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Performance Evaluation of PFC Based Dc Variable Voltage CSC Converter Fed BLDC Motor

Diana Xavier[1], Rosemin Parackal[2]

PG Student [PEPS], Dept. of EEE, Fisat, Angamaly, Kerala, India[1]

Assistant Professor, Dept. of EEE, FISAT, Angamaly, Kerala, India[2]

ABSTRACT:This paper 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 commutated 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 drive, which makes it a cost-effective solution.The validity of this proposed converter and its control performance are verified by MATLAB/SIMULINK.

KEYWORDS- Brushless dc motor (BLDCM), canonical switching cell (CSC)converter,discontinuous inductor current mode (DICM), power factor correction (PFC), power quality..

I.INTRODUCTION

The increasing growth in the use of electronic equipment in recent years has resulted in a greater need to ensure that the line current harmonic content of any equipment connected to the ac mains is limited to meet regulatory standards. This requirement is usually satisfied by incorporating some form of Power Factor Correction (PFC) circuits to shape the input phase currents. PFC can reduce the harmonics in the line current, increase the efficiency and capacity of power systems, and reduce customer's utility bill. The non linear characteri stics of loads such as televisions, computers, faxes and variable speed motor drives (used in air-conditioning) have made harmonic distortion in electrical distribution systems.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 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. A conventional scheme of BLDCM drive fed by an uncontrolled rectifier and a dc-link capacitor followed by a three-phase pulse width modulation (PWM)-based VSI is used for feeding the BLDCM . This type of scheme draws peaky, harmonic rich current from the supply and leads to a high value of total harmonic distortion (THD) of supply current and very low power factor at ac mains . A very high THD of supply current of 65.3 percent and a very poor power factor of 0.72 is achieved front-end power factor correction (PFC) converter is used after the diode bridge rectifier (DBR) for improving the quality. A boost half bridge PFC-based BLDCM drive using four switch VSI also requires a necessary PWM operation of VSI and PFC half bridge boost converter, which introduces high switching losses in the overall system. These switching losses are reduced by using a concept of variable dc-link voltage for speed control of BLDC motor . This utilizes the VSI to operate in low-frequency switching required for electronic commutation of BLDC motor, hence reduces the switching losses associated with it. A buck chopper operating as a front-end converter for feeding a BLDC motor drive also has higher switching losses associated with it due to high-frequency switching. These switching losses are reduced by using a concept of variable dc-link voltage for speed control of BLDC motor.This utilizes the VSI to operate in low-frequency switching required for electronic commutation of BLDC motor, hence reduces the switching losses associated with it..

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II.CANONICAL SWITCHING CELL

The concept of switching cells in power electronic circuits started in the late 1970's . It started with the canonical cell where an inductor, a capacitor, and a single-pole double throw switch form a basic canonical switching cell shown in Fig.1. The cell has three terminals A, B, and C and each of them can be used as an input/output/common terminal. If terminal A is used as an input, B as an output and C is used as the common terminal; the canonical circuit forms one kind of dc-dc converter. Six different combinations can be formed by changing the function of the three terminals in different combinations. Among these six combinations, only three distinct effective circuits are found, whereas the others are functionally the same. Thus, using these three combinations, the buck, boost, and buck-boost converter can be formed

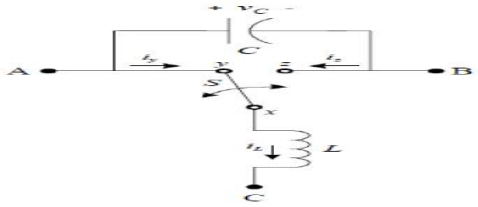

Fig 1. Basic Canonical Switching Cell

III. PROPOSED DRIVE USING IMPROVED DC CONVERTER

Fig. 2 shows the proposed BLDCM drive with improved dc converter which includes 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. The BLDCM drive uses a CSC converter operating in DICM . In DICM, the current in inductor becomes discontinuous in a switching period

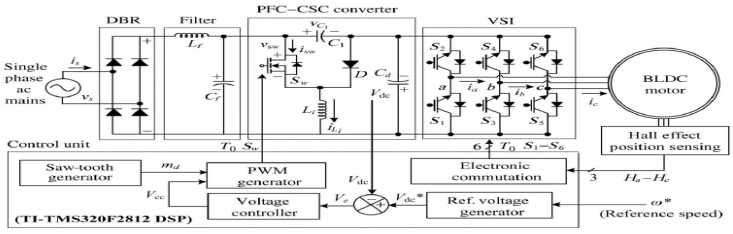

Fig.2. PFC converter fed BLDC motor drive

IV. OPERATING PRINCIPLE OF PROPOSED DC CONVERTER

The proposed BLDCM drive uses a CSC converter working in DICM . In DICM, the current in inductor Li becomes discontinuous in a switching period (Ts). Three states of CSC converter are shown in Fig. 3a-3c. Three modes of operation are described as follows.

Mode I: As shown in Fig. 3(a), when switchSw is turned ON, the energy from the supply and stored energy in the intermediate capacitor $C1$ are moved to inductor Li . In this process, the voltage across the intermediate capacitor$VC1$ reduces, while inductor current $iLi$and dc-link voltageVdc are augmented. The designed value of intermediate capacitor is large enough to hold enough energy such that the voltage across it does not become discontinuous.

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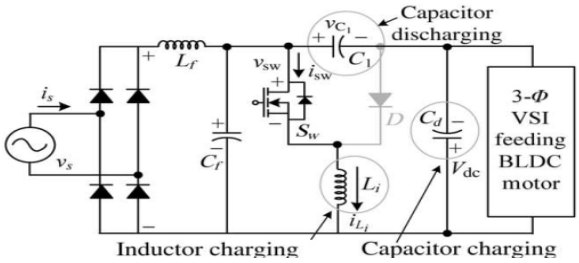

Fig 3(a).Operation Of CSC Converter in Mode 1

Mode II: The switch is turned OFF in this mode of operation as shown in Fig. 4(b). The intermediate capacitor $C1$ is charged through the supply current whereas inductor Li starts discharging hence voltage $VC1$ starts growing, while current iLi falls in this mode of operation. Furthermore, the voltage across the dc-link capacitor Vdc continues to rise due to discharging of inductor Li .

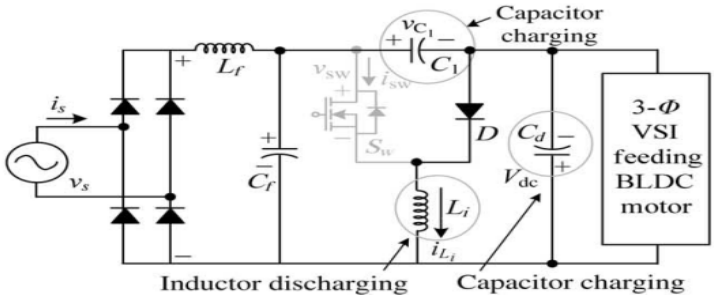

Fig 3(b):Operation of CSC Converter in Mode2

Mode III: This is the discontinuous conduction mode of operation as inductorLi is entirely discharged and current iLibecomes zero as shown in Fig. 4(c). The voltage across intermediate capacitor $C1$ remains to increase, while dc-link capacitor supplies the essential energy to the load, hence Vdc starts falling.

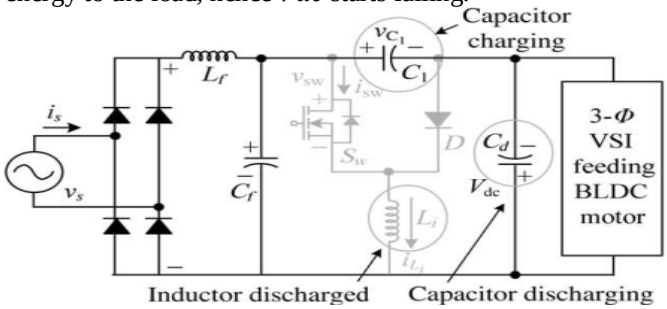

Fig 3(c):Operation of CSC Converter in Mode 3

V.DESIGN OF IMPROVED DC CONVERTER

The BLDCMdrive uses a PFC-based CSC converter operating in DICM. The front-end PFC-based CSC converter of is designed for a 314-W BLDCM. (Full specifications are given in the Appendix.) The dc-link voltage has to be controlled from 50 V to 200 V with a nominal voltage of 120 V . For the supply voltage of 220 V, the voltage appearing after the DBR is given as

$$\frac{2\sqrt{2}V_S}{\pi} \ldots\ldots\ldots\ldots (1)$$

A nominal duty ratio corresponding to is as

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$$d_n = \frac{V_{dcn}}{V_{dcn}+V_{in}} \text{.....(2)}$$

. The critical value of inductance to operate at boundary condition is given as

$$L_{ic} = \frac{V_{in}d_{nom}}{2I_{in}f_S} \text{.....(3)}$$

Now to operate this converter for PFC even at very low duty ratio, the value of inductor is taken around 1/10th of the critical value Hence, it is

$$L_i < L_{ic}/10 \text{.....(4)}$$

An intermediate capacitor is designed for permitted ripple voltage of across it and it is taken as 10% of where is the voltage across intermediate capacitor, i.e.,

$$V_{in} + V_{dcnom} \text{.....(5)}$$

and is given as

$$C_1 = \frac{V_{dcnom}d_{nom}}{\Delta V_{C1}R_l f_S} \text{.....(6)}$$

The equivalent emulated load resistance which is given as .

$$\frac{V_{dcn}{}^2}{P} \text{.....(7)}$$

Now for a permitted ripple of 1% of the nominal dc-link voltage across the dc-link capacitor , the value of dc-link capacitor is calculated as

$$C_d = \frac{I_d}{2\Delta V_{dc}\ w_L} \text{.....(8)}$$

To avoid the reflection of high-order harmonics in supply system, a low-pass inductive-capacitive (LC) filter is designed whose maximum value, is calculated as

$$C_{max} = \frac{I_{peak}}{w_L V_{peak}} \tan\theta \text{.....(9)}$$

Now, the value of filter inductor is designed by considering the source impedance of 4%–5% of the base impedance.

VII.SIMULATION RESULTS AND DISCUSSION

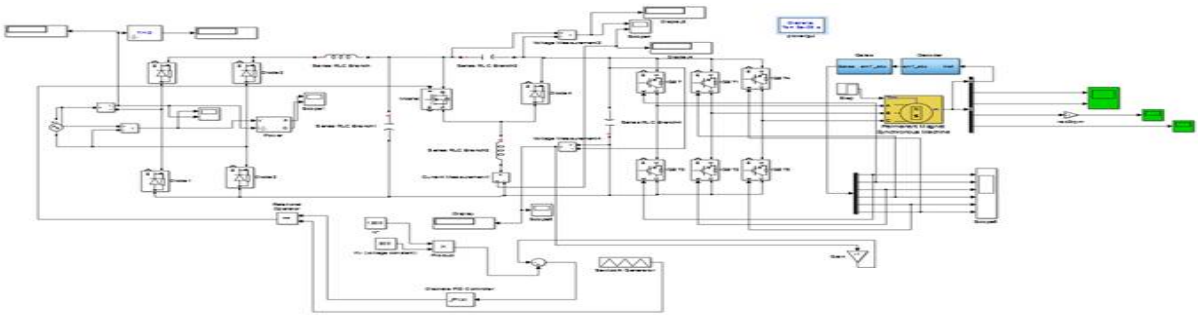

Fig 4:MatLab-Simulink model of the CSC converter fed BLDC motor

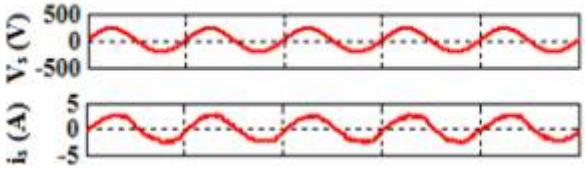

Fig 5:Input voltage and input current

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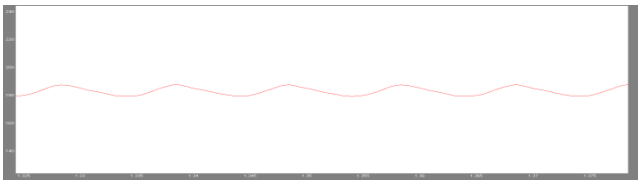

Fig 6:Variable DC link voltage

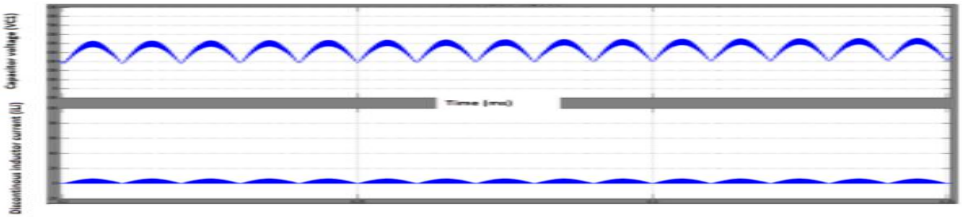

Fig 7 :Capacitor voltage and discontinuous inductor current

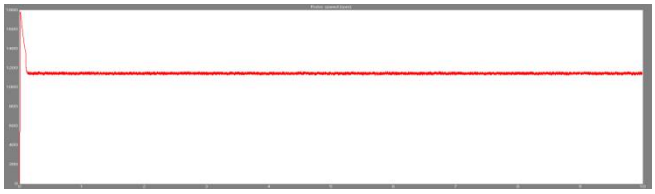

Fig 8: rotor speed

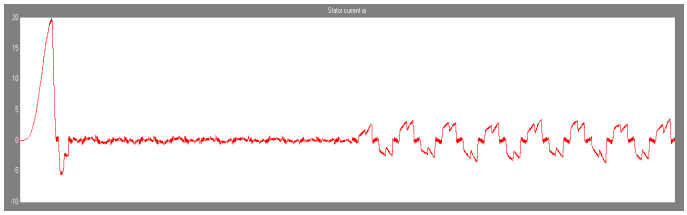

Fig 9:Stator phase a current

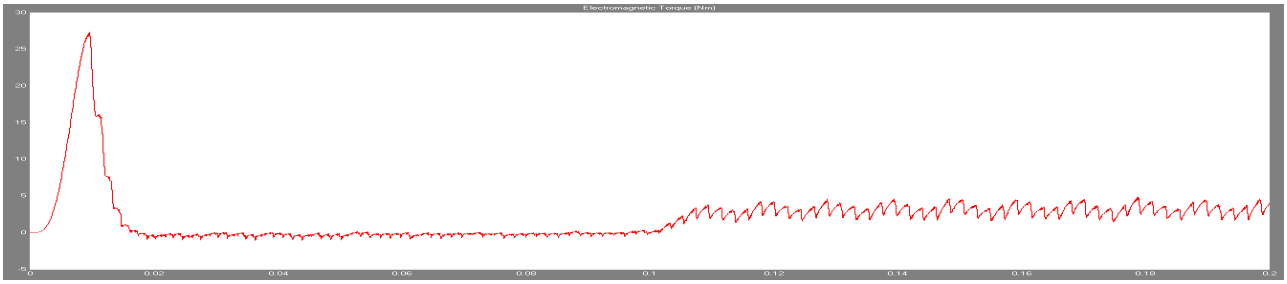

Fig 10:Electromagnetic torque

VIII.CONCLUSION

A PFC-based CSC converter-fed BLDCM drive has been proposed for targeting low-power household applications. A variable voltage of dc bus has been used for controlling the speed of BLDCM which eventually has

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given the freedom to operate VSI in low-frequency switching mode for reduced switching losses. A front-end CSC converter operating in DICM has been used for dual objectives of dc-link voltage control and achieving a unity power factor at ac mains. The performance of the proposed drive has been found quite well for its operation at variation of speed over a wide range. A prototype of the CSC based BLDCM drive has been implemented with satisfactory test results for its operation over complete speed range and its operation at universal ac mains.

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