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Grid connected solar water pumping system

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ABSTRACT

A grid-connected solar water pumping system (SWPS) uses solar power to pump water while simultaneously drawing power from the grid when necessary. These systems can benefit farmers in a variety of ways, including reliable power, lower electric bills, increased income, and improved economic viability. This study explores a solar photovoltaic (SPV) water pumping system designed to function with a single-phase distribution network. It utilizes an induction motor drive (IMD) and incorporates an advanced power-sharing technique for optimal performance. In addition to transferring power from SPV to IMD, a DC-DC boost converter functions as a grid interface and power factor adjustment device. Maximizing the power extracted from the SPV array is critical for optimizing its utilization. To do this, a control mechanism based on incremental conductance is implemented to track maximum power points. Simultaneously, the IMD connected to the power source inverter is regulated using a simple volt/frequency approach. The suggested system, which includes standalone, grid-interfaced, and mixed-mode situations, is developed and validated in a lab.

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1. INTRODUCTION

As global energy demand continues to increase, solar photovoltaic (SPV) electricity generation is emerging as the leading non-conventional energy source [1]. Considering its potential, SPV technology is a great fit for the creation of distributed networks in smart grids. In the coming years, it is expected that the cost of photovoltaic cells will drop significantly. There are many uses for water, such as drinking, irrigation, household use, raising cattle, and industrial processes. Since essential in use electricity this purpose is still being made [2]. As intelligent power-sharing concepts are introduced prevalent [3]. Moreover, it turns out to be an affordable option because it does away with the requirement for storage devices like batteries. There has been a reported [4]. In contrast, standalone SPV systems frequently rely on energy storage devices, such as batteries. On the other hand, if grid supply is available, grid-supported SPV water pumping technologies are advised due to battery-related concerns such a short lifespan, harmful substances, and acid leakage in lead-acid batteries [5]. Jain *et al.* [6] provide details on a hybrid water pump that can be powered. However, a system as a whole is not suited for high-power pumping requirements since the electricity from the inverter to the pump is transferred through an oversized and expensive transformer. Furthermore, a 185 mH high-value inductor connect, which presents problems for irrigation and farm in applications.

Numerous lacking grid interaction and power quality improvement features [7]-[9]. In notably, in this system utilize capacitors to meet reactive power requirements, introducing concerns about the reliability of capacitors as a system component. Furthermore, the suitability of wind energy conversion systems (WECS) for high-power generation systems raise questions about its justification for capital investment in small capacity pumps under 10 hp.

Efficient solar photovoltaic achieved through, as detailed in [10]-[12]. Various use, discussing its advantages and disadvantages [13], [14]. It is asserted, approach is particularly user-friendly with high tracking efficiency. Additionally, it automatically adjusts the step size to attain the maximum power point (MPP), enhancing response under different conditions. He introduced a novel maximum power point tracking technique that achieves efficient MPP tracking using only one sensor, simplifying the overall system. Another proposed technique, outlined in [15], [16], focuses on reducing steady-state losses at MPP by incorporating idle operation at that point. Furthermore, nature-inspired metaheuristic algorithms have been employed for MPP tracking [17], but their performance may decline during transients due to algorithmic complexity. Enhancements to the INC algorithm have been suggested, involving the intelligent update of the step-up converter while LC resonance is discussed.

In contemporary times, the primary contributors to the deterioration of power quality in distribution networks are large motors and power converters [18], [19]. The connection of these devices to the distribution network adversely affects power quality, leading to poor conditions for industries, commercial establishments, and households. The presence of large induction motor drives (IMDs) at the point of common coupling, along with unbalanced, further exacerbates the power issues [20].

Addressing this challenge, incorporating. While this method effectively serves, it does not delve into the aspect of power transferring from energy sources. Other works focus on power factor and efficiency improvement with innovative IMD concepts [21], [22], emphasizing efficiency and power factor improvements without delving into the topic of power sharing among several sources. Roggia *et al*. [23] emphasizes the use of a DC-DC boost converter for power factor correction (PFC) and for maintaining the DC bus voltage, with reports of power factor increase in [24], [25]. However, the complexity of controllers used in these studies raises concerns about computational burden.

The final values demonstrate the step-up converter effectively of the grid current below the limits specified by the IEEE-519 standard. Additionally, in a buck-boost converter is employed enhance p.f of a brushless DC drive. The model focuses on configuration, solar photovoltaic (SPV). In introduction highlights necessity of an SPV-based water pumping system and provides an overview of existing literature. The subsequent sections are organized as follows: Section 2 details the methodology, while section 3 shows results and discussion. The conclusion section is outlined in section 4.

2. METHOD

2.1. Mode 1

Mode 1 is turned on when there is enough solar electricity for it to run independently. In this setup, the boost converter on the photovoltaic (PV) side maintains the power (Vmp) baseline while working. A proportional-integral and for the motor by controlling DC bus voltage as shown in Figure 1. Any variation from reference value effects adjustment of power delivered to the pump. More specifically, when the DC bus voltage rises over the value used for reference, the speed increases and surplus power is directed into the pump; on the other hand, when the voltage falls down, speed decreases.

2.2. Mode 2

This mode is triggered when the solar panels are inactive or there is inadequate sunlight, such as at night. This step involves connecting a diode bridge rectifier (DBR) to a single-phase power source. Due to the inherent distortion, a voltage source inverter (VSI), an induction motor, boost converter, and DC link capacitor are added later. But now that a converter has been incorporated, the system can pull. Discharge while running at its rated speed as shown in Figure 2.

2.3. Mode 3

When the solar panels are unplugged or there is not enough sunshine, which occurs at night, this mode is activated. In this case, an induction motor, inverter for voltage source (VSI). According to IEEE 519, it is not permitted for the diode bridge that connects the rectifier with the DC link capacitor to draw current in such a distorted manner. Nevertheless, the system can take sinusoidal electrical current from the AC mains by integrating a power factor correction (PFC) boost converter. This method its maximum and produces that is in line with its rated capacity. The different modes of operations are shown in Figure 2. The equipment specification is given in Table 1. The component specification is given in Table 2.

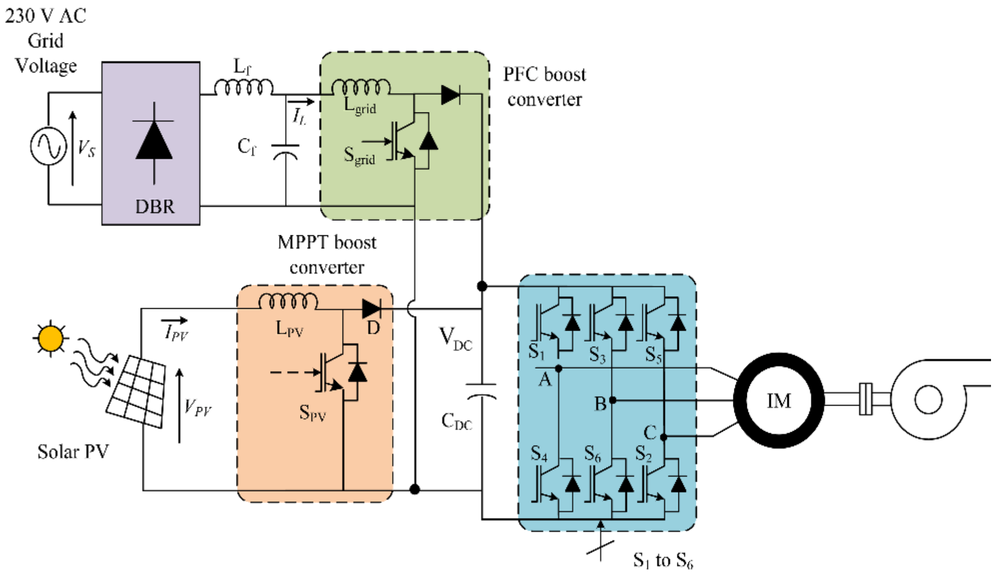


Figure 1. Grid connected solar water pumping system

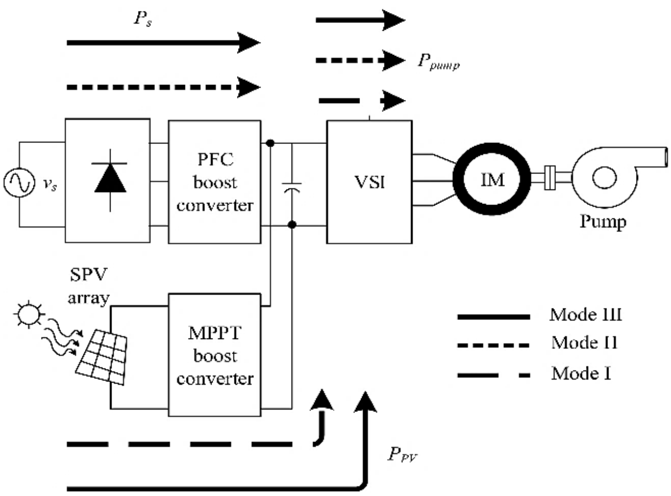


Figure 2. Power flow diagram of solar water pumping system

Table 1. Equipment specification

S.No	Parameter	Specification
1	Solar panel	2.3 KW
2	Max power of solar module	210 W
3	MPPT voltage besides current of module	28.7 V and 7.32 A
4	Voltage besides current of MPPT	315.7 V and 7.32 A
5	The quantity of modules connected in series and parallel	11 and 1

Table 2. Component specification

S.No	Component parameters	Used values
1	Grid voltage (Vs)	230 V
2	DC link voltage (Vdc)	400 V
3	Solar irradiance	1000
4	DC link capacitor	2200 microfarad
5	PV side inductance	5 mH
6	Gride side inductance	6 mH

3. RESULTS AND DISCUSSION

The research findings are presented in this section along with a thorough commentary. To help the reader grasp the results clearly, figures, graphs, tables, and other visual aids are used to explain the findings. The discussion is broken down into multiple subsections to cover different facets of the findings and offer a comprehensive interpretation and analysis.

3.1. Mode 1 operation: when solar supply is connected

The results are illustrated in Figure 3. The first mode of operation for a solar water pumping system is when the system is powered entirely by the solar panel array. The output power, voltage, and current vs time graphs are shown in Figure 3(a). The zero output voltage and current vs time graph is shown in Figure 3(b).

3.2. Mode 2 operation: when grid supply is connected

The results are shown in Figure 4. When solar panels are detached or there is insufficient radiation, such as at night, the system enters mode 2. In this mode, the system links a single-phase grid supply to a diode bridge rectifier (DBR), boost converter, DC link capacitor, voltage source inverter (VSI), and an induction motor. The output voltage and current vs time graphs are shown in Figure 4(a). The output power, voltage, and current vs time graphs are shown in Figure 4(b).

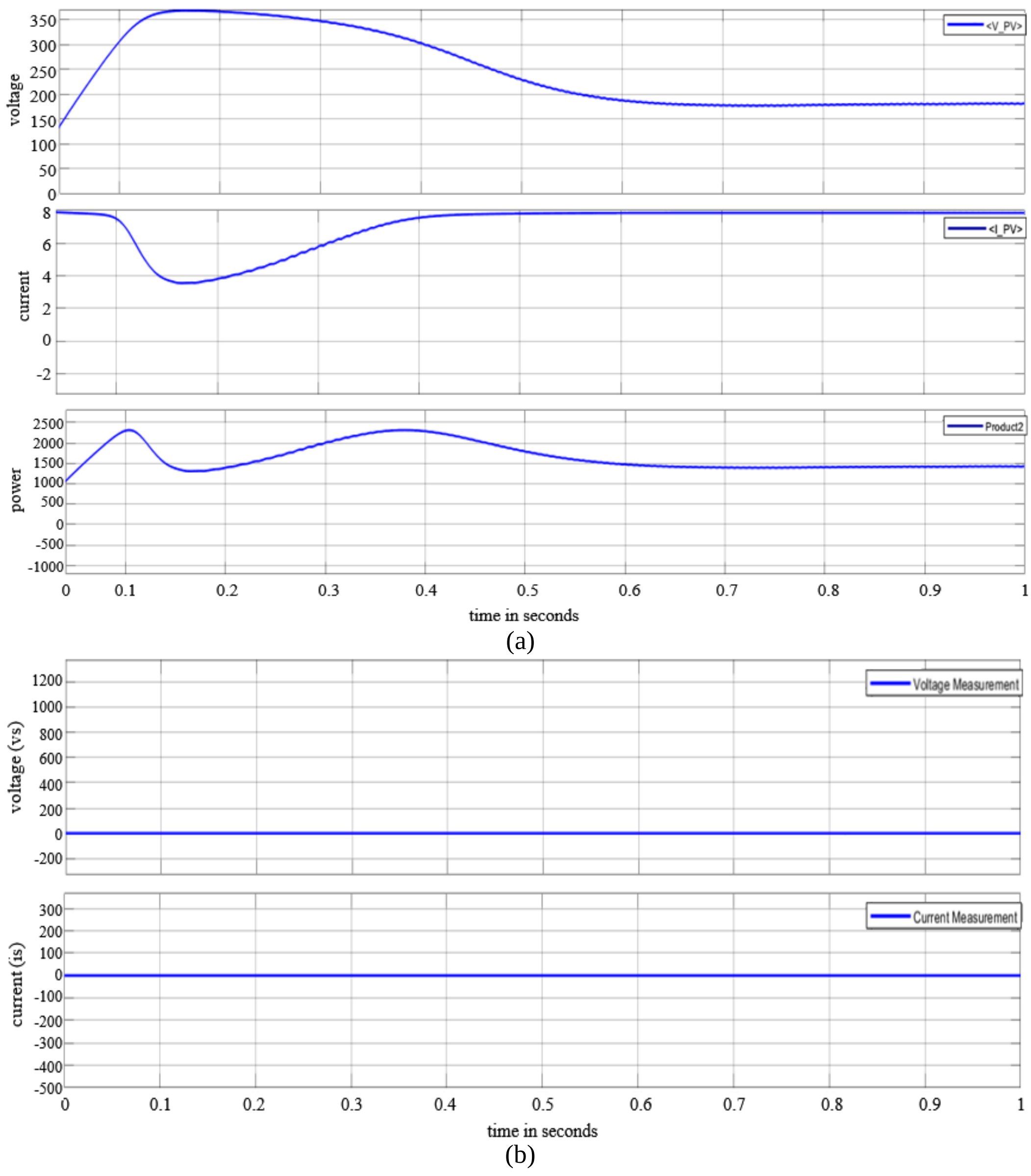


Figure 3. The results of solar supply when connected: (a) output power, voltage, and current vs time and (b) zero output voltage and current vs time

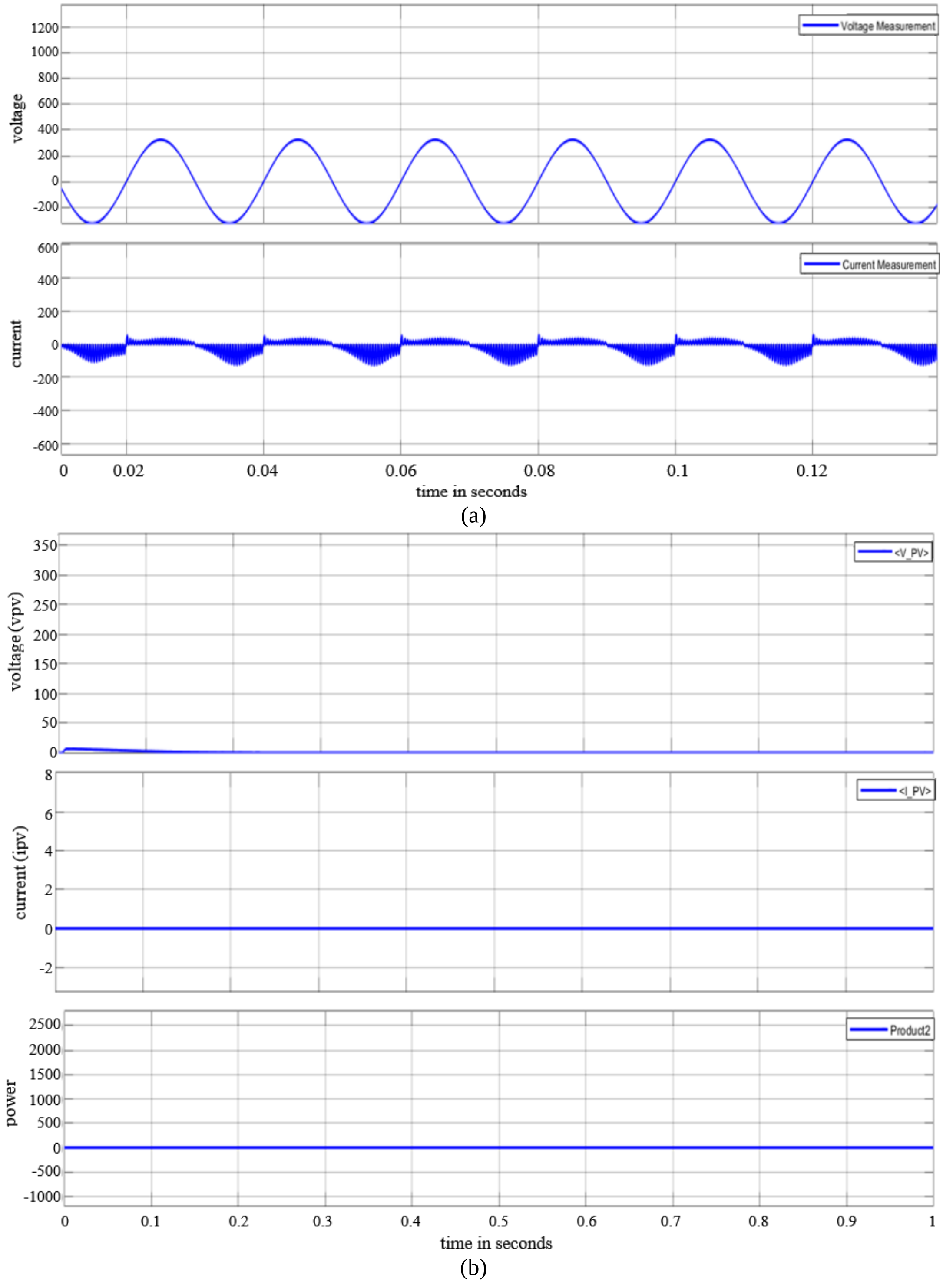
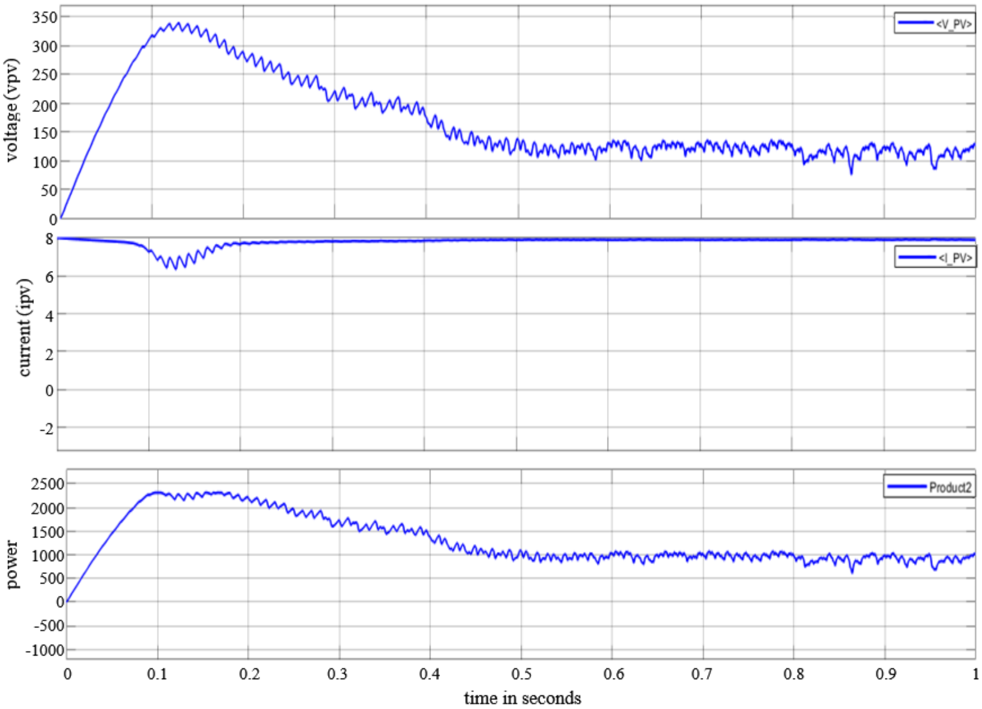


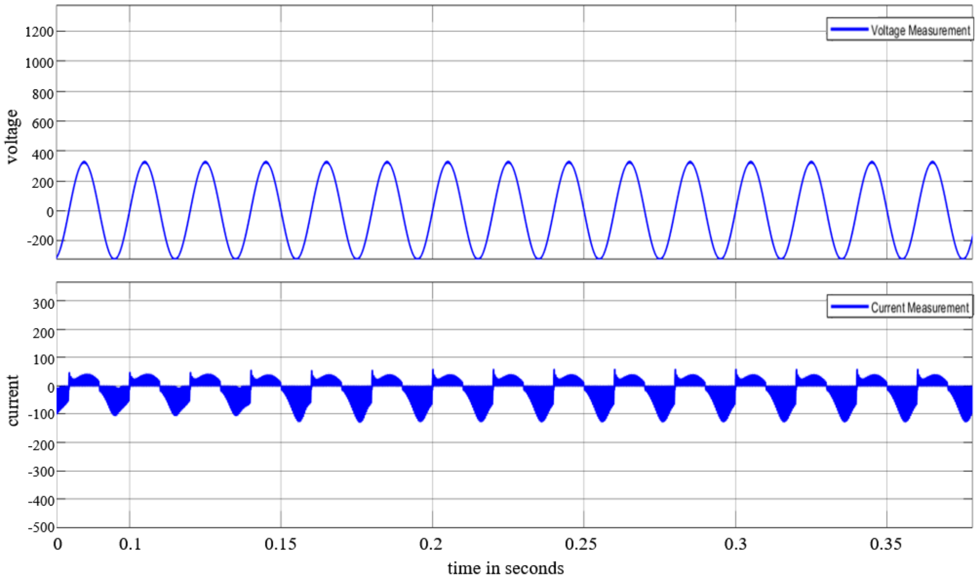
Figure 4. The results of solar supply when connected: (a) voltage and current vs time and (b) output power, voltage, and current vs time

3.3. Mode 3 operation: when both solar and grid are connected together

The results are shown in Figure 5. When power is available from both the SPV array and the grid, the system is in mode 3. In this mode, the system uses the maximum available power from the PV source and draws the remaining power from the grid supply. The output power, voltage, and current graphs are shown in Figure 5(a). The output voltage and current vs time graphs are shown in Figure 5(b).



(a)



(b)

Figure 5. The results of solar supply when connected: (a) output power, voltage, and current vs time and (b) output voltage and current vs time

4. CONCLUSION

A MATLAB model, simulation, and experimental validation of a grid-connected solar water pumping system have been conducted in a lab setting. The various modes of operation of the suggested system are described in depth, and experimental testing have been conducted to validate the simulated performance, which includes startup, steady state, and dynamic circumstances. The suggested water pumping system has several important features, such as intelligent power sharing, improved power quality at the utility grid supply, the removal of a speed sensor, and the use of straightforward scalar control for the induction motor, which makes the system easier to implement. The system's efficiency and compactness are further enhanced by the absence of a highly inductive transformer element. Effectively lowering the load on the utility grid, the method may result in lower electricity bills. The control strategy has been created aims to optimize the extraction of electricity from the solar photovoltaic (SPV) array while avoiding the need for quantitative measurements of radiation and ambient temperature. Additionally, it continuously provides, irrespective amount of radiation that is available. The suggested system functions satisfactorily when observed under startup and situations, appropriate usage in residential.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper. Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article.

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