



Input side PFC and Output side Voltage variation with Closed loop AC-DC Converter

Md Hakeem Baba

M-tech Student Scholar Department of Electrical & Electronics Engineering, VIF College of Engineering and Technology, Himiyatnagar, RangaReddy, TS, India

D. Subhani

M.Tech Assistant Professor Department of Electrical & Electronics Engineering, VIF College of Engineering and Technology, Himiyatnagar, RangaReddy, TS, India

Abstract-

In this paper closed loop control of a three-level integrated ac-dc converter is proposed. The proposed converter integrates the operation of the boost power factor correction and the three-level ac-dc converter. By the implementation of PI controller with PWM technique in closed loop, the switching sequence is under controlled condition and the output voltage of the proposed converter effectively increases. To improve the performance of the ac-dc converter, two bulk storage capacitors are adopted. Its excellent line regulation capability makes the converter suitable for universal input application. 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. They use passive elements such as inductors and capacitors to filter low frequency input current harmonics and make the input current more sinusoidal. Two stage converters, however, require two separate switch-mode converters (each with its own controller), and thus, can be expensive. Moreover, they have poor efficiency when operating under light-load conditions as there are two converter stages that are operating each with its own set of fixed losses while a small amount of power is actually transferred to the load. The simulations results are conferred using Matlab/Simulink platform.

Index Terms— AC-DC power conversion; single-stage power factor correction (SSPFC); three-level converters.

I. INTRODUCTION

Power-electronic inverters are becoming popular for various industrial drives applications. In recent years also high-power and medium-voltage drive applications have been installed. 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.

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. 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.

The open loop control of a three level integrated ac-dc has very less output voltage. To regulate the excessive dc bus voltages, minimize the large output ripples, distorted input currents and for better output voltage there is a need for a converter, which overcomes all these drawbacks.

In this paper, a closed loop control of a single stage three level integrated ac-dc converter that does not have the drawbacks of previously proposed single-stage and two-stage converters is proposed.

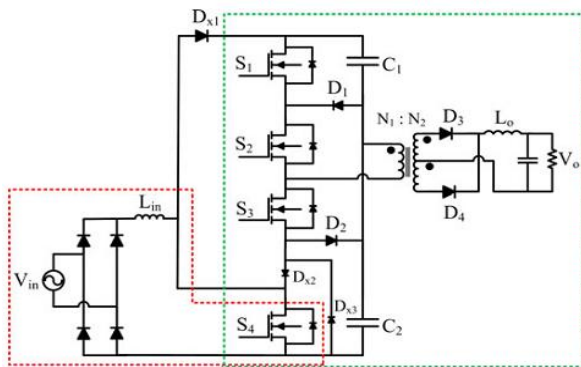


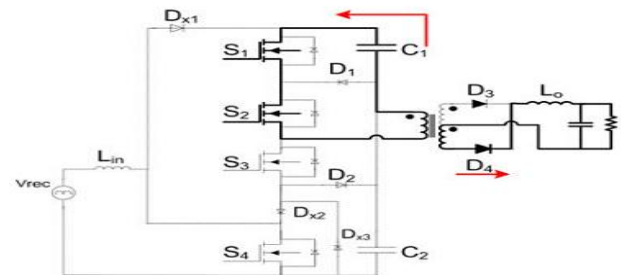
Fig.1.Single-stage three-level AC-DC converter in open loop condition

II. OPERATION OF THE PROPOSED CONVERTER

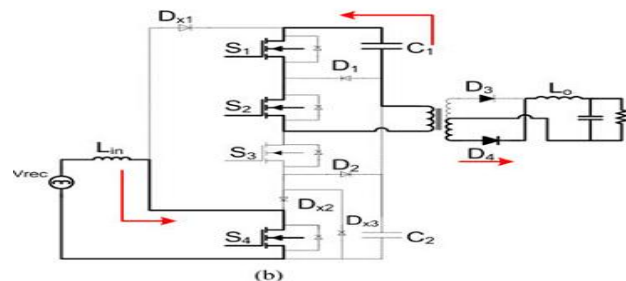
The operation of proposed converter in open loop condition, which is shown in Fig. 1, integrates an ac-dc boost PFC converter into a three-level dc-dc converter. The ac-dc boost section consists of an input diode bridge, boost Inductor L_{in} , boost diode D_{x1} , and switch S_4 , which is shared by the multilevel dc-dc section. When S_4 is off, it means that no more energy can be captured by the boost inductor. In this case, diode D_{x2} prevents input current from flowing to the midpoint of capacitors C_1 and C_2 and diode D_{x1} conducts and helps to transfer the energy stored in the boost inductor L_{in} to the dc bus capacitor. Diode D_{x3} bypasses D_{x2} 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 S_4 . The other controller is used to regulate the output voltage by sending appropriate gating signals to S_1 to S_4 . 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 S_1 , however, is dependent on that of S_4 , 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 S_2 and S_3 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* ($t_0 \leq t \leq t_1$): During this mode, switches S_1 and S_2 are ON and energy from dc-bus capacitor C_1 is transferred to the output load. In the output section, a positive voltage of $(V_{pri}/n) V_O$ (where n is the ratio of primary to secondary transformer turns) is impressed across L_o and the current through it rises.



2) *Mode 2* ($t_1 \leq t \leq t_2$): In this mode, S_1 and S_2 remain ON and S_3 turns ON. The energy from dc bus capacitor C_1 is transferred to the output load. At the same time, the diode bridge output voltage V_{rec} is impressed across input inductor L_{in} so that the current flowing through this inductor rises.



3) *Mode 3* ($t_2 \leq t \leq t_3$): In this mode, S_1 and S_2 remain ON and S_3 turns ON. The energy from dc bus capacitor C_1 is transferred to the output load. At the same time, the diode bridge output

voltage V_{rec} is impressed across input inductor L_{in} so that the current flowing through this inductor raises voltage V_{rec} is impressed across input inductor L_{in} so that the current flowing through this inductor rises.

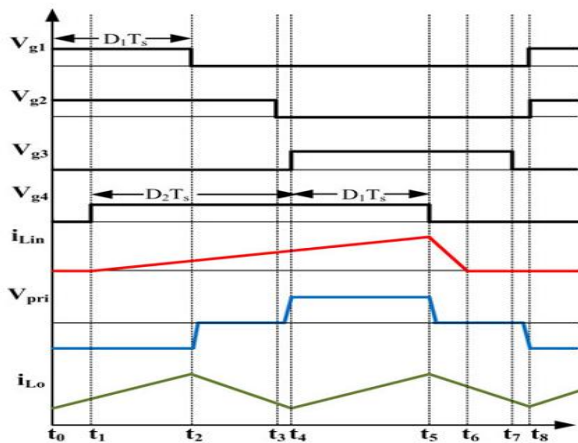
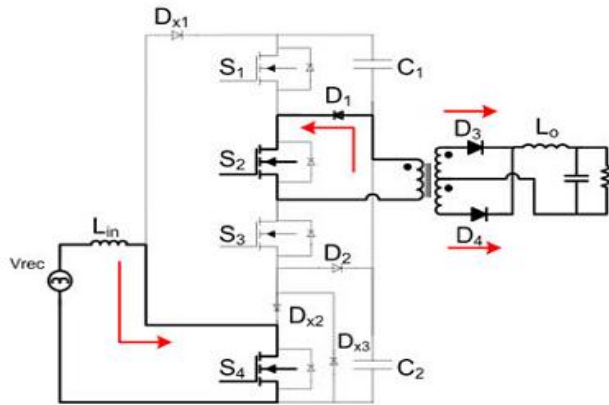
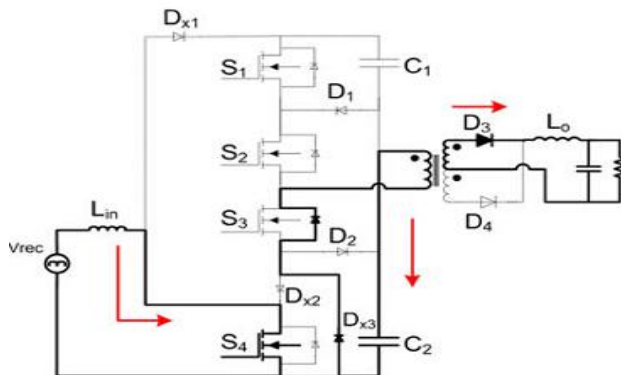
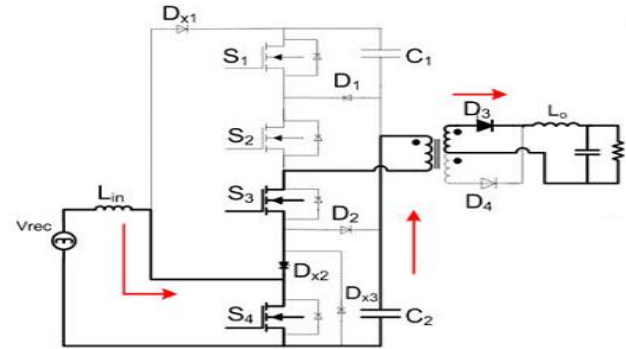


Fig. 2. Typical waveforms describing the modes of operation.

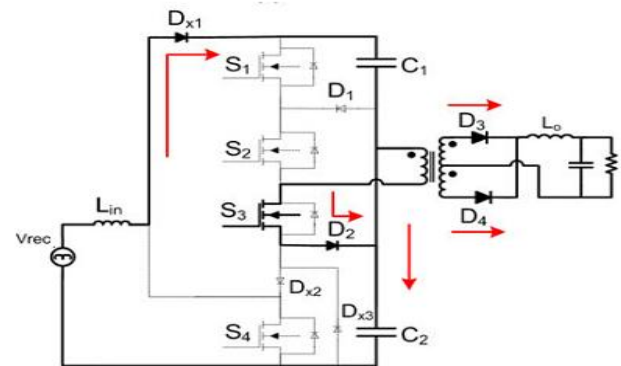
4) *Mode 4* ($t_3 \leq t \leq t_4$): In this mode, S_1 and S_2 are OFF and S_4 is ON. The current in the primary of the transformer charges capacitor C_2 through the body diode of S_3 and D_{x3} .



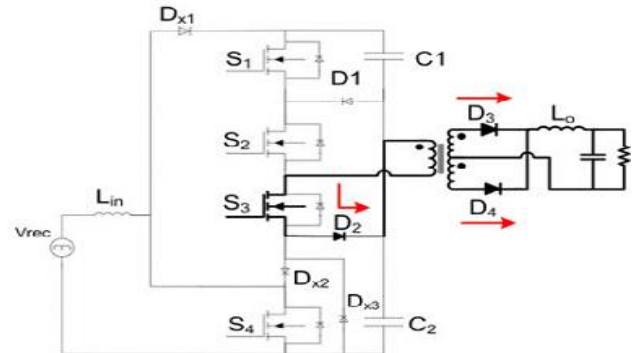
5) *Mode 5* ($t_4 \leq t \leq t_5$): In this mode, S_3 and S_4 are ON. Energy flows from capacitor C_2 flows into the load while the current flowing through input inductor L_{in} continues to rise.



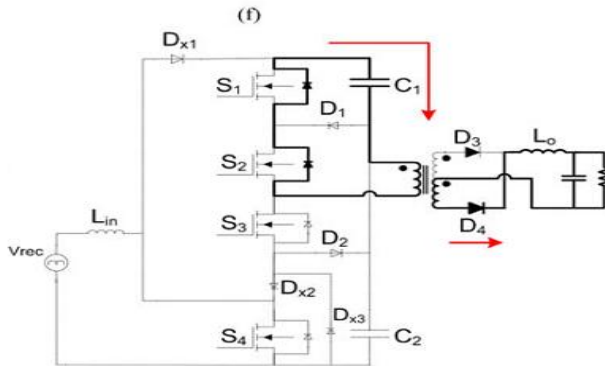
6) *Mode 6* ($t_5 \leq t \leq t_6$): In this mode, S_4 turns off. The current in input inductor flows through the diode D_{x1} to charge the capacitors C_1 and C_2 . The current in the transformer primary flows through the S_3 and D_2 . This mode ends when the inductor current reaches zero. Also during this mode, the load inductor current freewheels in the secondary of the transformer.



7) *Mode 7* ($t_6 \leq t \leq t_7$): In this mode, the load inductor current freewheels in the secondary of the transformer. This mode ends when the switches S_3 turns off.



8) *Mode 8* ($t_7 \leq t \leq t_8$): In this mode, S_3 is OFF and the current in the primary of the transformer charges capacitor C_1 through the body diodes of S_1 and S_2 . Finally, converter reenters Mode 1.



III. CONTROL STRATEGY

This section mainly focused on the control technique for the Single stage three level controllers. Closed loop PI controller with PWM technique gives the better performance as compared with the conventional converter. The block diagram of the proposed control technique is shown in Fig 3.

PI controller receives output voltage as input signal. Based on the input signal the PI controller generates a reference dc voltage signal which is an input signal to PWM generator. The values of PI controller gains (i.e Integral gain and proportional gain) are tuned in order to attain better output voltage. The PWM generator compares the dc reference signal with the saw tooth carrier signal and generates the pulses.

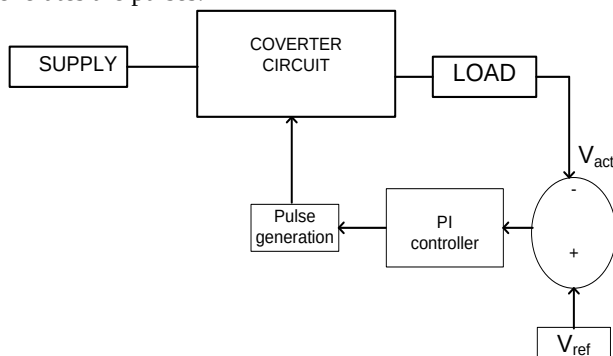


Fig.3. Block diagram of proposed system

IV. 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.

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 $400\text{ V} < V_{\text{bus}} < 800\text{ V}$. 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.

V. MATLAB/SIMULINK RESULTS

Case i: Single-Stage Three-Level Converter Under open loop condition.

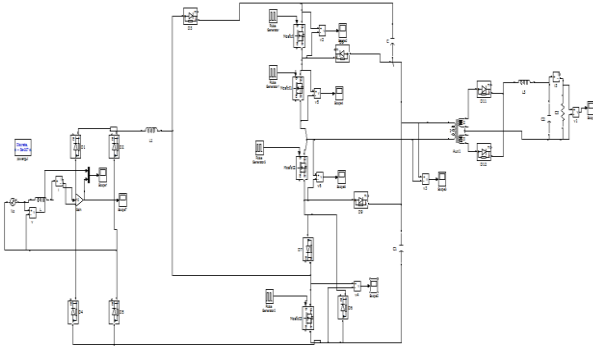


Fig.4:Matlab/Simulink circuit of Single-Stage Three-Level Converter in open loop condition.

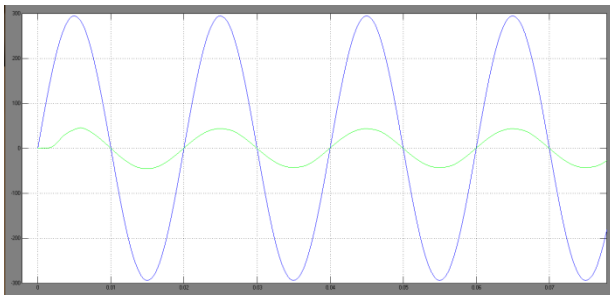


Fig.5: Input Current and Voltage Wave Forms

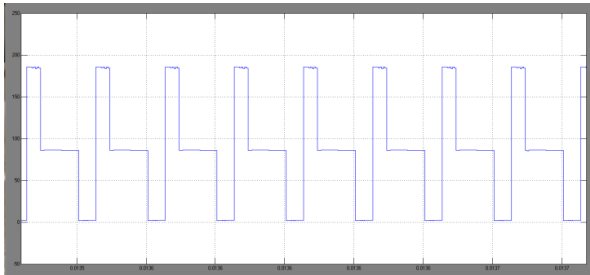


Fig.6: Voltage across Switch S1

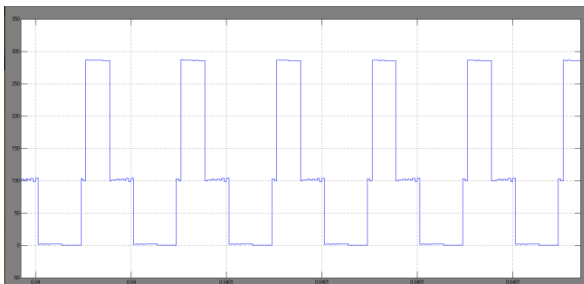


Fig.7: Voltage across Switch S2

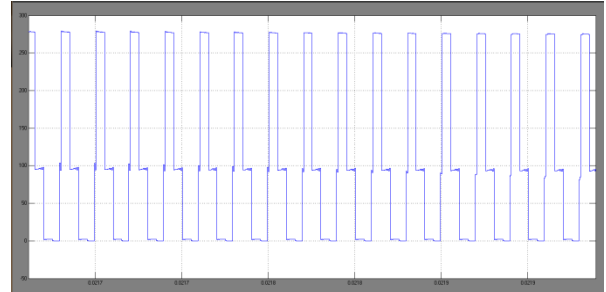


Fig.8: Voltage across Switch S3

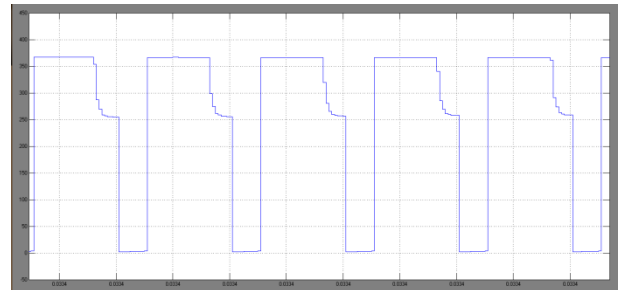


Fig.9: Voltage across Switch S4

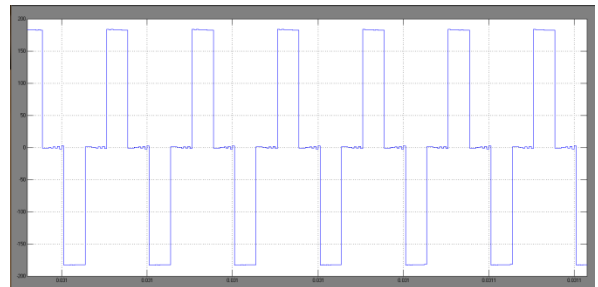


Fig.10: Three Level Output Voltage at primary side of transformer

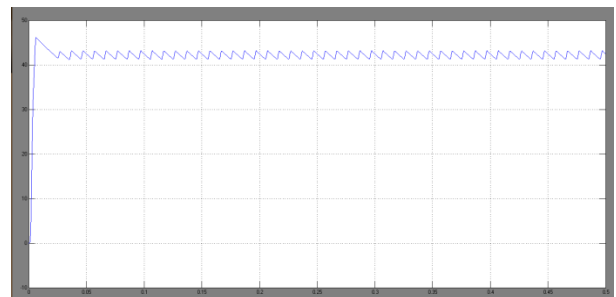


Fig.11: Output Voltage

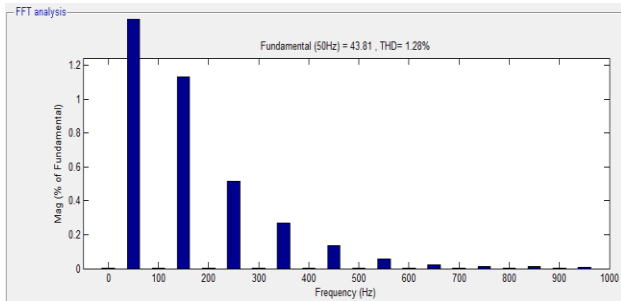


Fig.12. FFT window for input current

Case ii: Single-Stage Three-Level Converter Under closed loop condition

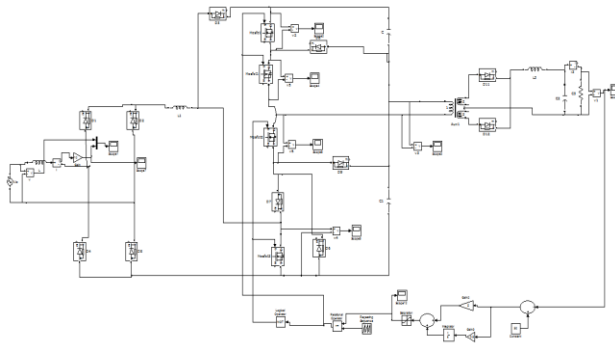


Fig.13:Matlab/Simulink circuit of Single-Stage Three-Level Converter in closed loop condition.

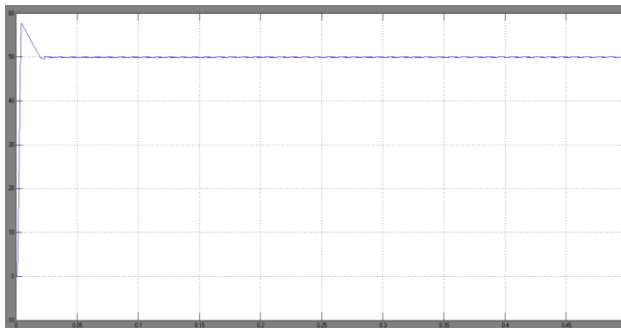


Fig.14: Output Voltage

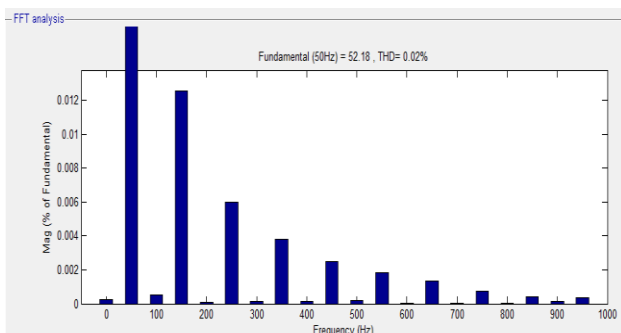


Fig.15. FFT window for input current

VI.CONCLUSION

A closed loop control of a three level integrated ac-dc converter is proposed in the paper. This converter is operated with two controllers, 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. By using PI controller with PWM technique in closed loop, the switching sequence is under controlled condition. Hence the proposed converter output dc voltage is effectively increased. Efficiency of the proposed converter is also comparatively more. For high dc voltage requirements this proposed converter is efficient.

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.

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.