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# Design of Landsman Converter Fed BLDC Motor using IFOC and Back EMF Estimation Method

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***Abstract***: *In this paper, sensor-less control of Brushless DC (BLDC) motor drive fed from Landsman Converter (LC) powered from photovoltaic (PV) is designed to improve the performance of the motor. For obtaining the torque ripple minimization and accurate speed control using simplified Indirect Field Oriented Control (IFOC) is applied to the motor with Back-EMF estimation method. It is used for estimation of speed in sensor-less approach and implements to tracks the continuous changes of speed. This estimated speed is used to initiate the rotor position, and hall commutation signals predicted from the rotor angle. The performance of sensor less BLDC motor with low voltage operation which expresses high efficiency at low cost and reduction in torque ripple are verified using MATLAB/Simulink.*

***Keywords***: *Back EMF, BLDC Motor, IFOC, LC converter, PV, Torque ripple.*

## I. INTRODUCTION

Brushless DC (BLDC) motor is high dependability, high proficiency, and high torque/inactivity proportion, improved cooling, low radio frequency interference and clamor and requires for all intents, purposes no support, and small in size to other motors. The supply from PV source to motor is difficult and through utilization of mathematical modeling an engine can draw a high power from PV source that sufficient to motor drives [1-3]. To extract the power from solar system, the MPPT technique is used in varying parameters condition and the incremental conductance based power extraction MPPT technique is tracking high power from solar system while compared with perturb and observe technique. The incremental and conductance is tracking power from PV source during the parameters variation such as given duty cycle, irradiance and temperature [4-6] In Interfacing a PV source for a BLDC motor drive is a challenging task that needs additional special converters and current limiting circuits. In [5,6] application of special DC-DC converters is limited within its drawbacks like the low step up ratio, count of passive elements, and requirement of a large capacitor.

The Landsman converter used only lesser passive components when compared with the special converter like Zeta, Cuk, SEPIC. Landsman converter used in found capable to overthrow the problems associated with these converters like requirement of input ripple filter in case of Canonical Switching Cell (CSC) converter and Luo converter and comparatively small input inductor requirement as compared to Cuk converter [7-10]. Landsman DC-DC converter is mainly from class of CSC converter and comprises all advantages of them. It is applied for carry out a good regulation at light load conditions and high efficiency, apart from at the cost of large quantity of inert constituents, as associated to a BL Landsman converter [11-12].

In [13] Brushless DC motors works on electronic commutation and it does not require mechanical commutation. Continuous rotor position monitoring is required for electronic commutation. For that continuous monitoring of rotor position is attained by using Hall Effect position sensors. For high speed power applications, the BLDC motors are mostly preferred and researches are developing BLDC drive motors due to improve the performance with low cost.

BLDC motor is driven from a landsman converter fed from a PV source, and a simplified IFOC control scheme is applied to enhance motors performance over previous approaches. Speed estimation algorithm involving a back EMF observer and then calculating the speed of BLDC motor based on the relation between back EMF and speed. A simplified Indirect Field Oriented Control technique is used where the speed of BLDC motor is estimated rather than obtaining from a sensor, back EMF observer method is in use to estimate speed [14-15].

Landsman converter (LC) is to extract the power from PV source as well as improving voltage gain. The implementation of LC is directing power to brushless DC motor from PV using power extraction technique of Inc & con MPPT algorithm. For controlling the motor speed, harmonics, torque ripple by using back EMF estimation with IFOC method is proposed.

## II. MATERIALS AND METHODS

PV source with Inc&Con MPPT algorithm is utilized to generate power to the LC. Landsman converter is used to optimize the power from the source.

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It also has the capability to overcome the conventional converter (SLQZSI) constraints such as high input current ripple, and low voltage gain.

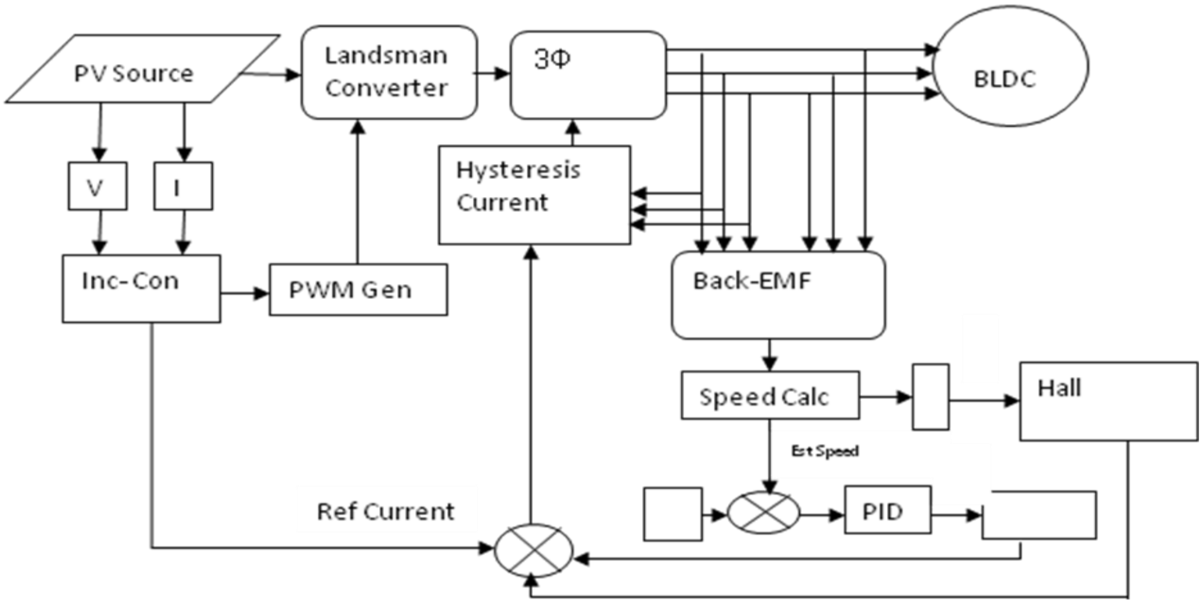


**Fig. 1. Overall Proposed System Diagram**

The main objective of the proposed system is to reducing the ripple in the torque at high efficiency using back EMF speed estimation method which relates with motor voltage and current values. The maximum value of back EMF is calculated after the estimation of back EMF. Subsequently, motor speed is obtained from the flux constant and back EMF. Simplified IFOC method is utilized to control the motor which uses the PID speed control device. Afterwards, reference signal is calculated by means of hysteresis current controller and it generates the pulses to switches in the inverter. Then the hall signal is produce from exact position of the rotor. Rotor speed is reached from the estimated speed of the rotor in the motor. This hall signal is modulated by reference current attained from the PID controller. And it gives reference torque which is used to achieve the reference current. Fig. 1 shows the overall proposed system diagram.

### A. Photovoltaic Power Generation

The PV cell which is said to be ideal consists of the current source and diode in parallel but practically there is some resistance hence the series and shunt resistance is added in the circuit. The PV array consists of series and parallel combination of photovoltaic cells. The series and parallel combination of photovoltaic cells are used to increase the voltage and current respectively. The solar cell consists of current source which is generated by the light energy, the current source and inverted diode are connected in parallel and then shunt and series resistance are connected with diode as shown in Fig. 2. Proposed photovoltaic model is designed by following equation and it's interfaced with dynamic single diode equivalent circuit as

$$I_{ph} = N_p\{I_{ph} - I_0\{\exp(\frac{qV_{mppt}}{nN_sKT})\}\} \qquad (1)$$

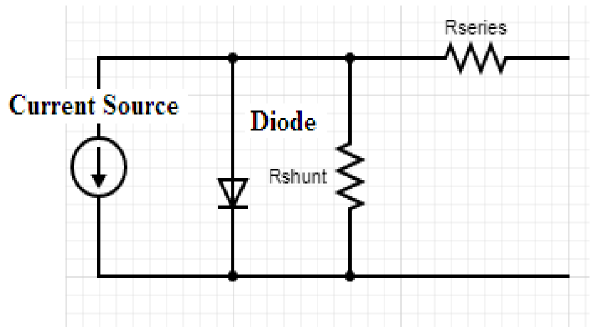


**Fig. 2.Two Diode PV Cell Equivalent Circuit**

The maximum power point tracking (MPPT) technique is used to utilize the solar power in efficient manner by tracking the maximum power point. The most commonly used MPPT algorithm are Inc & Con algorithm and incremental conductance. The Inc & Con MPPT [4] Scheme is introduced to extract maximum power from PV source. The Inc & Con algorithm has the advantages of simple structure and easy to implement because it demands less number of parameters but it has the disadvantage in accuracy. To overcome the problem of low accuracy incremental conductance method is introduced and the flow diagram is shown in Fig. 3.

Actual voltage $V_{act}$ and actual current $I_{act}$ in equation (1) is replaced by $V_{mppt}$ and $I_{mppt}$ is obtained by using Inc & Con method as equation 2. The power (P) and current (I) normal for photovoltaic exhibit is clarified on each $P_{ph} - V_{ph}$ characteristic can be extricated each working point for photovoltaic array is called MPPT Controller.

$V_K, I_K$ - Temporary voltage and current of PV array

$V_{K-1}, I_{K-1}$ - Voltage and current value of PV

$V_{ref}$ _ Output reference voltage

$V_{act}, I_{act}$ _ Actual voltage and current value

Output voltage references $V_{ref}$ are used to calculate the duty cycle values and also compare the various if conditions used in Inc& Con method as represent in Fig. 3

$$I_{mppt} = N_p\{I_{ph} - I_0\{\exp(\frac{qV_{mppt}}{nN_s KT})\}\} \quad (2)$$

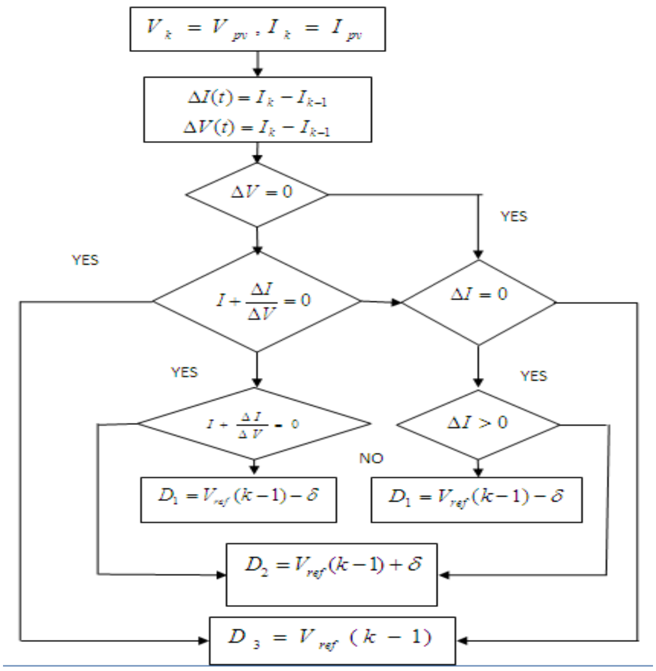


**Fig. 3.Inc & Con MPPT**

## B. Design of Landsman Converter and Its Modes of Operation

The proposed landsman converter is used to optimize the output voltage of PV panel and to provide smooth, safe, and noiseless starting of BLDC motor. It is also used to achieving the good regulation and reduces the high cost of passive elements. Landsman converter in this paper consists of two inductors (L1, L2), two capacitors (C1, C2), diode (D) and one MOSFET switch (S) represent in Fig. 4. Inductor in the front end of converter circuit neglect the requirement of additional filter and eliminates the snubber circuit in converter which creates noise.

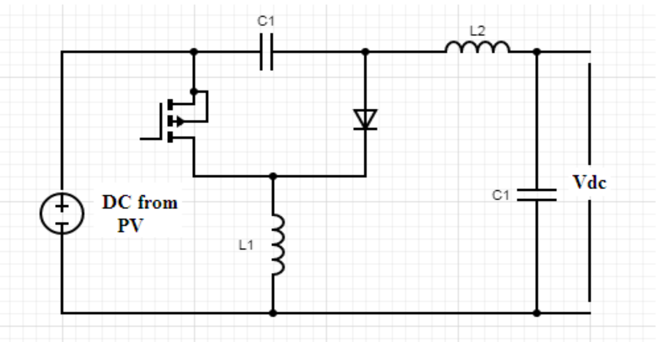


**Fig. 4.Circuit Diagram of Proposed Landsman Converter**

Normally, proposed converter is implements to operate in common conduction mode of operation (CCM) and discontinuous conduction mode of operation (DCM). Operating principle of landsman converter is classified into two types: when switch is "ON", and when switch is "OFF".

**In CCM:**

When the landsman converter switch (S) is "ON" diode (D) in the circuit operates at reverse biased and the input current flows from supply to switch (S). Energy from supply stored in the C1 and transfer to the inductor (L1). If the capacitor (C1) voltage is higher than the DC link voltage, then the C1 starts to discharge via switch and power transfer to the load. The converter switch (S) is "turns OFF" diode (D) operates at forward direction and input current flows through the D under this CCM mode.

**In DCM:**

In DCM mode, input side inductor current starts to discharge and it reaches zero current. Under DCM mode, output side inductor (L2) continuously is increasing and capacitor (C2) discharging simultaneously.

# III. CONTROL TECHNIQUE OF PROPOSED SYSTEM

## A. Back EMF and IFOC

Three phase voltage and current flowing from inverter to current flowing from inverter to BLDC motor is to be measured which is used to calculate the back EMF of the BLDC motor. Next step is to calculate line voltages and line currents from measured values. From mathematical modeling of BLDC motor back EMF equation can be calculated for three phase and absolute value of back EMF is obtained by equation (3) which helps to calculate the rotor speed of the motor. Flow chart of proposed speed estimation method is representing in Fig. 5.

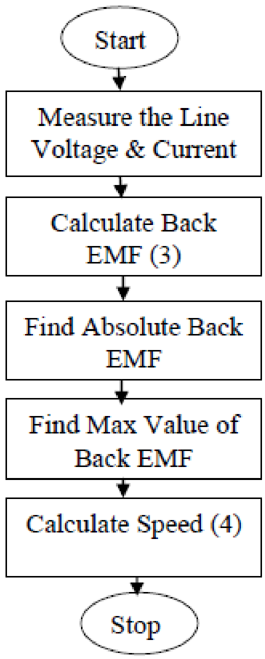


**Fig. 5.Flow Chart of Proposed Speed Estimation Method**

$$\begin{bmatrix}V_a\\V_b\\V_c\end{bmatrix}=\begin{bmatrix}R&0&0\\0&R&0\\0&0&R\end{bmatrix}\begin{bmatrix}i_a\\i_b\\i_c\end{bmatrix}+\begin{bmatrix}L-M&0&0\\0&L-M&0\\0&0&L-M\end{bmatrix}\frac{d}{dt}\begin{bmatrix}i_a\\i_b\\i_c\end{bmatrix}+\begin{bmatrix}e_a\\e_b\\e_c\end{bmatrix} \quad (3)$$

$$\omega_r=\frac{E_m}{2*P*\phi} \quad (4)$$

$$I_{ref}=\frac{T_{ref}}{2*P*\phi} \quad (5)$$

Where $V_a, V_b, V_c$ - phase voltages

$I_a, I_b, I_c$ - phase currents

$e_a, e_b, e_c$ - back EMF of BLDC motor.

$\omega_r$ - Rotor speed

$P$ - Number of pole pairs

$\phi$ - Flux

The initial work of the proposed simplified IFOC scheme is to estimate the BLDC motor speed, and it is estimated by using the back EMF estimation method. After the evaluation of speed error between estimated speed and reference speed is send to the PI controller and it act as speed regulator. The reference current is calculated from the reference torque and it relates from equation (5). By using the integral operator rotor angle is estimated. Hall signal of BLDC motor is to be computed which is multiplied with reference current for generating gate pulses by hysteresis current controller. Inc & Con calculation is utilized to remove most extreme power from source is executed and obligation cycle direction from MPPT algorithm balances reference current value determined.

### B. Hysteresis Current Controller

Current controller work appropriately just when we characterize two group's accurately viz. upper hysteresis band and lower hysteresis band of relay. Current error is feed as input of controller and it generates switching pulses if the error is within the hysteresis band limit or else it creates low gate pulse to the switches is turns off when pulse exceeds the band limit. Band limit should be kept at a less value, if the band limits is chosen as high switching frequency of the pulse is also high which leads to high switching losses of power electronic switches.

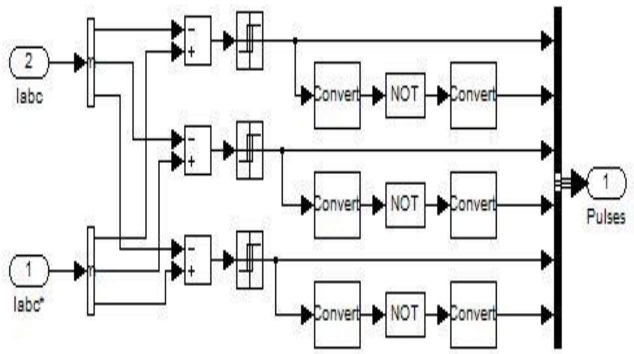


**Fig. 6.Hysteresis current controller**

## IV. SIMULATION RESULTS AND DISCUSSION

Fig. 7. Shows Simulink implementation of PV powered LC fed BLDC motor drive. PV source is designed from its resultant circuit and mathematical equations containing solar parameters like temperature, irradiance, open circuit voltage, short circuit current. PV output is fed to LC then the strengthen output from converter is feed inverter to drive BLDC motor. Fig. 8 and Fig. 9 represent DC link voltage waveform, and stator current of the BLDC motor.

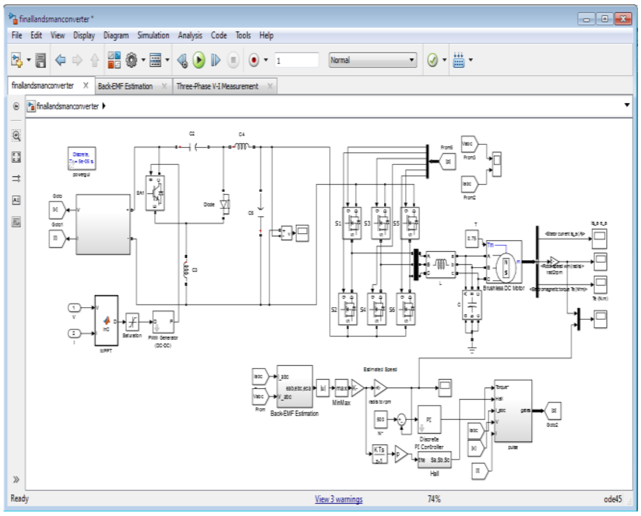

**Fig. 7. Overall Simulink Model of the Landsman Converter (LC) Fed BLDC motor**

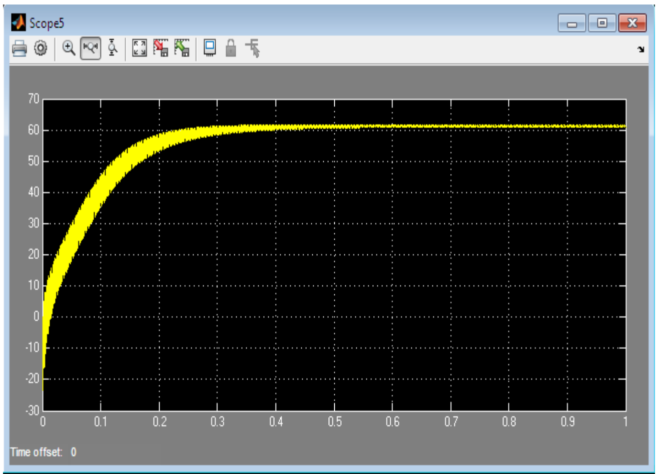


**Fig. 8. DC Link Voltage Waveform of the System**

In sensor less approach speed is estimated by back EMF estimation method, phase voltage and phase currents are sensed. By using the machine mathematical modeling back EMF is estimated. Rotor speed is calculated from the relation between back EMF and estimated speed of the motor. Reference torque generated by PI controller, if the error as input to the controller then this torque converts to the reference current. Hall signal is evaluation is depends on rotor angle of the drive. Hall signal product with reference current and the generating signal fed to the hysteresis current controller for production of pulses along with actual current signal.

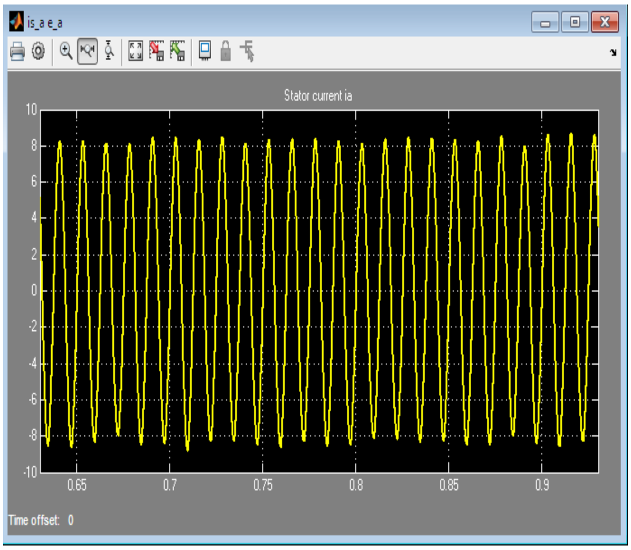


**Fig. 9.Stator Current of the BLDC Motor**

Single band hysteresis current controller with IFOC method is used to minimize the torque ripple in the drive. The IFOC technique has eliminated the higher order harmonics in stator current and decrease the THD content to the least in comparison over previously employed control techniques. The response of proposed drive under loaded conditions for a reference speed of 600 rpm is given below from Fig. 10 to Fig13.plot of BLDC motor speed estimated and actual, electro-magnetic torque and actual and reference speed is represented.

From results examine that estimated speed which is equal to actual speed at all instants of time even under varying load command and at different reference speeds. Fig. 14 represents the total harmonic distortion of BLDC drive is 9.04%. Table1.represents the simulation parameters applied in proposed circuit parameters, and BLDC motor parameters.

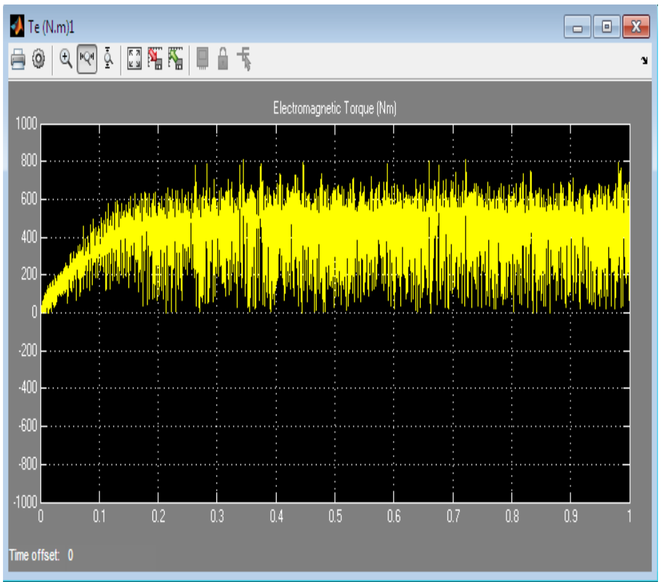


**Fig. 10. Estimated Speed of the Motor**

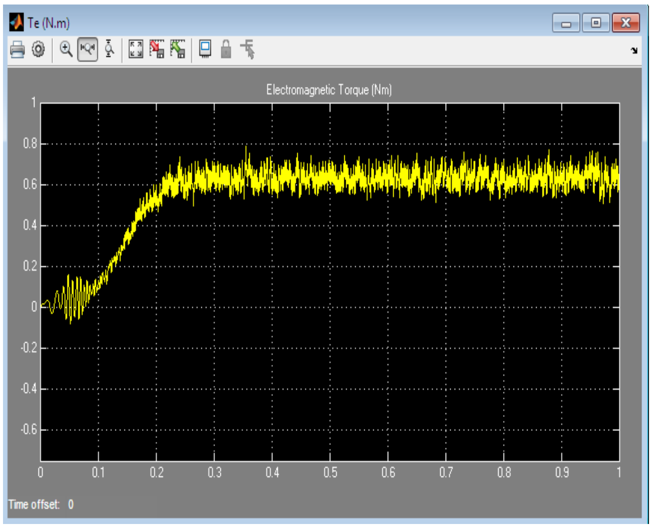


**Fig. 11. Electro-Magnetic Torque of the Motor**

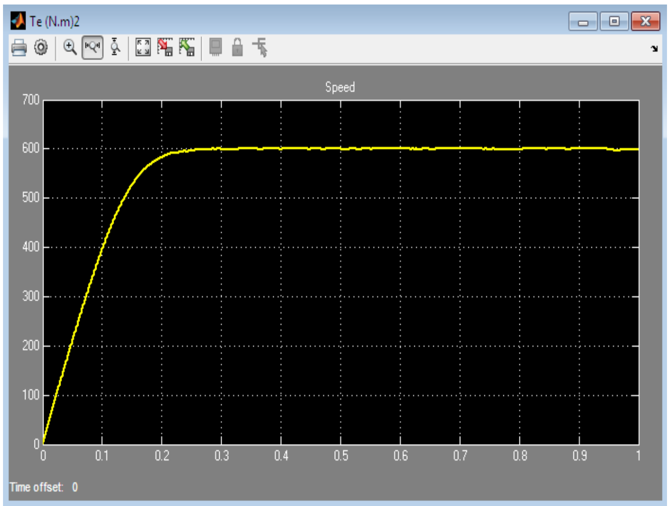


**Fig. 12. Speed Response of the Motor**

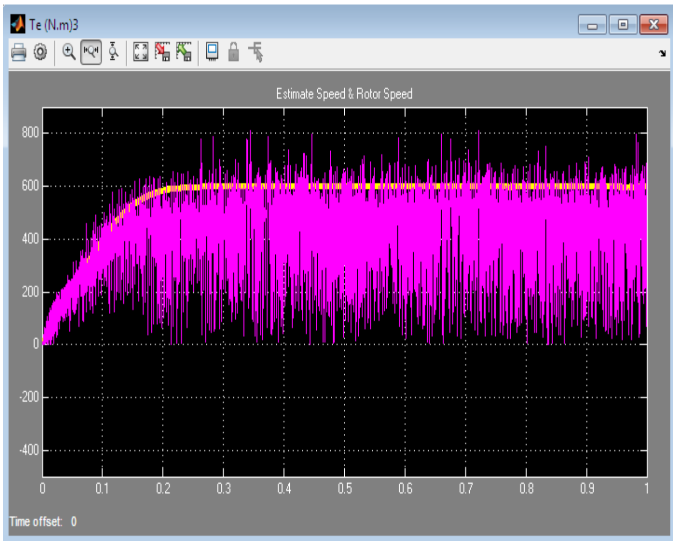


**Fig. 13. Actual Speed and Estimated Speed**

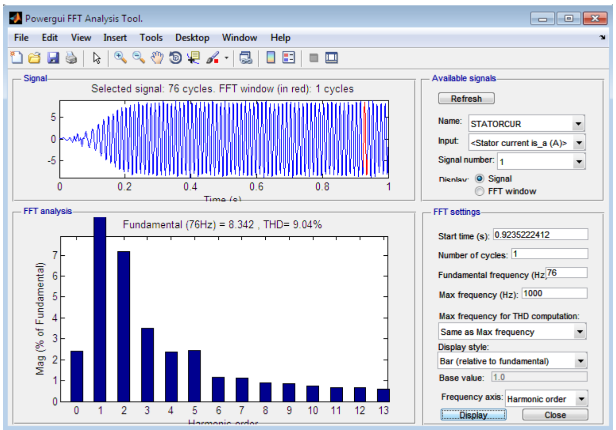


**Fig. 14. THD value of the stator current**

**Table- I: Simulation Parameter**

| Parameter | Values |
|---|---|
| Stator Resistance (Rs) | 0.7 ohms |
| Stator Inductance (Ls) | 2.72mH |
| Rotor Speed | 500 rpm |
| Flux Linkage | 0.019099 V.s |
| Poles | 4 |
| Torque Constant | 0.15279N.m/A |
| Stator Resistance (Rs) | 0.7 ohms |
| Impedance source inductors ($L_1$,$L_2$,$L_3$) | 0.1mH, 1mH, 1mH |
| Impedance source capacitors($C_1$, $C_2$) | 1000$\mu$F |
| DC-Link Voltage ($V_{DC}$) | 60v |

## V. CONCLUSION

This paper deals with performance improvement of sensor less BLDC motor fed from a PV source with landsman converter using IFOC control technique. The improved performances of sensor less BLDC motor with IFOC control technique is verified to reducing the THD of the drive by using FFT analysis on stator current. The DC link voltage, stator current harmonics is minimized, speed and torque characteristics is achieved using IFOC method. The performance of the proposed sensor less BLDC motor drive fed from PV powered landsman converter is verified through MATLAB/Simulink.

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