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Bridgeless Isolated Cuk PFC Implementation using PID and Neural Controller

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Abstract

The comparision of bridgeless isolated cuk converter using proportional integral derivative (PID) and neural controller (NC) is presented in this paper. Due to diode bridge rectifier (DBR) conventional converters suffer from high conduction loss. Bridgeless Cuk converter is used to eliminate the issues. bridgeless isolated (BLI) cuk converter is used to withstand high voltage. Compare to Continuous conduction mode (CCM) discontinuous conduction mode (DCM) utilize less number of sensors. To obtain unity power factor it is used to work in DCM mode. BLI Cuk converter is implemented in two controllers PID and neural controller to observe power factor. Performance of BLDC motor is simulated by using MATLAB/Simulink software.

***Keywords**: Bridgeless Isolated Cuk conveter, BLDC, Power factor, PID controller, Neural controller*

1. Introduction

BLDC motor has the advantages like compact size, noise free and less electromagnetic interference and hence it is easy to control and maintain [1-3]. BLDC motor is choosen for various applications in household like fan, pump, air conditioner and in industries. Brushes produce more amount of heat dissipation [4]. Hence sparking and noise is produced in conventional motor, so it needs regular maintanence. BLDC motor is used to overcome the disadvantages. To sense the position of motor Voltage Source Inverter (VSI) and Hall Effect sensor is additionally connected. It is also used for providing electronic commutation [5-7].

Diode Bridge Rectifier (DBR) is used to supply the input to inverter. High value of dc link capacitor draws current for short period and causes distortion in voltage and current [8]. Thus the Power Factor (PF) is low and Total Harmonic Distortion (THD) is high. Power quality problems in BLDC drive is reduced by power factor correction converters. Continuous Conduction Mode (CCM) and Discontinuous Conduction Mode (DCM) are two modes of conduction.CCM mode requires more number of sensors than DCM and hence DCM mode is mostly preferred to reduce the cost [9].

Compare to conventional PFC, Cuk converter protect from the inrush current and it is combination of Buck Boost operation [10]. To reduce switching loss Bridgeless (BL) Cuk converters are used. Non isolated converter cannot withstand high voltage hence Bridgeless Isolated (BLI) Cuk converters are choosen to prevent from unwanted current loop and it provide isolation between input and output [11].

2. PFC Controller

In PID controller reference speed and motor voltage constant is multiplied and it is given as reference voltage (Vr*) [12-13]. Control algorithm consists of reference voltage, speed control and PWM (Pulse width Modulation) generation. Voltage error generator is used to compare the actual and observed voltage to generate error [14]. Block Diagram of PFC Based Bridgeless Isolated Cuk Converter is shown in Figure 1.

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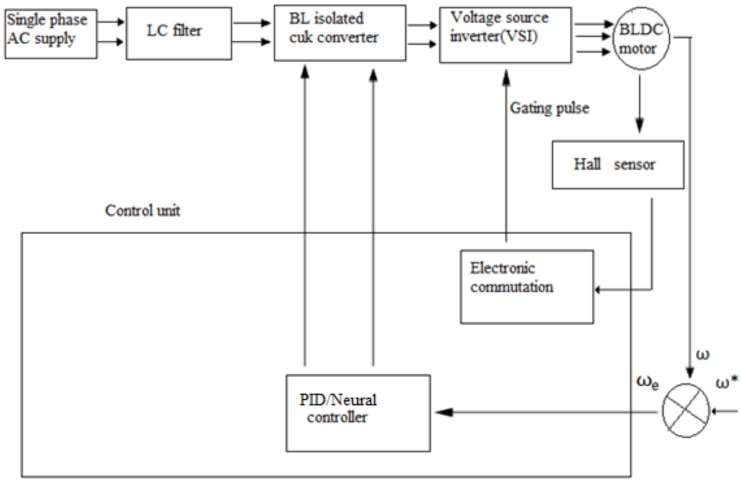

Figure 1. Block Diagram of PFC Based Bridgeless Isolated Cuk Converter

Error value is calculated by the following equation

$$V_e\ (k) = V_r\ (k)^* \ - V_r\ (k) \tag{1}$$

The error voltage is changed consequently when the gain values of PID controller is adjusted [15-16]. To meet the reference set value PWM generator is controlled. PID controller generates the controlled output voltage (Vo) and it is given as,

$$V_o\ (k) = V_o\ (k-1) + K_P\{ V_e\ (k)\ - V_e\ (k-1)\} + K_i\, V_e\ (k) \tag{2}$$

The most flexible and specific controller is Neural network (NN) and it behave like human neuron [17]. To transmit output to other neuron.Neural network receive the input and it store the data. Neural Network mathematical model is represented by the following equation

$$Y(k) = Y(k-1) - 0.5\ \tanh\ (Y(k-1)X(k-1)^3) \tag{3}$$

Where X=input signal given to the network
Y=output signal from the network

To generate an output, input parameters are multiplied by the corresponding weight factor wi [18-19]. The summation of weighted inputs is given as input to the sigmoid function and input and output parameters are related to give an output.

3. Simulation of BLI Cuk Converter using PID Controller

The performance of BLDC motor drive using BLI Cuk converter is simulated by using MATLAB/SIMULINK software. The simulink model is shown in Figure 2. K_p, K_i and K_d values of PID controller are used to control the converter. According to the error received from the PID controller PWM generator gives the switching pulse. The performance of BLDC motor like speed, torque, stator back emf and current of BLDC motor are measured for 230V input voltage.

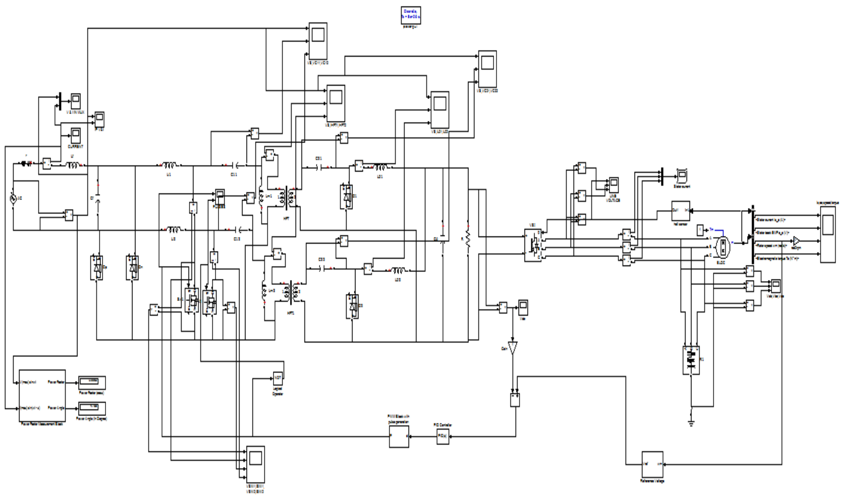

Figure 2. Simulink Model for BLI Cuk converter with BLDC motor

Power factor display block receive input from source voltage and current and an equivalent real and reactive power is calculated. Speed of BLDC motor controls the DC link voltage and switching of converter is varied. The power factor observed is 0.9965 for BLI Cuk converter with PID controller is shown in Figure 3.

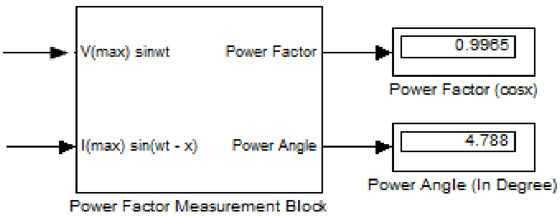

Figure 3. Power factor observation

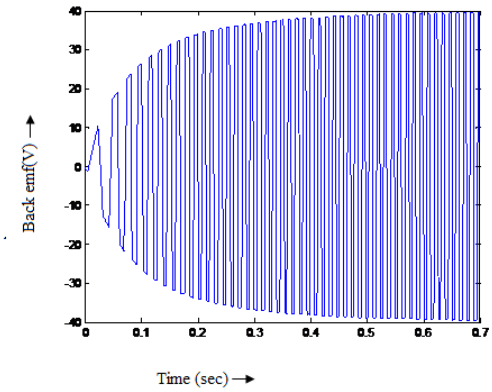

Figure 4. Observed stator back EMF of BLDC motor

Figure 4 shows the stator Back EMF obtained with the use of PID controller. The stator current of BLDC motor when controlled by PID controller is shown in Figure 5. At the time of 0.07 sec it starts to settle. BLDC motor torque waveform is shown in Figure 6.

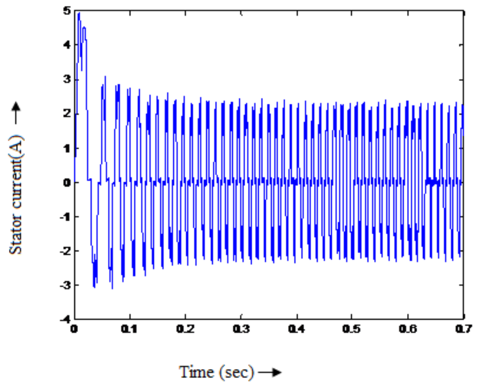

Figure 5. Stator Current of BLDC Motor by PID Controller

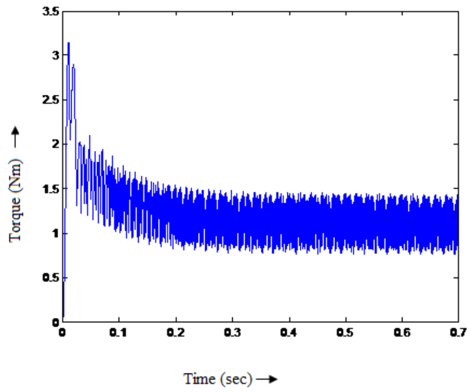

Figure 6. Electromagnetic torque of BLDC motor

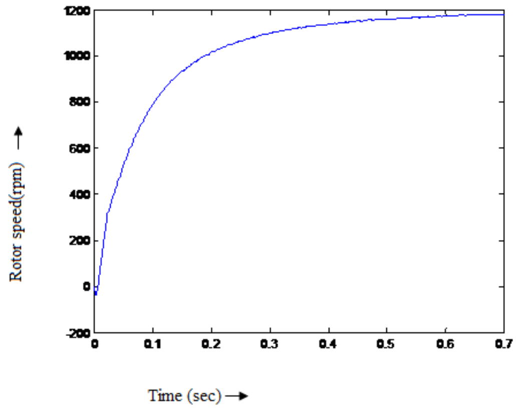

Figure 7. Speed response for BLI cuk based BLDC

DC link voltage is controlled to obtain stable speed response. Figure 7 shows the BLDC speed response using BLI Cuk converter.

4. Simulation of BLI Cuk Converter using Neural Controller

The simulink model for Neural controller based BLDC motor using Bridgeless Isolated Cuk converter is shown in Figure 8. Neural controller controls the operating cycle of converter switches. Nearly unity power factor is obtained and it is operated in DCM mode. Power factor observed using power factor display block is 0.9985 is shown in Figure 9.

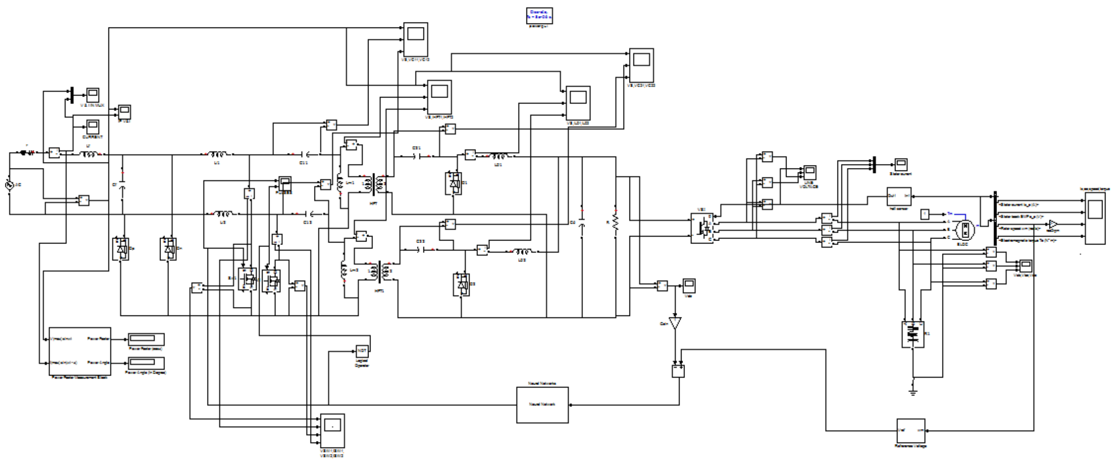

Figure 8. Simulink Model for BLI cuk based BLDC motor

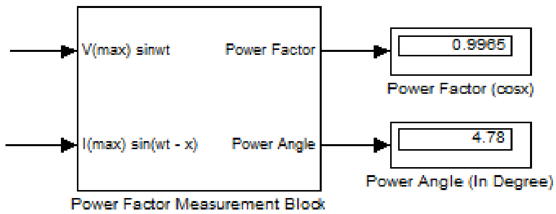

Figure 9. Power factor response for BLI cuk based BLDC

Neural based BLI Cuk converter fed BLDC motor drive speed response is shown in Figure 10. Steady state of motor is attained and settles at 0.08 sec. According to the reference value speed is tracked and generated.

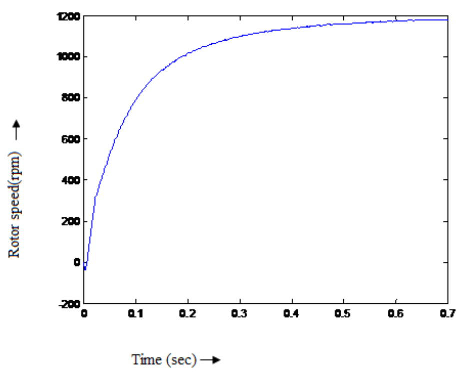

Figure 10. Speed response for BLDC with BLI cuk converter

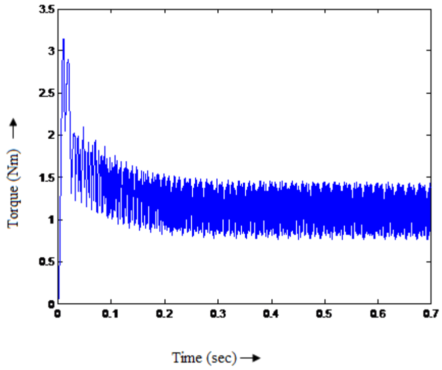

Figure 11. Electromagnetic torque for neural based BLI cuk converter

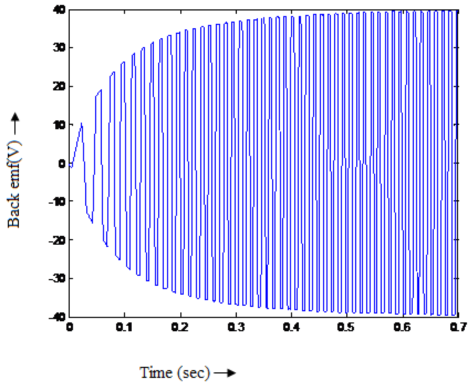

Figure 12. Stator back EMF of BLDC motor

Electromagnetic torque of BLDC is shown in Figure 11 and ripple in the torque waveform is observed. Figure 12 shows the stator back emf. Shape of back emf is decreased from its original position in the starting condition. As soon as possible it regain its original shape.

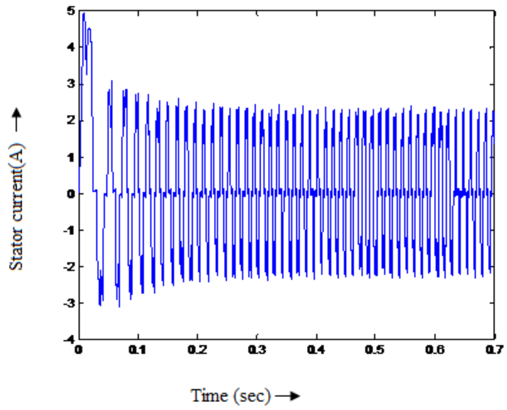

Figure 13. Stator current for BLI cuk based BLDC motor

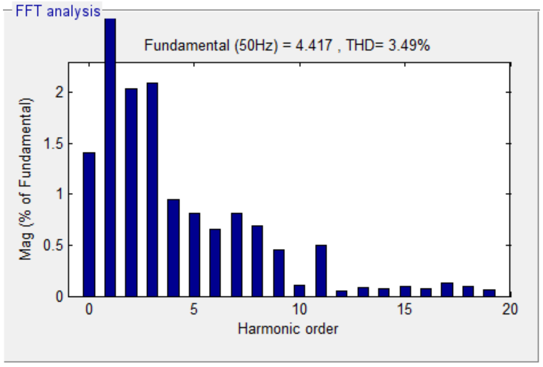

Figure 14. Harmonic spectrum

Stator current of BLDC motor is shown in Figure 13. Efficiency of motor is degraded due to high distortions in the current waveform. Total Harmonic Distortion (THD) for BLI Cuk converter is shown in Figure 14 and the observed THD is 3.49%. Neural controller is best controller when compared to PID controller. It has better dynamic performance because it has less distortion. So that power factor is improved.

5. Conclusion

Power Factor is inherently maximizes by Bridgeless Isolated Cuk Converter. Using PID controller the observed power factor is 0.9965. Power Factor of BLDC motor drive using Neural controller is 0.9985 and Total Harmonic Distortion (THD) is 3.49%. Neural controller has less settling time, minimum peak overshoot, good dynamic performance and better efficiency. It improves Power Factor than the conventional converter.

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