A Decisive Evaluation of Three-Level AC DC Converter Fed Induction Motor Drive for Residential Applications

G.Changala Rao
M-Tech Student Scholar,
Department of Electrical & Electronics Engineering,
Chirala Engineering College,
Chirala, Prakasam (Dt); Andhra Pradesh, India.

P.Balanagu
Associate Professor
Department of Electrical & Electronics Engineering,
Chirala Engineering College,
Chirala, Prakasam (Dt); Andhra Pradesh, India.

Abstract:

Large electric drives and utility applications require advanced power electronics converter to meet the high power demands. As a result, power converter structure has been introduced as an alternative in high power and medium voltage situations. To improve the performance of the ac–dc converter (i.e., good power factor correction, low total harmonic distortion (THD) and low dc bus voltage), two bulk storage capacitors are adopted. Its excellent line regulation capability makes the converter suitable for universal input application. The operation of the converter is discussed in the paper and its various modes of operation are explained in detail. The converter is made to operate with two independent controllers an input controller that performs power factor correction and regulates the dc bus and an output controller that regulates the output voltage.

They consist of an ac–dc boost pre regulator converter that shapes the input current and an isolated dc–dc full-bridge converter that converts the pre regulator output into the required dc voltage. Research on the topic of higher power ac–dc single-stage full-bridge converters, however, has proved to be more challenging, and thus, there have been much fewer publications. They use passive elements such as inductors and capacitors to filter low frequency input current harmonics and make the input current more sinusoidal. The dynamic analysis of proposed converter fed induction drive is evaluated by using Matlab/Simulink platform and results are conferred.

Index Terms:

AC–DC power conversion, single-stage power factor correction (SSPFC), three-level converters, Induction Drive.

I. INTRODUCTION:

Recently, developments in power electronics and semiconductor technology have lead improvements in power electronic systems. Pulse Width Modulation variable speed drives are increasingly applied in many new industrial applications that require superior performance. Hence, different circuit configurations namely inverters have become popular and considerable interest by researcher are given on them. Variable voltage and frequency supply to A.C drives is invariably obtained from a three-phase voltage source inverter. To overcome the limited semiconductor voltage and current ratings, some kind of series and/or parallel connection will be necessary. Due to their ability to synthesize waveforms with a better harmonic spectrum and attain higher voltages, multi-level inverters are receiving increasing attention in the past few years. THE ac–dc power supplies with transformer isolation are typically implemented with some sort of input power factor correction (PFC) to comply with harmonic standards such as IEC 1000-3-2 [1].

With the rapid rise in the use of electrical equipment in recent years, power converter manufactures are being pressed by regulatory to implement some form of PFC in their products. High power factor and low input current harmonics are more and more becoming mandatory performance criteria for power converters. Although it is possible to satisfy by adding passive filter elements to the traditional passive diode rectifiers/LC filter input combination. The result of this converter is very bulky and heavy due to the size of the low frequency inductors and capacitors. Active power factor correction techniques have been used in AC-DC converter to improve power factor and reduce the harmonics. Active power factor correction can be classified into two stage scheme. Two stages PFC contain two independent power stages in cascade with PFC stage and DC-DC regulator.

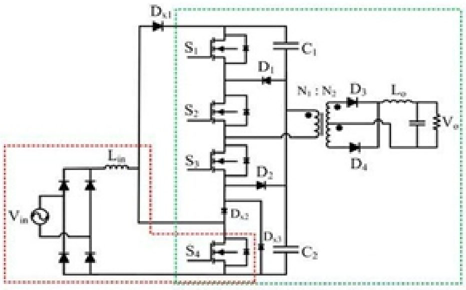

Fig.1. Proposed single-stage three-level converter.

The total efficiency of the two stages is lower because the total power has to be processed twice with two cascade power stage.

Cost of the circuit is increase several schemes have developed to combine stage into one stage [13]. This paper introduces the new converter is interfaced to induction machine drive to check the performance of the drive characteristics, explains its basic operating principles and its modes of operation, and discusses its features and its design.

II. OPERATION OF THE PROPOSED CONVERTER :

The proposed converter, which is shown in Fig. 1, integrates an ac–dc boost PFC converter into a three-level dc–dc converter. The ac–dc boost section consists of an input diode bridge, boost Inductor Lin, boost diode Dx1, and switch S4, which is shared by the multilevel dc–dc section. When S4is off, it means that no more energy can be captured by the boost inductor. In this case, diode Dx2 prevents input current from flowing to the midpoint of capacitors C1 and C2 and diode Dx1 conducts and helps to transfer the energy stored in the boost inductor Lin to the dc bus capacitor. Diode Dx3 bypasses Dx2 and makes a path for circulating current. Although there is only a single converter, it is operated with two independent controllers. One controller is used to perform PFC and regulate the voltage across the primary side dc-bus capacitors by sending appropriate gating signals to S4. The other controller is used to regulate the output voltage by sending appropriate gating signals to S1to S4.It should be noted that the control of the input section is decoupled from the control of the dc–dc section and thus can be designed separately. The gating signal of S1, however, is dependent on that of S4, which is the output of the input controller; how this signal is generated is discussed in detail later in this paper. The gating signals for S2 and S3 are easier to generate as both switches are each ON for half a switching cycle, but are never ON at the same time. Typical converter waveforms are shown in Fig. 2 and equivalent circuit diagrams that show the converter's modes of operation are shown in Fig. 3 with the diode rectifier bridge output replaced by a rectified sinusoidal source. As the input line frequency is much lower than the switching frequency, it is assumed that the supply voltage is constant within a switching cycle. It is also assumed that the input current is discontinuous, although there is no reason why the input current cannot be made to be continuous if this is what is desired. The converter has the following modes of operation:

1) Mode 1 (t0 ≤t≤t1): During this mode, switches S1and S2 are ON and energy from dc-bus capacitorC1 is transferred to the output load. In the output section, a positive voltageof (Vpri/n) VO (where n is the ratio of primary to secondary transformer turns) is impressed across Lo andthe current through it rises.

2) Mode 2 (t1 ≤t≤t2): In this mode, S1 andS2 remain ON andS3 turns ON. The energy from dc bus capacitor C1 is transferred to the output load. At the same time, the diode bridge output voltage Vrec is impressed across input inductor Lin so that the current flowing through this inductor rises.

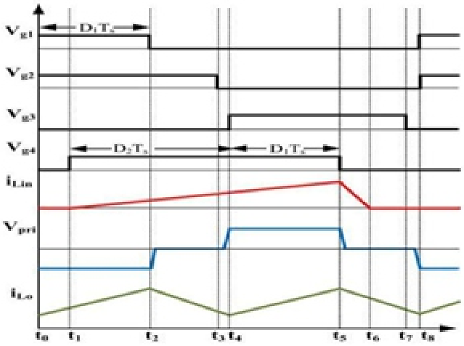

Fig. 2. Typical waveforms describing the modes of operation.

3)Mode3 (t2 ≤t≤t3): In this mode, S1 andS2 remain ON andS3 turns ON. The energy from dc bus capacitor C1is transferred to the output load. At the same time, the diode bridge output voltage Vrec is impressed across input inductor Lin so that the current flowing through this inductor raises voltage Vrec is impressed across input inductor Lin so that the current flowing through this inductor rises.

4)Mode 4 (t3 ≤t≤t4): In this mode, S1 andS2 are OFF and S4 is ON. The current in the primary of the transformer charges capacitorC2 through the body diode of S3 and Dx3.

5)Mode 5 (t4 ≤t≤t5): In this mode, S3 andS4 are ON. Energy flows from capacitorC2flows into the load while the current flowing through input inductor Lin continues to rise.

6)Mode 6 (t5 ≤t≤t6): In this mode, S4 turns off. The current in input inductor flows thorough the diodeDx1 to charge the capacitors C1 andC2. The current in the transformer primary flows thorough the S3 andD2.This mode ends when the inductor current reaches zero. Also during this mode, the load inductor current freewheels in the secondary of the transformer.

7)Mode 7 (t6 ≤t≤t7): In this mode, the load inductor current freewheels in the secondary of the transformer. This mode ends when the switches S3turns off.

8)Mode 8 (t7 ≤t≤t8): In this mode, S3 is OFF and the current in the primary of the transformer charges capacitor C1 through the body diodes of S1 andS2. Finally, converter reenters Mode 1.

The simplified schematic of the power converter and the respective controllers are shown in Fig.4.The decoupling of the input controller and output controller can occur because the Cross over frequencies of the two loops are very different. The Cross over frequency of the input controller, which performs input power factor correction and converts input ac into an intermediate dc-bus voltage (voltage across the two primary side dc-bus capacitors), is much lower than that of the output controller, which converts the intermediate dc-bus voltage into the desired output voltage. Since the two crossover frequencies are far apart, it is therefore possible to consider the design of one controller to be separate from that of the other. Since the two controllers are decoupled, the standard designs for an ac–dc boost converter controller and a dc–dc full-bridge converter controller can be used. Fig. 4 shows a simple diagram of the controller scheme that has two elements of control. One element is to control dc–dc conversion of the dc-bus voltage to the desired output voltage, and this can be done by controlling the gating signals of S1 to S4 through controlling duty cycle of D1. The other element is to control duty cycle of the switch S4 to regulate the dc-bus voltage and to perform input power factor correction. This can be done by controlling D2 and then adding duty cycle of D2 to D1 (where D1 andD2 are defined in Fig. 2); thus S4 performs two tasks; one part (D1) participate to control output voltage and another part (D2) to regulate dc-bus voltage.

III.CONVERTER FEATURES:

The proposed converter has the following features:

A.Reduced cost compared to two-stage converters:

Although the proposed converter may seem expensive, the reality is that it can be cheaper than a conventional two-stage converter. This is because replacing a switch and its associated gate drive circuitry with four diodes reduces cost considerably even though the component count seems to be increased—this is especially true if the diodes are ordered in bulk numbers.

B.Better performance than a single-stage converter:

The proposed single-stage converter can operate with a better input power factor for universal input line applications than a single-controller, single-stage because it does have a dedicated controller for its input section that can perform PFC and regulate the dc-bus voltage. The presence of a second controller also allows the converter to operate with better efficiency and with less output ripple as each section.

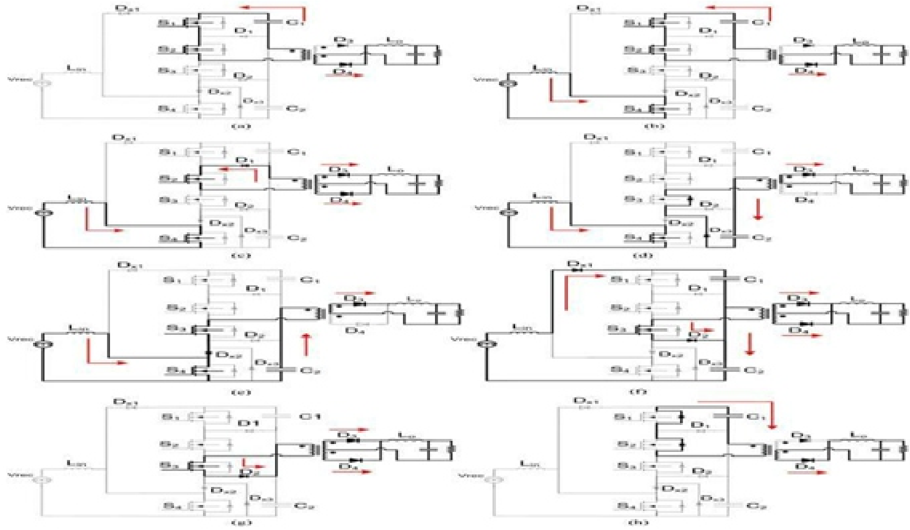

Fig. 3. Equivalent circuits for each operation stage for the converter. (a) Mode 1(t0 <t<t1). (b) Mode 2(t1 <t<t2). (c) Mode 3(t2 <t<t3). (d) Mode 4(t3 <t<t4). (e) Mode 5(t4 <t<t5). (f) Mode 6(t5 <t<t6). (g) Mode 7(t6 <t<t7). (h) Mode 8 (t7 <t<t8)

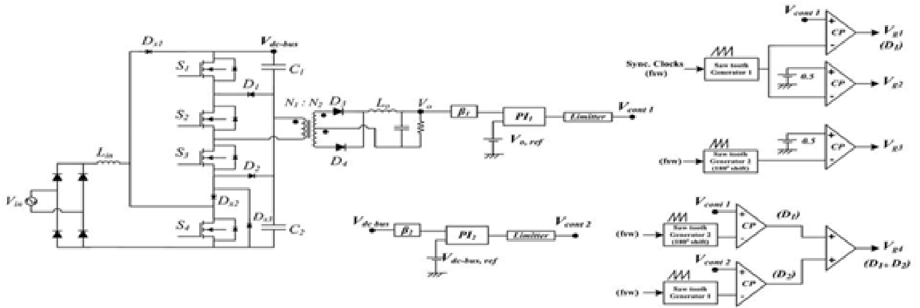

Fig.4 Simplified schematic control of the proposed converter of the converter can be made to operate in an optimal manner.

C. Improved Light-Load Efficiency:

The proposed converter can be designed so that it has a conventional dc-bus voltage of 400 V. Since the converter is a multilevel converter, a 400 V dc bus means that each switch will be exposed to a maximum voltage of 200 V. Having 200 V across a MOSFET device instead of 400 V (as is the case with two-level converters) results in a 75% reduction in turn on losses when the converter is operating under light-load conditions and there is an insufficient amount to current available to discharge the switch output capacitances before the switches are turned on.

D. Increased Design Flexibility:

Since the converter is a multilevel converter, it can be operated with high dc-bus voltage (800 V), standard dc-bus voltage (400 V), or any dc-bus voltage 400 V<Vbus<800 V. There are advantages to operating with high dc-bus voltage or with standard dc bus voltage. The fact there is flexibility in the level that the dc-bus voltage is set means that there is considerable flexibility in the design of the converter. This gives the designer options as to how to optimize the design of the converter for other factors such as efficiency profile and cost (i.e. cost of switches based on voltage rating considerations and availability). It should be noted that this design flexibility makes the design of the three-level converter to be much simpler than that of a single-stage two-level converter or that of a single-controller three-level single stage converter as the dc-bus voltage can be fixed to a desired level that is considered appropriate. It should be noted that although the proposed converter has the aforementioned advantages over the conventional two-stage converter, it will have lower heavy-load efficiency because of increased conduction losses as switch S4 must conduct both the input current and the full-bridge current. As a result, when determining whether to use the proposed converter versus a conventional two-stage converter, the main trade off that needs to be considered is lower cost and improved light-load efficiency versus heavy-load efficiency.

IV. MATLAB/SIMULINK RESULTS:

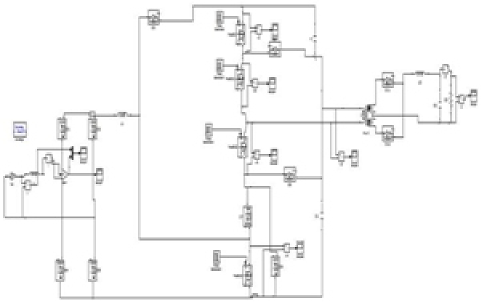

Fig.5:Matlab/Simulink Model of Single-Stage Three-Level Converter using Matlab/Simulink Software Package.

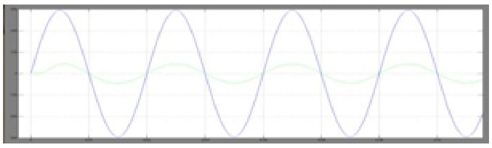

Fig.6: Input Current and Voltage Wave Form

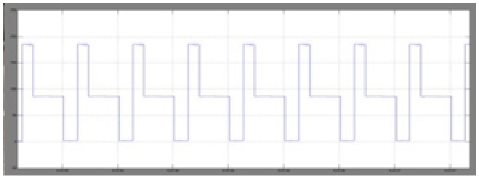

Fig.7: Switch Voltage S1

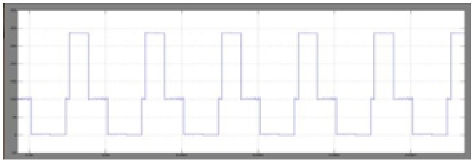

Fig.8: Switch Voltage S2

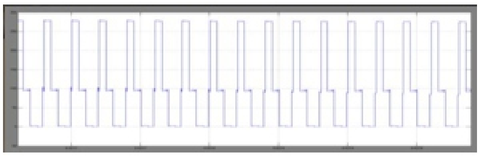

Fig.9: Switch Voltage Switch S3

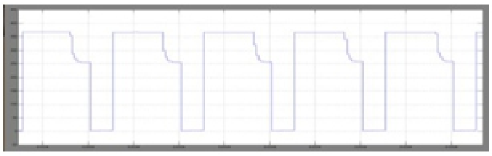

Fig.10: Switch Voltage S4

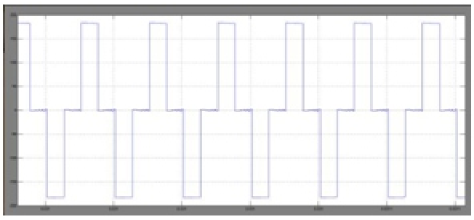

Fig.11: Three Level Output Voltage

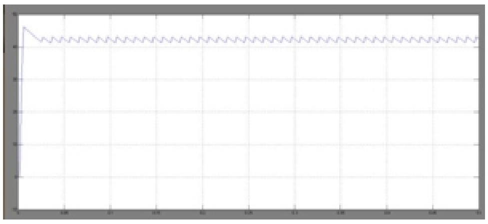

Fig.12: Output Voltage.

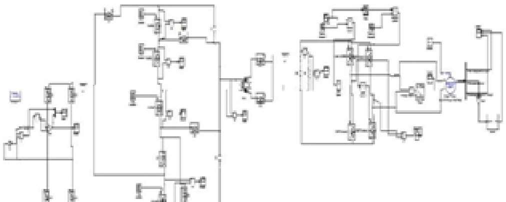

Fig.13:Matlab/Simulink Model of Single-Stage Three-Level Converter with Induction Motor Drive using Matlab/Simulink Platform.

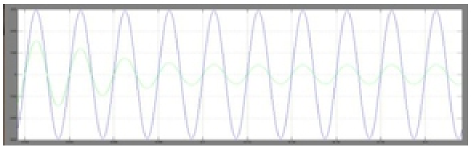

Fig.14: Input Current and Voltage Wave Form for Induction Motor

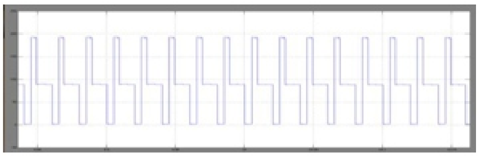

Fig.15: Switch Voltage S1

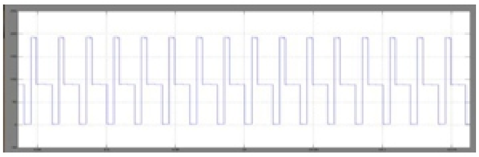

Fig.16: Switch Voltage S2

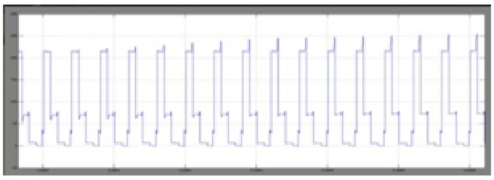

Fig.17: Switch Voltage S3

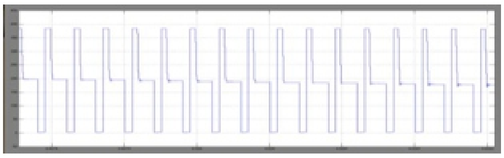

Fig.18: Switch Voltage S4

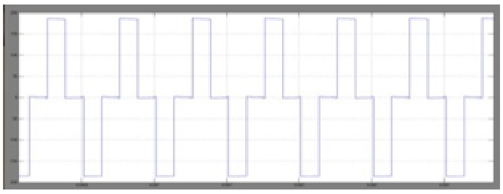

Fig.19: Three Level Output Voltage

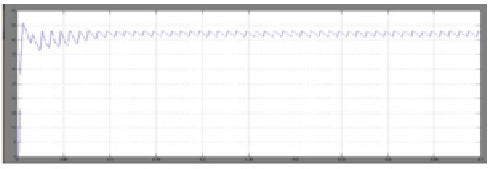

Fig.20: Output voltage

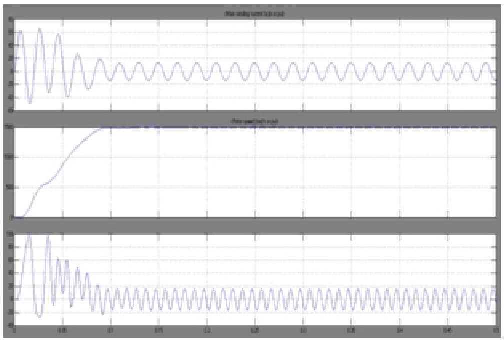

Fig.21 Stator Current, Speed, Electromagnetic Torque

Fig.21 Stator Current, Speed, Electromagnetic Torque of Single-Stage Three-Level Converter with Induction Motor Drive.

V.CONCLUSION:

In this paper, a new converter topology has been proposed which has superior features over conventional topologies in terms of the required power switches and isolated dc supplies, control requirements, cost, and reliability. This will add up to the efficiency of the converter as well as reducing the size and cost of the final prototype. A new multilevel single-stage ac–dc converter is proposed in the paper. This converter is operated with two controller, one controller that performs input PFC and a second controller that regulates the output voltage. The outstanding feature of this converter is that it combines the performance of two-stage converters with the reduction of cost of single-stage converters. The paper introduces the proposed converter, explains its basic operating principles and modes of operation, and discusses its design with respect to different dc-bus voltages. The proposed converter is updated by using drive control strategy with the help of induction machine drive and updates the characteristics of the drive.

REFERENCES:

[1]J.-Y. Lee, ―Single-stage AC/DC converter with input-current dead-zone control for wide input voltage ranges,‖IEEE Trans. Ind. Electron., vol. 54, no. 2, pp. 724–732, Apr. 2007.

[2]D. D.-C. Lu, H. H.-C. Iu, and V. Pjevalica, ―A single-stage AC/DC converter with high power factor, regulated bus voltage, and output voltage,‖ IEEE Trans. Power Electron., vol. 23, no. 1, pp. 218–228, Jan. 2008.

[3]H. Ma, Y. Ji, and Y. Xu, ―Design and analysis of single-stage power factor correction converter with a feedback winding,‖IEEE Trans. Power Electron., vol. 25, no. 6, pp. 1460–1470, Jun. 2010.

[4]H. S. Athab and D. D.-C. Lu, ―A high-efficiency ac/dc converter with quasi-active power factor correction,‖ IEEE Trans. Power
Electron., vol. 25, no. 5, p. 1103-1109, May 2010.

[5]J. M. Kwon, W. Y. Choi, and B. H. Kwon, ―Single-stage quasi-resonant fly back converter for a cost-effective PDP sustain power module,‖IEEE Trans. Ind. Electron., vol. 58, no. 6, pp. 2372–2377, Jun. 2011.

[6]H. J. Chiu, Y. K. Lo, H. C. Lee, S. J. Cheng, Y. C. Yan, C. Y. Lin, T. H. Wang, and S. C. Mou, ―A single-stage soft-switching fly back converter for power-factor-correction applications,‖IEEE Trans. Ind. Electron., vol. 57, no. 6, pp. 2187–2190, Jun. 2011.

[7]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.

[8]N. Golbon and G. Moschopoulos, ―A low-power ac–dc single-stage converter with reduced dc bus voltage variation,‖IEEE Trans. Power
Electron., vol. 27, no. 8, pp. 3714–3724, Jan. 2012.

[9]P. K. Jain, J. R. Espinoza, and N. Ismail, ―A single-stage zero-voltage zero-current-switched full-bridge DC power supply with extended load power range,‖IEEE Trans. Ind. Electron., vol. 46, no. 2, pp. 261–270, Apr. 1999.

[10]G. Moschopoulos, ―A simple AC–DC PWM full-bridge converter with integrated power-factor correction,‖ IEEE Trans. Ind. Electron., vol. 50, no. 6, pp. 1290–1297, Dec. 2003.

[11]G. Moschopoulos, Q. Mei, H. Pinheiro, and P. Jain, ―PWM full-bridge converter with natural input power factor correction,‖IEEE Trans. Aerosp. Electron. Syst., vol. 39, no. 2, pp. 660–674, Apr. 2003.

[12]P. Das, S. Li, and G. Moschopoulos, ―An improved AC–DC single-stage full-bridge converter with reduced DC bus voltage,‖ IEEE Trans. Ind. Electron., vol. 56, no. 12, pp. 4882–4893, Dec. 2009.

[13]M. S. Agamy and P. K. Jain, ―A three-level resonant single-stage power factor correction converter: analysis, design, and implementation industrial electronics,‖ IEEE Trans. Ind. Electron., vol. 56, no. 6, pp. 2095–2107, Jun. 2009.

[14]H. L. Cheng, Y. C. Hsieh, and C. S. Lin, ―A novel single-stage high power factor ac/dc converter featuring high circuit efficiency,‖ IEEE Trans.Ind. Electron., vol. 58, no. 2, pp. 524–532, Feb. 2011.

[15]M. S. Agamy and P. K. Jain, ―A variable frequency phase-shift modulated three-level resonant single-stage power factor correction converter,‖ IEEE Trans. Power Electron., vol. 23, no. 5, pp. 2290–2300, Sep. 2009.