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A Schematic Review on Solar Water Pumping System Using PMSM Drive

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Abstract: The use of technology in agriculture is advancing at a lightning pace. Improvements are always being made to farming technology, agricultural structures, and manufacturing infrastructure. Many farming tasks can be solved using photovoltaic (PV) technology. Water pumping for crops and cattle is only one example of a distant agricultural necessity that might be met by PV solutions. There are two primary parts to every solar-powered water pumping system. This set up consists of solar panels and pumps. The solar cell is the smallest component of a photovoltaic panel. Each solar cell consists of two or more layers of semiconductor material that have been properly prepared to generate direct current (DC) energy when exposed to light. This piece will describe the operation of a PMSM-driven solar-powered water pumping system.

Keywords: Renewable energy; Solar water pumping system; PMSM; Photovoltaic.

I. INTRODUCTION

Due to increasing energy problems, scientists are looking for ways to lessen their reliance on traditional energy sources. The use of renewable energy sources (RES) to replace traditional energy sources in a variety of contexts has been recently found. One such sector that uses a lot of fossil fuels is water pumping; using RES for this application would cut down on emissions of greenhouse gases and the impact on the environment. [1]

Solar water pumps are mostly used in:

Domestic water: There are a few options for solar-powered homes, including direct-coupled PV arrays, induction motors, and DC-to-AC inverters. Water is stored in tanks that are either raised or utilise a battery system to store electricity instead.

Irrigation: Small farms and orchards employ solar water pumps. There are vineyards and orchards around here. Water may be stored in a tank and distributed by gravity flow in a "direct-coupled system." Storage batteries stabilize the voltage for continuous flow and distribution and may obviate the requirement for a storage tank when pressurizing is necessary.

Livestock watering: Ranchers who reside in distant areas with limited power connections and significant transportation expenses often utilise solar water pumping devices.

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A. Solar Water Pumping System

The solar PV (photovoltaic) system generates electricity for the system. The motor pump set is powered by electricity generated by the photovoltaic array. An open well, bore well, stream, pond, canal or other water source may be accessed by the pumping system. The Solar panel must be installed in an area that is clear of shadows in order for the system to work. [2]

The following is an explanation of the SPVWPS design equations. PV cell models with a single diode may be characterized by the voltage-current relationship as follows:

$$I = I_L - I_0\left[\exp\left(\frac{q}{akT_c}(V + IR_s) - 1\right)\right] - \frac{V + IR_s}{R_{sh}},$$

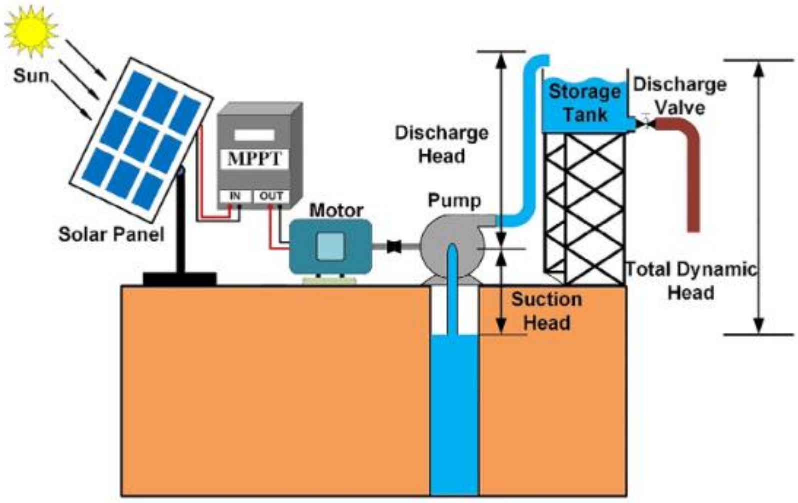

Figure 1: Components of solar water pumping system

Using a solar PV-powered water pumping system involves a combination of electrical, mechanical, and electronic subsystems. In order to improve efficiency, these components must operate in synchronization. Solar PV array, pump motor, and power electronic interface make up the SPVWPS's generic structure. [3]

The size of the PV array needed to pump water is determined by a number of criteria, including the location, temperature, solar insolation, daily water consumption, flow rate, and head, among others.

B. PMSM

The three-phase stator of the PM synchronous motor, like that of an induction motor, is a revolving electric machine. Permanent magnets are positioned on the rotor's surface.

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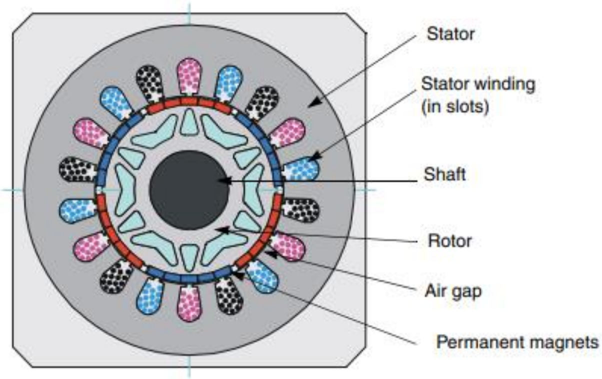

Figure 2: PM synchronous motor

The PM synchronous motor is the same as an induction motor in terms of performance. Rotor magnetic field is continuous because air gap magnetic field is generated by permanent magnet. Modern motion control systems benefit greatly from PM synchronous motors, which provide a variety of distinct benefits. Designing extremely efficient PM motors is made feasible by the employment of a permanent magnet to create significant air gap magnetic flux.[4]

Construction of electrical equipment may be improved by using permanent magnets (PM).

• This implies that the field excitation mechanism does not use any electrical energy, and so there are no excitation losses.

• greater output power and torque per volume than electromagnetic excitation

• in comparison to motors using electromagnetic excitation, superior dynamic performance (higher magnetic flux density in the air gap)

• reducing the complexity of building and maintaining it

• lowering the total cost of ownership for certain devices. [5]

II. LITERATURE REVIEW

(Chen & Hu, 2022) [6] This research presents “a gantry robot model reference adaptive control and fuzzy neural network (FNN) synchronous motion compensator.” MRAC and FNN online compensators for gantry robots are discussed in this study. MRAC is the first step in improving the model's accuracy and reducing tracking errors for a single axis using the cascade control approach. It is then recommended that a fuzzy neural network compensator be used for the gantry robot in order to increase the precision of movement. The parameters of the FNN may be fine-tuned using an online parameter training technique. Furthermore, the hardware and recommended methodologies are integrated and tested in this research, which is a success.

(D. Wang, 2022) [7] “SMO-based sliding mode control (SMC)” for nonlinear descriptor delay systems is examined in this work. The nonlinear descriptor system is first turned into a mixture of local linear models using the T-S fuzzy dynamic modelling approach. The error system is then equipped with an SMO based on an "integral-type sliding surface (ITSS)." LMI requirements are developed in the next section to assure the acceptability of sliding movements and to derive the observer gain matrix. The reachability requirements and descriptor systems are also stabilized using two new SMC laws. Finally, the method's efficacy is shown by simulations.

(Petro, 2022) [8] "Sensorless control of the permanent magnet synchronous motor" has gained a lot of attention owing to its excellent dependability, economic and safety advantages. In order to perform sensorless control, a rapid and high-precision rotor-position estimate is required. Many industrial firms choose the sensorless control method known as the "sliding-mode observer (SMO)." In sensor-less field-oriented control with SMO, the switching functions used in the control structure are compared in this article.

(P. Wang et al., 2021) [9] The glue pump motor, the actuator of a particleboard glue-dosing system, is impacted by external disturbances and unidentified uncertainties. A glue pump motor compound control approach was devised in this article in order to obtain precise glue flow tracking. A suitable performance function is designed to ensure that the glue flow tracking error will converge to a certain range using the prescribed performance management approach. For improved robustness of the controlled system, two more extended state observers were developed to estimate the state vector and the disturbance

(Nikhil, 2021) [10] To remove the intermittent nature of solar energy, we integrate a utility grid with the DC link of a solar water pumping system and interface a fuzzy logic controller to the system, which eliminates non-linearity and smooths out motor performance without ripples in the supply to "PMSM (Permanent Magnet Synchronous Motor)."

(Rai et al., 2020) [11] "Submersible induction motor-driven solar water pumping system" is the theme of this article, which proposes an effective and robust speed sensorless control method. SIMD's speed estimate and sensorless control are quite challenging. In addition, the motor parameters change, resulting in a decrease in sensorless control performance. A precise and durable stator current controller is thus required for a SIM sensorless control. In a single stage solar PV system, a sliding mode-based DC link voltage regulator is used to regulate motor power and speed. "Sliding mode current control (SMCC) and SIM's integrated sliding mode observer (ISMO)-based speed estimate" offer a robust control against changes in motor parameters. In order to test the efficacy of the PI controller-based speed sensorless control, a sliding mode-based control for motor parameter modification was created and tested.

(Madark et al., 2020) [2] Using an induction motor and a centrifugal pump, this work compared linear and nonlinear controllers for a solar photovoltaic (PV) water pumping system. Perturb and Observe, a classical linear controller, was chosen to ensure PV system operation at the "maximum power point (MPP)" and is combined with IRFOC, an indirect rotor field oriented control (IRFOC) based on a conventional proportional integral speed regulator, to control and optimize rotor speed. Backstepping and first-order sliding mode controls were presented for controlling the whole system in the second and third controllers. In order to build simple control rules for regulating and optimizing rotor speed in the nonlinear controller, all evaluated control strategies were coupled with IRFOC. A mathematical model of the DC-DC converter was used to design control rules that monitored MPP.

(Zerimeche et al., 2020) [12] In this research, a comparison of the PI and the cascaded sliding regulator for the solar pumping system is done based on rotor flux-oriented control. For the motor-pump to constantly run at its full power, it is important to include an MPPT tracking system, which we employed the fuzzy MPPT approach. Low reaction time and oscillation are hallmarks of the vector width modulation control technology used to operate the three-phase converter. The suggested structures' simulations have been validated using Matlab/Simulink. In terms of parametric robustness and appropriate functioning over the full speed range, the obtained findings demonstrate the advantages of cascaded sliding mode control paired with fuzzy MPPT technology.

(Patel et al., 2020) [4] It is hypothesized in this research that a PMSM water pumping system may be powered by both the PVA and the utility grid simultaneously. When the sun isn't shining or the irradiance is low, the utility grid takes care of the linked loads. Sensorless field-oriented control with a speed estimator is used to run the PMSM. The MRAS controller estimates the machine's speed utilizing voltage and current feedback from the motor in the FOC method. An estimated rotor angle theta for Parks and Clarks transformations was also obtained using MRAS controller. DSM-PI controllers have been added to the FOC scheme to ensure a steadier PMSM speed than standard PI controllers. MATLAB software is used to create the model, and the results are compared.

(Karthikeyan, 2020) [13] Electrifying our everyday lives and advancing our economy is of colossal significance. Every civilization must ensure that power is efficiently transmitted and distributed. The use of smart grid technologies is vital to ensuring that customers have a smooth and reliable transition to the new system. As a self-contained power distribution network, smart grids use digital automation technologies to keep track of, manage, and analyse the flow of electricity across its supply chain. Several investigations and studies on Smart Grids are reviewed in this publication. Integrated communications, sensing and measuring technologies, sophisticated components, better control techniques, and improved interfaces and decision support are all part of the Smart Grid Technology set.

III. CONCLUSION

Solar power becomes more cost competitive when the total dynamic head of the irrigation system it powers is low. This is because the price per increase in unit power output of a photovoltaic system is higher than that of a diesel, gasoline, or electric system. Because of this, a micro irrigation system powered by solar energy is more cost-effective than one powered by an overhead sprinkler system. If the whole system design and utilisation schedule is carefully researched and organised to utilise the solar energy as effectively as possible, photovoltaic electricity for irrigation is cost-competitive with conventional energy sources for tiny, distant applications. When the price of fossil fuels increases and the peak watt cost of the solar cell decreases thanks to the economies of scale, photovoltaic electricity will become more economically viable and widespread.

Examining the work of different academics, it became clear that PMSM has helped to boost the system's efficiency. Thus, the described system provides a quick, effective, and dependable method of solar water pumping.

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