A CLOSED LOOP CONTROL OF BUCK-BOOST AC-AC CONVERTER WITH REDUCED THD

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ABSTRACT:In this project we introduce a converter with a voltage feedback closed loop control scheme with control on output voltage amplitude. A high frequency operation is carried for reduction of THD in the output voltage waveform. In the previous work the output voltage is varied by changing the duty ratio manually here in the proposed method the duty ratio is changed automatically by closed loop system with respect to v reference.

The proposed converter utilizes six unidirectional current passing and bidirectional voltage blocking switches, executed by six reverse blocking insulated-gate bipolar transistors (IGBTs) or series MOSFET–diode sets, two input and output filters capacitors, and one inductor. It has no over shoot issue of voltage source not maintaining constant when all switches are turned-on, and in this manner, pulse width modulation dead-times are not required bringing about high quality waveforms, and takes care of the commutation issue without utilizing bulky and lossy RC snubbers or devoted soft commutation techniques. The design and analysis is carried out in MATLAB software with complete results and outputs with comparision of outputs with all possible modes.

KEYWORDS: closed loop control, output voltage, ac-ac converter, buck-boost, THD.

1. INTRODUCTION

Generally, in industry, the ac – ac power conversions are performed by utilizing ac thyristor power controllers, which utilize the phase angle or basic cycle control on input ac voltage, to get the desired output ac voltage. The drawbacks of ac thyristor controllers are low power factor, large total harmonic distortion in source current and lower efficiency, have restricted their utilization in ac- ac converters. For ac– ac power conversions with variable frequency and voltage, the utilization of indirect ac – ac converters with dc-link and matrix converters have been progressed on the grounds that they can get better power factor and efficiency, and littler filter requirements. In any case, for applications in which just voltage control is required, the direct pulse width modulation (PWM) ac– ac converters are more favored on the grounds that they can decrease the size and price of converter.

These direct PWM ac– ac converters in previous papers are acquired from their dc– dc counterparts, where all the unidirectional switches are supplanted with bidirectional. But every topology has its own particular constraints; the buck-type ac– ac converter can just step down the input voltage while boost type can just step up the input voltage. The buck– boost and Cuk topology can both step up and step down the input voltage; in any case, the phase angle is reversed. In addition, the two topologies have disadvantages of higher voltage stress across switches, and there are discontinuous input and output currents in the event of the buck– boost converter. The Cuk topology can eliminates the currents discontinuity at the price of extra passive components, expanding the size and price of converter and reducing the efficiency. The ac– ac converters in view of the impedance source organize likewise called (q)ZS ac– ac converters in previous papers, it can both step up and step down the input voltage. However the step-down operation always brings about reversing of phase angle.

In addition, they utilize more passive components and have higher current flowing through active switches amid shoot-through, which make their utilization less attractive. In buck-type multilevel ac– ac converters in view of the idea of flying capacitors are proposed, which can decrease the voltage stress of switches and reduce the quality of output voltage. In any case, they require RLC booster to be associated in parallel to load, keeping in mind the end goal to decrease the voltage imbalance issue of lying capacitors.

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The proposed converter is invulnerable from shoot-through of potential difference source (or capacitors) notwithstanding when all switches are turned on at the same time, which upgrades its dependability and it needn't bother with PWM dead-time which brings about superb output voltage. Despite the fact that it utilizes six unidirectional current directing bidirectional voltage blocking switches, just two of them are exchanged at high frequency in each half-cycle amid any working mode, bringing about littler switching losses. In the proposed converter, no current flows through body diodes of switches, and accordingly, it can utilize power MOSFETs alongside quick recuperation diodes in arrangement, which diminishes switching losses and poor turn around recuperation issue of MOSFETs body diodes is additionally dodged.

The non-inverting buck–boost methods of proposed converter are appropriate for applications with both step-up and step-down request while the inverting buck– boost mode can likewise be used in DVR application to remunerate both potential difference sags and swells.

2. LITERATURE SURVEY

Fig. 1(a), (b), and (c) demonstrate the traditional non inverting buck and boost converters and inverting buck– boost converter, individually. The buck topology in Fig.1 (a) has a voltage gain of D (where D is duty ratio, and D ≤ 1), and along these lines, it has just step-down operation. The boost topology in Fig. 1 (b)has a gain of1/(1 − D), with just voltage step-up operation. The buck– boost converter in Fig. 1 (c) has a voltage gain of D/(1 − D), with both step-up and step-down operations, but output voltage is inverted. Also, it has higher switch voltage stresses, higher inductor current and current ripple, and discontinuous input and output currents.

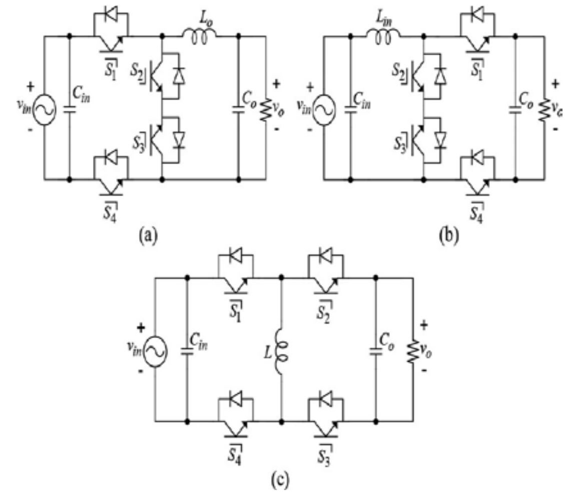

Figure 1. Basic PWM ac-ac converter.(a) Buck type. (b) Boost -type. (c) Inverting buck–boost type

Because of these conspicuous disadvantages, the dc–dc counterpart of this inverting buck– boost ac–ac converter is frequently replaced with non-inverting buck– boost converter (two switch buck– boost converter) which is acquired by cascading simple buck topology with boost topology. The non-inverting buck– boost ac– ac converter in Fig. 2 .(a) can be gotten by replacing all unidirectional switches in its dc–dc counterparts in with bidirectional switches. The gating signals design for buck and boost modes are given in Fig. 2(b) and 2.2(c), individually. This converter has a voltage gain of D in buck mode and 1/(1 − D)in boost mode. This non-inverting buck– boost converter has benefits in that it covers a wide range of input voltage, it has non-inverting output voltage, lower voltage stress on switches, and lower inductor current and current ripple. In any case, it has following drawbacks; it utilizes eight switches, needs PWM dead- - times and devoted safe commutation methodology to take care of commutation issue, and can't utilize MOSFETs as the current flows through body diodes of switches. In addition, it can get just non-inverting buck– boost voltage and lacks inverting buck– boost operation, which is additionally wanted in its application as DVR, to compansate both voltage sags and swells.

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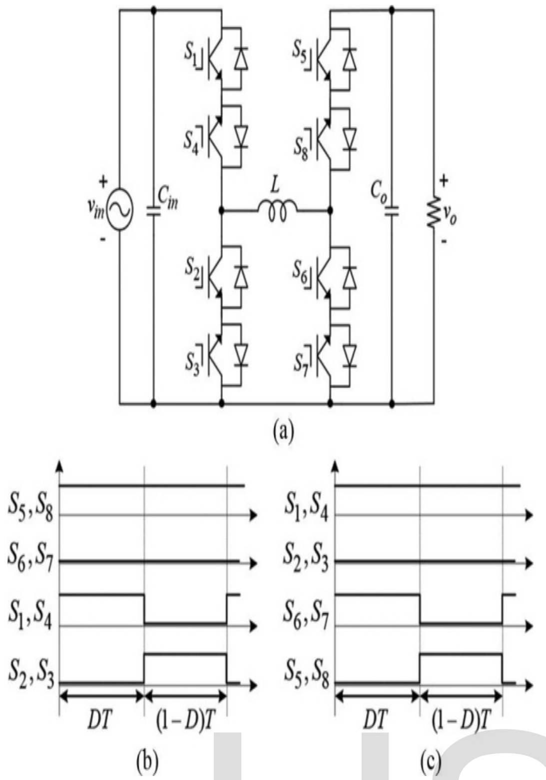

Figure 2. Non-inverting buck-boost ac-ac converter (a) Circuit topology.(b) Gating signal for buck mode operation. (c) Gating signals for boost mode operation.

3. A BUCK-BOOST AC-AC CONVERTER

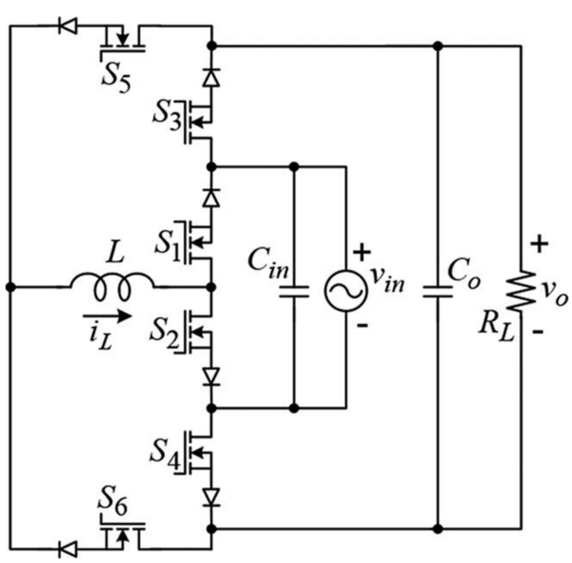

Figure 3. Circuit topology of the buck-boost ac-ac converter.

Fig. 3 demonstrates the circuit configuration of the ac– ac converter uses of six unidirectional current flowing bidirectional potential difference blocking switches S1 − S6, one inductor L, and two input and output filter capacitors Cin and Co. The six unidirectional current switches can be acknowledged by series combination of power MOSFETs with external quick recovery diodes, are in Fig. 3 In this figure, body diodes of MOSFETs are not appeared as they never conduct, and along these lines, their poor reverse recovery issue is neglected.

For high power applications, it can either utilize six reverse blocking IGBTs (RB-IGBTs) or six IGBTs (without body diode) with outside quick recovery diodes in arrangement. The proposed converter can work as conventional non-inverting buck and boost converters with voltage gain of D and 1/(1 − D), individually, and furthermore as inverting buck– boost converter with voltage gain of D/(1 − D). By utilizing just six switches, it can consolidate the usefulness of eight switches non-inverting buck–boost converter appeared in Fig. 2(a), and four switches inverting buck– boost converter appeared in Fig. 1 (c). In this way, it can be utilized as non-inverting buck– boost converter to replace the traditional inverting buck– boost converter in different ac– ac change applications. For its application as DVR, the non-inverting buck– boost mode can be utilized to compensate voltage sags (which happens all the more regularly), and inverting buck– boost mode for voltage swells (which happens less frequently).

The above figure can be operate in three modes they are buck, boost and buck-boost mode.

Non-inverting Buck Mode Operation.

The PWM switching sequence of the AC-AC converter during non-inverting buck mode operation and key waveforms are appeared in Fig.3.3.3.For positive half of input ac voltage (vin > 0), switches S1,S3,S6 are always turn on and S4,S5 are always turn off, while switch S2 is switched at high frequency. Fig.4.demonstrates the comparable circuits of the AC-AC converter for vin> 0. The circuit appeared in Fig. 4(a) is throughout DT interval in which switch S2 is turned on and the input energy is stored in inductor L. Despite the fact that the switch S1 is additionally turned on, in any case its outside series diode becomes reverse biased due to inverse input voltage vin across it. Along these lines, no current flows through switchS1 througout this interval, as appeared in Fig. 4.

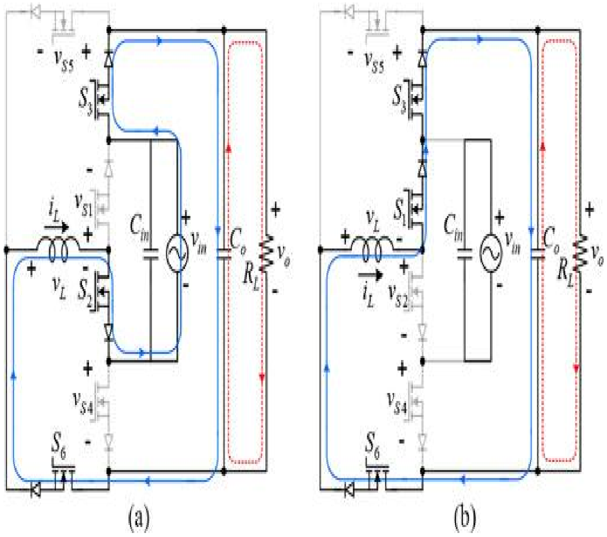

Figure 4. Non-inverting buck operation when v_{in}>0. Equivalent circuit (a) during *DT* and (b) during (1−*D*)*T* .

During (1 − D)T interval as in Fig. 3.3.2(b), switch S2 is turned off while S1conducts in this interval as its series diode become forward biased because of free-wheeling action of inductor L current. Energy stored in inductor is discharged to load in this interval.

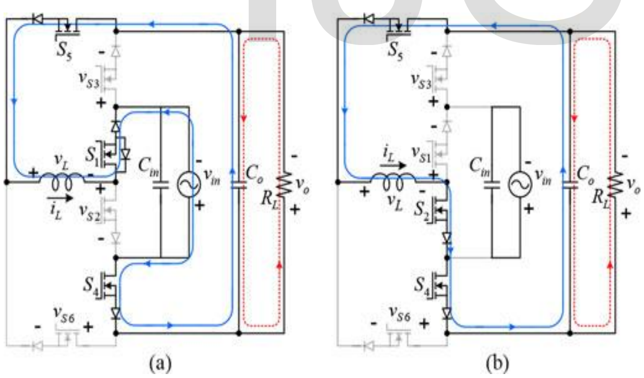

Figure 5. Non-inverting buck operation when v_{in}<0. Equivalent circuit (a) during *DT* and (b) during (1−*D*)*T* .

For vin < 0, switches S2,S4,S5 are dependably turn on while switches S3,S6 are dependably turn off, and S1becomeshigh frequency switch. The operation for vin < 0 is same as clarified for vin > 0, with only difference is that now the switchS1 performs same as S2 (for vin > 0), and the other way around. The comparable circuits amid this negative half-cycle are appeared in Fig. 5(a) and 5(b). By applying volt–second adjust condition on inductor L from (1) and (2), the pickup in this buck mode is given by

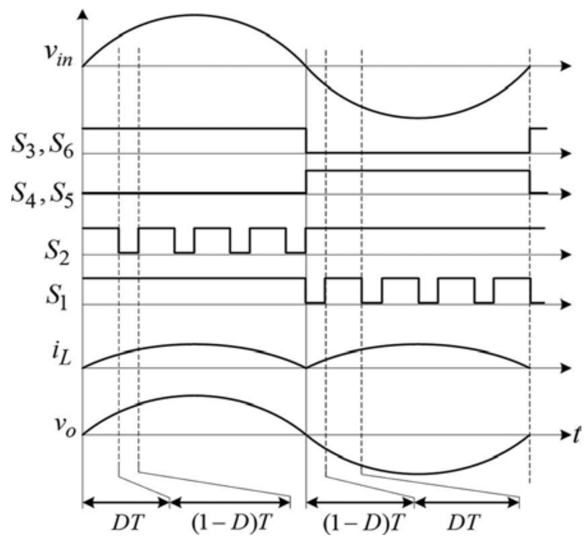

Figure 6. Key operational waveforms during non-inverting buck mode operation.

Non-inverting Boost Mode Operation.

The operation of boost mode is same as buck mode but only the pulses for switch s5 and s1 are interchanged and s2 and s6 are interchanged.

Inverting Buck–Boost Mode Operation.

The operation of buk-boost mode is same as boost mode but only the pulses for switch s6 and s4 are interchanged and s5 and s3 are interchanged.

Control strategy

The output voltage of the converter has to be maintained constantly as same as the desired value. The PI controller is employed to attain the buck-boost ac output voltage which is achieved by varying the duty ratio of the converter circuit. The feedback loop of the converter is designed to control the duty ratio and control the output voltage.

4 Simulation results

Simulation of a closed loop control of buck converter

In this system by applying the closed loop control scheme to previous converter for control on output voltage amplitude. In this system the high frequency operation is carried out for reduction of THD in output voltage.

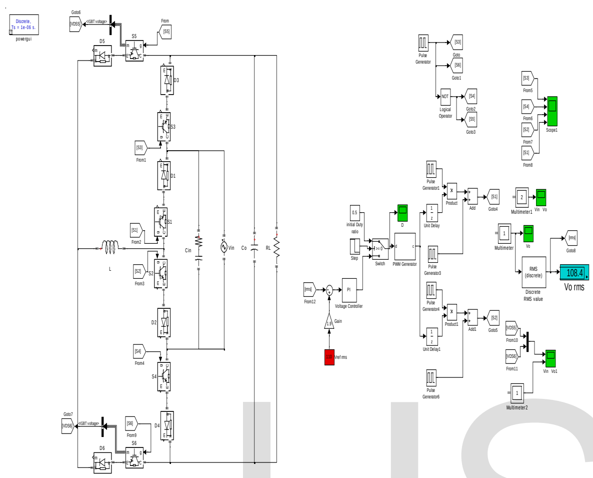

Figure 7. MATLAB simulation of a closed loop control of buck converter.

The above figure shows the MATLAB design of a proposed buck module. In our previous module we can step down the input voltage by changing the duty ratio. In our previous module the output voltage is not stable.But in our module by applying a closed loop PI controller to previous module we can get the stable output voltage.

In this module the feedback loop control as the RMS block it does not generate the finite value for one cycle or two cycles and it generates at least one or two cycles. So we have to provide initial duty ratio between 0 and 1. We have set a time of 0.05 sec at which the system change from open loop to closed loop.In this module we have give a v reference voltage and error detector in module generate error between v output voltage and v reference and it gives to PI controller then the PI controller reduced the error and gives to PWM. Here the changes the duty ratio. In the above module we can give v reference as $110V_{rms}$/ 60 HZ and after simulation we can get $109V_{rms}$/ 60 HZ in ac converters the output is not precies and it is instantaneously. In this module we can step down the input voltage.

Output results of a closed loop control of a buck converter

Switching waveforms

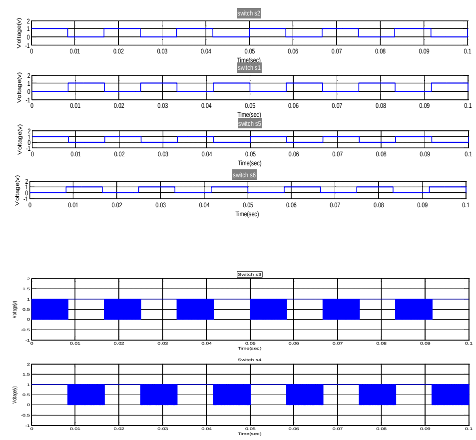

Figure 8. Switching waveforms of a closed loop control of a buck converter.

The above fig shows the switching operations of boost converter in inverting mode. In this mode switch s3,s6 on for positive half cycle and off for negative half cycle. switch s4,s5 off for positive half cycle and on for negative half cycle for fundamental frequency.S2 is pulse rating for positive half cycle with switching frequency off 25KHZ and completely on for negative off cycle. The switch s1 is completely on for positive half cycle and pulsating for negative half cycle with frequency of 25KHZ.

Input, output voltage

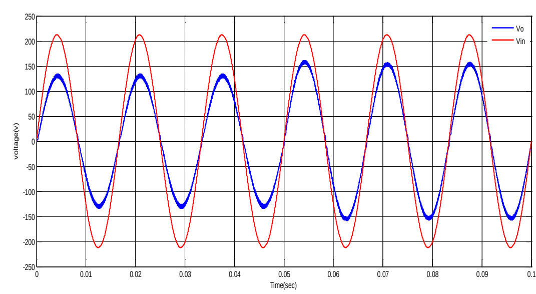

Figure 9. Voltage comparisionof a closed loop control of a buck converter.

The above figure shows the voltage comparision of input and output. In module the output is changed after 0.05 sec because we are giving initial time of 0.05 sec. But in our module the output voltage decreased. In this converter we can perform step down operation.

Automatic changing of Duty ratio in buck mode

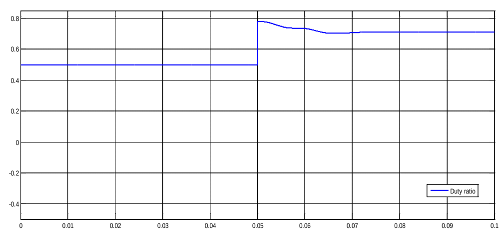

Figure 10. Duty ratio changes of a closed loop control of a buck converter

The above figure shows the changing of duty ratio in our module. In the previous module by changing the duty ratio to get the desired output voltage.But in this module by giving v reference we get the output voltage. In this module the duty ratio is automatically changed due to a closed loop control. In the feedback loop control of a RMS block does not generate the finite value for 1 cycle it provides finite value for 1 or 2 cycles. So we have to provide initial duty ratio value of 0.5. Previously the duty ratio is maintained at 0.73 by changing it manually where as here it is maintained constant i.e 0.73 by using a closed loop circuit.

THD of a closed loop control of a buck converter

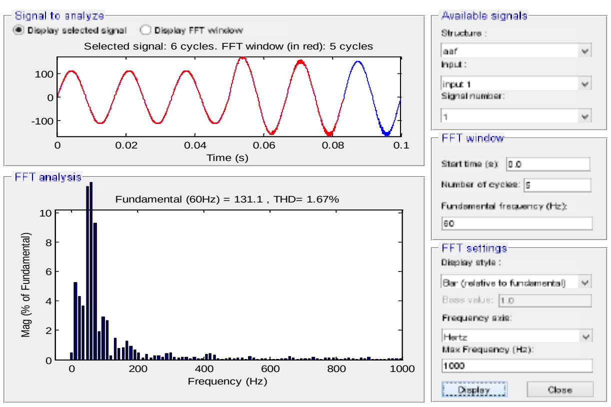

Figure 11. THD of a closed loop control of a buck converter.

In the previous we get the THD of 1.95%. But in this module by applying high frequency to get reduced the THD.Then after we get THD of 1.67%.

Simulation of a closed loop control of boost converter

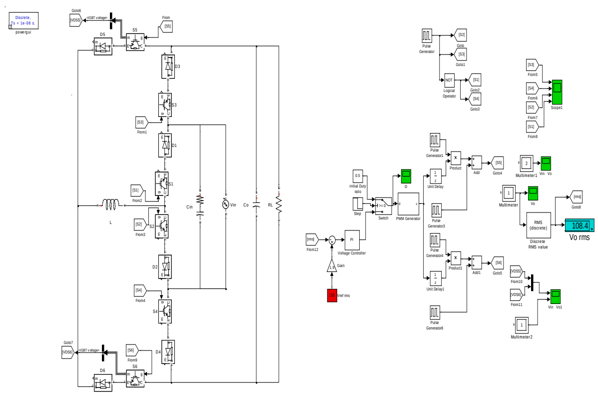

Figure 12. MATLAB simulation of a closed loop control of boost converter.

The above figure shows the MATLAB design of a proposed boost module. In our previous module we can step up the input voltage by changing the duty ratio. In our previous module the output voltage is not stable. But in our module by applying a closed loop PI controller to previous module we can get the stable output voltage.

. In the above module we can give v reference as $110V_{rms}$/ 60 HZ and after simulation we can get $109V_{rms}$/ 60 HZ in ac converters the output is not precies and it is instantaneously. In this module we can step up the input voltage.

Output results of a closed loop control of a buck converter

The below fig shows the switching operations of boost converter in inverting mode. In this mode switch s2,s3 on for positive half cycle and off for negative half cycle. switch s1,s4 off for positive half cycle and on for negative half cycle for fundamental frequency.

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Switching waveforms

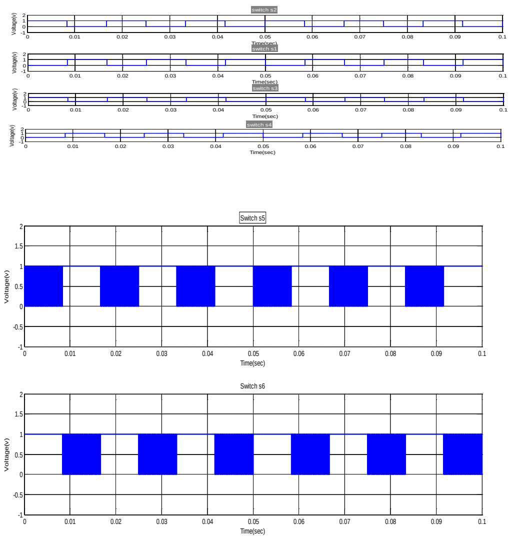

Figure 13. Switching waveforms of a closed loop control of a boost converter.

The above fig shows the switching operations of boost converter in inverting mode. In this mode switch s2,s3 on for positive half cycle and off for negative half cycle. switch s1,s4 off for positive half cycle and on for negative half cycle for fundamental frequency.

S5 is pulse rating for positive half cycle with switching frequency off 25KHZ and completely on for negative off cycle. The switch s6 is completely on for positive half cycle and pulsating for negative half cycle with frequency of 25KHZ.

Input, output voltage

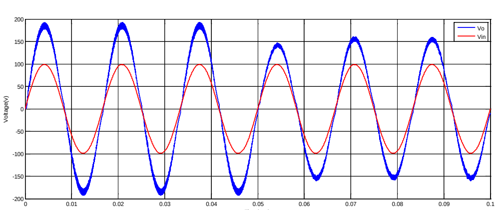

Figure 14. voltage comparision of a closed loop control of a boost converter.

The above figure shows the voltage comparision of input and output. In module the output is changed after 0.05 sec because we are giving initial time of 0.05 sec. But in our module the output voltage increased. In this converter we can perform step up operation.

Automatic changing of Duty ratio in boost mode

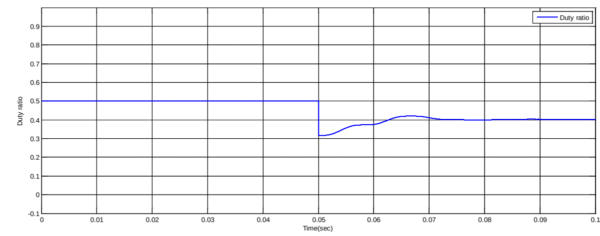

Figure 15. Duty ratio changes of a closed loop control of a boost converter

The above figure shows the changing of duty ratio in our module. In the previous module by changing the duty ratio to get the desired output voltage.

Previously the duty ratio is maintained at 0.37 by changing it manually where as here it is maintained constant i.e 0.39 by using a closed loop circuit.

THD of a closed loop control of a boost converter

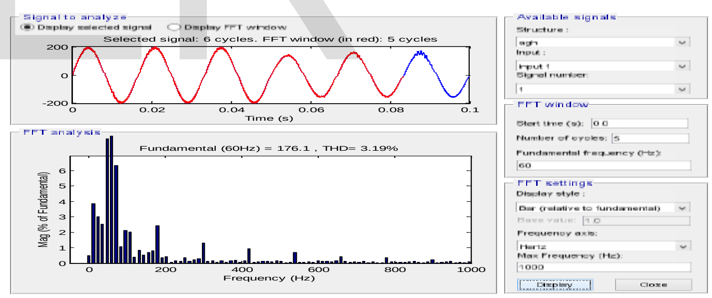

Figure 16. THD of a closed loop control of a boost converter.

In this module by applying high frequency to get reduced the THD.Then after we get THD of 3.19%.

Simulation of a closed loop control of buck-boost ac-ac converter

In this system by applying the closed loop control scheme to previous converter for control on output voltage amplitude. In this system the high frequency operation is carried out for reduction of THD in output voltage.

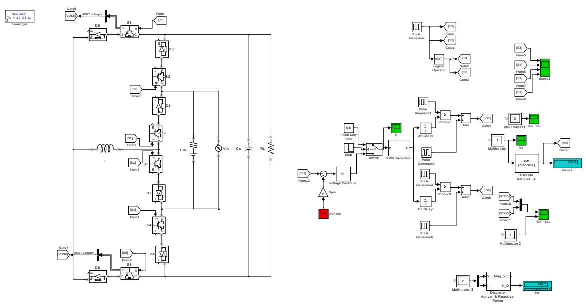

Figure 17. MATLAB simulation of a closed loop control of buck-boost ac-ac converter.

The above figure shows the MATLAB design of a proposed module. In our previous module we can step up and step down the input voltage by changing the duty ratio. But in our previous module the output voltage is not stable.In our module by applying a closed loop PI controller to previous module we can get the stable output voltage.

Output results of a closed loop control of a buck-boost converter

Switching waveforms

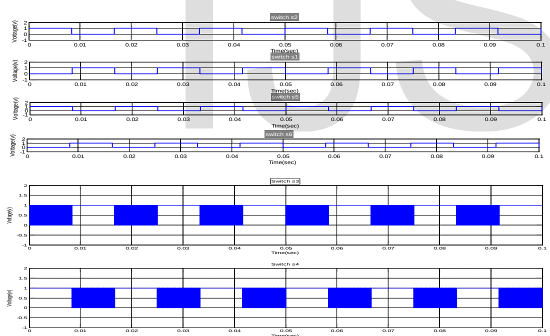

Figure 18. Switching waveforms of a closed loop control of a buck-boost converter.

Input, output voltage

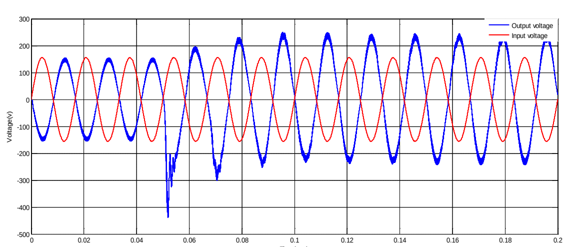

Figure 19. Voltage comparision of a closed loop control of a buck-boost converter.

The above figure shows the voltage comparision of input and output. In the above figure the output voltage is phase shifted to 180 degrees. In module the output is changed after 0.05 sec because we are giving initial time of 0.05 sec. In our previous module the output voltage is 180 degrees phase shifted. But in our module the output voltage is increased and decreased with 180 degrees phase shift. In this converter we can perform both step up and step down.

Input, output voltage and inductor current

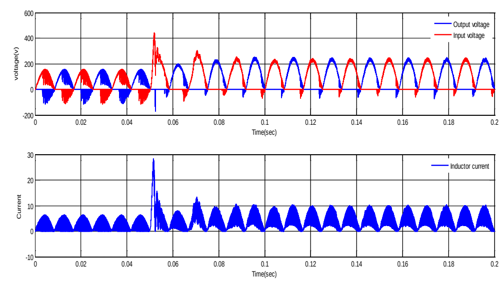

figure 20. Input voltage, output voltage and inductor current waveforms of a closed loop control of a buck-boost converter.

The above figure shows the input and output voltage and inductor current of our module. In after 0.05 sec the inductor current will be increased because we can give initial time of 0.05sec.

Automatic changing of duty ratio

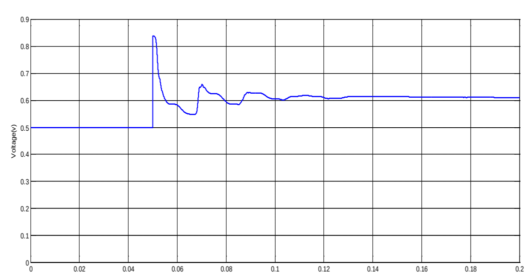

Figure 21. Duty ratio changes of a closed loop control of a buck-boost converter in boost mode

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THD of a closed loop control of a buck-boost converter

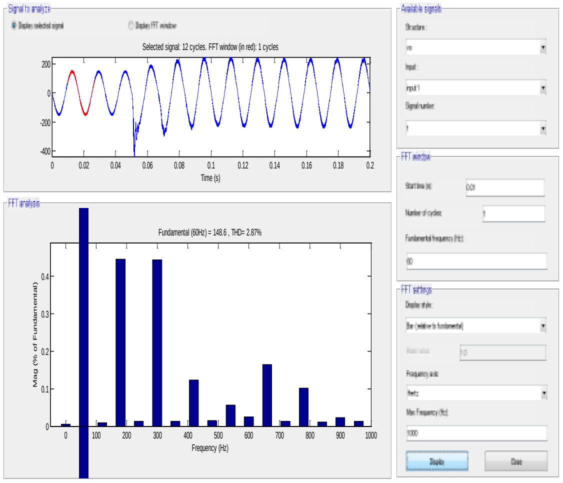

figure 22. THD of a closed loop control of a buck-boost converter.

In the previous we get the THD of 3.87%. But in this module by applying high frequency to get reduced the THD.Then after we get THD of 2.87%.

5 CONCLUSION

Earlier projects or works have done with open loop control system, so there is no feedback from the output side and hence there is no control of output voltage. So here have to control the output voltage has to maintain high gain which depends upon the duty ratio. In our project the duty ratio varied by manually. So that extension introducing a PI controller as a feedback loop system, the duty ratio of MOSFET is controlled dynamically, this controls the output voltage of the circuit topology with any change in input or load. In the previous project the THD will be high but in our project by applying high frequency to get reduced the THD.

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