Artificial Intelligence Based BLDC Motor-Driven Solar PV Fed Water Pumping System

Gudala Satya Pratap[1] Dr Midhunchakkaravarthy[2]

Research Scholar, Lincoln University College, Malaysia[1]
gspratap.phdscholar@lincoln.edu.my

Dean, Faculty of Computer Science and Multimedia[2]
Lincoln University College, Malaysia
midhun@lincoln.edu.my

Abstract-
The best alternative to the conventional sources of energy is ever lasting solar energy and it is one among the cheapest and widely used energy. The present paper deals with the design and analysis of zeta converters, as it has been used as intermediate between voltage source inverter (VSI) and solar PV array. Maximum power point tracking (MPPT) technique has been used for gaining maximum efficiency from solar PV array. In this paper, Artificial Intelligence(AI) Technique based Fuzzy logic controller is used for better results. When compared to other methods of MPPT technique, Fuzzy logic based MPPT technique is best because it provides better results for randomly varying atmospheric conditions. In our proposed system, BLDC motor which has higher efficiency and noise less operation is considered. Maximum power loss of PV generator is well matched with the load characteristic of BLDC motor. Matlab/Simulink results carried out for the different topology of the DC-DC converters and the results are analyzed and compared.

Keywords: Photovoltaic(PV) system, Maximum power point tracking (MPPT), Artificial Intelligence (AI) Technique, Fuzzy logic controller, BLDC motor, zeta converters.

1. INTRODUCTION

The drastic reduction in the cost of power electronic devices and annihilation of fossil fuels in near future invite to use the solar photo voltaic (SPV) generated electrical energy for various applications as far as possible. Water pumping, a standalone application of the SPV array generated electricity is receiving wide attention now days for irrigation in the fields, house hold applications and industrial use. Although several researches have been carried out in an area of SPV array fed water pumping, combining various DC-DC converters and motor drives, the zeta converter in association with a permanent magnet brushless DC (BLDC) motor is not explored precisely so far to develop such kind of system. However, the zeta converter has been used in some other SPV based applications. Moreover, a topology of SPV array fed BLDC motor driven water pump with zeta converter has been reported and its significance has been presented more or less in. None the less, an experimental validation is missing and the absences of extensive Literature review and comparison with the existing topologies have concealed the technical contribution and originality of the reported work. The merits of both BLDC motor and zeta converter can contribute to develop a SPV array fed water pumping system possessing a potential of operating satisfactorily under dynamically changing atmospheric conditions. The BLDC motor has high reliability, high efficiency, and high torque/inertia ratio, improved cooling, low radio frequency interference and noise and requires practically no maintenance.

Artificial Intelligence(AI) Technique based Fuzzy MPPT technique is proved the best by providing better results for varying weather conditions. BLDC motor is driven by inverter interface.

II. Conventional SPV-fed BLDC motor-driven water pumping system

The water pumping, a standalone application of the SPV array-generated electricity, is receiving wide attention nowadays for irrigation in the fields, household applications, and industrial use. Study have been carried out in an area of SPV array-fed water pumping, combining various dc–dc converters and motor drives, the zeta converter in association with a permanent-magnet brushless dc (BLDC) motor system. Moreover, a topology of SPV array-fed BLDC motor-driven water pump with zeta converter has been reported.

These merits of the zeta converter are favorable for proposed SPV array-fed water pumping system. An incremental conductance maximum power point tracking (INC-MPPT) algorithm [8], [13]–[18] is used to operate the zeta converter such that SPV array always operates at its MPP. The existing literature exploring SPV array-based BLDC motor-driven water pump [19]–[22] is based on a configuration shown in Fig.2.1 A dc–dc converter is used for MPPT of an SPV array as usual. Two phase currents are sensed along with Hall signals feedback for control of BLDC motor, resulting in an increased cost. The additional control scheme causes increased cost and complexity, which is required to control the speed of BLDC motor. Moreover, usually a voltage-source inverter (VSI) is operated with high-frequency PWM pulses, resulting in an increased switching loss and hence the reduced efficiency.

Although a Z-source inverter (ZSI) replaces dc–dc converter in [22], other schematic of Fig.4.1 remains unchanged, promising high efficiency and low cost. Contrary to it, ZSI also necessitates phase current and dc link voltage sensing resulting in the complex control and increased cost.

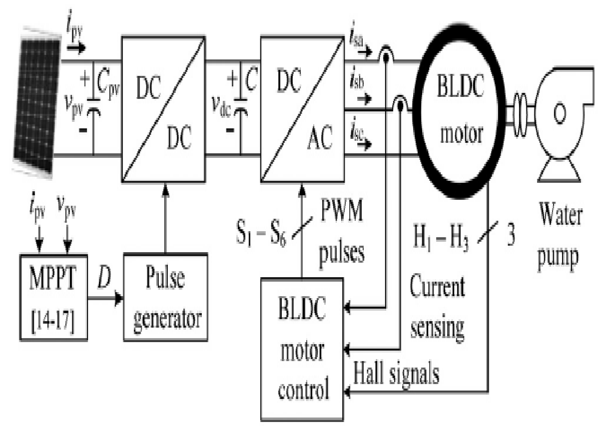


Fig2.1. Conventional SPV-fed BLDC motor-driven water pumping system

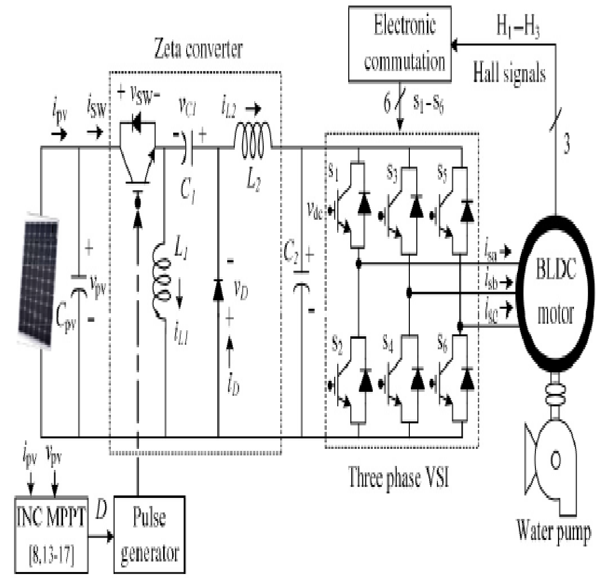
To overcome these problems and drawbacks, a simple, cost effective, and efficient water pumping system based on SPV array-fed BLDC motor is proposed, by modifying the existing topology as shown in Fig.4.2. A zeta converter is utilized to extract the maximum power available from an SPV array, soft starting, and speed control of BLDC motor coupled to a water pump. Due to a single switch, this converter has very good efficiency and offers boundless region for MPPT. This converter is operated in continuous conduction mode (CCM) resulting in a reduced stress on its power devices and components. Furthermore, the switching loss of VSI is reduced by adopting fundamental frequency switching resulting in an additional power saving and hence an enhanced efficiency. The phase currents as well as the dc link voltage sensors are completely eliminated, offering simple and economical system without scarifying its performance. The speed of BLDC motor is controlled, without any additional control, through a variable dc link voltage of VSI. Moreover, a soft starting of BLDC motor is achieved by proper initialization of MPPT algorithm of SPV array. These features offer an increased simplicity of proposed system. The advantages and desirable features of both zeta converter and BLDC motor drive contribute to develop a simple, efficient, cost-effective, and reliable water pumping system.

Based on solar PV energy. Simulation results using MATLAB/Simulink and experimental performances are examined to demonstrate the starting, dynamics, and steady-state behavior of proposed water pumping system subjected to practical operating conditions. The SPV array and BLDC motor are designed such that proposed system always exhibits good performance regardless of solar irradiance level.

III. OPERATION OF PROPOSED SYSTEM

The SPV array generates the electrical power demanded by the motor-pump. This electrical power is fed to the motor pump via a zeta converter and a VSI. The SPV array appears as a power source for the zeta converter as shown in Fig.3.1. Ideally, the same amount of power is transferred at the output of zeta converter which appears as an input source for the VSI. In practice, due to the various losses associated with a dc–dc converter [23], slightly less amount of power is transferred to feed the VSI. The pulse generator generates, through INCMPPT algorithm, switching pulses for insulated gate bipolar transistor (IGBT) switch of the zeta converter. The INC-MPPT algorithm uses voltage and current as feedback from SPV array and generates an optimum value of duty cycle. Further, it generates actual switching pulse by comparing the duty cycle with a high-frequency carrier wave. In this way, the maximum power extraction and hence the efficiency optimization of the SPV array is accomplished.

The VSI, converting dc output from a zeta converter into ac, feeds the BLDC motor to drive a water pump coupled to its shaft. The VSI is operated in fundamental frequency switching through an electronic commutation of BLDC motor assisted by its built-in encoder. The high frequency switching losses are thereby eliminated, contributing in an increased efficiency of proposed water pumping system.



.

Fig. 3.1. Proposed SPV-zeta converter-fed BLDC motor drive for water pump.

1V. AI Driven-Fuzzy controller:

Brushless DC (BLDC) motors are widely used across numerous applications due to their high efficiency and reliability. Advancements in Artificial Intelligence (AI) and Machine Learning (ML) can enhance the control and optimization of these BLDC motors. Some key ways AI is applied to BLDC motor control include:Fuzzy Logic Control:

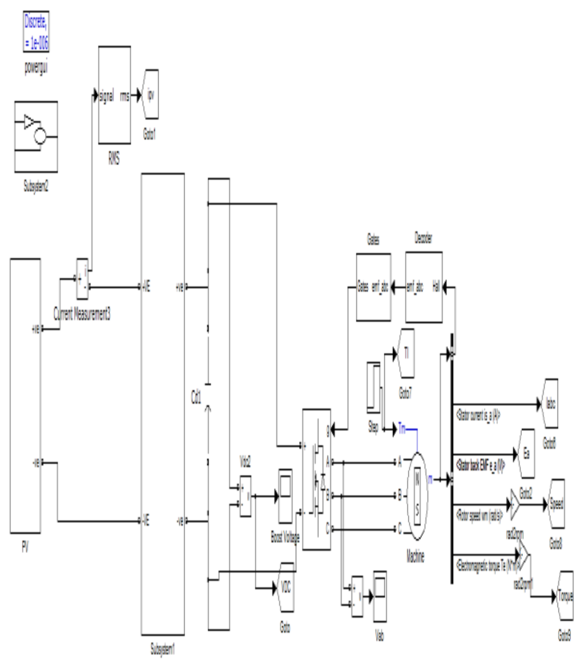
AI-driven fuzzy logic controllers provide adaptive and robust control, effectively handling non-linearities and uncertainties inherent in BLDC motor systems. Introduced the AI/ML applications in a more direct, topic-focused way.

VOLUME: 08 ISSUE: 09 | SEPT - 2024 SJIF RATING: 8.448 ISSN: 2582-3930

The result is a more polished, informative overview of how AI and ML are enhancing BLDC motor control across different advanced techniques

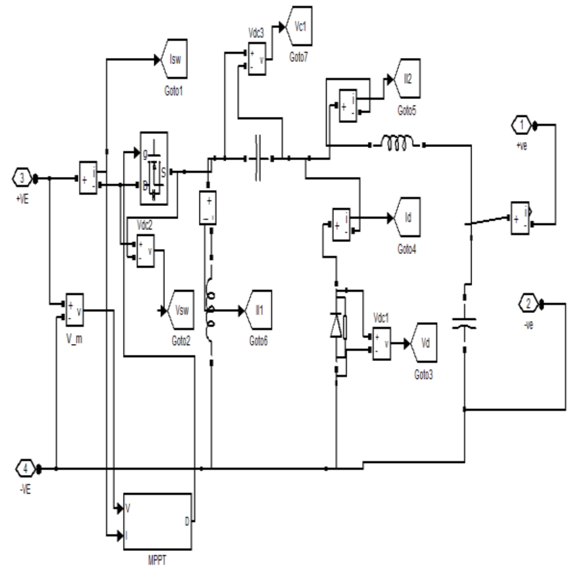
V. RESULTS AND ANALYSIS

MATLAB/ Simulink is used to develop and design the PV array system equipped with the MPPT controller using Fuzzy logic to drive a water pump.

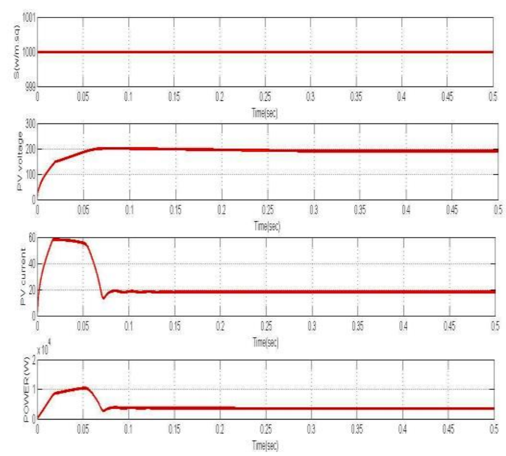


5.1 Proposed Simulink Model:

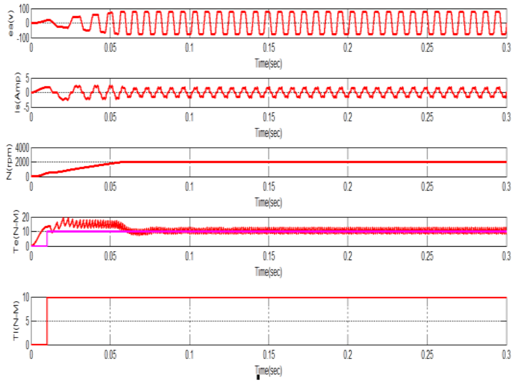
The controlled voltage source inverter has been used to interface the modeled panel with the rest of the system and zeta converter which are built using the Sim Power Systems module of MATLAB.



5.2 Design of Zeta Converter

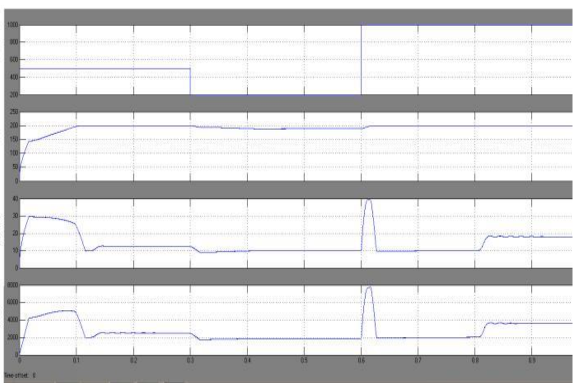


(a)

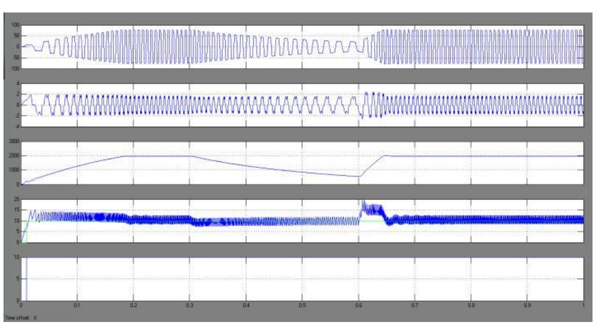


(b)

Fig. 5.3 the proposed SPV array based zeta converter-fed BLDC motor drive for water pump at steady state (a) SPV array variables. (b) BLDC motor-pump variables.



(a)



(b)

Fig. 5.4 the proposed SPV array based zeta converter-fed BLDC motor drive for water pump at dynamic state (a) SPV array variables. (b) BLDC motor-pump variables.

CONCLUSION

The Solar Photo Voltaic array-zeta converter-fed VSI–BLDC motor-pump has been proposed and its suitability has been demonstrated through simulated results with AI-Fuzzy logic Maximum power point tracking (MPPT) technique. The proposed system has been designed and modeled with Fuzzy logic control to accomplish the desired objectives and validated to examine various performances under starting, dynamic, and steady-state conditions of BLDC motor. The performance evaluation has justified the combination of zeta converter and BLDC motor for SPV array-based water pumping. The system under study has shown various desired functions such as maximum power extraction of the SPV array, soft starting of BLDC motor, speed control of BLDC motor without any additional control and elimination of phase current and dc-link voltage sensing, resulting in the reduced cost and complexity. The proposed system has operated successfully even under minimum solar irradiance.

REFERENCES :

[1] M. Uno and A. Kukita, “Single-switch voltage equalizer using multi stacked buck–boost converters for partially-shaded photovoltaic modules,” IEEE Trans. Power Electron., vol. 30, no. 6, pp. 3091–3105, Jun. 2015.

[2] R. Arulmurugan and N. Suthanthiravanitha, “Model and design of a fuzzy-based Hopfield NN tracking controller for standalone PV applications,” Elect. Power Syst. Res., vol. 120, pp.
184–193, Mar. 2015.

[3] S. Satapathy, K. M. Dash, and B. C. Babu, “Variable step size MPPT algorithm for photo voltaic array using zeta converter—A comparative analysis,” in Proc. Students Conf. Eng. Syst. (SCES), Apr. 12–14, 2013, pp. 1–6.

[4] R. Kumar and B. Singh, “BLDC motor driven solar PV array fed water pumping system employing zeta converter,” in Proc. 6th IEEE India Int. Conf. Power Electron. (IICPE), Dec. 8–
10, 2014, pp. 1–6.
[5] B. Singh, V. Bist, A. Chandra, and K. Al-Haddad, “Power factor correction in bridgeless-Luo converter-fed BLDC motor drive,” IEEE Trans. Ind. Appl., vol. 51, no. 2, pp. 1179–1188, Mar./Apr. 2015.
[6] B. Singh and V. Bist, “Power quality improvements in a zeta converter for brushless dc motor drives,” IET Sci. Meas. Technol., vol. 9, no. 3, pp. 351–361, May 2015.
[7] R. F. Coelho, W. M. dos Santos, and D. C. Martins, “Influence of power converters on PV maximum power point tracking efficiency,” in Proc. 10th IEEE/IAS Int. Conf. Ind. Appl. (INDUSCON), Nov. 5–7, 2012, pp. 1–8.
[8] M. A. Elgendy, B. Zahawi, and D. J. Atkinson, “Assessment of the incremental conductance maximum power point tracking algorithm,” IEEE Trans. Sustain. Energy, vol. 4, no. 1, pp. 108– 117, Jan. 2013.
[9] M. Sitbon, S. Schacham, and A. Kuperman, “Disturbance observer based voltage regulation of current-mode-boost-converter-interfaced photovoltaic generator,” IEEE Trans. Ind. Electron., vol. 62, no. 9, pp. 5776– 5785, Sep. 2015.