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Single Stage Hybrid Inverter with Quasi-Sinusoidal PWM

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ABSTRACT: Because of recent concerns about air and water pollution and the depletion of fossil fuels, interest on use of renewable energy is growing day by day. Solar energy is the most promising source of electricity for future. The energy generated by these renewable sources is in the form of uncontrolled d.c. To convert this uncontrolled dc to desired ac o/p we need the help of inverters. A Single Stage Hybrid Inverter with quasi-sinusoidal pwm & quasi-modified sinusoidal pwm is analysed and simulated in this paper. In the proposed hybrid inverter one of the full bridge is used for charging and discharging of inverter with constant duty cycle and other one is used for the production of a.c. output. Hence the two stage process of boosting and conversion is done on a single stage.

KEYWORDS: Hybrid inverter, single stage topology, H bridge, pulse width modulation, voltage boosting.

I. INTRODUCTION

Nevertheless, the thirst for money and development might have taken us too far that we forgot that the fossil fuels represent a conventional source of energy. [1] In fact this is the truth, but our planet holds limited resources of fossil fuels. The use of conventional sources of energy leads to dangerous global warming effects that damage the whole planet. [2] This is how human-made climate change occurred, disrupting numerous ecosystems and affecting hundreds of thousands of habitats and species all over the world. Most likely, when we would have explored all of them, we would be forced to use renewable source of energy. Living on the grid, most people will never have the need to use a power inverter. The integration of renewable energy sources with the grid plays an important role in energy utilization. [3] It is difficult to utilize electricity from renewable energy sources directly for the injection of power into the grid. Hence there is a need of power electronic converters as an interface between renewable energy sources and grid/load. [4] The power electronic interface like DC-DC converters and DC-AC inverters. These inverters are combined with transformer as the inverted power is very low so for the boosting purpose we need a transformer that will fulfil our requirement. [5] In this paper Hybrid Inverter with Quasi-Sinusoidal and Quasi-Modified Sinusoidal PWM technique has been simulated using MATLAB/Simulink.

II. LITERATURE SURVEY

In conventional view, attention has been drawn to increase the boost capability of inverters [4]. In recent time two stage topology is the frequently used topology and its foremost advantage is its simple control as each stage can be controlled independently [5]. But it has a disadvantage of high switching frequency and hence low efficiency. B. Xiao introduced a cascaded H-bridge multilevel inverter through which voltage boosting is achieved by connecting definite DC sources in series [6]. But the requirement of large no. of power switches makes the system bulky. A single stage topology called Z-source inverter has been introduced in 2003 which has both boost and buck operations on single stage [8]. A new single stage topology has been opted nowadays which is split source inverter (SSI) to overcome the demerits like input dc current discontinuity and higher voltage stress at higher overall voltage gain of Z-source inverter [9].

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II. HYBRID INVERTER

A. Conventional Topology

Conventional H-Bridge inverter plays its important role in Power Generation to regulate generated electrical power from available unregulated natural power like wind and solar, in electrical drive to regulate generated mechanical power from available constant voltage/current power source.

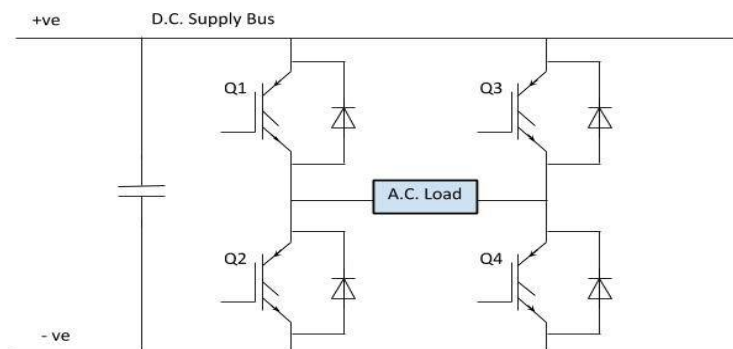


Figure 1 H-Bridge Inverter

Figure.1 Shows conventional H-Bridge Inverter Which Invert the source voltage by using four transistor based static switches. Sinusoidal PWM ensure lower current harmonics when provided with inductive filter or utilized with inductive load.

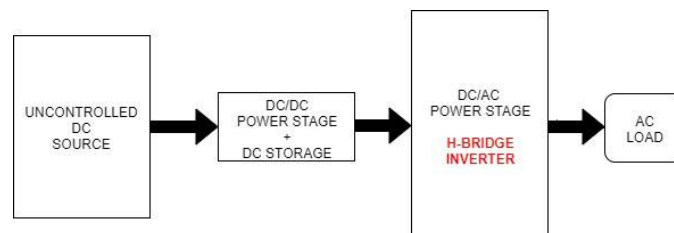


Figure 2 Conventional Topology-1

Figure.2 Shows standalone power generation topology, which extract power from unregulated DC source. It includes DC/DC stage for power/voltage regulation and DC/AC stage for inversion. This is two stage topology in which overall efficiency get reduced due to two stage of power modulation.

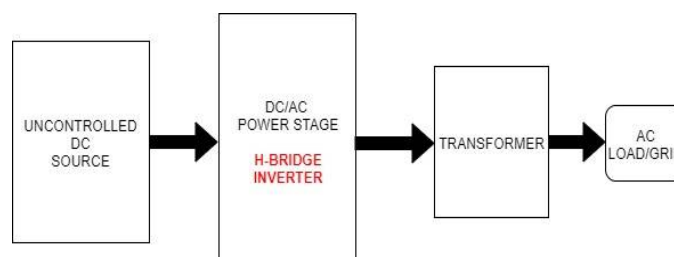


Figure 3 Conventional Topology-2

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Figure.3 Shows power generation topology excluding DC/DC stage, which incorporate MPPT stage for wind/solar into DC/AC stage. Excluding DC/DC stage introduce requirement of transformer for the voltage step up operation to meet the load requirement. Transformer being bulky and costly, make the system big in size and inefficient.

B. Hybrid Inverter Topology

Figure.4 shows Hybrid Inverter topology for regulated inversion. Hybrid inverter having voltage boosting capability, provide one stage solution for power regulation.

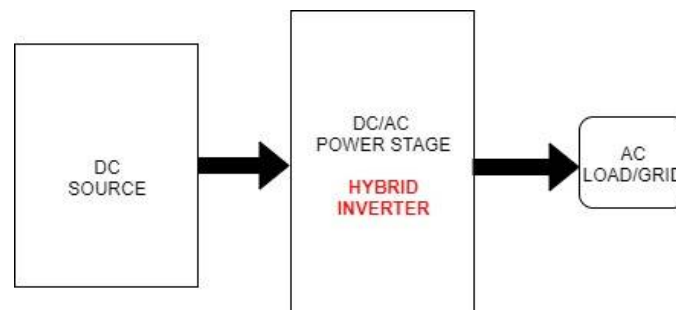


Figure 4 Hybrid Inverter Topology

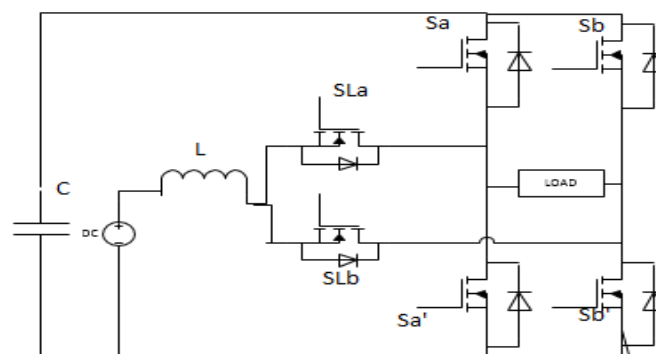


Figure 5 Hybrid Inverter Power Circuit

As shown in above figure hybrid inverter include internal boosting circuit and H-Bridge inverter. Inductor(L) and lower switches of H-Bridge inverter provide voltage boosting and charge capacitor(C) at voltage higher than supply voltage. This eliminate requirement of external DC/DC stage or AC/AC Stage for voltage boosting.

C. Principle of Operation

Hybrid inverter utilized boost converter topology to boost the voltage and H-Bridge inverter to invert that boosted voltage. It's a split source type of inverter which utilize dc link capacitor as a primary source for inversion. Its modes of operation are explained below.

Mode – I ($S_a = 0$ $S_b = 0$): when the upper switches of inverter is assumed to be in off condition, load get short circuited through the upper switches and antiparallel diode according to current direction(fig.A). Lower switches operating at constant high frequency PWM can provide high frequency current variation in inductor which result into the voltage development across it. In this mode inductor get charged from supply.

Mode- II ($S_a = 0$ $S_b = 1$): In this mode load gets connected to the capacitor in opposite direction and hence gets negative voltage across it. The current direction through the load depends on the real and imaginary part of load impedance. Meanwhile inductor remain in charging state through lower switch of negative leg.

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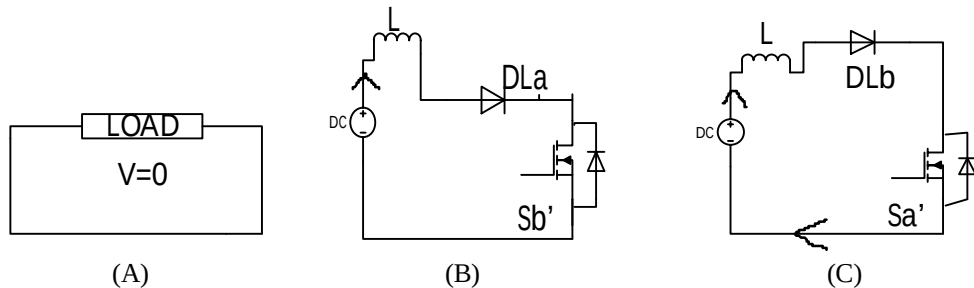
Mode – III ($S_a = 1$ $S_b = 0$): In this mode load gets positive voltage from the capacitor as S_a and S_b' is on. Inductor remain in charging condition in this mode. S_b' provides path for the inductor charging current.

Mode – IV ($S_a = 1$ $S_b = 1$): In this mode load voltage becomes zero. Current direction through the switches/diodes depends on the nature of load. In this mode as the supply voltage and inductor voltage cumulatively becomes more than capacitor voltage, energy flow from source side to the capacitor side.

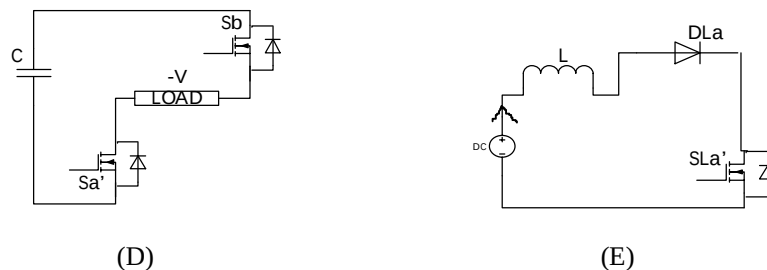
MODES

RESPECTIVE FIGURE

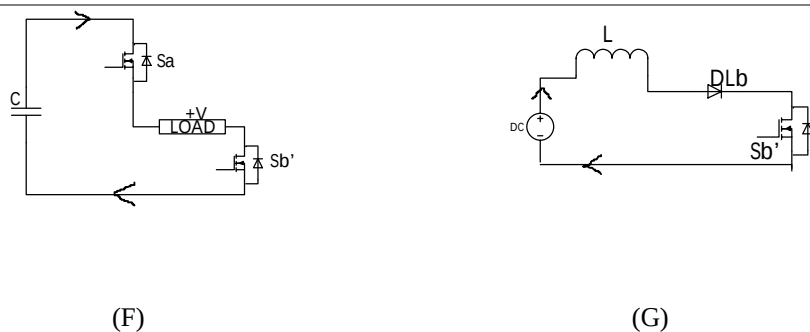
Mode-I
 $S_a=0$
 $S_b=0$



Mode-II
 $S_a=0$
 $S_b=1$



Mode-III
 $S_a=1$
 $S_b=0$



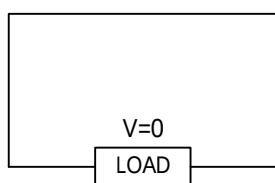
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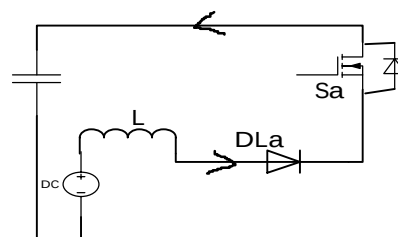
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Mode-IV
Sa=1
Sb=1



(H)



(I)

Table 1

Mode of Operation	Condition of Passive Elements		Load Voltage
	Inductor(L)	Capacitor(C)	
Mode – I	Charging	Floating	0
Mode – II	Charging	Discharging	-V
Mode – III	Charging	Discharging	+V
Mode – IV	Discharging	Charging	0

III. SIMULATION AND RESULTS

Hybrid Inverter has been simulated and analyzed using MATLAB/Simulink. Parameters of Hybrid Inverter has been provided below in table.2. Simulation diagram of Hybrid Inverter including power circuit and control circuit has been described in figure.6 and figure.7.

Table 2

PARAMETER	VALUES
Input Voltage	30 V
Inductance	11 mH
Load (Resistance, Inductance)	15 Ω , 11 mH
Capacitor	1000 μ F

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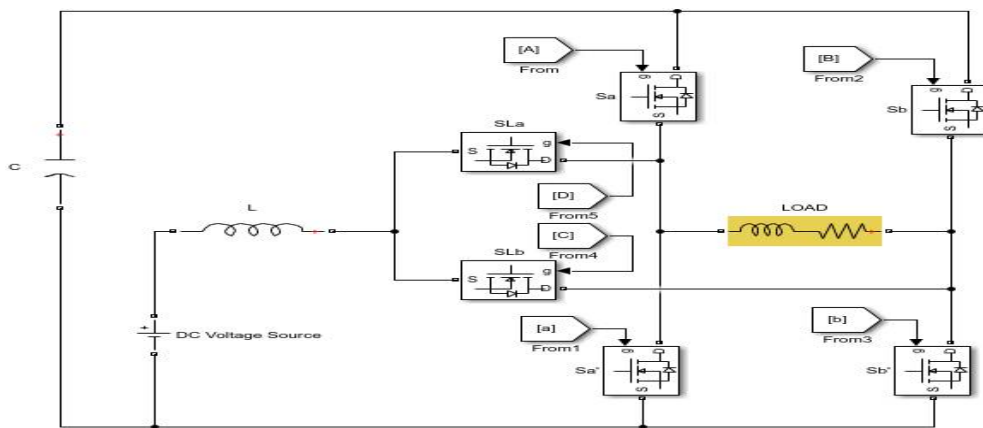


Figure 6 Power Circuit of Hybrid Inverter

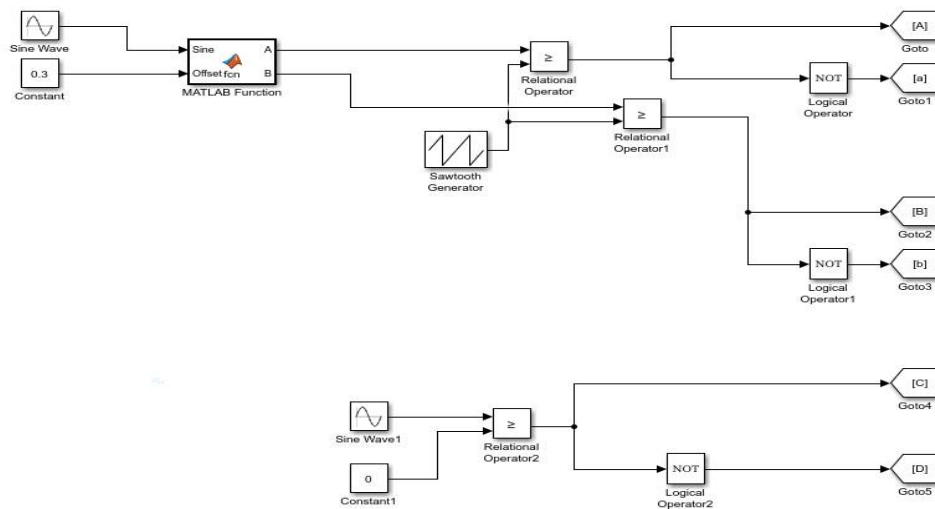


Figure 7 Control Circuit of Hybrid Inverter

Figure.6 Shows power circuit of Hybrid Inverter feeding RL load at 50 Hz. Quasi-Sinusoidal PWM is utilized to drive the H-Bridge of Hybrid inverter which has been shown in figure.7

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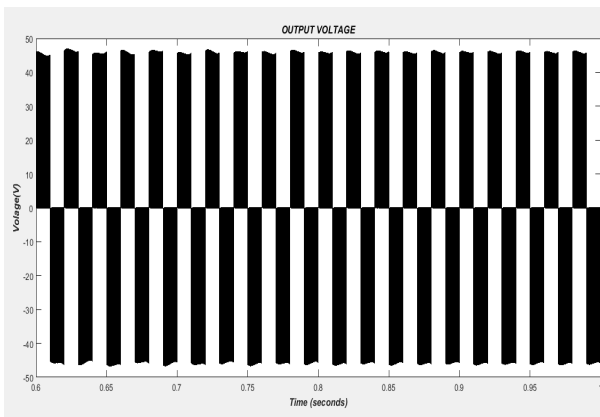


Figure 8 Load Voltage

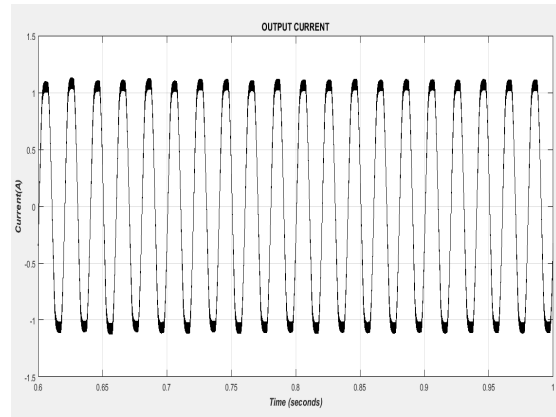


Figure 9 Load Current

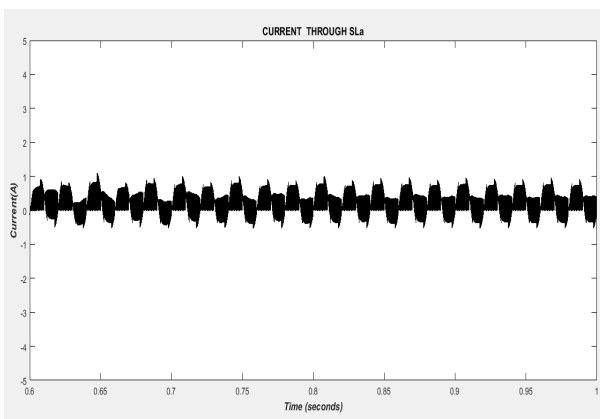


Figure 10 Current Through SLA

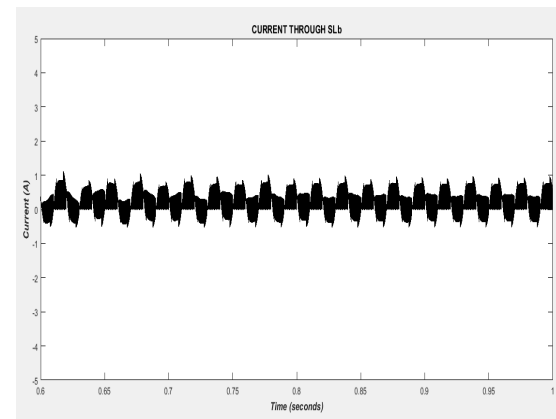


Figure 11 Current Through SLB

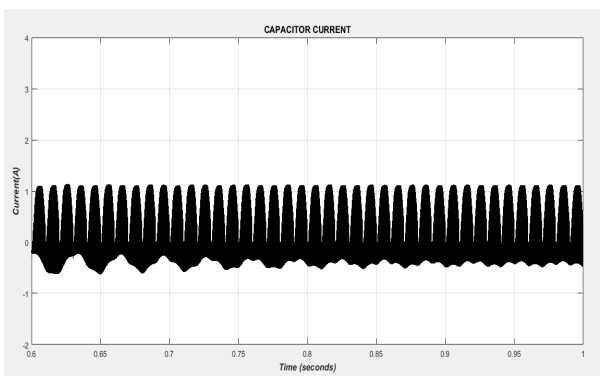


Figure 12 DC Link Current

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With input voltage of 30 V DC Hybrid inverter can provide boosted output V_{peak} of 45 V which is shown in Fig.8. Load inductance shape the output current into a sinusoidal form as shown in Fig.9. Charging current of inductor as well capacitor which flow through S_{La} or S_{Lb} are shown in Fig.10 and Fig.11. DC Link current having 100Hz ripple is shown in Fig.12. In quasi-sinusoidal PWM control of inverter, value of offset define level of boosting in hybrid inverter. Effect of offset on the RMS value of output voltage is shown in Fig.13 for DC input voltage of 30V. Performance parameters of inverter, %THD of voltage and current has been derived by performing FFT analysis and compared for the different boosting level. Fig.14 shows better %THD at lower value of offset. Lower value of offset also provides high amount of boosting.

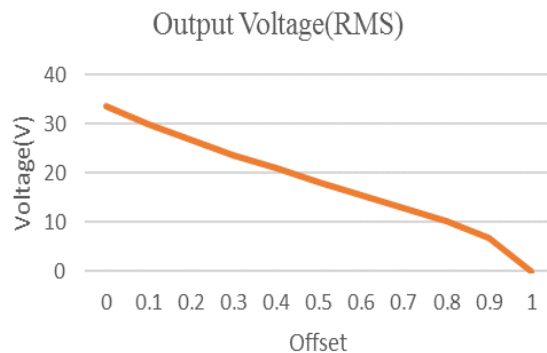


Figure 13 RMS Voltage Control by Offset

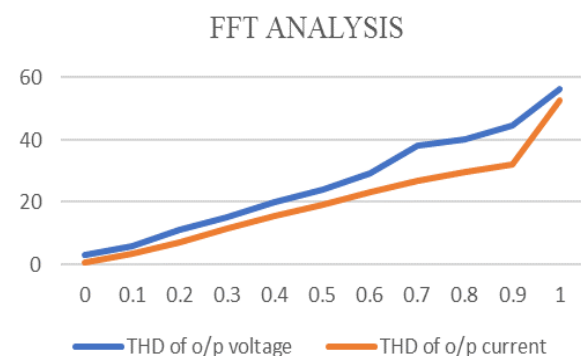


Figure 14 FFT Performance Parameters of Inverter

IV. CONCLUSION

Hybrid inverter can be used as a single stage solution for DC/AC conversion with inherent boosting facility. This can make system compact in size and efficient in nature. With quasi-sinusoidal PWM technique hybrid inverter can provide current having %THD within the acceptable limit of 5% specified in IEEE519 Standards.

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