International Journal of Scientific Research and Engineering Development-– Volume 3 Issue 4, July-Aug 2020

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RESEARCH ARTICLE OPEN ACCESS

ANALYSIS OF CASCADED H-BRIDGE MULTILEVEL INVERTER FED PMSM DRIVES

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***Abstract* - Large electrical drives and utility applications require advanced power electronics converter to meet high power demands, the development of electrical drives using multilevel inverter (MLI) will result in increased efficiency and better drives performance (acceleration and braking). It also improves the performance of whole system in terms of harmonics, dv/dt stresses, and stresses in the bearings of a motor. Proposed research work provide detail analysis of Cascade H- bridge multilevel inverter fed permanent magnet synchronous motor(PMSM) drives it also provide its control. Multilevel inverter controlling has done by using Phase opposite Disposition (POD), for POD techniques reference modulating signals are obtained from current synthesiser controller of PMSM drives. The proposed model is modelled on MATLAB 2015a/ SIMULINK and its satisfactory performance are obtained and depicted in performance result sections.**

***Index Terms* - Cascaded H-bridge multilevel inverter, Multi Carrier PWM, Permanent magnet synchronies motor (PMSM) Total Harmonic Distortion (THDs),**

I. Introduction

The PMSM (Permanent magnet synchronous Motor) has become more legendry. A days getting to be that's only the tip of the iceberg prevalent over ASDs (Adjustable pace Drives) again IM (Induction Motor) because of its noteworthy favorable circumstances for example, such that higher vitality efficiency, higher torque to weigh ratio, higher life, little maintains Also late improvements on lasting order engineering [1]. An PMSM motor, which the rotor winding are traded Eventually permanent magnet [2]. The element execution from claiming VSI (voltage source inverter) nourished PMSM drive framework generally relies on the connected control system. There are something like that huge numbers control systems to PMSM clinched alongside which VC (Vector Control) and DTC (Direct Torque Control) need aid All the more successful and extensively utilized within commercial enterprises [3]-[8]. For vector control method those stator current is deteriorated under flux Also torque transforming parts for getting the decoupled control of PMSM drive as it were comparative of the independently eager dc engine [9].

Multilevel voltage source inverters need to improve the quality of voltage by raising the voltage levels; it is breed voltage source inverters [10]. MLI would characterize similarly as gadgets that would skilled to process a stepped waveform for base sum for swell hold. Those yield voltage of the multilevel inverter need A large number levels, Subsequently the personal satisfaction of the yield voltage is progressed Similarly as those number of voltage levels increases, with the goal the amount for yield filters could be diminished [11]. Multilevel structure about inverter produces secondary force and secondary voltage yield without requiring higher appraisals from claiming distinct devices, so those energy rating of the converter could surpass those limit forced Eventually Tom's perusing the singular exchanging gadgets.

The term multilevel started for that three-level inverter acquainted Eventually Tom's perusing Nabae et al [12]. The vast majority normal MLI topologies need aid DC- MLI (Diode Clamped MLI), FC-MLI (Flying capacitor MLI) and CHB-MLI (Cascaded H-Bridge MLI) [13]-[16]. Vector control about PMSM could be characteristically broadened for multilevel inverter nourished drives but, those execution of this control technique relies up on those waveform created toward inverter, consequently it may be vital will control yield waveform about multilevel inverter. There may be a few present control systems bring been produced to multilevel inverters for example, such that SPWM (Sinusoidal Pulse Width Modulation), SHE-PWM (Selective symphonious Elimination), SVM (Space vector Modulation), sigma delta PWM modulation, straight current control, hysteresis present control Also optimized present control [17]-[19].

The paper is organized as follows, section II gives the system configuration including structure of multilevel inverter,, section III presents dynamic modelling of MPSM, section IV gives the control strategy, in section V performance evaluate using MATLAB 2015a/ SIMULINK, section and section VI provides conclusions of the work.

II. System Configuration

Seven level multilevel inverters with three phases 6 pole, 400v, and 5.53N-m PMSM drive is developed. To developed

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multilevel inverter fed PMSM drives multilevel for higher voltage various multi level inverters can be used. Fig.1 shows the Simulink model of three phase seven level cascaded H-bridge multilevel inverter with PMSM drive. In which it sub section of multilevel inverter is shown in Fig. 2. Multilevel inverter is cascaded H- bridge inverter which consists with IGBT and Fig. shows the MLI utilized in proposed system.

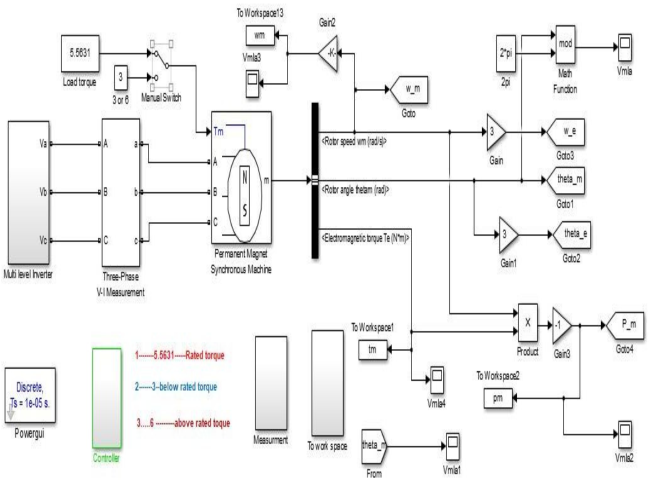

Fig. 1 Proposed system configurations

A. *Cascaded H-Bridge Multilevel Inverter*

The Cascaded H bridge multilevel inverter (CHBMLI) was come in research in 1975.CHBMLI is consisting by series combination of separated H- bridged inverter [13-15]. In separate H-bridge inverter separate dc energy sources is required the CHBMLI has been utilized in a wide range of applications. With its modularity and flexibility, the CHBMLI shows superiority in high-power applications, especially shunt and series connected FACTS controllers. The CMI synthesizes its output nearly sinusoidal voltage waveforms by combining many isolated voltage levels. By adding more H-bridge converters, the volume of the Volt ampere reactive can increase without redesigning the power phase, and build-in redundancy may be realized against the individual H-bridge converter failure. A series of single-phase full bridges make a phase for the inverter.

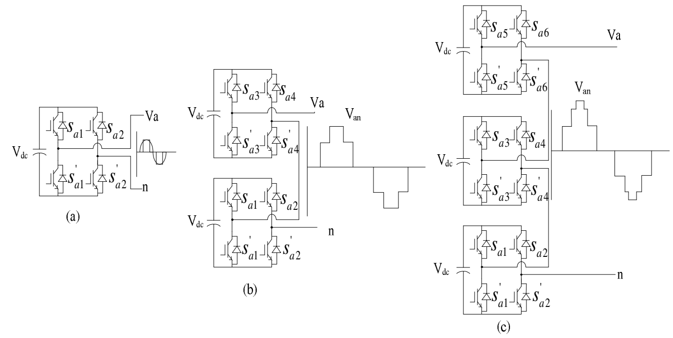

Fig. 2 Cascaded H bridge multilevel inverter circuit topologies (a) 3-level inverter and (b) 5-level inverter and (c) seven level inverter

In the Cascaded H bridge multilevel inverter (CHBMLI), the bridge are connected in series to make up the desired voltage rating and output levels, to developed one phase more than one h bridge are connected in series and each H bridge in consist by two leg. In *m*-level Cascaded H- Bridge multilevel inverter has,

- Number of power electronic switch = $2(m-1)$
- Output phase voltage level = m
- Output line voltage = (2m-1)

Fig.2 shows the circuit of Cascaded H bridge multilevel inverter Fig.2a shows the three levels while Fig. 2b shows the five levels and Fig. 4c shows seven levels cascaded H bridge multilevel inverter.

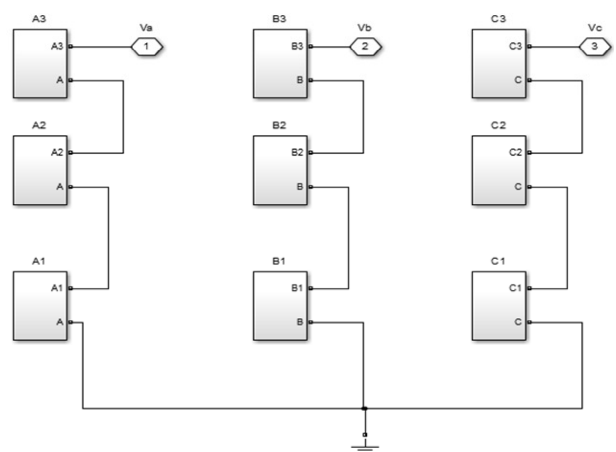

Fig.3 Utilized Cascaded H- bridge multilevel inverter

III. DYNAMIC MODELING OF PERMANENT MAGNET SYNCHRONOUS MOTOR

The dynamic model considers the instantaneous effect of varying voltages/ currents, stator frequency, and torque disturbances and this model is derived using the two-phase machine in direct and quadrature axis. The concept of power invariance is utilized in the modeling. According to this

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concept, the power in three-phase machine and its equivalent two-phase model is same. To analysis equivalent circuit of PMSM normally modeled in synchronous reference frame. To model PMSM rotor circuit there is no field winding so it can be replaced with constant current source with fixed magnitude.

The following mathematical manipulation can be done. The voltage equation of PMSM in synchronous reference frame is given by

$$V_{ds} = -\left(I_{ds}R_s + \omega_r\lambda_{qs} - \frac{d\lambda_{ds}}{dt}\right) \quad (1)$$

$$V_{qs} = -\left(I_{qs}R_s - \omega_r\lambda_{ds} - \frac{d\lambda_{qs}}{dt}\right) \quad (2)$$

The electromagnetic torque produced by PMSM can be define as

$$T_e = \frac{3P}{2}\left(I_{qs}\lambda_{ds} - I_{ds}\lambda_{qs}\right) \quad (3)$$

Or

$$T_e = \frac{3P}{2}\left(\lambda_r I_{qs} - (L_d - L_q)I_{ds}I_{qs}\right) \quad (4)$$

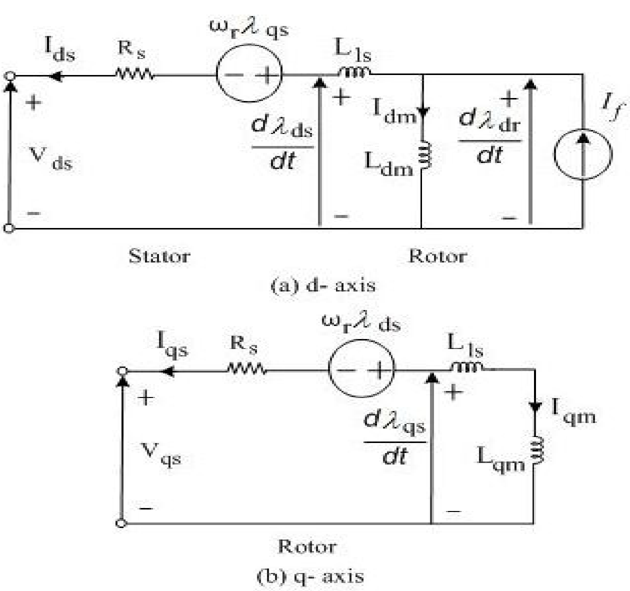
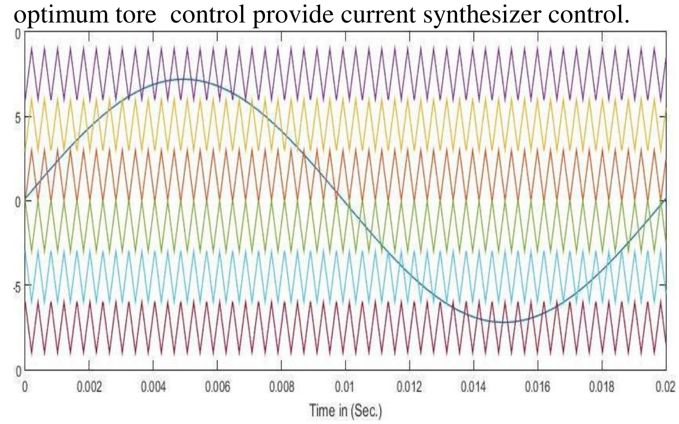


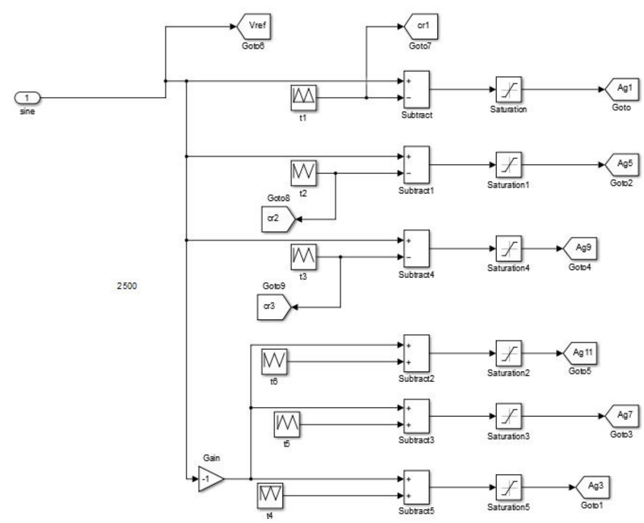
Fig.4 Equivalent circuit of PMSM in synchronous reference frame

IV. Proposed Control Strategy

This section described the control strategy for seven levels inverter employed in PMSM drives. Switching signal of MLI is obtained from phase apposition deposition (POD) pulse with modulation (PWM) technique. To generate switching signal, compare carrier signal with sinusoidal reference signal. Number of carrier signal is dependent on level of inverter which is given (N-1)/2 for N level inverter, Fig. 5 shows the pulse generation for POD modulation techniques, however Fig. 6 shows the control for PMSM drives to generate the switching signal based on optimum torque control the optimum tore control provide current synthesizer control.



(a)



(b)

Fig. 5 (a) Carrier arrangements for Phase opposition disposition (b) proposed control strategy for seven levels inverter

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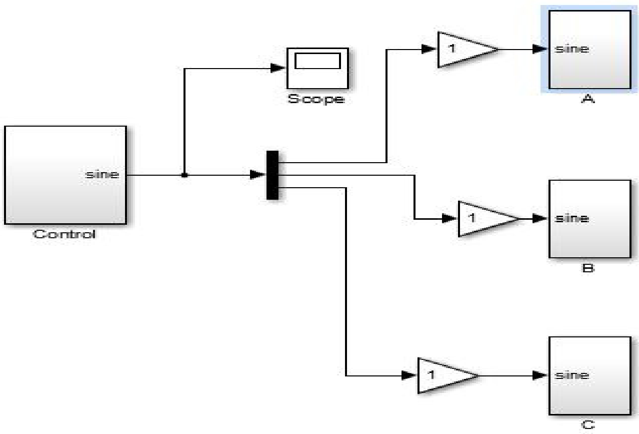
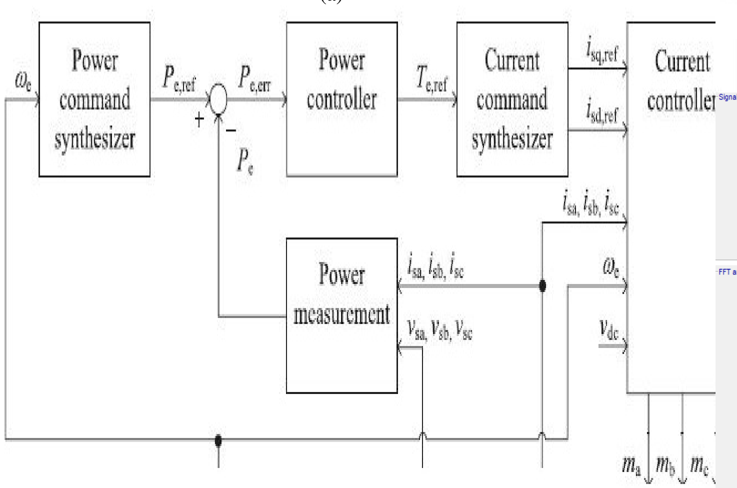


(a)



(b)

Fig. 6 Control of PMSM drives (a) System control (b) PMSM Control

V. Results And Discussion

The performance of seven levels H- bridge multilevel inverter fed permanent magnet synchronous motor drive under no load and dynamic change in loads is carried out using Matlab 2015a with proposed current synthesiser POD control scheme. Performances of proposed system are obtained in term of line voltages (V_{ab}), (V_{bc}) and (V_{ca}) line currents (I_a), (I_b) and (I_c), torque and speed. The results are shown in Fig. 7- Fig. 7.

A. *Performance seven level inverter under no load condition*

Fig. 7 shows the line voltage and observes that its peak value is 892 volt there are three waves which is 120^0 apart from each other. First waveform shows the voltage line voltage V_{ab}, second waveform shows the line voltage V_{bc} and last one is line voltage V_{ca}. Here each DC source voltage is 300V. Line voltage signal has traced from time 0-0.2 second and its frequency 50Hz is observed which desired frequency and its THDs is 4 .55% which is under the IEEE 1991 specification. As shown in Fig. 8.

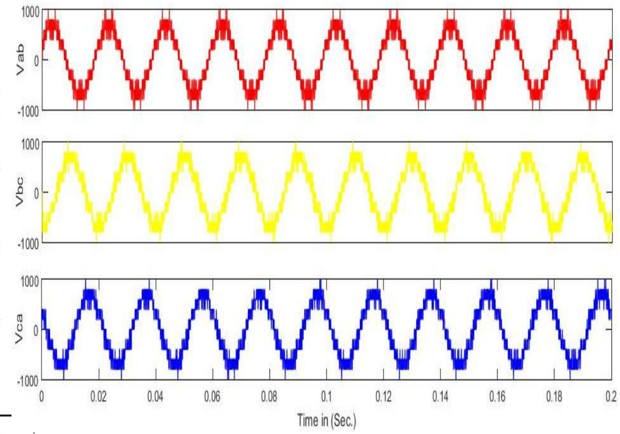


Fig. 7 Three phase line voltage of CHBMLI

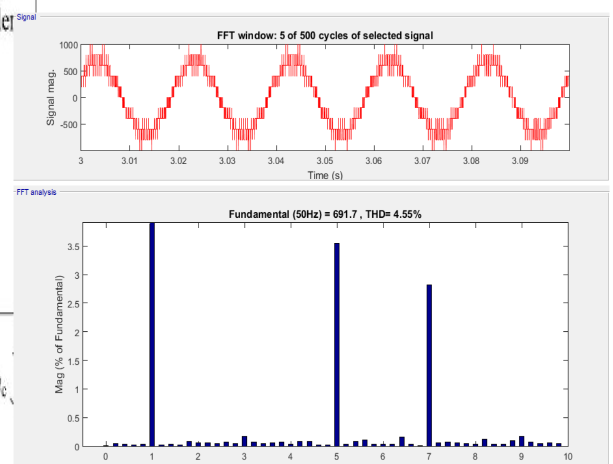


Fig. 8 FFT analysis of MLI output voltage

B. *Steady state performance of proposed system under rated toque*

Fig. 9 shows the steady state performance of proposed system at rated load demand it is observed that voltage waves is malty leveled and current is pure sinusoidal with 120^0 phase shifted.

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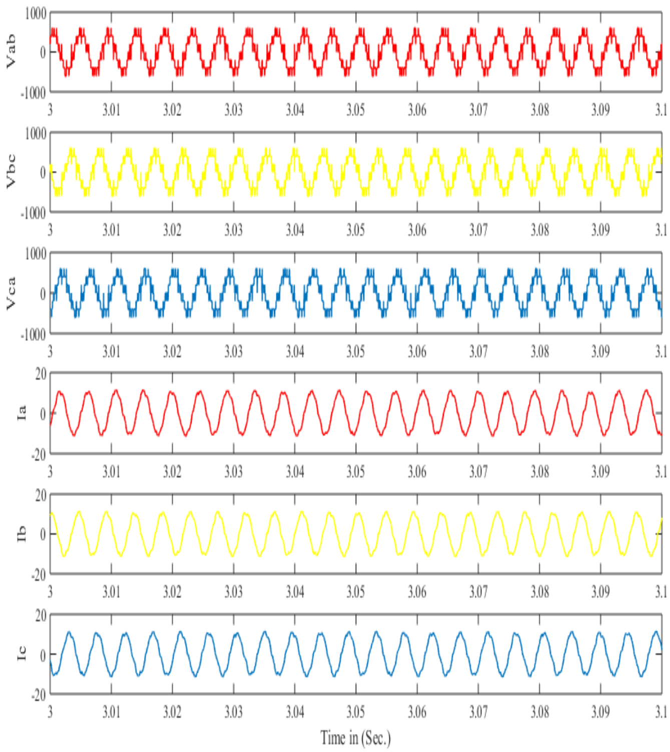

Fig. 9 Steady state performance

A. Dynamic performance of proposed system under change in torque

Fig. 10 shows the dynamic performance of proposed system dynamic torque is change from rated i.e. 5.3N-m to 3N-m at 5.45s hence current demand is decreases and torque is increases from 3 N-m to 6 N-m hence current demand is increases however voltage is remains same as shown in Fig. 10. Their sub plots are plotted for zoom view of dynamic response that is depicted in Fig. 11 (a) and Fig. 11 (b).

VI. CONCLUSION

In Proposed paper provide modelling and control of cascaded H- Bridge MLI fed permanent magnet synchronous motor drives. Seven levels cascaded H-bridge MLI are operate under POD switching scheme, the sinusoidal modulating signals of each phase are obtained from optimum torque and current synthesizer control.

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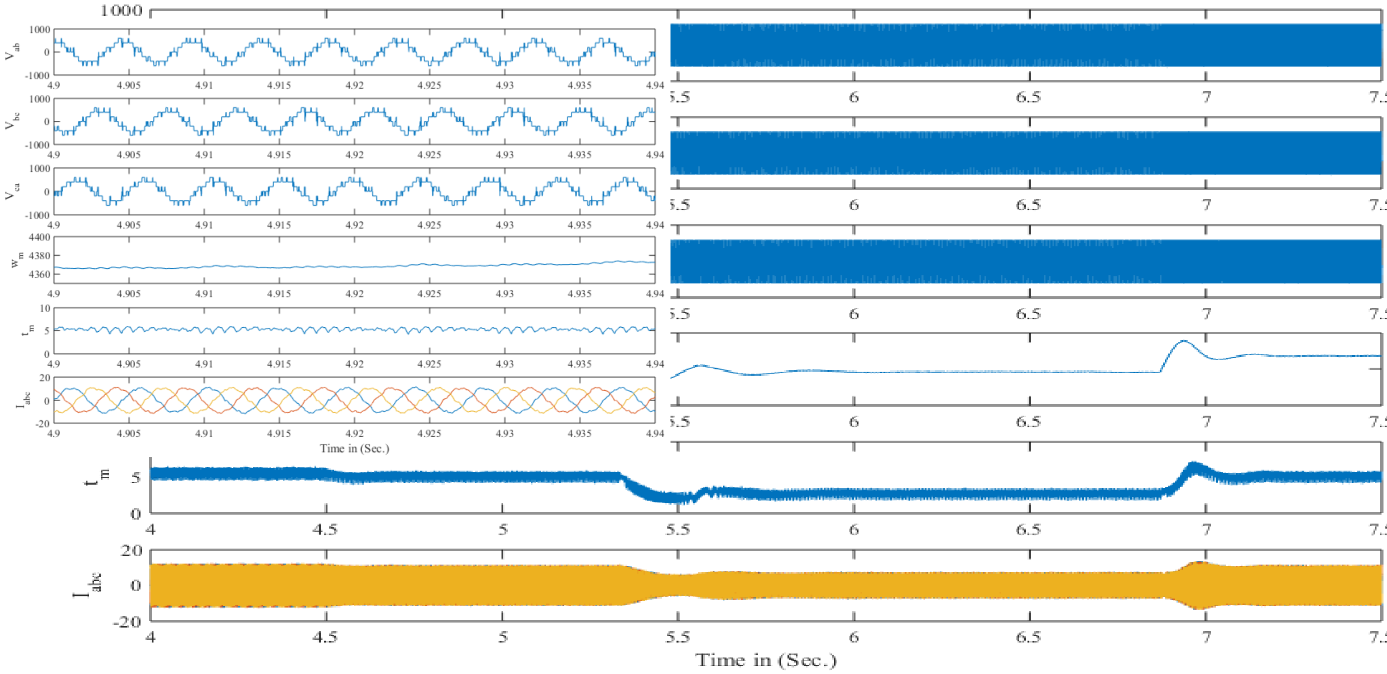
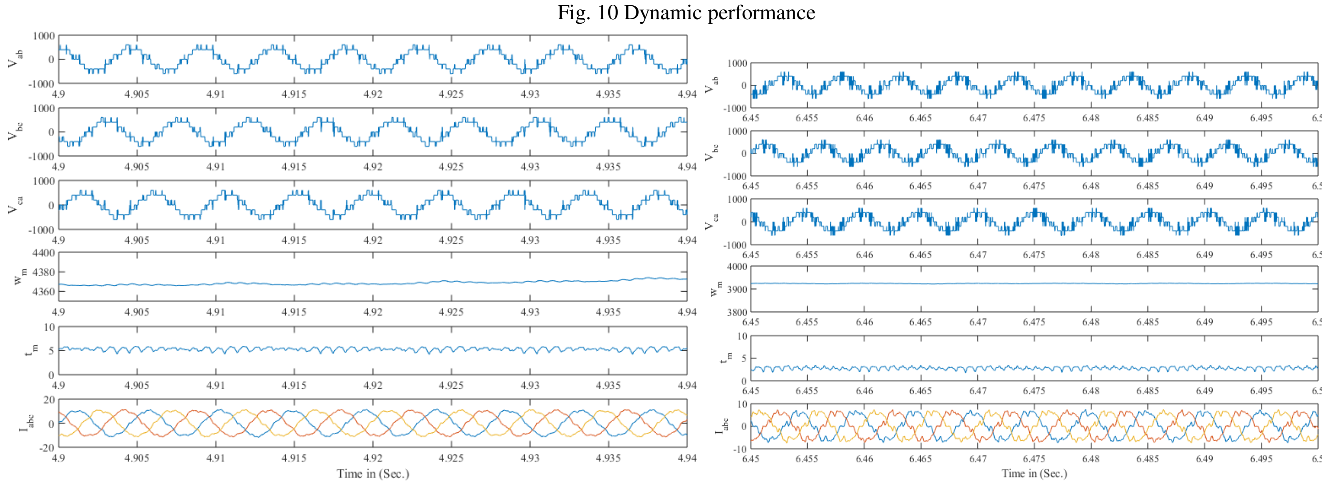


Fig. 10 Dynamic performance



(a) (b)

Fig. 11 Zoom View of proposed system

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