Investigation on implementing the swarm nano grid system for effective utilization of solar-powered agro-industries

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Article Info

ABSTRACT

The agro-industry is the backbone of the global economy, even in the twenty-first century. The agro-industry would not be what it is now without irrigation. The production and use of renewable energy in this sector of the agricultural economy have also expanded rapidly in recent years. Base-load power production and conversions dominate the literature. This research examines user concerns. The swarm nano grid system fixes this. The pulse width modulation (PWM) sinusoidal inverter converted stable DC power from the bidirectional DC-DC converter into sinusoidal AC voltage for the irrigation pump induction motor. Solar panels, batteries, and converters are costly, but they pay off. The nano grid distributes excess power generated during low demand to local loads. This technique works well when the load can be disconnected from the power grid. MATLAB is used to keep an eye on the reliability and efficiency of the induction motor. In the first simulation, solar power generation is modeled using the MATLAB Simulink software in two distinct modes. A PWM sinusoidal inverter that is driven by solar energy is what provides power to the 5.67 kW induction submersible motor. The simulation result provides a conceptual model of how induction motors powered by renewable energy sources function in practice.

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1. INTRODUCTION

Motor drives, pulse width modulation (PWM) inverters and converters are all powered by solar panels. In terms of effectiveness, dependability, and harmonic distortion, these inverters excel above challenging products. PWM inverters are easy to use, making them perfect for power networks thanks to microprocessors and digital signal processors (DSPs) [1]–[3]. "Nano grids" provide dependable, reasonably priced power to outlying places. For off-grid electricity, solar-powered nano networks have recently gained popularity as shown in Figure 1. In the agro-industry, where farmers and agribusinesses need dependable energy to run irrigation systems, processing machinery, and other equipment, this technology shows promise [4]–[6].

Nano networks driven by solar energy might lessen these businesses reliance on pricey and unreliable diesel generators. These gadgets utilize solar energy, which is environmentally friendly and lowers greenhouse gas emissions. For farmers and agribusinesses, solar-powered nano grids in the agro-industry may increase productivity with profitability. The quality in life and accessibility of energy for rural inhabitants may be enhanced by these methods [7].
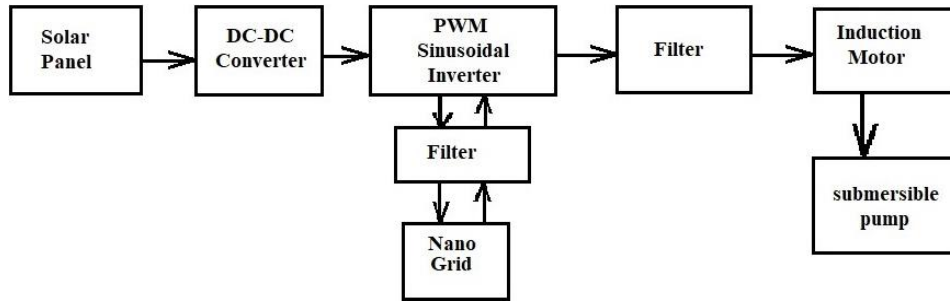
Figure 1. Basic block diagram of proposed work

Solar-powered nano networks in the agro-industry might transform how farmers and agribusinesses conduct business by providing a sustainable, affordable energy source that supports rural economic growth. Rural communities get affordable renewable energy from the swarm nano grid system [8]. System installation requires good design and execution. A feasibility study determines the target community's energy needs, renewable energy sources, and project viability before deploying the swarm nano grid system. Research will inform system design and implementation. Swarm nano grid system design follows feasibility research. This includes picking the system's size, architecture, and components and developing it to meet the target population's energy needs [9]–[12].

Swarm nano grid systems manage and distribute energy using swarm intellect and nano grid. A small grid network incorporates nano generators. For both cities and people, this system offers stable and environmentally friendly energy sources. A collection of coordinated entities is referred to as a "swarm". These elements in a swarm nano grid system are called nano generators, which may be solar cells, wind turbines, fuel cells, or other small-scale energy sources. To increase power production and distribution, nano generators cooperate and operate independently [13]–[16].

2.   PROPOSED CONVERSION SYSTEM

To enhance the stability of the suggested arrangement, the DC-DC bidirectional converter has been specifically built to provide a consistent voltage output to the inverter. A PWM inverter have its DC input voltage regulated and the required DC power supplied via a buck-boost converter. To generate the required output voltage, buck-boost DC-DC converters may either raise or lower the input voltage.

2.1. DC-DC converter

The buck-boost converter transforms the DC input voltage from a battery or other DC source, providing the PWM inverter with the stable DC voltage it needs as seen in Figure 2. The inverter produces AC using pulse width modulation after receiving DC electricity [17]–[19]. The buck-boost converter increases its output voltage when its input voltage is lower than what is required. PWM controls the converter's metal oxide semiconductor field effect transistor (MOSFET) switch. Inductors store energy while the PWM signal is active. A diode transfers energy from an inductor to the output when the switch is off, boosting the voltage there. The input voltage is greater than the output voltage, a buck-boost converter steps down the voltage. Since a switch and diode function differently in step-down mode, the converter may lower the output voltage in this mode.
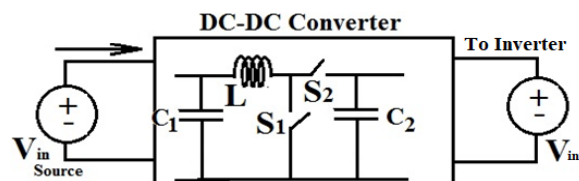

Figure 2. Block diagram of designed converter

PWM duty cycle impacts buck-boost converter output voltage. The converter adjusts duty cycle based on output voltage feedback to stabilize output voltage independent of input voltage. PWM inverter

buck-boost converter design and selection should include power rating, efficiency, and control system. Thermal management and component selection enhance converter reliability and efficiency. Buck-boost converters have zero-current switching (ZCS)-specific resonates. Auxiliary circuits have diode, inductor, and capacitor. The resonant circuit transfers energy when switching. The primary power switch powers the resonant circuit inductor. The main power switch turns on the load. Power-off accessories carry current through the inductor. Inductors play a role via resonance capacitors. During main switch off, resonant capacitor powers output or load. Recycled energy ZCS lowers switching losses with the primary power switches near-zero current semiconductors strain [20]–[23].

2.2. Solar-powered agro-industries

Solar agro-industries combine gardening and making things. Solar power improves viability, environmental impact, and crop yield. Solar power is used to grow crops, dry them, keep animals in check, and water them. Agro-industries can use solar power. Solar power is good for the earth. Replace fossil fuels that change the climate. PV lights up farming. These panels are used on roofs, in greenhouses, and on fields. In agriculture, power is used without a system or generators. Solar energy is used to water crops and farms. Solar pumps for watering collect water from the ground and the surface. Electric or solar pumps. Sunlight protects plants. Solar fans help veggies grow. Ventilation and temperature settings in a solar garden may help plants grow and work better. Solar power lights, air conditioning, and closing off cow sheds. When animals are calm, they use less fossil fuel [24]–[26]. Solar agro-industries provide power to off-grid communities. Renewable energy helps farmers in the country. Solar-powered agro-industries are growing because of better technology, cheaper solar panels, and a greater understanding of the environment. Solar-powered farming, lowering greenhouse gas emissions, and becoming energy independent are all funded by governments, businesses, and people. Solar farming will last. Solar electricity could be good for farming, the environment, and industry.

2.3. Swarm nano grid system

Compared to centralized power grids, swarm nano grid systems provide a number of advantages. Energy dependability is increased via decentralized power generation and distribution as shown in Figure 3. If one of the nano generators fails, the system may still provide electricity. Localization increases energy efficiency and reduces transmission losses [27]–[29]. By using renewable energy, the swarm nano grid system also lessens the carbon footprint of energy generation. Small-scale distributed energy generation is more environmentally beneficial since it reduces the demand for large power plants and transmission infrastructure. The swarm nano grid system might completely change how energy is distributed. Nanotechnology and swarm intelligence provide self-organizing and sustainable energy networks that provide communities and individuals with trustworthy, effective, and green electrical solutions [30].
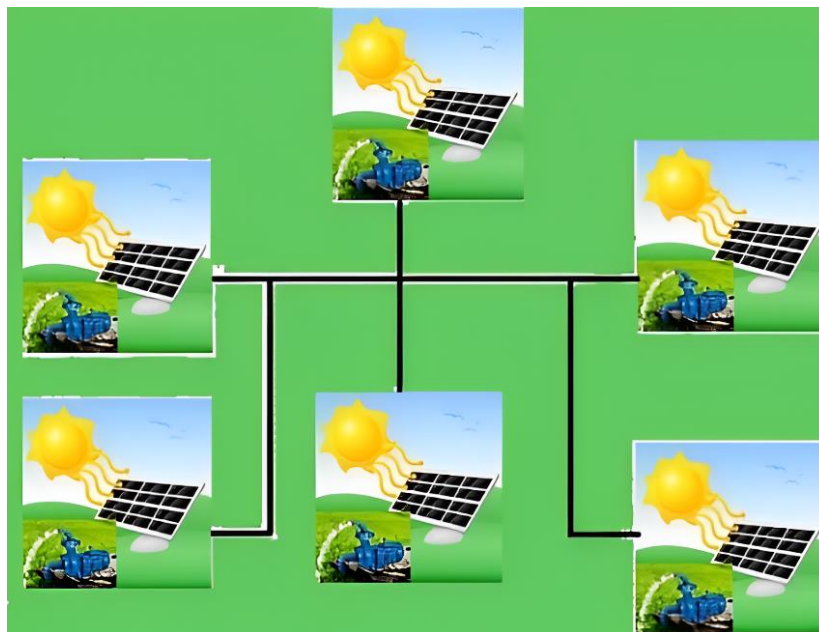

Figure 3. Basic outline views of proposed swarm systems

3. PROPOSED CONVERTER IN THE CIRCUITS

Semiconductor switches control DC-DC converter voltage and current. High-frequency input voltage switching. Filtering and controlling the fluctuating voltage waveform generates the right DC output voltage. DC-AC converters use insulated gate bipolar transistor or IGBTs or MOSFETs to convert DC to pulsating AC. This waveform filters into the sinusoidal AC output voltage. DC-DC and DC-AC converters assist power electronics transform energy and incorporate loads. Voltage, power, efficiency, and application determine converter design and control.

3.1. DC-AC converter circuit of the proposed converter

Using sinusoidal PWM, a high-frequency triangular carrier waveform is contrasted with a standard sinusoidal waveform. The adjusted PWM signal's pulse width is controlled by the amplitude of the sinusoidal reference waveform. Sinusoidal AC is the result of this modulation procedure. The DC-AC converter power switch switching is controlled by the modulated PWM signal. IGBTs or MOSFETs are turned on and off in a pattern by PWM signals. The output voltage waveform is influenced by this pattern (1) [31].

$$V_{Control} = \hat{V}_{Control} \, Sin(\omega 1 t) \tag{1}$$

Since, as shown in (2).

$$V_{AO} = \frac{V_{Control}}{\hat{V}_{tri}} \frac{V_d}{2} = \frac{\hat{V}_{Control}}{\hat{V}_{tri}} \, Sin(\omega 1 t) \frac{V_d}{2} = m_a \frac{V_d}{2} Sin(\omega 1 t) \tag{2}$$

For m_a calculation as (3) and (4).

$$V_{R-rms} = m_a \frac{V_d}{2\sqrt{2}} \, Cos\emptyset \tag{3}$$

$$V_{AB-rms} = \sqrt{3} V_{R-rms} = m_a \frac{\sqrt{3} \, V_d}{2\sqrt{2}} \, cos\emptyset \tag{4}$$

Hence, as shown in (5).

$$m_a = \sqrt{3} V_{R-rms} = \frac{V_{AB-rms}}{V_d} \frac{2\sqrt{2}}{\sqrt{3}Cos\emptyset} \approx 0.936 \tag{5}$$

We can choose $m_a = 0.936$, total dynamic head (TDH) $\leq 73\%$.

The converter may alter the triangle carrier waveform and reference sinusoidal waveform's frequency and amplitude to generate an AC output with the desired frequency and magnitude. Careful carrier waveform and modulation index construction may reduce harmonic distortion in the output waveform. Filters, safety circuits, and feedback control loops regulate and stabilize sinusoidal PWM-based DC-AC converters [32]. These components ensure power conversion, waveform reproduction, and fault avoidance.

3.2. DC to DC converter circuit of a proposed work

Semiconductor switches regulate the voltage and current of DC-DC converters [33]. The basic concept is the high-frequency switching of the input voltage. The fluctuating voltage's waveform must first be filtered before being adjusted in order to get the required level of DC output voltage. Output voltage (Vo) calculation as (6).

$$V_o = V_{in} \times \frac{(1-D)}{D} \tag{6}$$

V_o is the desired output voltage. V_{in} is the input voltage range and D is the duty cycle of the switching signal. Duty cycle (D) shown as (7).

$$D = \frac{1}{(1+(V_{in}/V_o))} \tag{7}$$

D is the switching signal's duty cycle. The input voltage range is called V_{in}. The intended output voltage is Vo. Selecting an inductor (L) as (8).

$$L = \frac{((V_{in}-V_o)\times(1-D))}{(f_S \times \Delta I_L)} \tag{8}$$

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L is the inductance value; V_{in} is the input voltage range; Vo is the desired output voltage; D is the duty cycle of the switching signal; fs is the switching frequency; and ΔIL is the maximum allowable ripple current in the inductor. Capacitor (C) selection as (9).

$$C = \frac{(I_{out} \times \Delta V)}{(f_S \times \Delta I_L)} \tag{9}$$

C is the capacitance value; I_{out} is the output current; ΔV is the maximum allowable output voltage ripple; fs is the switching frequency; and ΔIL is the maximum allowable ripple current in the inductor. Switching losses estimation as (10).

$$\text{Switching Losses} = \frac{(V_{in} \times I_{out} \times (1-D) \times D)}{f_S} \tag{10}$$

Vin is the input voltage range; I_{out} is the output current; D is the duty cycle of the switching signal; and fs is the switching frequency.

3.3. Methodology inspired swarm nano grid system

Drones resembled insect and bird colonies. Integrating numerous drones enhances dependability, coverage, mobility, and ability to complete complex tasks. Collaboration, disaster response, environmental monitoring, precision agriculture, and other drone services may revolutionize enterprises. Power management, navigation, communication, and safety are compromised. Drones will improve. Researchers optimize these collective systems. Organized gear is purposeful. This solar energy plant incorporates cutting-edge technology. MATLAB simulates one grid, and swarm all grids make nano grid networks.

4. MATLAB SIMULATION OF THE PROPOSED SYSTEM

In a MATLAB simulation for a PWM inverter, the PI controller may be constructed using a feedback control loop, and the MATLAB simulation schematic is shown in Figure 4. Calculations are made to determine the error signal, which is the difference between the reference value and the actual output of the inverter system. The PI controller analyzes this error and then generates a control signal to change the PWM signals duty cycle or switching pattern. The PWM modulator may modulate the inverter's operation and provide the desired output by using this control signal.
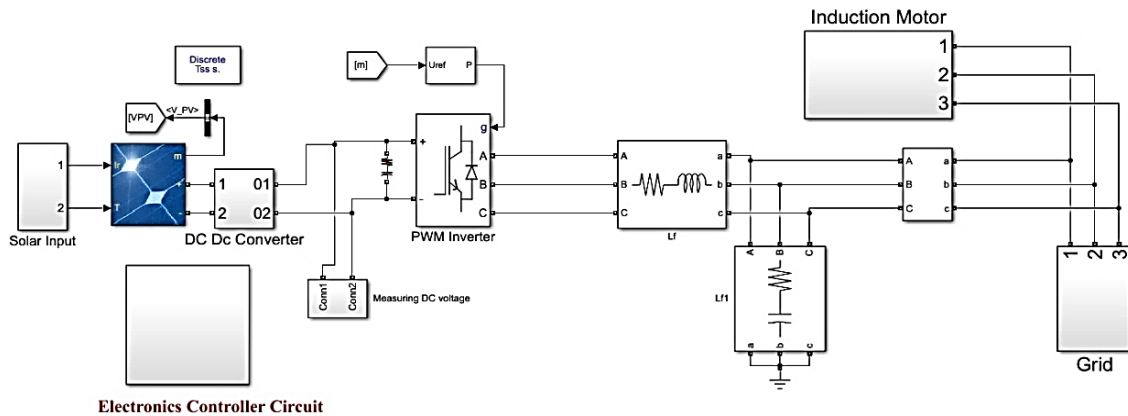

Figure 4. Simulation circuit of individual system of nano grid

For modeling a PWM inverter system using a PI controller, MATLAB offers a flexible platform. You may create the transfer function or state-space model of the inverter using MATLAB's control system toolbox and Simulink, build the PI controller, then simulate the system response to assess the controller's effectiveness. You may examine the simulation results and make any required changes to the controller design thanks to MATLAB's visualization features. In the Figure 5(a), it shows the simulation output of induction motor and Figure 5(b) shows the PWM inverter output as shown in below.

The swarm nano grid system's activities may be monitored over time using MATLAB simulations utilizing inputs like solar irradiance and load profiles. It assesses the supply-demand flexibility, system stability, economic effectiveness, and reliability of the power supply. Block view of system 1-4 is shown in the Figure 6.
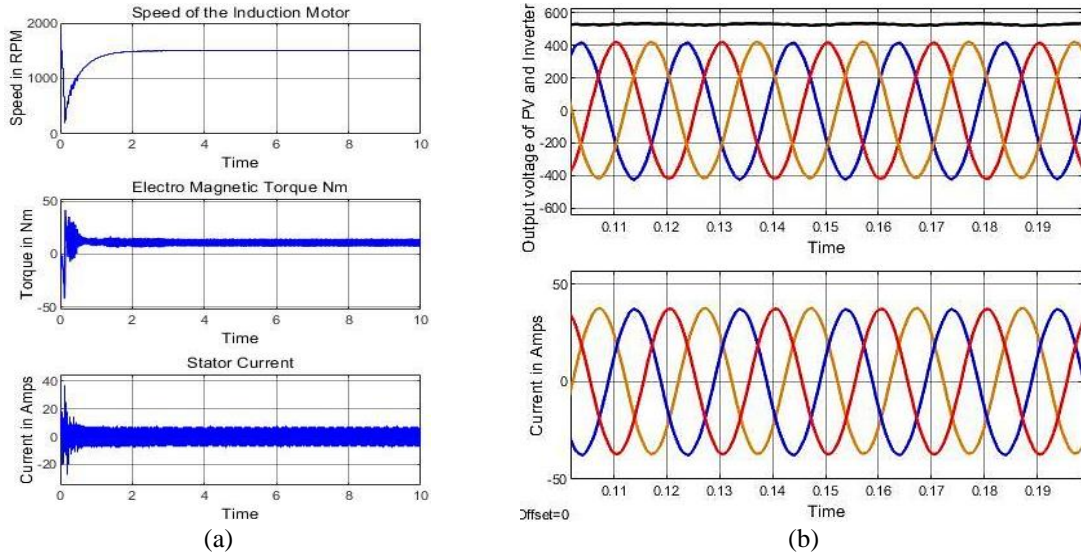

(a)   (b)

Figure 5. Simulation results of (a) T-S and I Characteristics of induction motor and
(b) V-I Characteristics of PWM inverter
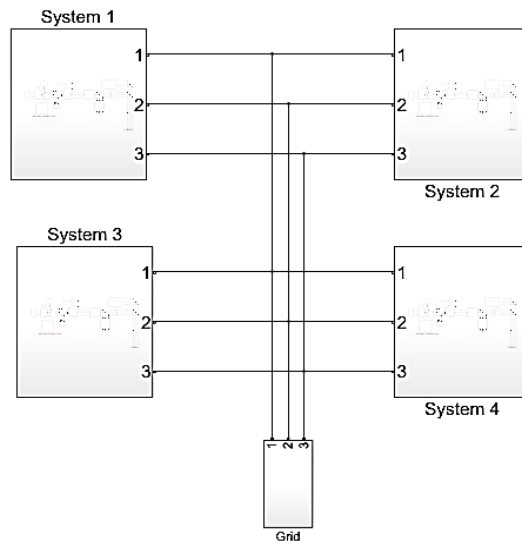
Figure 6. Simulation of nano grid systems with individual blocks

5. RESULT AND DISCUSSION

Predict load patterns, energy storage dynamics, conversion efficiency, and power flow equations. Nano grids cooperate or swarm. MATLAB simulations analyze system performance and make judgments. For trustworthy distributed energy systems, the insights could boost system design, control strategy advancements, and cutting-edge algorithms. Figure 7 displays the simulation results for system bus voltage and grid bus voltage.
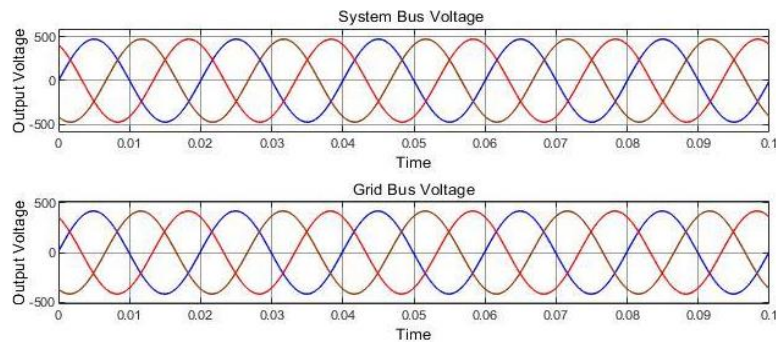
Figure 7. Simulated output voltage of grid and system bus voltage

MATLAB simulation enhances swarm nano grid system performance and control. Simulations test system behavior. Clarify nano grid solar panels, wind turbines, batteries, loads (houses and buildings), and power conversion equipment. MATLAB simulates nano grid activity. Sun irradiation profiles must be used to simulate demand and weather. Mathematical models simulate nano grid component dynamics and interactions.

This study examined four independent systems and total integrated nano grid systems. PV systems with DC-DC converters and PWM inverters power induction motors. Then the inverter supply is synchronized to the grid for power sharing. Cost-effective and dependable irrigation systems use three-phase induction motors. Figure 5 shows the motor speed raises from 0 to 450 rpm in 0.2 seconds. At 0-0.2, torque and current are maximal. Nano grid linked system helps regulate inrush current (0-0.2). Motor speed increases from 450 to 850 rpm in second stage (0.20-0.4) sec. This period (0.20-0.4) generates the most torque and current. At time (0.40-2), a nano grid-linked system helps regulate inrush current. Motor speed increases from 850 to 1500 rpm in third stage (0.40-2). At 0.40–2, torque and current are normal. Filter circuits address these circumstances if system is not grid-connected.

The following study shows individual system performance to control the motor at three stages: (0-0.2), (0.2-0.4), and (0.4-2) sec. This effort goes beyond grid sharing to irrigate the chosen region utilizing Swarm technology. Figure 6 shows the MATLAB Simulink simulation. Table 1 illustrates the power yield from the four systems that can be shared between them and the main grid.

Table 1 shows all systems' daily power use. Sharing systems for pump safety during inrush current and low irradiance. The 50-51 Hz frequency is okay. The controller decides whether to use system or grid electricity for voltage regulation. System 1 generates 37.54 kWh every day, however it needs 30 kWh. Nano grid receives 7.54 kWh. System 2 generates 36.3 kWh per day but needs 32 kwh, leaving 4.3 kWh for the nano grid. System 3 generated 35.3 kWh but needed 45 kWh, therefore nano grid supplied 9.7 kWh. Finally, system 4 generates 38.2 kWh solar electricity and uses 40 kWh, taking 1.8 kWh from the nano grid. Swarm Nano grid splits energy output amongst systems to irrigate the land.

Table 1. Parameter measured in the swarm nano grid system

	Energy yield (kWh)	Power consumption (kWh)	Frequency regulation	Voltage control	Power to grid (kwh)	Temperature
System 1	37.54	30	acceptable limits	415 V	7.54	25
System 2	36.3	32	acceptable limits	415 V	4.3	26
System 3	35.3	45	acceptable limits	415 V	-9.7	26
System 4	38.2	40	acceptable limits	415 V	-1.8	25

6. CONCLUSION

The work being done used a swarm nano grid distribution system, in which four systems were linked together through nano grid and split the allotted workload equally. The many different subsystems that make up each system include the solar panel, DC-DC converter, PWM-inverter, and series parallel filters, to name just a few. Although the simulated environment includes artificial disturbances such changes in irradiance (700-1000 kw/m^2) and temperature (25-36 °C), each structure's maximum solar array power output is 6.37 kW. As may be seen in Table 1, the modified system output differs. In system 1, the outputs go up when the amount of light changes. Because each adjustment to the panel affects the output differently, this situation calls for an in-depth analysis of the grid's overall efficiency. The stability of individual systems is ensured by their link to a nano grid. Motor requires 6-7 times as much current at startup. To further stabilize the system, a variety of delay timers will be made available in the near future to adjust the motor's start time

so as to prevent the same surge of current at startup. The use of AI interference can accomplish this. Human intervention and mistakes may be minimized in the future thanks to this AI addition. To achieve close to the expected results, standard components have been simulated using MATLAB Simulink, and the system's stability has been guaranteed by carefully setting the parameters.

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