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Intelligent Grid Interfaced Solar Water Pumping System

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Abstract

This paper deals with a single stage solar powered speed sensorless vector controlled induction motor drive for water pumping system, which is superior to conventional motor drive. The speed is estimated through estimated stator flux. The proposed system includes solar photovoltaic (PV) array, a three-phase voltage source inverter (VSI) and a motor-pump assembly. An incremental conductance (Inc.) based MPPT (Maximum Power Point Tracking) algorithm is used to harness maximum power from a PV array. The smooth starting of the motor is attained by vector control of an induction motor. The desired configuration is designed and simulated in MATLAB/Simulink platform.

Keywords: Brushless DC Motor, Water Pump, Solar, Photovoltaic Array, Buck-boost Converter, Voltage Source Inverter.

1. Introduction

A grid-connected PV power network is an energy producing system depends on PV controller structure that is accompanying with the usefulness grid. A method connected PV structure contains solar-powered panels, one or rare inverters, an energy molding unit and grid-connected equipment. They go from a little residence and commercial rooftop structures to large utility-scale sun-powered stations. Not at all comparable remain standalone power frame work; a network associated frame once in a while incorporates a coordinated battery arrangement, as they are still costly. At the point when conditions are correct, the grid associated PV framework supplies the excess power, past utilization by the associated load, to the utility grid. The association of the PV power framework can be made through an interconnection between the user and the administrative organization. The protocol details the various safety standards to be followed by the connection. Sunlight based power accumulated by photovoltaic panels, intended for delivery to a power grid, must be adapted, or handled for use, by a network associated inverter. On a fundamental level, an inverter changes the DC input voltage from the PV to AC voltage for the grid. This inverter sits between the sun based exhibit and the grid, draw energy from each, and maybe a sizeable stand-alone unit or may be a collection of small inverters, each physically attached to individual solar panels.

2. Literature Review

[I]Sharma, U., Singh, B., & Kumar, S. (2017). Intelligent grid interfaced solar water pumping system [1] proposed a solar photovoltaic (SPV) water pumping system integrated with the single phase distribution system by utilising induction motor drive (IMD) with an intelligent power sharing concept. In addition to the power exchange from SPV to the IMD, a DC–DC boost converter is utilised as a power factor correction unit and a grid interfacing device. For good utilisation of SPV array, it is necessary to extract maximum power from the SPV array. To meet this objective, an incremental conductance based maximum power point tracking control is implemented. Whereas, to control the IMD tied to voltage source inverter, a simple voltage/frequency control technique is used. The proposed topology is designed and tested in the laboratory under standalone, grid interfaced and in mixed mode under various operating conditions.

Diesel-powered pumps are widely employed in farming and grassland irrigation. However, there can be problems of reliability and availability where fuel supply is erratic and expensive, high maintenance cost, and short life expectancy. These and recent concerns for the environment associated with the diesel engines call for a viable alternative source of power for irrigational water pumping. Renewable energy sources have gained a lot of attention as a replacement for fossil fuels or as a supplement in hybrid systems. Solar-powered (photovoltaic) systems are one of the viable alternatives that have attracted considerable attention in this regard. They have been deployed in many remote regions for various applications, ranging from rural electrification and community water supplies to irrigation and livestock water supplies. Although photovoltaic (PV) systems generally have a high investment cost, it has many features which make it attractive as an alternative source of power for water pumping. It is clean, as it produces no carbon emission, it generates no noise, and it has low operational and maintenance cost.

[II]Aliyu, M., Hassan, G., Said, S. A., Siddiqui, M. U., Alawami, A. T., & Elam in, I. M. (2018). A review of solar-powered water pumping systems. Renewable and Sustainable Energy Reviews, [2] presents a detailed intensive review of solar-powered water pumping systems as reported in the literature to serve as a quick reference to researchers and engineers who are working or interested in the subject.

To make use of renewable energy sources is a critical need such as solar power to develop efficient and economical solutions to the energy crisis. This requirement is worsened in developing countries by the presence of unreliable electrical grids. An attractive solution is the use of solar based single phase micro-inverters feeding AC power to the grid. For the improvement of the efficiency of PV array in the photovoltaic system, there is a requirement of electronic power conversion and also the firmness of system. The photovoltaic water pumping system (PVWPS) is one of the needful applications for farmers in which solar energy supply can be used for agricultural process. The main objective is to produce higher output 2KW can be used for water pumping system for agricultural process is implemented using the DC to DC Boost Converter. In this work, improve the water pumping system and also improve the electrical efficiency of PV panels by reducing the operating temperature of the PV modules. The power circuit contains a DC to DC Boost Converter and an inverter with multistage to transform, as the voltage of grid is alternative current in nature and LCL filter. The demand of Control circuit is to get constant (DC) voltage at the output with the PV systems; it is continual varying in nature.

[III]Sundararaju, M. Hariprabhu, "Implementation Of Intelligent Grid-Interfaced PV With DC-DC Boost Converter Topology For Agricultural Water Pumping System K". [3], for a Grid-connected solar power plant with DC boost converter using sophisticated fuzzy rule set (SFRS) MPPT technique. Maximum power point tracking (MPPT) control is used to maximize the output power from a PV module with different operating conditions which gives the maximum system efficiency. Here, in [3], Boost Converter with MPPT technique and grid-connected PV represented by and has been simulated by using the SIMULINK. Over 97% efficiency has achieved at full load condition based on the sophisticated fuzzy rule set based grid connected PV water pumping system.

Dabra et al. Optimization of photovoltaic power system: a comparative study Protection and Control of Modern Power Systems [4] presents a comparative study of P&O, fuzzy P&O and BPSO fuzzy P&O control methods by using MATLAB software for optimizing the power output of the solar PV grid array. The voltage, power output and the duty cycle of the solar PV array are well presented and analyzed with an algorithm. The model consists of 66 PV Cells connected parallel and 5 PV cells connected in series to make solar PV array. The BPSO Fuzzy method generates 43.4820 MW output power more than P&O method and 150 KW more than P&O fuzzy method. This also shows that the time response of the photovoltaic system reduces to perturbations and insures the continuity of the operation at the time in response to the continued maximum power point. It also eliminates the fluctuations around MPPT.

[IV]Anoop J R1 , Reema N, "Evolution of Solar Powered Water Pumping System"[5] Simulation results also revealed that BPSO fuzzy P&O controller is more effective as compare with P&O and fuzzy P&O models Agriculture is one of the basic process which accounts for the sustainability of human kind. So scientific advancement in agriculture accounts directly for the economic and overall development of nation. Adaption of better irrigation methods will help in increasing the agricultural productivity. Solar water pumping was an important development in the area of irrigation. There are places where irrigation can't be dependent on electricity or other existing viable methods. In such circumstances Solar Water Pumping is an excellent alternative.

[V]Santos, L. M., Alves, A. J., Matias, C. A., & Calixto, W. P. (2017). Studies for the efficiency of a water pumping system for cooling and improving the electrical efficiency of photovoltaic panels [6], a study is carried out to improve the water pumping system, to be used to improve the electrical efficiency of photovoltaic panels by reducing the operating temperature of the modules. The methodology used modifications in the geometric height of the system and different types of pumping systems, with constant speed and variable speed using a frequency inverter. Through these changes it was verified that there were significant improvements on the cases of the structure elevation and the variation of the speed of the three-phase motor.

Jain, S., Karampuri, R., & Somasekhar, V. T. (2016). An Integrated Control Algorithm for a Single-Stage PV Pumping System Usi ng an Open-End Winding Induction Motor. [7], a single-stage solution for solar Photo Voltaic (PV) pumping system using a dual-inverter fed Open-End Winding Induction Motor (OEWIM) drive is presented. The three-level dual-inverter requires a low PV bus voltage compared to its conventional three-level counterpart.

This could avoid large string of PV modules and helps in reducing the voltage rating of the capacitors and semiconductor devices used in the system. This may further help in reduction of cost of the system. The proposed single-stage system is operated using an integrated control algorithm, which includes the Maximum Power Point Tracking (MPPT), V/f control and Sample-Averaged Zero-sequence Elimination (SAZE) Pulse Width Modulation (PWM) technique. While the MPPT algorithm ensures the extraction of maximum power from the PV source, V/f control improves the motor-pump performance. And further, the zero-sequence current is avoided by the SAZE PWM algorithm. Thus, the integrated control algorithm improves the overall performance of the system. Further, this paper also presents the details of system design and analysis of its dynamic behaviour during transient environmental conditions. The performance of the system is verified using MATLAB simulation and hardware prototype.

The transformerless inverters with leakage current suppression have become an urgent application tendency in gridconnected photovoltaic systems because of low cost and high efficiency concerns.

[VI]Cuiwhex guyliw Yang, B., & Luo, H. (2015). Hybrid-bridge transformerless photovoltaic grid-connected inverter [8], the half-bridge module and neutral point clamping (NPC) module are combined to derive an advanced hybrid-bridge transformerless inverter, which not only suppresses leakage current, but also reduces the required bus voltage compared to the conventional half-bridge or NPC inverters. A sinusoidal pulse-width modulation strategy without dead time is presented to enhance both the grid-connected power quality and system reliability. Furthermore, a detailed circuit performance comparison and practical evaluation are presented to show the clear advantages of the hybrid-bridge transformer less inverter. It also provides practical solutions for the leakage current minimisation by considering the contributing factors such as circuit parasitic parameters. Finally, a 3 kW prototype is tested to verify the theoretical analysis and main contributions of the study.

The deficit in electricity and high diesel costs affects the pumping requirements of community water supplies and irrigation; so using solar energy for water pumping is a promising alternative to conventional electricity and diesel based pumping systems. Solar water pumping is based on photovoltaic (PV) technology that converts solar energy into electrical energy to run a DC or AC motor based water pump.

[VII]S.S. Chandel a,n , M. Nagaraju Naik a , Rahul Chandel, "Review of solar photovoltaic water pumping system technology for irrigation and community drinking water supplies" [9] is to present a comprehensive literature review of solar pumping technology, evaluate the economic viability, identify research gaps and impediments in the widespread propagation of solar water pumping systems and technology. The study focuses on update on solar water pumping technology, performance analysis, optimum sizing, degradation of PV generator supplying power to pump, economic and environmental aspects and advances in PV materials and efficiency improvements. An update on the current state of research and utilization of solar water pumping technology is presented. Factors affecting performance of PV water pumping system, degradation of PV modules and efficiency improving techniques of PV water pumping systems are identified. Solar water pumping is found to be economically viable in comparison to electricity or diesel based systems for irrigation and water supplies in rural, urban and remote regions. The investment payback for some PV water pumping systems is found to be 4–6 years. The recent Indian incentives for PV pumping and policy initiatives for the promotion of solar water pumping in developing countries are also discussed. Potential follow-up research areas are also identified.

[VIII]B. Eker Trakia, "SOLAR POWERED WATER PUMPING SYSTEMS" [10] is to explain how solar powered water pumping system works and what the differences with the other energy sources are.

Agricultural technology is changing rapidly. Farm machinery, farm building and production facilities are constantly being improved. Agricultural applications suitable for photovoltaic (PV) solutions are numerous. These applications are a mix of individual installations and systems installed by utility companies when they have found that a PV solution is the best solution for remote agricultural need such as water pumping for crops or livestock. A solar powered water pumping system is made up of two basic components. These are PV panels and pumps. The smallest element of a PV panel is the solar cell. Each solar cell has two or more specially prepared layers of semiconductor material that produce direct current (DC) electricity when exposed to light. This DC current is collected by the wiring in the panel. It is then supplied either to a DC pump, which in turn pumps water whenever the sun shines ,or stored in batteries for later use by the pump.

3. Proposed System

3.1. System Methodology/Implementation Scheme

Presently a days, huge enlistment engine drives (IMDs) and force converters associated with the dispersion organize are the fundamental driver for the force quality decay. Industries, commercial foundations and families are exposed to poor force quality because of the enormous IMDs associated at purpose of regular coupling. Other than activity of enormous IMDs, utility voltage mutilation and unbalancing activity likewise crumble the force nature of circulation framework.

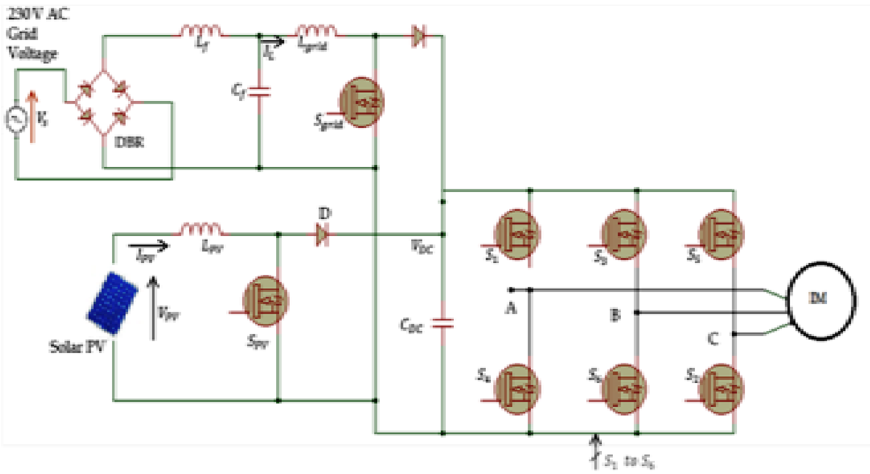

Figure.1. System configuration for the proposed intelligent grid interfaced solar water pumping system.

The structure, control and execution of a network interfaced unidirectional SPV took care of water siphoning framework. Fig. 1 depicts the framework arrangement for the proposed wise network interfaced SPV took care of water siphoning framework. The framework comprises of an IMD based siphon, a SPV exhibit, three force converters [two help converters and one voltage source inverter (VSI)], and one diode connect rectifier (DBR). VSI is utilized to give beat width tweaked AC voltage to the IMD. The network side lift converter is utilized to step up the voltage from amended framework voltage to the reference DC interface voltage just as for PFC at AC mains. The SPV boost converter is used for MPPT of SPV array. An L-C based EMI filter is connected at the output of DBR to eliminate the high switching ripple in AC mains. The data of the motor are given in appendix. A smart power sharing scheme between the two power sources is implemented. Whatever maximum energy from SPV array is available is given priority over the grid power on account of its negligible cost. The framework utilizes two lift converters, one for MPPT activity of a SPV cluster and other for PFC of the AC mains current. An INC algorithm is used for the MPPT while a closed loop current control is used for PFC operation in continuous conduction mode (CCM). Fig. 2 depicts the direction of power flow in three modes.

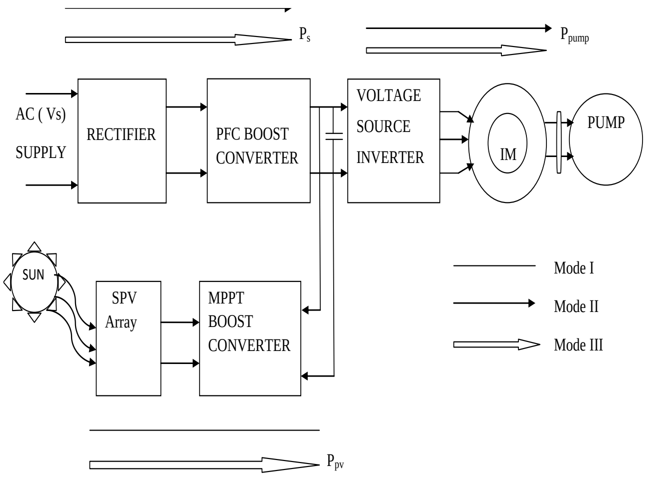

Figure. 2. Power flow in difference modes of operation

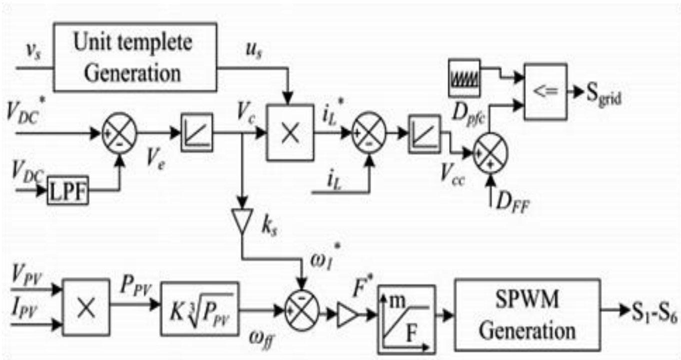

Figure.3. Control scheme for proposed grid interfaced water pumping system

Mode I: In nearness of sun based force for remain solitary activity, Mode I works. The lift converter at PV side builds the PV voltage from Vmp to reference voltage at DC transport while keeping up the PV working point at MPP. The DC transport voltage is kept up by PI controller which sets the reference speed/recurrence of IMD. As the force yield is relative to the speed of IMD, if there is an expansion in the DC transport voltage from the Reference esteem, overabundance power is taken care of into the siphon by speeding up and the other way around remains constant.

Mode II: This mode works when sun powered boards are separated or adequate radiation isn't accessible, for instance during evening. Single stage matrix supply is associated with a DBR, trailed by a lift converter, DC interface capacitor, VSI and an enlistment engine. The current drawn by a diode connect rectifier with DC interface capacitor is profoundly misshaped and isn't permitted by IEEE 519 standard. With a PFC support converter, the framework can draw a sinusoidal current from AC mains. Right now, engine runs at the appraised speed and gives an evaluated water release.

Mode III: This mode is in activity when the force from both SPV exhibit and framework are accessible. IMD separates the most extreme accessible force from the PV source, while taking the shortage power from the matrix supply. Under this mode, the framework expends significantly less force from the lattice even at appraised release, along these lines diminishing the weight on the network. Additionally, PFC help converter is utilitarian and keeps the THD of AC mains current under suitable cutoff points.

An IMD is controlled utilizing the scalar or V/f control calculation. A PI controller is utilized to control the DC interface voltage. A feed-forward term is determined from the force yield from the PV source utilizing the siphon's law and added to the PI controller's yield. The whole of the two amounts is the reference speed for acceptable execution of IMD with MPPT. The feed-forward term lessens the weight on PI controller and assists with improving the dynamic attributes of the framework. Produced reference speed is given to the scalar control square which decides the exchanging beats for the VSI. At beginning, the speed is sloped from halt condition, to a specific limit. From that point, the reference speed is determined from previously mentioned control conspire. Fig. 1c shows the control square chart for the lattice interfaced SPV water siphoning framework.

Where, ω_{ff} is the feed forward term. It reduces the burden on the DC link PI controller. An error V_e in the DC bus voltage is obtained by subtracting the actual DC bus voltage VDC from the reference DC bus voltage V_{DC}^*.

A proportional-integral (PI) controller is used to minimize V_c this error. The output of the PI controller is a signal.

$V_c(k) = V_c(k-1) + V_{pv}\{V_e(k) - V_e(k-1)\} + k_{iv}V_e(k)$ ……………………….........(1)

Where, k_{pv} and k_{iv} are the gains of the above mentioned PI controller. Moreover, this control voltage is fed to a proportional (P) controller for estimation of signal ω_1^*. The resultant reference speed ω^* for the induction motor is calculated by subtracting the ω_1^* from ω_{ff}.

$\omega_1^* = V_c(k) * k_s$ ……………………………..(2)

$\omega^* = \omega_{ff} - \omega_1^*$ ………………………………………………………………………….(3)

4. Simulation model & Result Discussion

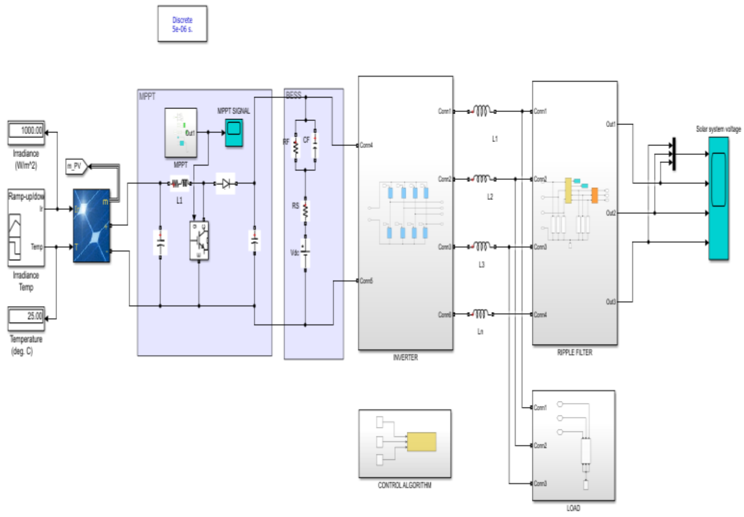

Figure. 4. Simulation Model

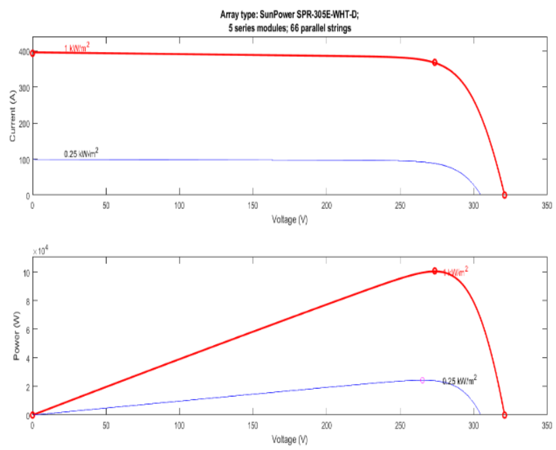

Figure.5. Solar 1

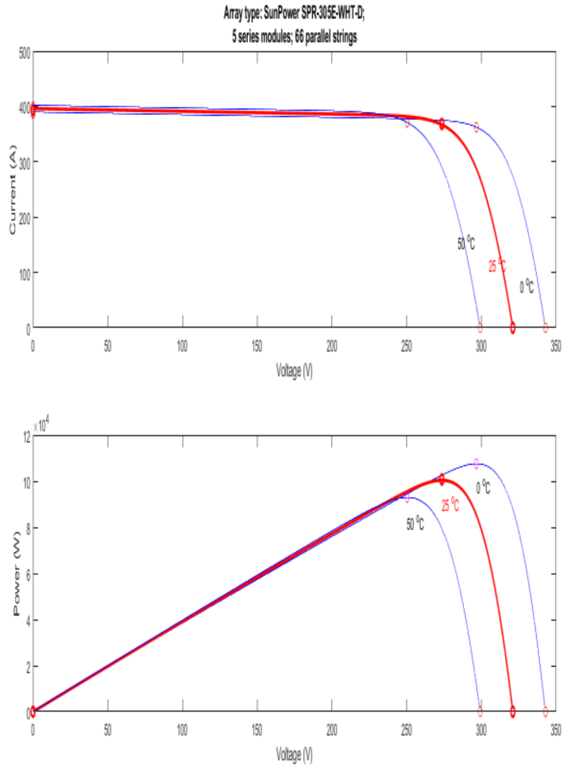

Figure.6. Solar 2

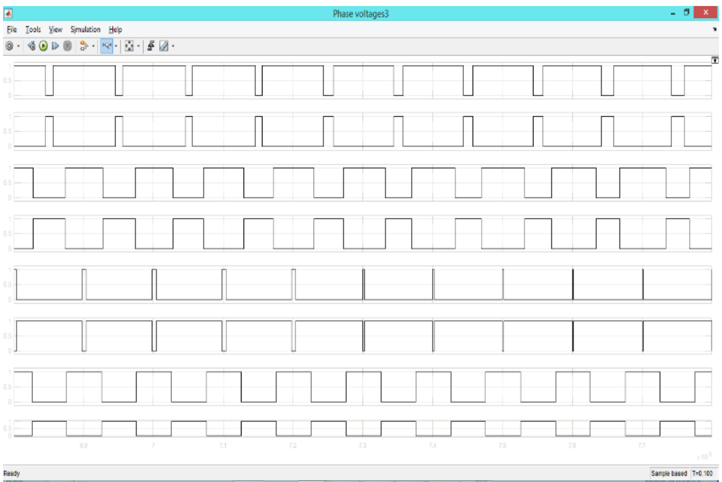

Figure.7. Control Signal

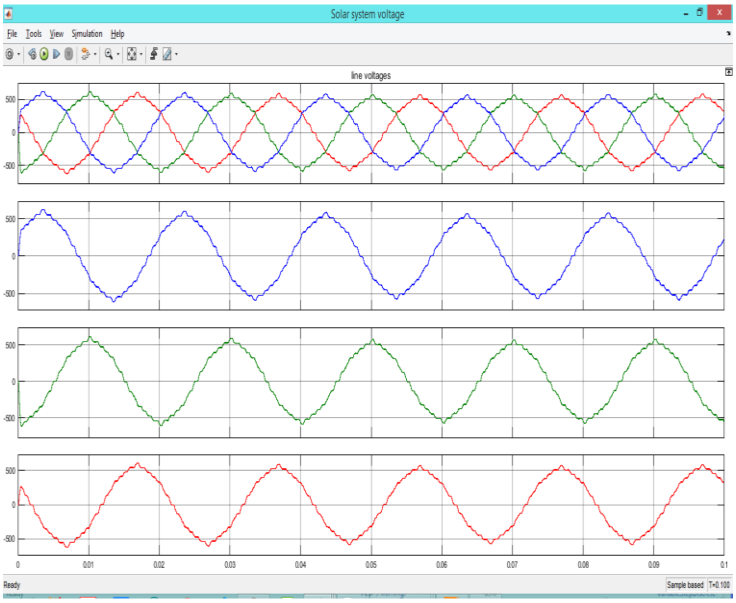

Figure.8. Output Voltage

5. Conclusion

An intelligent grid interfaced solar water pumping system has been modelled, simulated in MATLAB and experimentally verified in the laboratory. Different modes of operation of the proposed system have been elaborated. The simulated performance of the system at starting, steady state and under dynamic conditions has been validated through the experimental tests. The notable features of the proposed water pumping system are intelligent power sharing, power quality improvement at utility grid supply, elimination of speed sensor and simple scalar control of induction motor which is easy to implement. Moreover, the system is free from highly inductive transformer element, making it compact and efficient. The system manages to reduce the burden on the utility grid and is helpful in cutting down the electricity bill. The designed control scheme manages to draw maximum available power from SPV array without measuring the ambient temperature and radiation quantitatively. Moreover, irrespective of the available solar radiation, the pump provides the rated discharge, without any interruption in grid interfaced modes of operation. The performance of the proposed system at starting, in steady state and under dynamic conditions is observed to be satisfactory and the system is found suitable for water pumping in irrigation and household applications.

6. Future Scope

Nowadays, many farmers around the world have started implementing solar technologies on their farms. Solar PV and solar thermal technologies can be used in a wide range of applications, when it comes to the farming sector its application is water pumping. By interfacing MATLAB to the solar panel and grid it can be used not only for power sharing but also for the automation and controlling of water pumps in the agricultural fields. In fact, solar panels can be used to power an irrigation pump which can then be used to pump water for livestock. Solar dehydrators are another type of solar technology that is used in the agriculture industry. Using solar radiation to dry grain and crops is one of the oldest applications of solar energy. Solar dehydrators can dry crops faster than leaving them under the sun after harvest. This concept can also be further extended to few renewable resources like wind, etc. so that one can generate electricity on their own and can also control and analyse their grid or implemented equipment using MATLAB.

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