International Journal for Modern Trends in Science and Technology
Volume: 03, Issue No: 05, May 2017
ISSN: 2455-3778
http://www.ijmtst.com

A Fully Integrated Three-Level Isolated Single - Stage Fuzzy Based PFC Converter

Tarlada Gowri Ganesh[1] | G.Venkata Phanindra[2]

[1]PG Scholar, Avanthi Institute of Engineering & Technology, Vijayanagaram, India
[2] Assistant Professor, Avanthi Institute of Engineering & Technology, Vijayanagaram, India

To Cite this Article
Tarlada Gowri Ganesh, G.Venkata Phanindra, "A Fully Integrated Three-Level Isolated Single - Stage Fuzzy Based PFC Converter", *International Journal for Modern Trends in Science and Technology*, Vol. 03, Issue 05, May 2017, pp. 88-93.

ABSTRACT

An improved single stage three level isolated ac/dc power factor correction (PFC) converter topology is proposed in this paper. For high dc-link voltage low-power applications, achieved through an effective integration of ac/dc and dc/dc stages, where all of the switches are shared between two operations. With the proposed converter and switching scheme, input current shaping and output voltage regulation can be achieved simultaneously without introducing additional switches or switching actions. In addition, the middle two switches are turned on under zero current in discontinuous conduction mode operation, and the upper and bottom switches are turned on under zero voltage. Due to the flexible dc-link voltage structure, high power factor can be achieved at high line voltage. This proposed system is extended with the help of fuzzy controller for better power factor improvement. And the proposed system is tested and verified using Matlab/Simulink.

KEYWORDS: *AC–DC Converter, power factor correction (PFC), class C, high efficiency, high power factor (PF).*

I. INTRODUCTION

In order to operate at high frequency and reduce the size of the circuit, high frequency two-stage active PFC converters have been proposed. In this architecture, a front-end ac/dc PFC converter is operated with a switching frequency in the order of tenths to several hundred kHz for converters with Si semiconductor devices, and from several hundreds of kHz to tenths of MHz with wide-band gap devices, to shape the input current close to sinusoidal waveform in phase with the grid voltage. The second stage dc/dc converter provides the galvanic isolation and output voltage regulation. The controllers of the two stages are completely independent.

The flexibility in control allows optimizing power stages, fast output voltage regulation and operating with high PF and low THD. However, this method comes with the expense of more components and larger size. Moreover, the constant switching losses such as parasitic capacitance losses associated with power switches reduce the efficiency of the converter at light load condition.

A cost-effective approach to reduce the number of switches is to use single-stage ac/dc converters. In single-stage PFC converters, the front-end PFC stage and dc/dc stages are integrated and their operations are performed in a single-stage, basically, by sharing some of the switches and control scheme. An energy storage unit, capacitor or inductor, is located in between two stages, acting as a power buffer and providing sufficient

hold up time. Numerous PFC ac/dc single-stage topologies have been proposed in literature, particularly, operating in discontinuous conduction mode (DCM) for simple yet effective PF control.

Single phase switch mode AC/DC power converters have been increasingly used in the industrial, commercial, residential, aerospace, and military environment due to advantages of high efficiency, smaller size and weight. However, the proliferation of the power converters draw pulsating input current from the utility line, this not only reduce the input power factor of the converters but also injects a significant amount of harmonic current into the utility line. To improve the power quality, various PFC schemes have been proposed. There are harmonic norms such as introduced for improving power quality. By the introduction of harmonic norms now power supply manufacturers have to follow these norms strictly for the remedy of signal interference problem.

The various methods of power factor correction can be classified as:

1) Passive power factor correction techniques
2) Active power factor correction techniques

II. Architecture of Proposed System

The single stage power factor correction topology depending on the output power level and several configurations can be found in literature survey. The output power level lower than 300W, the single stage power factor correction topologies based on the isolated DC-DC fly back, forward and half bridge converter. The output power level higher than 300W, the single stage power factor correction topologies based on the isolated DC-DC full bridge converter. The output power level higher than 1KW, the single stage power factor correction topologies based on the isolated DC-DC three level converter.

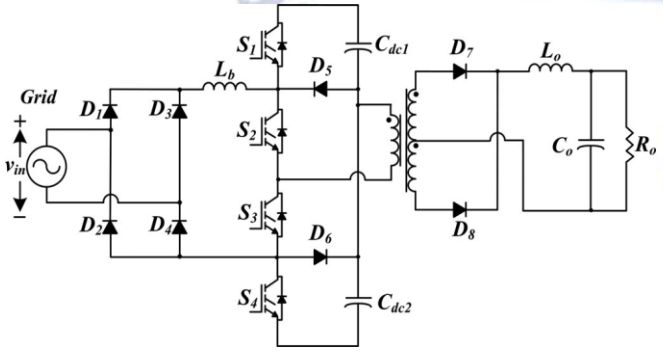


Figure 1. Proposed three-level single-stage fully integrated PFC ac–dc converter

The proposed converter is essentially an integrated version of a boost PFC circuit and three-level isolated dc–dc converter. Basically, a diode bridge and an inductor are added to the three level isolated dc–dc converter topology as shown in Figure 1. Here, the inductor is charged when S2 and S3 are turned on simultaneously. Body diodes of S1 and S4 serve as the boost are switched to apply Vdc/2, −Vdc/2, and zero voltage across the primary side of the transformer. Thus, all of the switches are shared between the two-stages, which makes it fully integrated single-stage converter without any additional auxiliary switches.

The switching scheme of the conventional three-level isolated dc/dc converter is given in Figure 2. In this conventional scheme, the duty ratios of S2 and S3 are fixed close to 50% for simplicity in control and to ensure upper or lower three switches are not turned ON simultaneously as this would cause short-circuit through dc-link capacitors. Overlapping these two signals, as long as short-circuit condition is avoided, has no impact on the operation of the circuit.Similar to that in the conventional scheme, zero voltage is applied across the primary side of the transformer. This modified switching scheme is presented in Fig. 3.3. When a boost inductor and a diode bridge is added to the nodes as in Figure 1, the overlap of gate signals of S2 and S3 enables applying input voltage across the boost inductor.

The switching scheme of the converter is given in Figure 2. The switches S2–S3, and S1–S4 have 180° phase shift with respect to each other. The duty ratios of S2–S3 should be greater than 0.5 such that two signals overlap. Here, the circuit is explained considering that input inductor current is discontinuous and the switching scheme is as follows; S1 is turned on right after S3 is turned OFF, and similarly, S4 is turned on when S2 is turned OFF. A dead-time should be inserted in between the turning ON instant of S1 and turning OFF instant of S3, and likewise between switching of S2 and S4 to avoid short-circuit.

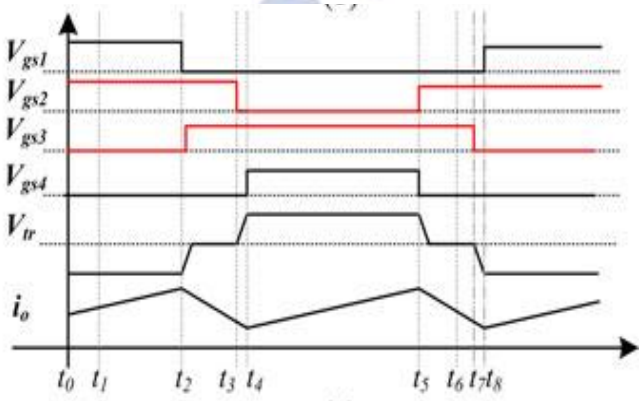


Figure 2: The proposed single-stage PFC converter modified switching scheme

III. Modes of Operation

The modes of operation is as follows

(a) Mode 1: (t_0<t<t_1)

In this mode, both S1 and S2 are on. The upper capacitor, *C*dc1, discharges to the load by applying −*V*dc/2 to the primary side of the transformer. The primary side current increases linearly under constant voltage. *D*8 conducts at the secondary side of the transformer. The voltage across the output inductor is *VL*o = *V*dc/2*N* − *Vo*. In this mode, the boost inductor, *Lb* , does not interfere to the operation of the circuit.

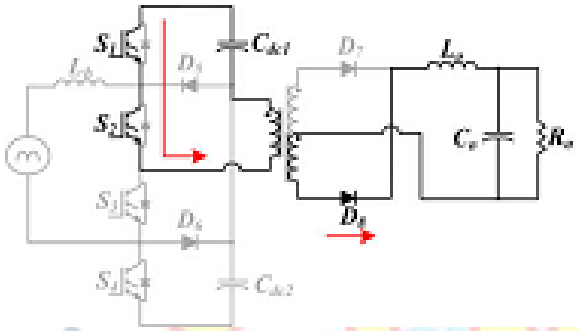
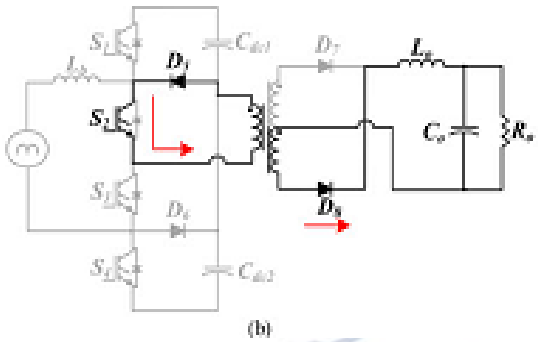


Figure 3 (a) Mode 1(t_0<t<t_1)

(b) Mode 2: (t_1<t<t_2)

At *t* = *t*1, S1 is turned OFF and S2 is kept on. The current in the leakage inductance conducts *D*5 and the primary side current freewheels; hence, zero voltage is applied across the primary side of the transformer. The output inductor voltage is equal to −*Vo*. The output inductor current decreases linearly.



(b)

Figure 3 (b) Mode 2(t_1<t<t_2)

(c) Mode 3: (t_2<t<t_3)

At *t* = *t*2, S3 is turned on, while S2 still remains on. The primary current continuous to freewheel and zero voltage is applied across the primary side; hence, the output inductor current continuous to decrease under output voltage. Meantime, *V*in is applied across *Lb* , and input current increases linearly storing energy in the inductor

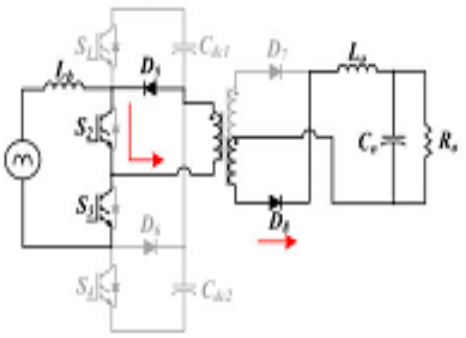


Figure 3 (c) Mode 3(t_2<t<t_3)

(d) Mode 4: (t_3<t<t_5)

In the beginning of this mode, S2 is turned OFF, S4 is turned ON, while S3 is kept on. Within this time interval, the following two operations are completed. The energy stored in the input inductor is transferred to the dc-link capacitors. The inductor current decreases linearly under *V*in − *V*dc. Meantime, *V*dc/2 is applied across the primary side of the transformer. The current in the leakage inductance is transferred to *C*dc2. This causes the output current to commute from *D*8 to *D*7.

At the end of this time interval, the energy in the input inductor is completely transferred to the dc-link capacitors and the commutation of the output diodes is completed. Depending on the dc bus voltage, and input current, one of these operations ends earlier than the other one. In this case, the energy stored in *L*b is transferred to the dc-link at *t* = *t*5. Then, the current commutation from *D*8 to *D*7 is completed at *t* = *t*6.

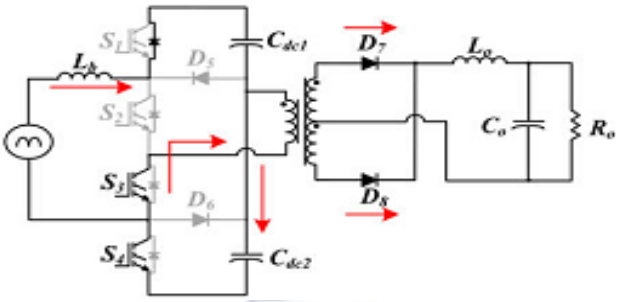


Figure 3(d) Mode 4(t_3<t<t_4)

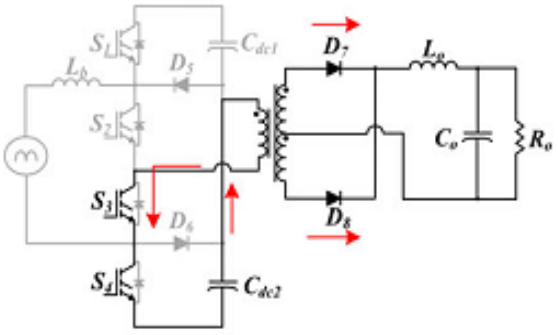


Figure 3 (e) Mode 4(t_4<t<t_5)

(e) Mode 5: (t_5<t<t_6)

*C*dc2 discharges over to the load and *V*dc/2 is applied across the primary side of the transformer. diode of the PFC boost converter. At the same time, S1 to S4 voltage across the output inductor is *V*Lo = *V*dc/2*N* − *Vo*. The input current remains at zero in DCM mode.

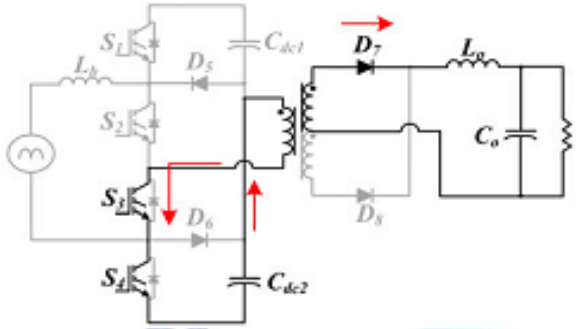


Figure 3 (f) Mode 5(t_5<t<t_6)

(f)Mode 6: (t_6<t<t_7)

At *t* = *t*6, S4 is turned OFF, and only S3 is on. This allows leakage current to freewheel through *D*6, and zero voltage is applied to the primary side. The output current decreases linearly under −*V*o.

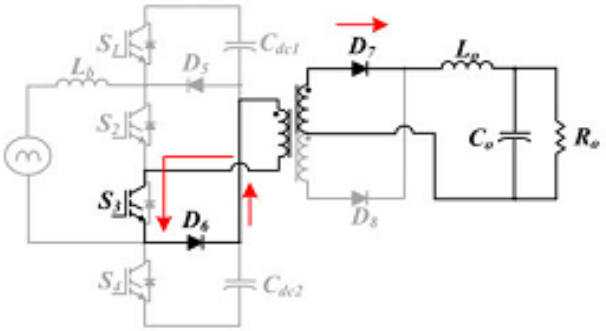


Figure 3 (g) Mode 6(t_6<t<t_7)

(g) Mode 7: (t_7<t<t_8)

At *t* = *t*7, S2 is turned ON. The energy from the input is stored in the inductor. This is similar to Mode 3, except that this time the primary side current is opposite to that in Mode 3 and freewheels through *D*6.

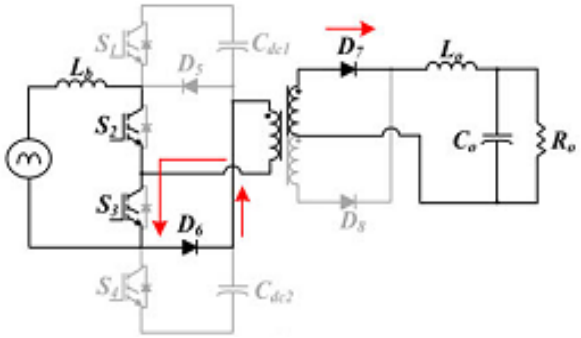


Figure 3(h) Mode 7(t_7<t<t_8)

(h) Mode 8: (t_8<t<t_{10})

At the beginning of this interval, S3 is turned OFF, S1 is turned ON, and S2 remains ON. This mode is similar to Mode 4, where the stored energy in the inductor is transferred to the dc bus capacitors, and −*V*dc/2 is applied to the primary windings. In the meantime, the output inductor current commutates from *D*7 to *D*8.

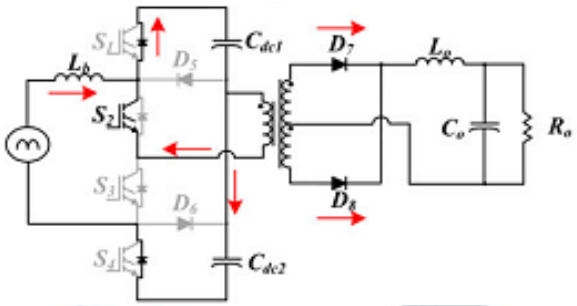


Figure 3 (i) Mode 8(t_8<t<t_9)

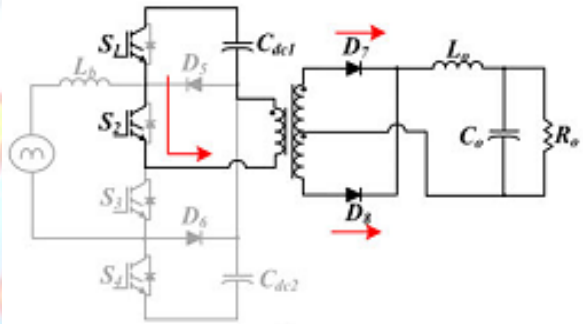


Figure 3 (j) Mode 8(t_9<t<t_{10})

IV. PWM Technique

The number of switching's for upper and lower devices of chosen MU is much more than that of intermediate switches in SHPWM using constant frequency carriers. In order to equalize the number of switching's for all the switches.

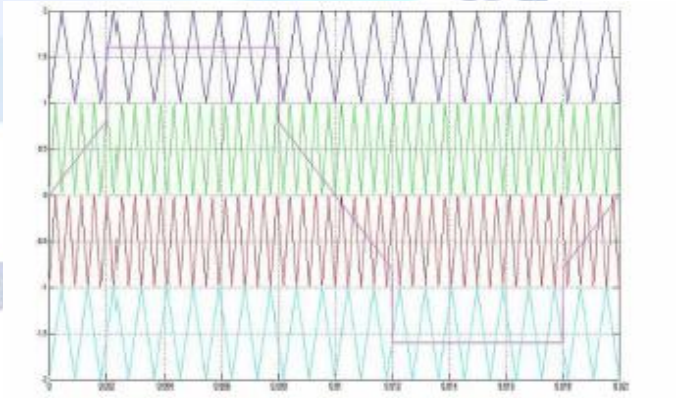


Figure 4: Multicarrier arrangement for VFPWM Technique

Variable frequency PWM strategy is used as illustrated in Figure 8 in which the carrier frequency of the intermediate switches is properly increased to balance the numbers of switching for

all the switches. Figure.4.13 shows the multicarrier arrangement for VFPWM technique (lower and upper switches).

Fuzzy Logic Controller

In the previous section, control strategy based on PI controller is discussed. But in case of PI controller, it has high settling time and has large steady state error. In order to rectify this problem, this paper proposes the application of a fuzzy controller shown in Figure 5. Generally, the FLC is one of the most important software based technique in adaptive methods.

As compared with previous controllers, the FLC has low settling time, low steady state errors. The operation of fuzzy controller can be explained in four steps.

1. Fuzzification
2. Membership function
3. Rule-base formation
4. Defuzzification.

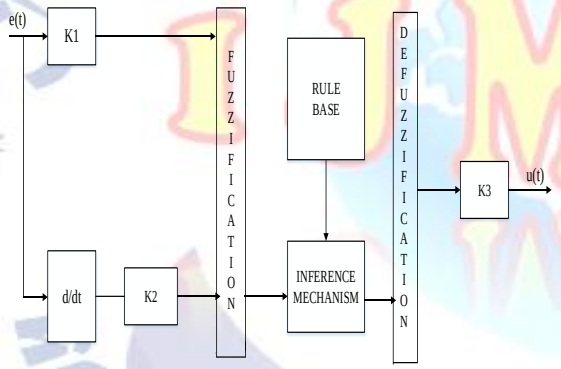


Figure 5: basic structure of fuzzy logic controller

In this paper, the membership function is considered as a type in triangular membership function and method for defuzzification is considered as centroid. The error which is obtained from the comparison of reference and actual values is given to fuzzy inference engine. The input variables such as error and error rate are expressed in terms of fuzzy set with the linguistic terms VN, N, Z, P, and Pin this type of mamdani fuzzy inference system the linguistic terms are expressed using triangular membership functions. In this paper, single input and single output fuzzy inference system is considered. The number of linguistic variables for input and output is assumed as 3.The numbers of rules are formed as 9. The input for the fuzzy system is represented as error of PI controller. The fuzzy rules are obtained with if-then statements. The given fuzzy inference system is a combination of single input and single output. This input is related with the logical operator AND/OR operators. AND logic gives the output as minimum value of the input and OR logic produces the output as maximum value of input

V. Simulation Model of Single Stage PFC Converter

The simulation results of three level isolated single stage PFC converter topology is as shown in Figures 6-9, considering a maximum output power of 500W and 48 V output voltage.

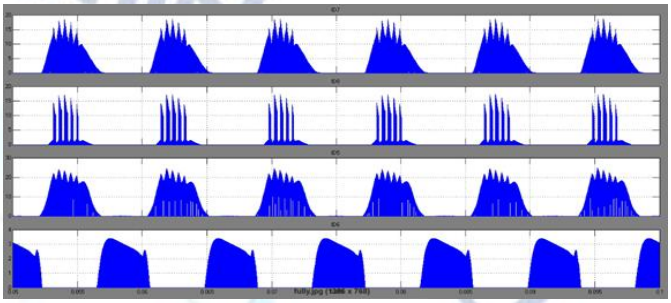


Figure 6: Simulation results of Diode currents ID7, ID8, ID5, ID6

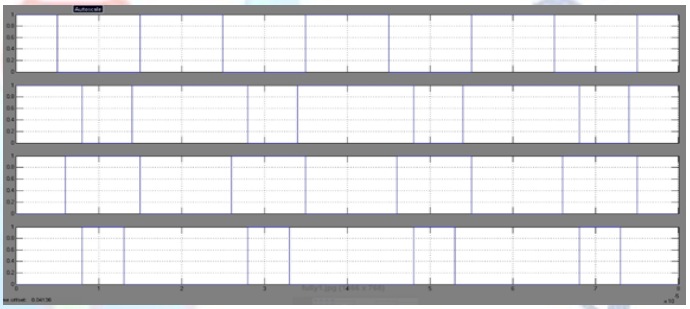


Figure 7: Simulation results of Gate voltages VGS1, VGS2, VGS3, VGS4

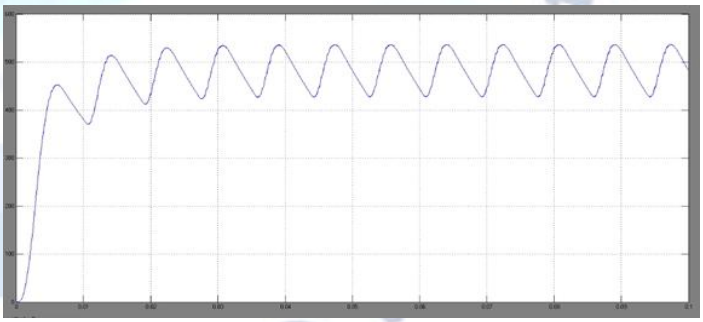


Figure 8: Simulation results of output power PO

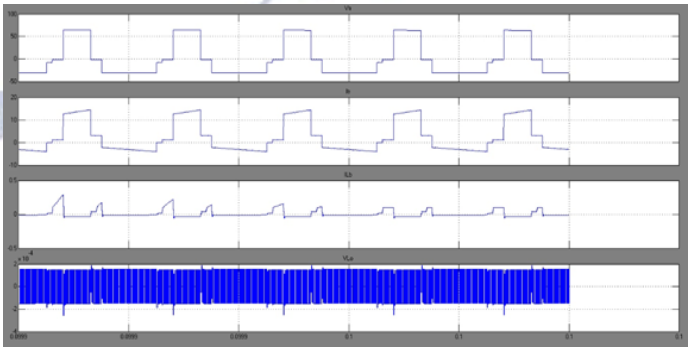


Figure 9: Simulation results of transformer voltage Vtr , current Itr, inductor current ILb, output inductor voltage VLo

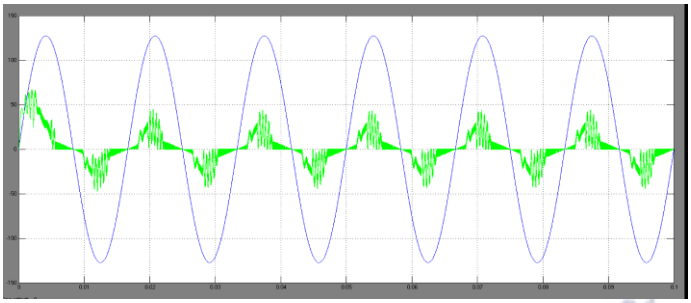


Figure 10: Simulation results of relation between source voltage and current for power factor measurement

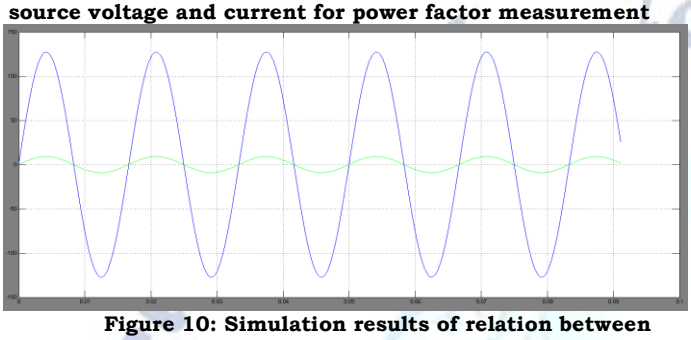


Figure 10: Simulation results of relation between source voltage and current for power factor measurement with fuzzy controller

Table 1: Power Factor Values

S.No	With Conventional PI Controller	With Fuzzy Controller
Power Factor	0.9	0.99

VI. CONCLUSION

A three-level single-stage Fuzzy based PFC ac/dc converter is proposed for low-power applications. The proposed converter exhibits high PF with less number of switches/diodes, operated at constant duty ratio. A PFC inductor and a diode bridge are added to the conventional three-level isolated dc/dc converter, while the switching scheme is modified to be compatible with single-stage operation. The input current ripple frequency is twice of the switching frequency contributing to using smaller PFC inductor. A fuzzy controller is proposed, in favor of shaping the input current and regulating the output voltage, are adopted which simplifies the design and control of the circuit.

REFERENCES

[1] Serkan Dusmez, Xiong Li, Bilal Akin, "A Fully Integrated Three-Level Isolated Single-Stage PFC Converter", IEEE TRANSACTIONS ON POWER ELECTRONICS, VOL. 30, NO. 4, APRIL 2015

[2] H. Athab and D. Lu, "A single-switch ac/dc fly-back converter using a CCM/DCM quasi-active power factor correction front-end, "IEEE Trans. Ind. Electron. vol. 59, no. 3, pp. 1517–1526, Mar. 2012.

[3] L. Huber, Y. Jang, and M. M. Jovanovic, "Performance evaluation of bridgeless PFC boost rectifiers," IEEE Trans. Power Electron., vol. 23, no. 3, pp. 1381–1390, May. 2008.

[4] Y. Jang and M. M. Jovanovic´, "A bridgeless PFC boost rectifier with optimized magnetic utilization," IEEE Trans. Power Electron., vol. 24, no. 1, pp. 85–93, Jan. 2009.

[5] W. Wei, L. Hongpeng, J. Shigong, and X. Dianguo, "A novel bridgeless buck-boost PFC converter," in Proc. IEEE Power Electron. Spec. Conf., 2008, pp. 1304–1308.

[6] W.-Y. Choi, J.-M. Kwon, and B.-H. Kwon, "Bridgeless dual-boost rec- tidier with reduced diode reverse-recovery problems for power-factor correction," IET Power Electron., vol. 1, no. 2, pp. 194–202, Jun 2014.

[7] B. Su and Z. Lu, "An interleaved totem-pole boost bridgeless rectifier with reduced reverse-recovery problems for power factor correction," IEEE Trans. Power Electron., vol. 25, no. 6, pp. 1406–1415, Jun. 2010.

[8] F. Yang, X. Ruan, Y. Yang, and Z. Ye, "Interleaved critical current mode boost PFC converter with coupled inductor," IEEE Trans. Power Electron., vol. 26, no. 9, pp. 2404–2413, Sep. 2011.

[9] B. Akın and H. Bodur, "A new single-phase soft-switching power fac- tor correction converter," IEEE Trans. Power Electron., vol. 26, no. 2, pp. 436–443, Feb. 2011.

[10] C.-M. Wang, C.-H. Lin, and T.-C. Yang, "High-power-factor soft-switched dc power supply system," IEEE Trans. Power Electron., vol. 26, no. 2, pp. 647–654, Feb. 2011.

[11] R. Redl, L. Balogh, and N. O. Sokal, "A new family of single-stage isolated power-factor correctors with fast regulation of the output voltage," in Proc. IEEE Power Electron. Spec. Conf., 1994, pp. 1137–1144.

[12] R. Redl and L. Balogh, "Design considerations for single-stage isolated power-factor-corrected power supplies with fast regulation of the output voltage," in Proc. IEEE Appl. Power Electron. Conf., 1995, pp. 454–458.

[13] C. Qiao and K. M. Smedley, "A topology survey of single-stage power fac- tor corrector with a boost type input-current-shaper," IEEE Trans. Power Electron., vol. 16, no. 3, pp. 360–368, May 2001.

[14] O. Garcia, J. A. Cobos, P. Alou, R. Prieto, and J. Uceda, "A simple single- switch single-stage AC/DC converter with fast output voltage regulation," IEEE Trans. Power Electron., vol. 17, no. 2, pp. 163–161, Mar. 2002.

[15] H. Ribeiro and B. Borges, "High performance voltage fed AC–DC full bridge single-stage PFC with reduced DC Bus capacitor, "IEEE Trans. Power Electron., vol. 29, no. 6, pp. 2680–2692, Jun. 2014

[16] M. Narimani and G. Moschopoulos, "A three-level integrated AC/DC converter, "IEEE Trans. Power Electron., vol. 29, no. 4, pp. 1813–1820,apil 2014.