Design of and Development of MPPT Solar Energy used in IoT based Pumping System

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Abstract:- **Renewable energy is the future of power sector. The intention of this paper is to design a low cost way to extract the maximum useful power from a PV module to power a water pump through maximum power point tracking (MPPT). This approach will yield maximum financial and technical accessibility for end users (Ex-Farmers). The MPPT controller is used get maximum energy from the PV panel as well control the switching system by a buck DC_DC converter. The solar photovoltaic cell is used as a primary source and the battery with inverter used as the backup.Although; the battery will discharged only under any bad c1imate situation or at night when the PV array is insufficient to feed the water pump.The battery will take all the charges from the PV panel, no external source will used. The project was successful in powering a water pump from a PV module as desired by a step-up transformer to provide require power, and the microcontroller driven control circuitry was capable of finding and maintaining operation at the maximum power point of the PV module. The BLDC motor is consistently operated at its rated speed and load. No current sensing is required for the speed control and the power devices of voltage source inverter (VSI) are switched at fundamental frequency. The BLDC motor is combine with a Nod-MCU IoT based system to provide real time data to the user. The various performance analysis of the proposed water pumping are carried out in MATLAB/ SIMULINK platform.**

Keywords:- MPPT P&O algorithms, solar energy, Brushless DC Motor, BLDC Water pump,Battery Storage, Inverter, IoT, Buck Converter, SIMULINK

I.INTRODUCTION

The standalone photovoltaic (PV) water pumping system has received increasing attention in the last few years because of the ongoing cost reductionsowing to its simplicity; high efficiency; easy-to-drive features; no maintenance requirement and compactness.. It is necessary to operate the PV energy conversion systems at the MPPT or near to it to increase the efficiency of the PV system because generation being intermittent in nature leads to an unreliable and interrupted water pumping. Moreover; in the course of bad c1imate condition; the motor-pump is Underutilized as the SPV power is insufficient to run it at its full capacity. In today’s era challenge is to reduce threats to energy security and to create pollution free environment; a conventional generator will no longer exist. The only remaining and feasible solution is to use a battery storage as a power backup, which practice; leading to a battery supported SPV hybrid power source; offers a continuous and reliable water pumping. The PV array has non-linear output current and power of the PV array depends on its operating terminal voltage. Also, the output power of PV array is fluctuating with the change in the ambient temperature and solar irradiation. Therefore, for most of the time under varying irradiation levels the DC motor and pump are operating the PV array far from the MPPT.To overcome these problems, many algorithms have been developed to provide maximum PV power, Here we used the perturb and observe (P&O) algorithm which is the most commonly used algorithm, due to its ease of implementation. A BLDC induction motor is used in a SPV battery hybrid power source to pump out water. A bi-directional buck converter is used to control the power flow control for charging/ discharging of the battery.The battery is charged when an SPV power is available but the water pumping is no more required. Furthermore; the battery is made nonfunctional when a full amount of power required by the water pump is available from solar PV array, thus no external power source is required. Also enables a full utilization of both PV installation and motor-pump system.The bidirectional power flow is accomplished by a common capacitor placed at the DC bus of voltage source inverter (VSI). The speed of BLDC motor-pump is maintained at its rated value by regulating the DC bus voltage of VSI. The required voltage is produced by a step-up transformer.The magnitude of stator current of BLDC motor at starting is controlled by operating the VSI in PWM (Pulse Width Modulation) mode for a pre-defined duration. However; once the motor is started; the VSI is operated with the pulses of fundamental frequency resulting in a minimized switching loss and an enhanced conversion efficiency. A nod-MCU sensor transistor is used to get all real time data from the cloud.The MPPT based hybrid pumping system with an IoT drive is simulated inMATLAB/ SIMULINK platform and its functionalities are evaluated through the simulation results to demonstrate the claims.

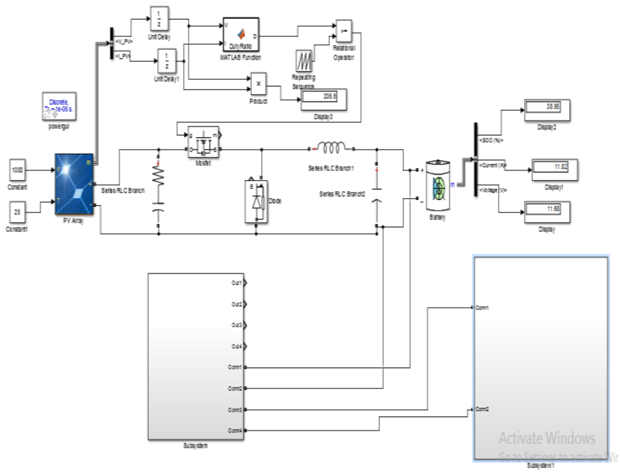

Figure 1

II. System Configuration

The configuration of proposed hybrid water pumping system is sketched in Fig. 1. An SPV array via a buck converter and a battery storage via a bidirectional buck converter create a common DC bus. A BLDC motor-pump is supplied by this common DC bus via a step-up transformer. The DC-DC buck converter is engaged to perform MPPT of SPV array through a P&O algorithm; while a buck converter plays a role of charge controller for the battery. A single phase inverter is used to supply the AC current When the battery is discharged; this converter acts as a boost converter and the battery feeds the common DC bus. A single phase ac invertor is used to use the current in ac frequency and run the motor with a connected step-up transformer to boost up the voltage at required level (ex- 240volt, 50Hz). In Fig.2, its show the complete circuit battery storage to motor load, through the invertor and step-up transformer.

III. CONTROL APPROACH

The various control techniques are applied to achieve the desired functionalities of proposed water pumping. The MPPT of an SPV array; charging control of the battery; electronic commutation and control of brushless DC motor; are required to be incorporated. A detailed description of each control is mentioned in the following sections.

A. Maximum Power Point Tracking of PV Array

An MPPT occurs when the incremental conductance ($\Delta p_{pv}/\Delta v_{pv}$) resembles with the conductance (p_{pv}/v_{pv}). Any variation from this condition needs either positive or negative perturbation; depending on the power slope; in the duty ratio. The SPV array voltage; $v_{pv}$and current; i_{pv} are sampled on an instantaneous basis to estimate ($\Delta p_{pv}/\Delta v_{pv}$) and ($p_{pv}/v_{pv}$) at each sampling instant. The duty ratio; D which is generated corresponding to MPPT is then used to generate the gating signal for the boost converter through a pulse generator.

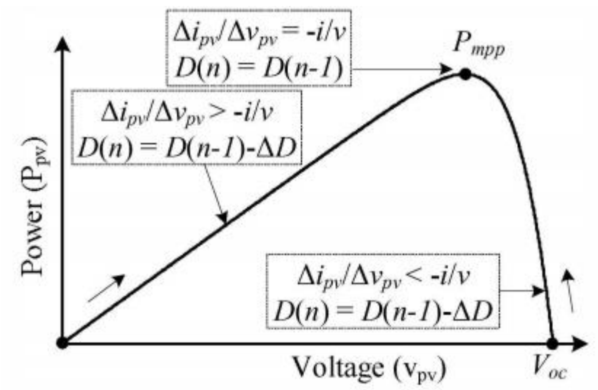

Figure 2

In Fig.2 represent the MPPT characteristic of Solar PV cell. With respect to the duty ratio; D which is generated corresponding to MPP is then used to generate the gating signal for the boost converter through a pulse generator. By using the perturb and observe (P&O) algorithm which use the power variation of the PV module.

B. Battery Charging Control

A bidirectional power transfer between the DC bus and storage battery is carried out using a bidirectional power flow control through a DC-DC buck converter as shown in Fig. 3

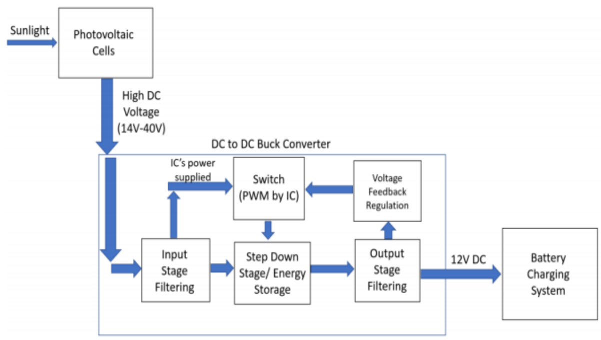

Figure 3

A simple buck converter typology that uses an inductor to store energy, transistor "V_{switch}" to charge the inductor with V_{in} supply, a diode to enable discharge of the inductor during off cycles, and a filtering capacitor. Buck converters contain other typologies that use various arrangements of transistors and energy storing techniques. This basic buck controller focusing on the basic typology for size and simplicity. In a buck controller, the duty cycle of the switching frequency determines the step-down voltage. An integrated circuit controls switching frequency and duty cycle. A proportional-integral (PI) controller is used as the voltage and current regulator. The current regulator provides the corresponding duty ratio which is further converted into the PWM pulse for buck-boost converter.

Table 1

Output Current = rated power / V Output = 210/12 = 17.5 Current ripple = 10% of 17.5 = 1.75 A Voltage ripple 1% of 12 = 0.12 V Inductance, L = $\frac{V_{op}(V_{ip}-V_{op})}{f_{sw}*Iripple*V_{ip}}$ Inductance, L = = 0.783 mH Capacitance, C = $\frac{Iripple}{8*f_{sw}*Vripple}$ Capacitance, C = $\frac{1.75}{8*5000*0.12}$ = 364 µF	Specification Rated Power = 210 W Vinput = 28-36 V Voutput = 12 V Fsw = 5Khz Iripple = 10% Vripple = 1%

Table 1 is contained the buck converter charging control dynamics with rated apparatus and required specification.

C. AC transformation and Voltage step-up

A single phase invertor is used to convert the current in alternative current. It's run the BLDC motor and for the required charge a step-up transformer used to supply of necessary power.

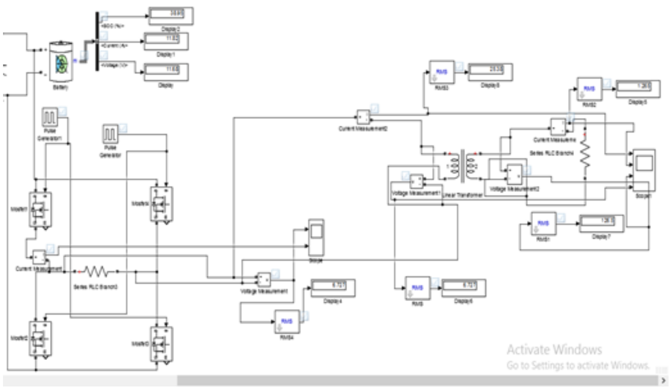

Figure 4

D. Remotely surveillance through IoT

The heart of the IoT system is Node-MCU ESP32/8266 Wi-Fi module. Data pin D8 of IC2 is connected to pin D0 of Node-MCUmodule (Board1) to provide the motor on/off status on a remote computer or smartphone over cloud. IoT platform is used to monitor the water-pump's status online.

IV.RESUL TS AND DISCUSSION

The performance analysis of the proposed water pumping system under different operating conditions is carried out using MA TLAB/ Simulink toolboxes. A hybrid generating unit composed of an SPV array of 2.55 kW peak power and a 72 V; 300 Ah lead-acid battery feeds a 3000 rpm @ 213v; 5.2 Nm BLDC motor-pump. A detailed design specifications of the system are mentioned inAppendices.The water pump may be operated with SPV array only; the battery only; with both SPV array and the battery; or may not be operated; as per the availability of sunlight and water output requirement. These operating conditions are demonstrated in the following sections.

A. MPPT Duty cycle Performance

The main objective of this analysis the MPP value to demonstrate the safe starting of BLDC motor pump. As shown in Fig. 5 and Fig. 7 shows the total output gain of voltage and current irrespectively.

Fig.6 represent the duty cycle ratio output gained from the MPPT of the solar panel.

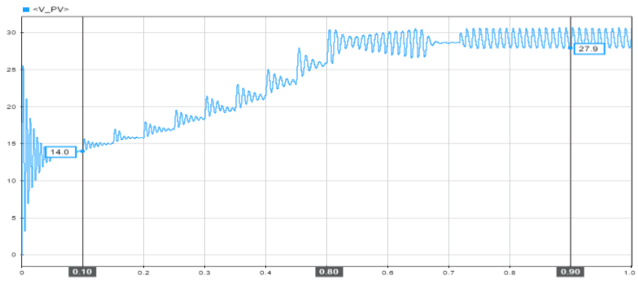

Figure 5, Solar PV Panel Voltage output

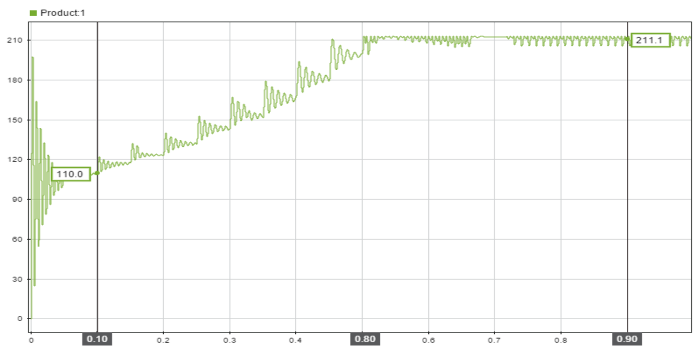

Figure 6, Duty Cycle Ratio

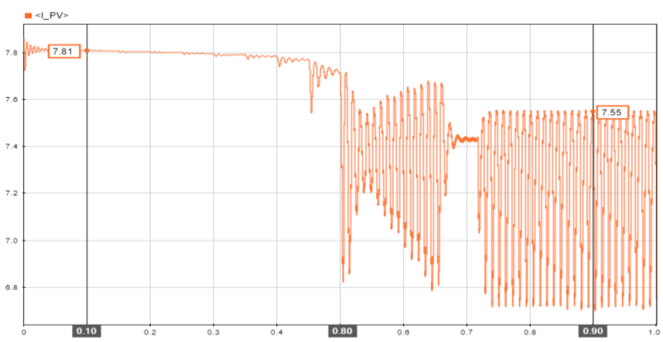

Figure 7,Solar PV Panel Curent-output

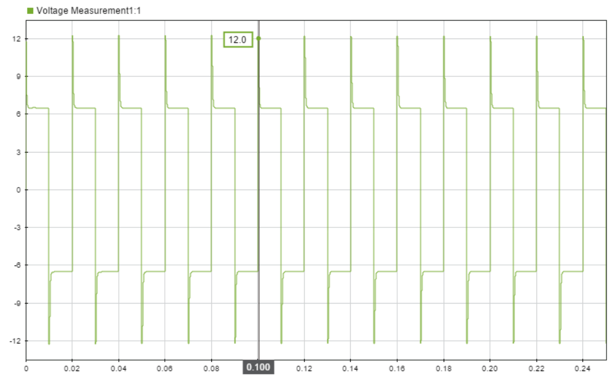

Figure 8, Voltage Output of the Battery

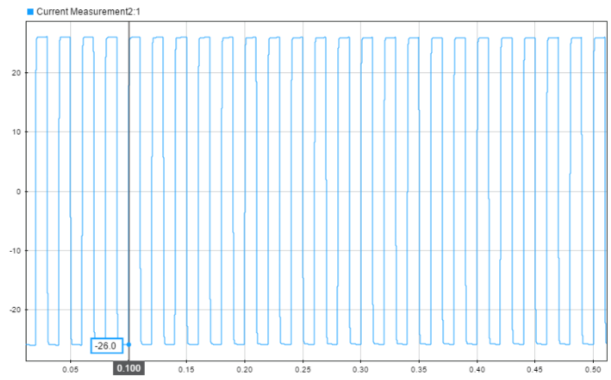

Figure 9, Current Output of the Battery

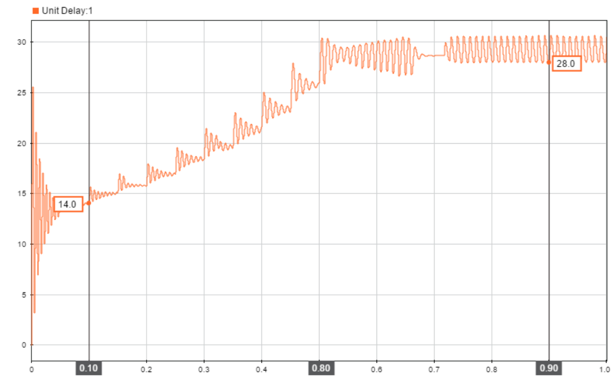

Figure 10, Unit Delay Pulse

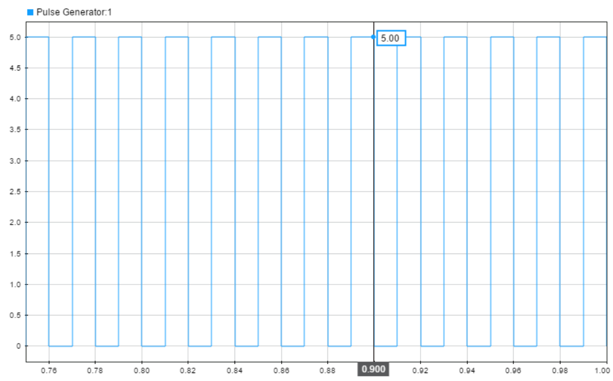

Figure 11, Output of Generating Pulse

B. Motor load Performance

In Fig. 8 and Fig.9 it shows the output of the voltage and current irrespectively.

Fig.10 shows the unit delay ratio in discrete manner to the output of duty cycle through Buck converter.

Fig.11 represent the required pulse generator through the step-up transformer.

Dynamic Performance under Transition from SPV Array Feeding Pump to Both SPV Array and Battery Feeding Pump; (a) PV Array Variables (b) Battery Variables (c) Motor-pump Variables. As an output power of the SPV array is reduced to half; it is required to share the load demand to run the pump at full capacity. The battery is now discharged by the bidirectional power flow control and a remaining power is drawn from the battery. Thus; the water pump is fed by both SPV array and the battery.

V. CONCLUSION

A motor driven water pumping fed by an SPV battery hybrid source has been proposed and its various performances have been analyzed under the dynamic conditions. The proposed water pumping has been demonstrated as a reliable system. Moreover; a full utilization of the SPV array and pumping system has been made possible. A power flow control has been applied to enable a power transfer between the DC bus and battery storage through a bi directional converter. A reduced sensor based BLDC motor drive has led to a low cost and compact pumping system. The Iot system always remotely check the data. This grid independent system has been found more useful for remote and isolated regions.

VI. ACKNOWLEDGEMENT

Primarily I would thank God for being able to complete this project with success. Then I would like to thanks our respected teacher ***Mr. Sudip Das***, whose valuable guidance has been the success his suggestions and his instructions has served as the major contributor towards the completion of the project.

I would like to thanks to our respected HOD sir ***Dr.Papun Biswas*** who has helped us with his valuable suggestion and guidance has been helped in various phase of the completion of the project.

Finally, I would like to thanks my project teammates for retain their concentrate only on the project and each member of our team give their best and finally the project has been successful by the profusely hard works.

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