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Power Quality Improvement Using Fuzzy Based Canonical Switching Cell Converter

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***Abstract*— In this project a design of Canonical Switching cell converter is proposed to achieve a power factor close to unity. A front end Canonical switching cell converter operating in Discontinuous Inductor Current Mode (DICM) is proposed for PFC operation at AC mains. Fuzzy logic is introduced in order to suppress the chattering and enhancing the robustness of the PFC control system. Thus International Electro-technical Commission standard (IEC) 61000-3-2 and IEEE-519 standard to power quality can be achieved.**

Keywords*— Diode Bridge Rectifier (DBR), Canonical switching cell (CSC) converter, discontinuous inductor current mode (DICM), Power factor correction (PFC), Power quality.

I. INTRODUCTION

Improving power quality considerations require two factors: achieving high power factor and low harmonics. In fact, a low power factor reduces the power available from the utility grid, while a huge harmonic distortion of the line current causes EMI problems and cross-interferences, through the line impedance, between different systems connected to the same grid. From this point of view, the standard rectifier employing a diode bridge followed by a filter capacitor performs poor. Thus, technologies are being developed to interface systems that improve the power factor of standard electronic loads. Figure 1 shows the conventional system with PFC-boost converter. A front end power factor correction (PFC) is used after the diode bridge rectifier (DBR) for improving the quality of power factor at ac mains [1].

Many topologies of PFC have been reported in the literature surveys. A PFC boost converter has been the most popular configuration [15]. A constant dc-link voltage is maintained at the de-link capacitor for controlling the speed of the drive. Conventional scheme of PFC includes a current multiplier approach which includes voltage and current sensors [2]. The front end SEPIC and Cuk regulator using a variable voltage control have been proposed in [2] and [5], but at the cost of two current sensors. Bridgeless SEPIC regulator of PFC have been proposed in [12], but at the higher cost due to larger inductance.

This project presents the improvement of power quality using fuzzy based canonical switching cell converter with voltage follower approach.

II. PROPOSED FUZZY BASED CANONICAL SWITCHING CELL CONVERTER

A front-end power factor correction (PFC) converter is connected after the diode bridge rectifier (DBR) for improving the quality of power and achieving a near unity power factor at ac mains. Figure 2 shows the proposed fuzzy based canonical switching cell (CSC) converter for power quality improvement. A CSC converter operating in DICM acts as an inherent power factor pre-regulator for attaining a power factor of nearer to unity at AC mains. The front end CSC converter is designed and its parameters are selected to operate in a DICM for obtaining a high power factor. A single voltage sensor is required for PFC converter operating in discontinuous conduction mode (DCM) using the voltage-follower approach but at the cost of high stresses on PFC converter's switch.

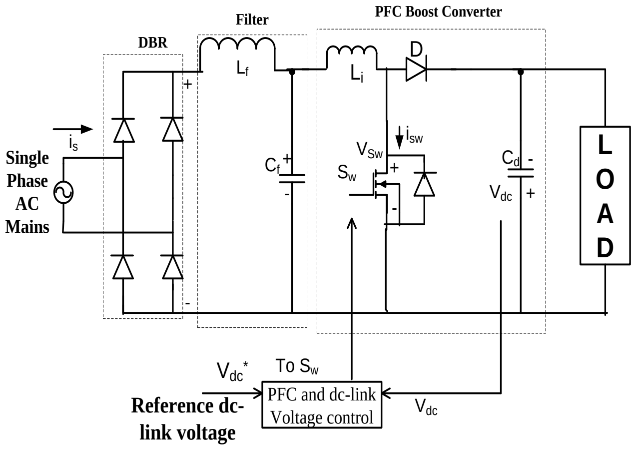

Fig.1 Conventional System with PFC-Boost Converter

III. OPERATING PRINCIPLE OF PFC-BASED CSC CONVERTER

The proposed PFC based CSC Converter operates in DICM. In DICM, the current in inductor L_i becomes discontinuous in a switching period (T_s).

Mode I: Figure 3(a) shows the operation of Mode I operation of CSC converter. The switch S_w is turned $_{ON}$, the energy from the supply and stored energy in the intermediate capacitor C_1 are transferred to inductor L_i. In this process, the voltage across the intermediate capacitor V_{c1} reduces, while inductor current i_{Li} and dc-link voltage V_{dc} are increased. The designed value of intermediate capacitor is large enough to hold enough energy such that the voltage across it does not become discontinuous.

Mode II: The switch is turned $_{OFF}$ in this mode of operation. The intermediate capacitor C_1 is charged through the supply current while inductor L_i starts discharging, hence voltage V_{c1} starts increasing, while current i_{Li} decreases in this mode of operation. Figure 3(b) shows the operation of Mode II operation of CSC converter. Moreover, the voltage across the dc-link capacitor V_{dc} continues to increase due to discharging of inductor L_i.

Mode III: This is the discontinuous conduction mode of operation as inductor L_i is completely discharged and current i_{Li} becomes zero. Figure 3(c) shows the operation of Mode III operation of CSC converter. The voltage across the intermediate capacitor C_1 to increase, while dc-link capacitor supplies the required energy to the load, hence V_{dc} starts decreasing.

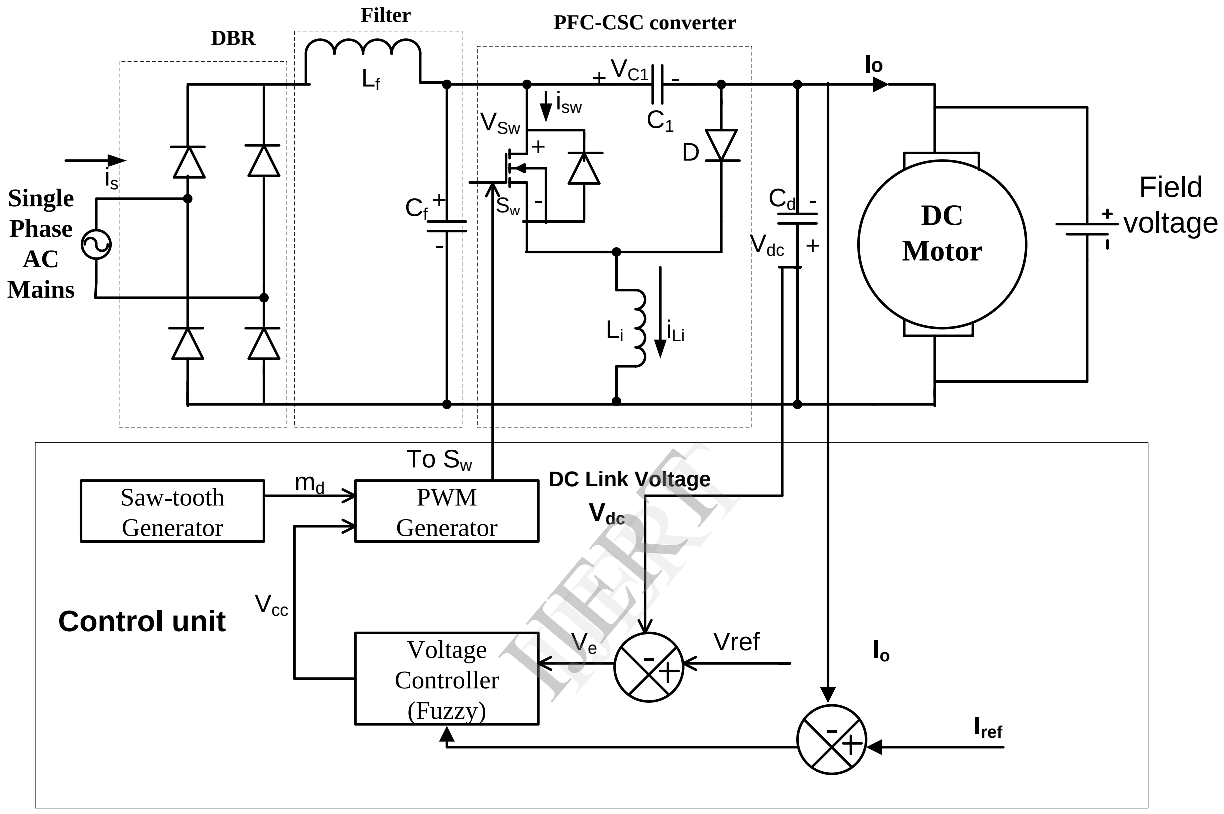

Fig. 2 Proposed Fuzzy Based Canonical Switching Cell Converter

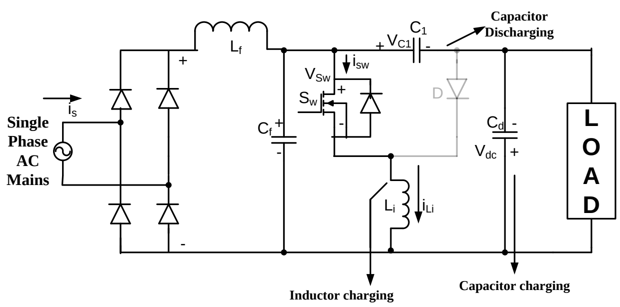

Fig. 3 (a) Mode I

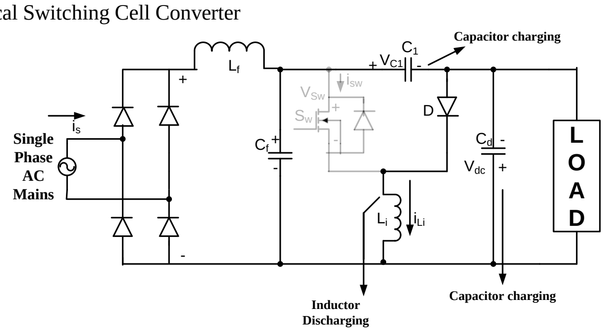

Fig. 3 (b) Mode II

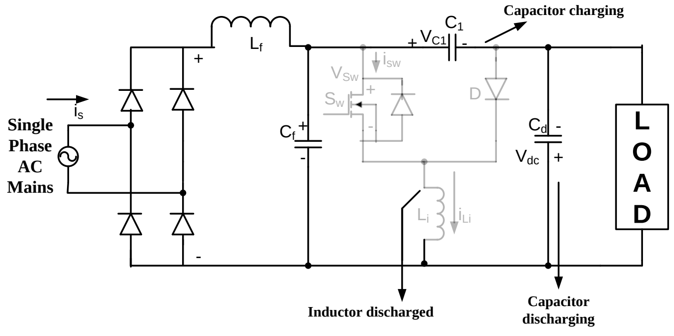

Fig. 3 (c) Mode III

IV. CONTROL OF PFC-BASED CSC CONVERTER

A. Control of Front-End PFC Converter

Conventionally, PI, PD and PID controller are most popular controllers and widely used in most power electronic closed loop appliances however there are many researchers reported successfully adopted Fuzzy Logic Controller (FLC) to become one of intelligent controllers to their appliances. A simple fuzzy logic control is built up by a group of rules based on the human knowledge of system behavior.

In this project FLC is introduced to improve the robustness and suppresses the chattering of the load. Furthermore, design of fuzzy logic controller can provide desirable performance which is not possible with linear control technique. Thus FLC has the potential to improve the robustness of dc-dc converters.

The PFC-based CSC converter operating in DICM is controlled using a voltage-follower approach. It generates PWM pulses for maintaining the necessary dc-link voltage. A single-voltage sensor is used for the control of a PFC-based CSC converter operating in DICM. The output of voltage controller is compared with a high frequency saw-tooth signal to generate PWM pulses which is given to the switch S_w.

V. SIMULATION OF PROPOSED SYSTEM

A. Implementation of proposed fuzzy based CSC Converter for power quality improvement

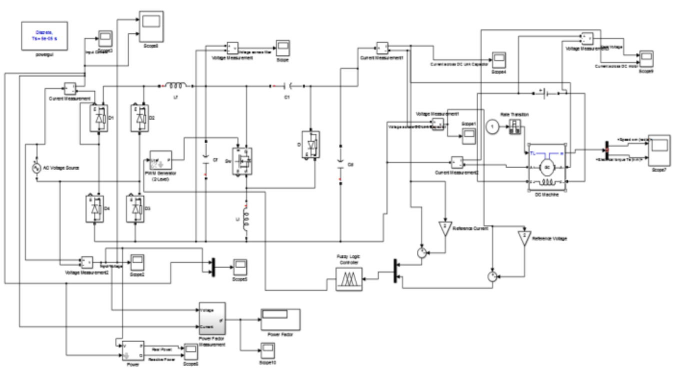

Fig. 4 (a) Simulation of fuzzy based CSC converter

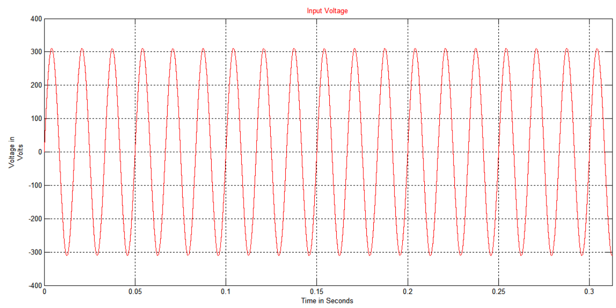

Fig. 4 (b) Measurement of input voltage

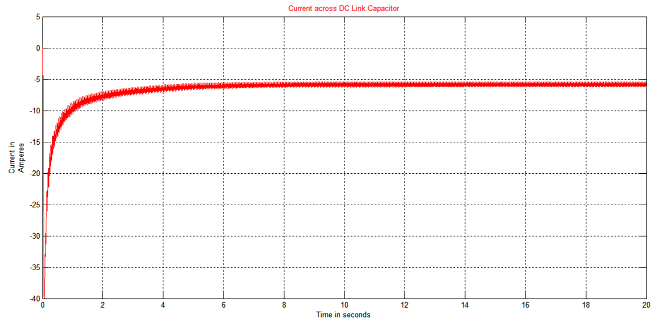

Fig. 4 (c) Current across DC link capacitor

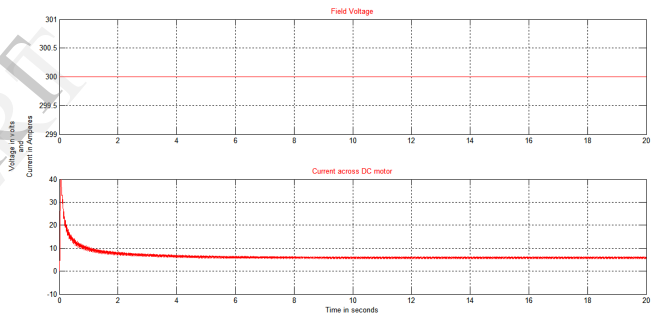

Fig. 4 (d) Field voltage and current across DC motor

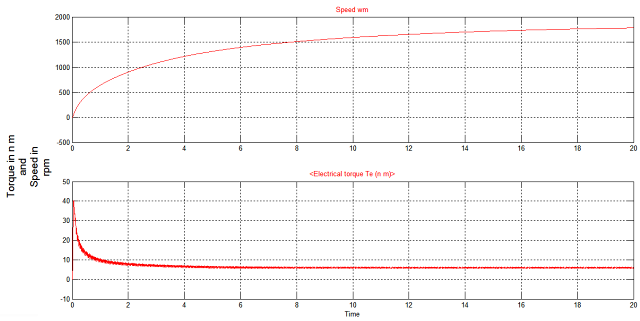

Fig. 4 (e) Electrical torque in N-m and speed in rpm

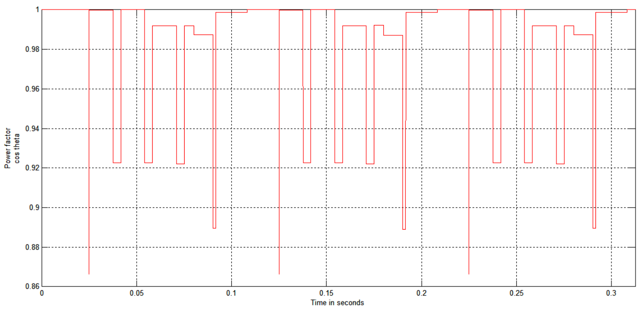

Fig. 4 (f) Measurement of power factor

Figure 4(f) indices that the power factor at the AC mains is close to unity and it is under the acceptable IEEE and IEC 61000-3-2 standards.

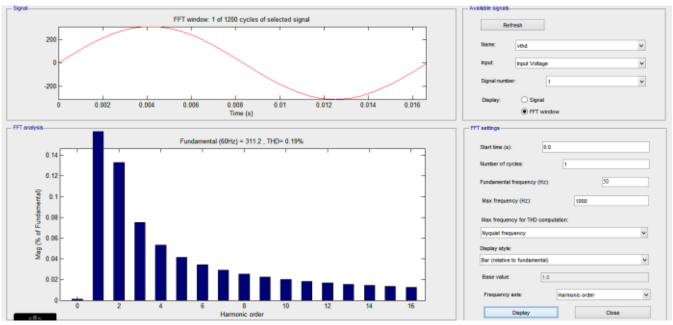

Fig. 4 (g) FFT Analysis of Source voltage for THD

Figure 4(g) indices that the total harmonic distortion of input voltage is reduced compared to conventional system and it is within the IEC 61000-3-2 and IEEE standards. Moreover using the intelligent controller we can obtain better THD and improved PF with reduced switching losses.

VI. Comparative Analysis of the Proposed System with Conventional System

A. *Comparison on Basis of Power quality and Power factor*

The power factor of supply current obtained in PFC converter is better compared to conventional system. Hence, the power quality indices achieved in the proposed system is under the acceptable limits of IEC 61000-3-2.

B. *Comparison on Basis of cost and system complexity*

Table I shows a comparative performance of the proposed configuration with the conventional scheme. The evaluation is based on the control requirement and losses in PFC-converter. Since the proposed configuration requires a single voltage sensor and a simple control for dc-link voltage control, a low cost processor can be used for the development purpose. Increased efficiency and requirement of minimum amount of sensing make the proposed system a good solution for low-power applications.

TABLE I. COMPARISON BETWEEN CONVENTIONAL AND PROPOSED SYSTEM

Attributes	Conventional system (Without PFC)	Conventional system (with PFC)	Proposed system
Control (PFC)	-	Current Multiplier	Voltage Follower
Losses (DBR + PFC)	High	Medium	Low
Efficiency	Medium (Upto 75%)	Low (Upto 80%)	High (> 80%)
Cost	Medium	High	Low

VII. Conclusion

A PFC-based CSC Converter using Fuzzy Logic Controller has been proposed for targeting low-power house hold applications. A variable voltage of dc bus has been used for controlling the speed of load. 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. Using this PFC-converter configuration, the limits various international PQ standards such as IEC 61000-3-2 can be achieved.

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