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SOFT-SWITCHING CURRENT-FED PUSH-PULL CONVERTER FOR PV APPLICATION

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ABSTRACT

In this paper, a soft switching single-inductor push-pull converter is discussed. A push-pull converter is suitable for low voltage photovoltaic applications, because the step up ratio of high frequency transformer is high. Photovoltaic is considered to be a popular source of renewable energy due to several advantages, specifically low operational cost, and maintenance free and environmental friendly. In the conventional converter, primary switches are turned ON at the zero voltage switching condition and turned off at zero current switching condition through parallel resonance between the secondary leakage inductance of a transformer and resonant capacitor. The proposed push-pull converter also decreases the switching loss using soft switching of the primary switching. The boost rectifier added reduces the turn's ratio of the transformer further when compared to the voltage doubler.

Keywords: current-fed push pull converter, soft switching, boost rectifier.

1. INTRODUCTION

The use of photovoltaic energy has been widely increased due to its renewable energy concept and environmental friendly. These PV energy generations uses PV system modules which are connected in series and parallel through string diodes for high power generations. These systems have disadvantages such as the use of high voltage dc cables between the PV modules and the inverter losses in the string diodes. String type inverters using PV modules in series can be used. These are no losses associated with string diodes, and separate maximum power point tracking (MPPT) can be applied to each string. These increase the overall efficiency compared to the centralized inverter.

2. CONVENTIONAL PUSH-PULL CONVERTER

The Push-Pull converter is utilized in PV ac module systems because of the fact that it has only few components and isolation between the PV modules and the ac grid line. Using a voltage-fed source in the primary side of the transformer in the circuit is not a good idea which should have high step-up ratio due to low input voltage and the high output voltage. Therefore, the push-pull converter is used with a current source which can decrease the turn ratio of the transformer.

In the secondary side of the transformer, the conventional push-pull converter is designed using center-tap or full-bridge types. In the center-tap, the voltage stress across diodes is higher than the voltage stress across the diodes in full-bridge type. Therefore the center-tap type is not suitable for a topology with a high secondary voltage of the transformer.

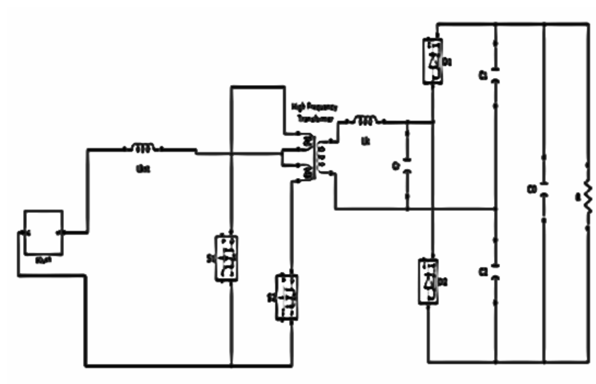

Figure-1. Main circuit of the conventional Push-Pull Converter.

The conventional push-pull converter is composed of switching devices (S_1, S_2), a boost inductor (L_{bst}), a high frequency transformer. The primary-side voltage (v_{T1}, v_{T2}) of the transformer is the sum of the input voltage v_{in} and L_{bst} voltage v_{Lbst}.

3. SOFT SWITCHING TECHNIQUE

The conventional converter uses soft switching technique so that the switching losses can be reduced and the lifetime of the switch is also improved. The switching losses can be reduced with the soft switching when the primary switches are turned ON and OFF. That is the primary side switches are turned ON at the zero voltage switching condition and turned OFF at the zero current switching condition through parallel resonance between leakage inductance and resonant capacitor.

A. ZCS for Switch S_1

At first, the current flow through S1. The flow of the resonant current at the resonant tank is reversed. i_{Lk} decreases linearly.

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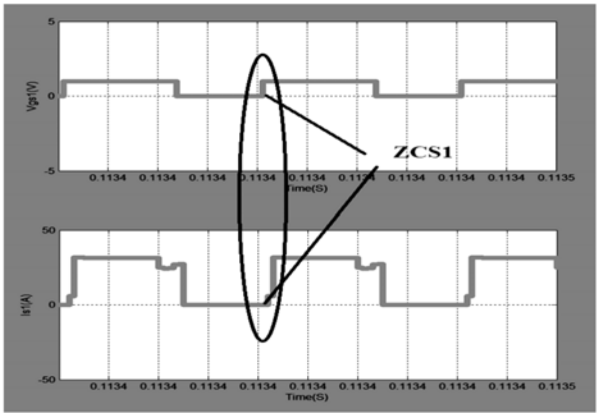


Figure-2. ZCS for S_1.

B. ZCS for switch S_2

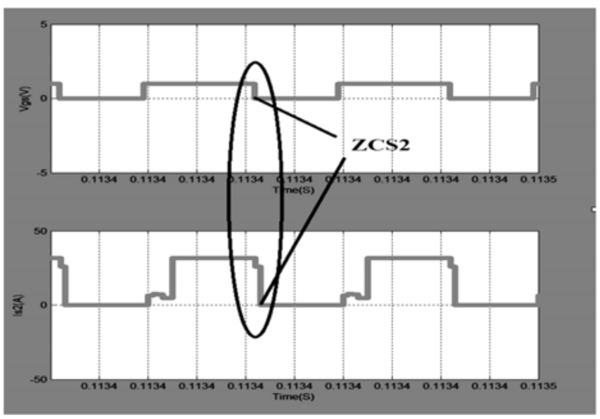


Figure-3. ZCS for switch S_2.

C. Parameters of simulation

Parameters	Value	Unit
Input voltage	20-40	V
MPP voltage	30.9	V
Output voltage	400	V
Output Power	250	W
Boost Inductor	127	μH
Secondary side magnetic inductance	950	μH
Secondary leakage inductance	34	μH
Resonant capacitor	4.7	nF
Switching frequency	50-100	KHz
Transformer turn-ratio	5.5	

Input voltage

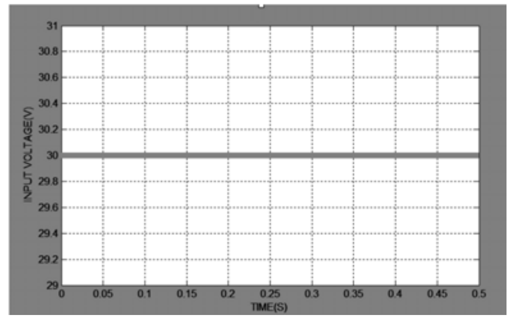


Figure-4. Input voltage of conventional converter.

Triggering pulses

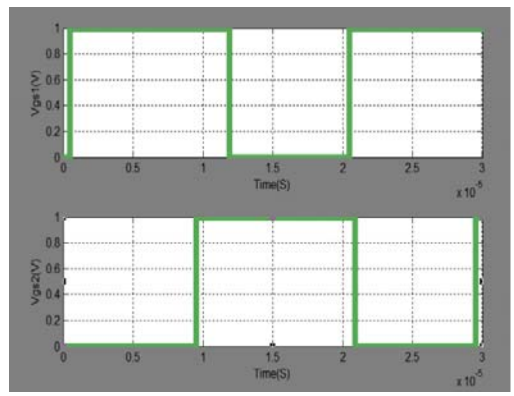


Figure-5. Triggering pulses of conventional converter.

Output voltage

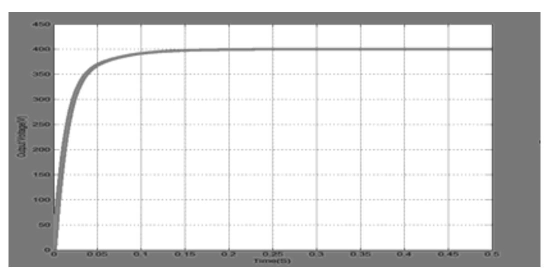


Figure-6. Output voltage of the conventional converter.

Output power

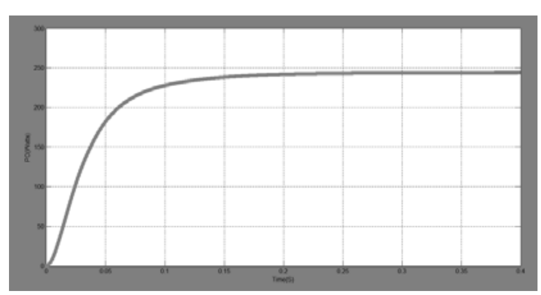


Figure-7. Output power of conventional converter.

4. PROPOSED PUSH-PULL CONVERTER

The conventional push-pull converter has turns ratio of the transformer to be 5.5. Inorder to reduce this turns ratio further the voltage doubler circuit is replaced by a boost rectifier. Therefore by using a Boost rectifier a high output voltage is obtained for the same turns ratio of the transformer or reduced transformer turns ratio is obtained.

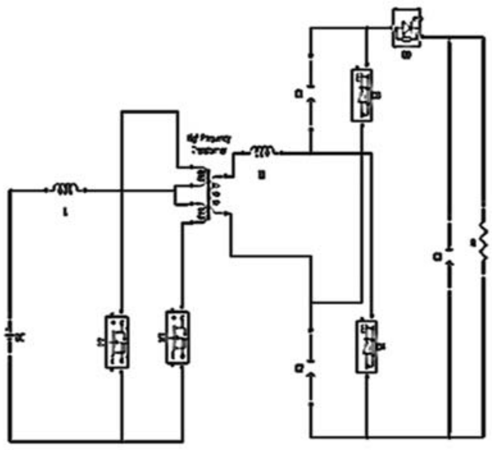
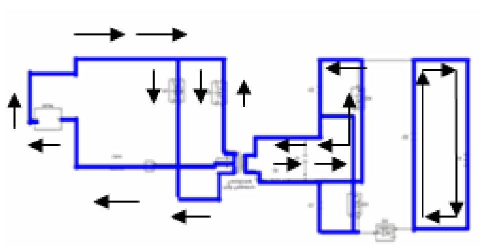


Figure-8. Main circuit of proposed push pull converter.

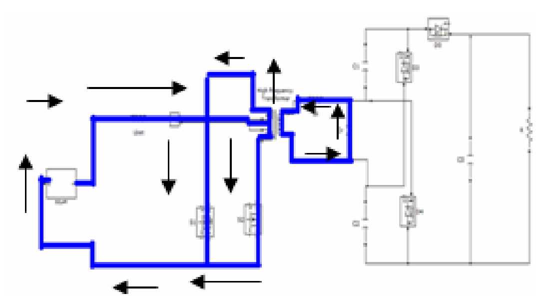
A. Modes of operation

Mode-1:



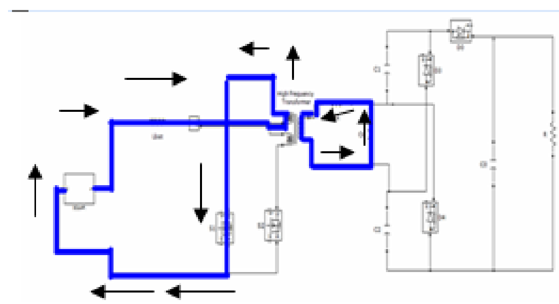
During mode 1 S1 and S2 are ON. The current flow of the resonant current at the resonant tank is reversed. i_{Lk} decreases linearly. During this mode D_3 and D_4 are in forward biased. C_1, C_2 are charging condition. C_o supplies the energy to the load.

Mode-2:



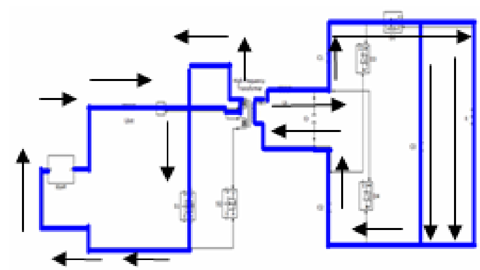
During mode 2 S1 and S2 are ON. During this mode all diodes are in reverse biased.

Mode-3:



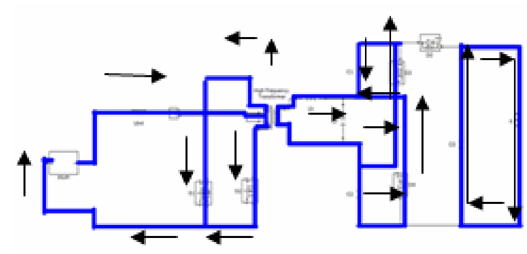
During mode 3 S1 is ON condition. S2 is off condition. The current flow of the resonant current at the resonant tank is reversed. i_{Lk} decreases linearly. During this mode diodes are reverse biased.

Mode-4:



During mode 4 S1 is ON condition. S2 is off condition. During this mode D0 is in forward biased. C0 is charging condition and the energy is transferred to the load.

Mode-5:



During mode 5 S1 and S2 are ON. The current flow of the resonant current at the resonant tank is forward. i_{Lk} increses linearly. During this mode D3 and D4 are in forward biased. Co supplies the energy to the load.

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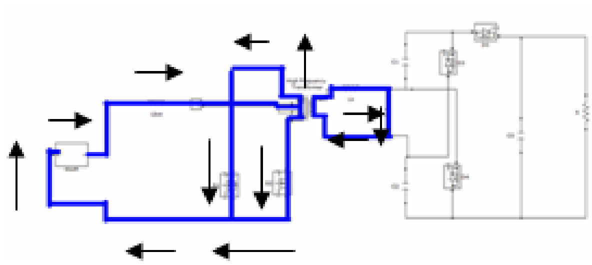
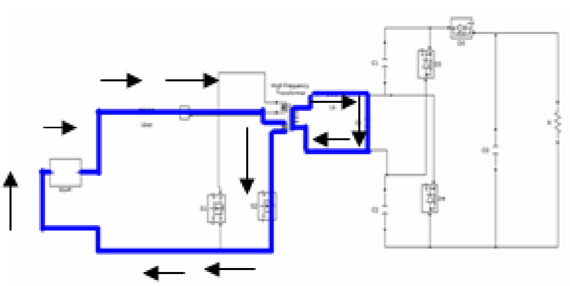
Mode-6:



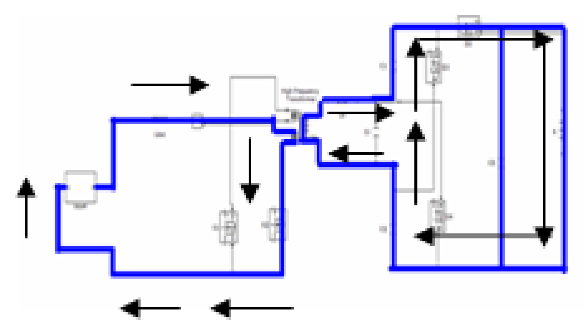
During mode 6 S1 and S2 are ON. During this mode all diodes are in reverse biased. Cr is charging.

Mode-7:



During mode 7 S2 is ON condition. S1 is off condition. The current flow of the resonant current at the resonant tank is forward. i_{Lk} increases linearly and all diodes are reverse biased.

Mode-8:



During mode 8 S2 is ON condition. S1 is off condition. During this mode D0 is in forward biased. C0 is charging condition and the energy is transferred to the load.

B. Simulation results

MATLAB has been used for simulating and the waveform is sketched for the proposed system.

Input voltage

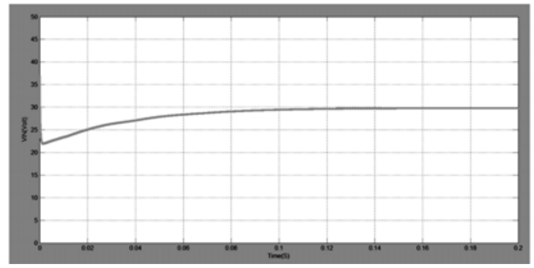


Figure-9. Input voltage of the proposed converter.

Output voltage

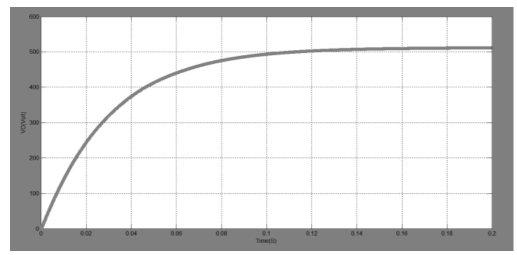


Figure-10. Output voltage of the proposed converter.

Thus the output voltage obtained here is in is the level of 500V which is higher than the voltage obtained in the conventional push pull converter.

Output power

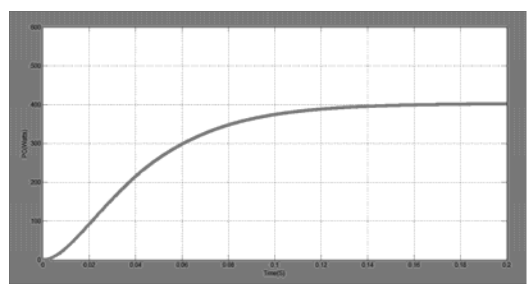


Figure-11. Output power of proposed converter.

The above results are simulated for the *R load.* The following results which are simulated for the proposed system are for the *motor load* .

Input voltage

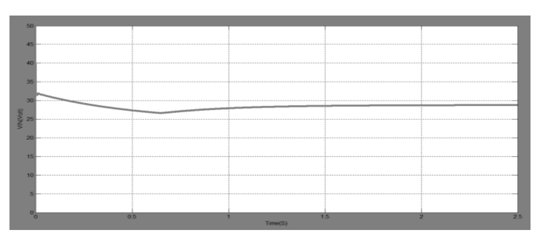


Figure-12. Input voltage of proposed converter.

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Current through inductor (L_{bst})

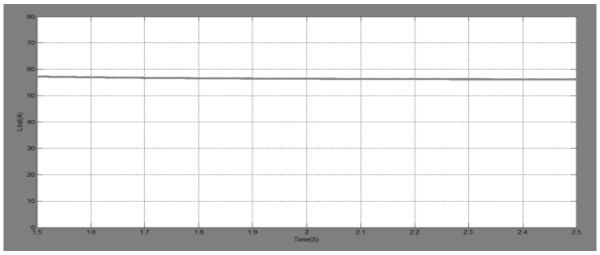

Figure-13. Current through Inductor (L_{bst}) of proposed converter.

Output voltage

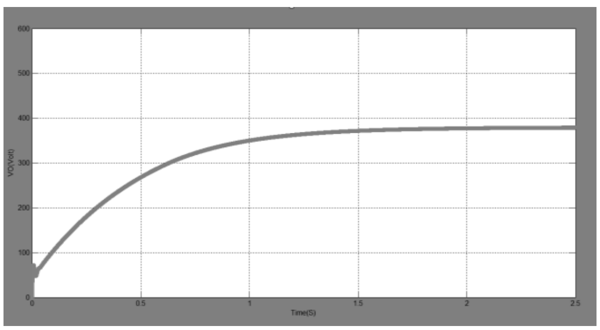

Figure-14. Output voltage of proposed converter.

The above results are sketched for the *open loop system.* The following results are simulated for the closed loop system. The closed loop system is advantageous over the open loop system in accuracy. It is otherwise called as the Automatic control system as they are not disturbed by any non-linearities. As the closed loop system is composed of a feedback mechanism, they clear the errors between the input and output signals and so they remain unaffected for the external noise sources.

Input voltage

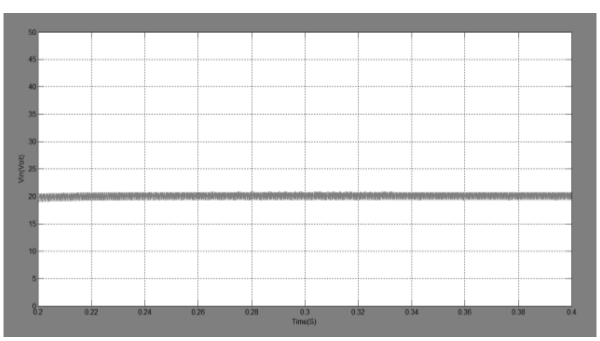

Figure-15. Input voltage of a proposed converter with R-load Closed loop system.

Output voltage

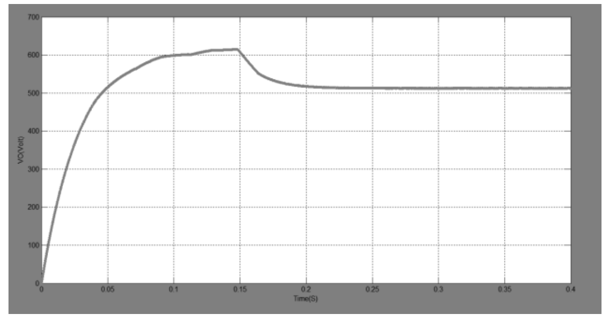

Figure-16. Output voltage of a proposed converter with R-load Closed loop system.

The above results are simulated for the closed Loop system of a R-Load.

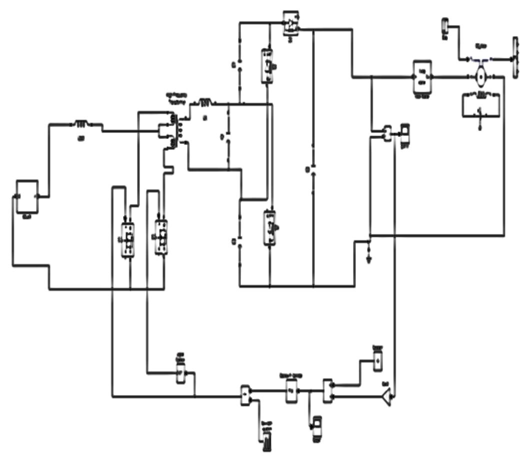

Figure-17. Circuit of the proposed converter driving a motor load of a closed loop system.

The above circuit shows the circuit of a Push-Pull converter driving a Motor load of a closed loop system. The simulation results are as follows.

Input voltage

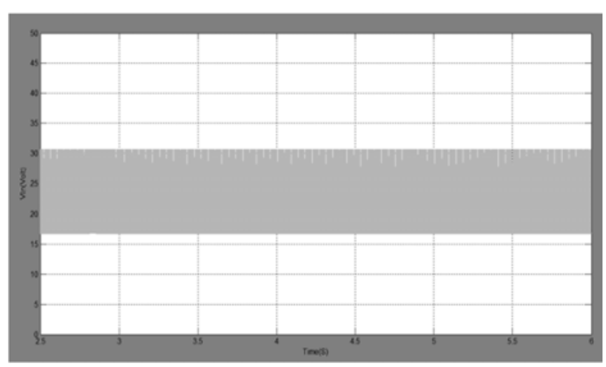

Figure-18. Input voltage of a proposed converter with motor load closed loop system.

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Output voltage

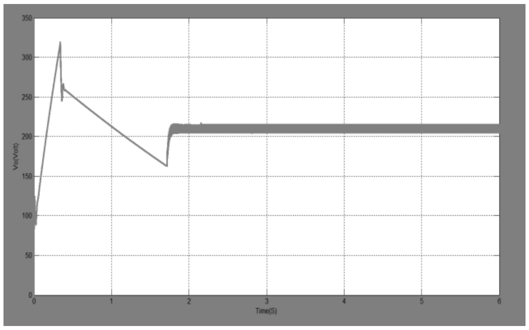
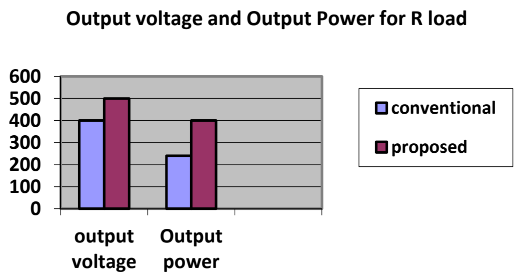


Figure-19. Output voltage of a proposed converter with motor load Closed loop system.

C. Performance evaluation



D. DC/AC conversion

This output which is obtained from the push pull converter is the DC. This can be converted to AC by using any one of the multilevel inverter. Here H-bridge inverter is proposed.

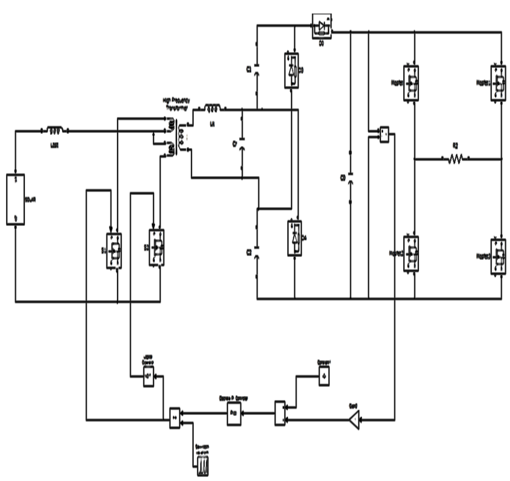


Figure-20. Circuit of the proposed Push-Pull Converter along with inverter.

5. CONCLUSIONS

Thus in this paper, the soft switching technique has been used inorder to reduce the switching losses. The boost rectifier added on the secondary side of the transformer reduces the transformer ratio to a greater value. In future various converters shall be used to analyse the performance.

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