SPEED CONTROL OF BLDC MOTOR USING PID TUNED FUZZY CONTROLLER

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Abstract - Brushless DC Motor (BLDC) is commonly used in the industrial applications which provide high efficiency, noise less operation, controllability, reliability and high power and torque density. The speed control of BLDC motor is controlled with PID based fuzzy tuned controller with load changing parameters as torque and current. The desired speed is achieved by proper adjustment of the gains of the PID controller. For power optimization a DC-DC Boost converter is used as an intermediate power conditioning unit in Solar Photo Voltaic (SPV) array fed to 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. The proposed method is designed and simulated in MATLAB/ Simulink for various values of load changing parameters.

***Key Words*: electronic commutation, Solar Photo Voltaic array, Boost converter, voltage source inverter, fuzzy tuned controller.**

1. INTRODUCTION:

Today the world is in predicament of energy crunch. Conventional energy sources are depleting at a very rapid rate which has led to the research and exploitation of nonconventional energy sources like wind, solar and tides. Solar radiations are available to us easily for the most of time and is easy to harness, therefore the research towards solar energy is emphasized more. Solar energy systems are in great demand in remote areas where electricity is not available. Hence to improve PV systems we need power electronics for interfacing and augmenting its efficiency. Sunlight is the source of electromagnetic radiation which produces electricity from solar cells without any moving parts hence minimal maintenance is required[2-3].BLDC motors are high efficiency, noise less operation, controllability, reliability and high power and torque density[4-5]

As there was a radical reduction in the cost of solar PV array modules, and rapid increase of fuel consumption made the industrialists, researchers and consumers are incited to use the PV arrays. 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 [6].For efficient usage of power i.e. power optimization or Maximum Power Point Tracking (MPPT) is preferred due to the advantages of continuous and low ripple output current. The Perturb and Observe Maximum Power Point Tracking (P & O-MPPT) algorithm results in soft starting of the BLDC motor i.e., the reduced starting current inhibits the harmful effect of the high starting current on the windings of the BLDC motor.

BLDC motors are a type of synchronous motor that revolves at constant speed giving stable operation. On the other side, the asynchronous motors find it difficult to attain constant speed under varying load conditions, though it can be obtained with some additional setups. The BLDC motors have many advantages and in fact a few disadvantages also. As the name specifies they have no brushes. Thus, all the issues caused by brushes are eliminated. This result in high efficiency improves the reliability and increases the life of the system. The working is quiet and there is less Electro Magnetic Interference (EMI). The commutation is done electronically based on the hall signals.

Here the interior Permanent magnet synchronous machine (IPMSM) is preferred because of the high efficiency, high starting torque, less electrical noise and reliability. For a desired speed of a BLDC motor for various load changing parameters like torque and current are varied and by using the PID based fuzzy controller desired output of the motor is obtained.

1.1 BLOCK DIAGRAM:

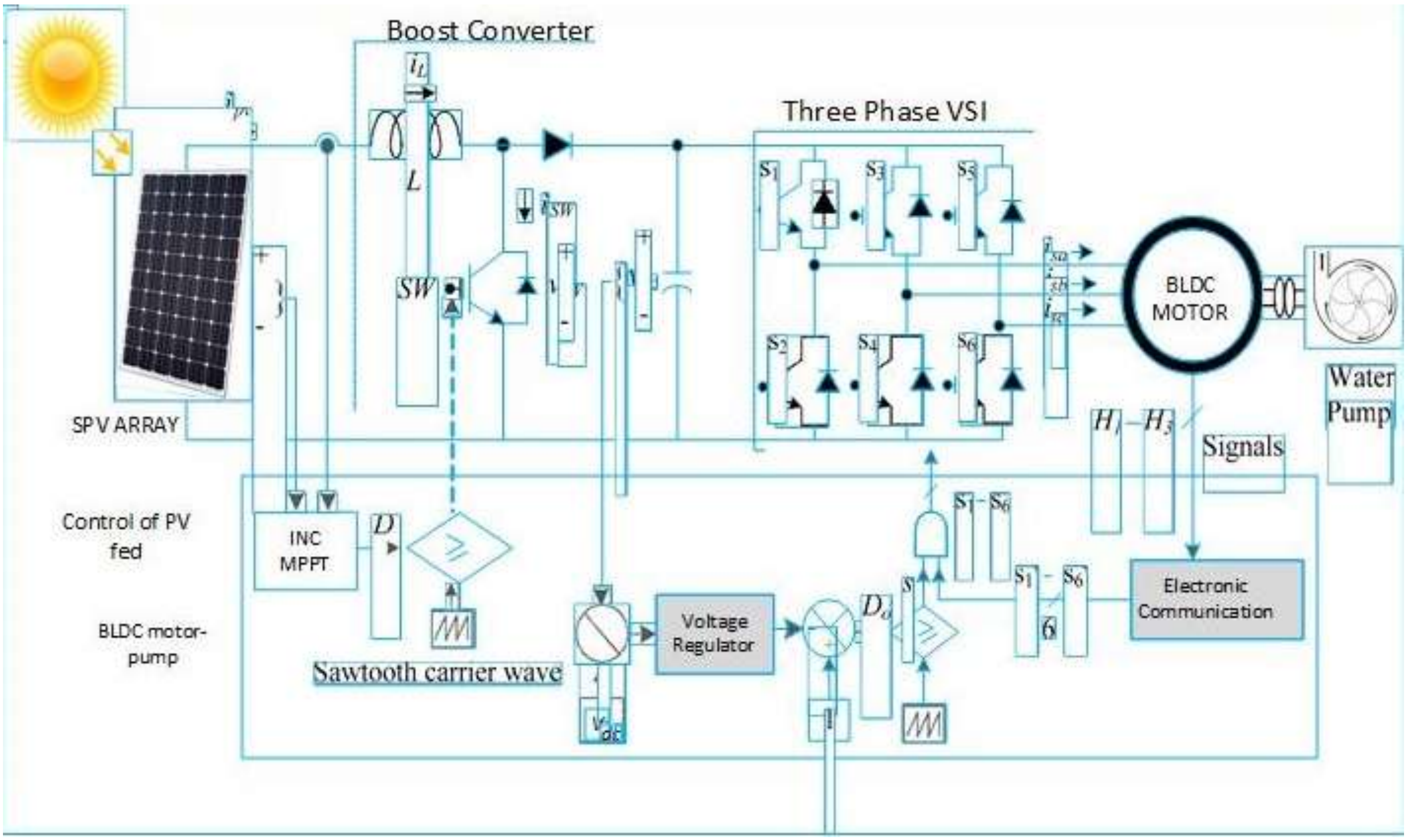

Fig.1. Block Diagram of Project

1.2 BLDC Drive Operation with Inverter:

The BLDC is fed by a three-phase inverter as shown below and is basically an electronic motor. In self-control mode, the inverter acts like an electronic commutator that receives the switching logical pulse from the absolute position sensors. The drive is also known as an electronic commutated motor. Basically, the inverter can operate in the following two modes.

1.3 Voltage and current control PWM model:

The 120 degree angle mode the inverter switches were controlled to give commutator function only when the devices were sequentially ON, OFF at $2\pi/3$ - angle duration. In addition to the commutator function, it is possible to control the switches in PWM chopping mode for controlling voltage and current continuously at the machine terminal. There are essentially two chopping modes feedback mode and freewheeling mode. In both these modes devices are turned on and off on duty cycle basis to control the machine average current I_{av} and the machine average voltage V_{av}.

International Research Journal of Engineering and Technology (IRJET) e-ISSN: 2395-0056
Volume: 06 Issue: 06 | June 2019 www.irjet.net p-ISSN: 2395-0072

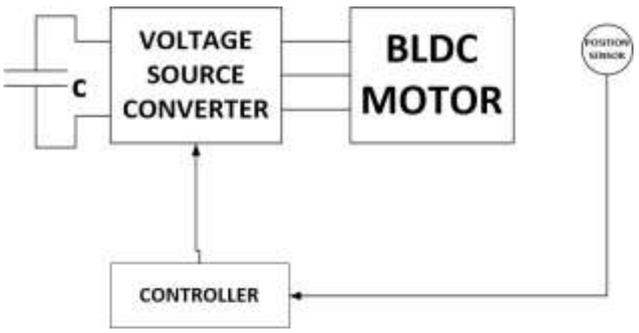

Fig.2. BLDC motor Drive

It symmetrically places the DC input current at the center of each phase for 120°. Six switching pulses are generated as per the various possible combinations of three Hall-effect signals. These three Hall-effect signals are produced by an inbuilt encoder according to the rotor position. A particular combination of Hall-effect signals is produced for each specific range of rotor position at an interval of 60°. The generation of six switching states with the estimation of rotor position is tabularized in Table II. It is perceptible that only two switches conduct at a time, resulting in 120º conduction mode of operation of VSI and hence the reduced conduction losses

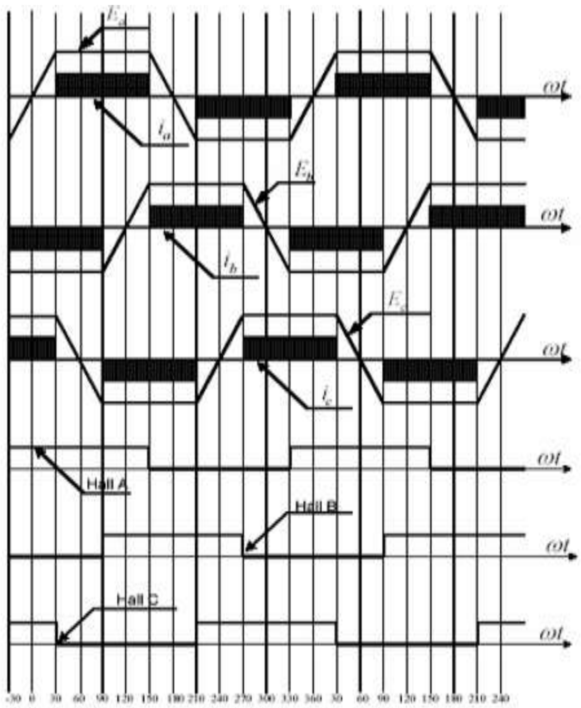

Fig.3. Waveforms of Hall Signals, Phase Currents and emf of a BLDC Motor

1.4 Switching States of Voltage Source Inverter :

Rotor position (^{0})	Hall signals			Switching states					
	H_1	H_2	H_3	S_1	S_2	S_3	S_4	S_5	S_6
NA	0	0	0	0	0	0	0	0	0
0-60	1	0	1	1	0	0	1	0	0
60-120	0	0	1	1	0	0	0	0	1
120-180	0	1	1	0	0	1	0	0	1
180-240	0	1	0	0	1	1	0	0	0
240-300	1	1	0	0	1	0	0	1	0
300-360	1	0	0	0	0	0	1	1	0
NA	1	1	1	0	0	0	0	0	0

The operation of BLDC motor is explained. One of the main component of BLDC drive system is voltage source inverter which provides power supply to the BLDC motor. The switching of the inverter is provided through hall sensor signals. The specifications of BLDC drive are demonstrated.

1.5 DESIGN SPECIFICATIONS:

The specification of BLDC motor used in this work is as follows:

Power, P	930W
Speed, N	3000 rpm
DC voltage	310 V
No. of poles	4
Moment of inertia	8 Kg.cm^2
Voltage constant, K_e	78 V/k rpm
Torque Constant	0.74 Nm/A
Phase inductor, L_s	9.13mH
Phase Resistance,R_s	3.58Ω

1.6 Design of solar PV array and PV module

For a PV Module	
Parameters	Value
Maximum power, P_M (W)	48.45
Voltage at maximum power point, V_{MPP} (V)	17
Current at maximum power, I_{MPP} (A)	2.85
Open circuit voltage, V_{oc}(V)	21
Short circuit current, I_{sc}(A)	3.11
For a PV array	
Maximum power, P_M (W)	1360
Voltage at maximum power point, V_{MPP} (V)	82
Current at maximum power, I_{MPP} (A)	16.58
Open circuit voltage, V_{oc}(V)	105
Short circuit current, I_{sc}(A)	18.66
Number of modules in series, N_s	182
Number of modules in parallel, N_p	6

1.7 Design of Boost converter:

S.No.	Parameter expression	Selected value
1	$L_1 = \frac{DV_{pv}}{f_s \Delta I_{L1}}$	6mH
2	$L_2 = \frac{(1-D)V_{pv}}{f_s \Delta I_{L1}}$	6mH
3	$C_1 = \frac{DI_{dc}}{f_s \Delta V_{C1}}$	22µF

Where f_s is switching frequency,

D is duty cycle[8],

which is obtained from below formula

$$D = \frac{Vdc - Vpv}{Vdc}$$

V_{pv} is voltage of PV array.

2. Control of Proposed method:

The control of proposed method is done by SPV Array which is controlled through INC-MPPT and VSI controlled through electronic commutation BLDC motor.

Here the speed control of BLDC motor is controlled with PID based fuzzy tuned controller with load changing parameters as torque and current. The desired speed is achieved by proper adjustment of the gains of the PID controller. At linear variation of the torque and current values a specified range is fixed and based on that range the values of the gains of PID controller is tuned.

The V_{pv} obtained at the solar PV array i.e. V_{pv}=153 V is boosted upto V_{dc}=310V with a current value of I_{dc}=5.22 A at the boost converter. This voltage is fed to the voltage source inverter and finally to the BLDC motor.

2.1 PID Controller:

Three-term controller/PID controller is a control loop feedback mechanism rapidly used in industrial control systems and a variety of other applications requiring continuously modulated control. A PID controller continuously calculates an error value as the difference between a desired set-point (SP) and a measured process variable (PV) and applies a correction based on proportional, integral, and derivative terms (denoted *P*, *I*, and *D* respectively), hence the name is PID controller.

The output equation of PID controller is

$$u(t) = k_p * e(t) + k_i \int_0^t e(t)dt + k_d \frac{de(t)}{dt}$$

where k_p= proportional gain

k_i= intergral gain

k_d= derivative gain

3. Fuzzy controller:

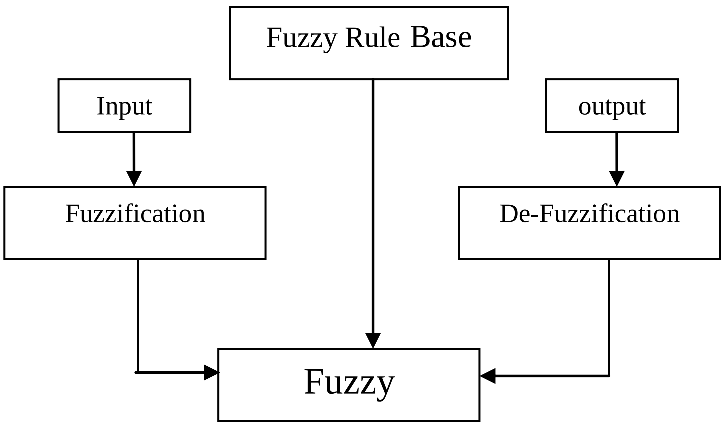

Fig.4. Basic Block diagram of FLC

Fuzzy control system is a control system based on fuzzy logic that a mathematical system that analyzes analog input values in terms of logical variables that take on continuous values between 0 and 1, in contrast to classical or digital logic, which operates on discrete values of either 1 or 0.

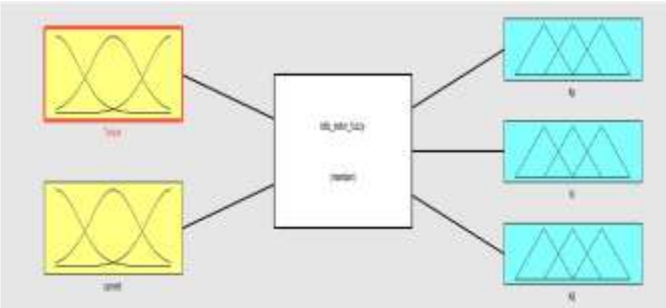

Fig.5. FIS for speed control of BLDC motor

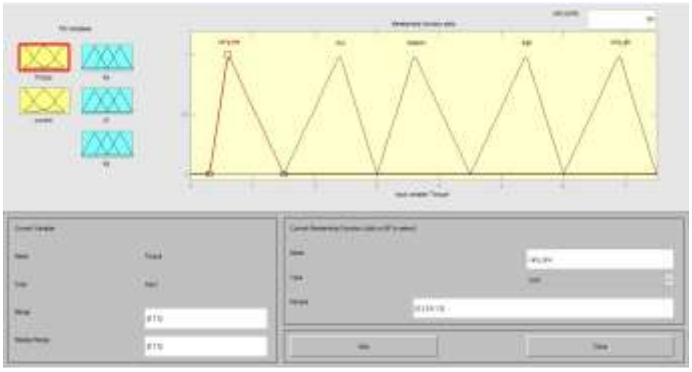

Fig.6. Input membership function

4. SIMULATION AND RESULTS:

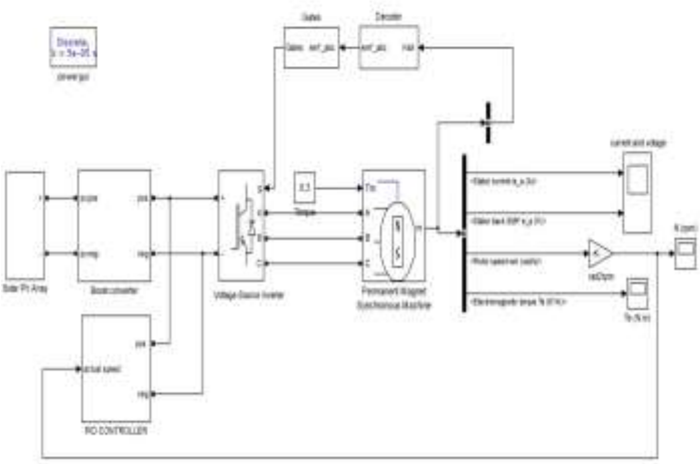

Fig.7.Matlab/Simulink block diagram using PID controller

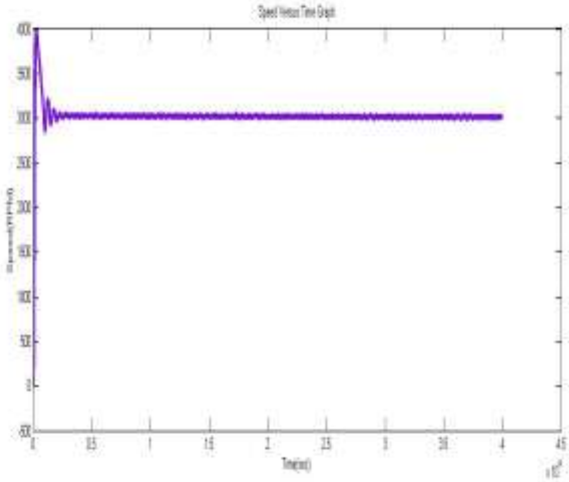

Fig.8.Speed versus Time

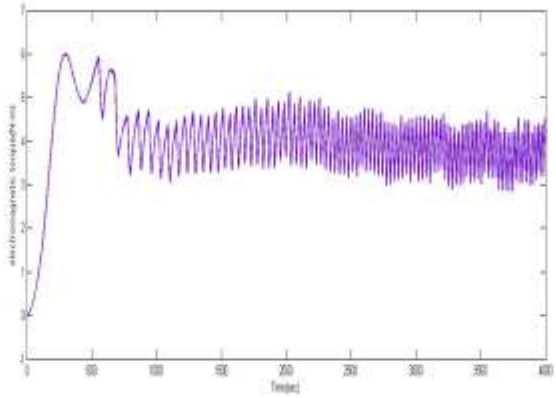

Fig.9.Electromagnetic Torque versus Time

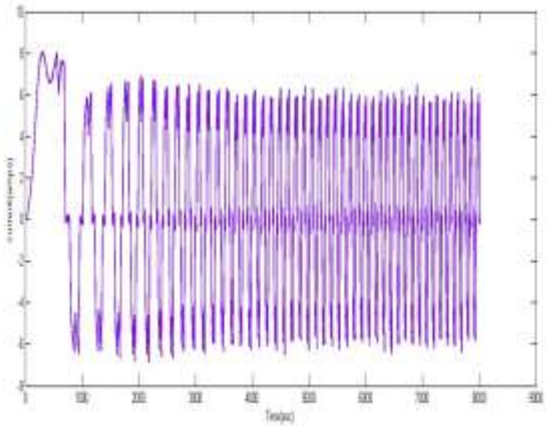

Fig.10.Stator Current Versus Time

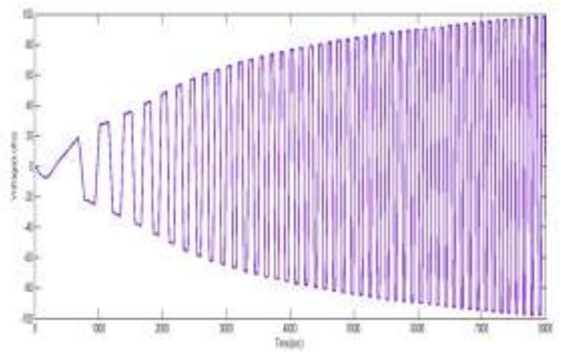

Fig.11.Stator Voltage Versus Time

4. Conclusions and Remarks:

The proposed solar powered boost converter fed BLDC motor has designed, modeled and simulated in the MATLAB/Simulink. The performance of proposed drive was observed from BLDC motor staring current, speed and torque curves. It has found that starting inrush current of the drive is low compared with conventional DC-DC converter. The performance of the motor speed and torque was found satisfactorily for constant temperature and irradiance condition and also for variable temperature and irradiance condition. The DC voltage and phase current sensing elements are eliminated, resulting in a simple and cost effective drive. Low starting inrush current results soft starting of motor pump. Based on the simulation results, BLDC motor with boost converter is suitable and compatible combination for solar PV based BLDC Drive at variable weather conditions .Hence for the desired speed of the motor is achieved by the proper adjustments of gains of PID based fuzzy controller for different variation of load.

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