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Fuzzy Logic Control Based Single Stage Integrated Three Level Converter

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Abstract**—** An improved three-level integrated ac–dc converter is presented. This converter improving or boosting power factor correction. And also this converter topology is advanced than previous ac-dc converters mainly the converter is operating with two independent controllers. An input controller is used to power factor correction and it regulates the dc bus, and the output controller is used to control the output voltage of this converter. The input controller prevents the dc-bus voltage from becoming excessive. The outstanding feature of this converter is that it combines the performance of two stage converters with single converter and reduce the cost of single-stage converters. PI and fuzzy logic is used to control the integrated ac-dc converter.

Keywords- *AC–DCpower conversion, single-stage power factor.*

1.INTRODUCTION

Advancement in the research of Power electronic converter is still increasing with the rapid demands in the industry. In search of better efficiency, cost, design flexibility, low harmonics in converters, many converters had been proposed so far. Besides multilevel converters plays a major role in increasing demands. Mostly the AC-DC converters are implemented with PFC to comply with harmonic standards like IEC 1000-3-2.Based on this; PFC methods are of two types namely passive and active methods. Passive methods are simple and inexpensive which uses L&C components to filter low frequency input current harmonics & shapes input current to improve power factor. But this makes the converter huge and bulky in size which is less preferred. Due to this active PFC are used nowadays.. Active PFC methods can be implemented either two stage or single stage approach. Two stage converters uses two controllers i.e. one controller for PFC and another controller for output regulation. This method gives poor efficiency in light loads, more losses &expensive too. But it is cost effective for higher power applications. In single stage converters it uses single controller for both PFC and regulation of output voltage[5]. It is used for fast regulation of output voltage which works on steady state[7]. On the analysis of previously proposed converters like voltage fed, current fed and resonant converters, some of their drawbacks are:

1) In current fed converters boost inductors are used at the input of full bridge converters. This gives close to unity power factor but it may lead to high voltage overshoots across the dc bus voltage due to lack of energy store capacitors. Besides it also results in large low frequency 120 Hz ripple output voltage[10] .

2) The resonant converters are good as overall but controlled by varying switching frequency . This makes difficult to design especially their magnetic components as it must operate with wide switching frequency.

3) In voltage fed single stage converters ,they have large energy storage capacitors connected across the primary of dc bus and it prevents voltage overshoots .It also prevents the 120 Hz component from output voltage. By doing so, it eliminates the problem faced by current fed and resonant converters. The converters are made to operate with an output inductor current to prevent the dc-bus voltage from becoming excessive. Still voltage fed converters may suffer from problems of excessive dc bus voltage under high input &low output load due to single controller. Doing so results in the need for components that can handle high peak currents and additional output filtering to remove ripple.

There is need of converter which solves previous problems like excessive dc bus voltage due to lack of dedicated controller[9], large output ripple, distorted input currents, design flexibility and in terms of cost factor. Considering all this a three level integrated converter has been proposed which uses the multilevel concept . With multilevel topologies, the dc bus voltage can be allowed to reach higher levels that are possible with a two-level topology as the converter components are exposed to half the dc bus voltage and, thus, have half the voltage stress. Freeing up the allowable limit of dc bus voltage allows the aforementioned limitations on output and input currents to be eased so that the converter can be made to operate with an output current that has less ripple and an input current that is less distorted than that of a two level converter.

2.SINGLE STAGE THREE LEVEL AC-DC CONVERTER

t An improved three-level integrated ac–dc converter is presented. It integrates an ac–dc boost PFC conver-ter into a three-level ac–dc converter. Here the operation of this converter is in three levels, in first level we are constructing a diode bridge with boost inductor Lin , boost diode Dx 1,.In second level we are using four switches along with two capacitors, named as C1 and C2 is used .In third level we are using center tapped transformer With half wave diode bridge and inductor Lo is used for dc generation.

The converter, which is shown in Fig.1, integratesan ac–dc boost PFC converter into a three-level dc–dc converter. In first level we are converting input ac into dc by using the full bridge diode bridge operation in and second level we are converting this dc into ac, In this level we are using Mosfets to convert dc into ac.Because Mosfets are having high switching frequency. When S4 is off, it means that no more energy can be captured by the boost inductor. In this case, diode $D_{x\,2}$ prevents input current from flowing to the midpoint of capacitors C1 and C2 .In this case we are using high switching frequency for Mosfets i.e 50Khz.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 dcbus capacitors by sending appropriate gating signals to S4. The other controller is used to regulate the output voltage by sending appropriate gating signals to S1 to S4.It should be noted that the control of the input section is decoupled from the control of the ac–dc section and thus can be designed separately .

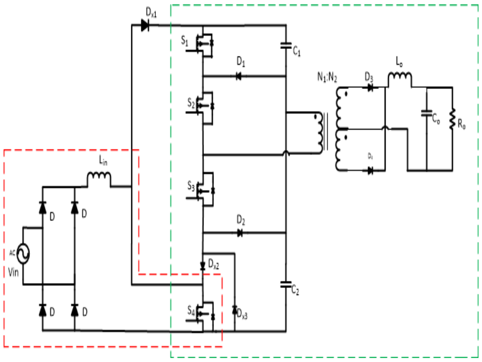

Figure 1 Single stage three level converter

Typical converter waveforms are shown in Fig.2, and equivalent circuit diagrams that show the converter’s modes of operation are shown . 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.

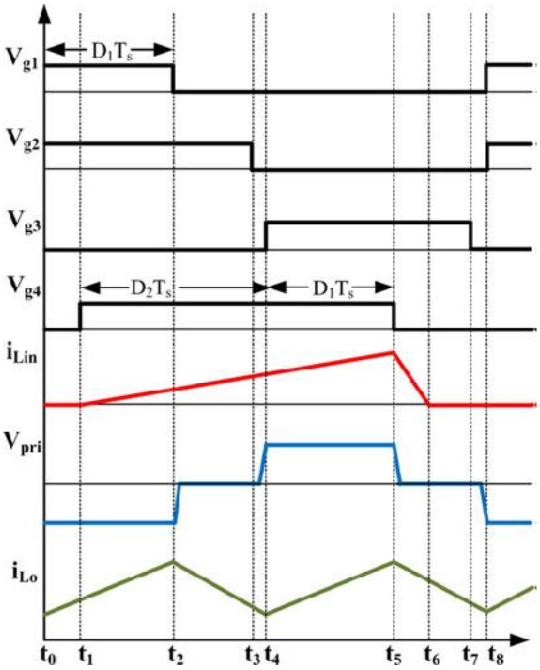

Figure 2 Waveform describing the modes of operation

The converter has the following modes of operation

1) *Mode 1* ($t0 \leq t \leq t1$)*:* 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*) – *Vo* (where *n* is the ratio of primary to secondary transformer turns) is impressed across *Lo* and the current through it rises.
2) *Mode 2* ($t1 \leq t \leq t2$)*:* 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* ($t2 \leq t \leq t3$)*:* 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 voltage *V*rec is impressed across input inductor *L*in so that the current flowing through this inductor rises.

4) *Mode 4* ($t3 \le t \le t4$)*:* In this mode, $S1$ and $S2$ are OFF and $S4$ is ON. The current in the primary of the transformer charges capacitor $C2$ through the body diode of $S3$ and $Dx3$
5) *Mode 5* ($t4 \le t \le t5$)*:* In this mode, $S3$ and $S4$ are ON .Energy flows from capacitor $C2$ flows into the load while the current flowing through input inductor Lin continues to rise.
6) *Mode 6* ($t5 \le t \le t6$)*:* In this mode, $S4$ turns off. The current in input inductor flows thorough the diode $Dx1$ to charge the capacitors $C1$ and $C2$. The current in the transformer primary flows thorough the $S3$ and $D2$. Thismode ends when the inductor current reaches zero. Also during this mode, the load inductor current freewheels the secondary of the transformer.
7) *Mode 7* ($t6 \le t \le t7$)*:* In this mode, the load inductor current freewheels in the secondary of the transformer. This mode ends when the switches $S3$ turns off.
8) *Mode 8* ($t7 \le t \le t8$)*:* In this mode, $S3$ is OFF and the current in the primary of the transformer charges capacitor $C1$ through the body diodes of $S1$ and $S2$. Finally, converter reenters Mode 1.

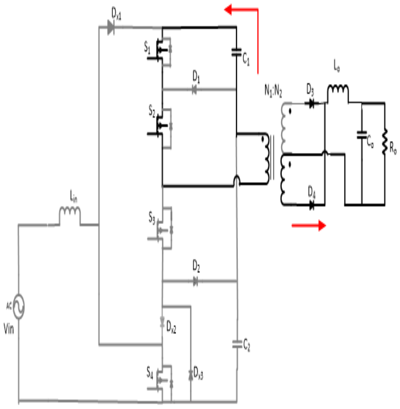

Figure 3. Mode 1

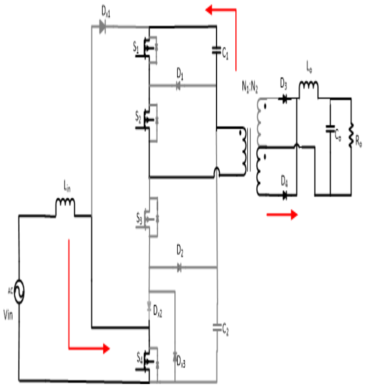

Figure 4. Mode 2

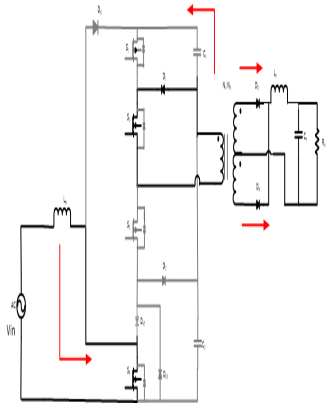

Figure 5. Mode 3

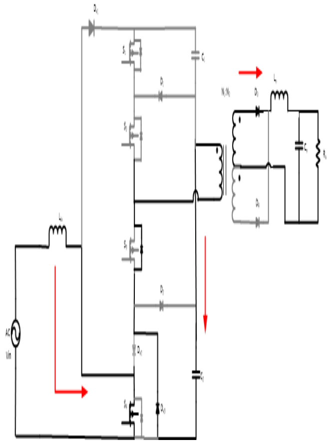

Figure 6. Mode 4

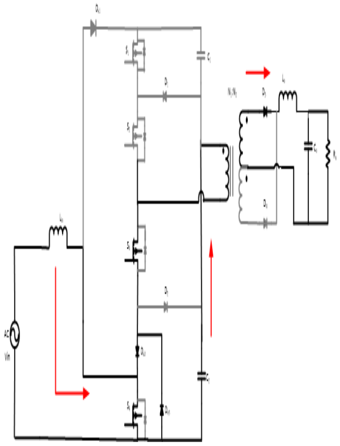

Figure 7. Mode 5

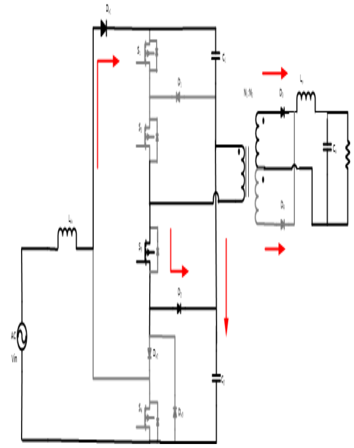

Figure 8. Mode 6

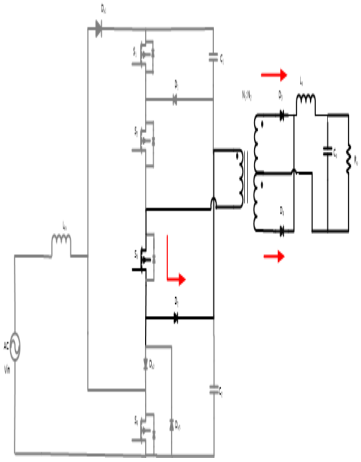

Figure 9. Mode 7

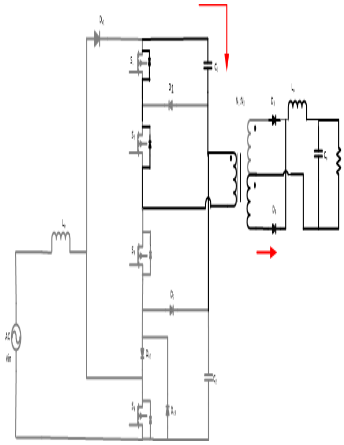

Figure 10. Mode 8

The simplified schematic of the power converter and the respective controllers are shown in Fig. 11. The decoupling of the input controller and output controller can occur because the crossover frequencies of the two loops are very different. The crossover 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.

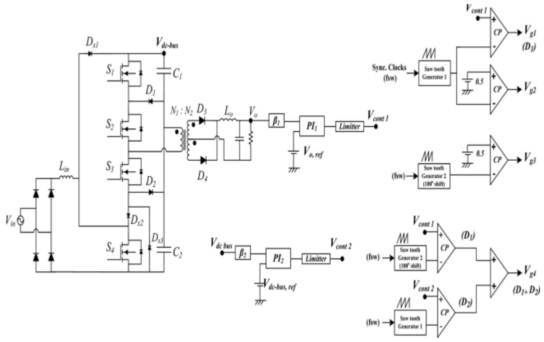

Figure 11 .Schematic control of the converter

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 *S*4 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 tradeoff that needs to be considered is lower cost and improved light-load efficiency versus heavy-load efficiency.

3.CONVERTER DESIGN

The output inductor should be designed so that the output current is made to be continuous under most operating conditions. The minimum value of *Lo* should be the value of *Lo* with which the converter's output current will be continuous on the when the converter is operating with maximum input voltage, minimum duty cycle (*D*min), and at least 50% of maximum load. The minimum value of *Lo* can, therefore, be determined to be

$$Lo \geq \frac{Vo \times Vo}{.5Po} * \frac{1-DTsw}{4}$$

The value for *L*in should be low enough to ensure that the input current is fully discontinuous under all operating conditions, but not so low as to result in excessively high peak current. For the case where *L*in is such that the input current remains discontinuous for all operating conditions, the minimum value of *L*in determine as

$$L_{in} \le \frac{(Vbus \times Vbus)*D\max*(1-D\max)}{2Pofsw}$$

4.SIMULATION RESULT

The simulation of the single stage three level ac dc converter circuit is simulated using corresponding SIMULINK model of the circuit in MATLAB R2014a. Closed loop operation of the circuit is modeled with PI controller and simulated. The simulation is done for obtaining a dc output voltage, Vo=5V from a sinusoidal input voltage , V_{in}=6V and frequency = 10kHz.

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 *S*1 to *S*4 through controlling duty cycle of *D*1 . The other element is to control duty cycle of the switch *S*4 to regulate the dc-bus voltage and to perform input power factor correction. This can be done by controlling *D*2 and then adding duty cycle of *D*2 to *D*1 (where *D*1 and *D*2 are defined in Fig. 3); thus *S*4 performstwo tasks; one part (*D*1) participate to control output voltage and another part (*D*2) to regulate dc-bus voltage.Feedback control is provided to control the output voltage to the desired level. Any change in the input voltage is sensed as change in output voltage accordingly the error signal also changes. The error signal is used to change the duty ratio of the switching pulses to keep the voltage constant. The error signal is compared with repetitive waveform. This method is known as Pulse Width Modulation (PWM).

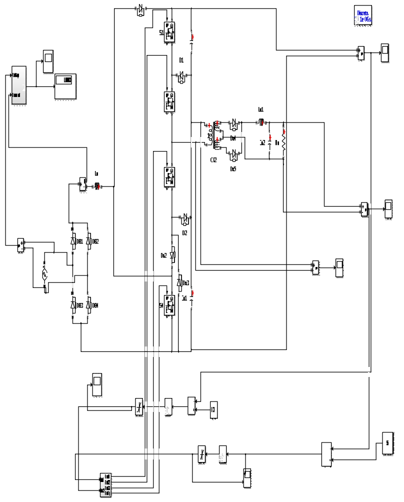

Figure.12.closed loop simulation circuit

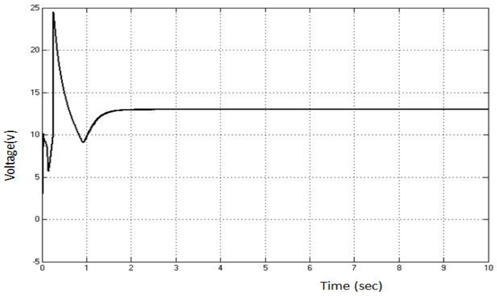

Figure.13.waveform of capacitor voltage

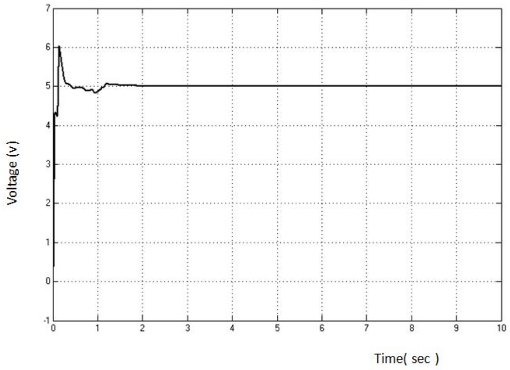

Figure.14.waveform of output voltage

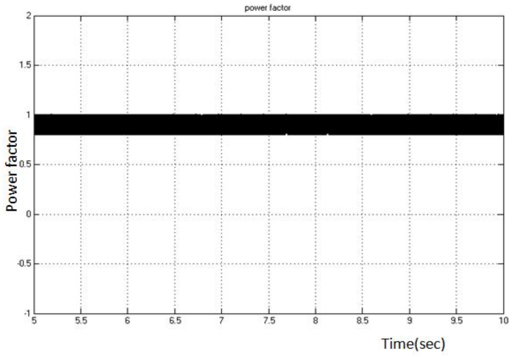

Figure.13.power factor

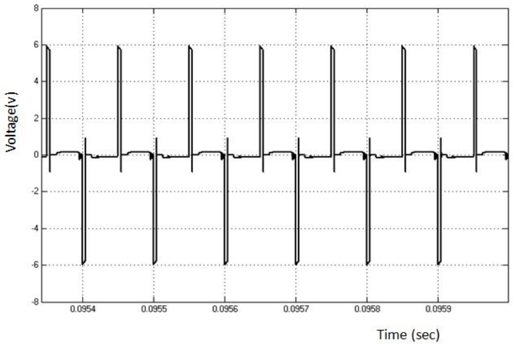

Figure.15.Transformer three level output

Fuzzy logic is widely used in machine control. The output voltage of the converter is compared with reference voltage by the comparator and the output of converter is error signal which is fed to the Fuzzy controller along with the change in error signal. The output of controller is duty cycle which is fed to PWM block and the PWM output is fed as switching signal to the converter

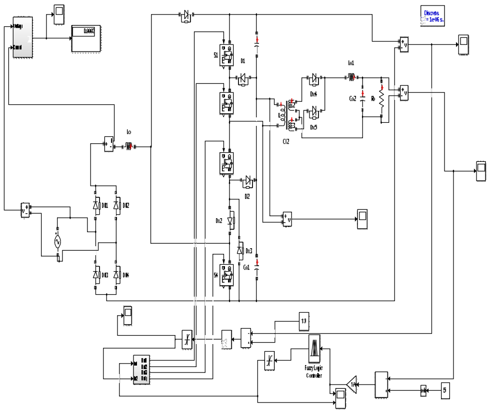

Figure 16 Overall MATLAB-Simulink Model By Using Fuzzy Logic Controller

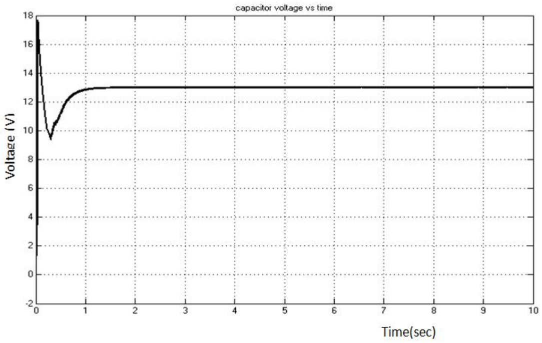

Figure17.Waveform Of Capacitor Voltage

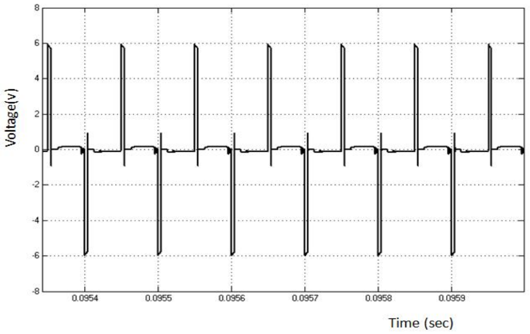

Figure18.Waveform Of Transformer Voltage

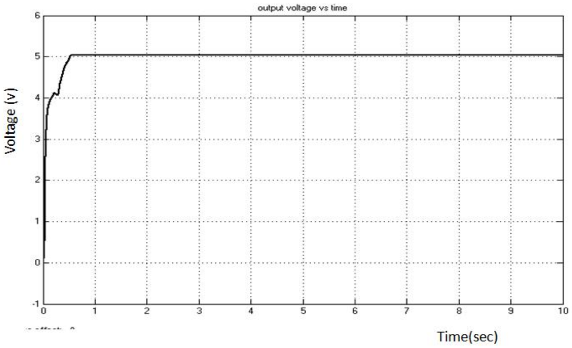

Figure19.Waveform Of Output Voltage

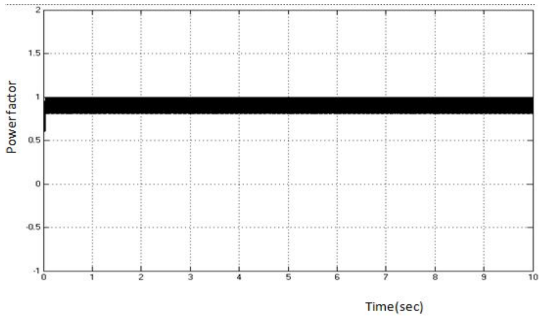

Figure20.Waveform Of Power Factor

The fuzzy logic control simulation model is shown in Fig 4. The input voltage = 6v , the output voltage = 5v.The power factor can be obtained upto unity.

5.HARDWARE IMPLEMENTATION

The hardware section consist power circuit and a control circuit to control the power circuit . The power circuit with components in the main circuit , and dsPIC30F2010 microcontroller , LM324 op amp ,voltage follower L7805. Power supply is provided for the converter, driver circuit and the microcontroller according to their requirements. The main section of the system is single stage three level integrated ac-dc converter which is controlled by microcontroller DSPIC30F2010. The controller is programmed for closed loop control. Here PI control is used to control the converter

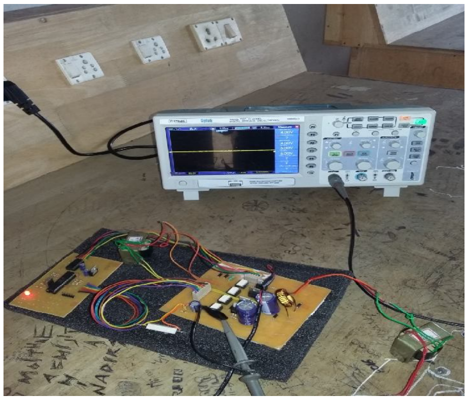

Figure. 21 Schematic of experimental setup.

Single stage three level integrated ac-dc converter is a single converter with two independent controllers which gives contolled capacitor voltage and output voltage.The figure shows the circuit diagram of the single stage three level integrated ac-dc converter . The switching frequency is selected as 10khz . The main section of the system which is controlled by microcontroller dsPIC30F2010. The controller is programmed for closed loop control

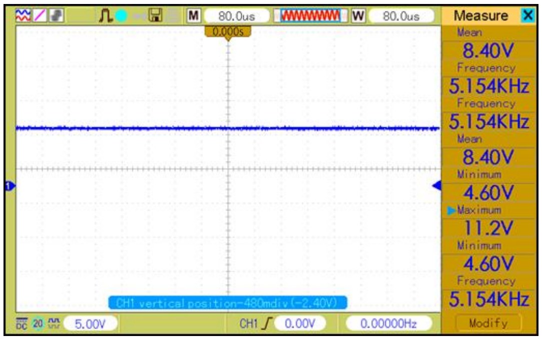

Figure 22 Capacitor Output

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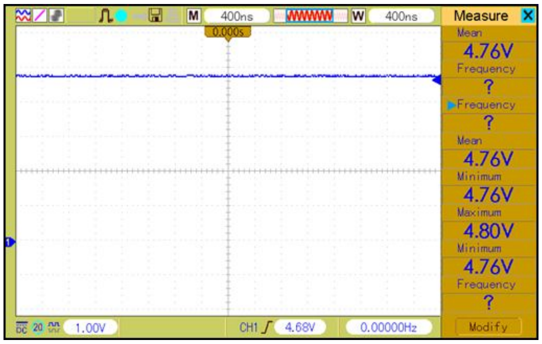

Figure 23 Output Voltage

6.CONCLUSION

Here a new three level integrated ac-dc converter is proposed. Normally this converter is operating with two independent controllers. And one controller is used to regulate the dc bus voltage and for PFC another controller is used to regulate the output voltage. The proposed converter has the advantages over the conventional two-stage converter and also this converter reduces the size when it compared to previous converter. The outstanding feature of this converter is that it combines the performance of two stage converters with single converter and reduce the cost of single-stage converters.

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