

Solar PV Fed System for Water Pumping and Domestic Load by using Bidirectional Grid

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ABSTRACT: The goal of this endeavor is to construct a bidirectional grid-based solar PV fed system for domestic load and water pumping. Reliability and uninterrupted water delivery are guaranteed by providing solar PV power with ongoing grid assistance. To power the water pump, a synchronous reluctance motor is employed. Additionally, the system includes a single-phase H-bridge inverter to deliver grid power and photovoltaic array electricity to local or household loads. Power flow from the grid to the DC connection is unidirectional and is made possible by a power factor corrected (PFC) boost converter. The system and control that are being offered guarantee that a customer will always receive water, regardless of the state of the atmosphere. The simulation and system performance are performed using the MATLAB/Simulink software environment

I. INTRODUCTION

The majority of nations are moving toward free and limitless renewable sources as the gap between supply and demand widens, and this adoption has accelerated over the last ten years. Because solar photovoltaics (PV) is portable, readily available in a wide range of locations, and requires less maintenance, it is the most promising renewable energy option. In addition, people are encouraged to install local PV systems by the latest advancements in solar PV technology and the declining cost of panels [1]. In addition, as research advances, there is an ever-growing demand for efficient energy management strategies. Because of their high power density, near-unity power factor, and lack of magnetizing currents, permanent magnet (PM) motors—such as PM brushless DC motors (PM-BLDCM) and PM synchronous motors (PM-SM)—inherently have high efficiencies to the more widely used induction motors [2–3]. It is an expensive option, nevertheless because of the additional expenditures for the motor and permanent magnet material. Reluctance synchronous motors, on the other hand, function similarly to PM-motors in terms of efficiency since they do not need

PMs and, in contrast to induction motors, have little rotor losses [4]. Additional advantages include durable and dependable functioning, low cost, simple structure, and great efficiency. These advantages make the synchronous When it comes to solar water pumping applications (WPS), reluctance motors stand out as the best drive option [5]. Installing a PV source has several benefits, but these systems are unpredictable and heavily dependent on external factors.

These elements Lessen the water pumping system's dependability. Since solar radiation is the system's primary energy source, water pumping stops at night and in inclement weather. Furthermore, the pump runs at a lower potential when the PV isolation obtained is less than the intended capacity. Consequently, a backup source must be introduced to assist pumping during periods of lower solar generation in order to boost system resilience. Grid power and battery energy storage are the best options in this regard.

Less service life and higher installation a operating expenses are associated with the addition battery storage. These systems' main goal is to guaran that the drive is fully utilized for the applicatio continuous operation, regardless of the surroundi environment. While interacting with the grid, a number grid-side power quality characteristics were maintained. this study, a PV array is interfaced with the utility g sources in a way that PV array generation is alwa regarded as the primary source and only supplementa power needs are drawn from the grid. Additionally, a Pl circuit is incorporated to keep the grid side currents at U constant.

II SYSTEM CHARACTERIZED

The system architecture for the grid-interfaced solar photovoltaic array fed Syrm-driven WPS is shown in Fig. 1. Solar photovoltaic arrays are the system's main component for converting solar energy into electrical energy.

The Syrm is driven by a 3-Ø VSC, and it is connected to a DC motor. A boost converter is used to adjust the input voltage to the reference DC bus voltage and for power factor correction (PFC); a single-phase H-bridge inverter is used to fulfill the local load requirement. A diode rectifier (DR) is used for AC to DC conversion. The rotor location and speed are estimated using the vector control technique. The incremental conductance (InC) MPPT technique is implemented for the single stage system.

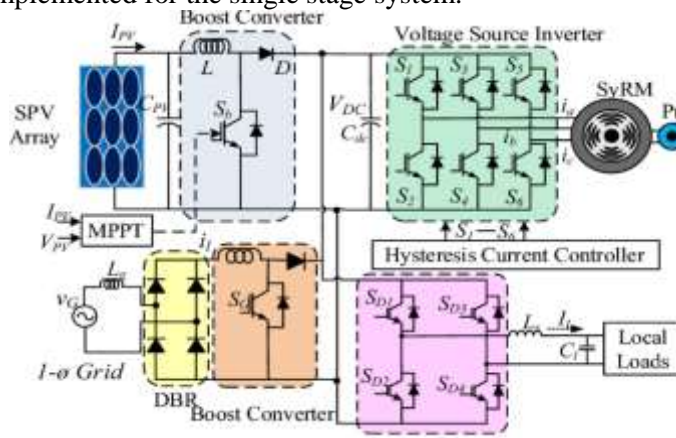


Fig .1 configuration of system characterized

The Photovoltaic System

Photovoltaic's

The topic of photovoltaic technology and research focuses on devices that use semiconductors that show the photovoltaic effect to directly convert sunlight into electricity. A substance will produce voltage when exposed to electromagnetic radiation; this phenomenon is known as the photovoltaic effect.

A PV system consists number of interconnected components designed to accomplish a desired task, which may be to feed electricity into the main distribution grid, to pump water from a well, to power a small calculator or one of many more possible uses of solar-generated electricity.

The design of the system depends on the task it must perform and the location and other site conditions under which it must operate. This section will consider the components of a PV system, variations in design according to the purpose of the system, system sizing and aspects of system operation and maintenance.

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III CONTROL MYTHOLOGY

The three phases VSI, PFC boost converter, single-phase H-bridge inverter, and InC-based MPPT approach are all controlled by the created system. Every control scheme is explained in detail in the subsection that follows

MPPT CONTROLLER

Maximum power point tracker (or MPPT) is a high efficiency DC to DC converter that presents an optimal electrical load to a solar panel or array and produces a voltage suitable for the load.

Solar photovoltaic array characteristic curves are nonlinear. Therefore, to permit operation at the maximum power point on the Ppv-Vpv curve, various MPPT approaches are available in the literature [10]. When the incremental conductance equals the instantaneous conductance value, the InC method controls the process. It allows for quick tracking of MPP even in situations when solar radiation is changing quickly. To get the reference DC bus voltage for the maximum power transfer, input PV voltage Vpv and PV current Ipv are employed.

$$P_{pv} = v_{pv} * I_{pv} \tag{1}$$

$$\frac{\Delta P_{pv}}{\Delta V_{pv}} = \frac{\Delta(V_{pv} I_{pv})}{\Delta V_{pv}} \tag{2}$$

At MPP

$$\frac{\Delta P_{pv}}{\Delta V_{pv}} = 0, \frac{I_{pv}}{V_{pv}} + \frac{\Delta I_{pv}}{\Delta V_{pv}} = 0 \tag{3}$$

$$\frac{\Delta P_{pv}}{\Delta V_{pv}} < 0, \frac{I_{pv}}{V_{pv}} + \frac{\Delta I_{pv}}{\Delta V_{pv}} < 0 \tag{4}$$

Left of MPP

$$\frac{\Delta P_{pv}}{\Delta V_{pv}} > 0, \frac{I_{pv}}{V_{pv}} + \frac{\Delta I_{pv}}{\Delta V_{pv}} > 0 \tag{5}$$

VECTOR CONTROL ALGORITHM FOR SYRM

The drive system in the developed configuration is a 3-Ø, 2000W Syrm. Fig. 2(a) displays the 3-Ø VSI control diagram. The speed proportional integral (PI) regulator receives the generated error signal from the vector control algorithm, which compares the rated and estimated motor speeds. The quadrature axis reference current is estimated using the torque reference, which is the PI regulator's output

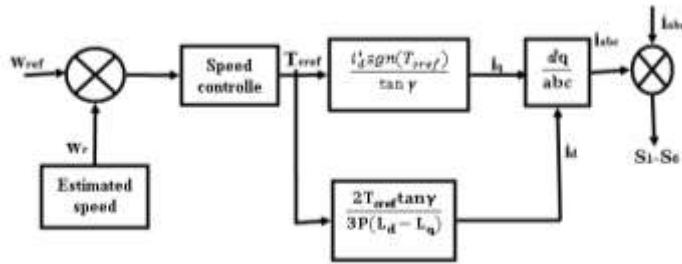


Fig. 2(a) Control of Syrm drive

$$T_{ref}(m) = T_{ref}(m - 1) + K_p\{\omega_{er}(m) - \omega_{er}(m - 1)\} + K_i\omega_{er}(m) \tag{6}$$

Where,

$$\omega_{er} = \omega_{ref} - \omega_r$$

ω_{er} is the speed error, KP and KI speed controller gains, ω_{ref} is the rated Syrm speed.

Thereferencedq-axis(i_d^* , i_q^*)currentsareestimated as,

$$i_d^* = \left[\frac{2T_{ref} \tan \gamma}{3P(L_d - L_q)} \right]^{1/2} \tag{7}$$

$$i_q^* = \frac{i_d^* \sin T_{ref}}{\tan \gamma} \tag{8}$$

The motor is modeled in the stator reference frame and therefore, the reference currents in d-q domain are converted to using inverse Park transform. These reference currents are compared against sensed motor currents and fed to the hysteresis band controller to obtain the switching gate pulses for the 3-Ø VSI. In the developed system, mechanical (speed & position) sensors are eliminated the position of Syrm is estimated using the switching sequence of VSI and DC bus voltage. The angle between the stator and rotor reference frames SD&RD, respectively, is the rotor angle. represents the angle between the stator reference frame, VD and the stator flux linkage, vs., δ represents the angle between the rotor reference frame, rd

$$\theta_r = \rho_s - \delta \tag{9}$$

$$\omega_r = \frac{d\theta_r}{dt} \tag{10}$$

Whereas, ρ_s stands for the angle between the stator flux

linkage, s , and the stator reference frame, sD , and δ_s for the angle between the rotor reference frame, rd .

$$\omega_r = \frac{\partial \rho_s}{dt} - \frac{\partial \delta}{dt} \tag{11}$$

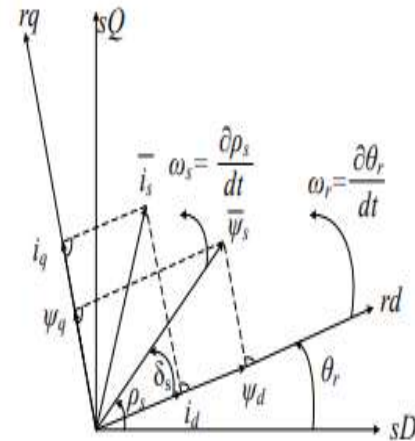


Fig. 2(b)Syrm state space vector diagram

Control of PFC boost converter

Fig. 2(c) shows the control structure of the PFC boost converter that is being described. The grid's power flow is one-way only. There is just one way that power can be transferred: from the grid to the DC link voltage. The designed control meets the applicable power quality criteria for both total harmonic distortion (THD) and unity power factor (UPF). The output of the InC MPPT is used to derive the reference DC link voltage, which is then compared to the detected DC link voltage (V_{dc}), which is first sent through a low pass filter to remove noise. A PI regulator receives the voltage error, multiplies its output by the grid unit template, and outputs.

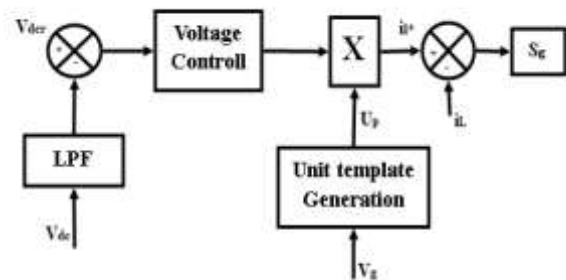


Figure 2(c) PFC boost converter control

Single – phase H-bridge inverter control

The schematic control scheme for the local load converter is shown in Fig 2(d) .The measured load voltage (V_l) and a grid voltage with amplitude of (230–2V) are compared, and the error that results is sent to the voltage proportional integral controller. A reference load current is created by feeding the voltage regulator the error. This reference load current is then compared to the measured load current, given to the hysteresis controller, and a single-phase inverter pulse is produced.

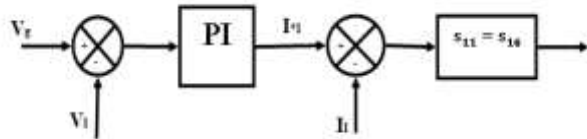


Fig. 2(d) Control of H-bridge inverter

The unit template(*u_p*)of diode bride rectifier is as follows,

$$\mu_p = \frac{|V_g|}{V_{peak}}$$

$$I_l = I_l(x - 1) + K_i\{V_e(x) - V_e(x - 1)\} + K_p V_c(x)$$

Where

$$V_e = V_g - V_l$$

IV RESULTS AND DISCUSSION

PV solar System

MATLAB simulations are used to analyze the behavior of the system that is being presented

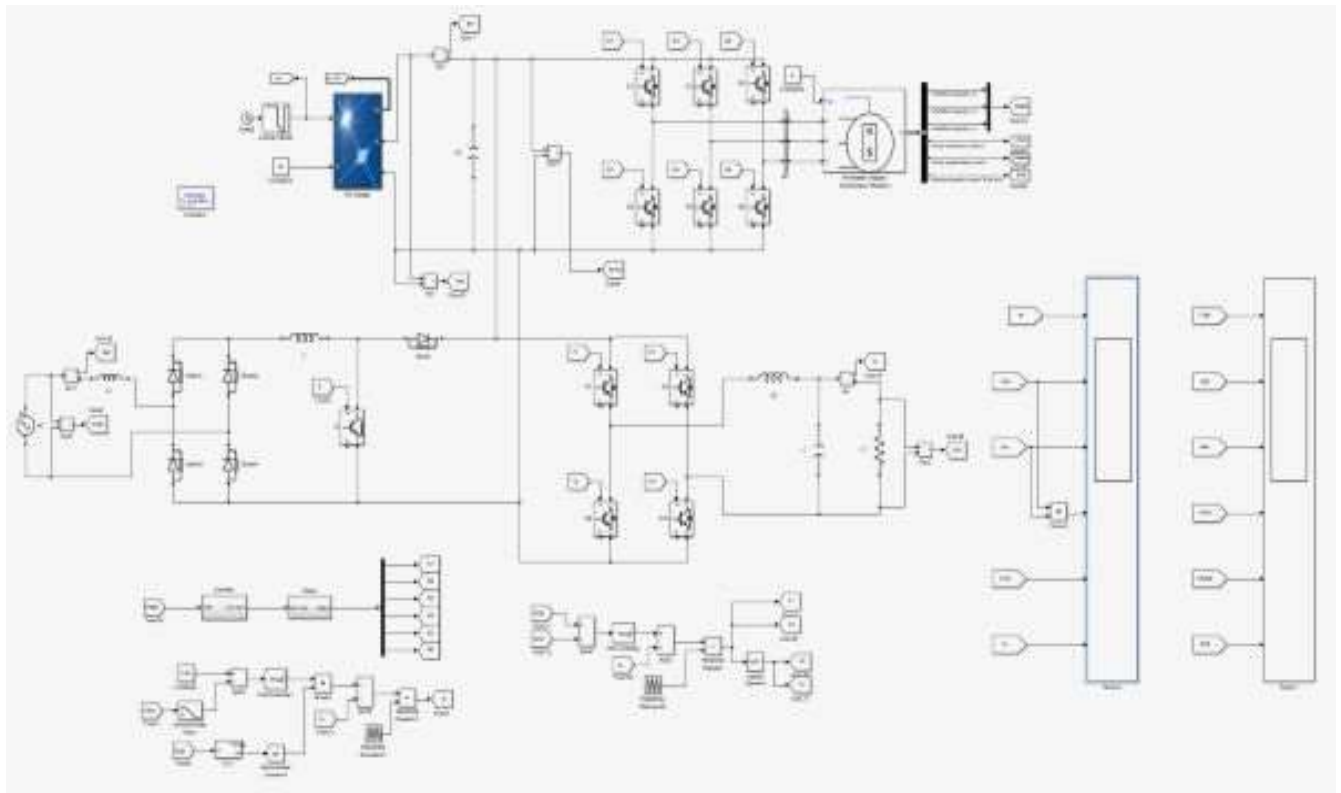


Fig. 3 Mat lab Simulink diagram

A. Consistent State Reaction

a) Syrm Pump is only fed by solar photovoltaic arrays.

The ensuing subsections cover the grid, Syrm parameters, and solar photovoltaic (SPV) array steady state functioning. 6.2.1 Syrm Pump is fed exclusively by solar photovoltaic array With 1000W/m² of solar isolation available, the system's steady state behavior is depicted in Fig. 3(a) under standard conditions. The solar photovoltaic array is providing enough electricity on its own to run the pump and meet load demand. A solar photovoltaic array can generate 3076W of power (P_{pv}), with a PV voltage of 399V. Throughout the experiment, the voltage control system used keeps the load voltage (V_l) at its rated value of 230–2V, and at the rated value of solar radiation, the Syrm estimated speed (ω_r) of 180rad/sec is obtained.

In this Fig. 3(b) shows the different parameters of syrm's three phase stator currents (i_{abc}), estimated rotor position(θ_r), electromagnetic torque (T_e), grid voltage (V_g), grid current (I_g).

b) Only Syrm Pump is fed by Grid.

In the event that solar power is unavailable (due to poor light or at night), Fig. 4(a) illustrates how the grid supplies electricity to the pump and loads. At unit power factor, the grid current (I_g) peak value of 20A is obtained. At 399V, the link voltage (V_{dc}) is kept constant. As seen in Fig. 4(b), the pump meets its rated speed and electromagnetic torque.

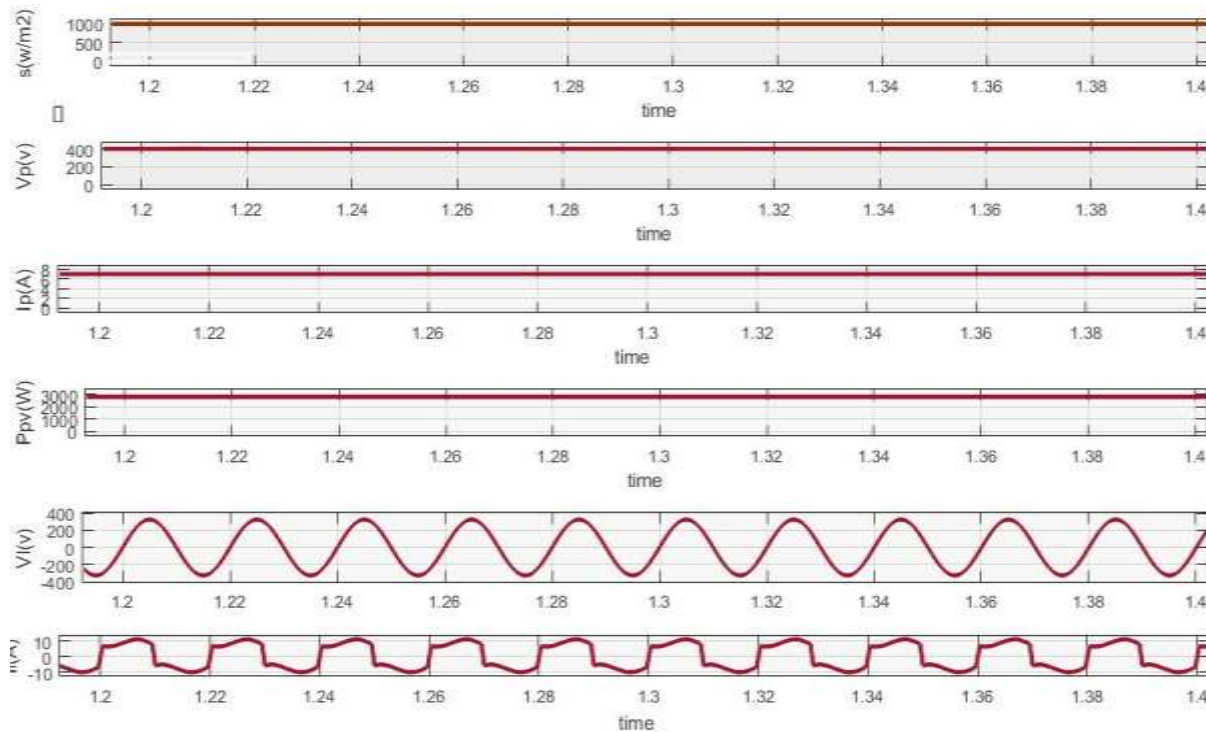


Fig. 3 (a) steady state response of the drive when photovoltaic array feeding to pump V(v),Pp(W),Ip(A),Vp(v)

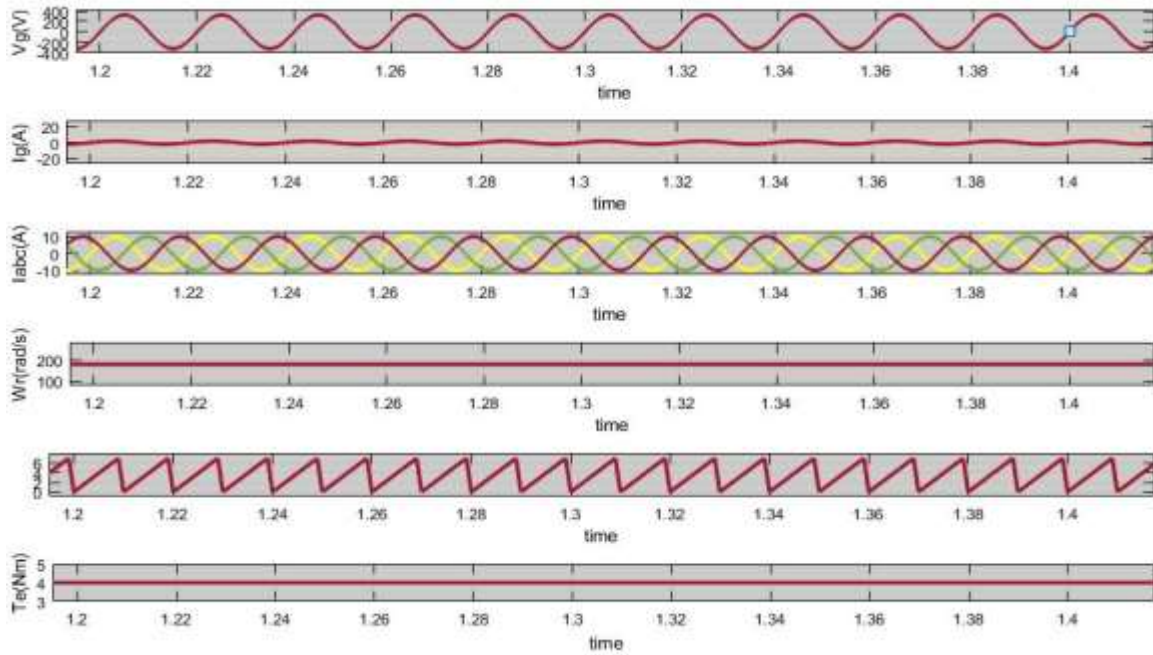


Fig. 3(b) Different parameters of Syrm as three phase stator currents (i_{abc}), estimated rotor position (θ_r), electromagnetic torque (T_e), grid voltage (V_g) grid current a

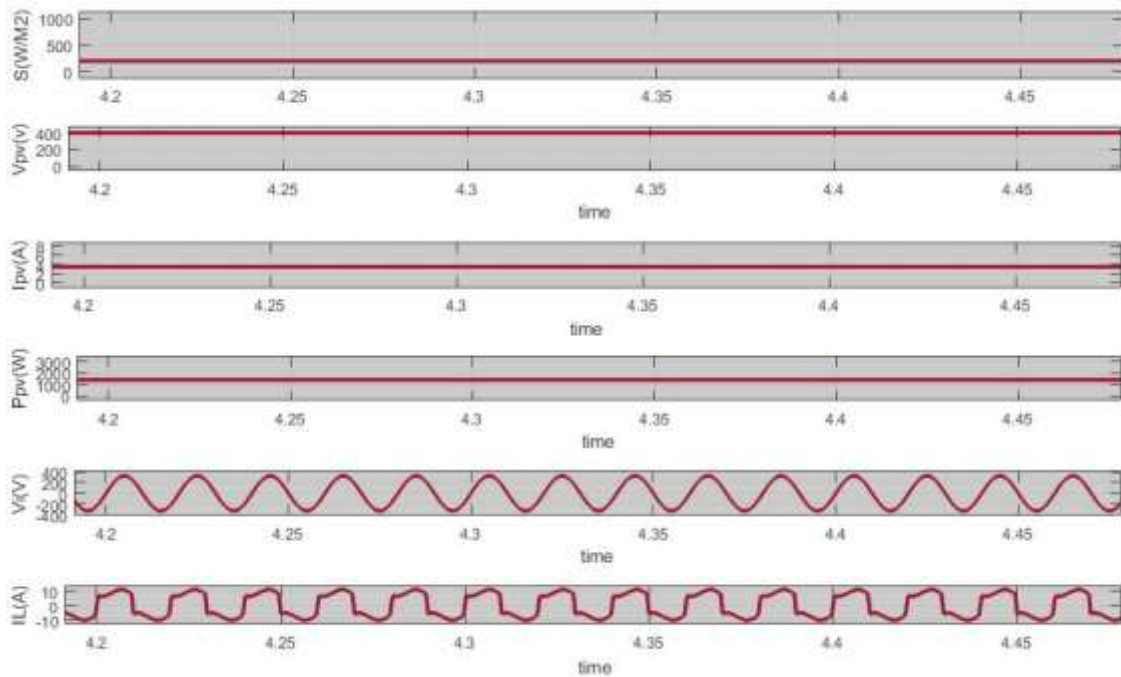


Fig. 4(a) System response in a steady state when the grid is the only source of power for the pump at S , V_{pv} , I_{pv} , P_{pv} , V_l ,

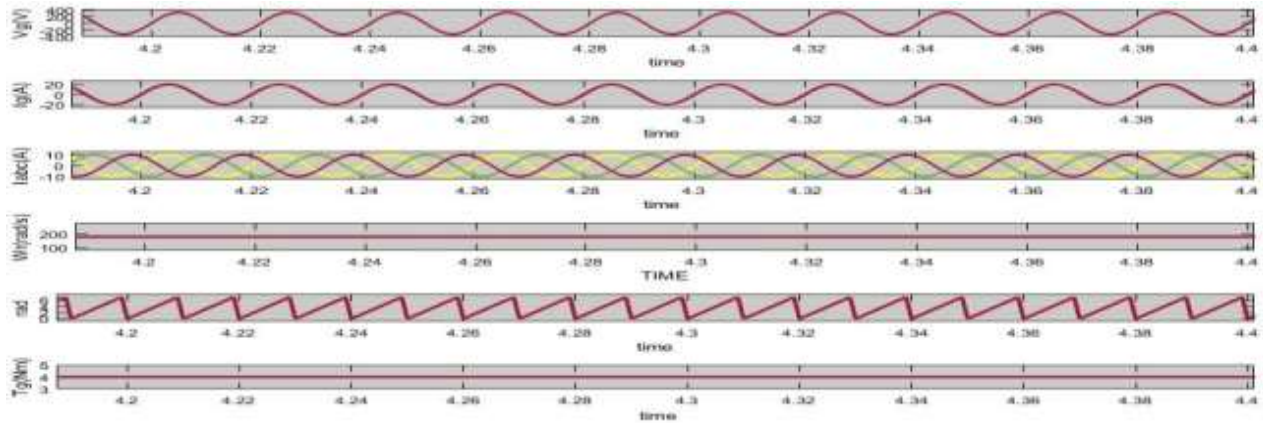


Fig. 4(b) System response in a steady state when the grid is the only source of power for the pump at V_g , I_g , i_{abc} , ω_r , θ_r , T_e

B.Adaptive Reaction

The system's dynamic reaction shows how well the system behaves under various climatic circumstances. When the home load and pump are fed by both the grid and the solar photovoltaic array in order to achieve the rated water discharge, this condition is taken into account in the dynamic response. The solar photovoltaic array cannot provide the necessary electricity when solar radiation drops from 1000 W/m² to

200 W/m². The grid supplies the remaining power in this instance.

Solar radiation reduced

Figure 5(a) illustrates the reduction in radiation from 1000W/m² to 200W/m² as well as the drop in solar PV Fig. 5(b) displays the Syrm and the grid reaction at different solar radiation levels. It contains the predicted speed and position (ω_r , θ_r), motor current (i_{abc}), grid voltage (V_g), grid current (I_g), and electromagnetic torque (T_e).

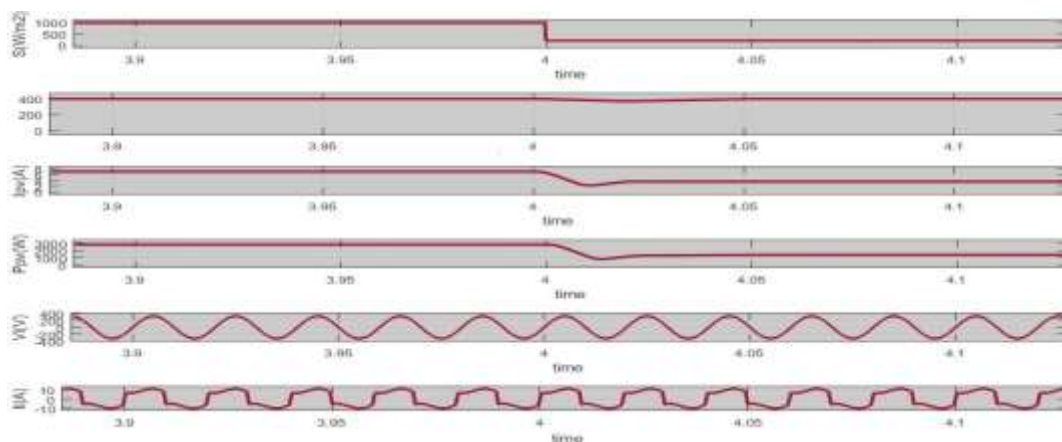


Fig. 5(a) Adaptive Reaction of system when solar radiation reduced at $s, V_{pv}, I_{pv}, P_{pv}, V_l, I_l$.

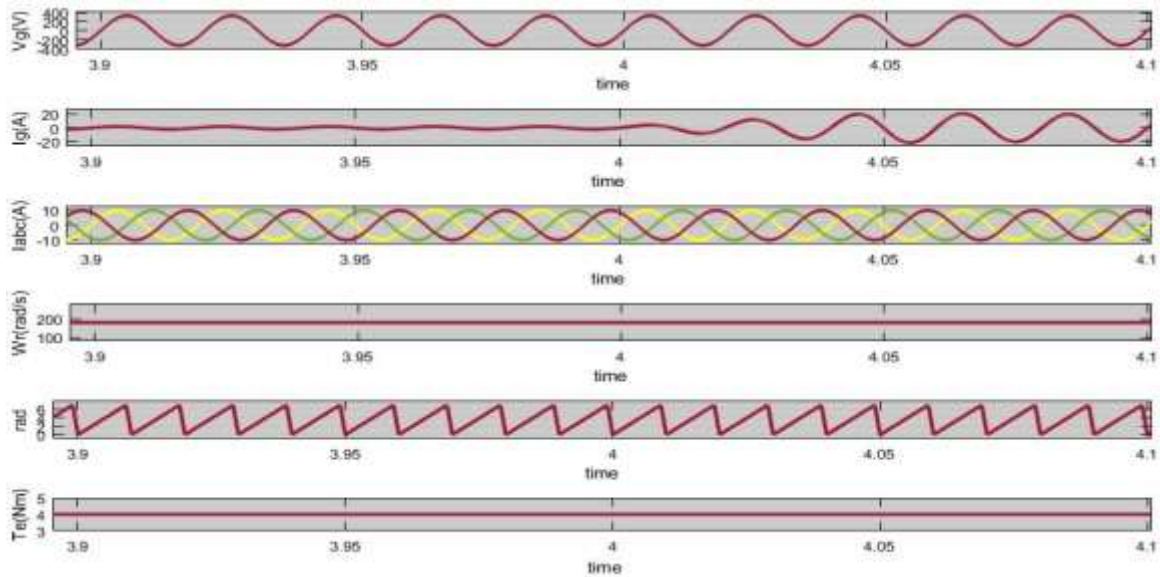


Fig. 5(b) Adaptive Reaction of system when solar radiation reduced at $V_g, I_g, i_{abc}, \omega_r, \theta_r, T_e$.

Solar radiation increased

The system response is depicted in Fig. 6(a) when the single phase grid operates the Syrm pump in the absence of solar radiation. At 6 seconds, a rated solar radiation value of 1000W/m2 is available. A significant degree of fluctuation in solar radiation is enforced to examine the behavior of the system during high transients. As shown in Fig. 6(b), when PV power generation

Ppv reaches its maximum value, grid current I_g reaches zero. Due to the photovoltaic array's MPP functioning, the I_g takes some time to zero, and the Syrm pump reaches its rated speed of 180 rad/sec, ensuring uninterrupted water pumping operation. The synchronous reluctance motor estimates the correct rotor position (θ_r) and draws a sinusoidal three-phase current (i_{abc}).

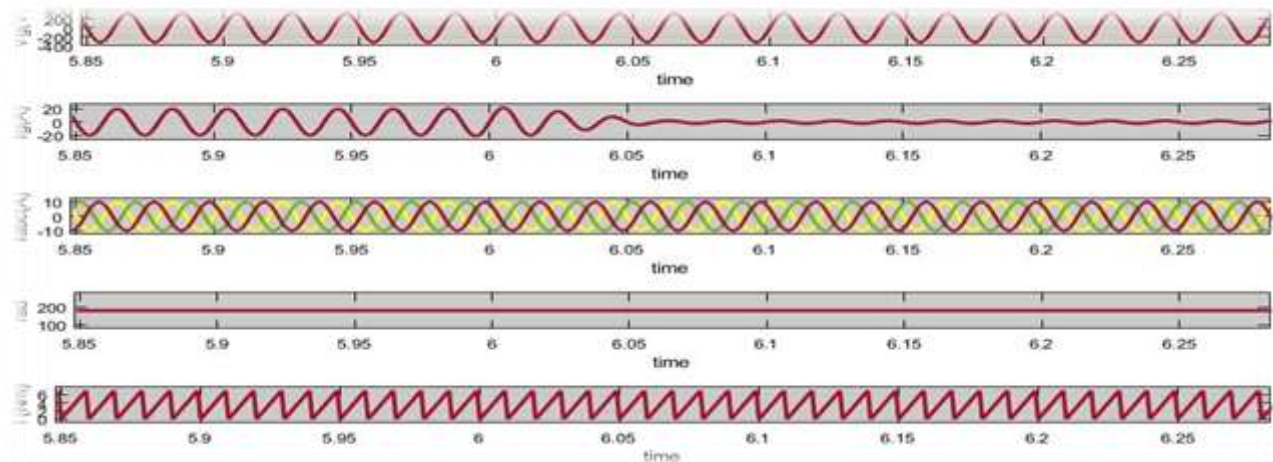


Fig. 6(a) Adaptive Reaction of system when solar radiation increased at $s, V_{pv}, I_{pv}, P_{pv}, V_l, I_l$.

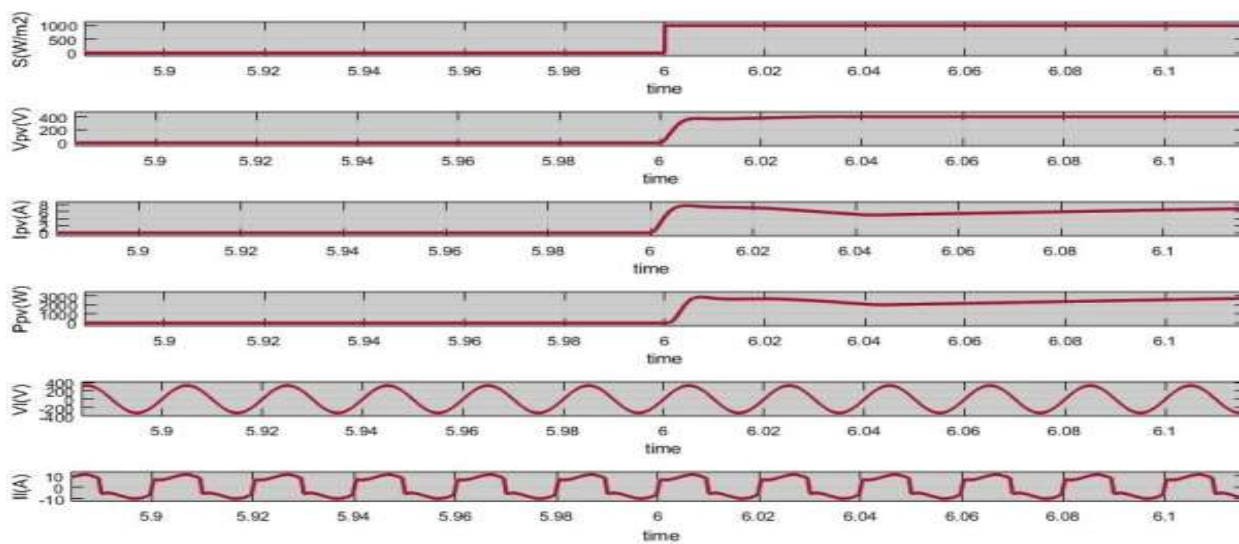


Fig. 6(b) Adaptive Reaction of system when solar radiation increased at $V_g, I_g, i_{abc}, \omega_r, \theta_r, T_e$

V.CONCLUSION

Using the MATLAB/SIMULINK environment, a solar PV fed system for water pumping and domestic load that uses a bidirectional grid and synchronous reluctance motor has been shown, along with a behavior demonstration. Power factor corrected PFC boost converters are used to regulate the power flow from the grid to the DC bus. The backup supply is the single-phase grid. To suit the demands of the local load, the system additionally includes a single phase H-bridge Voltage source converter. The power quality requirement has been satisfied. The infrastructure in place ensures continuous water pumping even in the face of varying atmospheric conditions. This water pumping system is shown to be dependable and efficient

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