A CANONICAL SWITCHING CELL CONVERTER FOR POWER FACTOR CORRECTION BASED- BRUSHLESS DC MOTOR DRIVE

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Abstract:- *Among numerous motors, brushless dc motor (BLDCM) is preferred in many low and medium power applications including household appliances, industrial tools, heating ventilation and air-conditioning(HVAC),medical equipments, and precise motion control systems. BLDCM is preferred because of its high torque/inertia ratio, high efficiency, ruggedness, and low-electro-magnetic interference (EMI) problems. The stator of the BLDCM consists of three-phase concentrated windings and rotor has permanent magnets. It is also known as an electronically commutated motor (ECM) since an electronic commutation based on rotor position via a three-phase voltage source inverter (VSI) is used. Therefore, the problems associated with brushes, such as sparking, and wear and tear of the commutator assembly are eliminated.*

This project presents a power factor correction (PFC)- based canonical switching cell (CSC) converter-fed brushless dc motor (BLDCM) drive for low-power household applications. The speed of BLDCM is controlled by varying the dc-bus voltage of voltage source inverter (VSI). The BLDCM is electronically com- mutated for reduced switching losses in VSI due to low-frequency switching. A front-end CSC converter operating in discontinuous inductor current mode (DICM) is used for dc-bus voltage control with unity power factor at ac mains. A single sensor for dc-bus voltage sensing is used for the development of the proposed drive, which makes it a cost-effective solution.

INTRODUCTION

The financial imperatives and new principles enacted by governments put progressively higher necessities on electrical power systems. New eras of hardware must have higher execution parameters, for example, better efficiency and decreased electromagnetic impedance. Power system adaptability must be high to encourage market changes and to decrease improvement time. Every one of these changes must be accomplished while, in the meantime, diminishing power system cost. Brushless motor technology makes it conceivable to accomplish these particulars. Such motors consolidate high reliability with high efficiency, and for a lower cost in correlation with brush motors. The Brushless DC Motor (BLDC) motor is ordinarily characterized as a changeless magnet synchronous motor with a trapezoidal back Electro Motive Force (EMF) waveform shape.

A power system in light of the Direct Current (DC) motor gives a decent, basic and proficient answer for fulfill the prerequisites of a variable pace drive. In spite of the fact that DC motors have great control attributes and toughness, their execution and applications in more extensive zones is repressed because of starting and recompense issues. Incitement motor don't have the aforementioned issues, they have their own constraints, for example, low power variable and non-straight speed torque attributes. With the progression of technology and improvement of advanced control systems, the Permanent Magnet Brushless DC (PMBLDC) motor can beat the constraints specified above and fulfill the prerequisites of a variable velocity drive.

Electric motors impact verging on each part of cutting edge living. Coolers, vacuum cleaners, ventilation systems, fans, PC hard drives, programmed auto windows, and large numbers of different machines and gadgets use electric motors to change over electrical vitality into helpful mechanical vitality.

LITERATURE SURVEY

T.J.E. Mill operator presented the perpetual magnet materials and qualities, B-H circle and demagnetization attributes, utilizations of changeless magnets in motors. He talked about the square wave perpetual brushless motor, sine wave changeless magnet brushless motor and their torque, e.m.f conditions and torque/speed attributes.

M.A.Jabbar, M.A.Rahman talked about the outline contemplations for perpetual magnet motors expected for brushless operation. Two rotor designs are portrayed - the cursed rotor and the portioned rotor. The portioned rotor is planned particularly for high speed operation. A brushless DC drive power system is likewise depicted on the execution of a neodymium-iron-boron energized p.m. motor with a cursed rotor in a BLDC drive is exhibited.

Another recreation model of the BLDC motor with about genuine back EMF waveform is proposed by the Jeon, Y.S.Mok, H.S.

Brushless DC Motors are changeless magnet motors where the capacity of commutator and brushes were actualized by strong state switches. BLDC motors come in single-phase, 2-phase and 3-phase setups. Comparing to its sort, the stator has the same number of windings. Out of these, 3-phase motors are the most well known and broadly utilized. On account of the extraordinary structure of the motor, it creates a trapezoidal back electromotive force (EMF) and motor current produce a throbbing torque.

DESIGNING OF CANONICAL SWITCHING CELL CONVERTER FED BRUSHLESS DC MOTOR

DC-DC converters are electronic gadgets utilized at whatever point we want to change DC electrical power productively starting with one voltage level then onto the following. They are required because dissimilar to AC, DC cannot simply be ventured up or down utilizing a transformer. From various perspectives, a DC-DC converter is the equivalent of a transformer.

The dc-dc converters can be seen as dc transformer that conveys a dc voltage or current at an alternate level than the info source. Electronic exchanging plays out this dc transformation as in conventional transformers and not by electromagnetic means. The dc-dc converters find wide applications in regulated switch-mode dc power supplies and in dc motor drive applications.

CANONICAL CONVERTER

Among Numerous motors, brushless dc motor(BLDCM) is preferred in many low and medium power applications including household appliances, industrial instruments, heating ventilation and air conditioning (HVAC), medical equipments, and precise movement control systems. BLDCM is preferred because of its high torque/inertia ratio, high efficiency, ruggedness, and low-electro-magnetic interference (EMI) problems. The stator of the BLDCM consists of three-phase concentrated windings and rotor has permanent magnets. It is also known as an electronically commutated motor (ECM) since an electronic commutation based on rotor position via a three-phase voltage source inverter (VSI) is used. Therefore, the problems associated with brushes, for example, sparking, and wear and tear of the commutator assembly are eliminated.Fig. 4.2 demonstrates a conventional scheme of BLDCM drive fed byan uncontrolled rectifier and a dc-link capacitor followed by a three-phase pulse width modulation (PWM)- based VSI is used for feeding the BLDCM.

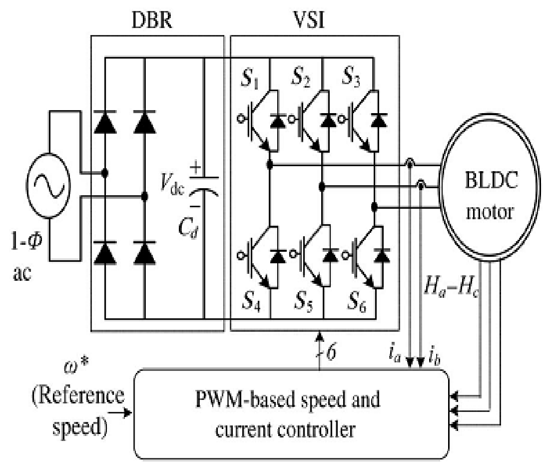

Fig.1 Conventional DBR-fed BLDCM drive.

A constant dc-link voltage is maintained at the dc-link capacitor and a PWM-based VSI is used for the speed control. Hence, the switching losses in VSI are very high due to high switching PWM signals and require huge amount of sensing for its operation.

But at the cost of two current sensors. This project presents the development of a reduced sensor-based BLDC motor drive for low-power application.

BRUSH LESS DCMOTOR DRIVE USING CANONICAL SWITCHING CELL CONVERTER

Fig 2 shows the proposed BLDCM drive with a front-end PFC-based canonical switching cell (CSC) converter. A CSC converter operating in DICM acts as an inherent power factor pre-regulator for attaining a unity power factor at ac mains. A variable dc-bus voltage of the VSI is used for controlling the speed of the BLDCM. This operates the VSI in low-frequency switching by electronically commutating the BLDCM for reducing the switching losses in six insulated gate bipolar transistor's (IGBT's) of VSI which share the major portion of overall losses in the BLDCM drive. The front-end CSC converter is designed and its parameters are selected to operate in a DICM for obtaining a high-power factor at wide range of speed control. A prototype of proposed drive is developed to experimentally demonstrate its performance for control of speed over a wide range with a unity power factor at universal ac mains (90–265 V).

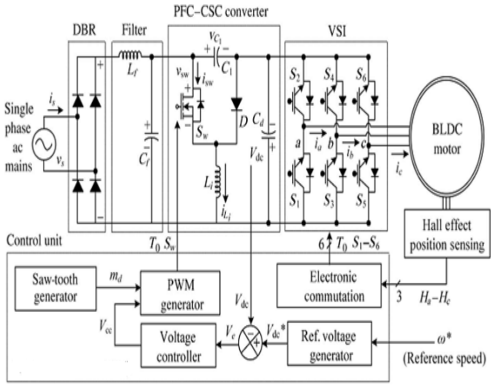

Fig.2

Proposed BLDCM drive using CSC converter.

OPERATING PRINCIPLE OF POWER FACTOR CORRECTION BASED CANONICAL SWITCHING CELL CONVERTER

The proposed BLDCM drive uses a CSC converter operating in DICM. In DICM, the current in inductor becomes Li discontinuous in a switching period (T_s). Three states of CSC converter are shown in Fig. 3 (a)–(c). Waveforms of inductor current $i_L$and intermediate capacitor's voltage V_{C1} for a complete cycle of line frequency are shown in Fig.3(a),whereas Fig. 3(b) shows the variation in different variables of CSC converter such as switch gate voltage (V_G), inductor current (i_{L1}), intermediate capacitor's voltage (V_{C1}), and dc-link voltage(V_{dc}) in a complete switching period. Three modes of operation are described as follows.

Mode I: As appeared in Fig. 3(a), when switch is turned ON, the vitality from the supply and put away vitality in the intermediate capacitor C1 are transferred to inductor Li. In this procedure, the voltage across the intermediate capacitor VC1 decreases, while inductor current ILi and dc-join voltage are increased as appeared in Fig. 3(b). The planned value of intermediate capacitor is sufficiently large to hold enough vitality such that the voltage across it doesn't get to be spasmodic.

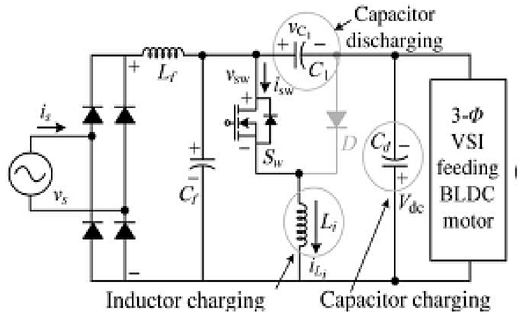

Fig.3(a) Mode I Operation of CSC converter

Mode II: The switch is killed in this method of operation as appeared in Fig. 3(b). The intermediate capacitor C1 is charged through the supply current while inductor Li starts discharging subsequently voltage VC1 starts increasing, while current iLi decreases in this method of operation as appeared in Fig. 3(b). Besides, the voltage across the dc-join capacitor Vdc keeps on increasing because of discharging of inductor Li.

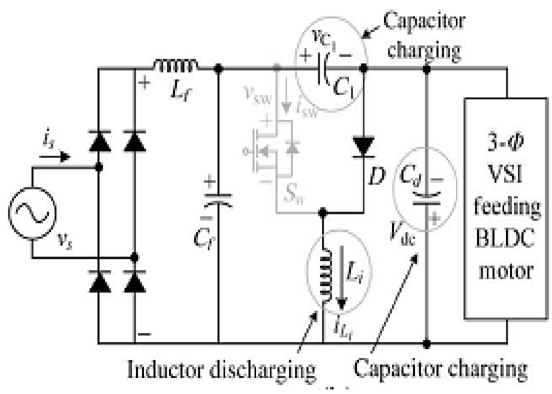

Fig.3(b) Mode II Operation of CSC converter

Mode III: This is the broken conduction method of operation as inductor Li is totally discharged and current iLi gets to be zero as appeared in Fig. 3(c). The voltage across intermediate capacitor C1 keeps on increasing, while dc-join capacitor supplies the obliged vitality to the load, henceforth Vdc starts decreasing as appeared in Fig. 3(b).

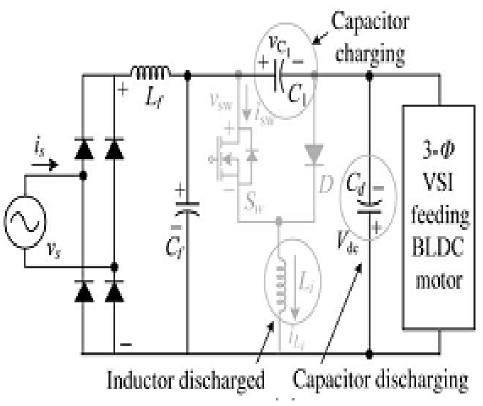

Fig.3(c) Mode III Operation of CSC converter

Control of Brush Less DC Motor Electronic Commutation

An electronic commutation of the BLDCM incorporates legitimate exchanging of VSI in a manner that a symmetrical dc current is drawn from the dc-join capacitor for 1200 and placed symmetrically at the focal point of back electro-thought process power of each phase.A Hall-Effect position sensor is utilized to sense the rotor position on a span of 600, which is required for the electronic commutation of BLDCM. The conduction states of two switches (S1 and S4) are appeared

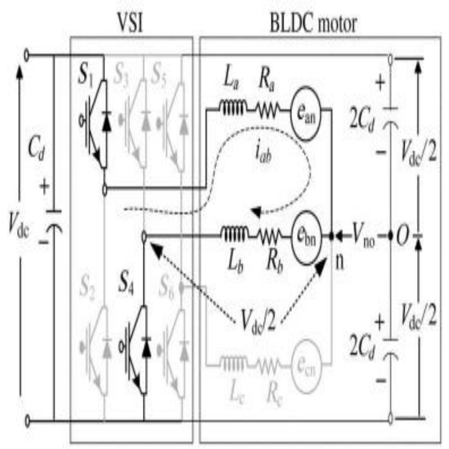

Fig.4 Operation of a VSI-fed BLDCM when switches $S_1$and S_4 are conducting.

A line current iab is drawn from the dc join capacitor in which magnitude relies on upon the applied dc-join voltage (Vdc), back-EMF's (ean and ebn), resistances (Ra and Rb),and self and mutual inductance (La,Lb, and M) of the stator windings. Table 4.1 demonstrates the diverse exchanging states of the VSI sustaining a BLDCM based on the Hall-Effect position signals (H1 – H3).

Table 1 Switching states of VSI corresponding to hall-Effect rotor Position signals

Hall signals			Switching states					
H_1	H_2	H_3	S_1	S_2	S_3	S_4	S_5	S_6
0	0	0	0	0	0	0	0	0
0	0	1	1	0	0	0	0	1
0	1	0	0	1	1	0	0	0
0	1	1	0	0	1	0	0	1
1	0	0	0	0	0	1	1	0
1	1	0	0	1	0	0	1	0
1	1	1	0	0	0	0	0	0

SIMULATION RESULTS

This Section details MATLAB simulink model of Canonical Switching Cell Converter fed Permanent Magnet Brushless DC Motor

PMBLDC Motor without power factor correction controller

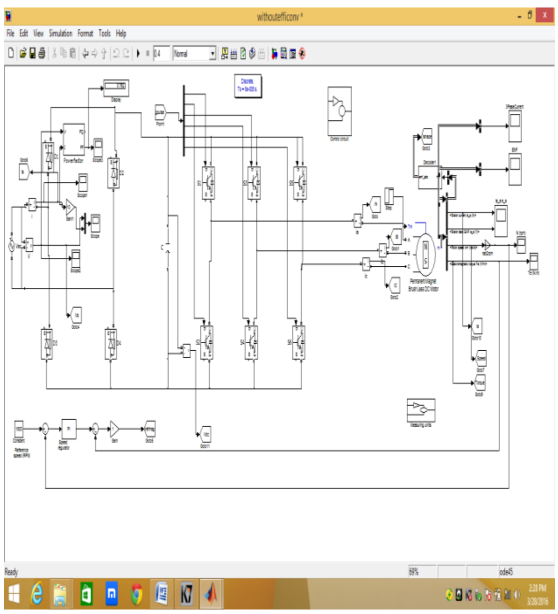

Fig.5 PMBLDC Motor without Power Factor Correction Controller.

Circuit consists of two groups of diodes: top group and base group. It is easy to see the operation of each group of diodes. The current id streams continuously through one diode of the top group and one diode in the base group. The circuit is simulated using Simulink and input current waveform is plotted. The input current waveform consists of Total Harmonic Distortion. Fast Fourier Transform (FFT) analysis is done to get the value of THD. THD of input current and THD percentage is 79.31%. High THD will affect the equipments connected and power factor will be 0.762.

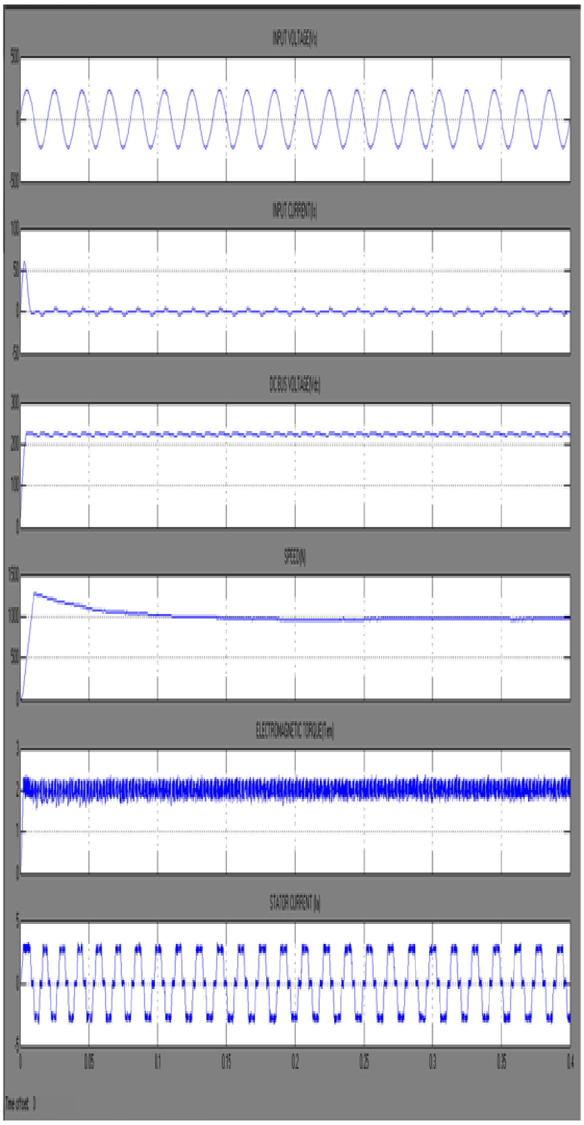

Fig.6 PMBLDC Motor without Power Factor Correction Controller Input Voltage, Current, Dc bus voltage, Speed, Electromagnetic torque and Stator current Waveforms

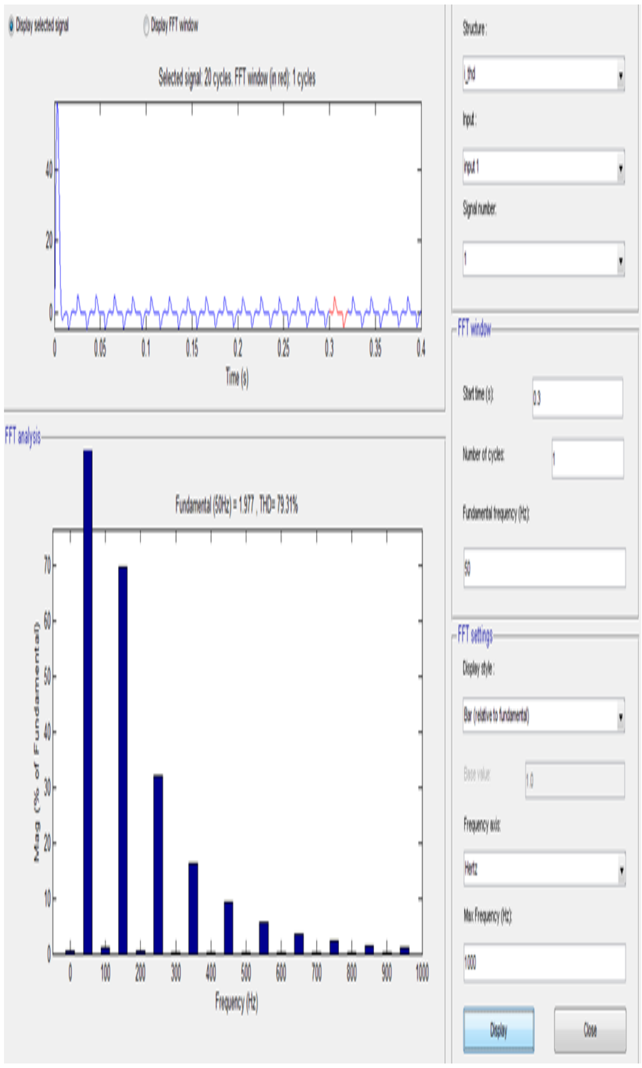

Fig.7 PMBLDC Motor without Power Factor Correction Controller Fast Fourier Transform (FFT) analysis of THD of Source current

PMBLDC Motor with PFC controller using Canonical Switching Cell Converter:

When the IGBT'S are in ON state, the proposed topology transfers energy from the dc source into the inductors. Here, the current divides and equal currents are flowing through top inductor and IGBT and base inductor and IGBT. Input current waveform is plotted in graph as shown.THD reduced from 48.54% to 10.32 %percentage is reduced further using this model and Power factor is raise from 0.943 to 0.953. Due to the addition of Canonical Switching Cells PFC controller is observed.

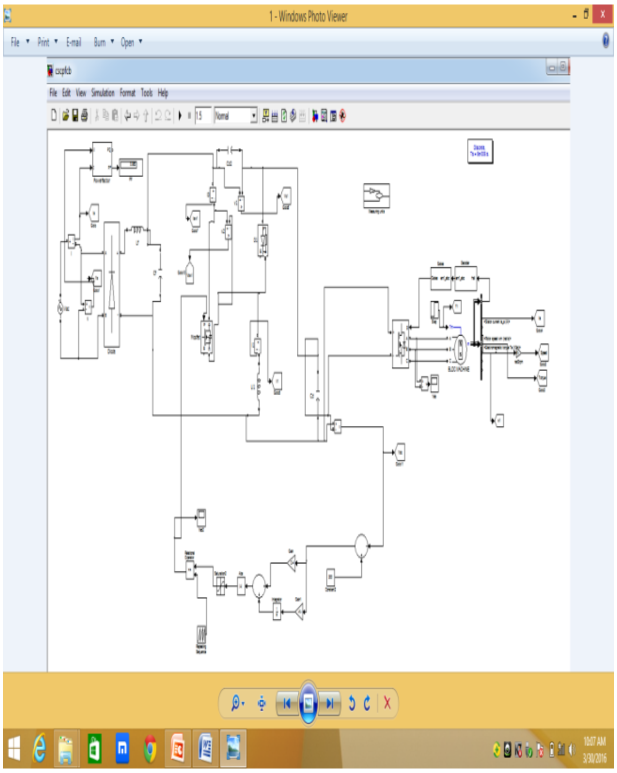

Fig.8 PMBLDC Motor with PFC controller using Canonical Switching Cell Converter

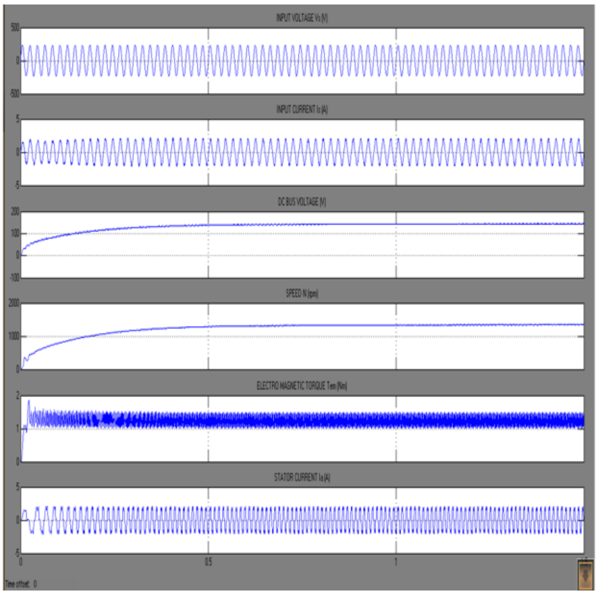

Fig.9 PMBLDC Motor with PFC controller using Canonical Switching Cell Converter Input Voltage, Input Current, DC bus voltage, Speed, Torque and Stator Current Wave forms

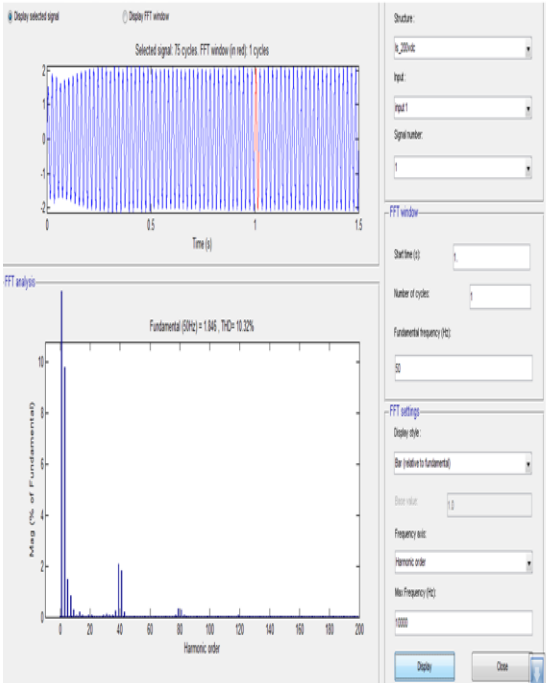

Fig 9 PMBLDC Motor with PFC controller using Canonical Switching Cell Converter Fast Fourier Transform (FFT) analysis of THD of Source current

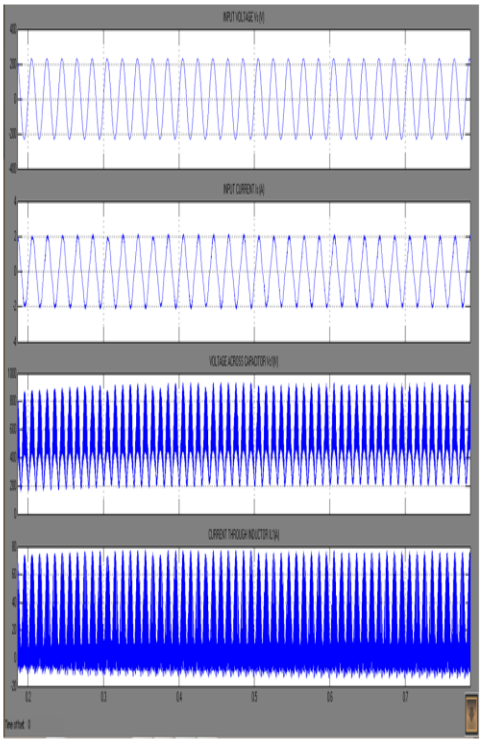

Fig.10 PMBLDC Motor with PFC controller using Canonical Switching Cell Converter Input Voltage, Input Current, Voltage across capacitor C_1, Current in inductor i_1 Wave forms

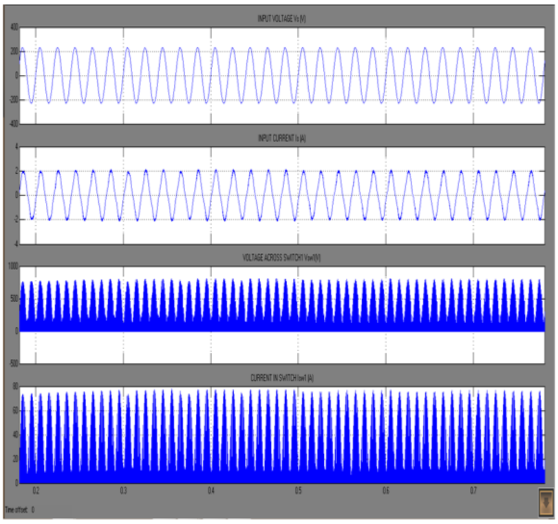

Fig.10 PMBLDC Motor with PFC controller using Canonical Switching Cell Converter Input Voltage, Input Current, Voltage across MOSFET switch, Current in MOSFET switch Wave forms

DYNAMIC PERFORMANCE OF PROPOSED BLDCM DRIVE:

Speed control for change in dc-link voltage from 100V to 150 V

In dynamic performance of proposed BLDC Motor Drive shown in Fig. 6.21 shows speed control for change in dc-link voltage from 100 V to 150 V input voltage, input current, DC bus voltage speed, torque and stator current wave form sare shown .Which shows that the supply current THD obtained is 7.77% within the IEC 61000-3-2 limits.

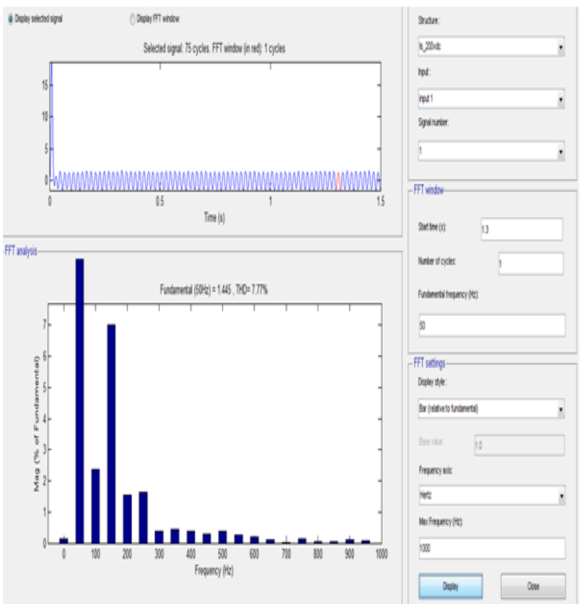

Fig.11 speed control for change in d+++-link voltage from 100 V to 150 V Fast Fourier Transform (FFT) analysis of THD of Source current

Performance under load change

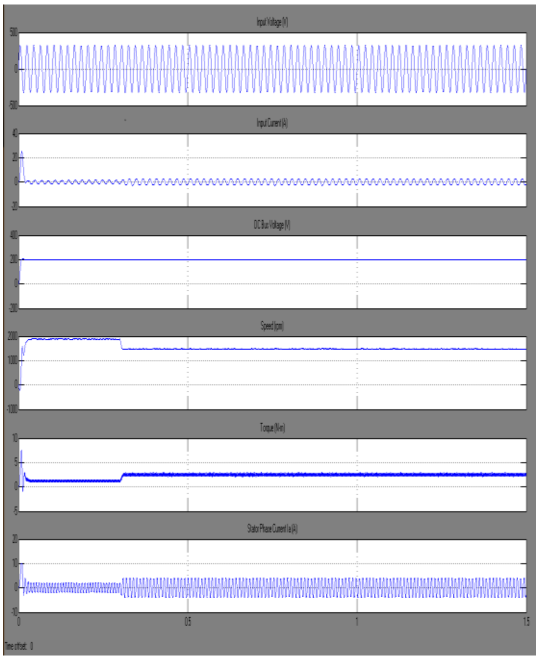

Fig.12 Load changes from 0.01 to 0.3 N-m Input Voltage, Input Current, DC bus voltage, Speed, Torque and Stator Current wave forms

In dynamic performance of proposed BLDC Motor Drive shown in Fig.6.24 shows load torque changes from 0.01N-m to 0.3 N-m the input voltage, input current, DC bus voltage speed, torque and stator current wave forms are shown.Which shows that the supply current THD obtained is10.91% within the IEC 61000-3-2 limits.

COMPARATIVE ANALYSIS OF PROPOSED CONFIGURATION WITH CONVENTIONAL SCHEMES:

Table 2 Comparative Analysis of proposed configuration with conventional schemes

Schemes	**Conventional PFC**	**Canonical Switching Cell Converter PFC**
Variable DC bus	No	Yes

Control Of BLDC Motor	Current controlled	Electronic Commutated
Control of PFC	No	Voltage follower
Sensor for PFC	No	Single (Voltage)
Sensors for BLDC Motor	2- current sensors and 1-hall sensor	1-hall sensor

CONCLUSION & FUTURE SCOPE

CONCLUSION

BLDC drives are very preferable for compact, minimal effort, low maintenance, and high reliability system. In this work, a mathematical model of brushless DC motor is developed. The simulation of the Permanent Magnet Brushless DC motor is done using the software package MATLAB/SIMULINK and its phase voltage, phase current speed and torque waveform are analyzed. A PI controller has been employed for position control of PMBLDC motor. Effectiveness of the model is established by performance prediction over a wide range of operating conditions.

Power Factor Correction based CSC converter-encouraged BLDCM drive has been proposed for focusing on low-control family unit applications. A variable voltage of dc transport has been utilized for controlling the pace of BLDCM which inevitably has given the opportunity to work VSI in low-recurrence exchanging mode for decreased exchanging misfortunes. A front-end CSC converter working in DICM has been utilized for double destinations of dc-link voltage control and accomplishing a solidarity power component at air conditioning mains. The execution of the proposed drive has been found entirely well for its operation at variety of velocity over a wide range. Sanctioned Switching Cell Converter based BLDCM drive has been actualized with agreeable test results for its operation over complete rate reach and its operation at widespread air conditioning mains. The got PQ records are found under the purposes of control different worldwide PQ measures, for instance, IEC 61000-3-2.

FUTURE SCOPE

The reproduction of BLDC drives execution with the multi-level inverter topology. An Artificial Intelligence Technique like neural system, molecule swarm streamlining, Genetic Algorithm based velocity controllers tuning methodology can be considered for BLDC engine drive to further improve its execution. Control calculations might be actualized in FPGA. Space Vector based Pulse width balance strategy might be practiced rather than customary heartbeat width tweak.

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