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H-Bridge Inverter with Sinusoidal Pulse Width Modulation Technique using Unipolar switching for PV applcations

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Abstract— ***Inverters plays an important role in renewable power generation systems for delivering ac output to the load. The main function of inverter is providing ac output with minimum total harmonic distortion (THD). This paper deals with the performance analysis of single phase H-bridge inverter with unipolar switching controlled sinusoidal pulse width modulation (SPWM) with load voltage regulation. From the point of view of minimization of THD of inverters different PWM switching strategies were used. The performance of single phase H-bridge inverter with unipolar switching controlled SPWM is analyzed using MATLAB simulation.***

Keywords— H-bridge inverter, Unipolar SPWM, THD.

I. INTRODUCTION

Energy is the indispensable need for the economic progress and social advancements. Based on the forecasting of the World Energy Forum the fossil fuels depletion will occur within another 10 decades. About 79% of world energy requirement were met by power generated by fossil fuels [1]. Further the usage of fossil fuels causes environmental problems [2]. In rural areas of growing nations power supply through grid system creates economic crisis because of the long transmission line requirement. The supply of electricity with small diesel generators is costly and creates green house effects. To overcome the above problems renewable energy sources such as wind, solar, hydro, tidal, etc can be used for power generation [3]. Among all renewable energy sources solar is the most suitable for power generation due to its non depleting nature, absence of CO_2 or any other gaseous emission and elimination of transmission lines for power supply from grid [1].

A stand alone PV system incorporates PV modules, storage batteries, dc-dc converters and dc-ac inverters as in Fig. 1. For supplying power to ac loads the inverter converts the dc output of PV panel or battery to ac output. The inverter converts the dc input voltage into ac voltage of required magnitude, frequency and phase. Sinusoidal pulse width modulation (SPWM) is widely used in power electronics to digitize the power so that a sequence of voltage pulses can be generated by the switching of the power switches [1].

The output voltage of the inverter can be either constant or variable based on the needs of the applications. For the industrial voltage source requirements voltage source inverters (VSI) capable of supplying controllable AC output voltage are suitable. Medium voltage industrial applications requiring current waveforms of good quality utilizes current source inverters (CSI). Inductive loads produce smooth output in VSI whereas capacitive loads necessitate the placing of an inductive filter between VSI and load to eliminate the large current spikes. Further CSI also generate large voltage spikes when inductive load connection occurs, creating a need for the usage of capacitive filter on the AC side of inverter and load [4]. Further inverters are classified based on the connection of semiconductor devices as bridge inverters, series inverters and parallel inverters. Bridge inverters are further divided into two types namely half bridge inverter and full bridge inverter [5-6].

The modulation techniques used for the control of inverter plays the major role in the harmonic reduction in the ac output of the inverter. The PWM techniques are of two types based on control techniques namely open loop type and closed loop type.

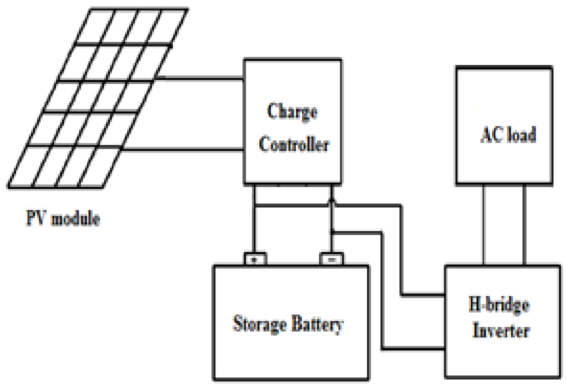

Fig.1. Block diagram of standalone PV system

The open loop type comprises SPWM, space vector PWM and Sigma-Delta modulation whereas closed loop current control system includes Hysteresis, linear and optimized current control techniques In both cases the ultimate aim is the realization of high operating performance, enhancement of efficiency and getting reliable operation [4].

The control of the output voltage of the inverters enables to deal with the variation of dc input voltage, inverter output voltage regulation and to provide the constant voltage and frequency at the output of the inverter. The method generally used for the effective control of output voltage is PWM technique [7].

The commonly used PWM techniques are single PWM in which a single pulse per half cycle will be produced by comparing the rectangular reference signal (Ar) with the triangular carrier signal (Ac), where the frequency of the carrier wave decides the frequency of the output voltage and harmonic in the output will be high. In multiple PWM or uni-form pulse width modulation, many pulses of equal width are produced per half cycle which helps to reduce the harmonic content [7], [9].

In sinusoidal PWM the multiple pulses will have different pulse width depending on the amplitude of the sinusoidal reference signal and the frequency of the inverter output depends on the frequency of the carrier wave. Modified sinusoidal PWM and Phase displacement control methods are the other methods used. [7], [9].

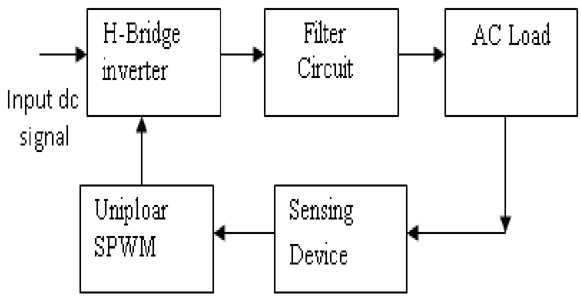

Fig.2. Block diagram of unipolar PWM control of H-bridge inverter

The sinusoidal PWM technique has two switching methods namely bipolar and unipolar methods. The block diagram of Full bridge inverter with unipolar PWM is shown in the Fig.2.

II. FULL BRIDGE INVERTER

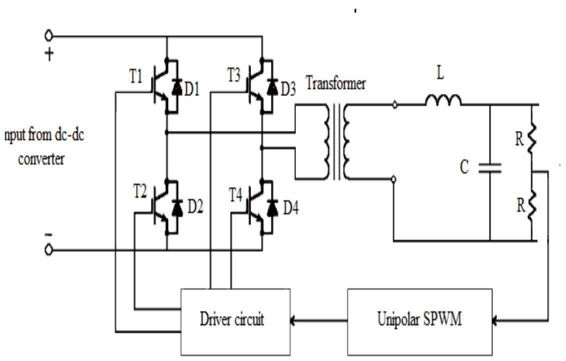

Fig.3. Circuit of Full Bridge Inverter

A single phase full bridge inverter is constructed by four switching elements T1 to T4. Switching on of T1 and T4 produces an output voltage of Vs across the load and switching on of T2 and T3 produces an output voltage of -Vs. For switching on the devices the gate pulses were applied using unipolar switching SPWM technique [10].

III. UNIPOLAR PUSE WIDTH GENERATION

The unipolar PWM signal generation is carried out by comparing the triangular carrier signal with a positive and negative reference signals as in Fig.5 for which two comparators were arranged as illustrated Fig. 4. The variation of output voltage will be between +Vdc to -Vdc in bipolar switching scheme where as in unipolar switching the output voltage variation between -Vdc to 0 or between 0 and –Vdc scheme as in Fig. 5. In unipolar switching SPWM technique the switching frequency is doubled and voltage magnitude is reduced as half compared to bipolar switching technique. Because of the above reason the harmonic in the output voltage of the inverter is reduced which necessitates a small size filter [5], [8].

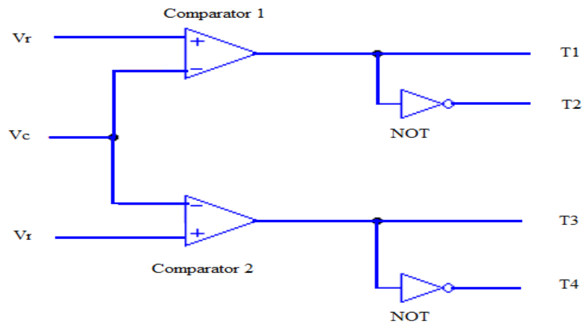

Fig.4. Unipolar PWM generator

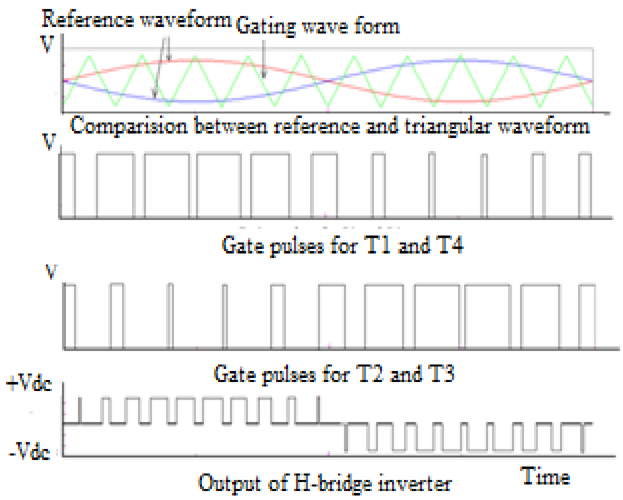

Fig.5. Output of H-bridge using unipolar switching PWM

In unipolar PWM switching the turn on and turn off of the switching devices in one arm based on the comparison of the reference signal with (Ar) with carrier signal (Ac) and the turn on and turn of the switching devices in the other arm is based on the comparison of the reference signal (-Ar) with the carrier signal (Ac).

The sequence of switching of the devices depends on the following conditions:

For First arm

If Ar>Ac then T1 is on and V_0=Vd/2 (1)

If Ar<Ac then T2 is on and V_0=-Vd/2 (2)

For Second arm

If -Ar>Ac then T3 is on and V_0=Vd/2 (3)

If -Ar<Ac then T4 is on and V_0=-Vd/2 (4)

In unipolar switching two comparators are necessary to compare the reference signals but in bipolar switching only one comparator is sufficient [9].

IV. SIMULATION OF UNIPOLAR SWITCHING CIRCUIT

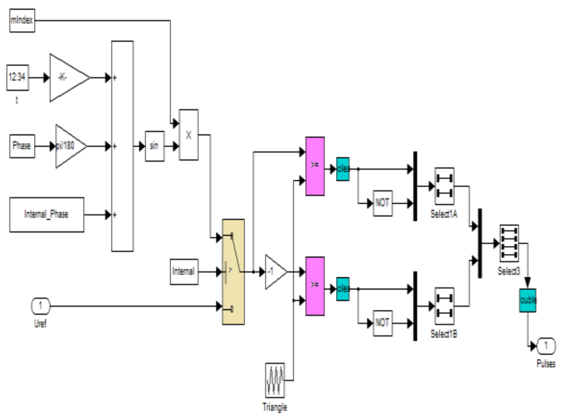

Fig. 6. Simulation circuit for generation of Unipolar SPWM

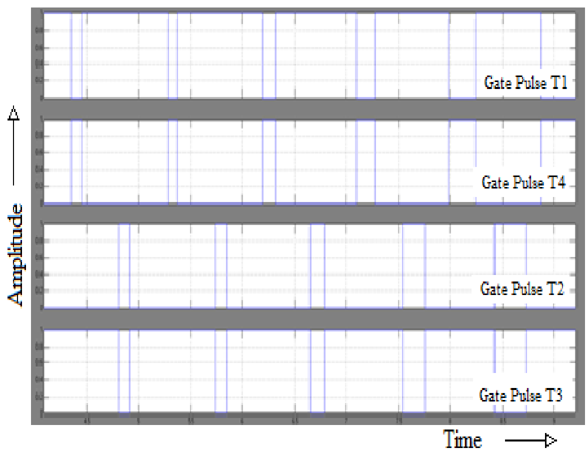

Fig. 7. Gate pulse output from Unipolar switching PWM

The simulation circuit for unipolar switching and gate pulses produced are shown in Fig. 6 and Fig. 7. These gate pulses are applied to the control circuit of the H-bridge inverter to control switching duration of the switches and to deliver the ac output voltage to the load.

V. SIMULATION OF H-BRIDGE INVERTER WITH UNIPOLAR SWITCHING

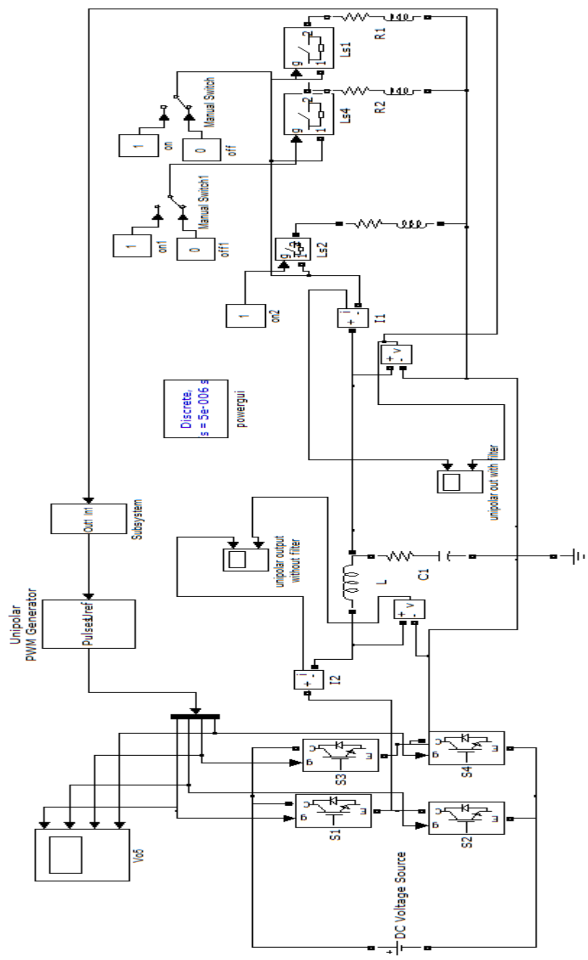

Fig. 8. Simulation of H-bridge inverter by Unipolar SPWM

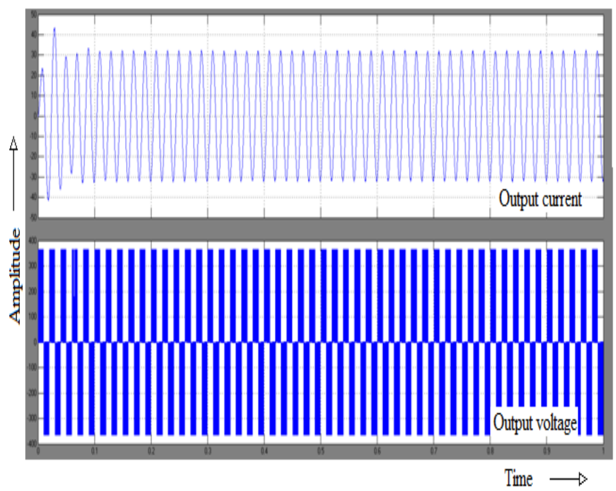

Fig.9. H-bridge inverter output without filter

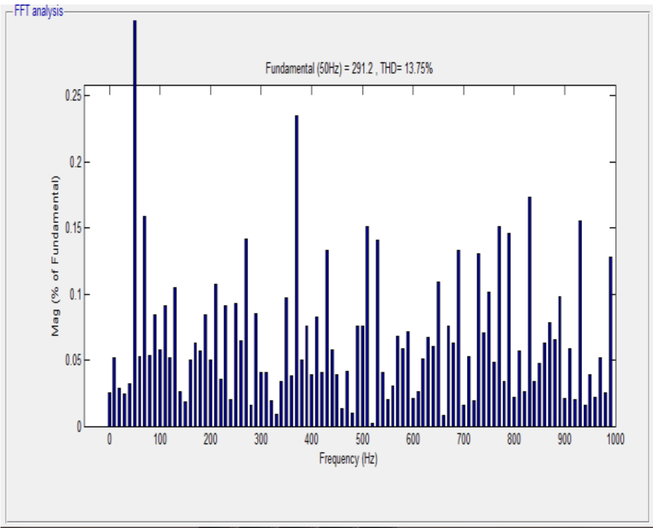

Fig.10. THD of H-bridge inverter output without filter

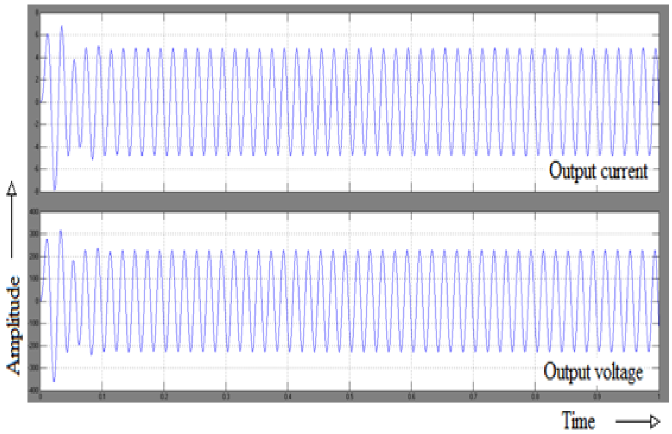

Fig. 11. H-bridge inverter output with filter

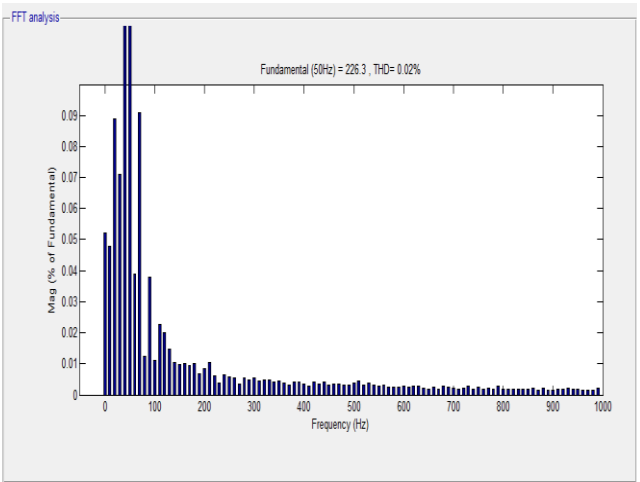

Fig. 12. THD of H-bridge inverter output with filter

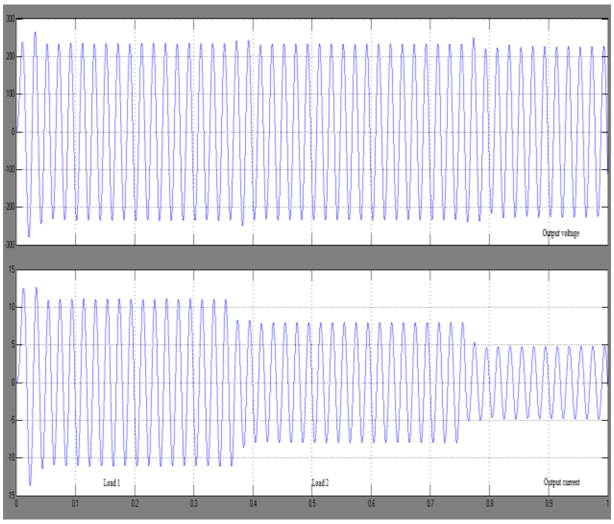

Fig. 13 H-bridge inverter output for varying loads

The simulation of full bridge inverter with unipolar switching connected to a variable load using MATLAB is depicted in Fig.8 and the output voltage and current waveforms obtained without connecting LC filter is shown in Fig.9 and Fig.10. The THD obtained without using filter is 13.75%. The output voltage and current waveforms obtained after connecting LC filter is shown in Fig.11 and Fig.12. The THD obtained using filter is.02%. Fig. 13 demonstrates the variation of output current according to the variation load for keeping the output voltage constant.

VI. CONCLUSION

The unipolar switching of SPWM is applied for a H-bridge inverter and the performance of the inverter with and without filter is obtained using MATLAB simulation. It was found that the THD of the output voltage of the inverter without filter is 13.75% and with filter was 0.02%. H-bridge inverter with filter can be used for applications requiring constant output voltage with minimum THD such as UPS, PV power generation systems, etc. The variation of output current with the variation of load to maintain constant output voltage ensures the suitability of the inverter for varying load applications.

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