IJMTST is UGC Approved Journal with Journal Id: 43137

International Journal for Modern Trends in Science and Technology, 8(S02):583-64, 2022

ISSN: 2455-3778 online
DOI: https://doi.org/10.46501/IJMTST08S0210
Available online at: https://www.ijmtst.com/icceeses2022.html

Design and Analysis of High Gain Interleaved DC-DC Converter for Solar Powered Sensorless BLDC Pump

M. Vikas | M. Dhanunjay | V. Mohan Vamsi | T. Amar Kiran

Department of Electrical & Electronics Engineering, Godavari Institute of Engineering and Technology (A), JNTUK, Kakinada

To Cite this Article
M. Vikas, M. Dhanunjay, V. Mohan Vamsi and T. Amar Kiran. Design and Analysis of High Gain Interleaved DC-DC Converter for Solar Powered Sensorless BLDC Pump. International Journal for Modern Trends in Science and Technology 2022, 8(S02), pp. 58-64. https://doi.org/10.46501/IJMTST08S0210

Article Info
Received: 26 April 2022; Accepted: 24 May 2022; Published: 30 May 2022.

ABSTRACT

This project proposes Sensor less control based Permanent magnet Brushless DC Motor for pump applications. The proposed MPPT (Artificial Neural Network) algorithm one offers improved reliability and tracks maximum power from the solar panel. Back EMF detection scheme is used for Sensor less control and V/F method is used for starting the BLDC motor. The voltage source inverter (VSI) is used to perform electronic commutation of the BLDC motor which is operated with the pulses of fundamental frequency, avoiding switching losses caused by the high frequency switching pulses. Furthermore, the speed of BLDC motor is controlled through the variable DC link voltage. Closed loop speed control algorithm is achieved by using Fuzzy controller and it is implemented in MATLAB simulation.

***KEYWORD:** Artificial Neural Network, BLDC motor, Fuzzy controller, EMF detection*

1.INTRODUCTION

The induction motors are widely used to drive a water pump due to its robustness, low cost, ability to operate in hazardous and contaminated areas, availability in local markets, and lower maintenance cost [1]. Some of the limitations of the induction motor are not favorable for SPV array based water pumping such as requirement of complex control and prone to overheating if the voltage is too low [2]. In the last decade, brushless DC (BLDC) motors have begun to replace induction motors for small scale pumping applications [3] due to its higher efficiency as compared to an induction motor, long life, high reliability, low radio frequency interference and noise and no maintenance [4-5], hence adapted in this work. The BLDC motor used in SPV array based applications so far requires additional control circuitry and sensors to facilitate the speed control, resulting in the increased complexity, cost, weight and size of the system [6]. Moreover, the voltage source inverter (VSI), feeding the BLDC motor is operated with the high frequency PWM pulses, resulting in an increased switching losses. In this work, speed of the BLDC motor is controlled through the variable DC link voltage, hence no additional sensors are required for speed control. Furthermore, the VSI is operated, by electronic commutation, with the pulses of fundamental frequency, which minimizes the switching losses. The power optimization or so called maximum power point tracking (MPPT) is mandatory for efficient utilization of SPV array. The numerous literature is available on MPPT techniques [7]. A DC-DC converter, as an intermediate power conditioning unit, is commonly used between the SPV array and the VSI to perform MPPT. The rate of adoption of solar photovoltaic (PV) based power generation by the industries and instant consumers is being increased owing to a rapid reduction in the cost of PV modules. In addition, fossil fuel resources are diminishing day by day, which further attracts towards PV technology. The said technology possesses several merits such as everlasting, no pollution and has a running cost nil. The brushless DC (BLDC) motor [8], being an energy efficient motor, suits the said application of solar PV energy. It possesses a high power density and a high torque/inertia ratio. A BLDC motor needs rotor position information to feed a rectangular current in phase with the back electromotive force (back-EMF) [9]. These information are usually provided by a set of Hall-effect position sensors. The position sensors make the motor costly and they require a precise mounting. Besides, Hall-effect sensors are very sensitive to the temperature, resulting in deterioration in the performance of the motor. The system reliability is certainly reduce. Towards finding of a low-cost and energy-saving solution for water pumping, several topologies are proposed, using PV array fed BLDC motor drive [10].

This paper propose a Sensor less control based Permanent magnet Brushless DC Motor for pump applications. The proposed MPPT (Artificial Neural Network) algorithm one offers improved reliability and tracks maximum power from the solar panel. Back EMF detection scheme is used for Sensor less control and V/F method is used for starting the BLDC motor. The voltage source inverter (VSI) is used to perform electronic commutation of the BLDC motor which is operated with the pulses of fundamental frequency, avoiding switching losses caused by the high frequency switching pulses. Furthermore, the speed of BLDC motor is controlled through the variable DC link voltage. Closed loop speed control algorithm is achieved by using Fuzzy controller and it is implemented in MATLAB simulation.

2. PROPOSED SYSTEM

The solar PV power is applied to the grid along a Interleaved cuk converter as well as a 1φ VSI. The point of functioning of PV array is at the maximum power point while the converter power is grid synchronized.For the controlling of landsman converter, an ANN MPPT is connected which tracks the maximum power by evaluating the current as well as voltage obtained from the PV array. It regulates the reference voltage or duty cycle for matching the power to instant power point. The MPPT controller exploits ANN MPPT and is non-linear and varies in accordance with time.

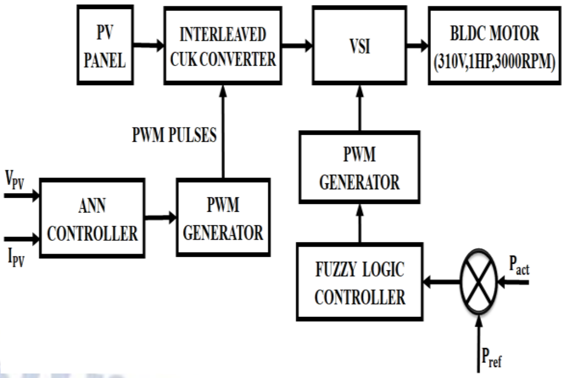

Figure 1:Proposed block diagram

The 1φ VSI converts the DC voltage obtained from the DC-DC Interleaved CUK converter to the grid synchronized AC voltage adopting fuzzy logic controller. Closed loop speed control algorithm is achieved by fuzzy controller and it is implemented in MATLAB simulation.

A. PV SYSTEM

The utilization of solar photovoltaic (PV) systems has gained a tremendous momentum due to decreasing costs of PV arrays and interface systems by as much as 50% during the last five years. The advancements on electric utility grid interface systems and utilization of PV arrays in standalone local power generation and smart buildings with storage battery and back-up hybrid systems are increasing the PV system utilization as the emerging form of renewable/alternative energy source. In many countries, the government has instituted special incentives and tax credits as well as feed-in tariff and energy purchase back legislation programs in order to promote and encourage manufacturers and consumers and boost new investments in solar PV energy use in different sectors. As the solar PV systems emerge as viable and economic source of green energy with increasing installation sites every year, attempts are made to find economic and technological solutions to the problems arising from various aspects of the PV utilization schemes. The state of the art research is continuing in all areas from material sciences to manufacturing and interfacing in order to ensure efficient utilization and commercial viability in terms of cost, security, and durability of PV and hybrid PV-wind-storage systems. Specific areas focus on PV array topologies, dynamic sun tracking, maximum power point control, storage devices, and efficient decoupled interface with smart grid and smart building to ensure dynamic matching of energy to load requirements with minimal impact on the host utility grid. Besides, energy management studies in smart grids and distributed generation have become other additional areas of demand side management and energy efficient hybrid utility-renewable energy. We invited investigators to contribute original research articles as well as review articles that will stimulate the continuing efforts and promote new research directions to address the undergoing challenges and technological requirements in PV systems utilization in order to ensure commercial viability and improve usability, security, reliability, and integration of sustainability of converting sun power to electricity. Hybrid PV-wind-fuel cell-microgas turbines with storage Li-ion batteries and super capacitors are promising to modify the way smart grid manages efficient electrical energy and ensure demand-side management and peak shifting as well as shaving of peak demand during summer months due to massive air-conditioning loads. The inherent problems of PV interfacing include the effects of solar insulation and temperature changes affecting the PV array power/energy as well as interface power quality and required dc-ac isolation and grid supply security and reliability.

B. DC-DC CUK INTEGRATED CONVERTER

The proposed converter is derived by integrating the traditional CUK converter, for attaining high voltage gain. DC-DC CUK Integrated Converter is based on the voltage transfer gain. The integrated converter limits the converter switches and controllers. In both of these converters, the input inductor, power switches and input source are organized in the same way. Hence, there is an opportunity to merge these two converters by keeping the power switch and input inductor commonly on the input side. Except for the input side boost inductor (L1) and the power switch T, the rest of the circuit is connected precisely in parallel with each other. Hence, the output side two capacitors (C1 and C3) are placed across the load. This hybrid structure increases the voltage gain by complementing the benefits of Cuk converters. The converter provides continuous current mode operation with the help of a single power switch, which provides less voltage stress on the controlled switch and diodes. Energies 2020, 13, x FOR PEER REVIEW 4 of 24 topology is illustrated in Figure 2 shows the typical conventional boost converter and classical Cuk converter, respectively. In both of these converters, the input inductor, power switches and input source are organized in the same way. Hence, there is an opportunity to merge these two converters by keeping the power switch and input inductor commonly on the input side. Except for the input side boost inductor (L1) and the power switch T, the rest of the circuit is connected precisely in parallel with each other. Hence, the output side two capacitors (C1 and C3) are placed across the load. This hybrid structure increases the voltage gain by complementing the benefits of boost and Cuk converters. The converter provides continuous current mode operation with the help of a single power switch, which provides less voltage stress on the controlled switch and diodes

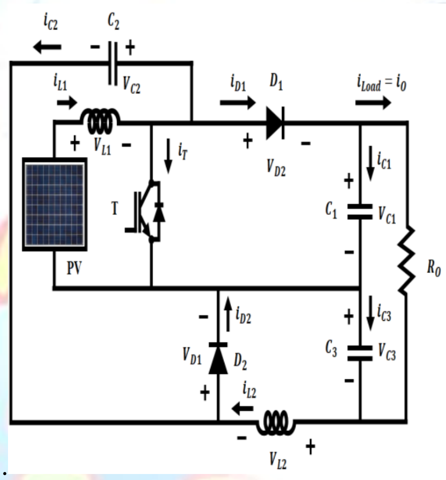

Figure 2: DC-DC CUK Integrated Converter Circuit Diagram

The proposed hybrid DC–DC converter mode operations, their capacitors (C1, C2 and C3) and inductors (L1 and L2) charging and discharging analysis derivations were considered as follows. The two assumptions were taken for this analysis: (1) all the components are ideal; (2) the converter works under continuous conduction. Figure 2 illustrates the continuous conduction operating mode waveforms of the proposed converter. This advanced hybrid DC–DC converter mode operation has three modes of operation.

C. ANN CONTROLLER

To obtain the required switching signals, the approach called ANN is introduced. It has the potential of providing an enhanced methodology for deriving nonlinear models. It possesses the self-adapting capability, which is suitable for handling the parameter variations, uncertainties and nonlinearities. Because of the ability of generalization and learning, it is generally utilized for identification. The ANN controller is utilized for rapid estimation and generation of reference voltage. The systematic diagram of ANN controller is given in figure 3. The input voltage vector ($V_{DC,LOW}, V_{DC,LOW}^{ref}$) is fed to the state generator as given by,

$$V = [V_{DC,LOW}^{ref} V_{DC,LOW}]^T \qquad (1)$$

The obtained states from the state generator are termed as x_1 and x_2,

$$x_1 = V_e(m), x_2 = \frac{\delta x_1}{\delta m} \qquad (2)$$

Where, $V_e(m) = V_{DC,L}^{ref}$-$V_{DC,L}(m)$. The output error $Z(m)$ is given by,

$$Z(m) = V_o(m) - V_o(m-1) \qquad (3)$$

For computing I_β, the generated output voltage $V_o(m)$ is applied to the output state. With the assistance of neuron cell, the controlling signals are generated across the interrelated gatherings as given by,

$$V(m) = V(m-1) + \sum_{k=i}^{ii} W_k\,(m) a_k(m) \qquad (4)$$

Where, W_k is the weight of the system.

By utilizing covariance algorithm, the weight of the neuron is updated by Hebb's rule, which is given by,

$$\Delta W_k(m) = F_k(Y(m), a_{k(m)}) \qquad (5)$$

The change in weight of m^{th} moment is characterized as,

$$\Delta W_k(m) = -c\frac{\delta F_k(m)}{\delta W_k(m)} \qquad (6)$$

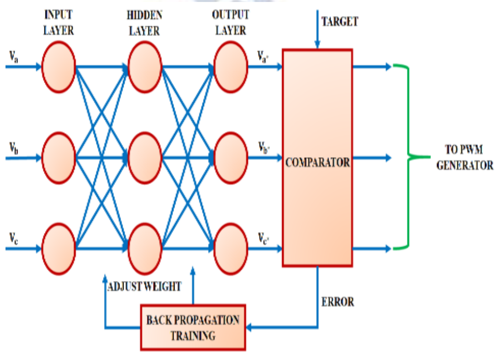

Figure 3: ANN Controller

D. PWM GENERATOR

The pulse width modulated signal is generated by PWM generator and applied to the switch present in the Landsman converter. PWM generator actually chops the reduction of the average power into discrete parts. The voltage and current average values supplied to the load side by keeping the switch ON for a longer time than OFF time. Due to this longer ON time, the power delivered will be more. The PWM generator is fed by the FLC based MPPT controller to obtain the high peak power values. The main function of the PWM generator is to produce pulse width modulated gate pulse signal and fed to the switch present in the Landsman converter.

E. FUZZY CONTROLLER

It is a nonlinear control approach applied for tracking the maximal power point of the nonlinear characteristics of the PV system. It has the ability to operate in conditions of uncertainty and does not rely on the actual system model. It also offers improved tracking as well as high robustness compared to other approaches. The basic fuzzy logic structure is shown in Figure 4.

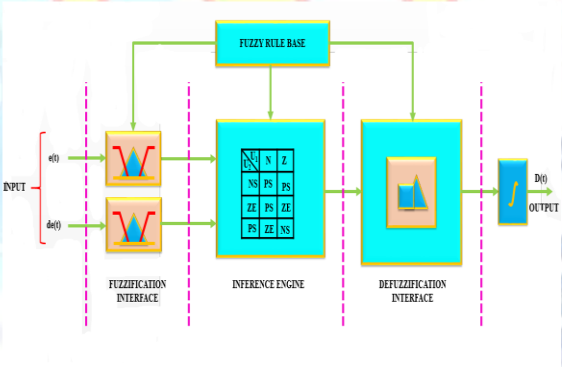

Figure 4: Basic fuzzy logic controller

During inference in fuzzification, the obtained real values from the PV system like power, voltage and control are used for obtaining the fuzzy input variables. The expression for error signal is given by,

$$e(t) = \frac{P(t)-P(t-1)}{I(t)-I(t-1)} \qquad (7)$$

Where, $P = V \times I$ and the change in error is

$$de(t) = e(t) - e(t-1) \qquad (8)$$

The inference engine performs fuzzification of input values for the determination of output values with the application of fuzzy rule base. The duty ratio is attained from defuzzification and is applied to the converter for controlling the gate pulse.

E. SINGLE PHASE VOLTAGE SOURCE INVERTER

Inverter in Power-Electronics refers to a class of power conversion circuits that operate from a dc voltage source or a dc current source and convert it into a symmetric ac voltage or current. It does reverse of what ac-to-dc 'converter' does. The input to the inverter is a direct dc source or dc source derived from an AC source. For example, the primary source of input power may be utility ac voltage supply that is converted to dc by an AC - DC rectifier with filter capacitor and then 'inverted' back to ac using an inverter. Here, the final ac output may be of a different frequency and magnitude than the input ac of the utility supply. If the input dc is a voltage source, the inverter is called a Voltage Source Inverter (VSI). The simplest dc voltage source for a VSI may be a battery bank or a solar photovoltaic cells stack. An AC voltage supply, after rectification into dc can also serve as a dc voltage source. A voltage source is called stiff, if the source voltage magnitude does not depend on load connected to it. All voltage source inverters assume stiff voltage supply at the input. Output of voltage waveforms of ideal inverters should be sinusoidal. However practical inverter waveforms are non-sinusoidal and contain certain harmonics. For low and medium power applications square wave or quasi square wave voltages are acceptable. A variable voltage can be obtained by varying the input dc voltage and maintaining the gain of the inverter constant. On the other hand, if the dc input voltage is fixed then variable output voltage can be obtained by varying the gain of the inverter. This can be accomplished by Pulse Width Modulation-PWM control within the inverter. PWM means the width of the square pulse in positive and negative halves can be adjusted according to the rms of the output required. The inverter gain may be defined as ratio of the ac output (rms) voltage to dc input voltage. In Square Wave PWM technique the output ac rms voltage is fixed when input dc voltage is fixed.

Figure 5 shows the power circuit diagram for single phase bridge voltage source inverter. In this four switches (in 2 legs) are used to generate the ac waveform at the output. Any semiconductor switch like IGBT, MOSFET or BJT can be used. Four switches are sufficient for resistive load because load current io is in phase with output voltage vo. However this is not true in case of RL load where the io is not in phase with vo and diodes connected in anti-parallel with switch will allow the conduction of the current when the main switch is turned off. These diodes are called as Feedback Diodes since the energy is fed back to the dc source.

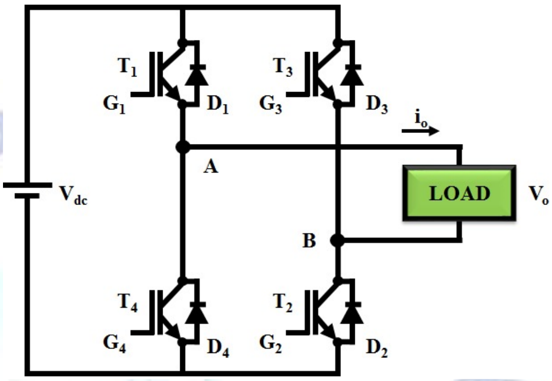

Figure 5: Single Phase Voltage Source Inverter

3. RESULTS AND DISCUSSION

A. SIMULATION RESULTS

The simulation results are examined using a software MATLAB/SIMULINK and the obtained results are given below.

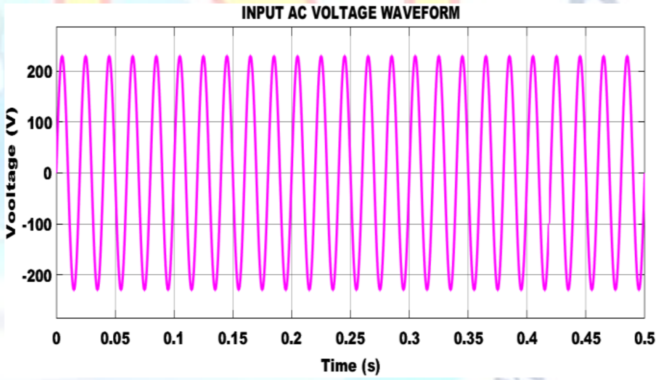

Figure 6: Input AC voltage waveform

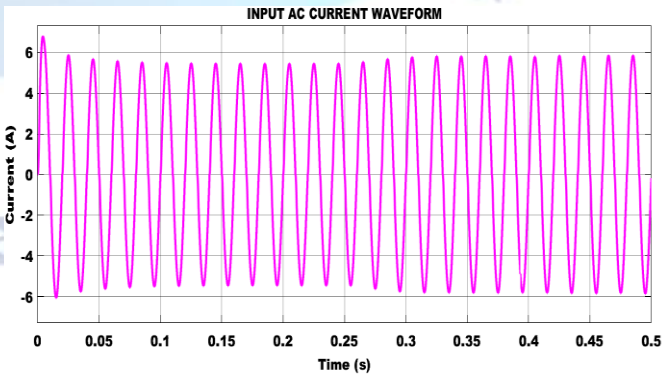

Figure 7: Input AC current waveform

Figure 6 indicates the fixed voltage waveform of AC source. Figure 7 indicates the current waveform of AC source, which varies from +5 A to -5 A.

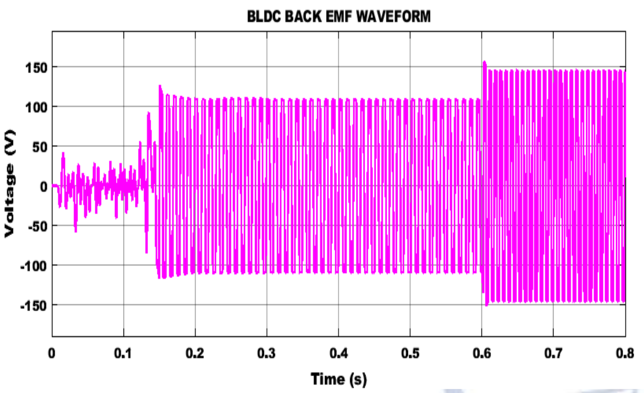

Figure 8: BLDC back EMF waveform

Figure 8 indicates the BLDC back EMF waveform of AC source, which varies from +140 A to -140 A.

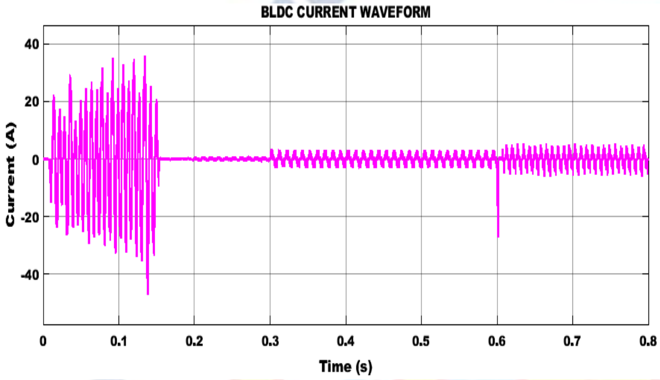

Figure 9: BLDC Current Waveform

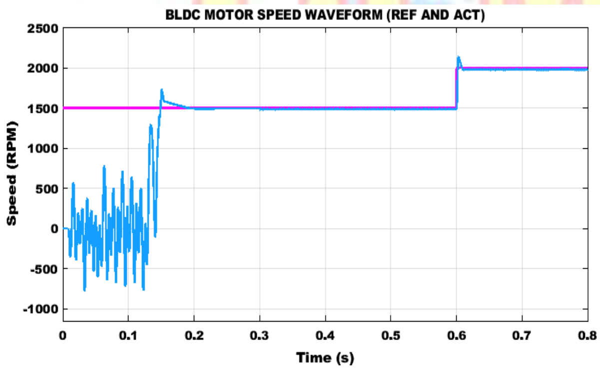

Figure 10: BLDC Motor Speed Waveform

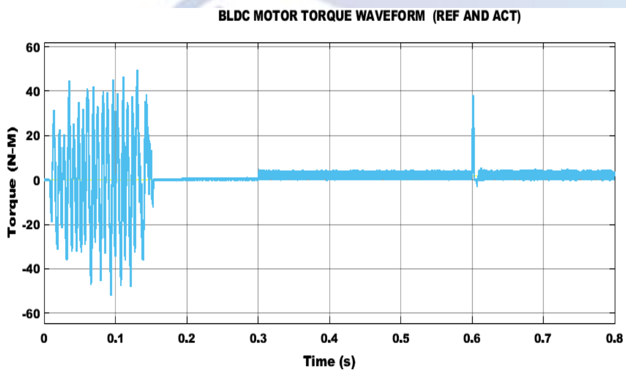

Figure 11: BLDC Motor Torque Waveform

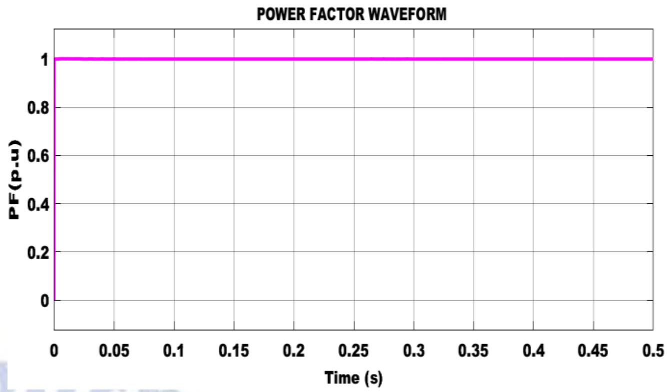

Figure 12: Power factor waveform

Figure 12 indicates the power factor waveform of the converter and the unity power factor is approximately maintained.

4. CONCLUSIONS

This paper presented a new approach to the sensorless control of the BLDC motor drives using the unknown input observer. This observer can be obtained effectively by using the equation of augmented system and an estimated line-to-line backEMF that is modelled as an unknown input. the speed of BLDC motor is controlled through the variable DC link voltage. Closed loop speed control algorithm is achieved by using Fuzzy controller. As a result, the actual rotor position as well as the machine speed can be estimated strictly even in the transient state from the estimated line-to-line back-EMF.

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

REFERENCES

[1] P. Siva Subramanian, D. Manoj, K. A. Deepak Raj, K. Sundar Rajan, I. Prasanth, P. Thanga Pandian, Year: 2019, "Enhancing the Performance of Luo Converter using ANFIS Controller for PV System", ICONEEEA, vol. 7, no. 2.

[2] D.Thamizhthendral, V.ashok kumar, Year: 2018, "A Grid Connected Luo Converter with MPPT Technique", SSRG – IJEEE, vol. 5, no. 1, pp. 11–14.

[3] Chaitanya Pansare, S. Sharma, Chinmay Jain, R. Saxena, Year: 2017, "Analysis of a modified positive output Luo converter and its application to solar PV system", IEEE, vol. 2, no. 3.

[4] K. Mohanraj, Sampada Raghatate, Astha Gupta, Year; 2019, "A High Step-up LUO Converter for Standalone Photovoltaic System", IJRTE, vol. 8, pp. 533–537.

[5] K.Kumar[a]RamjiTiwari[a]N. RameshBabu[b]K.R.Prabhu[a], Year: 2018, "Analysis of MISO Super Lift Negative Output Luo Converter with MPPT for DC Grid Connected Hybrid PV/Wind System", vol. 145, pp. 345–350.

[6] R.Elavarasu, C.Christober Asir Rajan, Year; 2018, "DC-DC Luo Converter based Smart Street Lighting using Arduino UNO", IJIET, vol. 10, no. 1, pp. 21–24.

[7] V. Bist and B. Singh, Year: 2014, "A PFC-Based BLDC Motor Drive Using a Canonical Switching Cell Converter," IEEE Trans. Ind. Inform., vol. 10, no. 2, pp. 1207–1215.

[8] S. Prakash, N. P. Gopinath, B. Kalaiselvi , Year: 2019, "ANN Fed High Gain Luo Converter based Reduced Switch Multilevel Inverter for Single Phase Network Bridged PV Arrangement", IJITEE, vol. 9, no. 284, pp. 604–610.

[9] Rui Li;Fangyuan Shi, Year:2019, "Control and Optimization of Residential Photovoltaic Power Generation System With High Efficiency Isolated Bidirectional DC–DC Converter", IEEE Access, vol. 7, pp. 116107–116122.

[10] Yuxiang Shi;Hui Li, Year: 2018, "Design and Development of a Novel High Voltage Gain, High Efficiency Bi-directional DC-DC Converter for Storage Interface", IEEE Transactions on Power Electronics, vol. 33, no. 3, pp. 2145–2161.