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Solar photovoltaic system fed water pumping system using BLDC motor with single input and multiple output converter

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ABSTRACT

In recent times energy based on renewable energy sources is a good long-term alternative compared with traditional fossil fuel energy sources solar photovoltaic model-based irrigation water pump systems have gained more popularity. The one-input and multi-output converters are focused on BLDC motor drive-based solar photovoltaic with water pump. To model one input and multiple output converter components are connected viz it achieves tracking purpose and BLDC drive soft starting. The one-input and multiple-output converter exhibits the features of all converters and remarkably appears with the converter in the application of solar photovoltaic systems. It describes performance under varying environmental and inspects the BLDC motor effective with the suggested single input and multiple output converter for solar photovoltaic with a water pump with 95% efficacy and the price is USD 0.6/W. Test results have confirmed the BLDC motor suitability for solar photovoltaic with water pump employing MATLAB Toolbox followed by the test result verification. It is simply developed for rural areas because it is low cost, simple, and low maintenance.

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1. INTRODUCTION

Recently, the usage of solar energy photovoltaics to power the water pumping system is an emerging expertise with great challenge. It can be employed on large scales and offers an environmentally approving alternative to the fossil fuel energy traditional water pump system. Moreover, solar photovoltaic energy to water pump significance increases due to continuous oil reserve depletion, uneven distributions, and electricity ever-increasing cost. The ongoing increase in total electricity demand and environmental concerns owing to the pollution from humankind activity may lead to the discovery for a clean energy system [1]. The solar photovoltaic system (SPVS) is one of the best solutions then it is renewable and examined for a long life [2]. Currently, it is widely employed for a variety of applications in our daily life [3]. Nevertheless, in the past years, solar photovoltaics were more expensive than conventional energy sources [4]. This can be changed as a result of increasing the fuel price and on the other hand less photovoltaic system price, improved efficiency, and increased manufacturing technology [5]. The price of energy production decreases as efficiency increases. India is a developing, agriculturally based, and densely populated country and its 30 percent of products come from the agriculture sector [6]. Based on the fact that SPVS is a secure energy source, clean, and environmentally friendly, SPVS installation is playing an important role in society [7]. Nonetheless, the disadvantage of SPVS is higher capital costs compared with traditional energy sources [8]. Recently,

researchers have been concentrating on the control of SPVS so that module numbers, storage battery capability, inverter capability, and SPVS array tilt angle are taken [9].

The photovoltaic system is either employed as a connected system or standalone to the power grid [10]. In the standalone model, the power from the photovoltaic array is directly fed to the customer load instead of connecting to the utility system [11]. In rural zones, the stand-alone system is one of the economic ways of using photovoltaic energy owing to the long-term convenience of solar radiation and rare access to the utility grid [12]. The numerous applications of photovoltaic stand-alone models are lighthouses, military applications, water pumping systems, and communication systems [13]. Other than giving auxiliary power the several disadvantages include cost, storage capacity is limited as a result of wastage and dissipation of the surplus energy generated [14]. As the standalone model is not connected to the utility grid there is a requirement of the storage elements during off-maximum demand periods [15]. Another significant standalone model feature is that there should be a balance between the operational capacity and the maximum load demands [16].

The SPVS performance and size are based on the meteorological variables viz solar energy system and the ambient temperatures, so to maximize a photovoltaic system, comprehensive research pertaining to the meteorological variables must be conducted [17]. Determining a promising alternative to power a pumping arrangement is essential with the increased electricity use and diesel cost [18]. The photovoltaic technology-based water pumping system is the best solution for rural areas where interconnection to the power grid is problematic and more expensive [19]. Therefore, SPVS is more consistent than a system based on the diesel pump because of lesser maintenance. The brushless direct current motor consists of good speed-torque characteristics, lower maintenance, higher efficiency, and extensive operating speed range [20] and is mainly employed in higher output drives applications viz. robotics, machine tools, medical, and space crafts. Mainly for small unmanned aerial vehicles, this motor is getting an increase of attention number with the benefits of easy operation, easy control, small size, and high-power density [21].

The typical elements of SPVS are as follows: photovoltaic array, controller, charger, and DC-AC inverter for charging the storing battery and AC load [22]. The SPVS is the key energy source in a standalone system. Meanwhile, there is no effectiveness line, which suggests that efficient energy use is crucial, the battery set is required to be able to supply the energy if the renewable source is irregular [23]. A power converter stage is also required to ensure output power, independent of power management [24]. The converter is suitable for standalone applications and is categorized into integrated stage or multistage schemes. The single input and multiple output converters are designed [25], [26]. The remainder of the paper is organized as follows: i) Section 2 contains the basic notions of SPVS; ii) Section 3 introduces a single input multiple output converter; iii) Section 4 gives the experimental results of our tests; and iv) Final considerations are reported in section 5.

2. SYSTEM CONFIGURATION

The overall system components modeling, specifications, and operation are solar photovoltaic array, single input and multiple output, brushless direct current (BLDC) motor, and water pump demonstrated in this section. A BLDC motor system with 2500 rpm and 5.7 kW is chosen. The SPVS array, single input and multiple output converter, and water pump are taken such that overall system functioning is not interrupting under any trouble in atmospherically condition. The photovoltaic system is energy gathered that receives the solar radiation and is converted to electrical energy. Batteries are employed when there is no opportunity to have a water storage system. A BLDC motor has three main components: the stator, the rotor, and the Hall effect Sensor. The BLDC is driven by a voltage source pulse width modulation inverter. An interleaved coupled inductor is used to model the converter. The converter is provided to regulate the constant output voltage under different conditions of a photovoltaic cell.

Figure 1 presents the photovoltaic cell electrical equivalent circuit corresponding to the current source connected with the diode, series of resistors, and shunt resistors. It is the intensity of the photovoltaic insolation and depends on the temperature change. The diode current corresponds to the temperature and the energy of the junction gap. The current passing through the parallel resistor is the shunt current. The solar system cell is a device that converts solar system radiation to electrical power energy.

The solar cells are interconnected in the series as well as parallel to the frame SPVS module. The SPVS module is connected series as well as parallel to the frame SPVS array. The SPVS panel is employed in the suggested system simulation The batteries are employed to store the electrical power generated from the SPVS array. Its efficiency is based on the charging state and discharging state. The suggested battery has 12 V, 200 Ah capacity. The battery lifetime is measured to be 5 years. The pumping system is estimated to be 500 W, 50 Hz, and 220 V. It is noted that the pumping system operates on peak hours. The inverter and charger controller are the circuits that are employed to convert from DC to AC and from DC to DC, respectively. The converter lifetime is up to 16 years with 95% efficacy and the estimated inverter price is USD 0.6/W. The

planned working system is discussed in Figure 2. BLDC is used to drive the water pump with a centrifugal pump because its load characteristics are well-matched to the photovoltaic system's maximum power locus.

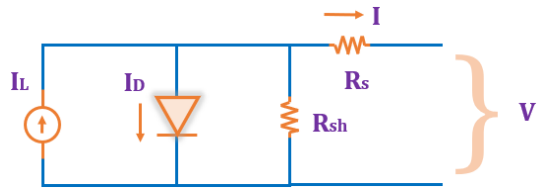

Figure 1. The SPVS cell

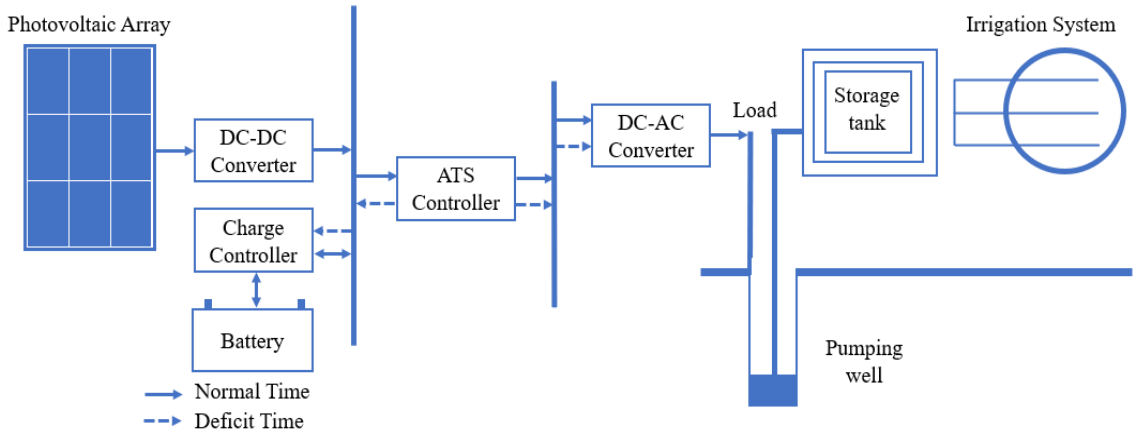

Figure 2. The working system

3. MODELING OF SINGLE INPUT MULTI OUTPUT DC-DC CONVERTER

The suggested converter system can discontinuous conducting mode and continuous conduction mode operated here. The suggested single input and dual output converter system is depicted in Figure 3. It has two diodes (D1 and D2), two switches (S1 and S2), load resistors (R1 and R2) two capacitors (C1 and C2), two inductors (L1 and L2), and load resistors (R1 and R2). In this structure, the output voltage is individually regulated at various voltage levels with the help of the duty ratio □1−□2. Figure 4 explains the suggested single input multi output model extended version by multiple outputs. It needs N switches, the N-resistor, the N-inductor, and the N-capacitor. The suggested N-output version structure can create individual outputs during its control. The converter parameters are illustrated in Table 1. The flowchart of the proposed work is shown in Figure 5:

- The topology is very simple;
- It does not require any operational constraint of duty cycle $\delta 1 > \delta 2$ *or* $\delta 1 < \delta 2$ *or* $\delta 1 = \delta 2$;
- It makes the individual outputs;
- There is no assumption for the inductor current during the controlling;
- The loads are in topology isolated during the controlling of the load; and
- The topology can also be extended for multiple outputs.

It has having reduced number of switches, more efficiency, no cross-regulation problems, and is cost-effective compared to the existing converter model for BLDC motor drive in solar photovoltaic water pumps. A high current is required for all switches.

Table 1. Converter parameters

Parameter	Units	Simulation value
Input voltage	V	48
Output current	Amp	4.3
Switching frequency	Hz	10
Capacitance	μF	360
Output voltage	V	12
Inductance	Mh	0.6

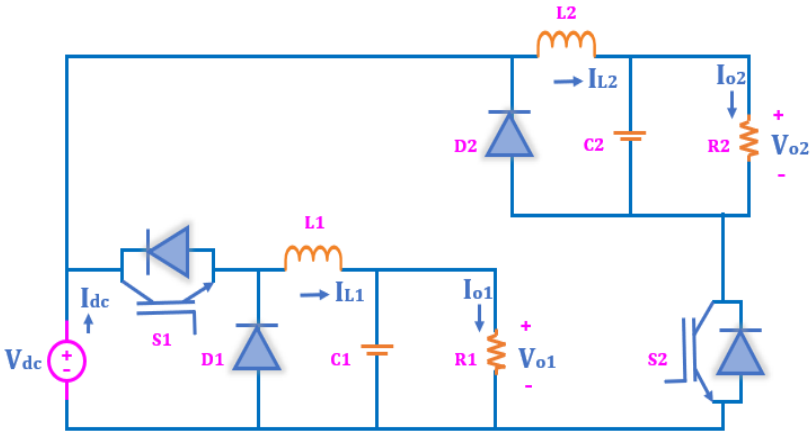

Figure 3. The proposed single input double output version

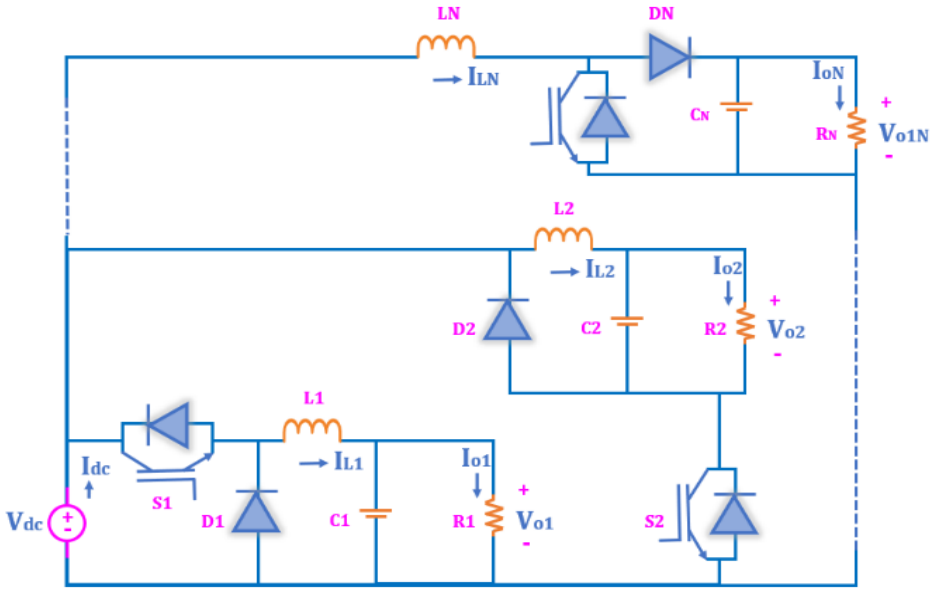

Figure 4. The proposed single input multiple output version

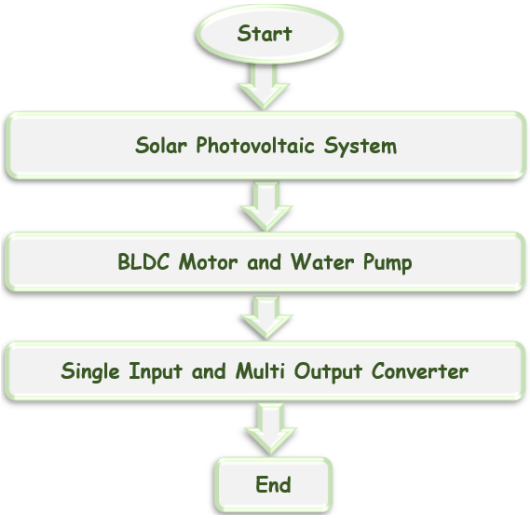

Figure 5. Proposed workflow chart

4. RESULTS AND DISCUSSION

The suggested topology performance is explained via MATLAB simulation study. The irradiance levels rose from 200 to 1100 W/m^2. The advantage of the suggested system is confirmed via a compared performance study. There are advantages of the suggested model over with conventional system. It appears better in all aspects. Furthermore, the conventional and proposed system efficacy at different irradiance (W/m^2), is estimated depending upon the test results; the power loss for water pumping is not involved in efficacy calculations. The efficiencies of conventional and suggested systems are comparing denoted in Figure 6. Irrespective of the operating condition, the suggested scheme seems more effective than a conventional system. The cost study of the suggested model in comparison with a conventional model is carried out to validate feasibility. Furthermore, the conventional-based water pump is involved in the cost study. Figure 7 illustrates the distribution of price the all components in INR. On the whole, the suggested model seems comparative to cost-effective.

There are several benefits of a suggested system over the traditional system [3]. The comprehensive compression study is explained. The cost study of a proposed system in comparison with conventional BLDC motor [5]. Furthermore, a photovoltaic-fed induction motor water pump is included in the cost analysis [9]. Overall, the suggested design seems comparatively better and cost-effective.

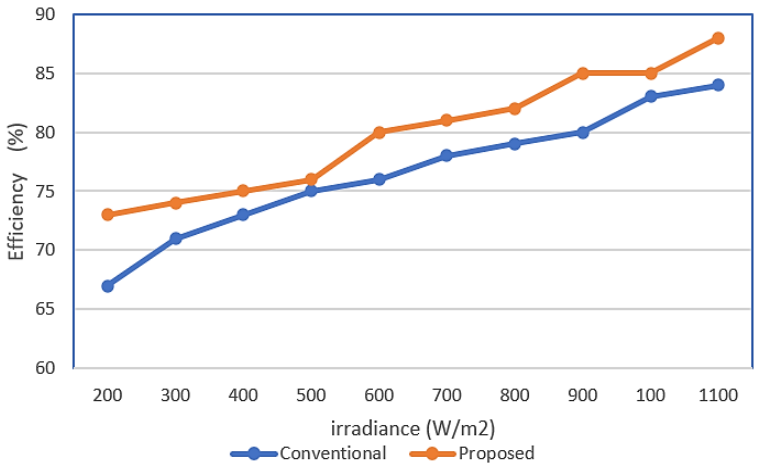

Figure 6. Efficacy comparison with conventional topology and proposed topology

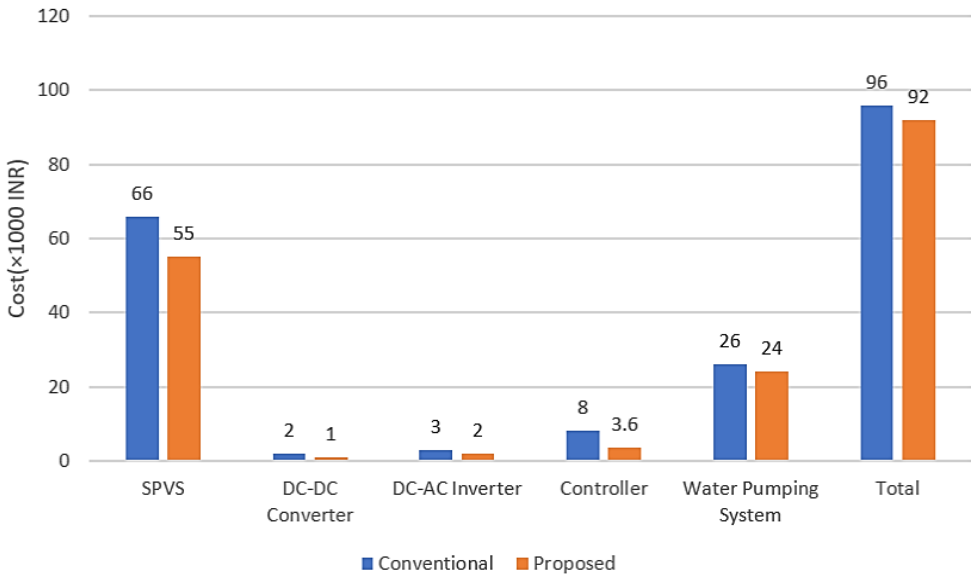

Figure 7. Price distribution for suggested topology in compared with conventional topology

5. CONCLUSION

This paper describes the SPVS water pump to gain the advantages of solar energy along with providing BLDC motor soft starting. An SPVS water pump using a BLDC motor drive with a single input and multiple output converter is focused. The topology is a trained analysis parameter effect upon SPVS with operated temperatures along with the solar irradiation levels. The BLDC motor speed is controlled through a DC-AC inverter. The efficacy at the utility grid side is improved and simulation implementation is carried out to display the topology performance. The complete comparative study of the suggested topology and the conventional topology has finally established the advantage of the suggested topology. In the future, we can design the solar photovoltaic water pump with BLDC using other types of converters.

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