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Simulation Modeling of Solar Hybrid Water Pumping System

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Abstract – The use of renewable energy sources continues to increase as they provide clean energy in every system. It has also been widely used in water pump systems. With its solar water pumps, it provides opportunities to the points where water and electricity cannot reach. Solar water pump systems operated with AC and DC motors are preferred. In this study, a solar water pump system was modeled in Matlab/ Simulink using a Brushless (BLDC) motor. In the system, bidirectional charge control is used for battery storage and a hybrid system modeling has been carried out. This study evaluates the dynamic behavior of the solar water pump system in the case of weak and high solar radiation. It recommends using BLDC motor for full efficiency water pump and bidirectional charge control for battery storage.

Keywords – Solar Water Pump, BLDC Motor, Bidirectional Control, Efficiency

I. Introduction

Solar water pump works with solar energy to provide water. These pumps are mainly used in irrigation and water supply. The pump requires solar energy to operate. It can pump both hot and cold water, it varies according to the variation of the pump. There are solar-specific integration units, ie there are no solar-specific pumps. There is an integrated product in the same stream. Solar submersible pumps can work with batteries. Solar-powered irrigation systems are off-grid systems. It is widely seen in irrigation areas, agricultural lands, irrigation areas as well as residential and commercial uses. Suitable solar pumps also eliminate energy costs thanks to solar panels. It provides a more viable option by using energy from the sun to pump water, not using energy from the sun as fuel. DC solar pumps provide simple and energy-saving alternative energy. It is environmentally friendly in agriculture. It can be used to irrigate any area. It has great potential in agricultural use as it is efficient and useful. Because of this, solar water pumps are now helping more and more agricultural projects [1]. Another issue is the type of motor to be used in solar water pumps. Although the cost of DC motors is high, they can provide water pumping with better efficiency than AC motors. Brushless DC motors are produced specifically as small powerful control motors. Because these engines; It is very advantageous in terms of high torque, high power/weight ratio, high efficiency, quiet operation, dense winding structure, reliability and low maintenance costs. Due to these advantages, brushless DC motors; It is widely used in computers, spacecraft, military equipment, automotive, industry and household appliances. Brushless DC motors are widely used today. Special driver circuits called ESC are used for their work. It is used in applications where high performance is required, thanks to its advantages, its very high efficiency due to the minimum level of friction and the absence of wearing parts such as brushes. The disadvantages are that it has to be driven with a driver [2]. However, after a certain period of time, a water pump can be made with full efficiency with high efficiency working by amortizing itself. In this study, solar battery-based hybrid water pumping system is modeled in Matlab/Simulink environment and the results show how it performs in the use of BLDC motor and pumps water at maximum efficiency with the use of bidirectional converter.

II. Materials and Method

A. Heading Incremental Conductivity Based MPPT

Each photovoltaic panel has its own characteristic curves (Fig. 1). There is a maximum power point on these curves. At the maximum power point, there is a relationship as shown in equation (1) [3].

$$\frac{dP}{dV} = 0 \qquad (1)$$

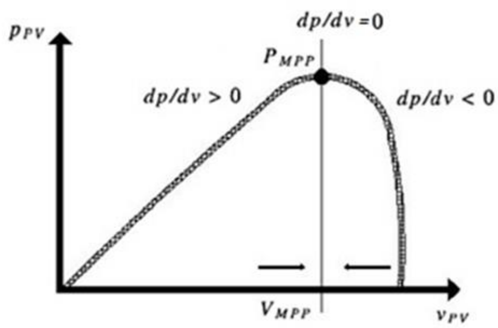


Fig. 1 Working region on Panel PxV curve

At MPP,

$$\frac{dP}{dV} = \frac{dI}{dV} + \frac{I}{V} = 0 \qquad (2)$$

The basic idea of the incremental conductivity method comes from the above processes. In practical applications (dP/dV=0) it rarely happens. For this reason, depending on the sensitivity of the MPPT methods, the point where the slope is zero can be found with a small margin of error.

$$\frac{dI}{dV} + \frac{I}{V} = e \qquad (3)$$

Error (e) is usually determined by trial and error method. If the detected error is large, the MPP can be found quickly, while in the steady state oscillation is made. If the error is small, reaching the maximum power point is delayed, while in the steady state, less oscillation occurs. In the IC method, current, voltage or duty time can be selected as the control variable. In this study, tenure was chosen as the control variable [3].

B. BLDC motor Commutation

Brushless DC Motors; It is a type of motor that provides the commutation process electronically, not mechanically. In DC motors containing brushes, the energy transmission to the windings in the rotor is transmitted by the brush collector structure. Thanks to the collector arrangement, which has a fragmented structure, the direction of the current passing through the rotor windings changes automatically while the motor is rotating. This system creates problems such as sparking, maintenance and wear on the brushes. In brushless DC motors, an electronic controller, motor drivers undertake the task of brush-collector assembly, that is, commutation. commutation; is the change of direction of the current. In motor drivers, there are solid-state circuit elements that carry out the high current switching task and a microcontroller that provides the timing related to the switching. The controller must follow the position of the body (rotor) at an appropriate speed so that the rotation of the motor is not disrupted. This process requires knowing the rotor position. Hall effect sensors are used for rotor position in most brushless DC motors with sensors.

C. Bidirectional Converter Control

The reliability, efficiency and dynamic performance of the system relies on the operation of the bidirectional converter under different modes of operation, so that individual parts of the system can operate properly. A buck-boost type high performance bidirectional converter, is used to charge and discharge the battery. This bidirectional converter is having the following properties which enhance its performance, [4]

- high step-up and step-down ratio
- power flow with large voltage diversity
- soft switching and zero voltage switching
- less conduction losses
- reduced switching losses due to fewer switches
- no transformers
- synchronous rectification
- less weight and volume
- no magnetizing current saturation [5]

D. System modelled in Matlab/Simulink

The modelled state of the whole system is shown in the Figure 2. Solar battery-based hybrid structure was modelled in Matlab/Simulink and BLDC motor was used, a converter model providing bidirectional charge control was preferred for control. 1.3kW solar PV array peak power, operating at 130 V dc at 2500 rpm, A solar hybrid water pump with a lead acid battery of 72 V 300 Ah and a torque of 4.14 Nm is modelled.

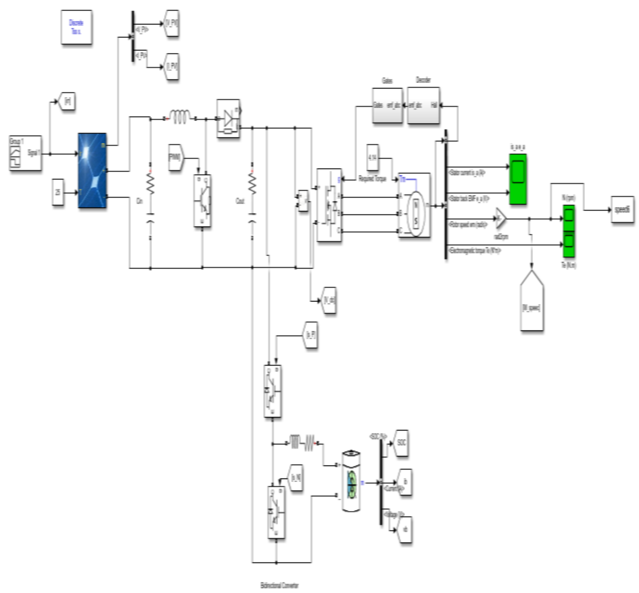


Fig. 2 Solar hybrid water pumping system

III. Results and Discussion

This study evaluates the dynamic behavior of the solar water pump system in the case of weak and high solar radiation [6]. In case of low radiation, as can be seen from the S (W/m2) unit curve, if the solar radiation drops from 1000 to 500 W/m2, the battery is automatically activated. This situation is illustrated in Figure 3. Coming from 2000w to 1000w from the Ppv curve as shown in Figure 3 results in the power output being reduced by almost half. in this case the water pump will be sufficient to run the pump at full capacity and is powered only by the SPV array. As shown by the SOC curve in Figure 3, the battery is idle after 4 seconds and no current is drawn from the battery. Since the output power of the SPV array is halved to 1000w, it is necessary to run the pump at full capacity to meet the load demand. The battery is discharged by the bidirectional controller and the remaining power is drawn from the battery. Like this; The water pump is powered by both the SPV array and the battery. In Figure 4(a) the buck-boost converter is holding Vdc at 130 V in Figure 4(b) while the motor is running at 2500 N (rpm) on the N curve. The battery current Ib and state of charge (%SOC) are also shown in Figure 3. Figure 5 shows the motor pump running at full capacity. It operates independently of the load and at rated speed. Pumping water at night is sometimes necessary. In these cases, the water requirement is met from the battery. Sometimes the water demand is zero even though there is full sunlight. In this case, instead of wasting SPV array power; A generated SPV power is used to charge the battery. This dynamic situation is illustrated in Figure 4. Figure 3 shows that solar radiation is not present until 6 s, after 6 s a full radiation ie 1000 W/m2 is present. This result is highly accurate even in the worst case of the system. It is also assumed that no water pumping is required after 6 seconds.

In Figure 3, since SPV array power will not be available for up to 6 s, a battery is discharged to draw all the power a water pump needs. The battery is then charged by the SPV array as it does not need to pump water and full sunlight is available.

During charging, the direction of the bidirectional controller is reversed and the buck-boost converter is operated in buck mode while keeping the Vdc set at 130 V. Figure 5 shows the BLDC motor-pump indexes under this operating condition. During charging, the direction of the bidirectional controller is reversed and the buck-boost converter is operated in buck mode while keeping the Vdc set at 130 V. Figure 5 shows the BLDC motor-pump indexes under this operating condition.

As shown in Figure 5; While the stator current Is increases at a controlled rate, the electro-force Ea (V) continues to rise at the same rate according to the soft start performance of the BLDC motor pump.

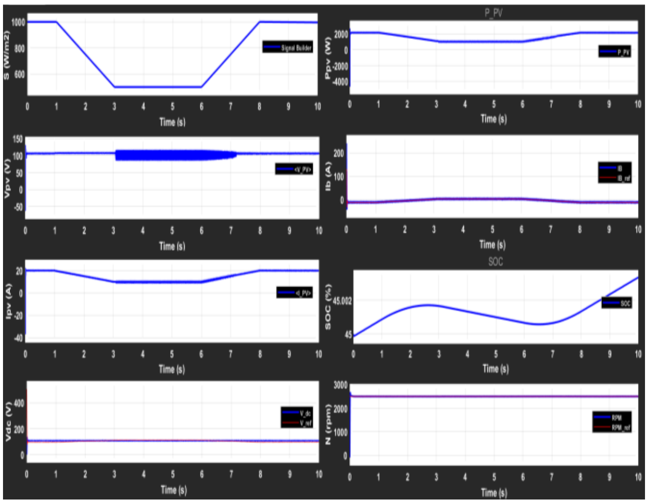
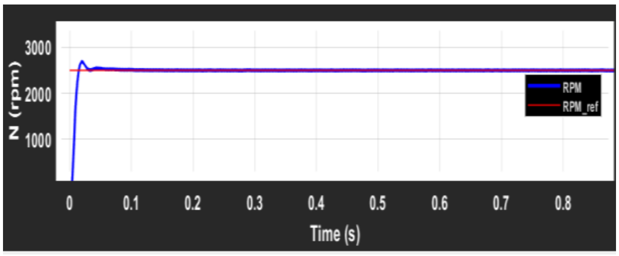
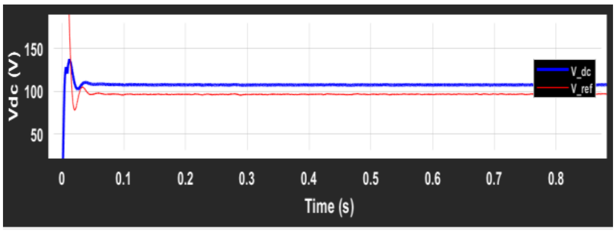


Fig. 3 Simulation results



(a)



(b)

Fig. 4 (a) Speed (b) dc link voltage

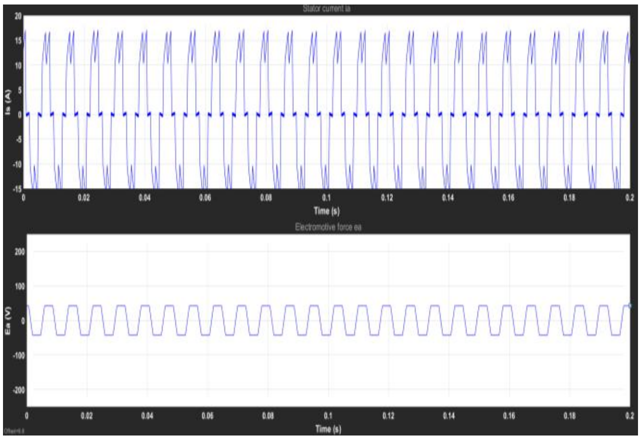


Fig. 5 Stator current and Electromotive force (Ea)

IV. CONCLUSION

In this study, solar hybrid water pump was modelled in Matlab/Simulink environment and BLDC motor was used. Battery charging was carried out with bidirectional charge control. Battery and solar energy are used for water pumping at full efficiency. In the study, when the simulation results are examined, a water pump with maximum efficiency is provided. Although DC motor is not preferred because it is costly, it has high performance in terms of efficiency. In this study, performance analysis of a battery-based BLDC motor-based water pump system was performed in case of weak and high solar radiation.

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