field Problems and Applications, Dalian, Liaoning, China, 2012.

[15] W. V. Jones, "Motor selection made easy: Choosing the right motor for centrifugal pump applications," IEEE Ind. Appl. Mag., vol. 19, no. 6, pp. 36-45, Nov./Dec 2013.

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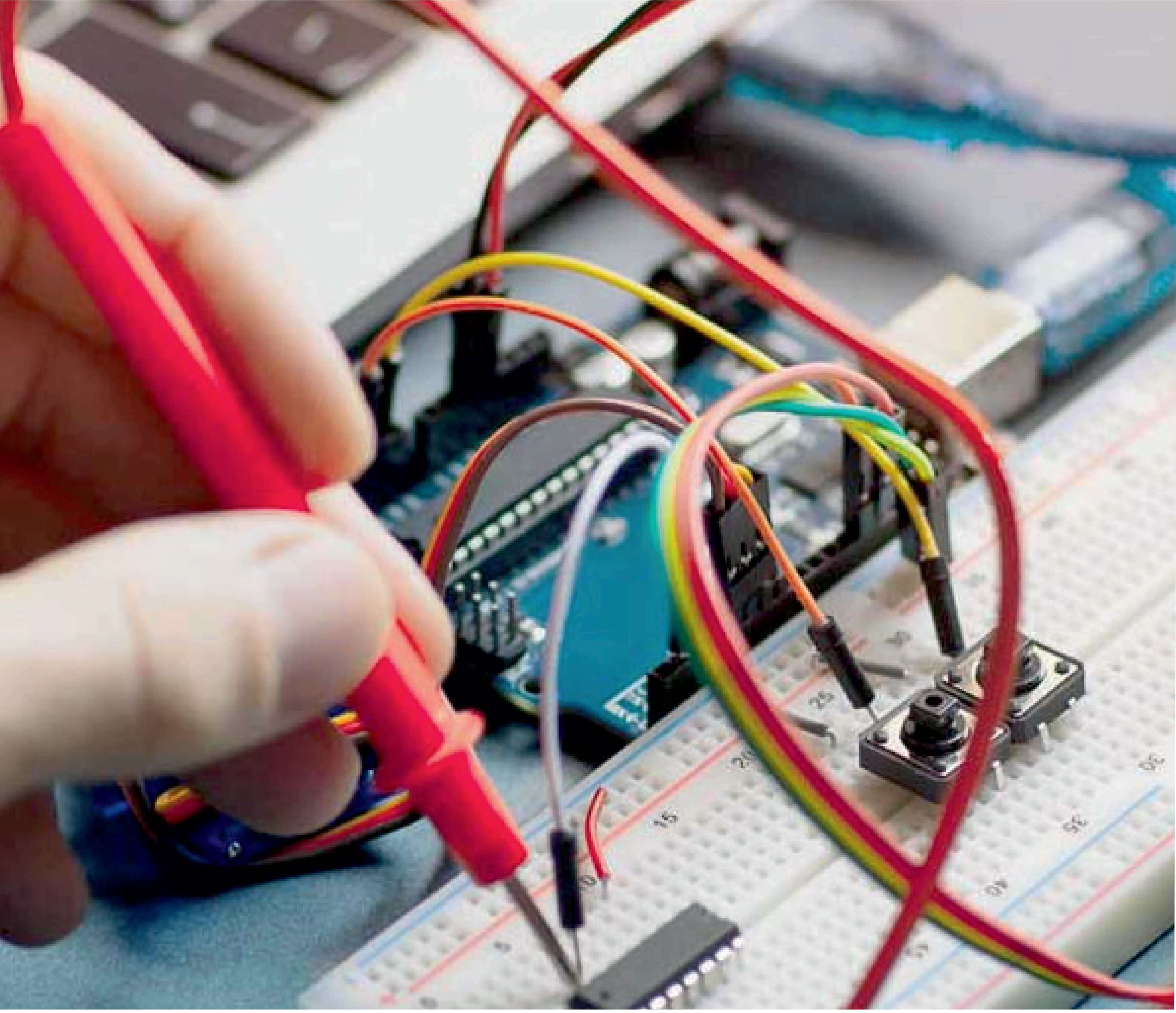

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