

Grid connected Solar Powered Water Pumping System Utilizing Improved Control Technique

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Abstract- Present paper aims to discuss scope and limitations of photovoltaic solar water pumping system. Components and functioning of PV solar pumping system are described. In addition, review of research works of previous noteworthy researchers has also been done. Irrigation is well established procedure on many farms in world and is practiced on various levels around the world. It allows diversification of crops, while increasing crop yields. However, typical irrigation systems consume a great amount of conventional energy through the use of electric motors and generators powered by fuel. Photovoltaic energy can find many applications in agriculture, providing electrical energy in various cases, particularly in areas without an electric grid. This paper proposes a single stage grid interactive solar powered switched reluctance motor (SRM) driven water pumping system with an efficient control technique. The control of proposed system provides the proficient maximum power point technique (MPPT) tracking and motor drive control with bidirectional power flow between the photovoltaic (PV) array and single phase grid. It has harmonics components elimination, improved dynamic performance and a DC offset rejection capability compared to other control. A PV feedforward term is also incorporated in developed control to enhance the dynamic performance of the system and to minimize the size of DC link capacitor with improved MPPT performance. The novel scheme of fundamental switching of SRM drive over its maximum operational time (when the grid is present) makes system efficient and reliable. An improved perturb and observe (P&O) based maximum power point tracking (MPPT) algorithm is used in this system to minimize the undesirable losses in a PV array specially under varying insolation levels. The proposed control is tested on a developed prototype and its suitability is authenticated through simulated and test results under various conditions.

Keywords- Grid connection, Renewable energy, Power system.

I. INTRODUCTION

The concept of microgrid is gaining lot of popularity worldwide due to their ability of working independently in islanding mode. The microgrid also allows the optimal utilization of available renewable energy sources (RES) in a coordinated way in order to feed remotely placed isolated locations where grid is not readily available. Thus, the microgrid is expected to work both in grid tied mode and off grid (islanded) mode. In grid tied mode, the grid voltage sets the reference for DG interfacing VSC's and chances of internal conflict among different VSC's are very rare.

However, in islanded mode of operation, the different VSC's are needed to be controlled in such a way that the load demand must be shared by all interconnected VSC's in proportion to their individual rating. Therefore, the VSC's in microgrid may either be controlled in centralized manner with dedicated communication channel between them or they may be controlled individually with droop

control which may require low bandwidth communication channel or no communication channel at all. The later one is more preferable; as it is easily implementable with enhanced security and reliability. [1-5]

The traditional droop control method have some issues related to the inaccuracy in determining the power to be shared by individual DG and deviation in voltage at PCC due to fluctuation as well as unbalance in load demand. To mitigate the aforementioned disadvantages of conventional droop control, several control algorithms have been proposed by researchers all over the world.

As a primary control measure, virtual impedance and negative-sequence impedance methods have been proposed to share the unbalance load demand by various DG's. In such kinds of methods, a measurement unit is required to transmit the negative-sequence component of unbalanced load to all interconnected DG's. Moreover, any mismatch in actual impedance of feeder due to connected transformer, filtering inductor or capacitor and

cable connection may result in inaccurate power sharing among DG's. Therefore, within a control loop the virtual impedance adjusts the equivalent inverter impedance to have proper power sharing among DG's. In the positive, negative and zero sequence components of the VSC current and the Voltage at PCC have been controlled separately. However, setting the control limits for all the three sequence current components is very cumbersome task.

A hierarchical control based centralized secondary control approach has been presented. However, such control scheme requires dedicated communication channel and also eliminates the major advantages of plug & play capability of microgrid. In proposed work, a novel based add-on controller has been proposed to compensate the ill effect of dynamically varying unbalance load. [20] [21]

The capability of adaptive neuro inference systems are well known as it has both the capabilities of handling the uncertainties like system and learning from processes like neural system. Therefore, the difficulty in settling the control limit under dynamic conditions is adaptively handled by controller. In proposed approach, the unbalance voltage factor is determined by extracting -ve sequence voltage component.

This -ve sequence voltage component is fed to controller, which in turns yields the equivalent unbalance current component. The equivalent unbalance current component is added to the output of outer voltage control loops in order to have modified reference current for the inner current control loops [6]. The photovoltaic (PV) system uses the sun's energy to generate power for domestic or industrial appliances that require the use of conventional electricity. This technology directly converts sunlight into electricity using semiconductor cells, called PV cells [15-18].

II. RELATED WORK

This article introduces the reproduction model of solar power generation with a dual-axis solar viewer powered by MATLAB/Simulink. Its advancements include continuous climate generators (solar power), auto-acceleration, and use with two-cell systems, such as monocrystalline silicon and silicon polycrystalline. This paper introduces the results of model and demonstrates practical implications of the two-axis converter of the modern solar attacker in comparison to the static model.

In addition, based on examination of model power plants, the actual conditions used for generating photovoltaic electricity. The proposed model will allow the study of the features of solar power plants or predict energy produced by solar panels in precise locations. S.V. Mitrofanov et.al (2018) solar power plants have a way of identifying the failure of solar panels.

In this article, propose an automated remote sensing method using PV cable data. Some string measuring devices are used for remote control of solar panels. [23]

The sun's surface produces a small amount of energy due to plate friction, structural shading, grass, etc. If two small ear canal measurements can be used to classify these defects by categorizing the defects, maintenance work can be reduced and more efficient preparation is possible. We use machine learning to calculate for them the reasons for the decline in electricity generated from the sun, such as plates, shadow, or grass. [16-20]

We apply this diagnostic method to a few large power plants. Experimental results show that the study accuracy of this method is 100%. When we tested this classification in other power plants, it was 99% correct. (Tadatashi Babasaki et al.) (2018)

III. PROPOSED SYSTEM

The SRM drive has been chosen for proposed 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. [8]

The manifold benefits and contributions of proposed system are enlightened here.

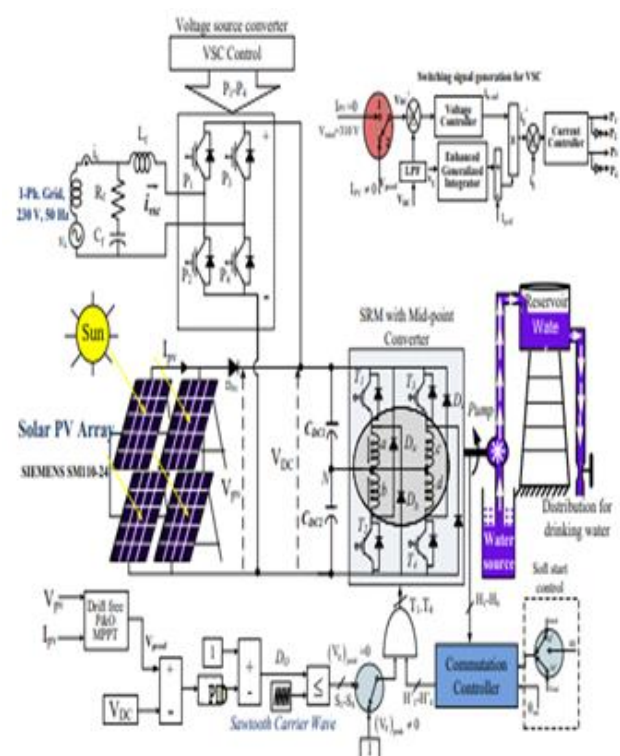


Fig 1. Proposed block diagram.

- It is first time that SRM is being used as a drive for the grid connected solar powered water pumping system either for double stage or single stage. A high-efficiency SRM drive substantially reduces the size of PV array and hence its installation cost.
- The proposed system has low losses due to absence of DC-DC conversion stage. Thus, the system becomes compact and efficient.
- Since the proposed topology is single stage, it has additional advantage of variable DC link voltage depending upon the PV power. It helps to reduce the power loss in the system. The semiconductor and ohmic losses in the interfacing inductor, are dependent on dc link voltage. The ripple content in the interfacing inductor can be reduced by variable dc link voltage.
- An improved generalized integrator based grid side control algorithm is presented for a single-phase grid interfaced solar energy conversion system, which has good DC offset and harmonic components rejection capability. This controller has incorporated a PV feed forward approach to enhance the dynamic performance of overall system and to minimize the size of DC link capacitors with improved MPPT performance. It also overcomes the oscillations present in grid voltage and PV output voltage.
- The seamless power streaming is facilitating the system to work in all possible conditions without using a battery or any other storage device by just maintaining the DC link voltage.
- The switched reluctance motor (SRM) drive is highly inductive and so it is the most suited for single stage PV fed system as it is able to mitigate the ripple in PV output current and minimizes a need of high DC link capacitors.

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The switched reluctance motor (SRM) drive is highly inductive and so it is the most suited for single stage PV fed system as it is able to mitigate the ripple in PV output current and minimizes a need of high DC link capacitors. The proposed system requires very less number of current and voltage sensors for seamless operation of overall system and able to provide the continuous operation of drive over whole day. The novel scheme of fundamental switching of SRM drive over its maximum operational time (when the grid is present) makes system efficient and reliable.

The MPPT and the motor drive control are simultaneously realized by an integrated control technique. An efficient MPPT algorithm is also presented for proposed system, which minimizes the tracking time of operating point of PV voltage especially under dynamic conditions and able to optimize the size of PV panel.

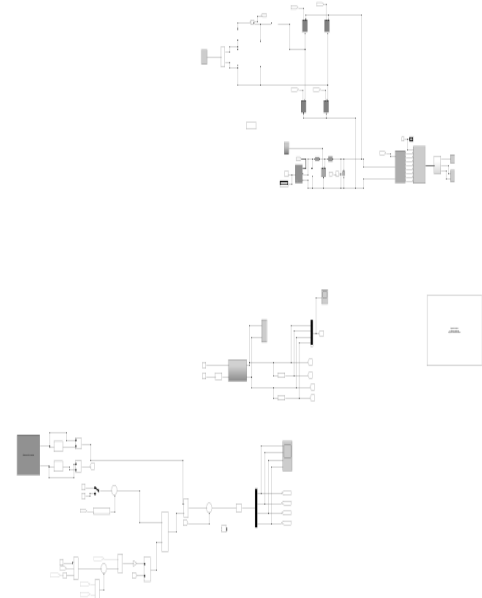


Fig 2. Proposed simulink model.

A number of configurations have been reported in the literature to integrate the utility grid to solar PV array to offer uninterrupted power to the motor-pump arrangement so that a continuous water supply can be obtained. However, most of the configurations involved are the double stage arrangement with unidirectional power flow [11-13].

Although, these are able to provide continuous water supply, the proposed systems suffer from high converter losses, control complexity, unable to mitigate and overcome the harmonics and oscillations in the grid voltage and provides only unidirectional power flow from the grid to load side. However, the system discussed in [14] has bidirectional power flow capability utilizing a bidirectional converter and the transformer. The presence of isolated transformer and its noisy operation, make the system unreliable and inefficient.

The another system discussed in [20], is able to acknowledge most of the constraints of conventional systems but the incapability to handle the disturbance generated in the grid side and inefficient MPPT controller, make system unsuitable. Moreover, the limited operating area for MPPT execution, losses due to boost converter and large DC link capacitor, make the system impractical for solar powered water pumps. Such, a hybrid arrangement including PV array, a battery and utility grid, is discussed in [16].

In this system, PV array charges the battery and then water pump is run with the discharging of the battery. The utility grid is connected with an optional switch. The complete system becomes costly due to presence of a battery. All these abovementioned topologies are double stage, need large size DC link capacitor and have no provision to handle the disturbance in the grid parameters. So, a single stage system without DC-DC converter and having the capabilities to handle all these issues yet to be developed.

Therefore, the present single stage PV array powered SRM driven water pumping system with proposed controller, has multiple intents such as DC offset rejection, harmonic components removal, efficient MPPT tracking and DC link current compensation.

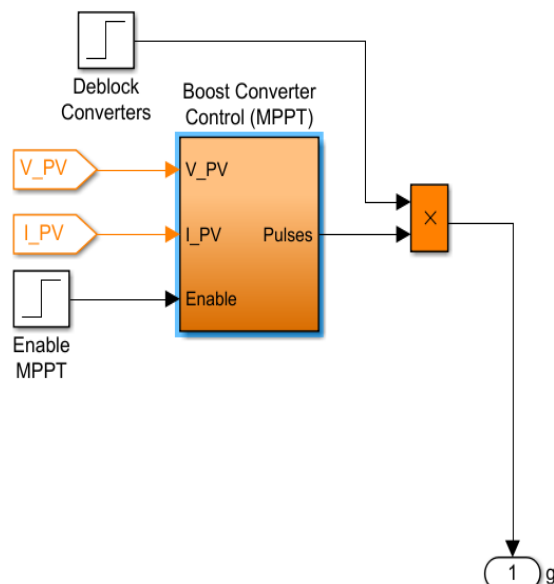


Fig 3. Boost Converter Simulink Model.

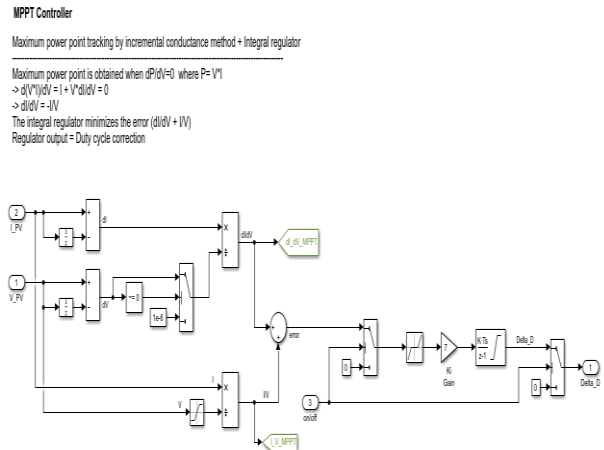


Fig 4. MPPT simlink model.

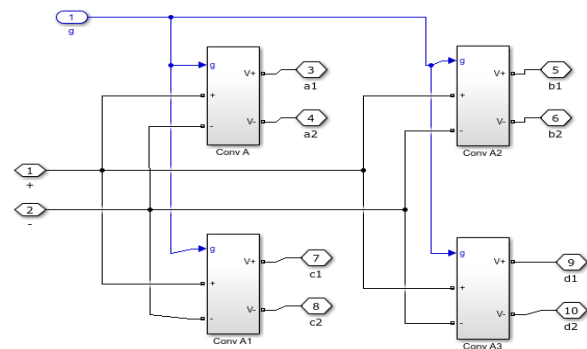


Fig 5. Converter Simulink Model.

IV. BIDIRECTIONAL DC-DC CONVERTER

When buck or boost converters are related together in an antiparallel fashion, the resulting circuit basically has same construction as the basic buck or boost structure, but with the additional bi-directional power flow function. The following figure shows basic structure of a non-isolated half-bridge bidirectional DC-DC converter.

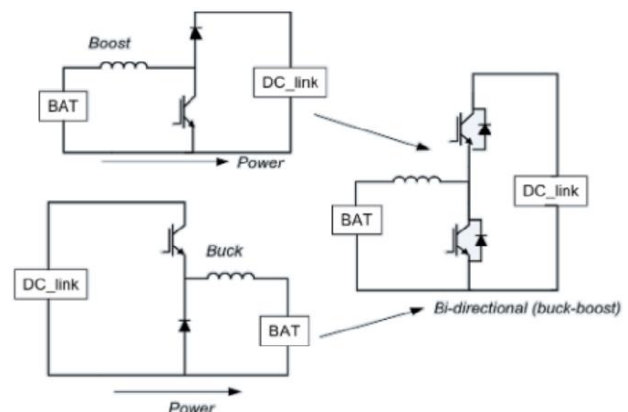


Fig 6. Bidirectional Dc-Dc Converter.

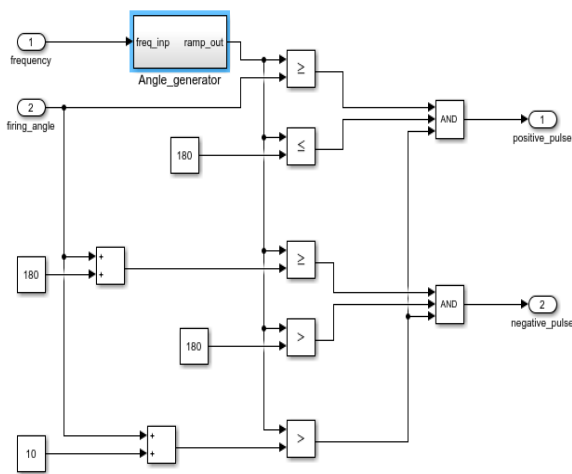


Fig 7. Motor Subsyem.

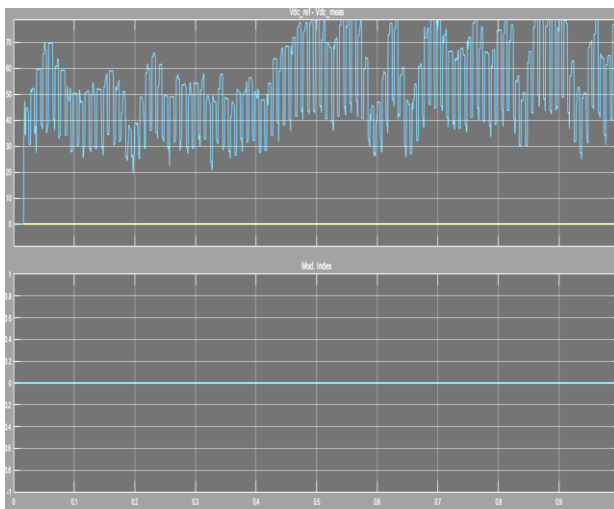


Fig 8. Output Mode Index And Voltage Source Converter.

The logic to commutate the srm converter at fundamental frequency while doing the mppt tracking through VSC has enhanced the efficiency of overall system.

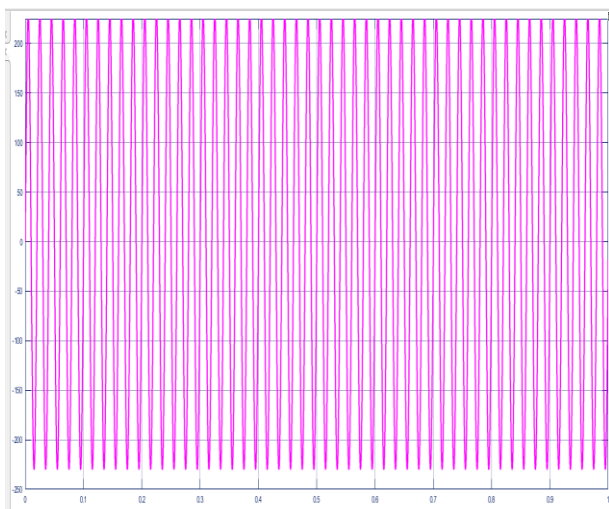


Fig 9. Grid Power.

Under situation when the solar power is completely absent and the pump is driven only through the grid power. Illustrates the grid components, 'vg', 'ig', and SRM indices 'ipha' and speed.

Both 'vg' and 'ig' are in phase and govern the supply of grid power to the load illustrates the system operation, when only grid is feeding the pump.

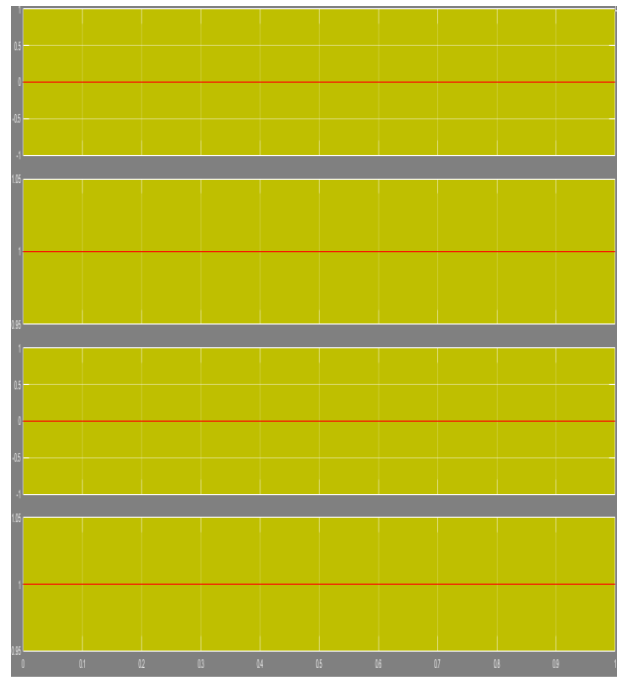


Fig 10. Switching Pulses.

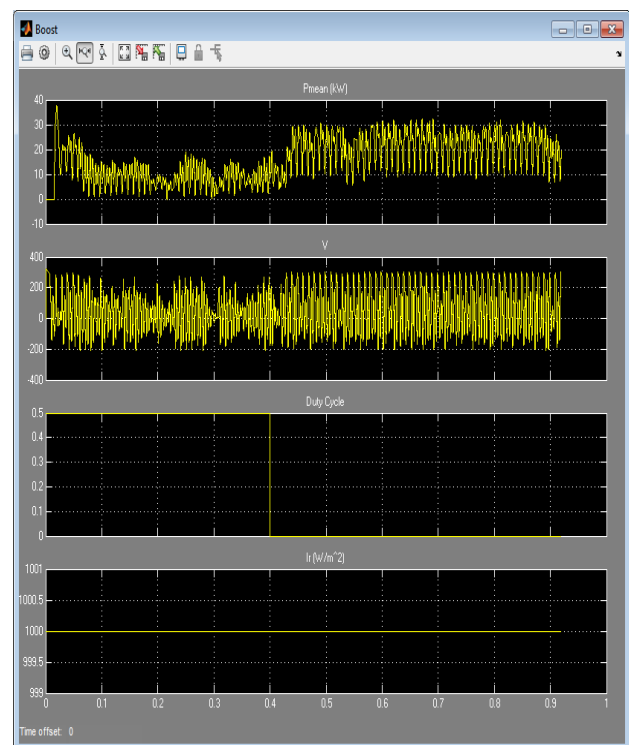


Fig 11. Boost Converter Output.

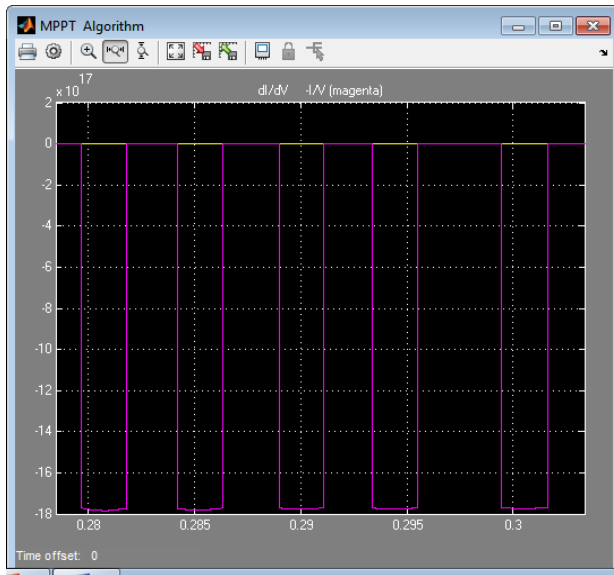


Fig 12. MPPT Output.

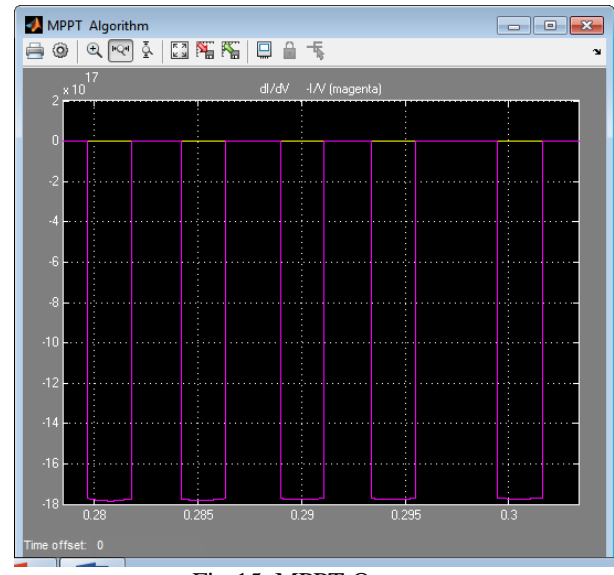


Fig 15. MPPT Output.

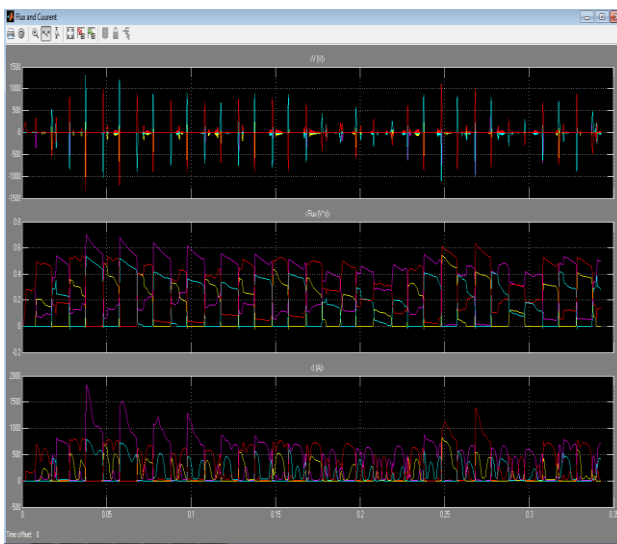


Fig 13. Flux and Motor Current.

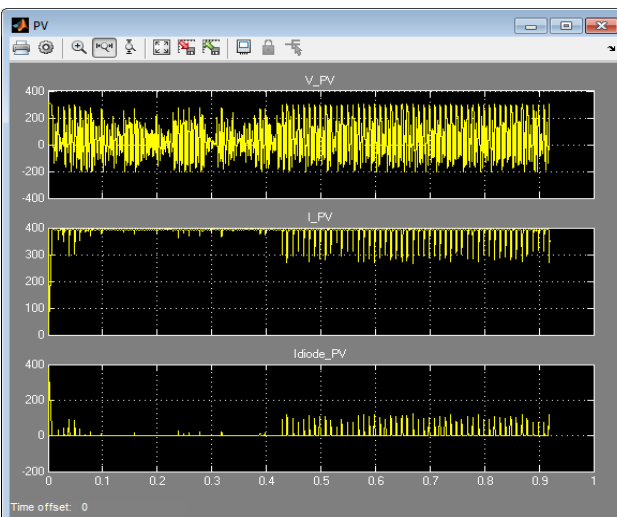


Fig 14. Solar Panel Output.

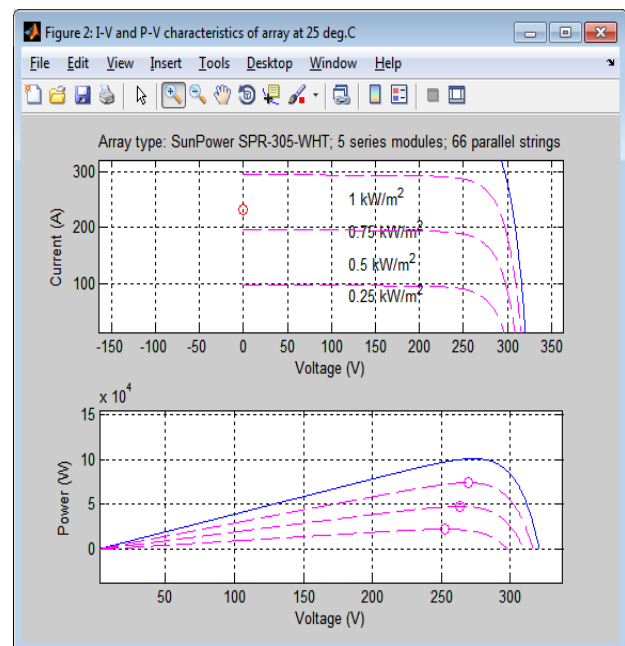


Fig 16. Solar Voltage At Different Irradiance Level.

The developed control technique has merits of eliminating the effect of grid voltage imbalance as well as DC offset, demonstrates the performance under both the conditions when there is change in insolation from 1000W/m² to 200W/m² and then when PV power is totally unavailable. Fig. 9 (a) shows the insolation, 'V_{pv}', 'P_{pv}', 'i_g', 'v_g' and 'N'.

The drive speed remains constant under variation in solar irradiance and DC link voltage tracks the 'V_{pvref}' value at all irradiance levels. The magnitude of 'i_g' is increasing under decrease in insolation levels to meet the power demand of the pump. Besides, when P_{pv}=0, the total power needed by motor-pump system is supplied by the grid while maintaining the PQ of utility grid.

Moreover, the smooth variation in the grid current under change in irradiance governs the effectiveness of PV feed-forward term incorporated in proposed.

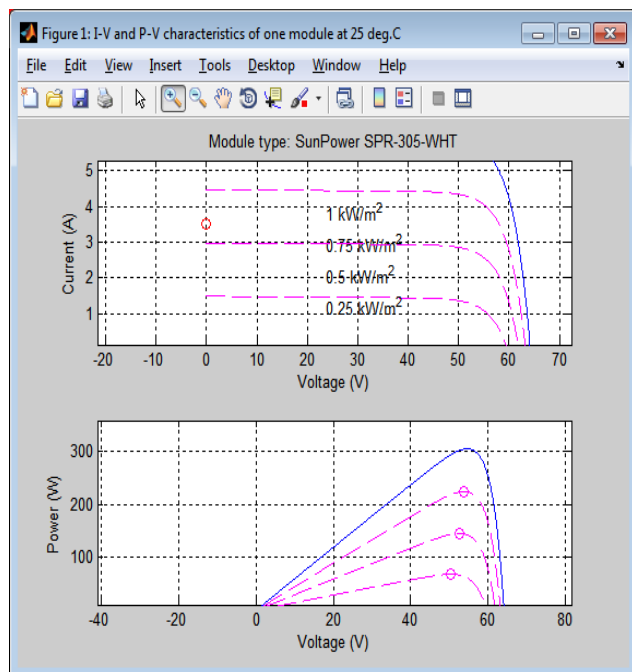


Fig 17. Solar power and voltage at different irradiance level.

As far as the condition of rapid change of insolation, the proposed system with proposed MPPT controller, has proficiently handle the rapid change of insolation by quickly adjust the DC link voltage and therefore speed of the motor drive as the logic given in Fig.1. So, the technique to control the speed of SRM drive via PWM control is highly effective in continuously changing insolation levels.

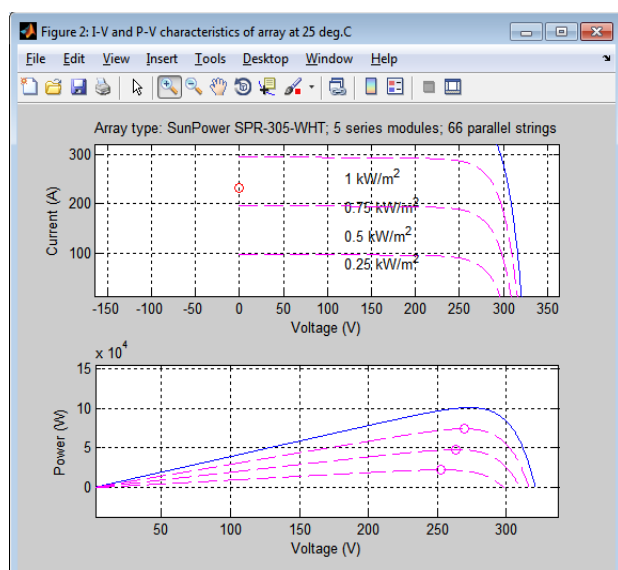


Fig 18. Solar power and voltage at different irradiance level.

The characteristics of motor speed and one of the winding current under the change in PV power due to variation in insolation level from 1000W/m² to 600W/m² and from 600W/m² to 1000W/m² are shown in Figs.12 (a) and (b). Both the figures govern the smooth performance of proposed system even when the PV power is less than motor power and grid is absent.

V. CONCLUSION

Here, PV pumping system has been analyzed with its scope and limitations. Photovoltaic systems are especially designed to supply water and irrigation in areas where there is no mains electricity supply. Their main advantages over hand pumps or internal combustion engine pumps are their practically zero maintenance, their long useful life, that they do not require fuel, that they do not contaminate, and finally that they are straightforward to install.

Another important characteristic is that, as they use the sun as their energy source, the periods of maximum demand for water coincide with the periods of maximum solar radiation. When compared to diesel powered pumping systems, the cost of solar PV water pumping system without any subsidy works out to be 64.2% of the cost of the diesel pump, over a life cycle of ten years. Solar pumps are available to pump from anywhere in the range of up to 200m head and with outputs of up to 250m³/day.

In general photovoltaic pumps are economic compared to diesel pumps up to approximately 3kWp for village water supply and to around 1kWp for irrigation. Solar Photovoltaic (SPV) sets represent an environment-friendly, low-maintenance and cost effective alternative to irrigation pump sets which run on grid electricity or diesel. It is estimated that India's potential for Solar PV water pumping for irrigation to is 9 to 70 million solar PV pump sets, i.e. at least 255 billion lit/year of diesel savings.

A solar irrigation pump system methods needs to take account of the fact that demand for irrigation system water will vary throughout the year. Peak demand during the irrigation system seasons is often more than twice the average demand. This means that solar pumps for irrigation are under-utilized for most of the year. Attention should be paid to the system of irrigation water distribution and application to the crops. The irrigation pump system should minimize water losses, without imposing significant

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