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Design of Solar PV based Water Pumping System with Grid Interactive Control Technique

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***Abstract*— The increasing demand for sustainable agricultural practices has spurred interest in renewable energy solutions for water pumping systems. This paper explores the design of a solar photovoltaic (PV) based water pumping system integrated with a grid interactive control technique. The proposed system leverages solar energy to drive water pumps, enhancing the efficiency and reliability of irrigation systems, particularly in remote areas with limited access to electricity. This paper presents a design of solar photovoltaic based water pumping system with improved control technique. The novel scheme of fundamental switching of SRM drive over its maximum operational time makes system efficient and reliable. Simulation is done using MATLAB simulink software. Simulated results show significant improvement in present model performance than existing model performance.**

Keywords*— Solar, Water Pumping System, Photovoltaic, Sustainable Solution, Irrigation, MATLAB.

I. INTRODUCTION

The quest for sustainable and efficient agricultural practices has led to a significant rise in the utilization of renewable energy sources. Among these, solar photovoltaic (PV) technology has emerged as a promising solution for powering water pumping systems, especially in regions with abundant sunlight [1]. Traditional water pumping systems typically rely on diesel generators or grid electricity, both of which have significant drawbacks including high operational costs, maintenance issues, and environmental impact. Solar PV based water pumping systems offer a cleaner and more sustainable alternative, harnessing solar energy to meet the water needs of agricultural operations [2].

The primary objective of this research is to design a solar PV based water pumping system with an integrated grid interactive control technique. This design aims to maximize the efficiency of water pumping operations while ensuring a reliable and continuous supply of water [3]. The integration with the electrical grid serves a dual purpose: it allows for the utilization of solar energy during periods of high solar irradiance and facilitates the use of grid electricity when solar power is insufficient. This hybrid approach ensures that water pumping operations are not interrupted, thereby supporting agricultural productivity [4].

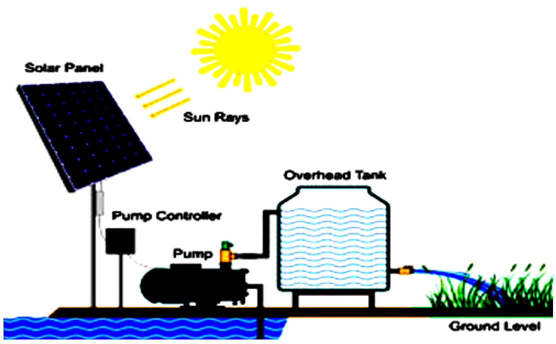

Figure 1: Solar power water pumping system

The system comprises several key components: solar PV panels to capture and convert solar energy, an inverter to transform the DC output of the panels into AC power suitable for driving the water pump, and a control unit that manages the interaction between the solar PV system and the grid [5]. The control unit plays a crucial role in optimizing energy use, switching seamlessly between solar power and grid electricity as needed. Additionally, it monitors and regulates the system to prevent overloading and to ensure efficient operation [6].

In designing this system, several factors must be considered, including the sizing of the solar PV array, the selection of the inverter and water pump, and the development of a robust control algorithm. The sizing of the PV array is critical to ensure that sufficient power is generated to meet the water pumping demands. The inverter must be capable of handling the power output from the PV panels and converting it efficiently for use by the pump [7]. The water pump must be selected based on the specific requirements of the irrigation system, including the head and flow rate [8].

The grid interactive control technique is a novel aspect of this design, providing a sophisticated means of energy management. By interfacing with the electrical grid, the system can sell excess solar energy back to the grid or draw energy when solar production is low [9]. This bidirectional energy flow not only enhances the reliability of the water pumping system but also contributes to the overall stability of the grid. Moreover, this approach can lead to significant cost savings for farmers, as it reduces the dependency on expensive grid electricity and diesel fuel [10].

The effectiveness of the proposed system is evaluated through a combination of simulation studies and field experiments. Simulations are conducted to model the performance of the system under various conditions, including different levels of solar irradiance and water demand. Field experiments are carried out to validate the simulation results and to demonstrate the practical feasibility of the system.

II. PROPOSED METHODOLOGY

The main contribution of the rresent research work is as followings-

The SRM drive has been chosen for present system due to its highly inductive nature, which makes it most appropriate for single stage system.

The other benefits such as low cost, high efficiency and requirement of simple power converter for phase energizing, make it suited for the grid interactive solar powered water pump.

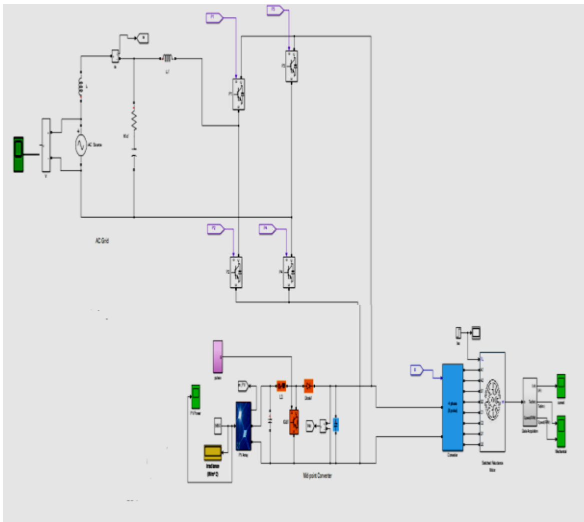

Figure 2: Proposed model

Standard Solar, as of late finished one of the primary solar microgrid frameworks with a grid interactive battery bank in the nation. Being a first was a test it took a very long time of commitment, creative engineering and coordination with key accomplices, utilities and government workplaces to make this undertaking a reality. The primary portion of this work will set the stage by clarifying how the microgrid is arrangement, its usefulness and what makes it extraordinary. At that point I will investigate the stuff to plan and introduce a solar microgrid framework, the exercises gained from this historic task and what specialized contemplations should be made while executing this new innovation.

Maximum power point tracking (MPPT) is a calculation executed in photovoltaic (PV) inverters to ceaselessly change the impedance seen by the solar cluster to keep the PV framework working at, or near, the pinnacle power point of the PV panel under differing conditions, such as changing solar irradiance, temperature, and burden.

The description of flow chart is as followings sub modules-

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Solar Panel

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MPPT Algorithm

Maximum power point tracking (MPPT) is a calculation executed in photovoltaic (PV) inverters to ceaselessly change the impedance seen by the solar cluster to keep the PV framework working at, or near, the pinnacle power point of the PV panel under differing conditions, such as changing solar irradiance, temperature, and burden. Engineers creating solar inverters execute MPPT calculations to boost the power produced by PV frameworks.

Microgrid

An electrical lattice is an interconnected organization for conveying power from makers to customers. It comprises of creating stations that produce electrical power, high voltage transmission lines that convey power from inaccessible sources to request focuses, and dissemination lines that associate individual clients. An AC/AC converter with around sinusoidal info currents and bidirectional power stream can be acknowledged by coupling a pulse-width modulation (PWM) rectifier and a PWM inverter to the DC-interface.

DC-DC Boost converter

This part gives a depiction and review of power electronic technologies including a portrayal of the major frameworks that are the structure squares of power electronic frameworks. Technologies that are portrayed include: power semiconductor exchanging gadgets, converter circuits that cycle energy starting with one DC level then onto the next DC level, converters that produce variable recurrence from DC sources, standards of redressing AC input voltage in uncontrolled DC yield voltage and their augmentation to controlled rectifiers, converters that convert to AC from DC (inverters) or from AC with fixed or variable yield recurrence (AC regulators, DC/DC/AC converters, lattice converters, or cycloconverters). The section likewise covers control of power converters with center around pulse width modulation (PWM) control procedures.

AC-DC converter

AC-DC converters have been created to a developed level with improved power quality as far as power-factor rectification, diminished complete sounds contortion at input ac mains, and controlled dc yield in buck, boost, buck-boost, staggered and multipulse modes with unidirectional and bidirectional power stream.

Switched Reluctance Motor (SRM)

The switched reluctance motor (SRM) is an electric motor that runs by reluctance torque. In contrast to normal brushed DC motor sorts, power is conveyed to windings in the stator (case) as opposed to the rotor. This significantly works on mechanical plan as force doesn't need to be conveyed to a moving part, however it confounds the electrical plan as a type of exchanging framework should be utilized to convey capacity to the various windings.

Pulse Width Modulation (PWM)

The generation of a sinusoidal PWM signals, which discovers more applications in enterprises. The gating sign can be produced by contrasting a sinusoidal reference signal and a three-sided transporter wave and the width of each pulse changed relatively to the sufficiency of a sine wave assessed at the focal point of a similar pulse. The yield recurrence (fo) of the inverter can be found by utilizing the recurrence of the reference signal (fr). The rms yield voltage (vo) can be constrained by modulation record M and thusly modulation file is constrained by top sufficiency (Ar). The voltage can be determined Vo = Vs (S1-S4). The quantity of pulses per half cycle relies upon the transporter recurrence.

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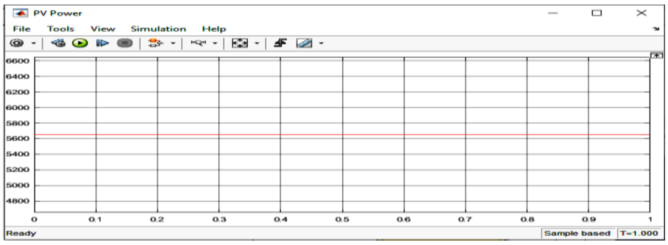
III. SIMULATION RESULTS

The implementation of the Present algorithm is done over MATLAB 9.4 (R2018a). The simulation toolbox helps us to use the functions available in MATLAB Library for various models, some of the blocks are scope, sink sin generator etc.

Stand-alone PV Water Pumping System

Case-I: In stand-alone system, when PV-power is 5650W, the motor runs at rated speed i.e. 14000 rpm by giving output as 5650 W.



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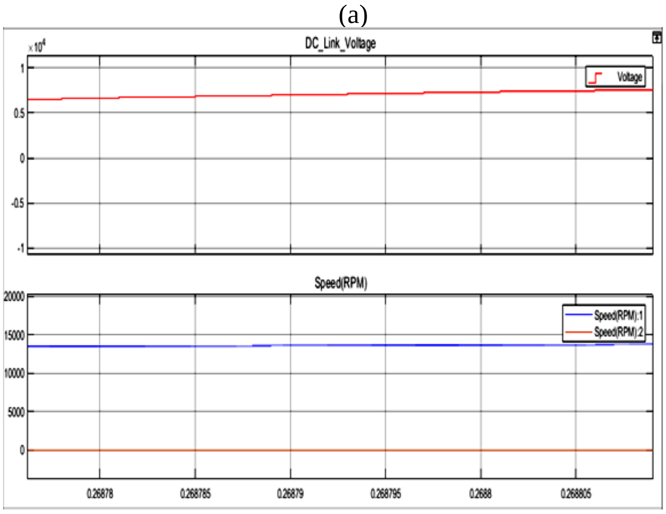
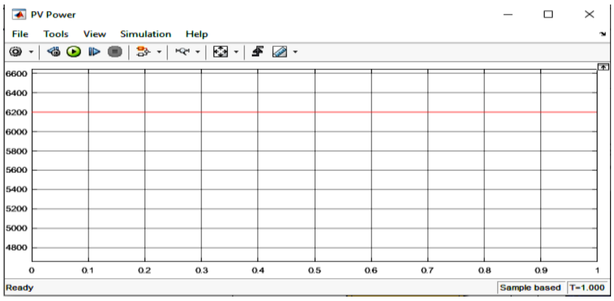


(b)

Figure 3: Performance of standalone solar water pumping system (a) DC-link voltage vs time (b) Speed vs time

Figure 3 is showing the output performance of the PV power, motor speed and DC link voltage. Here it is clear from the waveform the PV power is 5650W, motor speed is 14000rpm and DC link voltage is 6000V.

Case-II: When PV-power increases to 6200 W, speed and power output of motor increased to 14000 rpm to 14250 rpm respectively.



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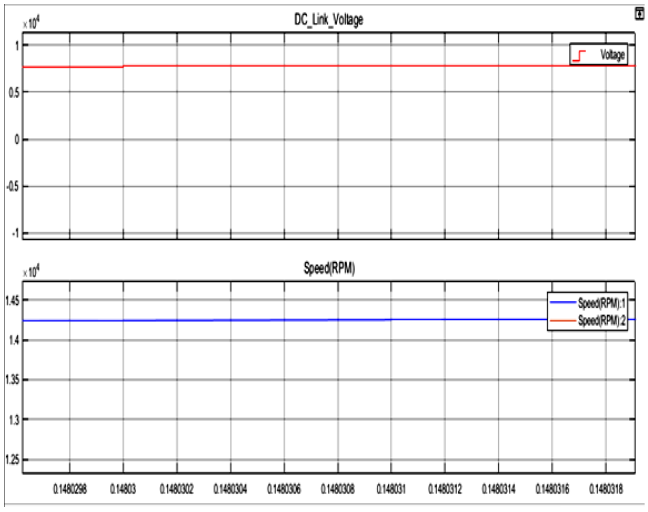


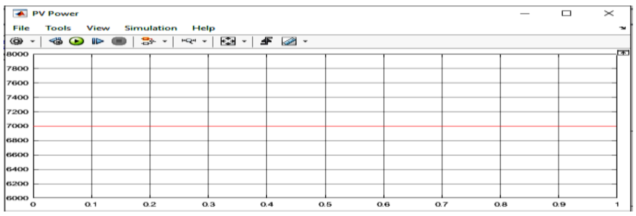
(b)

Figure 4: Performance of standalone solar water pumping system (a) DC-link voltage vs time (b) Speed vs time

Figure 4 is showing the output performance of the PV power, motor speed and DC link voltage. Here it is clear from the waveform the PV power is 6200W, motor speed is 14250rpm and DC link voltage is 7500V.

Grid-connected PV- Water Pumping System

In grid-connected system, here connected the microgrid system, the power exchange between grid and PV system is analyzed by considering PV power and rated grid power.



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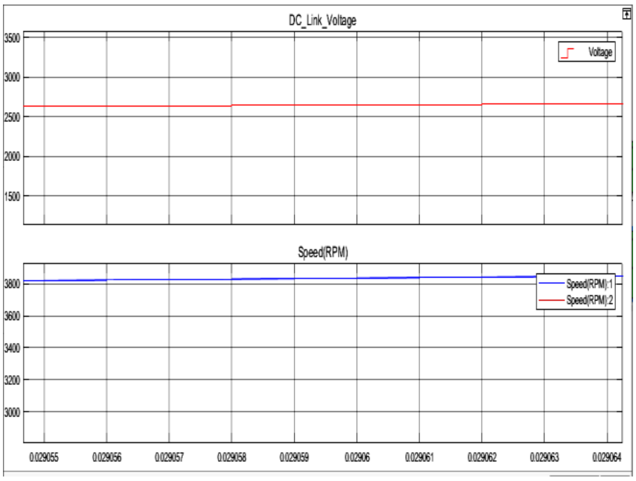

(b)

Figure 5: Performance of grid connected solar water pumping system (a) DC-link voltage vs time (b) Speed vs time

Figure 5 is showing the grid connected condition, the output performance of the PV power, motor speed and DC link voltage values as per the simulation waveform. Therefore the PV power is 7000W, motor speed is 3800rpm and DC link voltage is 2600V.

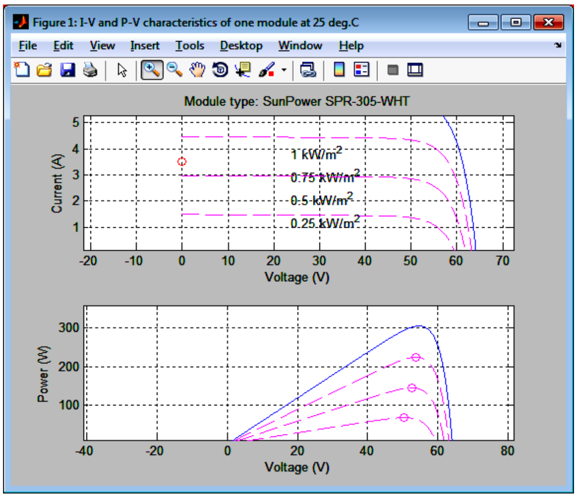

Figure 6: IV and PV waveform -1

Figure 6 is showing the IV and PV waveform. An I-V curve measurement is performed by applying a series of voltages to the device. At each voltage, the current flowing through the device is measured. The supplied voltage is measured by a voltmeter connected in parallel to the device, and the current is measured by an ammeter connected in series.

Table 1: Simulation Result when single solar panel

Sr. No	Parameter	Value
1	Sun Power	Single panel
2	Current	5A
3	Voltage	60V
4	Power	300W

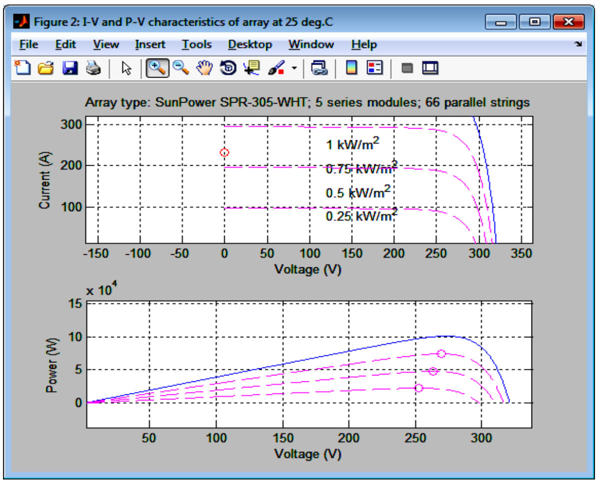

Figure 7: IV and PV waveform-2

Figure 7 is showing the solar array panel. % series modules and 66 parallel strings array type solar panel used.

Table 2: Simulation Result when array solar panel

Sr. No	Parameter	Value
1	Sun Power	Array
2	Current	300A
3	Voltage	320V
4	Power	1,00000W

Table 2 is showing the performance parameters of array solar in water pumping system.

Table 3: Results comparison

Sr. No	Parameter	Previous Work	Present Work
1	Solar Panel Type	Array	Array
2	Current	20 A	5A (single), 300A (Array)
3	Power	8300W	Upto 1,0000 W
4	Speed	5000	14500

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Table 3 is presenting the result comparison of the previous and the proposed model simulation results. The solar panel array is used for the generation or collecting the solar power with MPPT control techniques. The previous model work is based on the intelligent grid integrated solar photovoltaic (PV) powered water pumping system driven by three-phase reluctance synchronous motor (RSM) drive and the proposed model work is based on the grid interactive (GI) control techniques with Solar PV based water pumping system driven by switched reluctance motor (SRM).

IV. CONCLUSION

The solar PV based water pumping system operates on power generated using solar PV (photovoltaic) system. The photovoltaic array converts the solar energy into electricity, which is used for running the motor pump set. This research presents the design of solar PV based water pumping system with improved control technique. The switched reluctance motor provides many benefits against other types of electric motors because of its control flexibility, simple structure, lower cost and high efficiency. The Simulation is performed using the MATLAB-SIMULINK software. Simulation results achieved better RPM of motor with more power generation from the solar. Therefore, from the simulation results it can be say that the proposed model is giving the better results in terms of speed, voltage, current and power.

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