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Fuzzy Logic Based Power Factor Correction for BLDC Drive

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Abstract : ***This paper deals with a Cuk Topology for Power Factor Correction (PFC). Most of the front-end PFC converters are designed using diode bridge and has lower efficiency due to losses with reduced power factor.The current flow, during each intervals of the switching cycle reduces the conduction losses compared to the conventional Cuk PFC Rectifier. The converter also provides protection against starting current occurring at start-up, decreases input current ripple and reduces Electromagnetic Interference (EMI).It works in the Discontinuous Conduction Mode (DCM) to provide almost unity power factor and low distortions in the input current. To analyse the performance of this converter, a model based on the CUK topology has been designed by using MATLAB/ SIMULINK software and implemented Fuzzy logic controller.***

Keywords: CUK Bridgeless Topology, Fuzzy Logic Controller (FLC), Power Factor Correction (PFC), Proportional- Integral (PI) Controller.

I. INTRODUCTION

1.1 GENERAL

Brushless DC (BLDC) motors are used for many low and medium power applications due to their high efficiency, high flux density per unit volume, low maintenance requirement, low EMI problems, high ruggedness and a range of speed control. The commutation in PMBLDCM is achieved by solid state switches of a three phase voltage source inverter (VSI). There is a necessity of an improved power quality (PQ) as per the international PQ standard IEC 61000-3-2 that recommends a high power factor (PF) and low total harmonic distortion (THD).

The conventional scheme, as shown in fig 1.1,of a BLDC motor is fed by a diode bridge rectifier (DBR) and a high value of dc-link capacitor that draws non-sinusoidal current from ac mains, which has high harmonics such that the THD of supply current is nearly 60%, resulting in PF as low as 0.7. Hence, single-phase power factor correction (PFC) converters are implemented to attain a unity PF. The switched mode DC-DC converters are used often as the power factor correction circuits in recent years especially for low power applications. These circuits provides high power factor at the input side and ensures a purely resistive operation.

This introduces electromagnetic interference and leads to poor utilization of the utility. The approaches like passive and active power factor correction are used to enhance the power factor with low line current Total Harmonic Distortion (THD).The features of the good power factor correction circuit are as follows:

1. A suited regulated output voltage.
2. Isolation between input AC mains and output DC mains.
3. A line current with minimum THD that achieves the requirements of international standards.
4. High efficiency by eliminating or reducing the conduction and switching losses.

1.2 EXISTING SYSTEM

In conventional PFC rectifier, during the switch ON-time, the current flows through the rectifier bridge diodes, power switch (Q) and during switch OFF-time current flows through two diodes of Rectifier Bridge and the output diode (Do). Thus three semiconductor devices are involved at each switching cycle resulting in voltage drop across the bridge diode that causes a significant conduction loss and also the heat generated may damage the diodes. Research has been focused on this recently in order to have bridgeless topologies to improve the efficiency of the converter.

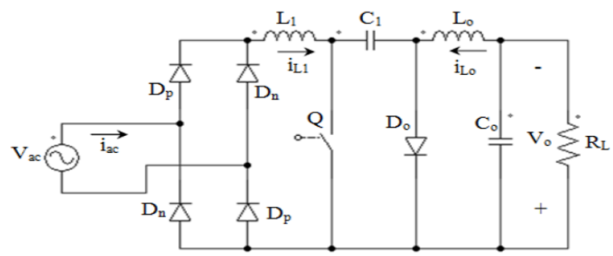

Fig 1.1 Classical Cuk PFC converter.

1.3 BRIDGELESS PFC TOPOLOGIES

A bridgeless PFC rectifier based on the Primary-Inductance Converter topology has been implemented but it has its disadvantage of discontinuous output current which results in a high output ripple. The topology used for the low power applications is the Cuk converter. It offers certain advantages such as isolating the transformer of a circuit in easy way, protection against starting current or overload current, lower input current ripple and low electromagnetic interference (EMI).

There are three bridgeless Cuk converter topologies. Of these three types, Type 2 has the lowest number of semiconductors. Type 1 has the advantage of lower component count but a high current peak. Type 3 has a higher component count but low stresses and higher efficiency. So Type-3 PFC rectifier circuit is considered for this power factor correction.

1.4 MODES OF OPERATION FOR CUK PFC RECTIFIER

During the positive half cycle, the first DC–DC Cuk circuit, L1–Q1–C1–Lo1–Do1, is connected to the input AC source via diode Dp and it reaches the output. During the negative half cycle, the second DC–DC Cuk circuit, L2–Q2–C2–Lo2–Do2, is active through diode Dn that connects the input AC source to the output.

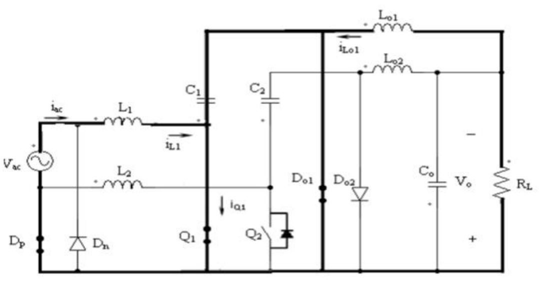

Fig 1.2 Operation of type-3 converter during positive half cycle.

The operation of the rectifier in DCM offers certain advantages such as near-unity power factor, turn ON of power switches during zero current and output diodes (Do1 and Do2) turn OFF during zero current.

Stage 1 operation [t0, t1]

This stage operates when the switch Q1 is turned ON . Diode Dp is forward biased due to the inductor current iL1. As a result, the diode Dn is reverse biased due to the input voltage. The output diode Do1 is reverse biased by the reverse voltage (vac + VO), while Do2 is reverse biased due to the output voltage Vo. At this time, the currents through inductors L1 and Lo1 increases with the input voltage, while the current through Lo2 is zero due to the constant voltage across C2.

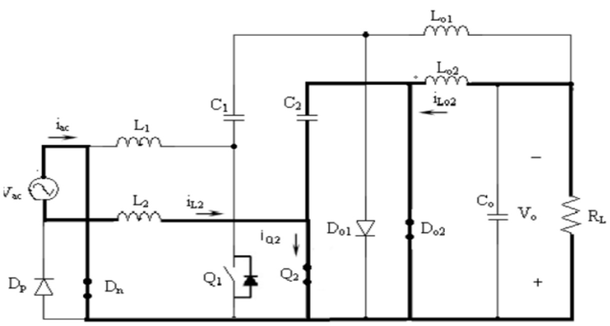

Fig 1.3 Operation of type-3 converter during negative half cycle.

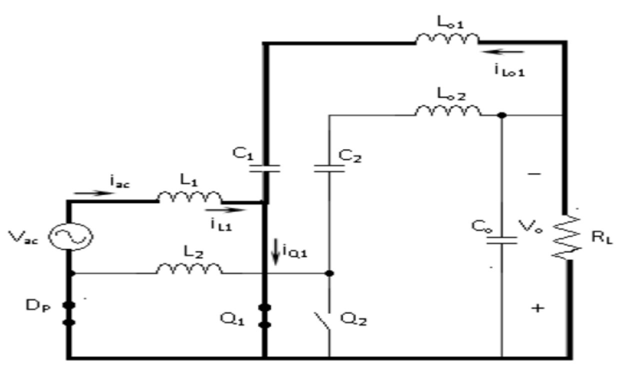

Fig 1.4 Stage 1 operation of type-3 converter.

Stage 2 operation [t1, t2]

This stage works when the switch Q1 is turned OFF and the diode Do1 is turned ON simultaneously providing a path for the inductor currents iL1 and iLo1.

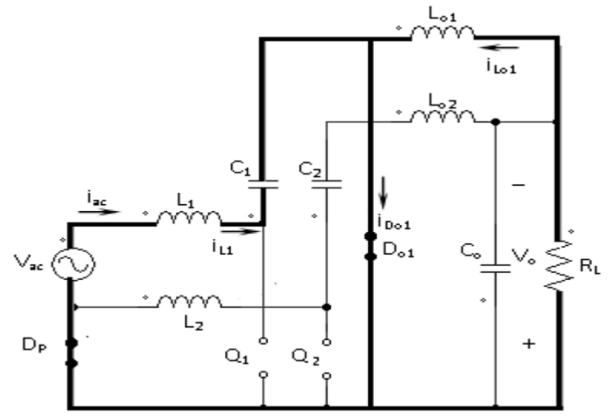

Fig 1.5 Stage 2 operation of type-3 Cuk converter.

Diode Do2 remains reverse biased at this stage. And ends when iDo1 reaches zero and Do1 is reverse biased.

Stage 3 operation [t2, t3]

During this stage, only the diode Dp conducts to provide a path for iL1 as shown in Fig. 7. Also the inductors in this stage behave as constant current sources.

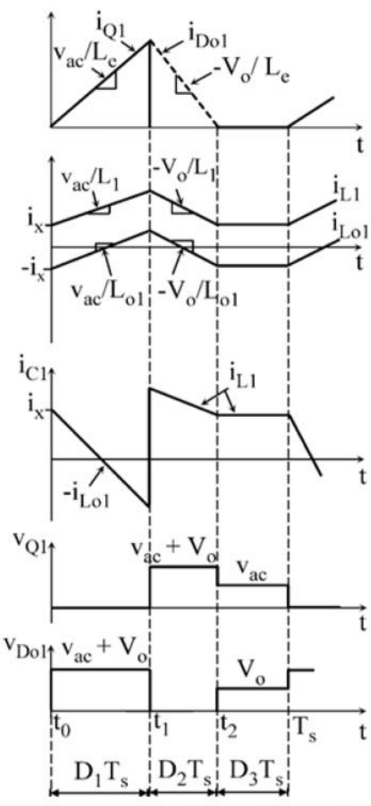

Fig 1.6 Switching waveform of switches in Cuk PFC converter.

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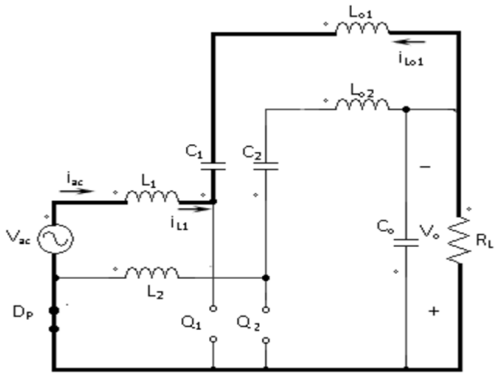

Fig 1.7 Stage 3 operation of type-3 Cuk PFC converter.

Hence, the voltage across the three inductors is zero.= This period ends when Q1 is turned ON.

II. METHODOLOGY

2.1 PI CONTROLLER FOR CUK CONVERTER

The actual output voltage and reference voltage are compared and error is given as the input to the PI controller. The gain values of PI controller are varied in such a way in order to give pure input supply current at near unity power factor by controlling the switching of converter. The gain values for obtaining the power factor improvement here are kp=0.1 and ki=0.1.

2.2 FUZZY LOGIC CONTROLLER FOR CUK CONVERTER

Fuzzy logic uses several unique features that make it a good choice for many problems.

1) It is robust as it does not require accurate, noise-free inputs and can be programmed to meet safety if a feedback sensor gets destroyed. The output control is a smooth function despite of a wide range of input variations.

2) Since the FL controller evaluates user-defined rules governing the target control system, it can be modified easily to improve or drastically change system performance. New sensors can be easily incorporated into the system by generating appropriate governing rules.

3) FL is not restricted to a few feedback inputs and one or two control outputs and its not necessary to measure or compute rate-of-change parameters in order to be implemented. Any sensor data which provides indication of a system's actions and reactions is sufficient.

III. RESULTS AND TABLES

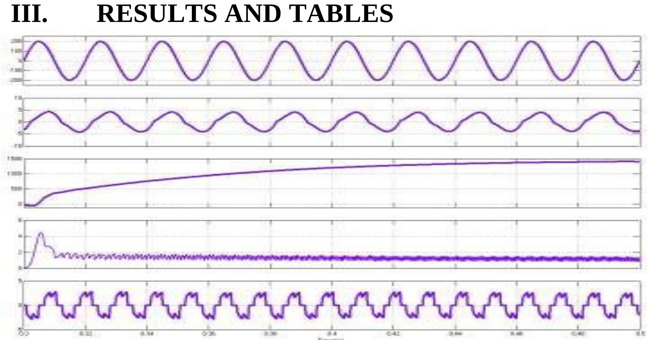

Fig 3.1 Vs, Is, speed, torque, stator current of PFC Cuk Converter-Fed BLDC Motor Drive.

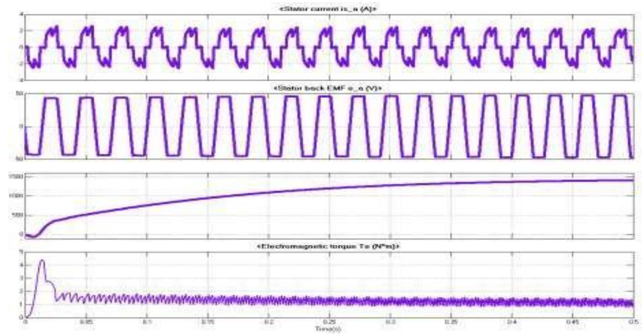

Fig 3.2 motor output of PFC Cuk Converter-Fed BLDC Motor Drive.

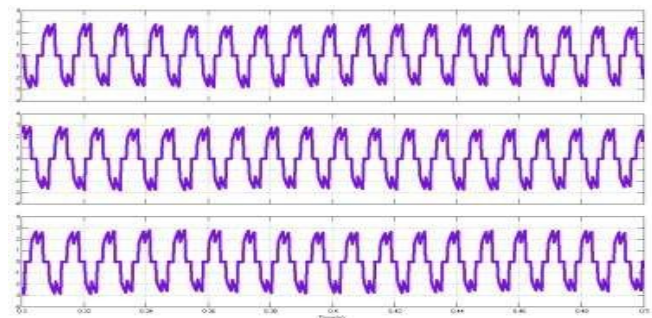

Fig 3.3 stator currents of PFC Cuk Converter-Fed BLDC Motor Drive.

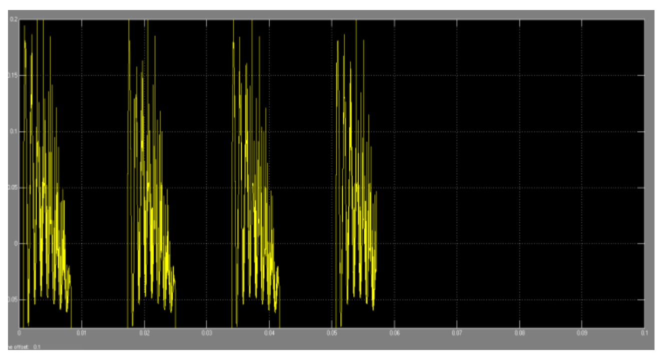

Fig 3.4 Output current of fuzzy logic based BLDC drive

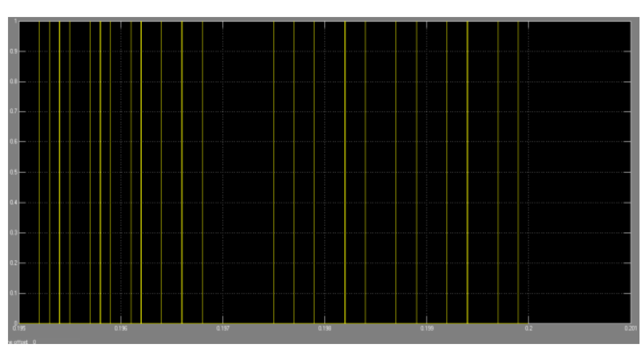

Fig 3.5 DC voltage of fuzzy logic based BLDC drive

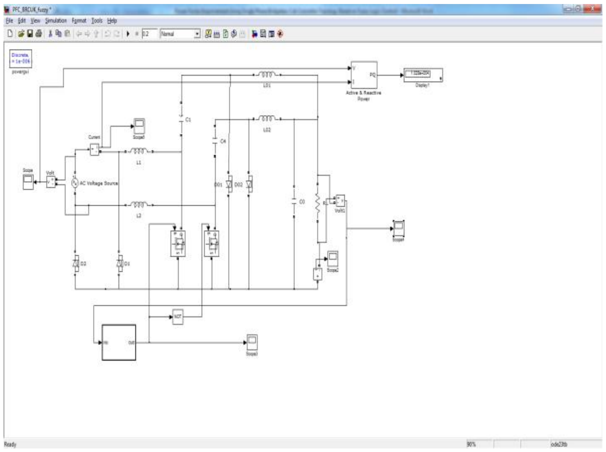

Fig 3.4.Simulink model

Table 1. Fuzzy rule table.

		e				
		NB	NS	Z	PS	PB
ce	NB	NB	NB	NB	NS	Z
	NS	NB	NS	NS	Z	PS
	Z	NB	NS	Z	PS	PB
	PS	NS	Z	PS	PS	PB
	PB	Z	PS	PB	PB	PB

IV. CONCLUSION

The speed of the BLDC motor drive has been controlled by changing the DC link voltage of VSI; allowing the VSI to operate in fundamental frequency switching mode for low switching losses. And finally fuzzy controller is applied to the suitable mode i.e DCM (Lo) mode due to its low switch stresses when compared to DCM (Li) mode. Hence the Total harmonic distortion for the Cuk converter fed BLDC motor using fuzzy and pi controller has been studied.

The proposed system has shown satisfactory results in all aspects and stands as a solution for low power BLDC motor drives.FLC shows to be the suited controller concerning the performance of BLDC motor drives to achieve power factor near unity.

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