A Closed Loop Control of Three Phase Dual-Switch Buck-Boost Converter

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Abstract— **This paper investigates the integrated 3-Phase AC-DC Buck-Boost converter designed to works with a great range of input AC voltages and produce a great range of output DC voltages which is similar to Conventional Converter with a sophisticated control in input section. The reduced switch converter with input Filter see through per phase voltage instead of Line voltage as in case of Conventional Converter to reduce the peak voltage stress is operated in Boost mode is discussed. Based on the results of analysis the design of converter is developed and demonstrated with 180V peak-peak input 500V output 0.5KW power and 100 KHz operating frequency and implemented with MATLAB SIMULINK, The voltage mode controller has been used to control the required voltage.**

Keywords*— *Three phase buck boost converter, Voltage mode controller.

1. Introduction

We know that rectifier is a power electronic device which converts AC to DC. Since last two decades these rectifiers have become more popular and used in domestic, laptops, computers and industrial applications. Rectifier is an individual device feeds single and multiple DC loads from applied AC supply because of its unlimited power output and fine controllability. 1-Ø rectifiers are deles with low power applications like home and small scale commercials applications equipments, but 3-Ø rectifier is used in high power applications in industries, battery charger circuits, SVC and HVDC power transmission for long distance power transceivers. Physically these rectifiers are available in vacuum tube diode, mercury arc values, semiconductor diodes, silicon controlled rectifiers and other silicon based semi conductor switches.

The output of a converter is controlled by either voltage mode or current mode i.e. switch of the converter is controlled. In many cases voltage supply is used as a source. Rated voltage is applied to any equipment but depending on load the current drawn varies from minimum value to rated value. In many cases rectifiers are operated in voltage mode by maintaining constant output voltage and required load current to drive the application. A voltage mode operated rectifier offers low output impedance in short circuit, but in current mode operated rectifier regulates its output current up to its rated value. Current source is designed to provide high output impedance. These two regulating modes work together to provide continuous control over the supply, but only one mode regulation at a time.

Power electronic converters when operated directly from main supply can generate harmonics that get injected into the mains, these harmonics are generally minimized using certain power factor improvement methods to ensure that input currents are sinusoidal and in phase with the input voltage. The non-ideal character of the input phase current drawn by the converter affects the power distribution system at the vicinity of the converter. System designers are increasingly incorporating active input power factor methods to combat the effects of harmonics in the system. Harmonic Reduction in the current is done in many different ways which includes.

- Harmonic injection with help of extra equipment in conjunction with rectifier but it is an expensive approach.
- Forced commutation technique with the help of six switches where the output voltage is controlled while maintaining sinusoidal input current at UPF.
- By using 3 single phases isolated AC-DC high input power factor converter but which is less expensive than compared to forced commutation technique but it needs a complex approach.

Now days, a 3- phase AC version of DC to DC boost converter with single switch where input line current operating in discontinuous mode (DCM) was described that facilitates three phase low frequency rectification without use of large low-frequency passive elements and active control of the line currents. To get better input current line inductors must operate in discontinuous mode. The property of a pulsating input current during each switching period with peak proportional to input phase voltages yields average or low frequency component in the line current approximately proportion to phase voltage and thus low harmonic rectification is obtained, this can be also modified by inserting input filter formed by having capacitor which is small enough to operate discontinuous mode and produce nearly sinusoidal input capacitor average voltages that follow input inductor line currents provided with switching frequency higher than line frequency, this dual agreement at AC input side facilitates high power factor or low harmonic rectification function as compared to using only inductors. Thus a three phase AC-DC single switch converter that operates in wide range of input AC voltages to provide wide range of output DC voltages in constant duty cycle is obtained, but here the switch has very high peak voltage stress regardless to whether it is operated buck or boost mode. In this article the operation of advanced version of three phase AC-DC single switch buck boost converter is explained by mainly focusing voltage across

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the switch in order to reduce the peak voltage stress and also the converter provides large operational range for the same condition.

II. CIRCUIT OPERATION OF 3-PHASE BUCK-BOOST CONVERTER.

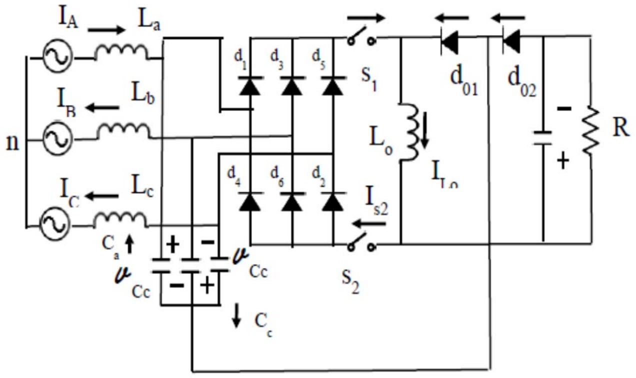

Fig.1. Reduced Switch Buck-Boost Converter.

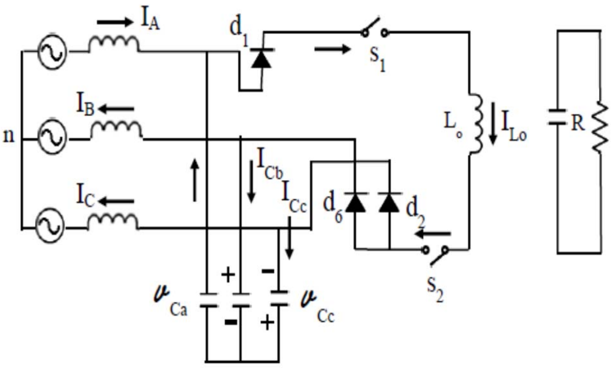

Fig.1 (a) Mode1 (t0<t<t1)

Mode1: At t = t_o , S_1 is switched ON and C_a starts to discharge; therefore, $I_{a,k}$ and the discharging current of capacitor C_a ($I_{Ca,k}$) flow through switch $S_1$and charge L_o, before coming to the input side through switchs S_2 , D_6 and D_2 . The discharging current of C_b is $I_{Cb,k}$. The current in D_6equals $I_{b,k}+I_{Cb,k}$. The current in D_2 consists of $I_{c,k}$and discharging current of C_c ($I_{Cc,k}$). Both diodes D_{o1} and D_{o2} are OFF. This mode ends when C_b and C_c are charged in the opposite direction to a voltage level that equals the output voltage $–V_2$.

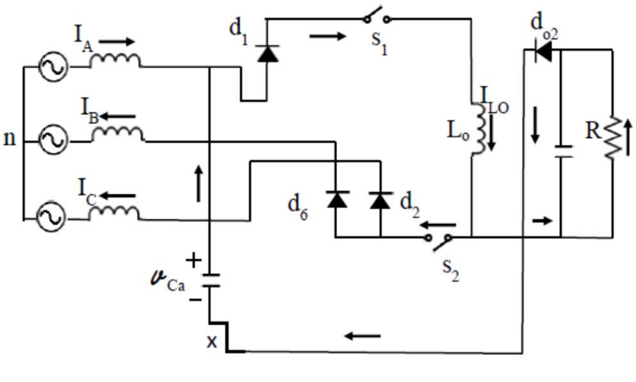

Fig.1 (b) Mode2 (t1<t<t2)

Mode2: During Mode 2, Ca continues to discharge as in Mode 1 and $I_{ca,k}$ flows through S_1 , L_o, and D_{o2} . Line current $I_{a,k}$ flows through D_1 , S_1 , L_o and S_2 before it divides into $I_{b,k}$ and $I_{c,k}$. Currents $I_{b,k}$ and $I_{c,k}$ flow through D_6 and D_2 respectively. The voltages across C_b and C_c remain at a voltage level of $–V_2$.

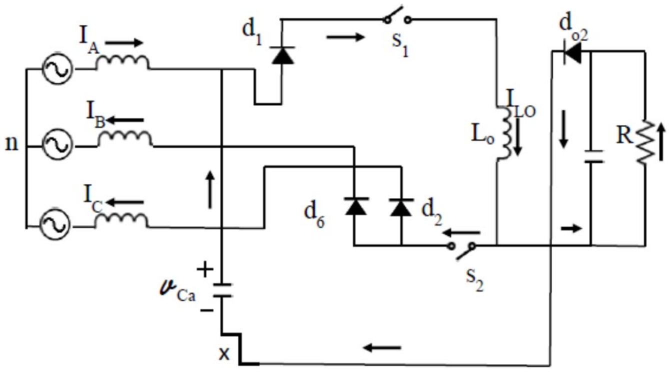

Fig.1(c) Mode3 (t2<t<t3)

Mode3: : $S_2$is switched OFF at the start of this mode. C_a continues to discharge and ($I_{a,k}+I_{ca,k}$) flows through L_o, R and D_{o2} and goes to the AC side. C_c can be charged according to (5) and that C_b can be charged in a similar manner by current $I_{b,k}$ .Ibk=Ick=Ia/2.

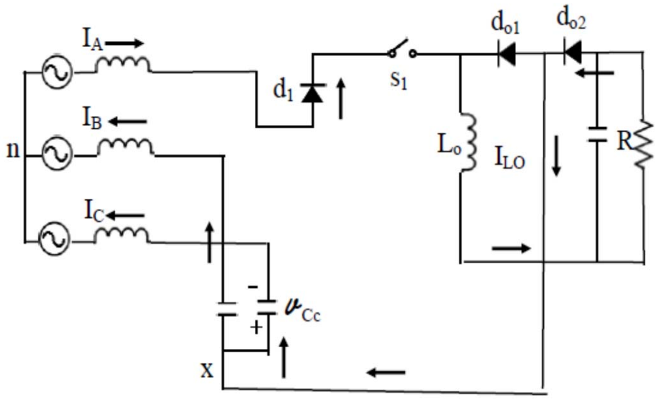

Fig.1 (d) Mode4 (t3<t<t4)

Mode4: During Mode 4, Ca remains fully discharged. Throughout in this mode, both diodes D_{o1} and D_{o2} acts as short circuit and the current $I_{a,k}$ flows through D_1, S_1 , L_o and $D_{o2}$and returns to the input side. $I_{b,k}$ charges C_b and $I_{c,k}$ charges C_c

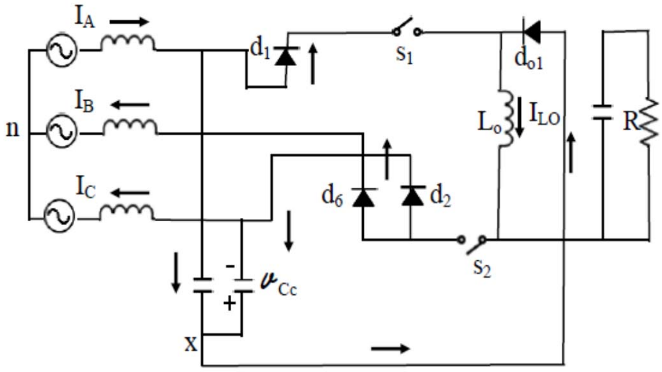

Fig.1 (e) Mode (t4<t<t5)

Mode5: S_2 is turned ON at t = t_4 . Current $I_{Cb,k}$ flows out of C_b and $C_{Cc,k}$ flows out of C_c so that current ($I_{Cb}+I_{Cc}$) flows through $D_{o1}$and L_o. C_a remains discharged.

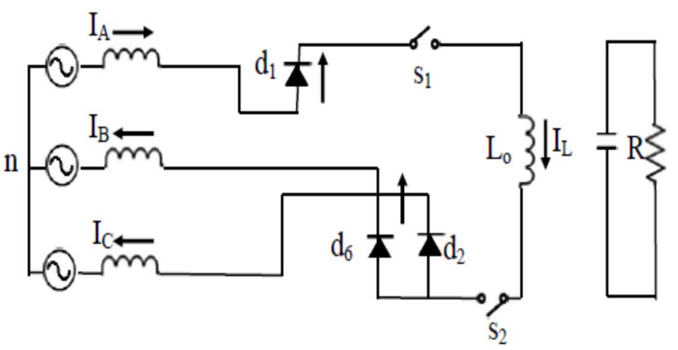

Fig.1 (f) Mode6 (t5<t<t6)

Mode6: This mode begins when voltages of C_b and C_c are zero. All the input capacitors remains completely discharged as dc bus is short circuited.

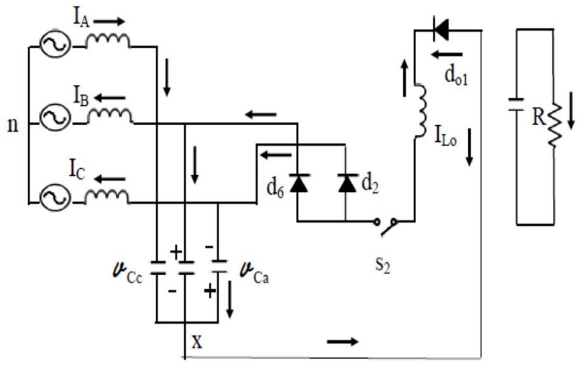

Fig.1 (g) Mode7 (t6<t<t7)

Mode7: At t = t_6, $S_1$is switched OFF and $I_{a,k}$ starts to charge C_a.

III. DESIGN EXAMPLE

Input line-line rms voltage Vin=220V.

Output Voltage V2=300(D>0.5)

Output Power Po = 500W.

Switching Frequency = 100khz.

$M = V_2/(1.732*V_1)$

$M=V_2/(1.732*180)$

$M=0.55.L_aC_a = \left(\frac{1}{2\pi fr}\right)^2\left(1+\frac{Itfr}{0.2Itfr}\right)$

La = 0.04mh.

$$C_0 = \frac{I_0 \times 100 \times (1-D)}{\sqrt{2} \times (\text{ripple}\%) \times f \times V_{i(peak)} \times \sqrt{3}}$$

C_0 = 34.027μF.

$L_0 = (1\text{-}D)*R)/(2*f)$

L_0 = 0.407mh

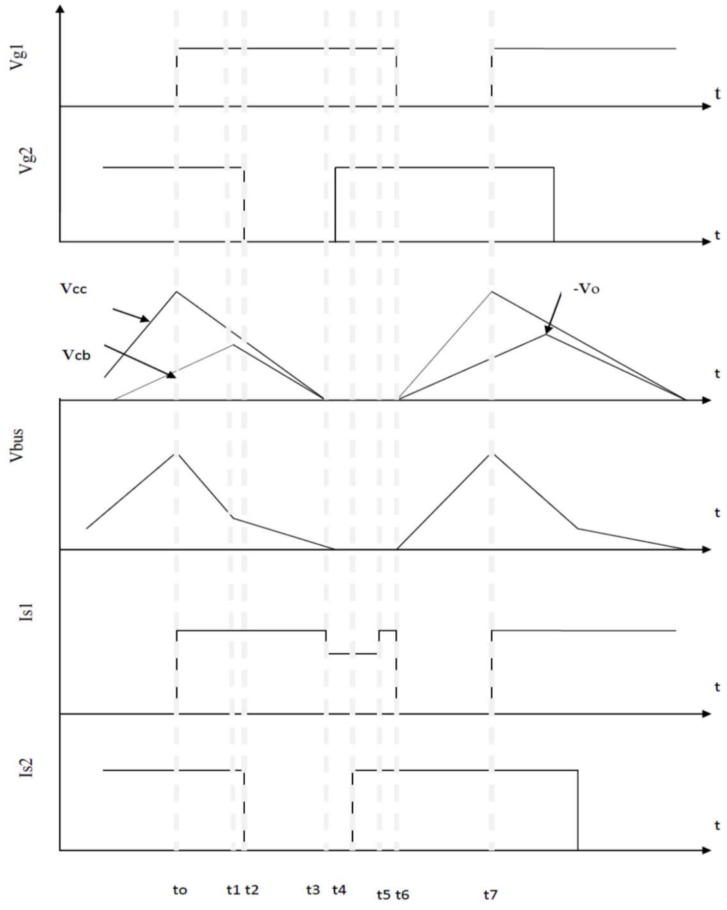

Fig.2. Waveforms of 3 phase Buck-Boost converter D>0.5

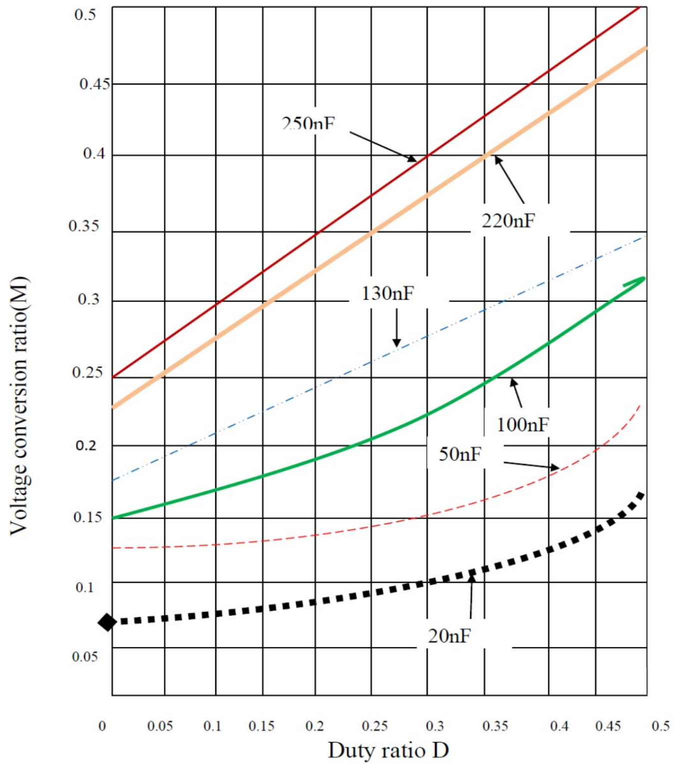

Fig.3. Voltage Conversion Ratio (M) Versus Duty ratio (D)

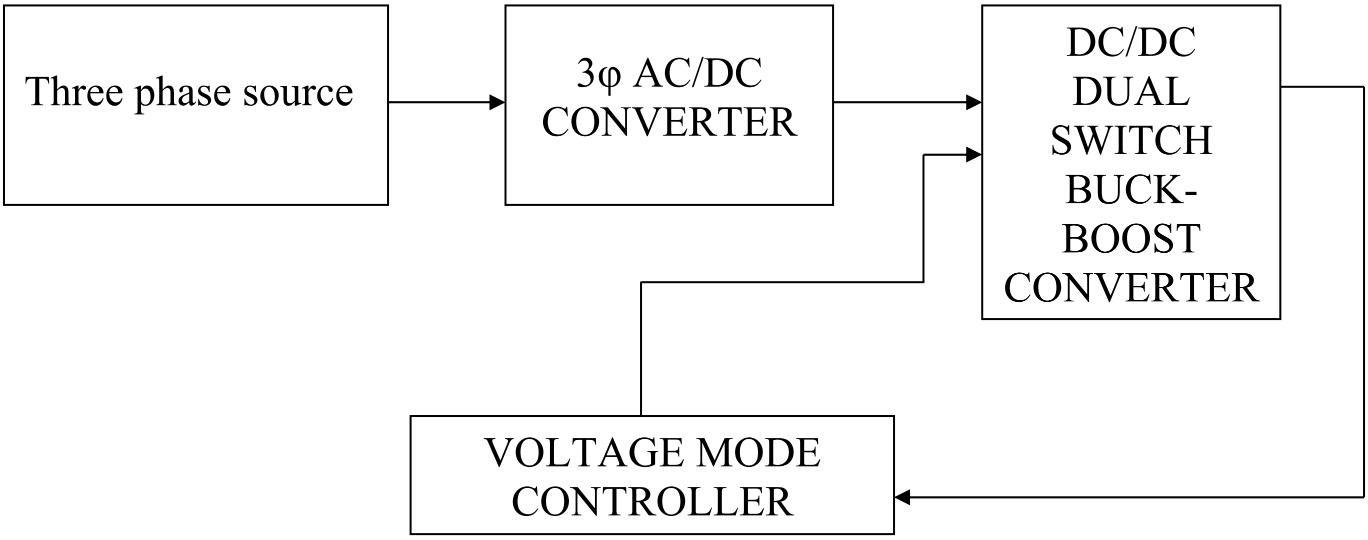

Fig.4. Block Diagram for Closed Loop 3-Phase Buck –Boost AC/DC Converter

IV. SIMULATION RESULTS

By using Matlab-Simulink the 3-phase buck-boost converter will be implemented for closed loop and open loop systems and Fig.5 shows that output voltage and Fig.6 shows output current and Fig.7 shows Input current and Input voltage waveform and Fig.8 shows THD for closed loop system. Fig.10 shows output voltage waveform and fig.11 shows output current and fig.12 shows input current &output current waveforms and fig.13 shows THD for open loop system.

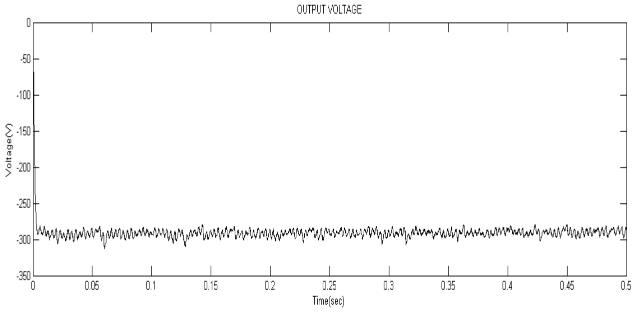

Fig.5. Output Voltage

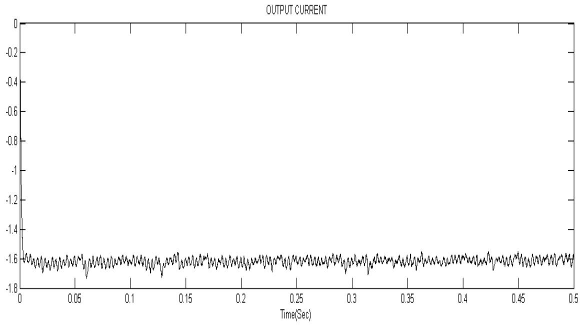

Fig.6.Output Current

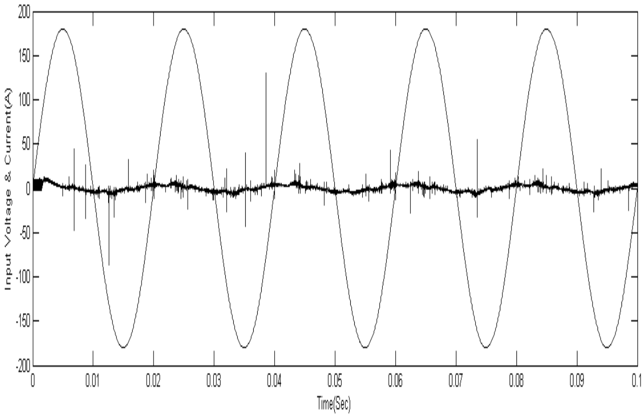

Fig.7. Input Current &Voltage Waveforms

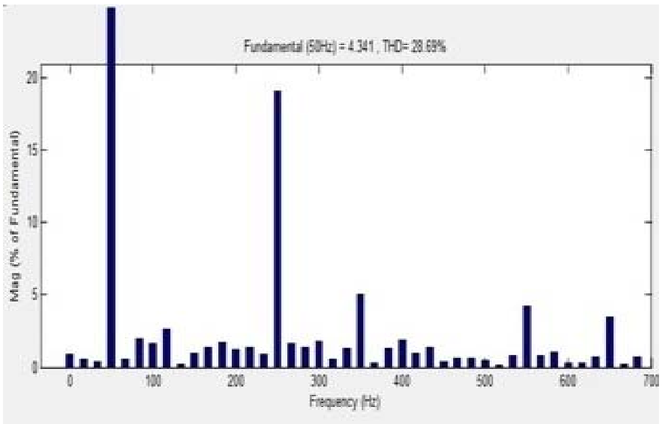

Fig.8. THD 28.69%

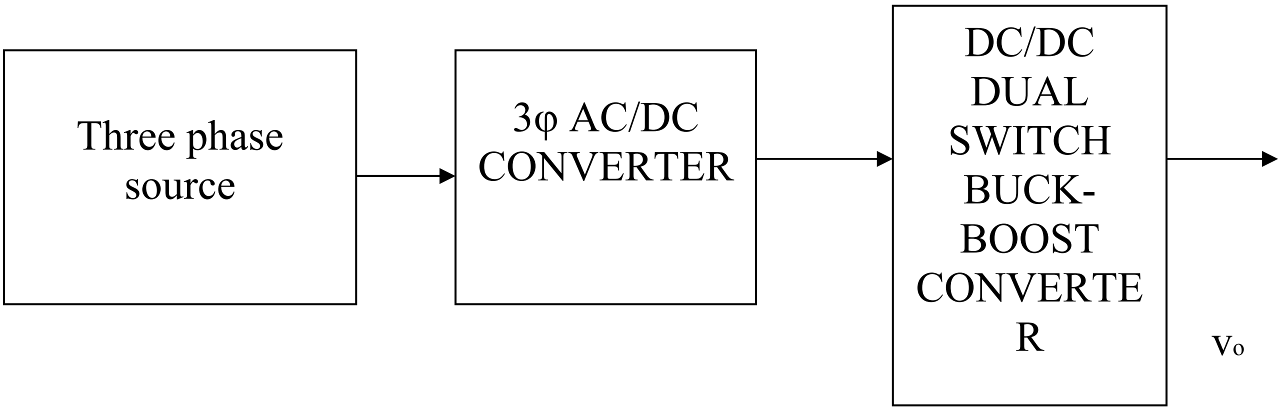

Fig.9. Open Loop Control of 3 –Phase Buck-Boost AC/DC Converter

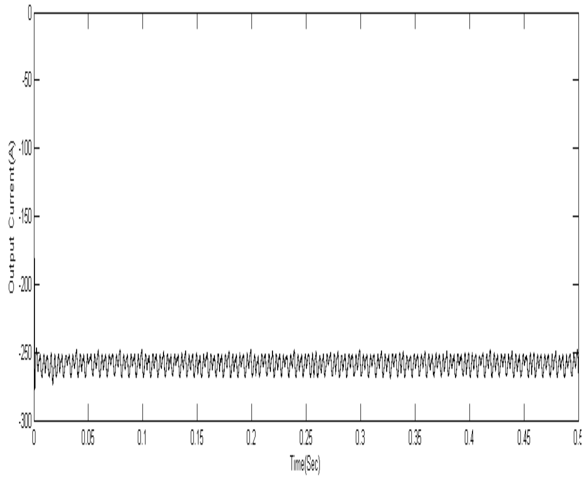

Fig.10. Output voltage

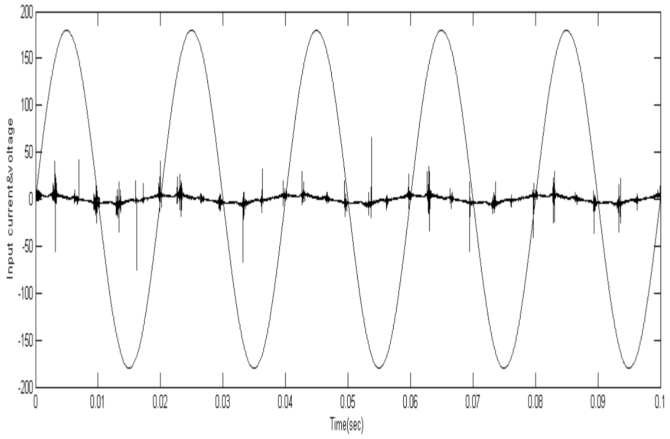

Fig.12.Input Current and Voltage

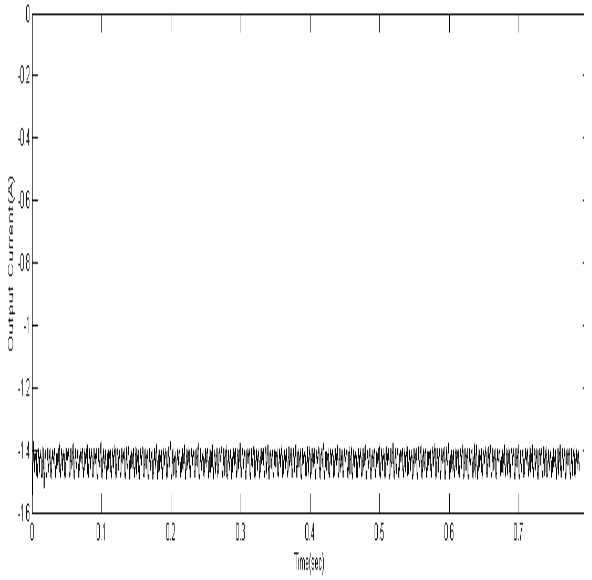

Fig.11. Output current

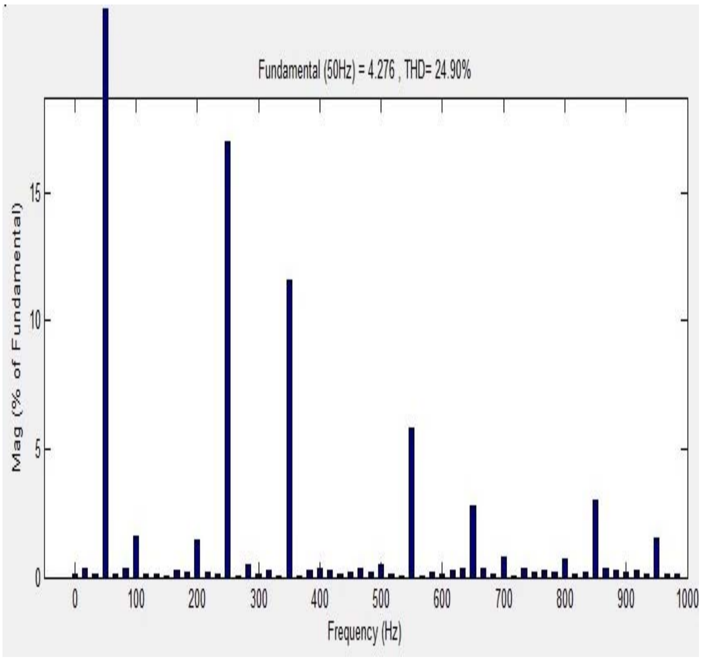

Fig.13. THD =24.90%

CONCLUSION

In this article a 3-phase dual switch Buck boost converter has been implemented by using closed loop and open loop control. In this article, the circuit operation of the converter was discussed in detail and conventional boost operation was implemented, as well as a design example. The open loop control have the disadvantage that it does not produce the required voltage and required power where as the closed loop control producing the required voltage as well as required power with a less total harmonic distortion. The future work comprises of current control techniques and intelligent control techniques to get better results.

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