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A new vector control for Brushless DC Motor using effective photovoltaic power source

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Abstract

In increasing demand of non-renewable power source, renewable power generation is create impact on power demand. PV (Photovoltaic) source is having notable merits such as noiseless, pollution free and high efficient power generation over wind power generation. This paper proposed a sensor less vector control of Brushless DC (BLDC) Motor using space vector Pulse width modulation generation. Photovoltaic power sources is used for supplying power for brushless DC drive and power generation capability of PV (Photovoltaic) is improved by fuzzy logic based maximum power point tracking scheme is proposed in this paper. Proposed MPPT is a modified form of incremental conductance and its overcome demerits such as extraction in local area, extended commutation time of solar array. The control and estimation of parameters are effectively derives in proposed vector control scheme without need of additional loops. The enhanced of proposed scheme is implemented using MATLAB/Simulink results.

Index terms: PV **(**Photovoltaic system), Two-diode PV system, MPPT (Maximum Power Point Tracking), Fuzzy MPPT (Fuzzy based IC), VSI (Voltage Source Inverter), Sensor-Less Vector Control

Introduction

Increasing of energy demand in a world, renewable power generation is a best and suitable alternative power source. So many analyses are carried out to development of renewable source in literatures [1]-[3]. Photovoltaic system is a suitable system in renewable generation which wind power source and fuel cell power sources [4]. The photovoltaic system is having notable unique merits which pollution free in nature, less maintenance, high efficient power delivery and noise less power generation.

The most common photovoltaic system is single diode photovoltaic system [5], [6] because it has a perfect relationship between voltage and current and simplified structure. Even though the single diode based photovoltaic module is having merits but computation time is large and iteration speed of parameters is been considered.

The two diode scheme is implemented for increasing efficiency, processing of iteration speed and reducing of computation time while comparison with single diode based photovoltaic system [7], [8]. The topology is proposed that two diode photovoltaic system with having high efficiency, simplified structure and neglecting series/ parallel resistor. Photovoltaic performance and its characteristic is varied by temperature variation, solar irradiation and output power so parameters of saturation current I_0 , series resistance R_S , shunt resistance R_{SH} , photovoltaic current I_{PV} and ideality constant A . The most common photovoltaic system is single diode photovoltaic system , because it has a perfect relationship between voltage and current and simplified structure. Even though the single diode based photovoltaic module is having merits but computation time is large and iteration speed of parameters is been considered.

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A maximum power point tracking is introduces to extract power from photovoltaic system by varying condition of irradiation and temperatures. A fuzzy logic based MPPT (Maximum Power Point Tracking) is presented for proposed two-diode photovoltaic system. This is modified form of incremental conductance scheme and reached high power extraction over classical MPPT topology.

This paper is presented a two-diode photovoltaic system is fed with BLDC (Brush Less DC) Motor Control. Fuzzy logic approach is used to improving efficiency of maximum power extraction in Two-diode photovoltaic system. Brushless DC Motor is effectively controlled by presented sensor-less vector control using space vector Pulse width modulation scheme. An angle and speed reference estimation greatly derived by presented vector control scheme without need of additional loop. The performance of presented topology is verified by using MATLAB/Simulink result

Photovoltaic system

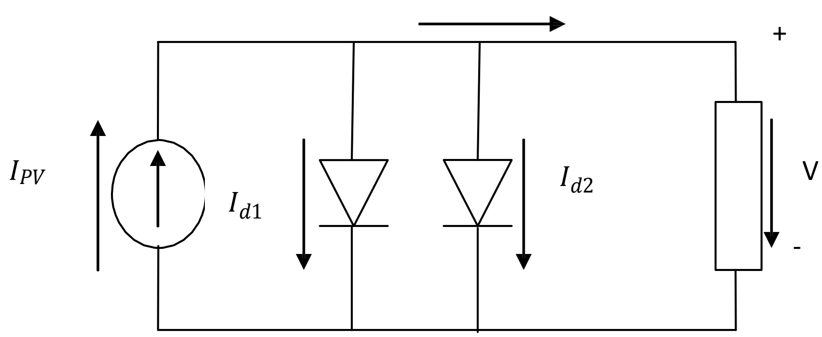

Fig. 1 equivalent circuit for two diode photovoltaic system

From the Fig.1, two-diode model the current equation can be represented in equation (1) accordingly;

$$I = I_{PV} - \exp\left(\frac{q(V+IR_S)}{N_S KT A_1}\right) - 1 - I_{02}\exp\left(\frac{q(V+IR_S)}{N_s KT A_2}\right) - 1 - (V + IR_S)/R_{sh} \quad (1)$$

Where;

q - Electron charge (1.6 × 10−19C)

K - Boltzmann constant (1.38 × 10−23Nm/K)

T- PV module temperature in Kelvin

I_{01} - reverse saturation current of diode 1

I_{02} - reverse saturation current of diode 2

A_1 -diode ideality constant of diode 1

A_2 - Diode ideality constant of diode 2

I_{PV} - Light generated current of PV module in amperes

R_s -series resistance of PV module

R_{sh} -parallel resistance of PV module

N_s - Number of PV cells connected in series.

I- PV current (A).

A mathematical model of the PV module is constructed by using five parameters, such as

reverse saturation current (I_0), photoelectric current (I_{PV}), series resistance (R_s), shunt resistance (R_{sh}), and ideality constant (A), are required to be calculated its magnitude of I_{02} is found that nonlinear equations (5) and some of the parameters are assumed arbitrarily, since required to reduce the number of unknowns. A two diode model is attempt to reduce mathematical computation time and complexity, the proposed model has reduces the series and parallel resistances [9],

$$I = I_{PV} - I_{01}\ \exp\ \frac{q\ V}{N_S KTA_1} - 1\ - I_{02}\ \exp\ \frac{q\ V}{N_S KTA_2} - 1 \qquad (2)$$

I_{PV} , I_{01} , I_{02} , A_1 , A_2 are unknown parameters to be found in pv model respectively. I_{02} is derived from I_{01} ; however the further unknown parameters are estimated. Those are determined from the constructed datasheet, which is obtained below. PV current (I_{PV}) can be derived from in terms of a short-circuit current under well standard test conditions (STC) in which the PV cell surface irradiation and temperature are 900W/m2 and 300 K by (3), consider variation of

temperature and irradiation. I_{PV} Has a linear relationship to irradiation (G) and short-circuit current (I_{sc}) [10], and which can be follows as

here I_{SC} is the short-circuit current under STC, ΔT is the temperature difference between module temperature (T) and the STC temperature, K_I is called short-circuit current constant and this is preferred from the datasheet, G is surface irradiation, and GSTC is the surface irradiation under short-circuit current. The equation to describe the saturation Where K_v is called voltage temperature constant and the value is taken from data sheet, and V_{oc} is

the open-circuit voltage. it can be describes as equation (5)

TABLE I

ESTIMATED PARAMETERS OF THE PROPOSED MODEL

S = 1000 W/m2				T = 250C	
Parameters	I(A)	V(V)	T(0C)	V(V)	S(W/m2)
1	3.1	21.5	00	24.6	400
2	3.2	22.9	250	24.7	600
3	3.3	24.8	500	24.8	800
4	3.4	26.5	750	24.9	1000

The calculation of ideality factors A1 and A2 values and drawing in I–V curves and the model is simulated in the MATLAB environment. The intelligent and simplified two-diode model of PV array I–V curves and p-v curve should be validated for different temperature(℃) and irradiate value.

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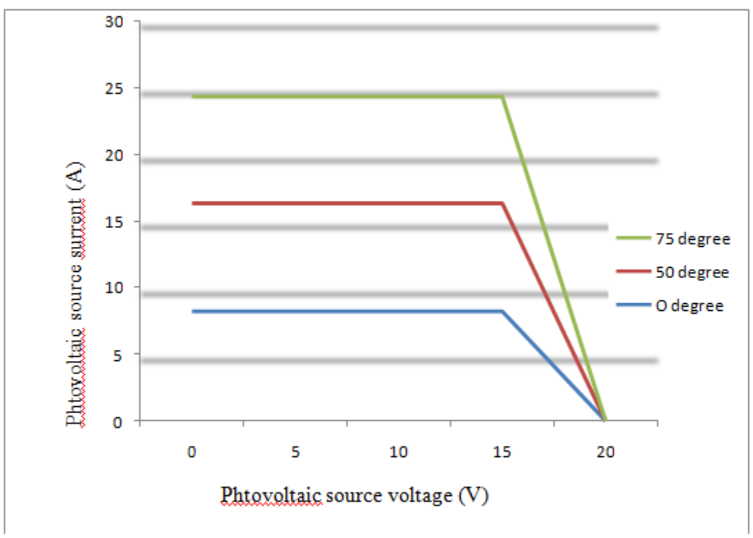


Fig 2. I–V curves of two-diode model for constant S=1000W/m2 irradiation level, different temperature.

From Fig.2, performance of the two diode modeling I-V curve should draw between different temperature variations, constant irradiation S=1000W/m2 illustrated. The temperatures examined are 25◦C, 50◦C, and 75◦C, respectively. Ideality factor constants are major parameters that can able to affects the performance of a PV setup. Ideality constant factors are calculated by using a simple iterative matching algorithm, which is shown in Fig.3.Short-circuit current of the PV module is not changed by constant Ideality factor($A_1 A_2$).whereas , the open-circuit voltage varies linearly with ideality constant[11]-[12] .

Proposed MPPT (Maximum Power Point Tracking) Algorithm

In this chapter, fuzzy logic based Maximum Power Point Tracking (MPPT) technique is presented for improving photovoltaic generation. This is a modified form of incremental conductance algorithm.

[i]. MPPT (Maximum power point tracking) using fuzzy logic scheme

The maximum power point tracking is implemented using fuzzy logic scheme to introducing an advancement of maximum power point tracking control. The photovoltaic system was tested under different irradiation level 100 $m^2 to$ 1200 m^2 . Maximum peak power is located at particular region alone but in voltage of optimal working is classified into four types (N for N string level). The old approach of perturb and observer method and incremental conductance method is track or perform with in local area or region. The given enhancement of fuzzy logic based MPPT (Maximum Power Point Tracking) is presented in this approach for improving photovoltaic power generation over P&O (Perturb and Observer) and IC (Incremental Conductance method).Aim to achieve good performance in generation a fuzzy logic scheme is been initiated in incremental conductance algorithm to increase in performance. Control system is tested in two-diode photovoltaic system. The rules derivation is based voltage, current under various irradiations, temperature in average 40° and data given in data sheet. The buck boost converter is used to implement MPPT (Maximum Power Point Tracking) using fuzzy logic approach is shown in Fig.3.

The duty cycle is calculated for present MPPT approach is given as

$$V_{ref} = C - 0.5\ V_{OC}.STC \quad (13)$$

$$D_{ref} = V_{out} / V_{ref} \quad (14)$$

The flow chart given for proposed MPPT scheme given in Fig.7 for two-diode photovoltaic system as follow by

Initialization: initiate value calculated duty cycles references D_{ref} and old and sudden changed value of power for P_{old} and P_{sudden} respectively.

Fuzzy rules generation: drive a V-I curve for each irradiation level condition and calculate MPPT for each irradiation and temperature level, output of this applied to fuzzy logic control to generated rules for this scheme with respect photovoltaic system power conditions.

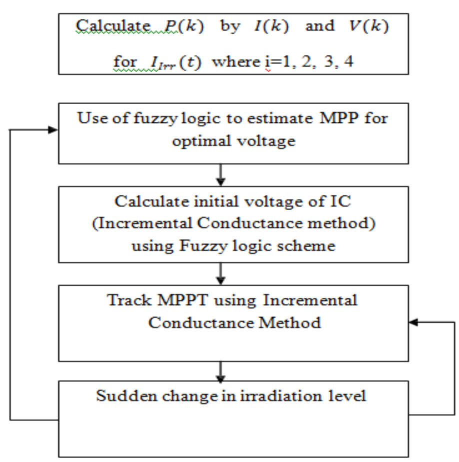


Fig.3 proposed MPPT (Maximum Power Point Tracking) method using Fuzzy Logic scheme

Speed control method using Vector control topology

The presented voltage source inverter controller is generating reference signals by comparing with positive sequence of supply voltage with load voltages is shown in Fig.4 Supply voltage V_{ia}, V_{ib}, V_{ic} is transformed as $d - q - 0$ using transformation method as given by equation

(15) and (16).

$$Trans = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} & \frac{1}{\sqrt{2}} \\ sin\ \omega t & \sin(\omega t - \frac{2\pi}{3}) & \sin(\omega t + \frac{2\pi}{3}) \\ \cos(\omega t) & cos(\omega t - \frac{2\pi}{3}) & cos(\omega t + \frac{2\pi}{3}) \end{bmatrix} \quad (15)$$

$$Trans^{-} = \sqrt{\frac{2}{3}} \begin{bmatrix} \frac{1}{\sqrt{2}} & \sin(\omega t) & \cos(\omega t) \\ \frac{1}{\sqrt{2}} & \sin(\omega t - \frac{2\pi}{3}) & \cos(\omega t - \frac{2\pi}{3}) \\ \frac{1}{\sqrt{2}} & sin(\omega t + \frac{2\pi}{3}) & cos(\omega t + \frac{2\pi}{3}) \end{bmatrix} \quad (16)$$

V_{ia}

V_{i0}

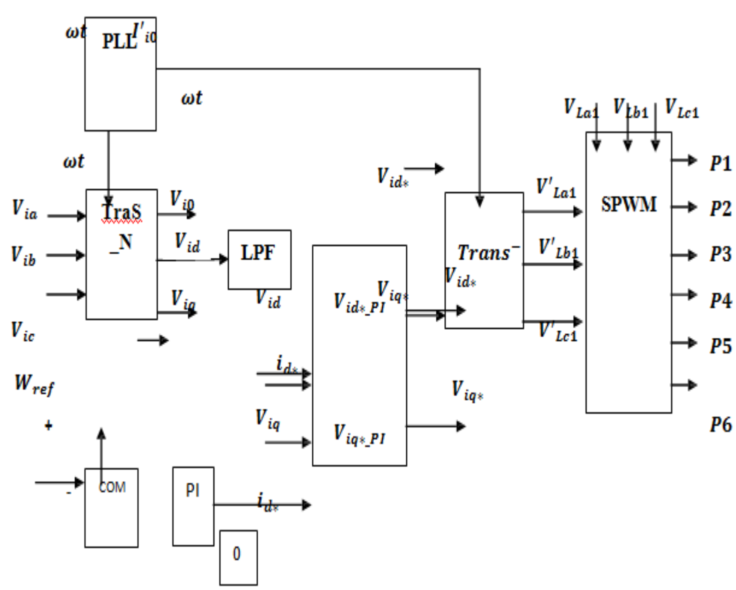


Fig.4 Proposed controller circuit diagram using vector speed controller

A rapid voltage V_{id}, V_{iq} is having both oscillation elements V_{id}, V_{iq} and mean elements V_{id}, V_{iq} with respect to unbalancing utility grid supply and harmonics condition. The same rapid voltage V_{id}, V_{iq} is having negative sequence components and harmonics occurrences on distorted supply voltage conditioS_N. Positive sequence is occurs on mean value of elements and zero sequence is occur on unbalancing voltage condition. One of rapid voltages $\boldsymbol{V_{id}}$ is consists of mean value and oscillation components is given by

$$V_{id} = V_{id} + V_{id} \tag{18}$$

The reference voltages on load side $V_{La1b1c1}$ are calculated is given by

$$\begin{matrix} V'_{La1} \\ V'_{Lb1} \\ V'_{Lc1} \end{matrix} = Trans^{-} \begin{matrix} V_{i0} \\ V_{id} \\ V_{iq} \end{matrix} \tag{19}$$

Inverse transform calculation is described on (20) is applying by mean components across supply voltage and ωt in proposed speed based vector control. Direct axis of positive sequence components voltages is calculated by low pass filters which is presented on controller circuit is shown in Fig.8. In equation (17), zero sequence components and negative sequence components becomes zero for control and overcoming an unbalancing, distorted and harmonics on system. A sinusoidal pulse width modulation is generated by comparing generated reference signals $V'_{La1,Lb1,Lc1}$ with load voltage $V_{La1,Lb1,Lc1}$.

Direct axis references current is calculating by comparing reference speed ω_{ref} and actual speed ω_{act} and given to speed control (PI control) to smooth and eliminate peak overshoot and gives a controlled direct axis current i_{d*} as an output. The output waveform is described by following mechanical equation [13]

$$\frac{d\omega_r}{dt} = \frac{1}{j}\left(T_e - T_m - B\omega_r\right)$$

Where, j is inertia of motor, B is viscous coefficient, T_m is a mechanical and T_e is an electrical torque.

Space vector pulse width modulation

A simple space vector based pulse width modulation scheme is introduces for controlling IBGT on inverter using reference voltage generation is shown in Fig.5 can be represented by switching states. Switching states are defined by torque error and flux errors shown in Table-1 and Table-2.

Table I. Switching State for proposed inverter configuration

state	Leg A			Leg B			Leg C		
	S_1	S_4	V_{an}	S_3	S_6	V_{bn}	S_5	S_2	V_{cn}
1	on	off	V_d	on	off	V_d	on	off	V_d
0	off	on	0	off	on	0	off	on	0

Table II. Switching State for proposed inverter configuration

Space vector		Switching state (three phases)	ON-state switch	Definition
Zero vector	V_1	1 1 1	S_1, S_3, S_5	0
		0 0 0	S_4, S_6, S_2	
Active vector	V_2	1 0 0	S_1, S_6, S_2	$V_1 = \frac{2}{3} V_d e^{j0}$
	V_3	1 1 0	S_1, S_3, S_2	$V_1 = \frac{2}{3} V_d e^{j\frac{\pi}{3}}$
	V_4	0 1 0	S_4, S_3, S_2	$V = \frac{2}{3} V_d e^{j\frac{2\pi}{3}}$
	V_5	0 1 1	S_4, S_3, S_5	$V = \frac{2}{3} V_d e^{j\frac{3\pi}{3}}$
	V_6	0 0 1	S_4, S_6, S_5	$V = \frac{2}{3} V_d e^{j\frac{4\pi}{3}}$
	V_7	1 0 1	S_1, S_6, S_5	$V = \frac{2}{3} V_d e^{j\frac{5\pi}{3}}$

Voltage state is derived from α and β reference frame below [14].

2

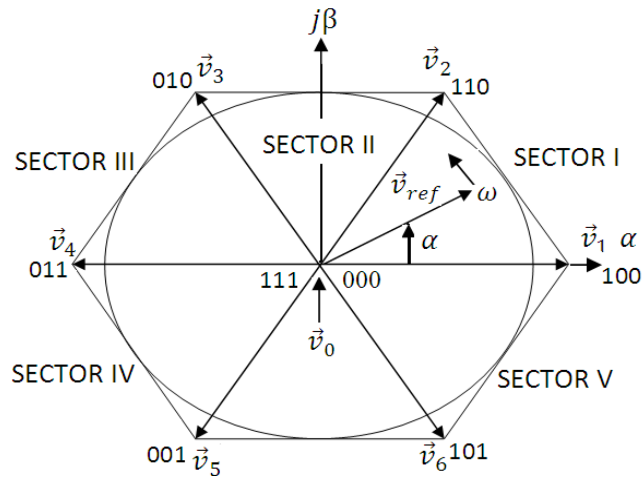


Fig. 5. Space vector diagram for two level inverter

By equating the real and imaginary parts derived by,

$$V_\alpha = \frac{2}{3}\left(V_a + \cos\frac{2\pi}{3} V_b + \cos\frac{2\pi}{3} V_c\right)$$

$$V_\beta = \frac{2}{3}\left(0V_a + \sin\frac{2\pi}{3} V_b - \sin\frac{2\pi}{3} V_c\right)$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \cos\frac{2\pi}{3} & \cos\frac{2\pi}{3} \\ 0 & \sin\frac{2\pi}{3} & \sin\frac{2\pi}{3} \end{bmatrix} \cdot \begin{bmatrix} V_a \\ V_b \end{bmatrix} \qquad (21)$$

3 3 V_c

The proposal of space vector modulation used to improved brushless DC Motor performances such as speed and current via vector control loop. Space vector modulation is interacting with vector control loop which phase lock loop circuit, park transform/park inverse transform, speed regulator using PI controller.

Simulation result and discussion

The presented scheme of two-diode photovoltaic fed Brushless DC Motor control is implemented using MATLAB/Simulink software to verify the performance of presented topology. Speed based vector control is presented to control of motor parameters even at load or power supply variation occur. Simple space vector based pulse width modulation is giving a better motor performance and also improving proposed control by interacting with control loop.

Table I parameters for Two-Diode photovoltaic system

Kyocera KC200GT for Two-Diode photovoltaic system	
Parameters	Value
$I_{sc}(A)$	8.20
$V_{oc}(V)$	32.90
$I_{mp}(A)$	7.61
$V_{mp}(V)$	26.3
$I_{o1}(A)$	5.0122×10^{-4}
$I_{o2}(A)$	1.298×10^{-5}
$I_{PV}(A)$	17
A1	1.7
A2	2.5

The two-diode photovoltaic system is designed using parameters given in Table I for applying voltage source inverter as an input supply via buck-boost converter system. And proposed system is designed using parameters given in Table II.

Table II Parameters for proposed system

Parameters	Value
PV (V)	200
$MPPT$ (V)	600
$INV(V)AC$	600
RL	300
Inverter frequency (f)	1kHz
$Load\ power$	500W
$duty\ cycle\ for\ buck - boost$	0.5
Buck-boost converter frequency (f)	25kHz

The given merits are proved by implementing proposed configuration as given in Fig.6 and performance waveform given in Fig.7 for photovoltaic system using fuzzy based MPPT. Motor performance is obtained and given in waveform in Fig.8 using parameters given in Table III

Parameters	Value
Nominal Power (W)	200
Voltage (V)	600
Frequency (f)	600
R_s	2.8750Ω
L_s	8.5mΩ
Rotor flux linkage	0.18Wb
P_P	4
J	0.0008 $kg.m^2$

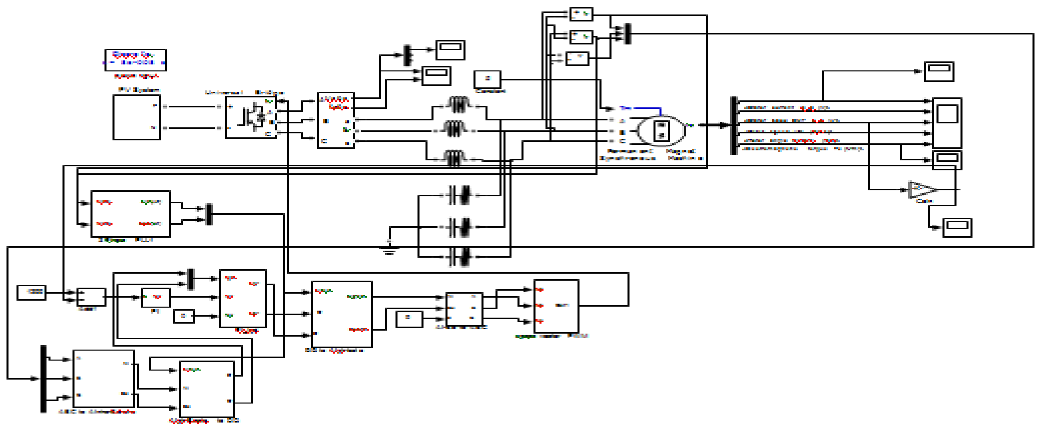
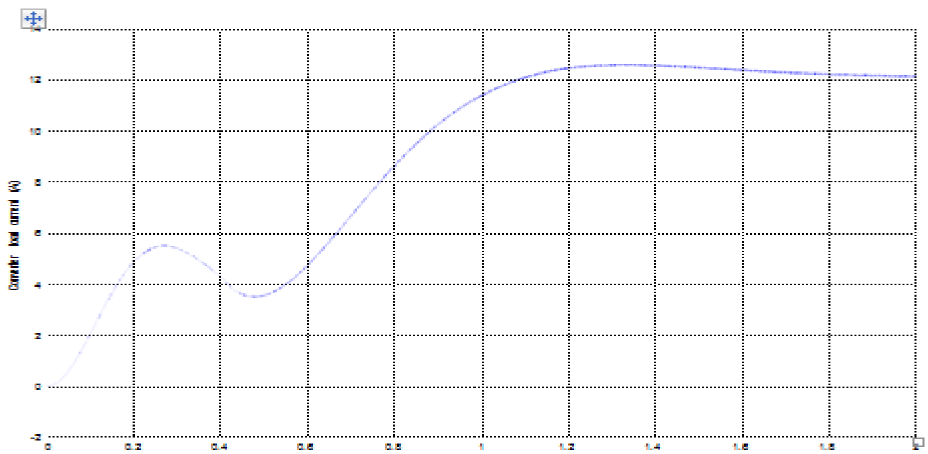
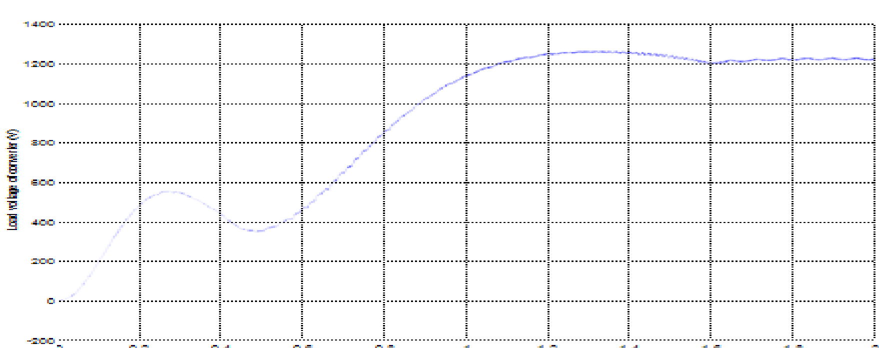


Fig.6 simulation implementation circuit for proposed configuration

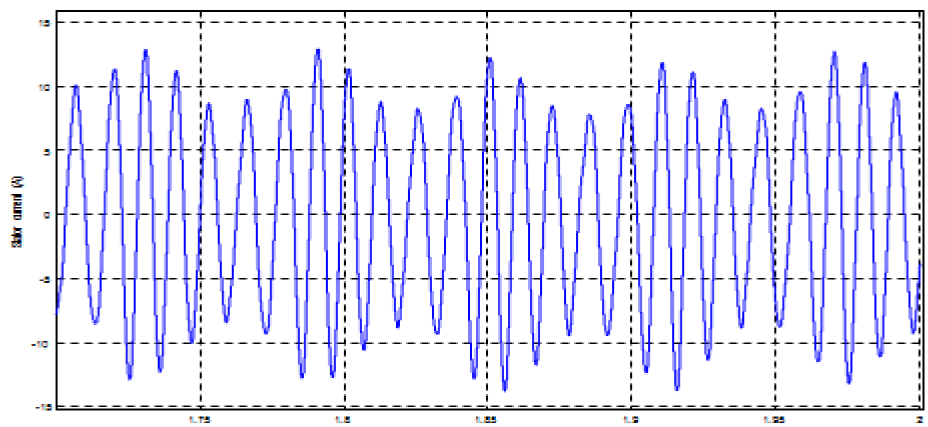


(a)

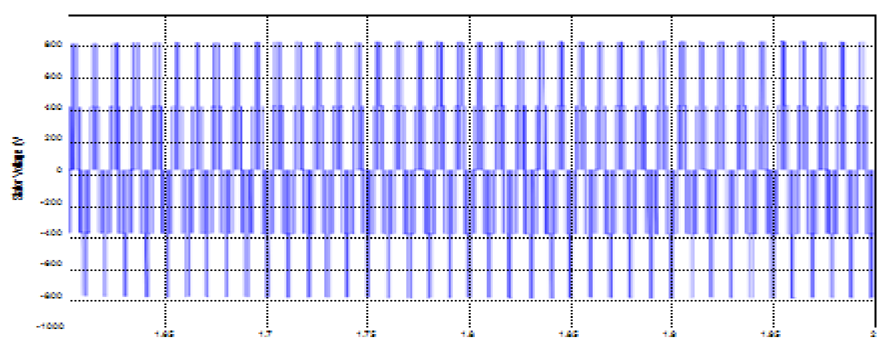


(b)

Fig.7. photovoltaic performance: (a) Photovoltaic current (A) (b) converter load voltage (V)



(a)



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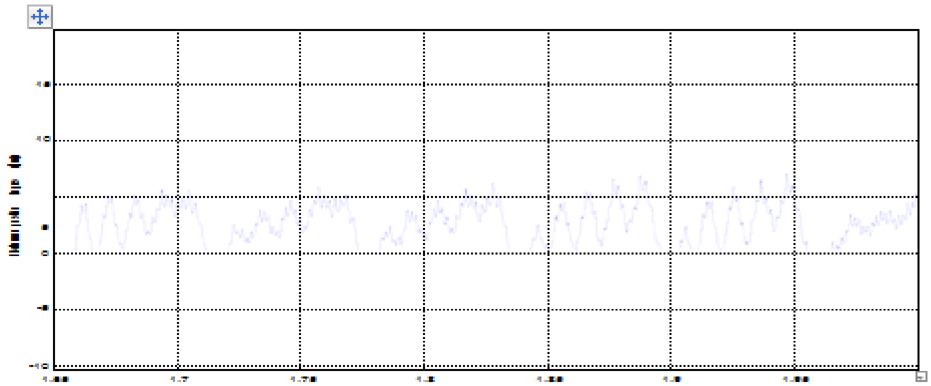
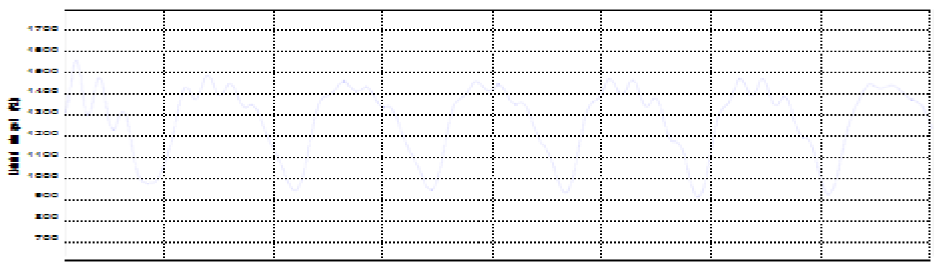


(c)



(d)

Fig.8. Motor performances: (a) Load current (A) (b) Load voltage (V) (c) Electromagnetic torque (d) Rotor speed (RPM)

Conclusion

This paper is proposed that control and operation of Brushless DC Motor control using speed based vector approach. Two-diode photovoltaic system is implemented for power supply and fuzzy logic based maximum power point technique for improving performance of photovoltaic. Commutation speed and efficiency aspects two-diode photovoltaic module is presented in this paper and also giving continuous power supply to Brushless DC Motor. BLDC (Brushless DC Motor) performance is controlled in both high power and low power supply with respect to photovoltaic conditions. The proposed speed based vector controller is implemented for smoothing brushless DC Motor performance in speed and current characteristics. A simple space vector modulation is given in control unit to improving vector control performance with respect to load conditions. The proposed circuit and control configuration is implemented using MATLAB/Simulink software and performance is greatly improved by obtained results.

References

[1] Shuang, G., Lei, D., Chengwei, T and Xiaozhong, L. (2011, April) "Novel converter of Wind Power Generation System of Non-Grid-Connection for Radio Base Station" In Electric Information and Control Engineering (ICEICE), 2011 International Conference on (pp. 2396-2400). IEEE.

[2] Hui, J., Bakhshai, A and Jain, P. K. (2010, February) "A hybrid wind-solar energy system: A new rectifier stage topology" In Applied Power Electronics Conference and Exposition (APEC), 2010 Twenty-Fifth Annual IEEE (pp. 155-161). IEEE.

[3] Emadi, A., Rajashekara, K., Williamson, S. S and Lukic, S. M. (2005) "Topological overview of hybrid electric and fuel cell vehicular power system architectures and configurations" Vehicular Technology, IEEE Transactions on, 54(3), 763-770.

[4] Yarlagadda, S. K., & Shireen, W. (2014, March) "A maximum power point tracking technique for single-phase PV systems with reduced DC-link capacitor" In Applied Power Electronics Conference and Exposition (APEC), 2014 Twenty-Ninth Annual IEEE (pp. 2950-2957). IEEE.

[5] Walker, G. (2001) "Evaluating MPPT converter topologies using a MATLAB PV model" Journal of Electrical & Electronics Engineering, Australia, 21(1), 49.

[6] Yetayew, T.T.; Jyothsna, T.R., "Improved single-diode modeling approach for photovoltaic modules using data sheet," India Conference (INDICON), 2013 Annual IEEE , vol., no., pp.1-6, 13-15 Dec. 2013

[7] Babu, B. C., & Gurjar, S. (2014) "A novel simplified two-diode model of photovoltaic (PV) module" Photovoltaics, IEEE Journal of, 4(4), 1156-1161.

[8] Salam, Z., Ishaque, K and Taheri, H. (2010, December) “An improved two-diode photovoltaic (PV) model for PV system,” in Proc. Joint Int. Conf. Power Electron., Drives Energy Syst.,New Delhi, India, Dec. 2010, pp. 1–5

[9] Y. Mahmoud, W. Xiao, and H. H. Zeineldin, “A simple approach to modelling and simulation of photovoltaic modules,” IEEE Trans. Sustainable Energy, vol. 3, no. 1, pp. 185–186, Jan. 2012.

[10] S. Liu and R. A. Dougal, “Dynamic multiphysics model for solar array,”IEEE Trans. Energy Convers., vol. 17, no. 2, pp. 285–294, Jun. 2002

[11] Dong-Hee Kim, Gyu-Yeong Cheo, Byoung-Kuk Lee “Design and Control of an Optimized Battery Charger for an xEV Based on Photovoltaic Power Systems,” J Electr .Eng. Technol Vol. 9, No. 5: 1602-1613, 2014.

[12] Wenfei Hu, Hongfei Wu, Yan Xing, Kai Sun, “A Full-Bridge Three-Port Converter for Renewable Energy Application,” IEEE Trans. 978-1-4799-2325-0/14. 2014.

[13] Puspendu Maji, Prof. G KPanda and Prof. P KSaha “Field Oriented Control of Permanent Magnet Synchronous Motor Using PID Controller” International Journal of Advanced Research in Electrical, Electronics and Instrumentation Engineering, Vol. 4, Issue 2, February 2015,pp.632-639.

[14] Mourad Masmoudi, Bassem El Badsi, and Ahmed Masmoudi “DTC of B4-Inverter-Fed BLDC Motor Drives With Reduced Torque Ripple During Sector-to-Sector Commutations” IEEE Transactions on Power Electronics, Vol. 29, No. 9, September 2014,pp.4855-4865.