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Improvement Of High Response And Variable Speed Operated With PV Based Voltage Converter And Hybrid Fuzzy Logic Controller Fed BLDC Drive

SANAM RAVI KIRAN
P.G Scholar
Department of Electrical and Electronics Engineering
Avanthi Institute of Engineering and Technology
Makavarapalem, Visakhapatnam (INDIA)
E mail:ravikiran.sanam@gmail.com.

TEGALA SRINIVASA RAO
Associate Professor
Department of Electrical and Electronics Engineering
Avanthi Institute of Engineering and Technology
Makavarapalem, Visakhapatnam (INDIA)
E mail:srinivasarao_tegala@yahoo.co.in

Abstract: This paper introduces a new converter called solar reconfigurable converter (SRC) for PMBLDC drive with photovoltaic (PV)-battery application. The basic concept of the SRC is to use a single power conversion system to perform different operation modes such as PV to BLDC drive (dc to ac), PV to battery (dc to dc), battery to BLDC drive (dc to ac), and battery/PV to BLDC drive (dc to ac) for solar PV systems with energy storage. For BLDC drive FUZZY LOGIC controller is used to control the motor drive in closed loop. This paper proposes an artificial-intelligence-based solution to interface and deliver maximum power from a photovoltaic (PV) power generating system in standalone operation. BLDC motor is connected at the output side which acts as a load and efficiently utilizes the power obtained from solar using controllers like PI and Fuzzy. An electronically commutated Brushless DC drives are enormously used in many applications. A drive system consists of power circuit with converter and inverter and the control unit. Due to the switching operation of the power circuit, the shape of the current drawn from the source is distorted. This increases the apparent power than the real power of the circuit. Electrical utilities will charge a higher cost to commercial customers where there is a low power factor. There is a need for power factor improvement and reduction of source current harmonics at ac mains. This can be achieved by proper switching operation of the converter. Fuzzy logic controller helps to control the switching pulses to the switch by voltage follower approach. Compared to PI and fuzzy controller, hybrid fuzzy controllers provide better speed response but conventional controllers offer better response with changing load at the cost of long settling time. Matlab/Simulink environment is used to carry out the above investigation.

Keywords— BLDC Motor; Current Control, Proportional Integrator, Fuzzy, Fixed Speed and Variable Speed, hybrid fuzzy.

I. INTRODUCTION

The World pays growing attention to the renewable, clean, and practically inexhaustible energy sources such as Photovoltaic (PV) [1], wind, tidal, geothermal energy. Among these PV energy is a main and appropriate renewable energy, owing to the merits of clean, quiet, pollution free, and abundant.

The Brushless DC (BLDC) motor continues to attract the drive industry owing to its simplicity, low-cost and robust Structure. It is suitable for variable-speed applications. Ac-dc conversion of electric power is widely used in adjustable speed drives. Power factor is varied depends on the load connected to the system [2]. In the case of linear load, the shape of the load current will follows the shape of the applied voltage. Non-linear loads, such as rectifiers, DC motor drives make distortion in the current drawn from the system because of the switching operation [3].
So, they have the disadvantages of poor Power Quality (PQ) due to the injected current harmonics, voltage distortion and poor power factor at input ac mains. However with the increasing demand for improved power quality, there is a definite need for better strategies to accomplish a high performance in the motor drive [4]. It can be achieved by reducing the harmonic distortion. The increasing preference of BLDC motors has raised the need for PQ concern with customers. Therefore, the need of improved power quality at the ac mains is essential.
Solar PV electricity output is also highly sensitive to shading. Therefore, solar PV [5] electricity output significantly varies. As a result, energy storage such as batteries and fuel cells for solar PV systems has drawn significant attention and the demand of energy storage for solar PV systems has been dramatically increased, since, with energy storage, a solar PV system becomes a stable energy source and it can be dispatched at the request, which results in improving the performance and the value of solar PV systems [6].
Brushless dc (BLDC) motors are preferred as small horsepower control motors due to their high efficiency, silent operation, compact volume, long operating life, high speed response, high output power, reliability, and low maintenance [7-8]. However, the problems are encountered in these motor for variable speed operation. Over last decades, continuing technology development in power semiconductors, microprocessors, adjustable speed drivers control schemes and permanent-magnet brushless electric motor production have been combined to enable reliable, cost-effective solution for a broad range of adjustable speed applications [9-11]. Household

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appliances are expected to be one of fastest-growing end-product market for electronic motor drivers over the next five years. The major appliances include clothes washers, room air conditioners, refrigerators, vacuum cleaners, freezers, etc. Household appliance [12-13] have traditionally relied on historical classic electric motor technologies such as single phase AC induction, including split phase, capacitor-start, capacitor– run types and universal motor. These classic motors typically are operated at constant-speed directly from main AC power without considering the efficiency. Consumers now demand for lower energy costs, better performance, reduced acoustic noise, and more convenience features. Those traditional technologies cannot provide the solutions.

- **BLDC Motor Applications**

BLDC motors find applications in every segment of the market. Some of the applications are described below:

i) Consumer: PC cooling fans, washing machine, vacuum cleaner, air conditioner, refrigerator, toys.

ii) Medical: artificial heart, microscopes, centrifuges, dental surgical tools, organ transport pump system.

iii) Automobile: automotive applications, electric and hybrid vehicle etc.

We can categorize the BLDC motor control into three major types such as

a) Constant load

b) Varying loads

c) Positioning applications

a) Constant Loads

For single-speed applications, induction motors are more suitable, but if the speed has to be maintained with the variation in load, then because of the flat speed-torque curve of BLDC motor, BLDC motors are a good fit for such applications.

b) Varying Loads

BLDC motors become a more suitable fit for such applications because variable speed induction motors will also need an additional controller, thus adding to system cost.

c) Positioning Applications

BLDC motors used in Position control application require more complex controller, optical encoders or High resolution resolvers to calculate speed of motor, two or more closed loop are operated simultaneously.

II.PRINCIPLE OF OPERATION

A BLDC motor is a permanent magnet synchronous that uses position detectors and an inverter to control the armature currents. The BLDC motor is sometimes referred to as an inside out dc motor because its armature is in the stator and the magnets are on the rotor and its operating characteristics resemble those of a dc motor. Instead of using a mechanical commutator as in the conventional dc motor, the BLDC motor employs electronic commutation which makes it a virtually maintenance free motor. There are two main types of BLDC motors: trapezoidal type and sinusoidal type. In the trapezoidal motor the back-emf induced in the stator windings has a trapezoidal shape and its phases must be supplied with quasisquare currents for ripple free operation. The sinusoidal motor on the other hand has a sinusoid ally shaped back – emf and requires sinusoidal phase currents for ripple free torque operation. The shape of the back – emf is determined by the shape of rotor magnets and the stator winding distribution.

The sinusoidal motor needs high resolution position sensors because the rotor position must be known at every time instant for optimal operation. It also requires more complex software and hardware. The trapezoidal motor is a more attractive alternative for most applications due to simplicity, lower price and higher efficiency. BLDC motors exist in many different configurations but the three phase motor is most common type due to efficiency and low torque ripple. This type of motor also offers a good compromise between precise control and number of power electronic devices needed to control stator currents. Position detection is usually implemented using three Hall - an effect sensor that detects the presence of small magnets that are attached to the motor shaft.

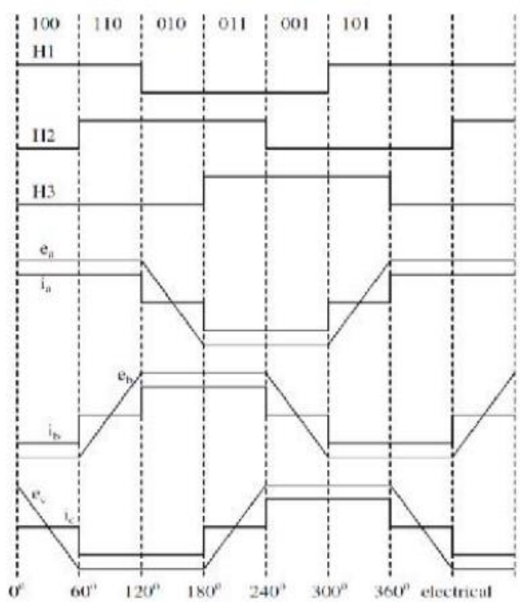

Fig.1 Ideal Back-Emf's, Phase Currents, and Position Sensor Signals.

Typically, a Brushless dc motor is driven by a three phase inverter with, what is called, six-step commutation.

The conducting interval for each phase is 120o by electrical angle. Each interval starts with the rotor and

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stator field lines 1200 apart and ends when they are 600 apart. Maximum torque is reached when the field lines are perpendicular. The commutation phase sequence is like AB-AC-BC-BACA-CB. Each conducting stage is called one step. Therefore, only two phases conduct current at any time, leaving the third phase floating. In order to produce maximum torque, the inverter should be commutated every 600 so that current is in phase with the back EMF. The commutation timing is determined by the rotor position, which can be detected by Hall sensors as shown in the Fig.1 (H1, H2, and H3). Current commutation is done by inverter as shown in a simplified from in Fig.2. The switches are shown as bipolar junction transistors but MOSFET switches are more common. Table 1 shows the switching sequence, the current direction and the position sensor signals.

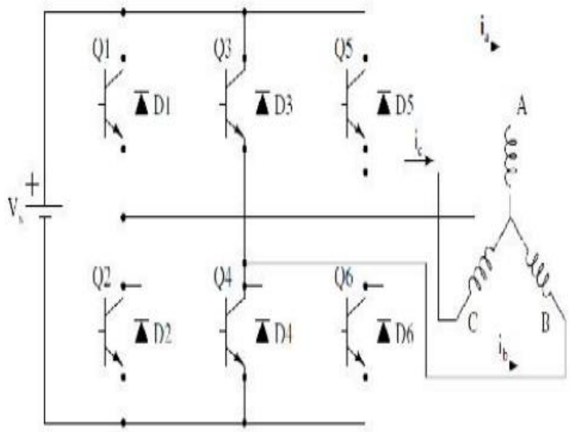

Fig.2 Simplified BLDC Drive Scheme

Switching interval	Seq. number	Pos. sensors H1	H2	H3	Switch closed		Phase Current A	B	C
0° – 60°	0	1	0	0	Q1	Q4	+	-	off
60° – 120°	1	1	1	0	Q1	Q6	+	off	-
120° – 180°	2	0	1	0	Q3	Q6	off	+	-
180° – 240°	3	0	1	1	Q3	Q2	-	+	off
240° – 300°	4	0	0	1	Q5	Q2	-	off	+
300° – 360°	5	1	0	1	Q5	Q4	off	-	+

Table 1.Switching Sequence

Implementation of a BLDC motor can be developed in the similar manner as a three phase synchronous machine. Since its rotor is mounted with a permanent magnet, some dynamic characteristics are different. Flux linkage from the rotor is dependent upon the magnet. Therefore, saturation of magnetic flux linkage is typical for this kind of motors. As any typical three phase motors, one structure of the BLDC motor is fed by a three phase voltage source as shown in Fig.2. The source is not necessary to be sinusoidal. Square wave or other wave- shape can be applied as long as the peak voltage is not exceeded the maximum voltage limit of the motor. Similarly, the model of the armature winding for the BLDC motor is expressed as follows.

III. PROPOSED CLOSED LOOP CONTROLLING TECHNIQUE

Many applications, such as robotics and factory automation, require precise control of speed and position. Speed Control Systems allow one to easily set and adjust the speed of a motor. The control system consists of a speed feedback system, a motor, an inverter, a controller and a speed setting device. A properly designed feedback controller makes the system insensible to disturbance and changes of the parameters.

A.PI Controller:

The purpose of a motor speed controller is to take a signal representing the demanded speed, and to drive a motor at that speed. Closed loop speed control systems have fast response, but become expensive due to the need of feedback components such as speed sensors. Speed controller calculates the difference between the reference speed and the actual speed producing an error, which is fed to the PI controller. PI controllers are used widely for motion control systems. They consist of a proportional gain that produces an output an output proportional to the input error an integration to make the steady state error zero for a step change in the input. PI controller is a generic control loop feedback mechanism (controller) widely used in industrial control systems – a PI is the most commonly used feedback controller and calculates an "error" value as the difference between a measured process variable and a desired set point. The controller attempts to minimize the error by adjusting theprocess control inputs. The PI controller calculation (algorithm) involves two separate constant parameters, and is accordingly sometimes called two-term control: the proportional, the integral values, denoted P, I. Heuristically, these values can be interpreted in terms of time: P depends on the present error, I on the accumulation of past errors, based on current rate of change. The weighted sum of these three actions is used to adjust the process via a control element such as the position of a control valve. There are several methods for tuning a PI loop.

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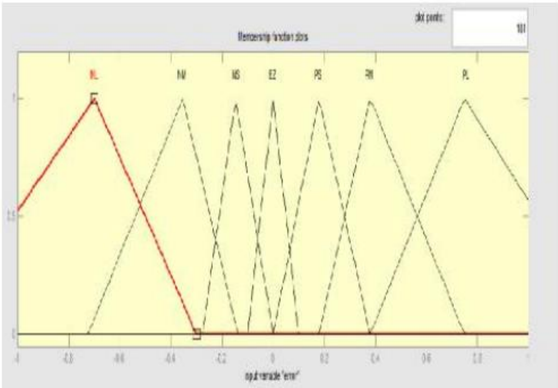

Fig.3. Membership functions of FLC

B.FLC Controller:

Fuzzy logic is widely used in control technique. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as "true" or "false" but rather as "partially true". Although alternative approaches such as genetic algorithms and neural networks can perform just as well as fuzzy logic in many cases, fuzzy logic has the advantage that the solution to the problem can be cast in terms that human operators can understand, so that their experience can be used in the design of the controller of BLDC. The linguistic variables are defined as (NB, NS, Z, PS, PB) which mean big, negative small, zero, positive small and positive big respectively. The membership functions are shown in Fig. 3.

u		e						
		NB	NM	NS	Z	PS	PM	PB
Δe	PB	Z	PS	PM	PB	PB	PB	PB
	PM	NS	Z	PS	PM	PB	PB	PB
	PS	NM	NS	Z	PS	PM	PB	PB
	Z	NB	NM	NS	Z	PS	PM	PB
	NS	NB	NB	NM	NS	Z	PS	PM
	NM	NB	NB	NM	NM	NS	Z	PS
	NB	NB	NB	NB	NB	NM	NS	Z

Table 2. The decision table of FLC.

As seen from table 2, each interval of each variable is divided into seven membership functions:
Negative Big (NB), Negative Medium (NM), Negative Small (NS), Zero (Z), Positive Small (PS), Positive Medium (PM) and Positive Big (PB).

C. Hybrid Fuzzy-PID Controller

Although it is possible to design a fuzzy logic type of PID controller by a simple modification of the conventional ones, via inserting some meaningful fuzzy logic IF- THEN rules into the control system, these approaches in general complicate the overall design and do not come up with new fuzzy PID controllers that capture the essential characteristics and nature of the conventional PID controllers. Besides, they generally do not have analytic formulas to use for control specification and stability analysis. The fuzzy PD, PI, and PI+D controllers to be introduced below are natural extensions of their conventional versions, which preserve the linear structures of the PID controllers, with simple and conventional analytical formulas as the final results of the design. Thus, they can directly replace the conventional PID controllers in any operating control systems (plants, processes).
The main difference is that these fuzzy PID controllers are designed by employing fuzzy logic control principles and techniques, to obtain new controllers that possess analytical formulas very similar to the conventional digital PID controllers.

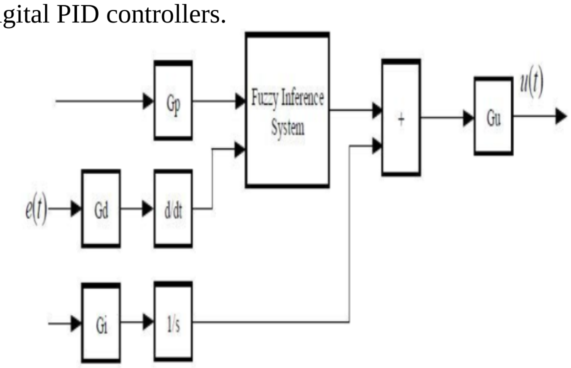

Figure.4. Hybrid Fuzzy PID Controller.

IV. PHOTOVOLTAIC SYSTEM

A Photovoltaic (PV) system directly converts solar energy into electrical energy. The basic device of a PV system is the PV cell. Cells may be grouped to form arrays. The voltage and current available at the terminals of a PV device may directly feed small loads such as lighting systems and DC motors or connect to a grid by using proper energy conversion devices this photovoltaic system consists of three main parts which are PV module, balance of system and load. The major balance of system components in this systems are charger, battery and inverter.

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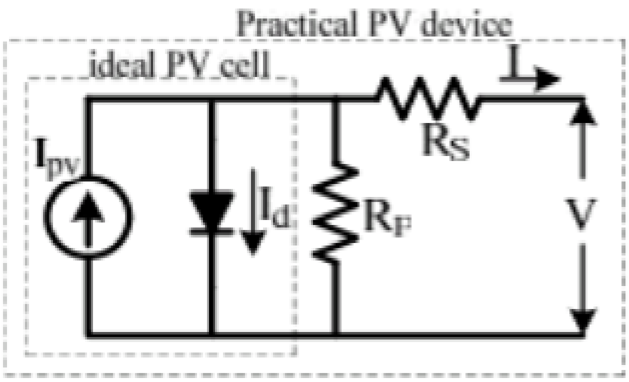

Fig.5.Practical PV device.

A photovoltaic cell is basically a semiconductor diode whose p–n junction is exposed to light. Photovoltaic cells are made of several types of semiconductors using different manufacturing processes. The incidence of light on the cell generates charge carriers that originate an electric current if the cell is short circuited1

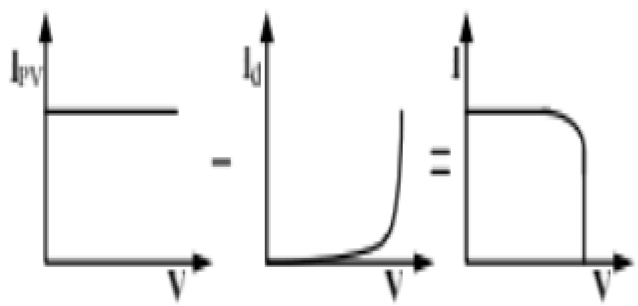

Fig.6.Characteristics I-V curve of the PV cell.

The equivalent circuit of PV cell Inthe above figure the PV cell is represented by a current source in parallel with diode. Rs and Rp represent series and parallel resistance respectively. The output current and voltage form PV cell are represented by I and V. The I-Characteristics of PV cell are shown in fig.6. The net cell current I is composed of the light generated current IPV and the diode current ID

V.BOOST CONVERTER

A boost converter (step-up converter) is a DC-to-DC power converter that steps up voltage (while stepping down current) from its input (supply) to its output (load). It is a class of switched-mode power supply (SMPS) containing at least two semiconductors (a diode and a transistor) and at least one energy storage element: a capacitor, inductor, or the two in combination. To reduce voltage ripple, filters made of capacitors (sometimes in combination with inductors) are normally added to such a converter's output (load-side filter) and input (supply-side filter). Power for the boost converter can come from any suitable DC sources, such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power display style P=VI} P=VI) must be conserved, the output current is lower than the source current.

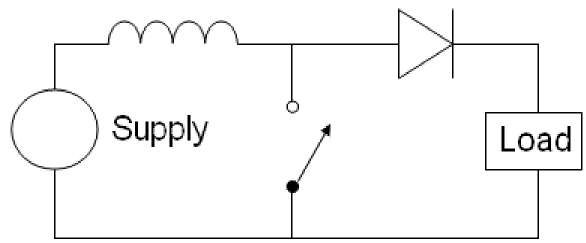

Fig.7 The basic schematic of a boost converter

Operation

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current by creating and destroying a magnetic field. In a boost converter, the output voltage is always higher than the input voltage. A schematic of a boost power stage is shown in Figure 7.

(a) When the switch is closed, current flows through the inductor in clockwise direction and the inductor stores some energy by generating a magnetic field. Polarity of the left side of the inductor is positive.

(b) When the switch is opened, current will be reduced as the impedance is higher. The magnetic field previously created will be destroyed to maintain the current towards the load. Thus the polarity will be reversed (means left side of inductor will be negative now). As a result, two sources will be in series causing a higher voltage to charge the capacitor through the diode D.

Applications

Battery power systems often stack cells in series to achieve higher voltage. However, sufficient stacking of cells is not possible in many high voltage applications due to lack of space. Boost converters can increase the voltage and reduce the number of cells. Two battery-powered applications that use boost converters are used in hybrid electric vehicles (HEV) and lighting systems.

The NHW20 model Toyota Prius HEV uses a 500 V motor. Without a boost converter, the Prius would need nearly 417 cells to power the motor. However, a Prius actually uses only 168 cells and boosts the battery voltage from 202 V to 500 V. Boost converters also power devices at smaller scale applications, such as portable lighting systems. A white LED typically requires 3.3 V to emit light, and a boost converter can step up the voltage from a single 1.5 V alkaline cell to power the lamp.

An unregulated boost converter is used as the voltage increase mechanism in the circuit known as the 'Joule thief'. This circuit topology is used with low power battery applications, and is aimed at the ability of a boost converter to 'steal' the remaining energy in a battery. This energy would otherwise be wasted since the low voltage of a nearly depleted battery makes it unusable for a normal load. This energy would otherwise remain untapped because many applications do not allow enough current to flow through a load when voltage decreases.

VI.MATLAB/SIMULATION RESULTS

Case 1: the BLDC motor without current controller at fixed speed.

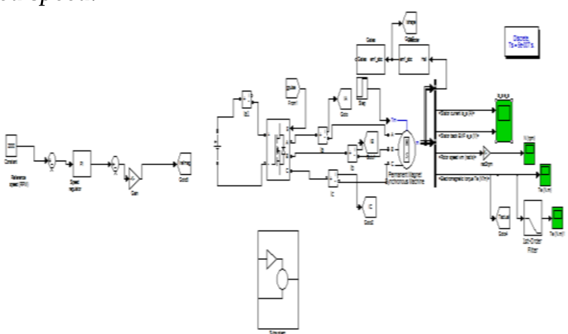

Fig 8: Matlab/Simulink model of BLDC motor without current controller with fixed speed.

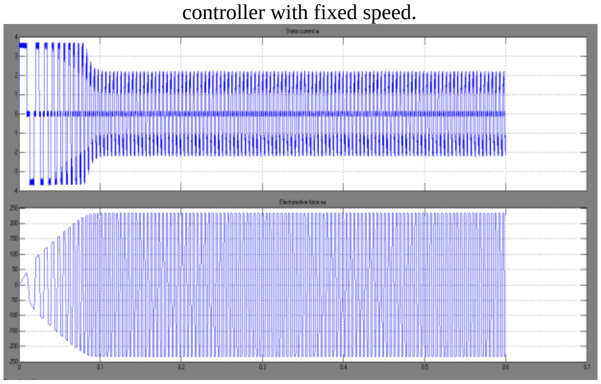

Fig 9: Simulated output wave form of stator current and Back emf of the BLDC motor without current controller at fixed speed.

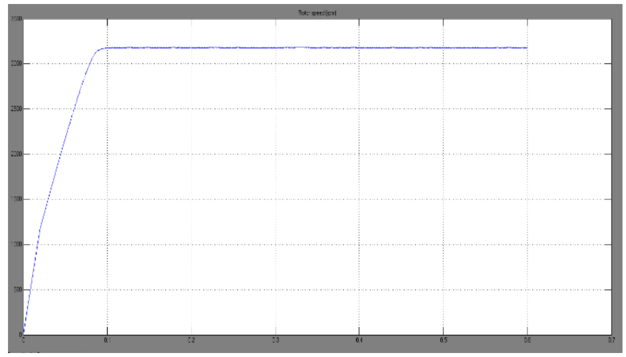

Fig 10: Simulated output wave form of the BLDC motor speed without current controller at fixed speed.

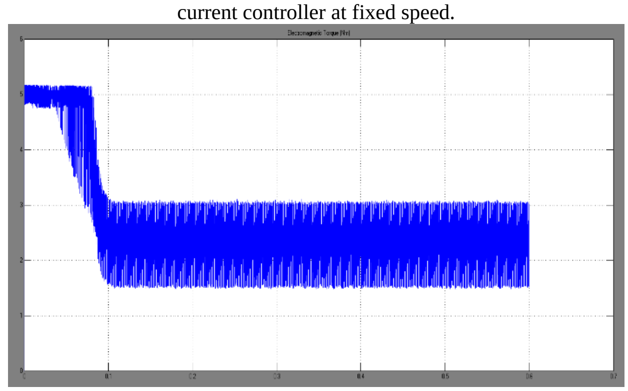

Fig 11: Simulated torque wave form of the BLDC motor without current controller at fixed speed.

Case 2: the BLDC motor without current controller at Variable speed.

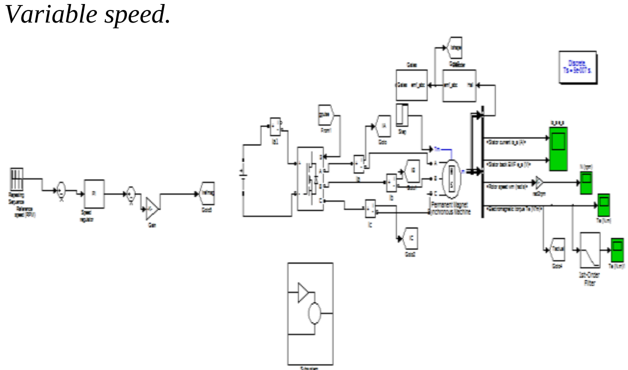

Fig 12: Simulink model of the BLDC motor without current controller at Variable speed.

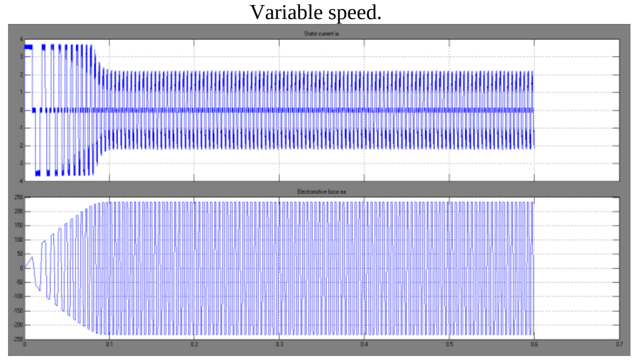

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Fig 13: Simulated output wave form of stator current and Back emf of the BLDC motor without current controller at variable speed.

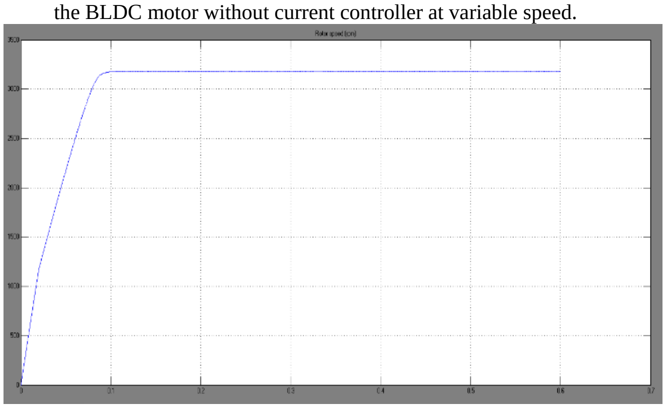

Fig 14: Simulated output wave form of the BLDC motor speed without current controller at variable speed

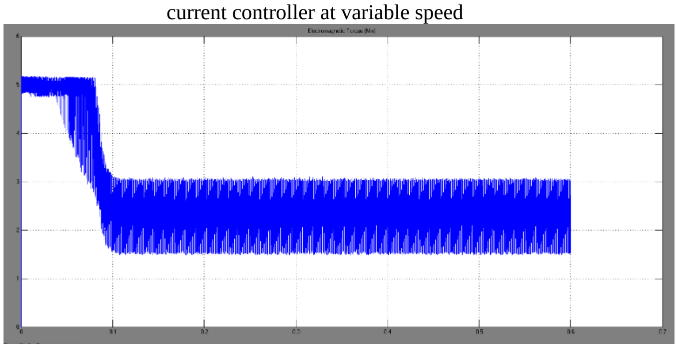

Fig 15: Simulated torque wave form of the BLDC motor without current controller at variable speed.

Case 3: Performance of BLDC Motor Drive with PI based current controller at Fixed Speed.

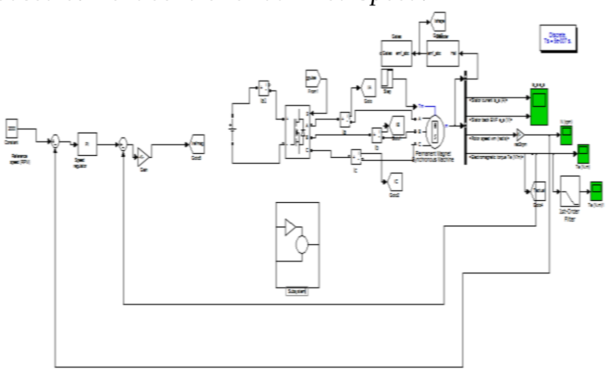

Fig 16: Matlab/Simulink model of BLDC motor under fixed speed with PI based current controller.

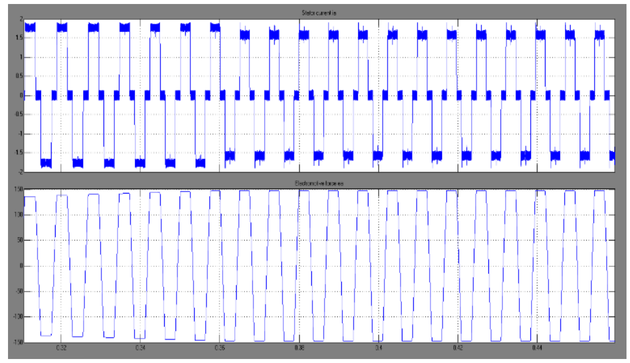

Fig 17: Simulated output wave form of Stator current and EMF of BLDC motor under fixed speed with PI based current controller.

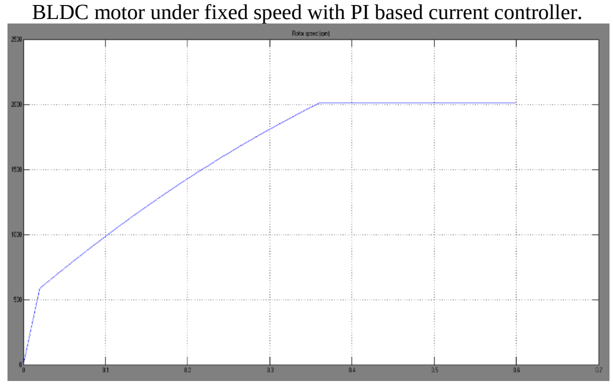

Fig 18: Simulated output wave form of BLDC motor speed at fixed reference speed with PI based current controller.

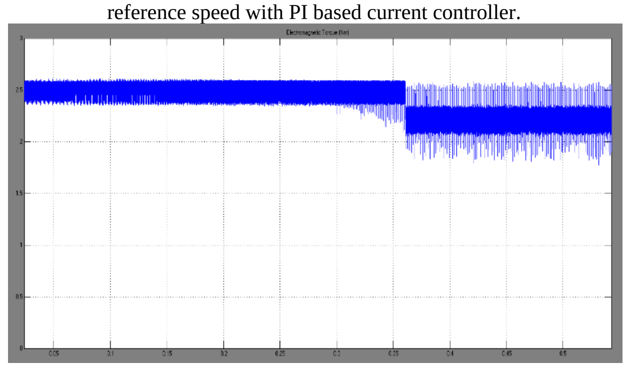

Fig 19: Simulated output wave form of Torque of the BLDC motor under fixed speed with PI based current controller.

Case 4: Performance of BLDC Motor Drive with PI based current controller at variable Speed.

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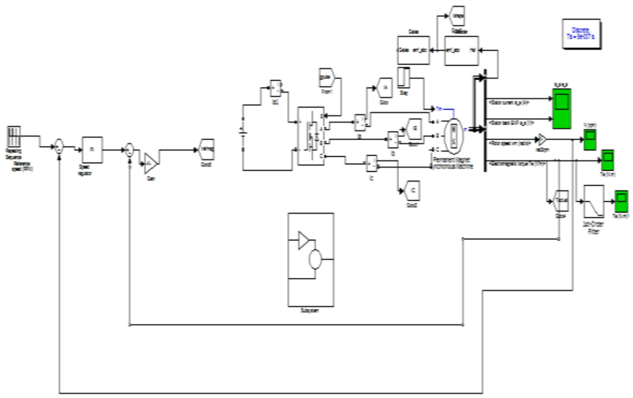

Fig 20: Matlab/Simulink model of BLDC motor under variable speed with PI based current controller.

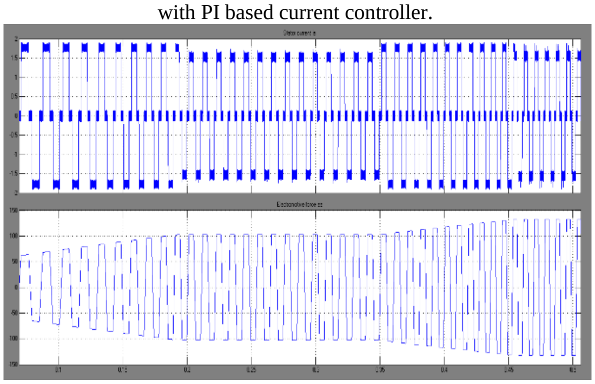

Fig 21: Simulated output wave form of Stator current and EMF of BLDC motor under variable speed with PI based current controller.

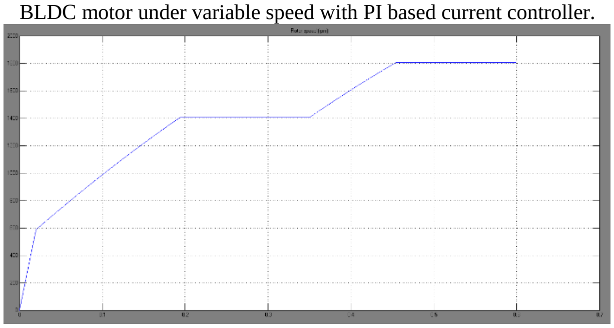

Fig 22: Simulated output wave form of BLDC motor speed at variable reference speed with PI based current controller.

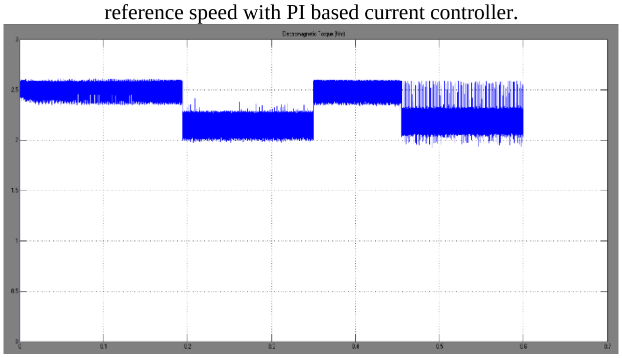

Fig 23: Simulated output wave form of Torque of the BLDC motor under variable speed with PI based current controller.

Case 5: Performance of BLDC Motor Drive with Fuzzy controller atFixed Speed

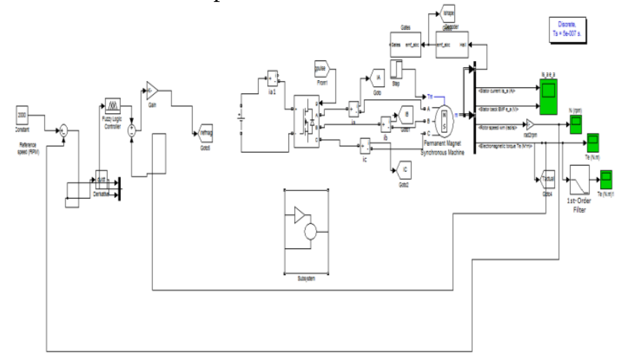

Fig 24: Matlab/Simulink model of BLDC motor under fixed speed with Fuzzy control.

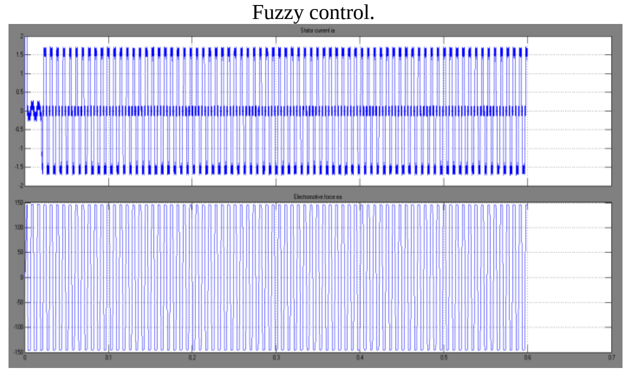

Fig 25: Simulated output wave form of Stator current and EMF of BLDC motor under fixed speed with Fuzzy control.

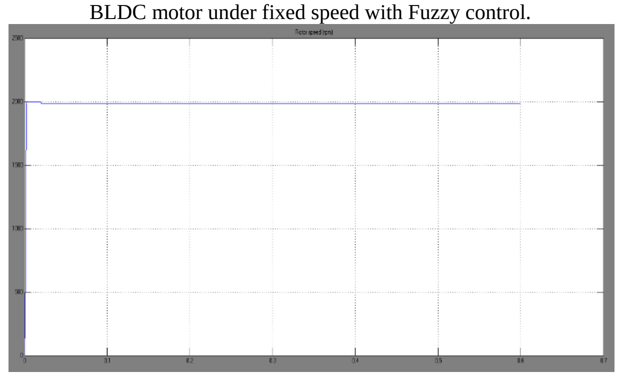

Fig 26: Simulated output wave form of BLDC motor speed at fixed reference speed with Fuzzy control.

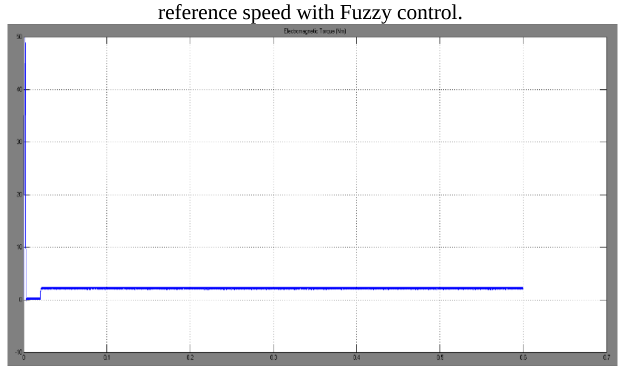

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Fig 27: Simulated output wave form of Torque of the BLDC motor under fixed speed with Fuzzy control.

Case 6: Performance of BLDC Motor Drive with Fuzzy controller at variableSpeed

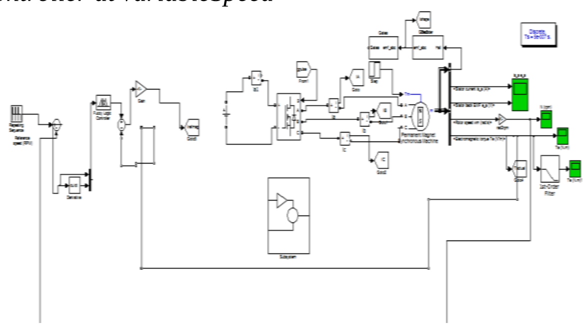

Fig 28: Matlab/Simulink model of BLDC motor under variable speed with Fuzzy control.

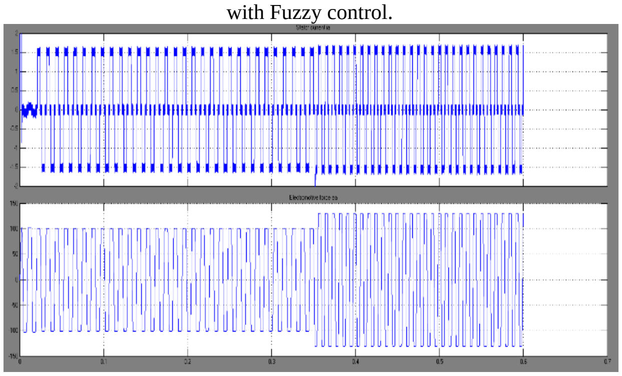

Fig 29: Simulated output wave form of Stator current and EMF of BLDC motor under variable speed with Fuzzy control.

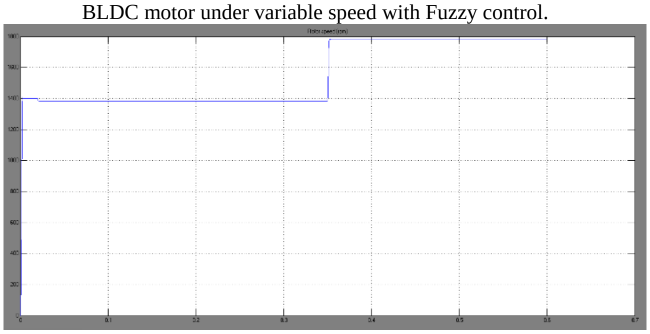

Fig 30: Simulated output wave form of BLDC motor speed at variable reference speed with Fuzzy control.

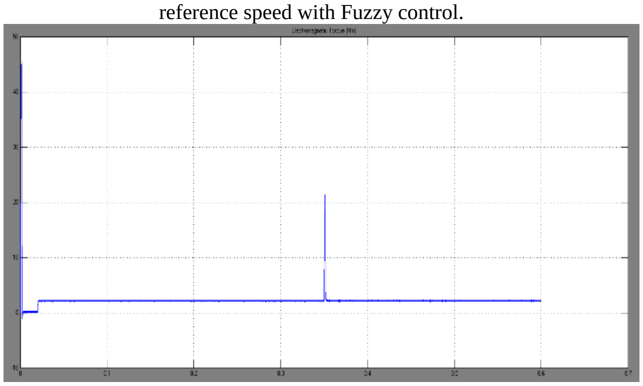

Fig 31: Simulated output wave form of Torque of the BLDC motor under variable speed with Fuzzy control.

Case 7: Performance of BLDC Motor Drive with hybrid Fuzzy controller at fixedSpeed

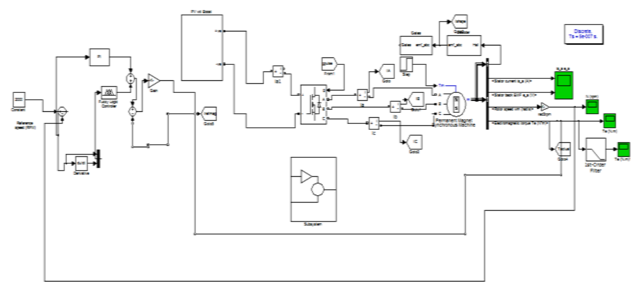

Fig 32: Matlab/Simulink model of BLDC motor under fixed speed with hybrid Fuzzy control.

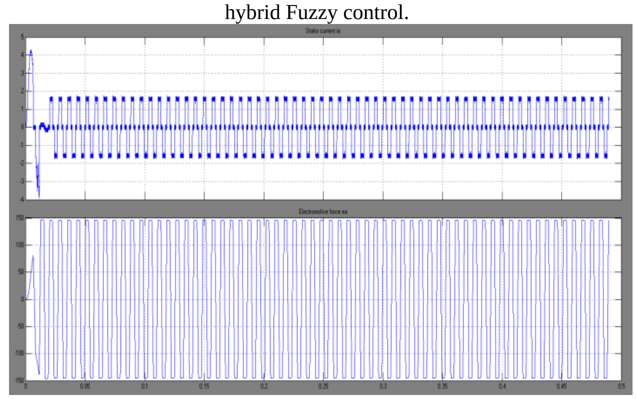

Fig 33: Simulated output wave form of Stator current and EMF of BLDC motor under fixed speed with hybrid Fuzzy control.

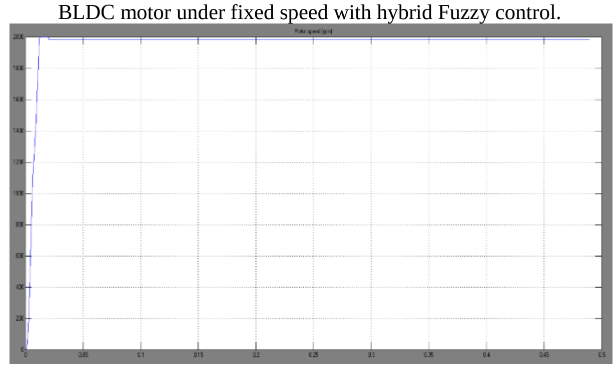

Fig 34: Simulated output wave form of BLDC motor speed at fixed reference speed with hybrid Fuzzy control.

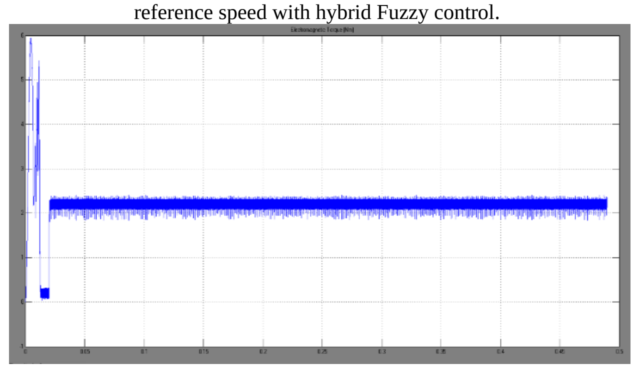

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Fig 35: Simulated output wave form of Torque of the BLDC motor under fixed speed with hybrid Fuzzy control.

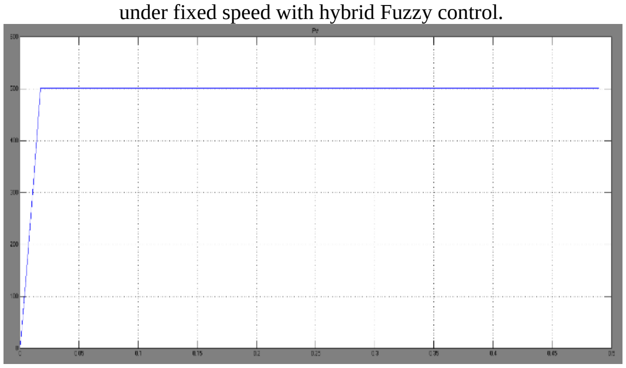

Fig.36.PV Voltage.

Case 8: Performance of BLDC Motor Drive with hybrid Fuzzy controller at variableSpeed

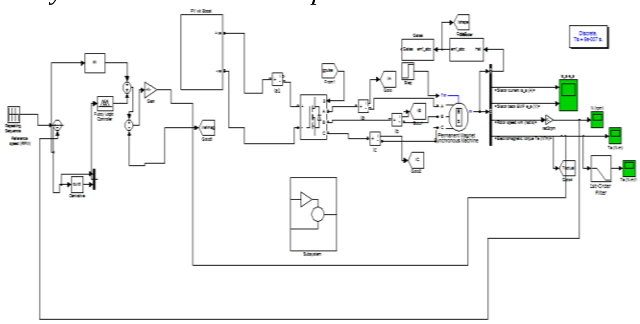

Fig 37: Matlab/Simulink model of BLDC motor under variable speed withHybrid Fuzzy control.

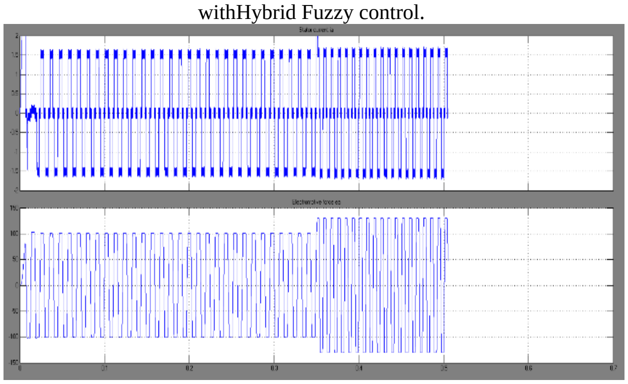

Fig 38: Simulated output wave form of Stator current and EMF of BLDC motor under variable speed with hybrid Fuzzy control.

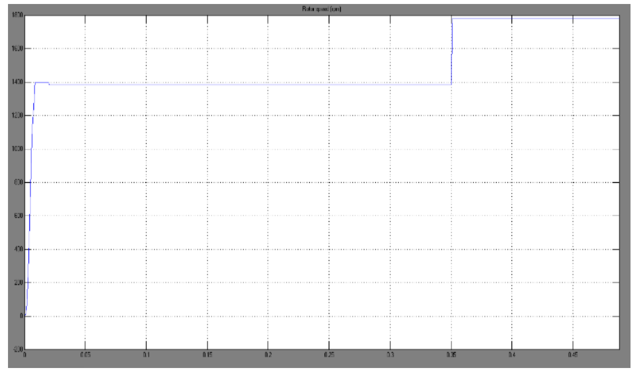

Fig 39: Simulated output wave form of BLDC motor speed at variable reference speed with hybrid Fuzzy control.

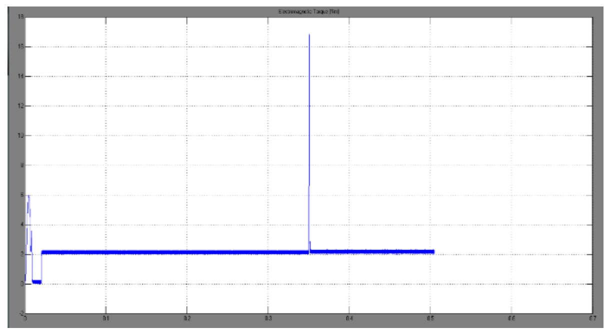

Fig 40: Simulated output wave form of Torque of the BLDC motor under variable speed with hybrid Fuzzy control.

Table 3
Comparative Analysis of Steady state speed response value with PI, Fuzzy and hybrid fuzzy based current controllers for BLDC Drive

Controller	**Time taken for speed to reach steady state**
PI Controller	0.35sec
Fuzzy Controller	0.02sec
Hybrid Fuzzy Controller	0.009sec

VII.CONCLUSION

This project analysis the main factors that the new converter called SRC Solar Reconfigurable converter used to drive the PMBLDC motor. The basic concept of the SRC is to use a single power conversion system to perform different operation modes such as PV to BLDC Drive (dc to ac), PV to battery(dc to dc), Battery to BLDC drive (dc to ac), and PV/battery to BLDC drive(dc to ac) for solar PV systems with energy storage. The proposed solution requires minimal complexity and modifications to the conventional three phase solar PV converters for PV –battery application. Therefore, the solution is very attractive for PV-battery application, because it minimizes. A hybrid fuzzy logic controller (HFLC) has

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been employed for the speed control of BLDC motor drive and analysis of results of the performance of a fuzzy controller is presented. A performance comparison between the hybrid fuzzy logic controller and the conventional PI controller has been carried out by simulation runs confirming the validity and superiority of the fuzzy logic controller for implementing the hybrid fuzzy logic controller is adjusted. The performance of the BLDC drive with reference to PI controller, hybrid fuzzy logic controller and fuzzy logic controller experimental verified with conventional controller. Hybrid fuzzy logic speed controller improved the performance of BLDC Drive of the fuzzy logic speed controller. For further extent of the work, new Artificial Intelligence (AI) technique can also be used for multiple control of BLDC motor.

REFERENCES

[1] Hongrae Kim, Babak Parkhideh, D. Bongers, and Heng Gao "Reconfigurable Solar Converter: A Single-Stage Power Conversion PV- Battery System" , IEEE Trans.Power Electronics, Aug. 2013.

[2] Dr.T.Govindaraj, and A.Kanimozhi," Instantaneous Torque control of Small Inductance Brushless DC Drive,"International Journal Of Advanced and Innovative Research.ISSN: 2278-7844, Dec- 2012 ,pp 468- 474.

[3] M. G. Villalva, J. R. Gazoli, E. Ruppert F, "Modeling and circuit based simulation of photovoltaic arrays", university of Campinas - UNICAMP,Brazil. Brazilian journal of power electronics, 2009.

[4] P. Barrade, S.Delalay, and A. Rufer, "Direct connection of Super capacitors

[5] to photovoltaic panels with on-off maximum power point tracking," IEEE Trans. Sustainable Energy, vol. 3, no. 2, pp. 283– 294, Apr. 2012.

[6] Z. Zhao, M. Xu, Q. Chen, J. Lai, and Y. Cho, "Derivation, analysis, and implementation of a boost-buck converter-based high-efficiency PV inverter," IEEE Trans. Power Electron., vol. 27, no. 3, pp. 1304–1313,Mar. 2012

[7] Yasuhiro Komatsu, Syed Abdul Kadir Zawawi, Hirotaka Ito and Yoshihiko Arakins, "The study of unidirectional energized BLDC motor for E-type iron core," Electrical Machines and Systems (ICEMS), 2011 International Conference, 20-23 Aug. 2011.

[8] Seyed Mohammad Hossein Mousavi, Seyed Sajjad Salehi Ghaleh Sefid and Seyed Ebrahim Salehi Ghaleh Sefid "Simulation of a new multiphase BLDC motor drive," 2012 IEEE International Conference on Power Electronics, Drives and Energy Systems (PEDES), 16-19 Dec. 2012.

[9] Meagan Mathew, M. Jayakumar, "Isolating faults in BLDC motors using discrete square root filtering and Bayes Classification," 2012 Annual IEEE India Conference (INDICON), 7-9 Dec. 2012.

[10] Muhammad Nizam, Agus Mujianto, Hery Triwaloyo and Inayati, "Modelling on BLDC motor performance using artificial neural network (ANN)," Rural Information & Communication Technology and Electric-Vehicle Technology (rICT & ICeV-T), 2013 Joint International Conference, 26-28 Nov. 2013.

[11] Tashakori and M. Ektesabi, "Torque A simple fault tolerant control system for Hall Effect sensors failure of BLDC motor," 2013 IEEE 8th Conference on Industrial Electronics and Applications (ICIEA), 19-21 June 2013.

[12] Ranganth Muthu, M. Senthil Kumaran, L. A. Abishek Rajaraman and P. Ganesh, "Direct Torque Control of matrix converter fed BLDC motor," 2014 IEEE 6th India International Conference on Power Electronics (IICPE), 8- 10 Dec. 2014.

[13] Taywin Nilsakorn, Kaweepoj Woranetsuttikul, Kittapas Pinsuntia, "Harmonic effect on BLDC motor temperature caused by driving system," Electrical Engineering Congress (IEECON), 2014 International, 19-21 March 2014.