DESIGN OF PUSH PULL MICRO INVERTER FOR SMALL SCALE APPLICATIONS

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Abstract
In this article, a single phase push pull micro inverter is proposed for small scale residential applications. The inverter is designed for 375 W load at 100 kHz switching frequency. Sinusoidal pulse width modulation (SPWM) is proposed for two input switches and a high frequency transformer is used for isolation purpose. An LC filter is used after diode rectifier to reduce high frequency harmonics and rectified sinusoidal output at 310 V peak is generated at output side. To produce utility equivalent pure sine wave, a full bridge is used at output stage. The overall power conversion efficiency is high and total harmonics distortions are very less.

Keywords: Push-pull converter; Power electronics; PSpice

I. INTRODUCTION

India has maximum scope of solar energy generation due to its geographic location. As per the recent government policy and encouragement from the government, there is tremendous boost in generation and utilization of solar energy. This will encourage the development of different power converter topologies for solar energy utilization. Majority of our existing electrical devices are designed and operates on alternating current (AC) supply systems, and that is why design and development of dc-ac converters with different configuration topologies is desirable. Efficient and diagonal based micro inverter design was proposed in [3,4] for solar PV system. DSP based signal processing for inverter based control is presented in [5,6]. Standard push pull converter with a dynamic modulation control has been proposed in [7]. Here in this article, push pull inverter is proposed with sinusoidal pulse width switching technology. Single PWM, Multiple PWM, SPWM, Modified SPWM, Phase displacement control PWM are the popular voltage control techniques of single phase inverter. Among all the voltage control methods, Sinusoidal Pulse Width Modulation (SPWM) is suitable for voltage control as it has lower Total Harmonic Distortion. By increasing the SPWM frequency harmonics get reduced after filtering. Here SPWM is applied to the input switches of isolated push pull converter topology which provides high efficiency.

II. PUSH PULL MICRO INVERTER TOPOLOGY

Proposed push pull inverter topology schematic is as shown in Fig. 1. It is made up of two main switches M1 and M2 on the input side. The output side four switches M3 to M6 are switched at 50 Hz frequency just to produce proper sinusoidal output. When M1 is turned ON, V_{dc} appears across one half of the primary windings as shown in Fig 2. When M2 is turned ON ,-V_{dc} is applied across the other half of the transformer as shown in Fig. 3. The voltage of the primary swings form –V_{dc} to V_{dc}. An ac line filter is used to remove high frequency components from the output. A bridge circuit is used to convert the rectified sine into the full sine wave on the output side.

This section provides operation of push pull inverter topology. Fig. 1 shows the schematic diagram of push pull converter. When M1 is turned ON with M2 turned OFF, as shown in Fig 2 the voltage across half of the primary winding is V_{dc}. The primary current starts to build up and transfers energy from the primary winding to secondary winding and into ac line filter and the load through the rectifier diode D1 which is forward biased.

When M2 turns ON with M1 is turned OFF as shown in Fig. 3, the polarity of the transformer voltage reverses. This causes D1 to turn off and D2 to turn ON. While D2 is conducting, energy is delivered to load through diode D2, line LC filter and output side two switches.

Generally, high switching frequency is used at input switches. High frequency switching is generated using SPWM technique. Conceptually, high frequency triangular wave or saw tooth wave is compared with low frequency sine wave to produce SPWM gating signals. These pulses are used to switch input switch M1 and inverted of these pulses are used to switch input switch M2 as shown in Fig. 1.

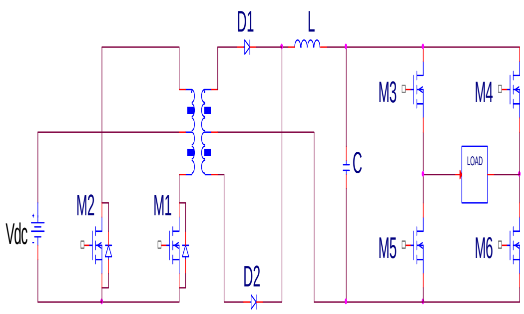

Fig. 1 Push Pull Micro Inverter

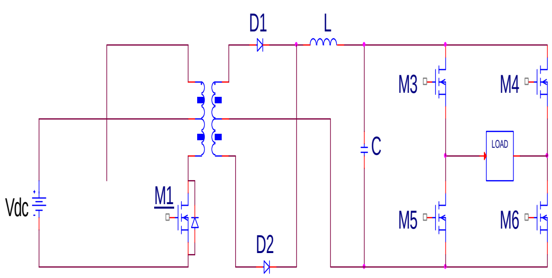

Fig. 2 Conduction Mode1: Push Pull Micro Inverter

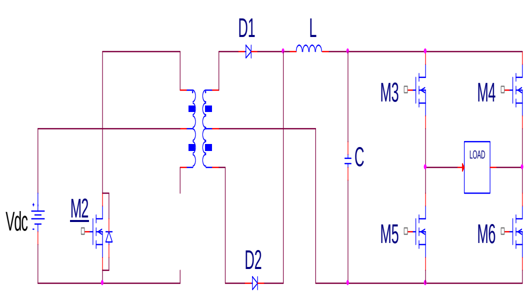

Fig. 3 Conduction Mode 2: Push Pull Micro Inverter

III. DESIGN PARAMETERS

This section discusses design parameters of various components used for proposed push pull inverter topology. The specifications of inverter is provided in Table I.

(a) Design of transformer

Table II provides the input parameters of the push pull inverter topology. The input parameters are set such a way that if it is connected to proper solar panel, the same topology will work for ac output from regenerative energy. Here, the output voltage requirement is 310 V_p and input voltage is 36V dc. Thus the turns ratio of the transformer is calculated as follows

$$\frac{N_2}{N_1} = \frac{V_{Out}}{V_{in}} = \frac{310}{36} = 8.61 = 9 \quad (1)$$

Step 1: Primary turns selected to satisfy the ac voltage stress and core saturation property is calculated by using equation (2).

$$N_p = \frac{VT}{BA_e} = \frac{V}{FBA_e} = 3.7 \quad (2)$$

Where,

N_p= Minimum Primary turns

V= Maximum Primary Voltage

T = Maximum Period

F= Switching Frequency =100 kHz

A_e= Effective Center pole area of the coil (0.97 cm^2)

B= Magnetic Flux Swing typically 200mT

Step 2: The value of primary inductance of coil wound on core is calculated by using equation (3)

$$L_p = A_L {N_P}^2 \geq 41\mu H \quad (3)$$

Where,

L_p = Primary inductance value

L_s =Secondary inductance value

A_L= 3 μH

Secondary inductance value is calculated by using equation (4)

$$L_s = N^2 L_P \geq 3.6mH \quad (4)$$

Table I: Specifications of Push Pull Micro Inverter

Parameter	Value
Power Rating	375 W
Input Voltage	36 V dc
Input Current	10.41 A
Output Voltage	310V(Peak) & 219.85 V (RMS)
Output Current	1.96 A(Peak) & 1.4A (RMS)
Switching Frequency	100kHz
Power Conversion Efficiency	82.13%
THD	2.40%
Simulation Tool	Orcad Capture CIS Lite 17.2 & Orcad Capture Pspice Lite 17.2

Table II. Input Parameters of Push Pull Inverter

Parameter	Value
Input Power	375 W
Input Voltage	36 V dc
Input Current	10.41 A
Switching Frequency	100 kHz

Inductor is designed in such a way that it can tolerate maximum current. The compromised value of the inductor is 4mH. Capacitor can be calculated by choosing the corner frequency 10% of the switching frequency. The compromised value of the capacitor is 2μF. The input switch, rectifier diode and output switch parameters are as shown in Table III, Table IV and Table V respectively.

Table III. Input MOSFET Specifications (IRFZ40)

Parameter	Value
Drain to Source Voltage	60V
Drain Current	36A
Drain to Source ON state Resistance	R_{DS}=0.028Ω
Turn ON delay Time	14ns
Rise Time	110ns
Turn OFF delay Time	45ns
Fall Time	92ns

Table IV: Rectifier Diode Specifications (MUR4100)

Parameter	Value
Maximum Recurrent Peak Reverse Voltage	1000V
Maximum RMS Voltage	700V
Maximum DC Blocking Voltage	1000V

$$L = \frac{V_{in}}{4 \times fs \times \Delta I_{pp}} \quad (5)$$

$$f_c = \frac{1}{2\pi\sqrt{LC}} \quad (6)$$

Where,
f_c= Corner Frequency =10 kHz
f_s=Switching Frequency =100 kHz
L= Filter Inductor
C=Filer Capacitor
V_{in}= Input DC Voltage
ΔI_{pp}= Inductor Ripple Current

Table V: Output MOSFET Specifications (IRF460)

Parameter	Value
Drain to Source Voltage	500V
Drain Current	21A
Drain to Source ON state Resistance	R_{DS}=0.30Ω
Turn ON delay Time	35ns
Rise Time	120ns
Turn OFF delay Time	130ns
Fall Time	98ns

IV. RESULTS

This section provides the results of the proposed push pull micro inverter. The simulation tool used here is Orcad Capture Pspice lite version 17.2. The input voltage to the circuit is assumed to be provided from constant dc source like battery and it is 36 V. The average input current is found to be 10.41 A. The output voltage and output current can be found as 310 V peak and 1.96 A peak respectively as shown in Fig. 5 and Fig. 6.

i. Input current

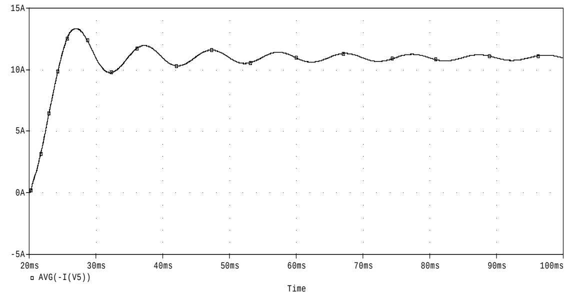

Fig .4 Average Input Current from dc source

ii. Output voltage

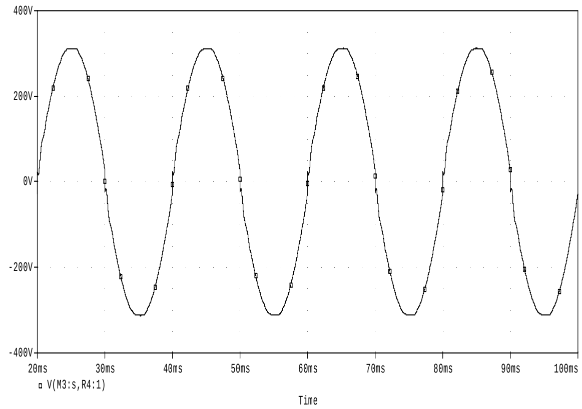

Fig. 5 Output Voltage

iii. Output Current

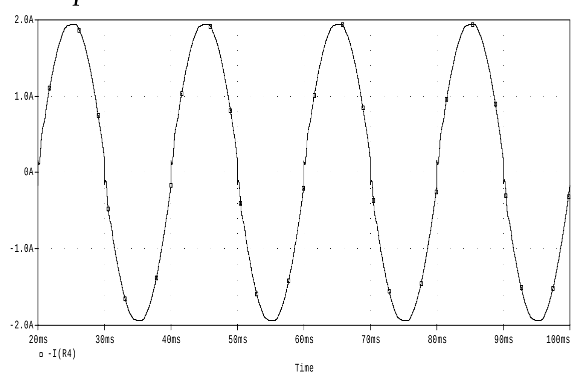

Fig .6 Output Current

V. CONCLUSION

Here, a detailed simulation of single phase push pull micro inverter is performed for 375 W load at 100 kHz switching frequency for small power applications. At input side two switches are used and rectified sine is generated at output side. To make pure sinusoidal ac of 220V (rms) or 310V (peak) at 50Hz frequency, full bridge is used at output side of high frequency transformer after filter. The overall power conversion efficiency is calculated as 82.13 % with 2.4 % total harmonic distortion.

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