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PV Solar Multi-Carrier H-Bridge Inverter Topology

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***Abstract* — Renewable energy resources are best alternative for the fossil fuels to achieve pollution reduction. Photovoltaic technology is one of the biggest renewable energy resources to generate electrical power and the fastest growing power generation in the world. PV solar farm generate power only during day-time and remain completely idele during night. FACTS devices can improve operation of power system. STATCOM can improve power factor and voltage stabilty in terms of injecting or absorbing power. PV solar farm and STATCOM, both have inverter. In this paper, different multilevel inverter topologies and SPWM multi carrier techniques for gate pulse are described. Simulation of single and three phase H-bridge multilevel inverter with multi carrier SPWM techniques are done in MATLAB/Simulink.**

Keywords— Multi-Carrier PWM (MCPWM), Total Harmonics Distortions (THD), Phase Shift (PS), Variable Frequency (VF), Carrier Overlapping (CO), Phase Opposition Disposition (POD), Alternative Phase (APOD), Flexible AC Transmission System (FACTS)

I. INTRODUCTION

Photovoltaic (PV) solar energy is one of the green energy sources which can play an important role in the program of reducing greenhouse gas emissions [1]. Although, the PV technology is expensive, it is receiving strong encouragement through various incentive programs globally. As a result, large scale solar farms are being connected to the grid. Transmission grids worldwide are presently facing challenges in integrating such large scale renewable systems (wind farms and solar farms) due to their limited power transmission capacity.[2],[3] To increase the available power transfer limits/capacity of existing transmission line, series compensation and various FACTS devices are being proposed. In an extreme situation new lines may need to be constructed at a very high expense. Cost effective techniques therefore need to be explored to increase transmission capacity [4]. A novel research has been reported on the night-time usage of a PV solar farm where a PV solar farm is utilized as a STATCOM – a Flexible AC Transmission System (FACTS) device for performing voltage control, thereby improving system performance and increasing grid connectivity of neighbouring wind farms [5]. It is known that voltage control can assist in improving transient stability and power transmission limits, several shunt connected FACTS devices, such as, Static Var Compensator (SVC) and STATCOM are utilized worldwide for improving transmission capacity.

A key component of PV solar farm is voltage source inverter, which in fact also core element of STATCOM [6]. Multilevel inverters have been drawing growing attention due to its high voltage operating capability, possible suitability for high power application and advantages in EMI problems [7].

Multilevel inverter is an array of power semiconductor switches and voltage sources which is switched in a manner that an output voltage of stepped waveform is generated. Several multilevel topologies have evolved: most common are the Diode Clamped Multilevel Inverter (DCMLI), flying-capacitor multilevel inverter and Cascaded Multi cell / H Bridge Inverter (CMCI). In recent years, the cascaded H-bridge inverters have wide applications. The merit includes modularity and the ability to operate at higher voltage levels and as the number of levels increases, the quality of the output signal will be improved. In addition inverter output voltage waveform will be closer to a sinusoidal waveform. Moreover, high voltages can be managed at the dc and ac sides of the inverter, while each unit endures only a part of the total dc voltage. Needs of high number of semiconductor switches, involvement of separate DC source for each of H-bridge, voltage balancing issues are the notable drawbacks of cascaded H bridge inverter.

II. H – BRIDGE MULTILEVEL INVERTER

On comparing with the usual Cascaded H-Bridge multilevel inverters, for the same nine level output, this Hybrid H-Bridge multilevel inverter topology, the number of switches used reduced is only twelve switches. Therefore for this cost & simplicity reason, this multilevel inverter has some value of importance. Hence this paper focuses on applying various multi carrier based PWM techniques to this Hybrid H Bridge multilevel inverter to analyze and compare the various parameters like THD & Vrms[11]. The triggering signals of multilevel converter are designed using the carrier based pulse width modulation (PWM) scheme, since the PWM provides high power with low harmonics. A three phase CHB multilevel converter circuit is designed and simulated using the MATLAB Sim Power Systems software.

This type of CHB multilevel converter has been designed and simulated using MATLAB Sim Power Systems. IGBT has been chosen as the power semiconductor switches in each H-bridge, since it has more features than other power semiconductor switches. The five levels multilevel converter requires two separate dc sources per phase leg, this means that two H-bridge inverters are used for single phase structure. One of the terminals of each single phase five levels CHB multilevel inverter is connected as star, while the other terminal of each single phase CHB multilevel converter is connected to a three phase series load. In Fig. 1 matlab simulation of single phase 5 level H – bridge inverter is shown with SPWM control technique.

Both IGBTs connected in series in half H-bridge can not be turned on at the same time to avoid the shoot through fault. Hence, a twelve pulses triggering circuit is designed to trigger 24 IGBTs to obtain the staircase output voltage.

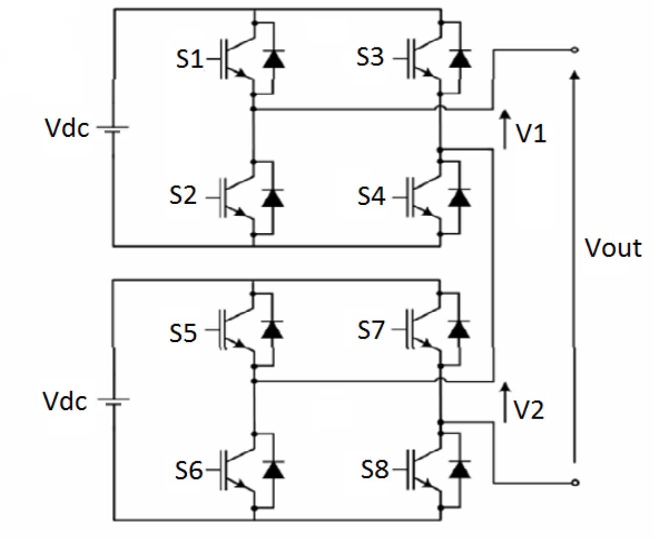

Fig. 1 single phase 5 level H - Bridge Inverter

III. PULSE WIDTH MODULATION

The triggering circuit is designed based on the three phase sinusoidal modulation waves, V_a, V_b, and V_c. Three of the sine wave sources have been obtained with same amplitude and frequency. displaced 120° out of the phase with each other.

A. *Sinusoidal Pulse Width Modulation*

In the sinusoidal pulse width modulation, the reference wave is the sine wave. That is compared with the carrier triangular wave, the pulses are produced. That is given to the inverter. [8] The sine wave is greater than the carrier wave the top switches are ON. Otherwise the bottom switches are ON.

B. *Space Vector Pulse Width Modulation*

The SVPWM have the constant switching time calculations for each state. This SVPWM can easily be changed to higher levels. SVPWM have good utilization of the DC link voltage, low current ripple and relative easy hardware implementation. Compared to the SPWM, the SVPWM has a 15% higher utilization ratio of the voltage. [9] As the number of level increases, the redundant switching states increases and also the complexity of selection of the switching states.

IV. MULTI CARRIER BASED SPWM

Several modulation strategies have been developed for multilevel inverters. The principle of the multicarrier PWM is based on a comparison of a sinusoidal reference waveform with triangular carrier waveforms. m-1 carriers are required to generate m levels. The carriers are in continuous bands around the reference zero. They have the same amplitude Ac and the same frequency fc. The sine reference waveform has a frequency f_r and A_r is the peak to peak value of the reference waveform. At each instant, the result of the comparison is 1 if the triangular carrier is greater than the reference signal and 0 otherwise. The output of the modulator is the sum of the different comparisons which represents the voltage level. [9]

A. *Level shifted PWM (LS-PWM)*

The level shifted multi carrier modulation schemes are classified into three,

1) Phase Disposition (PD): In this method all the carriers above and below zero reference line are in same phase. If all the carriers are selected with the same phase, the method is known as Phase Disposition (PD) method. Carrier and reference wave arrangements are as shown in Fig. 2. [10] The PDPWM is the widely used strategy for Modular Multilevel converters and conventional multilevel inverters because it provides load voltage and current with lower harmonic distortion.

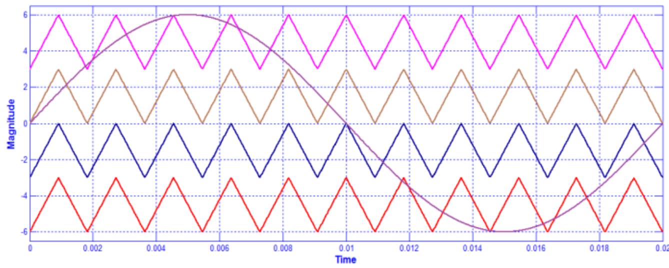

Fig. 2 Carrier arrangement for PDPWM (m_f=11)

2) Phase Opposition Disposition (POD): In this method all the carriers have the same frequency and the adjustable amplitude. But all the carriers above the zero value reference are in phase among them but in opposition (180 degrees phase shifted) with those below. Carrier and reference wave arrangements are as shown in Fig. 3.

3) Alternative Phase Opposition Disposition (APOD): In this method all the carriers have the same frequency and the adjustable amplitude. All the carriers have 180 degree phase shift between them as shown in fig. 4.

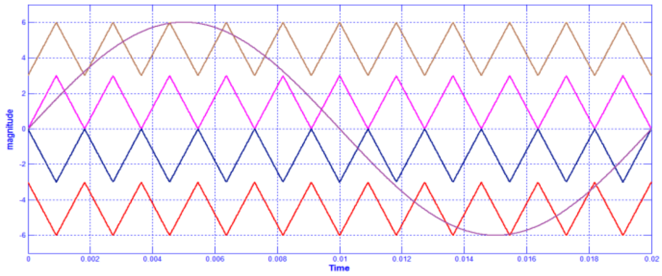

Fig. 3 Carrier arrangement for PODPWM (m_f=11)

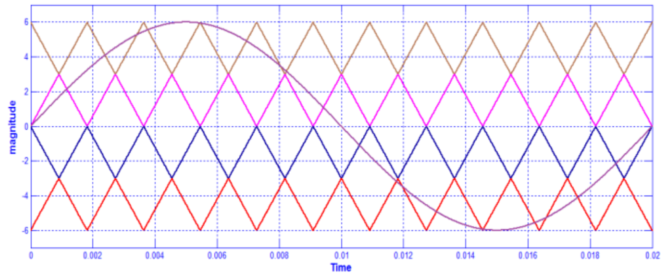

Fig. 4 Carrier arrangement for APODPWM (m_f=11)

B. *Variable Frequency PWM (VF-PWM)*

The number of switching for upper and lower devices of chosen MLI is much more than that of intermediate switches in SHPWM using constant frequency carriers. In order to equalize the number of switching for all the switches, variable frequency PWM strategy is used as illustrated in Fig. 6, in which the carrier frequency of the intermediate switches is properly increased to balance the numbers of switching for all the switches.

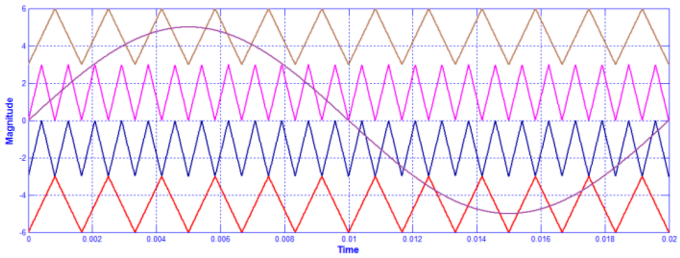

Fig. 5 Carrier arrangement for VFPWM (m_f=11)

C. *Phase shifted PWM (PS-PWM)*

In the phase shifted multi carrier modulation, all triangular carrier wave are having same peak to peak voltage and same frequency, as shown in Fig. 5. But phase shift will be vary depends upon the level according to levels of the inverter by using the formula is, Ø=360/ (m-1).

D. *Carrier Overlapping PWM (CO-PWM)*

For an m level inverter using carrier overlapping technique, m-1 carriers with the same frequency f_c and same peak-to- peak amplitude A_c are disposed such that the bands they occupy overlap each other (Fig.7). The overlapping vertical distance between each carrier is $A_c/2$. [11] The reference waveform has amplitude of A_r and frequency of f_r and it is centred in the middle of the carrier signals. The reference wave is continuously compared with each of the carrier signals.

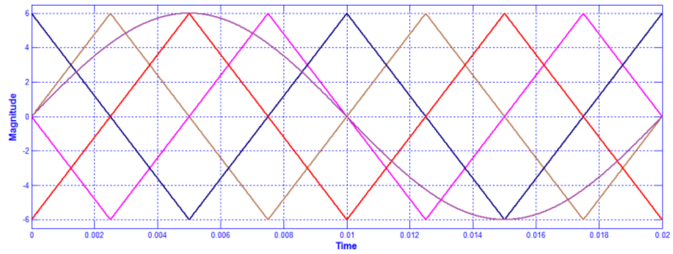

Fig. 6 Carrier arrangement for PSPWM (m_f=11)

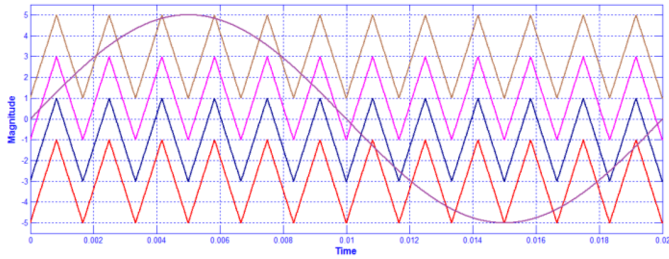

Fig. 7 Carrier arrangement for COPWM (m_f=11)

The amplitude modulation indices for PDPWM, PODPWM, APODPWM and VFPWM are same, 2Ar/ ((m-1)*A_c). For carrier overlapping it is, A_r/ ((m/4)*A_c) and for phase shift PWM, it is A_r/ (A_c/2).

V. SIMULATIONS AND RESULTS

Simulation studies are performed by using MATLAB-SIMULINK to verify the proposed multi carrier based PWM strategies for chosen single phase H- bridge five level inverter.

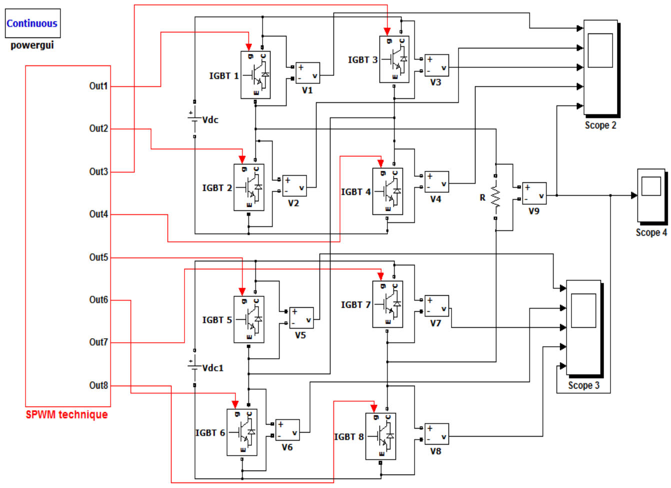

Fig. 8 Simulation single phase 5-level H-bridge inverter

TABLE I SWITCHING TABLE

	IGBT SWITCH							
Voltage Level	IGBT-1	IGBT-2	IGBT-3	IGBT-4	IGBT-5	IGBT-6	IGBT-7	IGBT-8
200	0	1	1	0	0	1	1	0
100	0	1	0	1	0	1	1	0
0	1	0	0	1	0	1	1	0
-100	1	0	0	1	1	0	1	0
-200	1	0	0	1	1	0	0	1

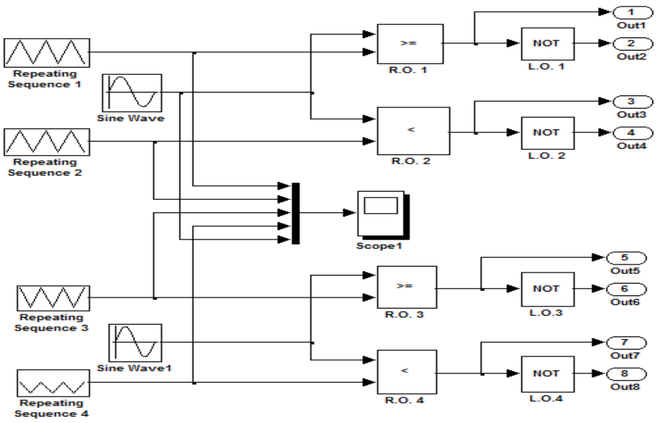

Fig. 9 SPWM control technique to generate gate pulse for inverter switch

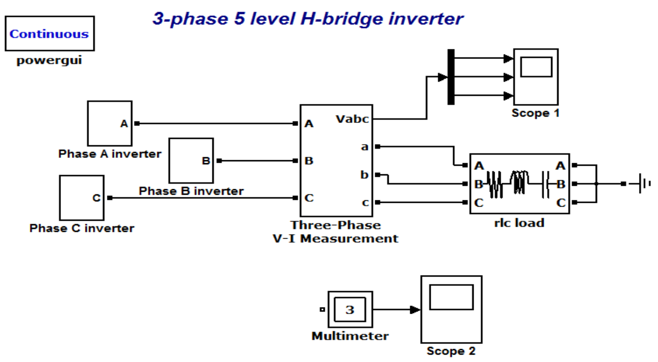

Fig. 10 three phase 5 - level H-bridge inverter with RLC load

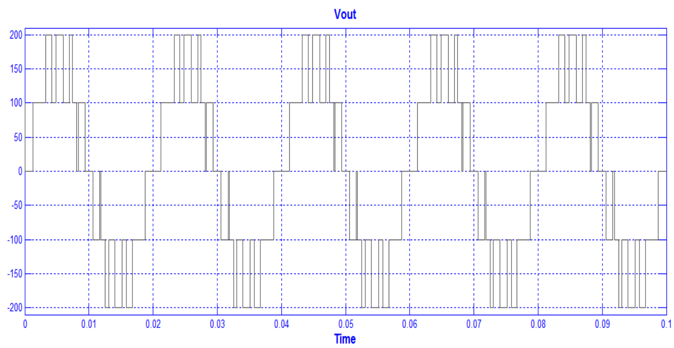

Fig. 11 Output voltage of single phase inverter

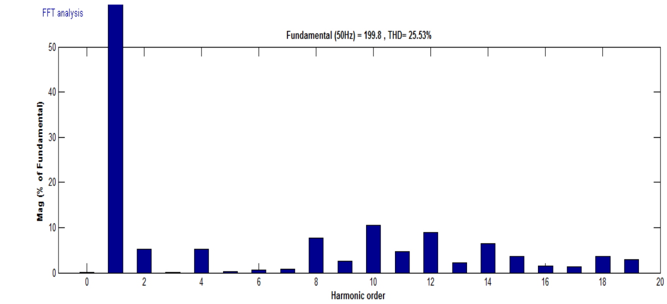

Fig. 12 Harmonic spectrum for PODPWM

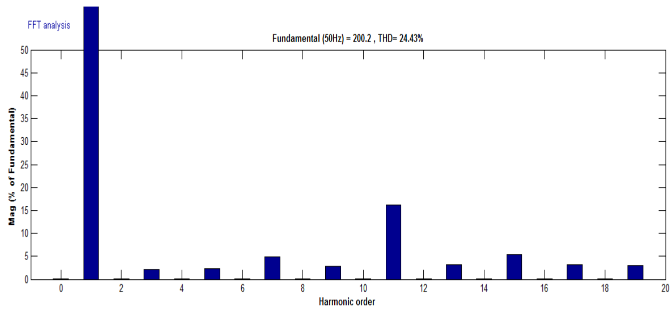

Fig. 13 Harmonic spectrum for PDPWM

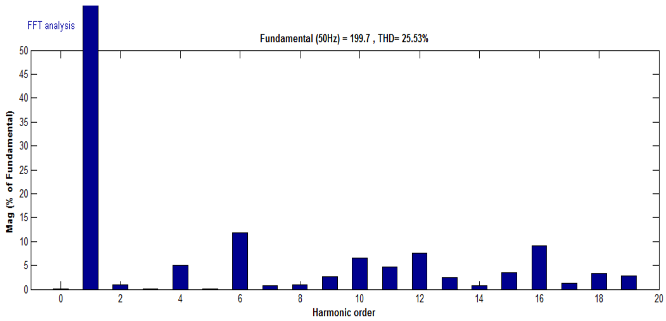

Fig. 14 Harmonic spectrum for APODPWM

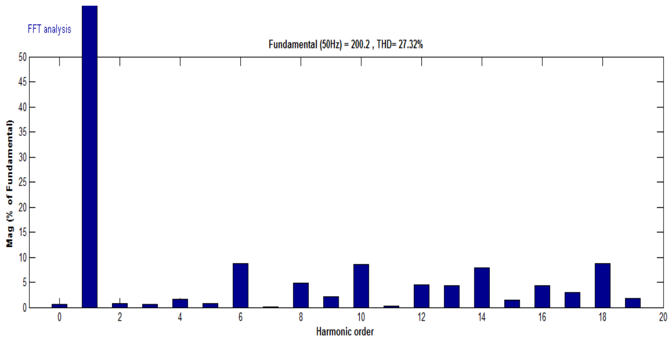

Fig. 15 Harmonic spectrum for VFPWM

VI. CONCLUSIONS

This paper propose multilevel inverter topologies. H-bridge multilevel inverter is more preferable then other topologies. For gate pulse generation, multicarrier SPWM techniques are described and compared.

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