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Power Factor Correction and Speed Control of BLDC Motor Using Sepic Converter

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ABSTRACT

This paper proposes a SEPIC converter-fed BLDC motor drive for power applications. The speed of BLDC motor is controlled by changing the DC link voltage. The circuit has is designed to operate the SEPIC converter in discontinuous inductor current mode (DICM) for the power factor correction (PFC) at the AC mains for a good range of speed control. This topology has less conduction losses and requires small heat sink for the switches. The designed system has been simulated for a system to operate over a wide range of speed control. A MATLAB/ Simulink environment has been used to simulate the developed model to achieve the wide range of the speed control with high PF (Power Factor).

Keywords: SEPIC Converter, DICM Mode, PFC

1. INTRODUCTION

Nowadays brushless DC motor (BLDC) is commonly used as it has high efficiency, flux density per unit volume and low maintenance requirements. The BLDC motors have household as well as industrial applications such as medical equipments, HVAC, motion control etc. In this paper, the front end bridgeless SEPIC DC-DC converter maintains the DC link voltage to a set reference value. The SEPIC converter switch has to be operated at high switching frequency for the effective control. The inverter output has been fed to the BLDC motor. A high - frequency MOSFET of the suitable rating has been used at the front end converter for its high-frequency operation and IGBT (Insulated Gate Bipolar Transistor) for low-frequency operation respectively.

2. EXISTING BL-BUCK-BOOST

The speed control of BLDC drive is achieved using conventional bridgeless (BL) buck–boost converter. The BL buck–boost converter also improves the power factor at the AC mains when operated in discontinuous inductor current mode (DICM) [1]. The buck–boost conversion functions on low-frequency resonant condition with polarity reversal. The AC input is fed to the bridgeless buck - boost converter which is fed to the inverter [9]. The inverter output feeds the BLDC motor. The control unit maintains the switching signal of the system. It senses the speed change of BLDC motor. The buck – boost converter varies the dc link voltage of VSI to control the speed of BLDC motor.

In the positive half cycle, switch Sw_1, inductor Li_1, and diodes D_1 and Dp conducts to charge the dc link capacitor Cd. During the negative half cycle, switch Sw_2, inductor L_{i2}, and diodes D_2 and Dn conducts.

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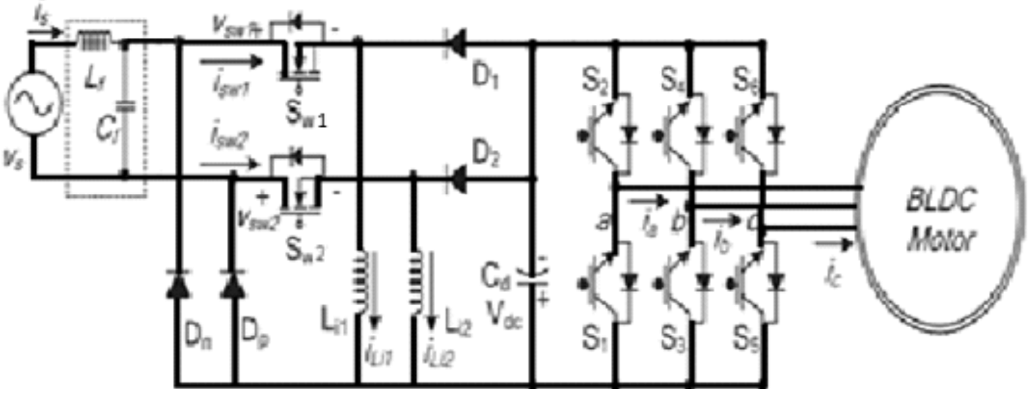

Figure 2.1: Existing circuit diagram

3. BLDC MOTOR USING SEPIC CONVERTER

3.1. Block Diagram

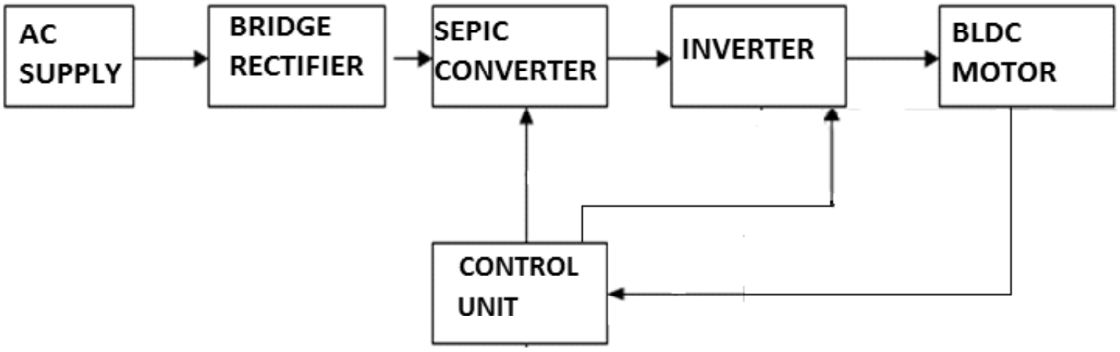

Figure 3.1: Block diagram of proposed system

The bridge rectifier circuit converts AC input to DC, which is fed to the SEPIC converter. The function of the control unit is to control the switching pulses for the inverter and to provide isolation [5]. The Driver circuit is used to amplify the 5V pulses to 12V pulses and to provide isolation. Some applications of converters may need to buck or boost the voltage and hence use the corresponding converters. However, sometimes if the desired output voltage needs to be variable, it is best to use a converter that provides variable voltage.

Buck-boost converters can be can be used for this purpose as they only require a single inductor and a capacitor [1]. But input current ripple are more pronounced in these converters which can create harmonics. These harmonics necessitates the use of large capacitor or an LC filter which makes the buck-boost expensive or inefficient. Buck-boost converters also have the disadvantage of inverting the voltage. Cuk converters solve both the problem by using an extra capacitor and inductor. The above said converters have high switching loss, resulting in overheating. To overcome this, SEPIC converter has been used. Moreover, performance parameters show an improved power quality with less torque ripple and smooth speed control of the PMBLDCM drive.

3.2. SEPIC Converter

Single-ended primary-inductor converter (SEPIC) is a DC-DC converter which can buck or boost its input voltage. The duty cycle of the control switch S controls the output of the SEPIC. A SEPIC Converter is similar to a traditional Buck-boost converter but has the output the same voltage polarity as the input. It uses a series capacitor to couple energy from the input to the output. When the switch is off, its output voltage becomes 0 V. This type of converter finds applications where battery voltage is needed to be above or below that of the regulator's output.

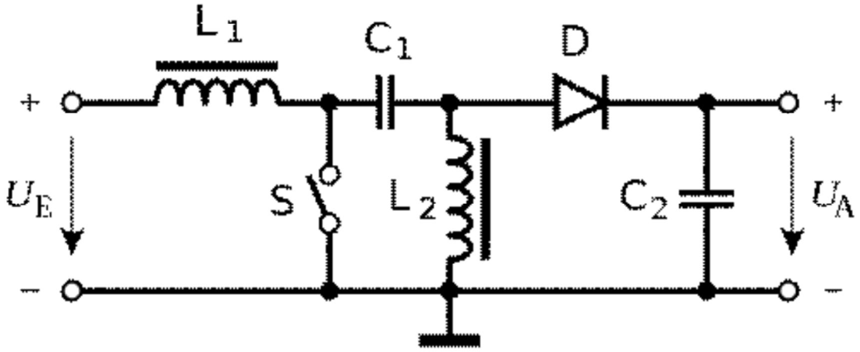

Figure 3.2: SEPIC Converter

3.3. Sepic on State

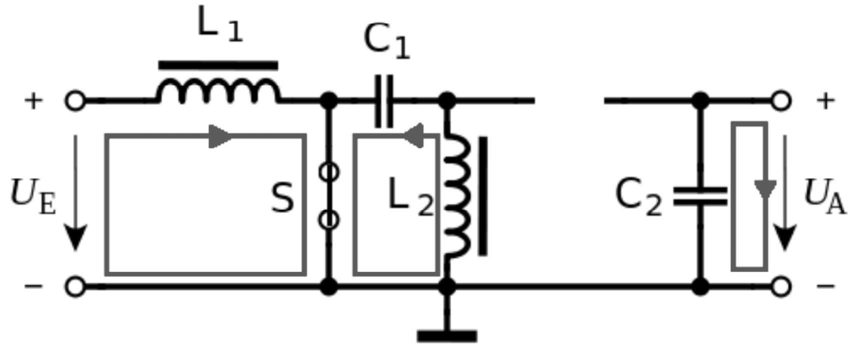

Figure 3.3: SEPIC ON State

When switch S on, current I_{L1} increases and the current I_{L2} goes more negative. The input source provides energy to increase the current I_{L1}. Since S is closed, and the instantaneous voltage Vc_1 is approximately the supply voltage V_{in} and the voltage V_{L2} is approximately $-V_{in}$. Hence, the capacitor C_1 tends to increase the magnitude of the current in $I_{L2,}$ thus increasing the energy stored in L_2.

3.4. Sepic Off State

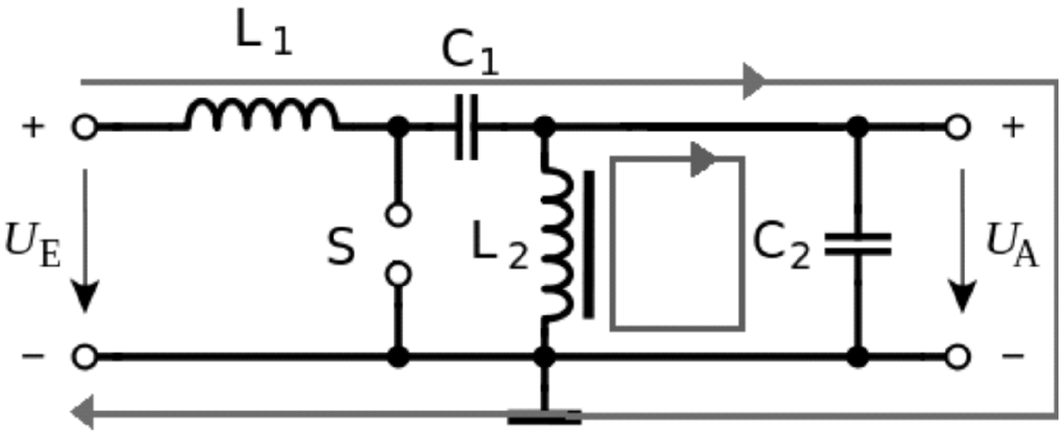

Figure 3.4: SEPIC OFF State

When switch S is off, the current Ic_1 is same as the current I_{L1}, because the inductor doesn't allow instantaneous current changes. The current I_{L2} will continue in the same direction. From the Fig 3.4, the current I_{L2} will add to current I_{C1} to increase the load current. Applying KCL, we get load current, $I_{d1}=I_{c1}+I_{L2}$. Hence, when the switch S is off, both L_2 and L_1 delivers power to the load. But C_1 is charged by L_1 during this *OFF* cycle, which in turn recharges L_2 during *ON* cycle[8].

4. SIMULATION AND RESULTS

4.1. Simulink Circuit diagram

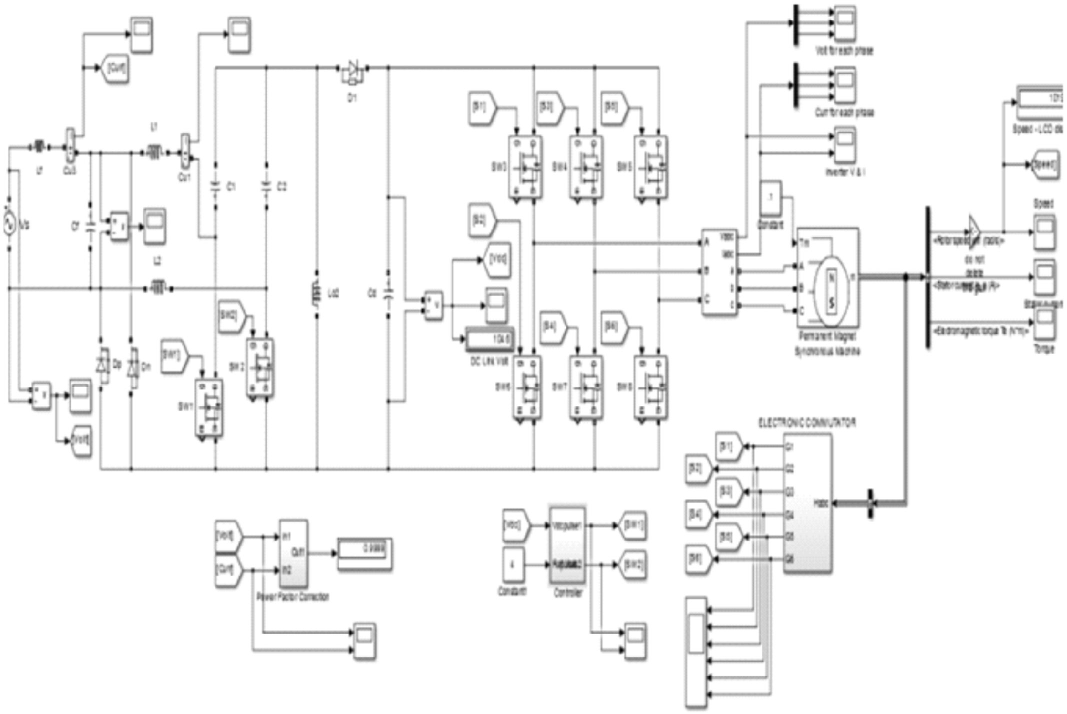

Figure 4.1: Simulation of proposed circuit diagram

The simulated proposed circuit diagram consists of SEPIC converter whose dc voltage is varied with the reference voltage to achieve a wide variation and control over the BLDC motor.

4.2. Simulation Output of Speed

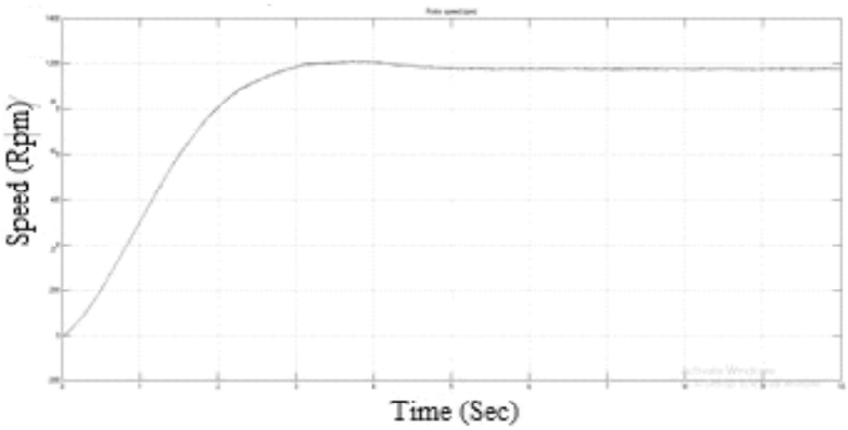

Figure 4.2: Speed – Time Curve

4.3. Speed Variation and Power Factor

Table 4.1

Vref	0.5	0.75	1.25	1.50	2.0	2.50
Vdc	39.24	59.11	98.9	120	158	199.6
Rpm	358	575	982	1189	1550	1949
P.F	0.908	0.918	0.935	0.956	0.972	0.999

4.4. Simulation Output of Speed with corresponding voltage

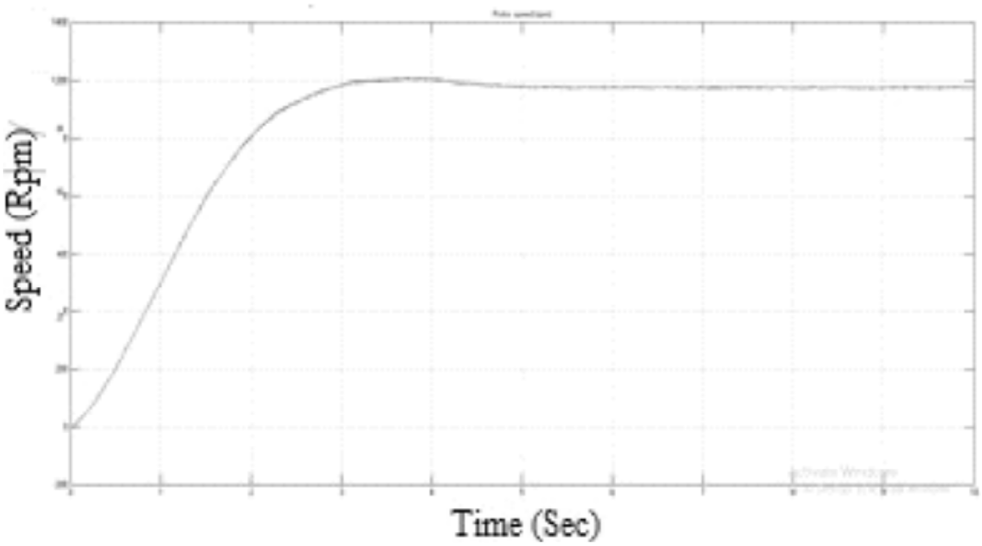

Figure 4.3: Speed for 120 volts

The simulated output has been obtained from the table for 120v Vdc, which turns the BLDC motor to run in 1189 rpm and gives the power factor as 0.956 by keeping the reference voltage as 1.5v.

4.5. Power Factor Correction

Power factor correction is usually achieved by the addition of capacitors to the electrical network which reduces the burden on the supply by compensating the reactive power demand of the inductive load. Capacitors neutralize much of the magnetizing current and draw current that leads the voltage, thereby producing a leading power factor.

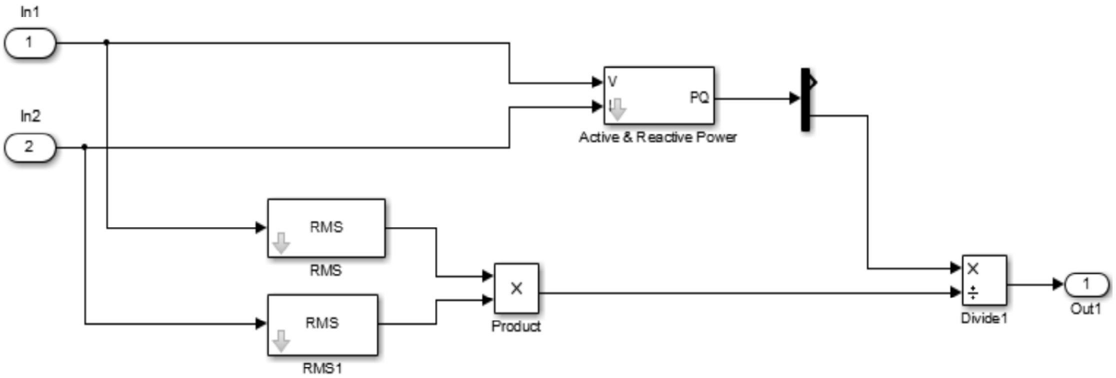

Figure 4.4: Power Factor Simulation Circuit

4.6. Voltage waveform

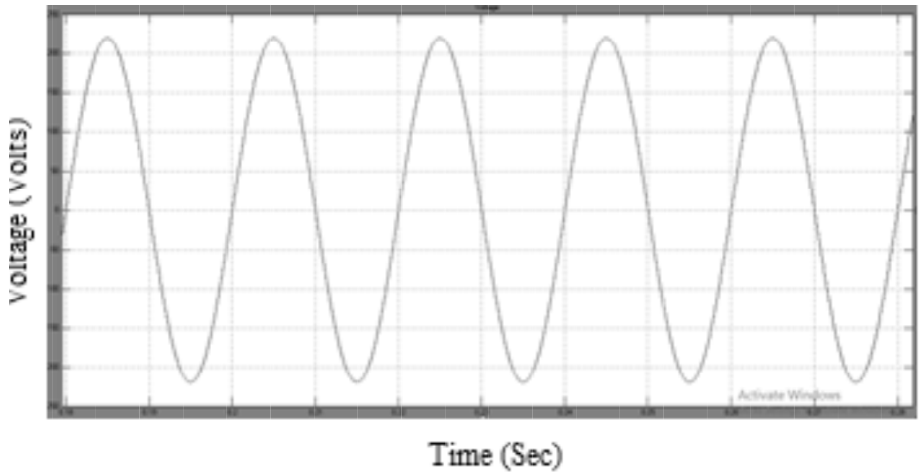

Figure 4.5: Voltage at AC mains

4.7. Current waveform

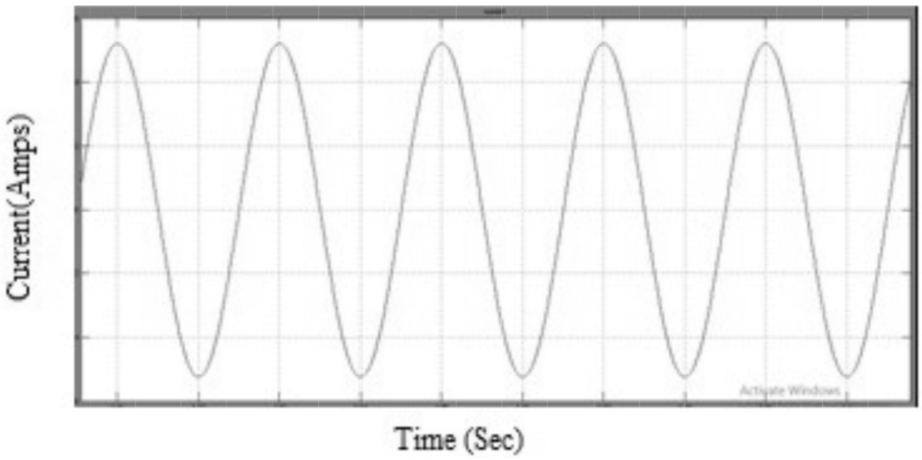

Figure 4.6: Current at AC mains

4.8. Simulation Output of Power factor Correction

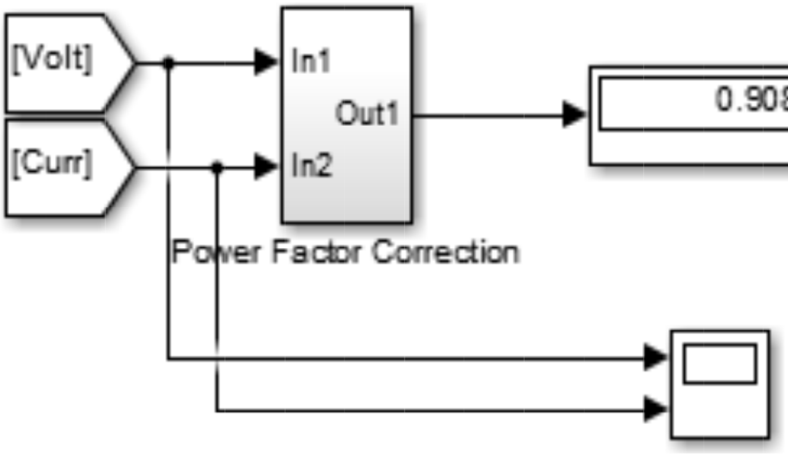

Figure 4.7: Power Factor Simulation Existing Output

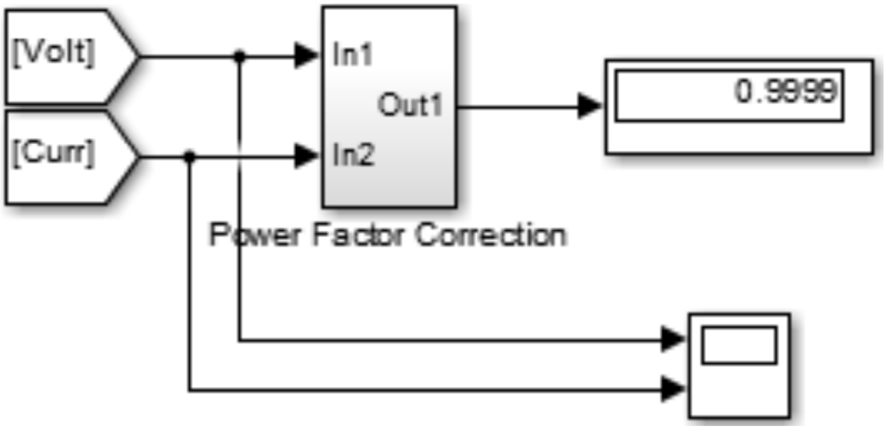

Figure 4.8: Power Factor Simulation Proposed Output

5. CONCLUSION

A SEPIC dc–dc converter is proposed for power-factor-correction for a variable speed permanent magnet brushless dc drive. A three - phase VSI is used as an electronic commutated switch to operate the PMBLDCM. Thus, the power factor is corrected at the AC mains and the speed variation is obtained by varying the dc link voltage using the SEPIC converter. By setting a corresponding constant value of a reference voltage, the dc link SEPIC Converter voltage is varied to control the BLDC motor.

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