Design of Solar-PV Powered BLDC Motor Drive for Water Pumping System with Grid Integrated Features

[1]R. Subba Reddy, [2]V. Sobhan babu, [3]T. Kanishka, [4]M. Trisurya, [5]V. Yesuraju, [6]A. Krishna Prasad
[1]Associate Professor, [2,3,4,,56]UG Student
[1,2,3,4,5,6]Department of Electrical & Electronics Engineering
[1,2,3,4,5,6]Kallam Haranadhareddy institute of Technology, chowdavaram, Guntur (Dt); Andhra Pradesh, India.
Email: [1]rsreddy.tech@gmail.com, [2]babusobhan021@gmail.com

ABSTRACT

The full utilization of a PV array and motor-pump is made possible in addition to an enhanced reliability of the pumping system. A single phase voltage source converter (VSC) with a unit vector template (UVT) generation technique accomplishes a bidirectional power flow control between the grid and the DC bus of voltage source inverter (VSI), which feeds a BLDC motor. Additionally, regulation of DC capacitor voltage in UVT controller at a desired level using a PI controller is not suitable for enhanced PQ features. But, this controller is unpopular due to tuning issues of current controller; the above-mentioned issues are regulated by using novel intelligent based Fuzzy-Logic controller achieving good performance features. The proposed intelligent Fuzzy control schemes are highly used in several applications, has been greatly recognized due to enhanced performance over the classical PI controller. This work compares the performance of solar-PV and grid integrated water pumping system with classical PI and intelligent Fuzzy-Logic controller in PQ enhancement. The maximum power point (MPP) operation of a PV array and power quality improvements such as power factor correction and reduction of total harmonic distortion (THD) of grid are achieved in this system by using Matlab/Simulink platform, results are presented.

Keyword: *- Brushless DC motor, Unit vector template, Voltage source inverter, Maximum power point, Power quality, Fuzzy-Logic Controller, Total Harmonic Distortion*.

---

1. INTRODUCTION

Irrigation is a well-established procedure on many farms and is practiced on various levels around the world. The continuously increasing carbon emission and diminishing of fossil fuels encourage the instant consumers to adopt the renewable energy. A solar photovoltaic (PV) generation is emerging as the best alternative of conventional sources for various appliances. With reference to this, the water pumping has gained a broad attention in last few decades as a crucial application of PV energy. The DC motors have been used initially to pump the water followed by an AC induction motor. An innumerable research has been carried out on electric motor drives to improve the performance and efficiency of PV fed pumping systems with cost benefit. A permanent magnet brushless DC (BLDC) motor, due to its high efficiency, high power density, no maintenance, long service life, low electromagnetic interference (EMI) issues and small size, is being opted from last decade. It has been determined that introducing this motor reduces the cost and size of PV panels in addition to improved performance and maintenance free operation [1]-[3].

Being a grid-isolated or standalone system, the existing BLDC motor driven water pumps fed by a PV array rely only on solar PV energy. Due to its intermittency, the solar PV generation exhibits its major drawbacks, which results in an unreliable water pumping systems. In the course of bad climatic condition, water pumping is severely interrupted, and the system is underutilized as the pump is not operated at its full capacity. Moreover, an unavailability of sunlight (at night) leads to shutdown of the water pumping system. These short comings are required to be overcome in order to acquire a reliable PV based pumping system. Associated with a bidirectional control, the battery is charged and discharged during full and poor solar radiation (or no radiation) respectively, thus it ensures a full water delivery continuously. Contrary to it, introducing battery energy storage in PV based water pumping not only increases the overall cost and maintenance but also reduces its service life. A lead acid battery which is mostly used has a useful life of only 2-3 years [4]-[8].

All these aforementioned existing topologies of a PV based pumping systems present a unidirectional power flow control which either feeds the grid or draws power from the grid. A multifunctional system which may enable a bi-directional power flow depending on the operating circumstances such that both PV installation and pumping system are fully utilized, is yet to be developed. This work presents suchlike system employing first-time a BLDC motor drive. As mentioned, the proposed system deals with the development of a bi-directional power flow control, enabling the flow of power from PV array to the single phase utility grid in case a water pumping is not required, and from the grid to BLDC motor-pump in case the PV array power is not sufficient (or at night) to run the pump at its full capacity. This practice offers a source of earning to the consumers by sale of electricity to the utility. A unit vector template (UVT) generation, due to its simplicity and ability to serve the objective, is applied to perform a bi-directional power transfer. The proposed system also meets the power quality standards required by a utility grid as per IEEE-519 standard [9]-[15].

The MPPT (Maximum Power Point Tracking) of PV array is achieved by an incremental conductance (InC) technique using a DC-DC boost converter. The magnitude of stator current of BLDC motor at starting is controlled by operating the VSI (Voltage Source Inverter) in PWM (Pulse Width Modulation) mode for a pre-defined duration. The full utilization of a PV array and motor-pump is made possible in addition to an enhanced reliability of the pumping system. A single phase voltage source converter (VSC) with a unit vector template (UVT) generation technique accomplishes a bidirectional power flow control between the grid and the DC bus of voltage source inverter (VSI), which feeds a BLDC motor. Additionally, regulation of DC capacitor voltage in UVT controller at a desired level using a PI controller is not suitable for enhanced PQ features. But, this controller is unpopular due to tuning issues of current controller; the above-mentioned issues are regulated by using novel intelligent based Fuzzy-Logic controller achieving good performance features [16]-[18] .

The proposed intelligent Fuzzy control schemes are highly used in several applications, has been greatly recognized due to enhanced performance over the classical PI controller. This work compares the performance of solar-PV and grid integrated water pumping system with classical PI and intelligent Fuzzy-Logic controller in PQ enhancement. The maximum power point (MPP) operation of a PV array and power quality improvements such as power factor correction and reduction of total harmonic distortion (THD) of grid are achieved in this system by using Matlab/Simulink platform, results are presented.

2. CONFIGURATION OF PROPOSED WATER PUMPING SYSTEM

A configuration of the proposed water pumping system is presented in Fig.1, wherein a BLDC motor runs a water pump. A PV array feeds a BLDC motor-pump via a boost converter and VSI. The boost converter performs MPPT of PV array through InC algorithm while the VSI performs an electronic commutation of BLDC motor. An inbuilt encoder generates three Hall-Effect signals to carry out an electronic commutation. The DC bus of VSI is supported by a single phase utility grid. A voltage source converter (VSC) enables a bi-directional power transfer through a DC bus capacitor. The PV array feeds the grid only when water pumping is not required otherwise it is a preferred objective. An interfacing inductor is placed in the line to allow power flow between the grid and VSC, and to limit the harmonics current into the supply.

2.1 Conventional Water-Pumping System Using UVT-PI Controller Fed BLDC Motor

As discussed before, the proposed BLDC motor drive eliminates the phase current sensors. It is desired to operate the BLDC motor-pump at its rated speed irrespective of the climatic condition. This is achieved by continuously regulating the DC bus voltage of VSI at the rated DC voltage of BLDC motor. A bi-directional power flow control enables, by regulating the DC bus voltage and hence the operating speed, to deliver a full amount of power required to pump the water with full capacity. In case the grid is not available, the DC bus voltage is not maintained at the rated DC voltage of BLDC motor under bad climatic conditions, and the speed is governed by a variable DC bus voltage.

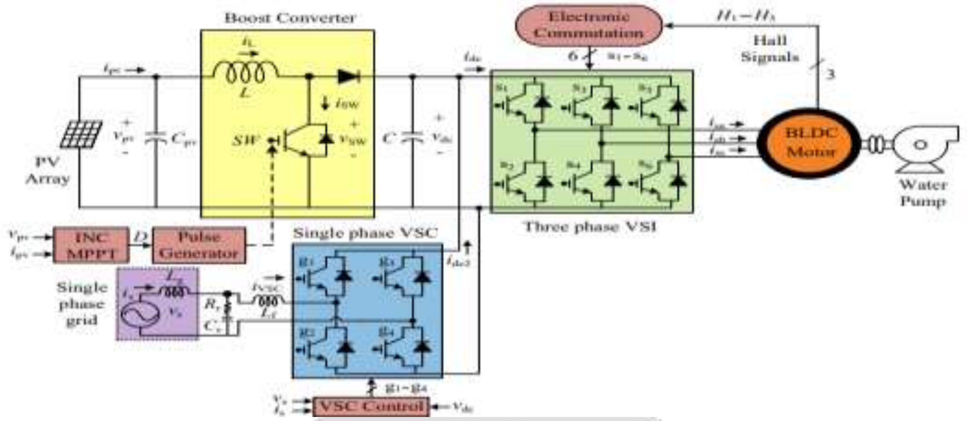


Fig.1 Schematic of the grid interactive PV array based water pumping system using a BLDC motor drive with UVT-PI Controller

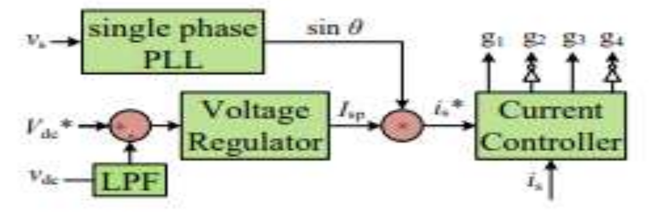


Fig.2 UVT-PI based bi-directional power flow control of VSC.

The development of reliable water pumping system and full utilization of the resources are realized by a grid interactive PV generation. To allow the flow of power in either direction, a bi-directional power control based on a UVT generation is applied as shown in Fig.2. This is the simplest technique and is easy to implement as it does not require any complex mathematical model or algorithm. A single phase PLL (Phase Locked Loop) is used to synchronize the utility grid voltage and current. It generates a sinusoidal unit vector of supply voltage, sin θ at fundamental frequency. On the other hand, an amplitude of fundamental component of supply current, Isp is extracted by regulating the DC bus voltage, Vdc. A proportional-integral (PI) controller is used as a voltage regulator. Vdc is sensed and passed through a first-order low pass filter to suppress the ripple contents. The filtered Vdc is then compared with a set value, Vdc*. A fundamental component of supply current, is* is extracted by multiplying Isp and sin θ. The sensed supply current, is is compared with is* and error is processed through a current controller to generate the gating pulses for VSC. When it is required to draw power from utility, the voltage regulator generates a positive Isp. Therefore, an in-phase supply current is drawn from the grid. Likewise, when the utility is fed by PV array, a negative Isp is generated resulting in an out-of-phase supply current. Thus, by reversing the direction of current, direction of power flow is controlled as per the requirement. An improved power quality at the utility grid is also ensured by the applied control technique in terms of total harmonic distortion (THD) and power factor. In case the grid is not available, the DC bus voltage cannot be regulated. Nevertheless, the PV array is able to feed the water pump in standalone mode although being sensitive to the climatic condition.

3. PROPOSED FUZZY LOGIC CONTROL SCHEME

The proposed fuzzy controller has been used extensively for many applications in control engineering, automation which is related to associate problems is designed easily. By utilizing the fuzzy evolution method which is relative functions of qualities work for designing the real time control objective. The fuzzy system in the process/plant is reflected by the control action of the design capabilities in both experience as well as intuitive specific functioning manner. It is mostly commanded for the control scheme of resembled on efficient mathematical plant model. The fuzzy control strategy uses the linguistic information which has many advantages may include the high robust performance, greater strength, model free, attain the universal approximation theorem with rule based algorithm has been selected.

The fuzzy logic controller has been distinctly characterized by the input data coming from the fuzzy scheme as depicted in Fig.3. Automatic translation of fuzzy from the overall fuzzification process, this fuzzy process is carried out by the effective control action. The creation of input information with the evaluation of the IF....THEN rules which are produced by the several linguistics logics. After the fuzzification process the rule processing stage reaches at the point of outcome summary, de-fuzzification process is started. The de-fuzzification process is carried during the final stage; the coming inferences are transformed to real data output by fuzzy enhancer. Hence, data is utilized as interfaced module for the need of processing.

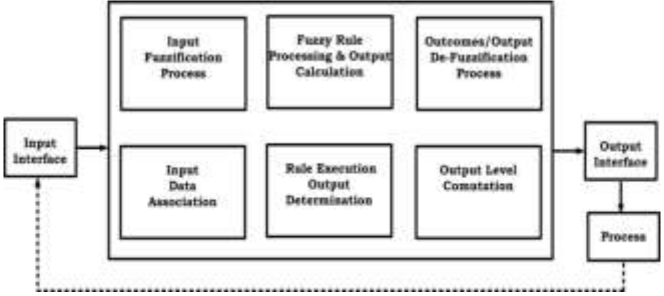


Fig.3 Block Diagram Representation of Fuzzy Control Logic

The operational logics of the fuzzy logic control objective have been illustrated by linguistic nature is differentiated from the mathematical notations. In spite of linguistic terms delivers the derived methods that are most enhanced and feasible operational characteristics. This fuzzy logic control objective belongs to the symbolic nature control action that regards to a special class. The configuration of fuzzy logic inference control objective is depicted in Fig.4.

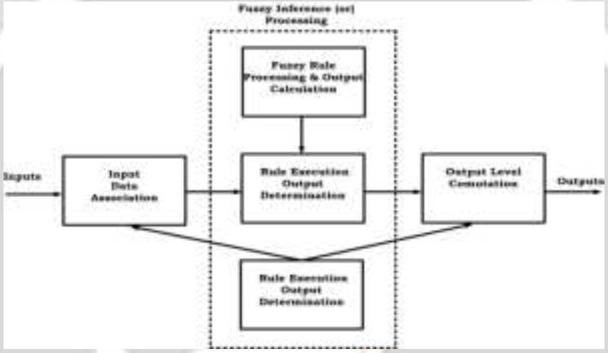


Fig.4 Configuration of Fuzzy Logic Inference Control Objective

The proposed fuzzy-logic controller membership functions are depicted in Fig.5 and the rule base is illustrated in Table.1. The block diagram of proposed Fuzzy-Logic Controlled water-pumping system is depicted in Fig.6.

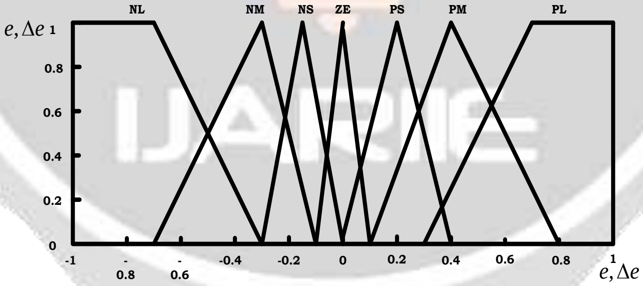


Fig.5 Fuzzy Logic Membership Functions

Table.1 Fuzzy Logic Rules

e / Δe	**NB**	**NM**	**NS**	**ZE**	**PS**	**PM**	**PB**
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	NM	NS	ZE	PS	PM	PB

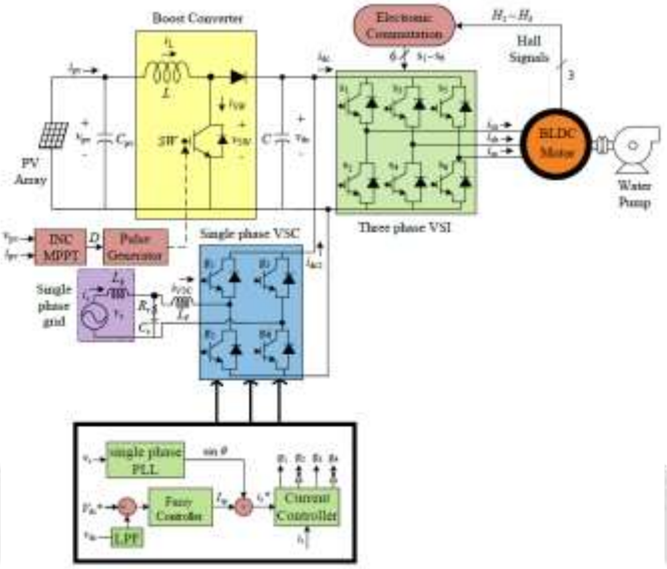


Fig.6 Block Diagram of Proposed Grid Interactive Solar PV Fed BLDC Motor Drive Based Water Pumping Using Proposed Fuzzy Controller

4. MATLAB/SIMULINK RESULTS & ANALYSIS

The Matlab/Simulink modelling is carried based on various cases and the proposed models are developed by using described system specifications illustrated in Table.2.

Table.2 System Specifications

S.NO	System Specifications	Values
1	Input Source Voltage	Vrms-230V, Fs-50Hz
2	Solar-PV System	Peak power = 1.5 kW; PV voltage = 200 V; PV current = 7.5 A.
3	DC-Link Capacitor	Vdc-270V, Cdc-1000 µF Interfacing inductor = 3.3 mH, R-C filter = 5 Ω, 5 µF
4	Switching Frequency	Fs-5KHz
5	BLDC Motor	V-270V, Speed = 3000 rpm; Stator resistance = 3.58 Ω; Stator inductance = 9.13 mH

4.1 The Proposed Solar-PV Interface Grid Connected System Fed BLDC Drive System Is Verified Under Starting and Steady-State Condition Using Pi-UVT Control Scheme

4.1.1 When Only PV Array Feeds BLDC Motor-Pump

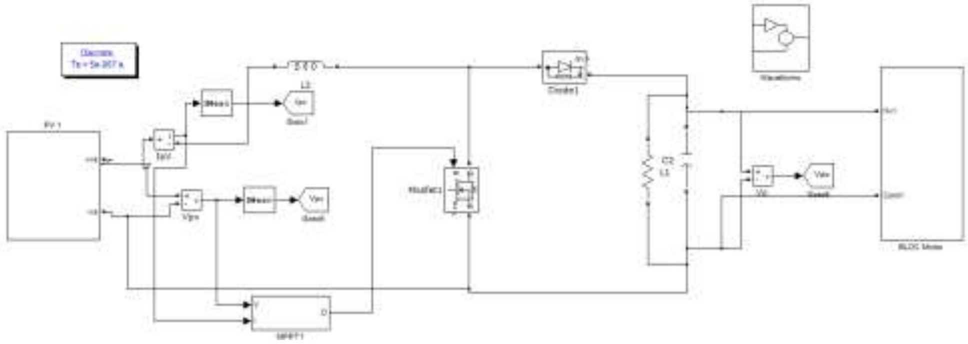
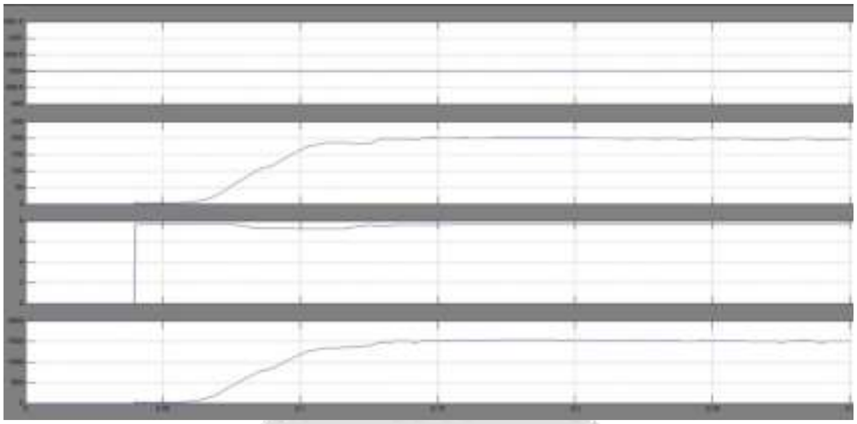
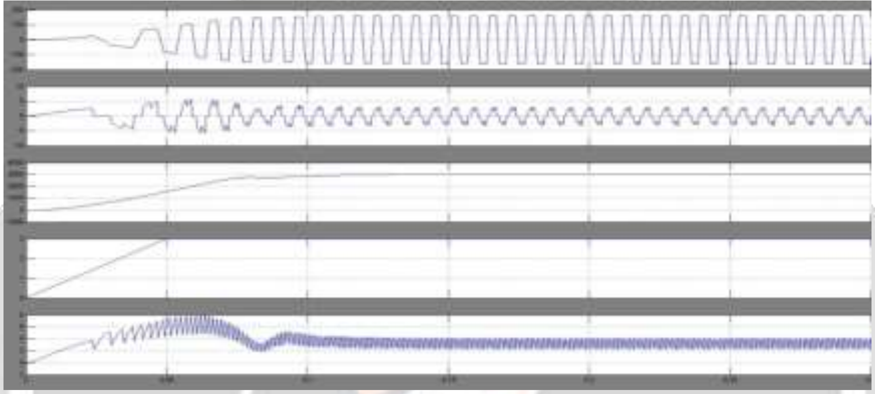


Fig.7 Matlab/Simulink Model of Proposed Solar-PV PV Feeds BLDC Motor-Pumping System



(a) PV Array Outcome



(b) BLDC motor-pump, when only PV array feeds BLDC motor-pump

Fig.8 Simulation Results of Proposed Solar-PV PV Feeds BLDC Motor-Pumping System

The Matlab/Simulink Model of Proposed Solar-PV PV Feeds BLDC Motor-Pumping System is depicted in Fig.7. The Simulation Results of Proposed Solar-PV PV Feeds BLDC Motor-Pumping System is depicted in Fig.8. It includes, (a) PV Array Outcome, (b) BLDC motor-pump, when only PV array feeds BLDC motor-pump, respectively. When PV array is operated at its MPP under the radiation level of 1000 W/m2. Therefore, the BLDC motor-pump is also operated at its full capacity and it runs at rated speed i.e. 3000 rpm. No grid power is required as the PV array generates a sufficient power to run the pump at its full capacity. The various indices refer to back-EMF, *e*a, stator current, *i*sa, speed, *N*, electromagnetic torque, *T*e, and load torque, *T*L. These results demonstrate a soft starting along with the successful steady state operation of the motor-pump.

4.1.2 When Only Utility Grid Feeds BLDC Motor-Pump

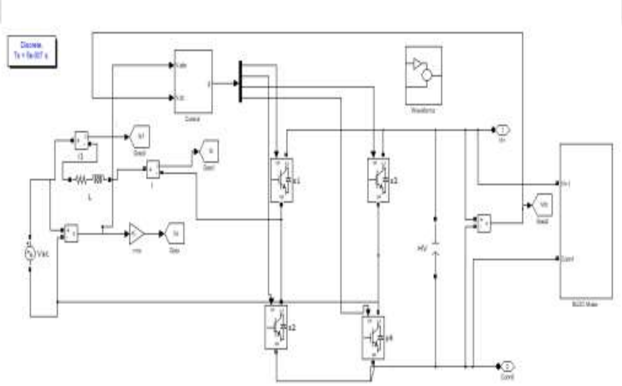
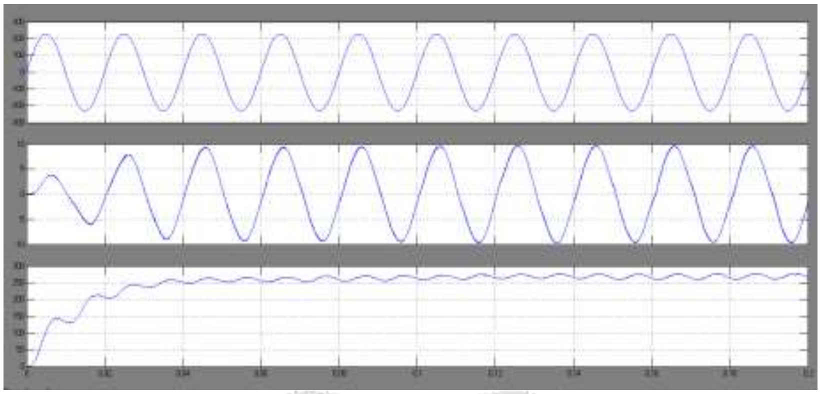
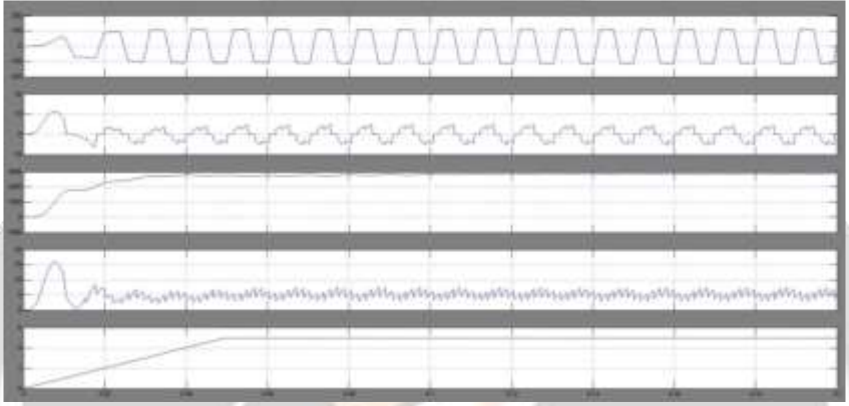


Fig.9 Matlab/Simulink Model of Proposed Utility Grid Feeds BLDC Motor-Pumping System



(a) Utility-Grid Outcome



(b) BLDC Motor-Pump Outcome

Fig.10 Simulation Result of Proposed Utility Grid Feeds BLDC Motor-Pumping System

The Matlab/Simulink Model of Proposed Utility Grid Feeds BLDC Motor-Pumping System is depicted in Fig.9. The Simulation Result of Proposed Utility Grid Feeds BLDC Motor-Pumping System is depicted in Fig.10. This operating condition occurs when water pumping is required at night. Fig.10 (a) depicts that an in-phase sinusoidal supply current of 8.3 A (rms) is drawn and DC bus voltage is maintained at 270 V. The motor draws a sufficient power from utility to run at full capacity, as shown in Fig.10 (b). A full utilization of pumping system is demonstrated in this case.

4.1.3 When Water Pumping is not required

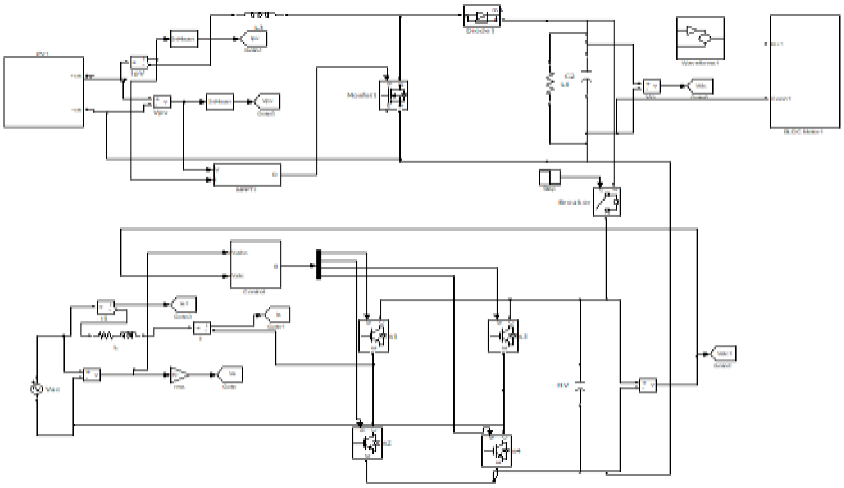
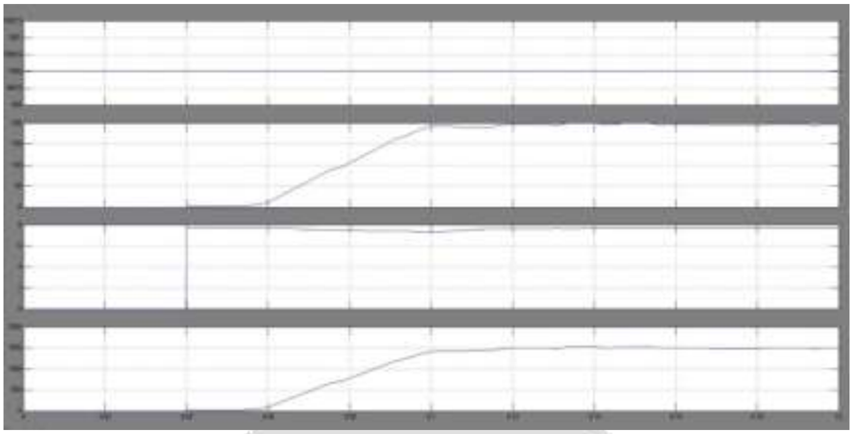
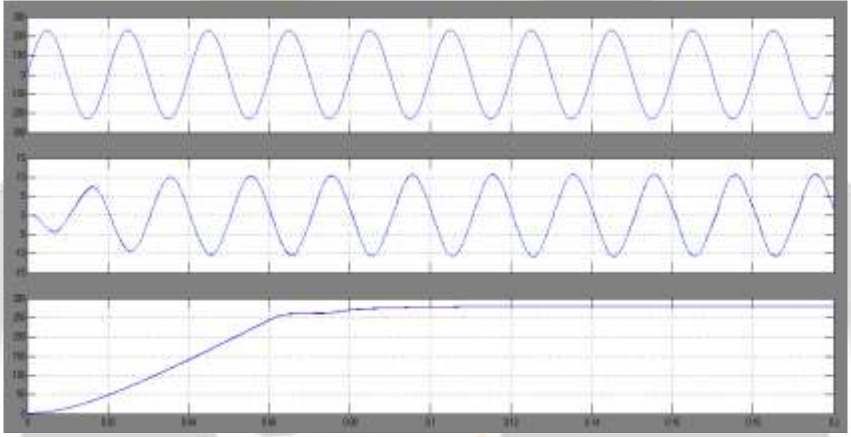


Fig.11 Matlab/Simulink Model of When Water-Pumping System is not required



(a) PV Array Outcome



(b) utility grid & DC-Link Voltage

Fig.12 Simulation Results of When Water-Pumping System is not required

The Matlab/Simulink Model of When Water-Pumping System is not required is depicted in Fig.11. The simulation results of When Water-Pumping System is not required is depicted in Fig.12. In this case, the pump is not operated and power generated by the PV array is fed to the utility grid. Fig.12 (a) shows the MPP operation of PV array at 1000 W/m2. Fig.12 (b) exhibits an out-of-phase sinusoidal supply current which indicates that the utility is fed by a PV array and the power flow is reversed while maintaining the DC voltage at 270 V.

4.2 The Proposed Solar-PV Interface Grid Connected System Fed Bldc Drive System is Verified Under Dynamic Condition Using PI-UVT Control Scheme

4.2.1 Transition from Grid Feeding Pump to PV Array Feeding *Grid*

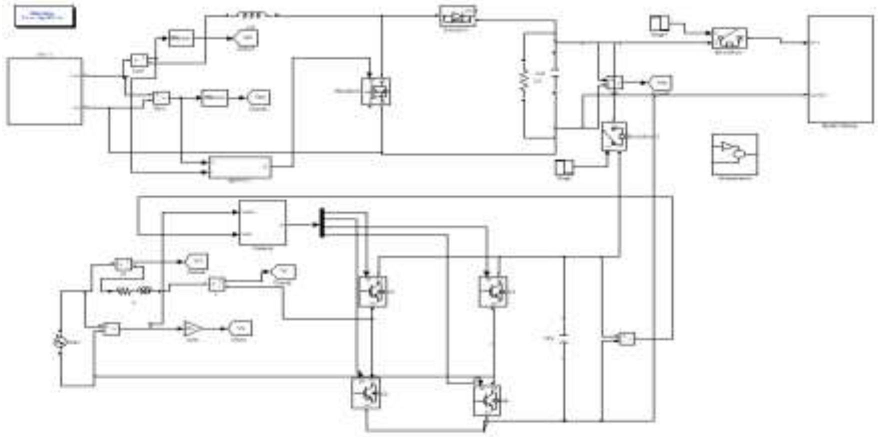
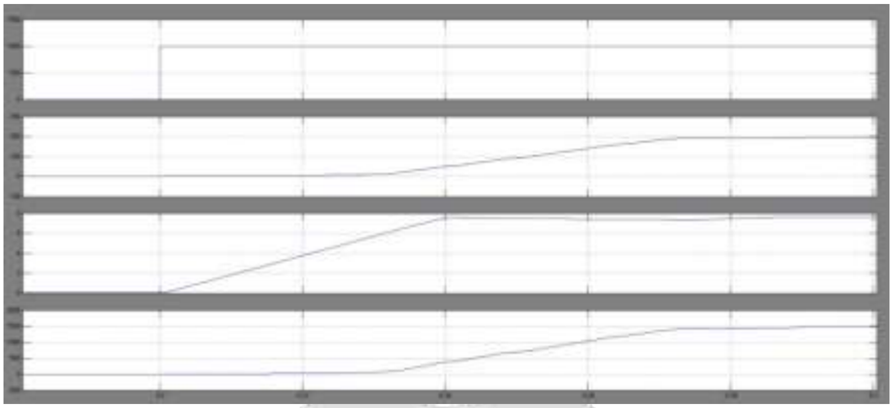
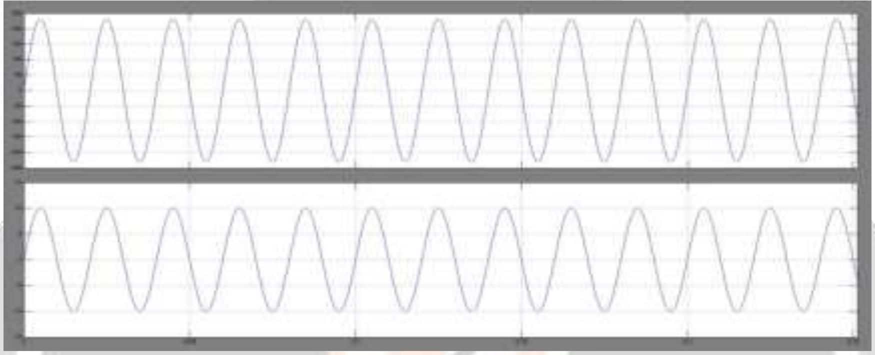


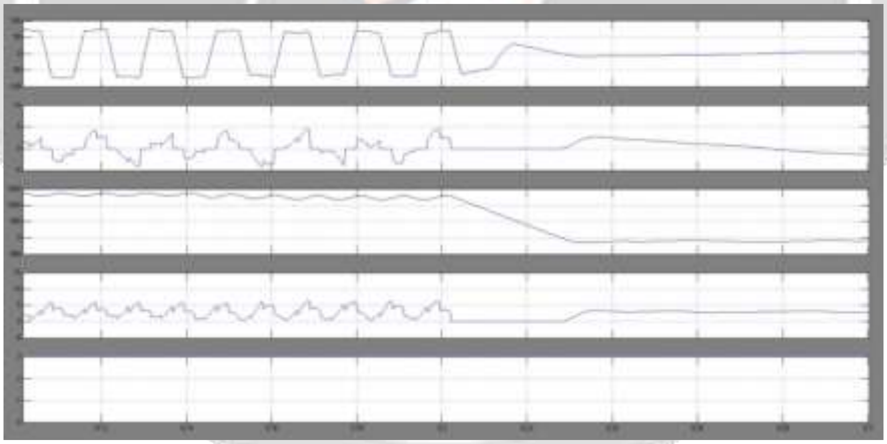
Fig.13 Matlab/Simulink Model of Water-Pumping System under a transition from grid feeding pump to PV array feeding grid



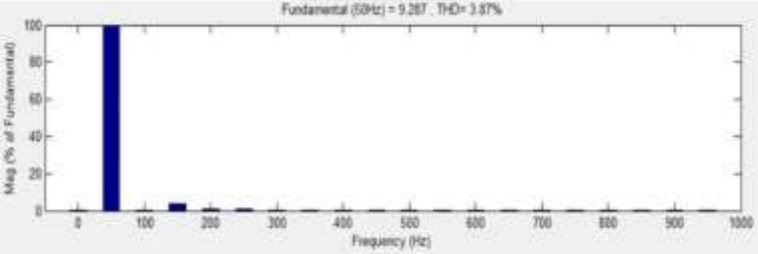
(a) PV Array Outcome



(b) Utility-Grid Outcome



(c) BLDC Motor Outcome



(d) The THD value of Grid Current

Fig.14 Simulation Results of Water-Pumping System under a transition from grid feeding pump to PV array feeding grid

The Matlab/Simulink Model of Water-Pumping System under a transition from grid feeding pump to PV array feeding grid is depicted in Fig.13. Simulation Results of Water-Pumping System under a transition from grid feeding pump to PV array feeding grid is depicted in Fig.14. This analysis assumes that the water pump is operated initially through utility grid when PV array power is not available. The mode of operation is suddenly changed by considering that the water pumping is no more required but PV array power is available. Therefore, it is desired now to feed the utility by PV array. The mode of operation is changed at 0.2 s. Figs.14 (a), 14(b) and 14 (c) respectively present the PV array indices, utility grid indices and BLDC motor-pump indices. As shown in Fig.14 (b), the direction of current flow reverses within a half cycle. The DC bus voltage is regulated at 270 V as shown in Fig.14 (c). A reduction in the speed starts at 0.2 s and motor-pump reaches standstill after a while as shown in Fig.14 (c). The THD value of grid-current is shown in Fig.14 (d), THD of supply current is observed as 3.87% which meets the IEEE-519 standard.

4.2.2 Transition from PV Array Feeding Pump to Both PV Array and Grid Feeding Pump

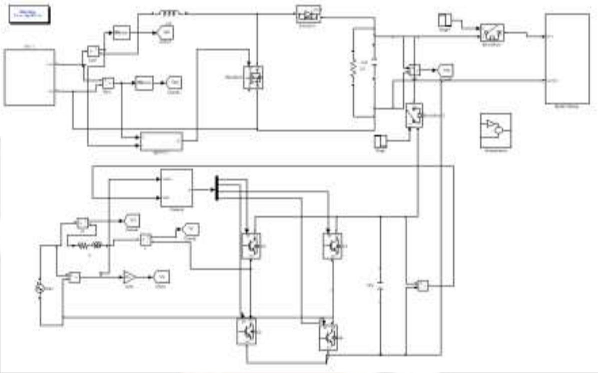
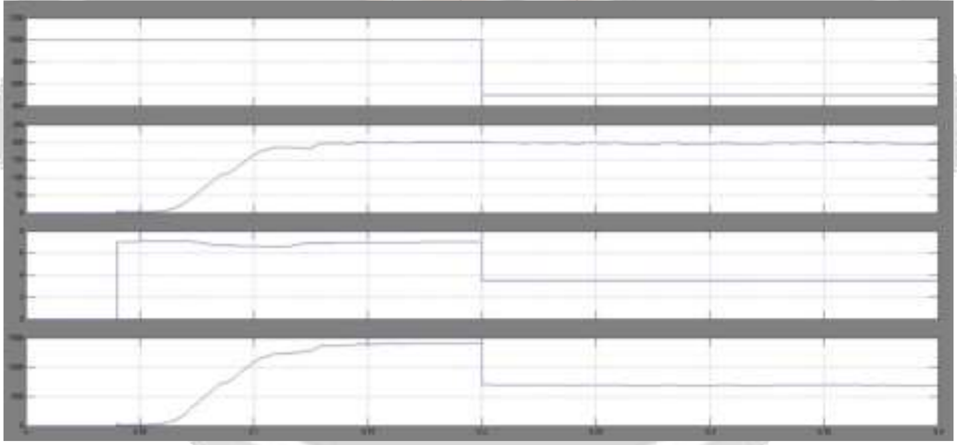
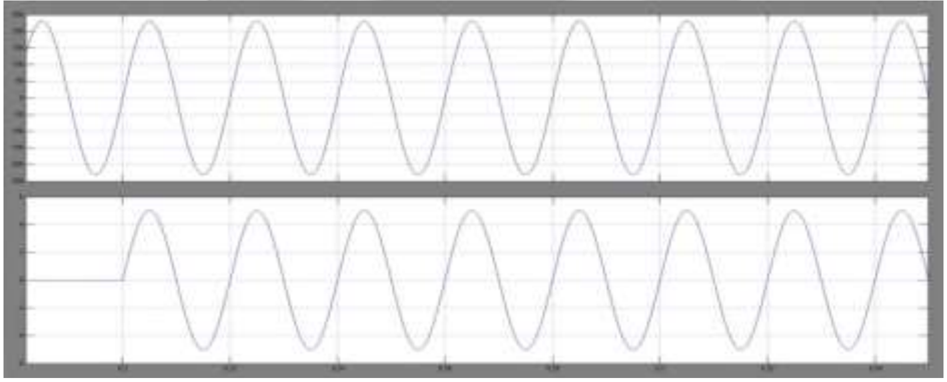


Fig.15 Matlab/Simulink Model of Water-Pumping System under a transition from PV array feeding pump to both PV array and grid feeding pump



(a) PV Array Outcome



(b) Utility-Grid Outcome

(c) BLDC Motor Outcome

Fig.16 Simulation Results of Water-Pumping System under a transition from PV array feeding pump to both PV array and grid feeding pump

The Matlab/Simulink Model of Water-Pumping System under a transition from PV array feeding pump to both PV array and grid feeding pump is depicted in Fig.15. Simulation Results of Water-Pumping System under a transition from PV array feeding pump to both PV array and grid feeding pump is depicted in Fig.16. In this case it is assumed that only the PV array is feeding the pump initially as it is sufficient to run the water pump at its full capacity. A reduction in radiation level from 1000 W/m2 to 500 W/m2 is observed at 0.2 s. Since the PV array alone is unable to run the water pump at its full capacity at 500 W/m2, it is desired to draw the remaining power from the utility. As shown in Fig.16 (a), the maximum PV array power reduces corresponding to a radiation level of 500 W/m2. Prior to 0.3 s, no power is drawn from the utility as shown by is in Fig.16 (b). From 0.2 s onwards, the remaining power is drawn from the utility resulting in a flow of in-phase supply current of 4.3 A (rms). Fig.16 (c) depicts that the motor-pump is operated at its full capacity regardless of climatic conditions. The motor runs at 3000 rpm as the DC bus voltage is regulated at 270 V.

4.3 The Proposed Solar-PV Interface Grid Connected System Fed Bldc Drive System is Verified By Using Fuzzy Logic-UVT Control Scheme

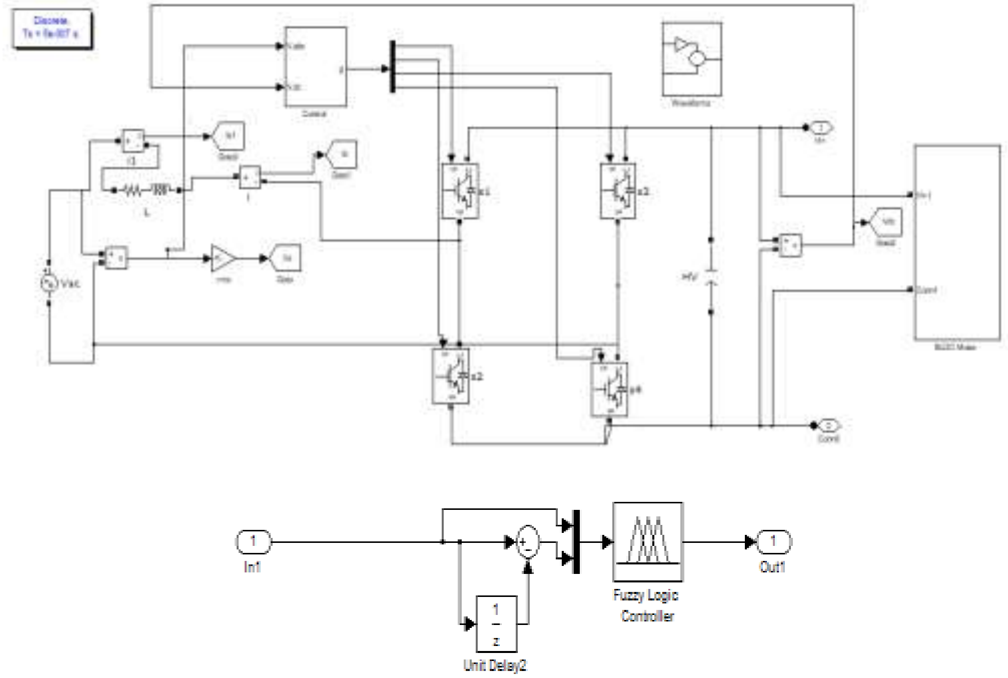
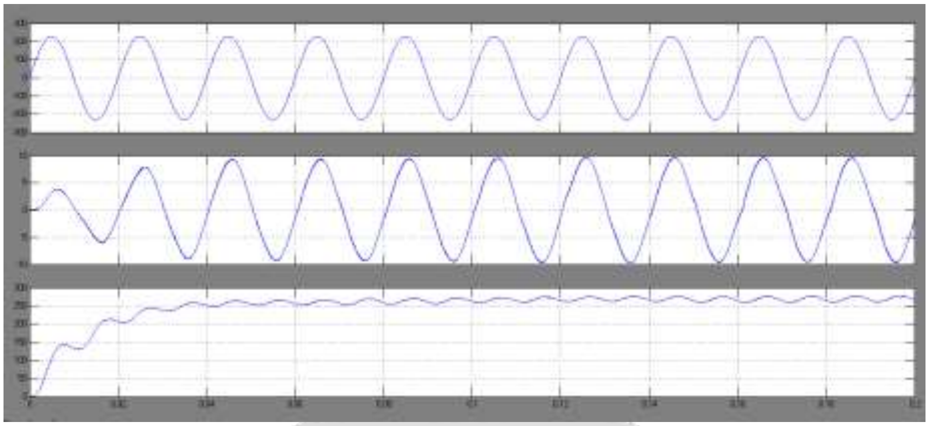
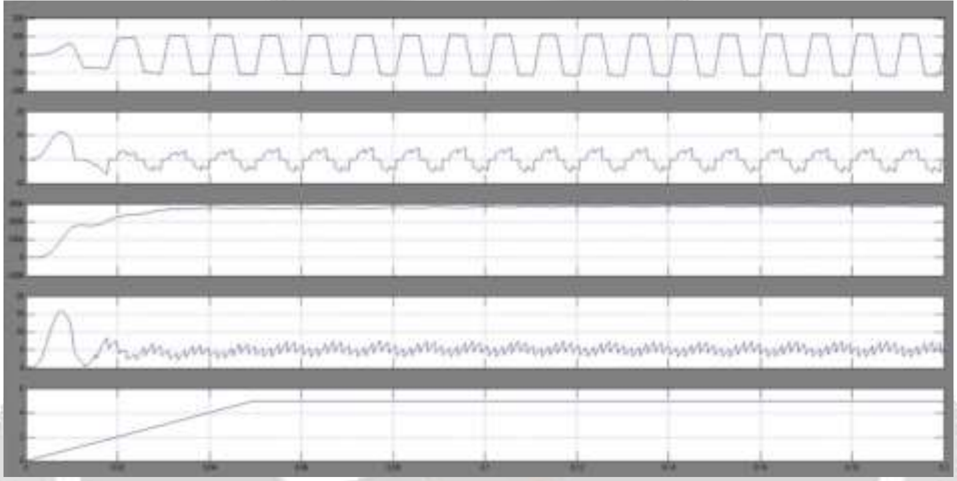


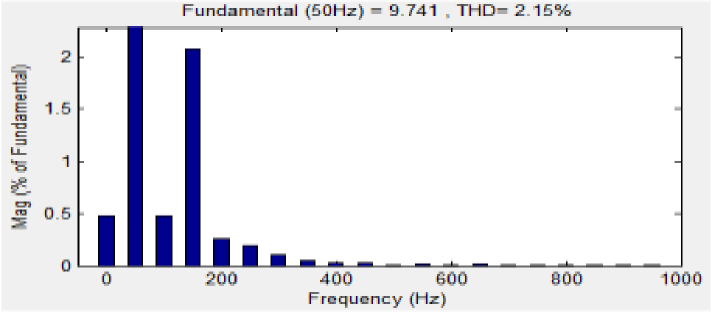
Fig.17 Matlab/Simulink Model of Proposed Utility Grid Feeds BLDC Motor-Pumping System in UVT-Fuzzy Control Scheme



(a) Utility-Grid Outcome



(b) BLDC Motor-Pump Outcome



(c) The THD value of Grid Current

Fig.18 Simulation Result of Proposed Utility Grid Feeds BLDC Motor-Pumping System

The Matlab/Simulink Model of Proposed Utility Grid Feeds BLDC Motor-Pumping System with UVT-Fuzzy-Logic control scheme is depicted in Fig.17. The Simulation Result of Proposed Utility Grid Feeds BLDC Motor-Pumping System with UVT-Fuzzy-Logic control scheme is depicted in Fig.18. This operating condition occurs when water pumping is required at night. Fig.18 (a) depicts that an in-phase sinusoidal supply current of 8.3 A (rms) is drawn and DC bus voltage is maintained at 270 V. The motor draws a sufficient power from utility to run at full capacity, as shown in Fig.18 (b). A full utilization of pumping system is demonstrated in this case. The THD value of grid-current is shown in Fig.18 (c), THD of supply current is observed as 2.15% which meets the IEEE-519 standard.

5. CONCLUSION

A single phase grid interactive solar-PV array based water pumping system using a BLDC motor drive has been proposed by using attractive control scheme. A bi-directional power flow control of VSC has enabled a full utilization of resources and water pumping with maximum capacity regardless of the climatic conditions. A simple

UVT generation technique has been applied to control the power flow as desired. All the power quality aspects have been met as per the IEEE-519 standard. The speed control of BLDC motor-pump has been achieved without any current sensing elements. A fundamental frequency switching of VSI has contributed to enhance the efficiency of overall system by reducing the switching losses. The proposed solution has emerged as a reliable water pumping system, and as a source of earning by sale of electricity to the utility when water pumping is not required. But, due to improper selection of PI control gains, the system stability goes to affected which is improved by using proposed intelligent fuzzy-logic controller. It reduces the sudden fluctuations and maintaining DC-link voltage as constant with enhanced features.

6. REFERENCES

[1] M. T. A. Khan, G. Norris, R. Chattopadhyay, I. Husain and S. Bhattacharya, “Autoinspection and Permitting With a PV Utility Interface (PUI) for Residential Plug-and-Play Solar Photovoltaic Unit,” *IEEE Trans. Ind. Appl*., vol. 53, no. 2, pp. 1337-1346, March-April 2017.

[2] M. Montorfano, D. Sbarbaro and L. Morán, “Economic and Technical Evaluation of Solar-Assisted Water Pump Stations for Mining Applications: A Case of Study,” *IEEE Trans. Ind. Appl.*, vol. 52, no. 5, pp. 4454-4459, Sept.-Oct. 2016.

[3] Billel Talbi, Fateh Krim, Toufik Rekioua, Saad Mekhilef, Abdelbaset Laib and Abdesslam Belaout, “A high-performance control scheme for photovoltaic pumping system under sudden irradiance and load changes,” *Solar Energy*, vol. 159, pp. 353-368, 2018.

[4] Packiam Periasamy, N.K. Jain and I.P. Singh, “A review on development of photovoltaic water pumping system,” *Renewable and Sustainable Energy Reviews*, vol. 43, pp. 918-925, March 2015

[5] R. Kumar and B. Singh, “BLDC Motor Driven Solar PV Array Fed Water Pumping System Employing Zeta Converter,” *IEEE Trans. Ind. Appl.*, vol. 52, no. 3, pp. 2315-2322, May-June 2016.

[6] Bhim Singh and Rajan Kumar, “Solar PV Array Fed Water Pump Driven By BLDC Motor Using Landsman Converter,” *IET Renewable Power Generation*, vol. 10, no. 4, pp. 474-484, April 2016.

[7] K. Rahrah, D. Rekioua, T. Rekioua and S. Bacha, “Photovoltaic pumping system in Bejaia climate with battery storage,” *International Journal of Hydrogen Energy*, vol. 40, no. 39, pp. 13665-13675, 19 October 2015.

[8] Abla Khiareddine, Chokri Ben Salah and Mohamed Faouzi Mimouni, “Power management of a photovoltaic/battery pumping system in agricultural experiment station,” *Solar Energy*, vol. 112, pp. 319-338, February 2015

[9] Sara Ghaem Sigarchian, Anders Malmquist and Torsten Fransson, “Modeling and Control Strategy of a Hybrid PV/Wind/Engine/Battery System to Provide Electricity and Drinkable Water for Remote Applications,” *Energy Procedia*, vol. 57, pp. 1401-1410, 2014

[10] A. Khiareddine, C. Ben Salah and M. F. Mimouni, “Strategy of energy control in PVP/battery water pumping system,” *International Conference on Green Energy*, Sfax, 2014, pp. 49-54

[11] J. H. Ugale and M. S. Panse, “Single phase AC drive for isolated solar photovoltaic water pumping system,” *International Conference on Green Computing and Internet of Things (ICGCIoT)*, Noida, 2015, pp. 1285-1287.

[12] A. Boussaibo, M. Kamta, J. Kayem, D. Toader, S. Haragus and A. Maghet, “Characterization of photovoltaic pumping system model without battery storage by MATLAB/Simulink,” *9th International Symposium on Advanced Topics in Electrical Engineering (ATEE)*, Bucharest, 2015, pp. 774-780.

[13] Zhao Yan, “Photovoltaic Pumping System Using Power Grid as Energy Storage Device,” Chinese Patent CN 202455296 U, Sept. 26, 2012.

[14] Huang, “Photovoltaic Water Pumping and Residual Electricity Grid- Connected System,” Chinese Patent CN 204131142 U, Jan. 28, 2015.

[15] Wang Xing, “High-Efficiency Photovoltaic Pump System,” Chinese Patent CN 203884338 U, Octo. 22, 2014

[16]G. Satyanarayana, K. Lakshmi Ganesh "Grid Integration of Hybrid Generation Scheme for Optimal Switching Pattern Based Asymmetrical Multilevel Inverter" is published in Springer LNEE Series-326, ISSN-1876-1100, pp.295-303, November, 2014.

[17]G. Satyanarayana, K. Lakshmi Ganesh “Incorporate of FB-MMCs Converter Topologies for Hybrid PV/FC Based EV Applications” is Published in International Journal of Procedia Technology (ELSEVIER), Vol-21, ISSN-2212-0173, pp.271-278, November 2015.

[18] G. Sri Hari Priya, K. Lakshmi Ganesh, G. Satyanarayana, “Enhancement of Harmonics in a Grid Connected Advanced Three-Phase Multilevel Inverter with Hybrid Co-Generation Scheme”, is Published in International Journal of Informative & Futuristic Research (IJIFR), Vol-2 Issue-5, ISSN-2347-1697, p.p. 1201-1214, January, 2015