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A Three Level Ac-Dc Conversion with Boost Converter

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***Abstract*—A new three level AC-DC conversion along with boost converter is proposed. The proposed converter integrates the operation of the boost power factor correction and the three level dc-dc converters. The converter is made to operate with two independent controllers-an input controller and output controller. The input controller that performs power factor correction and regulates the dc bus. The output controller regulates the output voltage. The input controller prevents the dc-bus voltage from becoming excessive while still allowing a single-stage converter topology to be used. The Boost converter is also called as step-up converter is used to increase the voltage obtained from the proposed converter.**
***Index Terms*—AC-DC power conversion, single-stage power factor correction (SSPFC), three-level converters.**

I. INTRODUCTION

The AC-DC conversion is gaining immense popularity due to its high efficiency and improved power factor. An ac to dc converter is an integral part of any power unit used in all the electronic equipment's. Also. It is used as an interface between utility and most of the power electronic equipment's form a major part of load on the utility. Also, as power electronic equipment's are increasingly being used in power conversion, they inject low order harmonics into the utility. Nowadays,ac/dc converters are widely used in many offline power supplies. The increasing amount urges researchers to develop more efficient, smaller size and low-cost ac/dc converters. The use of single-stage power factor correction(SSPFC) converter topologies have been restricted to low power applications due to existence of some major limitations on their performance ,such as: high ripple in the output due to absence or small value of storage capacitors, reduction of time hold up capabilities ,the need for very complicated power and/or control circuits, the absence of control over the dc bus voltage also leads to the occurrence of wide range of bus voltage variations and that voltage can become very high especially at light loading conditions, leading to high voltage stresses on the converter switches, another drawback is the presence of high circulating currents, which in addition to the presence of high voltage rating lead to a drastic reduction in the converter efficiency making it unsuitable for high power applications. However this voltage reduction comes at the expense of the increased circuit complexity, reduced quality of the input current waveform or increased circulating currents Therefore, these techniques still do not make it practical to extend the power range of the SSPFC converters. Three level dc/dc converters were introduced in order to alleviate the problems of high voltage stresses across switches. Their application was extended to resonant converters in order to provide a high power converter operating over a wide input voltage range and suitable for high voltage applications. This paper presents a new three-level SSPFC converter. The primary –side dc-bus voltage of the converter may become excessive under high input-line and low-output-load conditions. This is because SSPFC converters are implemented with just a single controller to control the output voltage and the dc-bus voltage results in the need for higher voltage rated devices and very large bulk capacitors for the dc bus. The input power factor of a single-stage voltage-fed converter is not as high as that of current-fed converters.

II. OPERATION OF THE PROPOSED CONVERTER

The proposed converter which is shown in fig 1 interfaces an ac-dc boost PFC converter in to a three-level dc-dc converter. The ac-dc boost section consists of an input thyristor 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 Dx1 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's only a

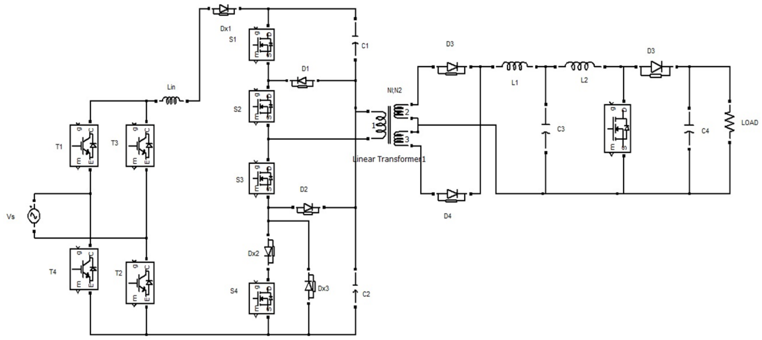

Fig .1: Circuit Diagram

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 S1 to 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 $S_{1,}$ 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. The output from the three level dc/dc converter is fed to the linear transformer. The input to the transformer is 240V and the transformer step downs to a voltage of 48V. Then the voltage obtained from the transformer secondary is given to the diode half rectifier. In order to filter out the harmonics the LC filter is used to remove the harmonics from the output power of the diode rectifier. Then the pure dc power is given to the boost converter circuit.

III. POWER FACTOR CORRECTION

Power factor correction is the method of improving the power factor of a system by using suitable devices. The objective of power factor correction circuits is to make the input to a power supply behave like purely resistive or a resistor. When the ratio between the voltage and current is a constant, then the input will be resistive hence the power factor will be 1.0. When the ratio between voltage and current is other than one due to the presence of nonlinear loads, the input will contain phase displacement, harmonic distortion and thus, the power factor gets degraded.

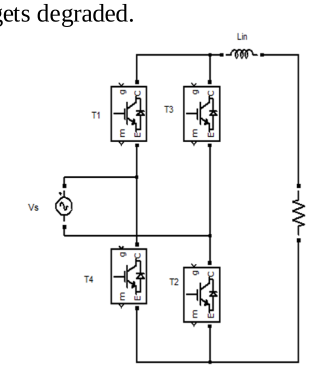

Fig 2: controlled rectifier

Controlled rectifiers find many uses in electronics, and in particular for power control. These devices have even been called the workhorse of high power electronics. IGBT are able to switch large levels of power are accordingly they used in a wide variety of different applications. IGBT even finds uses in low power electronics where they are used in many circuits from light dimmers to power supply over voltage protection The controlled rectifier converts AC voltage to a DC voltage in a controlled manner. In this section, we will discuss on the control and modelling of a controlled rectifier applied in DC drive systems. The modeling of this converter is an important step in the designing of a controller for the closed loop control system typically found in electrical drives. We will limit our model to a *continuous current mode* for a single-phase rectifier (The continuous current mode means that the output current of the converter will always be larger than zero). The modeling and control discussed for the single-phase rectifier can be readily applied to a three-phase controlled rectifier. In controlled rectifier, the output DC voltage is controlled by

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controlling the delay angles (or firing angles) of the IGBT used in the converter.

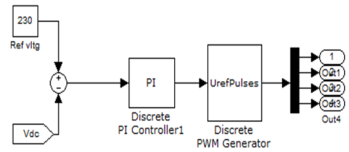


Fig.3 pi based pwm controller

A. Three Level dc/dc Converter

The output from the controlled rectifier is fed to the three level Dc/dc converters. In which the input is dc and four switches S1 to S4 is used . The gating signals for the switch is obtained from SPWM(Sinusoidal Pulse Width Modulation). In this technique the g ating pulses are generated by comparing the reference triangular signal With the sinusoidal signal and the firing pulses are generated and fed to the switches S1 to S4. The output obtained from the three level dc/dc converter is dc power.

IV. INVERTER

These topologies require only a single dc source and for medium output power applications the preferred devices are n-channel IGBTs. Needless to say that physical layout of positive and negative bus lines is also important to limit stray inductances. Q_1, Q_2, Q_3 etc. are fast and controllable switches. D_1, D_2, D_3 etc. are fast recovery diodes connected in anti-parallel with the switches. whereas a single-phase inverter has only one pair of load terminals. The magnitude of dc link current often changes in step (and sometimes its direction also changes) as the inverter switches are turned on and off. The step change in instantaneous dc link current occurs even if the ac load at the inverter output is drawing steady power. However, average magnitude of the dc link current remains positive if net power-flow is from dc bus to ac load. The net power-flow direction reverses if the ac load connected to the inverter is regenerating. Under regeneration, the mean magnitude of dc link current is negative. However a practical voltage supply may have considerable amount of output impedance. The supply line impedance, if not bypassed by a sufficiently large dc link capacitor, may cause considerable voltage spike at the dc bus during inverter operation. This may result in deterioration of output voltage quality, it may also cause malfunction of the inverter switches as the bus voltage appears across the non-conducting switches of the inverter. Also, in the absence of dc link capacitor, the series inductance of the supply line will prevent quick build up or fall of current through it and the circuit behaves differently from the ideal VSI where the dc voltage supply is supposed to allow rise and fall in current as per the demand of the inverter circuit.

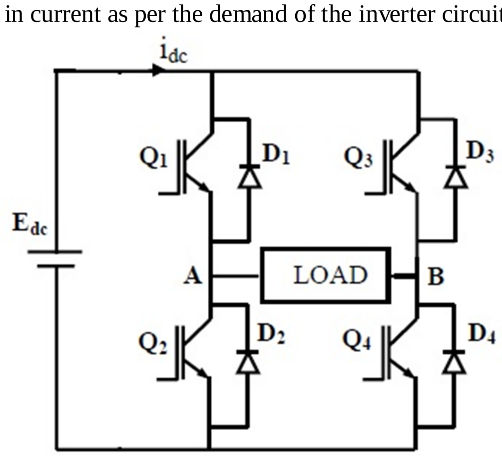
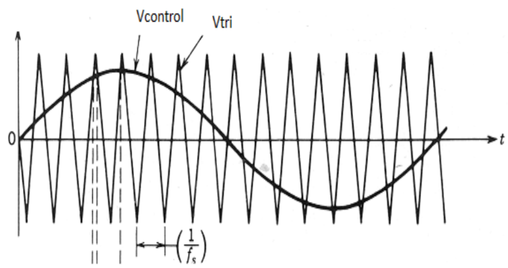


Fig .4 Inverter circuit

SINUSOIDAL PULSE WIDTH MODULATION (SPWM)

Instead of, maintaining the width of all pulses of same as in case of multiple pulse width modulation, the width of each pulse is varied in proportion to the amplitude of a sine wave evaluated at the centre of the same pulse. The distortion factor and lower order harmonics are reduced significantly. The gating signals are generated by comparing a sinusoidal reference signal with a triangular carrier wave of frequency Fc.The frequency of reference signal Fr determines the inverter output frequency and its peak amplitude Ar, controls the modulation index M,and Vrms output voltage VO .The number of pulses per half cycle depends on carrier frequency. Inverters that use PWM switching techniques have a DC input voltage that is usually constant in magnitude. The inverters job is to take this input voltage and output ac where the magnitude and frequency can be controlled. There are many different ways that pulse-width modulation can be implemented to shape the output to be AC power. A common technique called sinusoidal- PWM will be explained. In order to output a sinusoidal waveform at a specific frequency a sinusoidal control signal at the specific frequency is compared with a triangular waveform. The inverter then uses the frequency of the triangle wave as the switching frequency. This is usually kept constant . The triangle waveform, vtri, is at switching frequency fs; this frequency controls the speed at which the inverter switches are turned off and on. The control signal, vcontrol, is used to modulate the switch duty ratio and has a frequency f1. This is the fundamental frequency of the inverter voltage output. Since the output of the inverter is affected by the switching frequency it will contain harmonics at the switching frequency. The duty cycle of the one of the inverter switches is called the amplitude modulation ratio, ma.



Fis.3 Desired frequency is compared with a triangular waveform

Ma = Vcontrol / Vtri .... (1)

Where Vcontrol is the peak amplitude of control

M f = fs/ f1 ....(2)

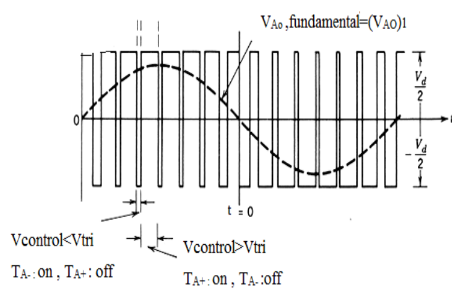


Fig. 5Pulse-width Modulation (PWM)

A. Spwm with Bipolar Switching

The basic idea to produce PWM Bipolar voltage switching signal is shown in Fig It comprises of a comparator used to compare between the reference voltage waveform V*r* with the triangular carrier signal Vc and produces the bipolar switching signal. If this scheme is applied to the full bridge single phase inverter as shown in Fig.6, all the switch S11, S21, S12 and S22 are turned on and off at the same time. The output of leg A is equal and opposite to the output of leg B. The output voltage is determined by comparing the reference signal, Vr *and* the triangular carrier signal, Vc.

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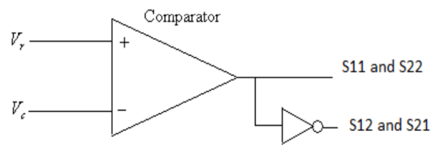

Fig.6 Bipolar PWM generator

In this scheme the diagonally opposite transistors S 11, S21, and S12 , S22 are turned on or turned off at the same time. The output of leg A is equal and opposite to the output of leg B. The output voltage is determined by comparing the control signal, Vr and the triangular signal, Vc as shown in Fig. 5 to get the switching pulses for the devices, and the switching pattern and output waveform is as follows.

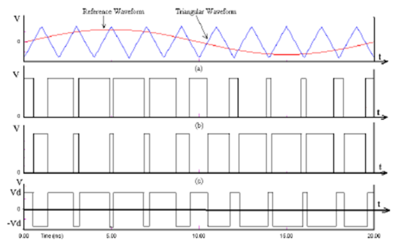

Fig. 7: SPWM with Bipolar voltage switching (a) Comparison between reference waveform and triangular waveform (b) Gating pulses for S1 and S4 (c) Gating pulses for S2 and S3 (d) Output waveform

IV. BOOST CONVERTER

Boost converter steps up the input voltage magnitude to a required output voltage magnitude without the use of a transformer. The main components of a boost converter are an inductor, a diode and a high frequency switch. These in a co-ordinated manner supply power to the load at a voltage greater than the input voltage magnitude. The control strategy lies in the manipulation of the duty cycle of the switch which causes the voltage change

V. MODES OF OPERATION

There are two modes of operation of a boost converter. Those are based on the closing and opening of the switch. The first mode is when the switch is closed; this is known as the charging mode of operation. The second mode is when the switch is open; this is known as the discharging mode of operation

A. Charging Mode

In this mode of operation; the switch is closed and the inductor is charged by the source through the switch. The charging current is exponential in nature but for simplicity is assumed to be linearly varying. The diode restricts the flow of current from the source to the load and the demand of the load is met by the discharging of the capacitor.

B. Discharging Mode

In this mode of operation; the switch is open and the diode is forward biased . The inductor now discharges and together with the source charges the capacitor and meets the load demands. The load current variation is very small and in many cases is assumed constant throughout the operation.

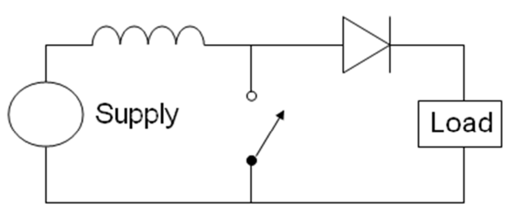

Fig.8.boost converter

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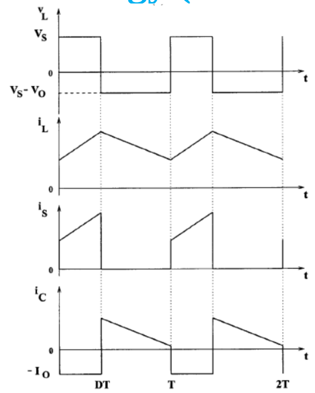

Fig 9.Waveforms of boost converter

The operation of electronic switches known as power semiconductor switches like transistor, SCR's, MOSFET, IGBT….. in the boost circuit needs a driver to operate it periodically opening and closing, this is done by PWM which is used for power semiconductors switches. The closed loop circuit of boost converters needs to operate on CCM as it can produce a constant voltage 48V DC converter with less ripple magnitude in transient states. In these cases at the end of ON-state of power switches, current in inductor never goes zero and continuously supply current for output. The output then is feedback to PID controller where PID are programmed to measure error occur at output terminal and compare it to set point/reference voltage and make a correction to produce suitable PWM signal . The proposed closed loop block model of Boost converter has components like power switches {transistor, MOSFET, IGBT….}, diode, filter capacitor, PWM; PID controller that as shown in Fig 10. Here a proposed model of boost converter is design which will operate in closed loop which has feedback to stabilize the system. The converter is PWM based boost converter incorporated with PID controller and implementing this system in MATLAB/SIMULINK environment.

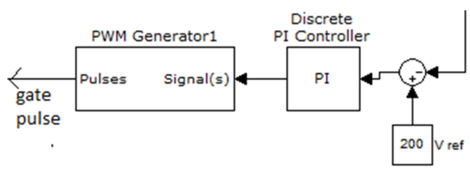

Fig. 10 PI based controller

VI. SIMULATION

Parameter:
Input AC voltage: 230 V
Output DC Voltage: 230 V

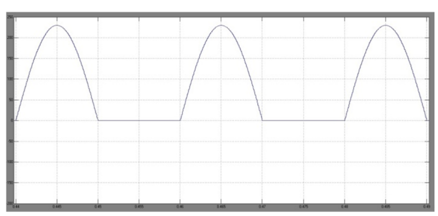

Fig. 11 controlled rectifier Dc output voltage

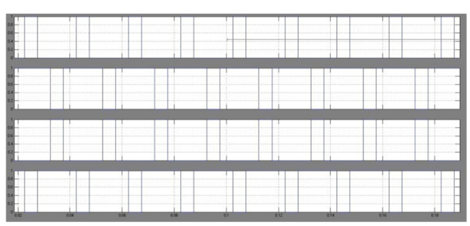

Fig .12 Inverter Gate pulse

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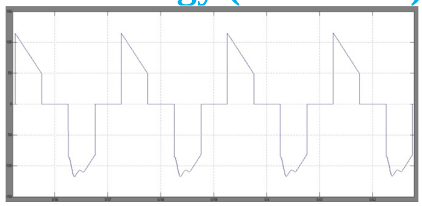

Fig 13. Inverter DCoutput Voltage

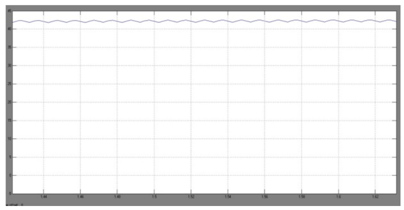

Fig.14 Diode Rectifier output DC voltage

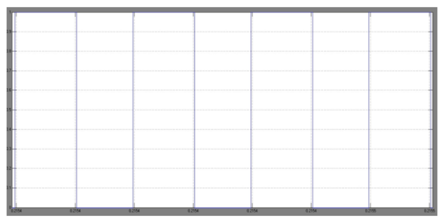

Fig 15 Boost converter gate pulse

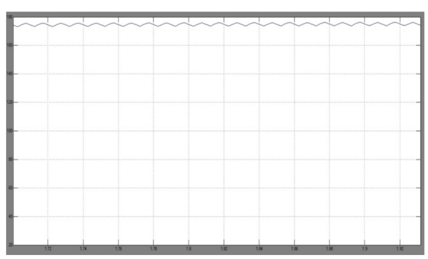

Fig 15 Boost converter DC output Voltage

Parameter:
Input DC voltage:35
Output DC voltage :180

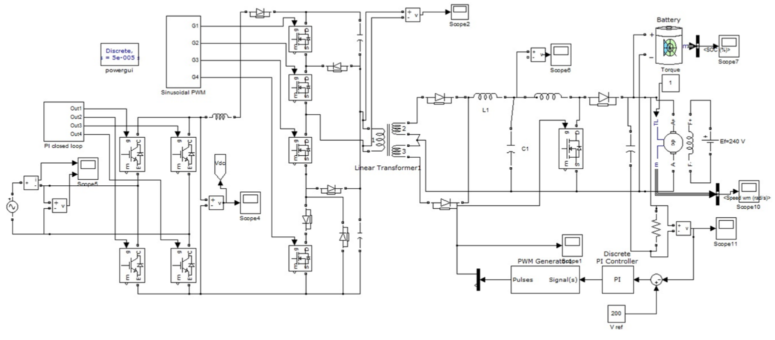

Fig 17.Full simulation circuit

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VII. CONCLUSION

Thus a new Three level AC-DC converter with Boost converter is designed and simulated using MATLAB simulink 2009. The proposed converter performs both power factor correction and regulates the output voltage with two independent controllers. The Sinusoidal PWM method is used for gate pulse generation in three level dc/dc converter. The Boost converter is used inorder to increase the voltage. The output voltage obtained from the Boost converter is fed to three different loads a battery, a motor and a resistor. The output voltage is much higher than the input voltage and it also supplies three different loads. The paper introduces the proposed converter and explains it basic operating principles and modes of operation.

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