COMPARISION of PWM and HYBRID MODULATION TECHNIQUE for HYBRID MULTILEVEL INVERTER

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Abstract— **This paper presents Matlab simulation for single phase hybrid multilevel inverter. This topology consists of H-bridge with half bridge in series and separate D.C. voltage source. The inverter can be used in hybrid electric vehicles (HEV) and electric vehicles (EV). A Matlab / Simulink based model is developed for Multi carrier based PWM method and Hybrid modulation technique. Thus, simulation results are also discussed.**

Keywords— **Cascade systems, inverters, multilevel systems, pulse width modulation (PWM), Hybrid Modulation Technique .**

I. INTRODUCTION

The multilevel inverters are very popular in recent years due to its advantages in high power with low harmonics applications. The general function of the multilevel inverter is to synthesize a desired high voltage from several levels of dc voltages that can be batteries, fuel cells, etc. In this paper, the proposed hybrid cascaded multilevel inverter includes H-bridge in series with half bridge. It can use a single DC power source to supply H-bridge and half bridge [2-6]. Multi carrier based PWM method and Hybrid Modulation Technique are used to produce a five level voltage.

The inverter can be used in hybrid electric vehicles (HEV) and electric vehicles (EV). An HEV combines a conventional internal combustion engine, a battery pack, and an electric motor. An EV includes rechargeable batteries and an electric motor. The power inverter that drives the electric motor is a key device of a HEV and EV. To develop the model of a hybrid multilevel inverter, a simulation is done based on MATLAB/SIMULINK platforms

II. OPERATIONAL PRINCIPLE OF THE HYBRID MULTILEVEL INVERTER

The topology of the proposed hybrid multilevel inverter is shown in Fig. 1 [1]. Fig. 2[1] shows a simplified single-phase topology. The bottom is one leg of a standard 3-leg inverter with a DC power source. The top is an H-bridge in series with each standard inverter leg. The H-bridge can use a separate DC power source or a capacitor as the dc power source [7-11].

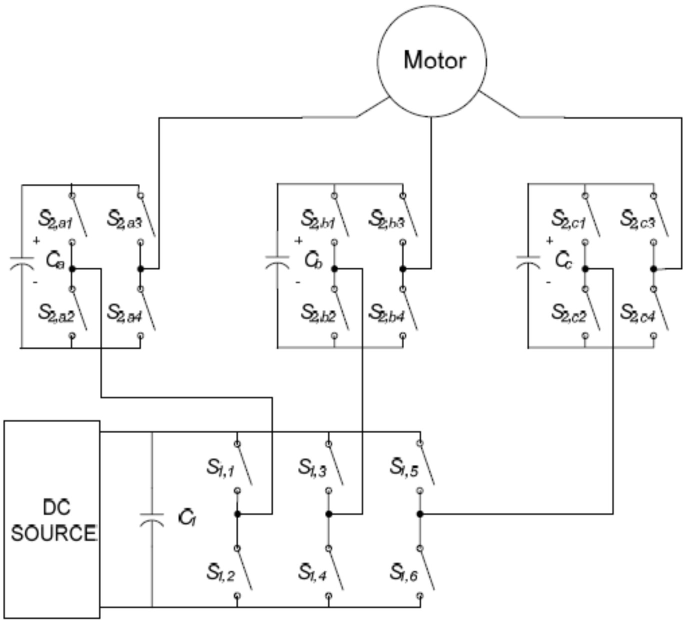

Fig.1Topology of Hybrid cascaded multilevel inverter

The output voltage V1 of this leg (with respect to the ground is either +Vdc/2 (S5 closed) or − Vdc/2 (S6 closed). This leg is connected in series with a full H-bridge that in turn is supplied by a capacitor voltage. If the capacitor is kept charged to Vdc/2, then the output voltage of the H bridge can take on the values + Vdc/2 (S1, S4 closed), 0 (S1, S2 closed or S3, S4 closed), or − Vdc/2 (S2, S3 closed). An example output waveform that this topology can achieve is shown in Fig. 3 (a)[1]. When the output voltage V = V1 + V2 is

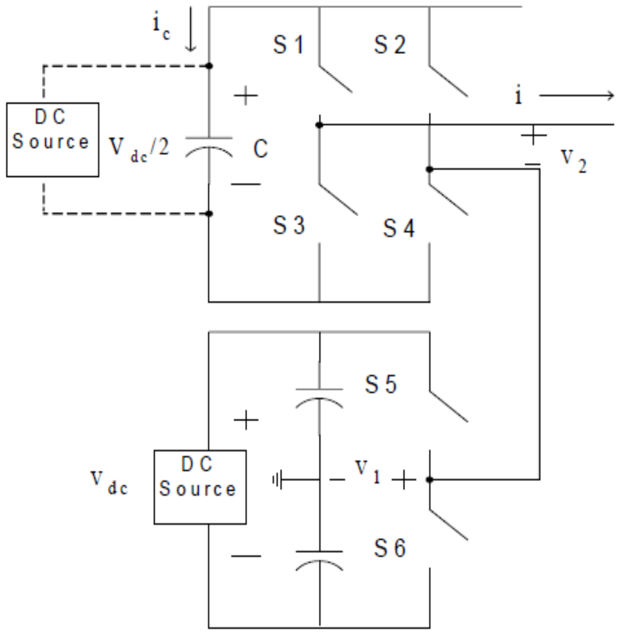

Fig.2Single phase topology of hybrid cascaded multilevel inverter

required to be zero, one can either set V1 = + Vdc/2 and V2 = − Vdc/2 or V1 = − Vdc/2 and V2 = + Vdc/2 It is this flexibility in choosing how to make that output voltage zero that is exploited to regulate the capacitor voltage.

When only a dc power source is used in the inverter, that is, the H-bridge uses a capacitor as the dc power source, the capacitor's voltage regulation control details are illustrated in Fig. 3[1]. During $\theta 1 \le \theta \le \pi$, the output voltage in Fig. 2 is zero and the current I > 0. If S1, S4 are closed (so that V2 = +*Vdc*/2) along with S6 closed (so that V1 = −*Vdc*/2), then the capacitor is discharging (Ic = −I < 0 see Fig. 3 (b)) and V = V1+V2 = 0. On the other hand, if S2, S3 are closed (so that V2 = −*Vdc*/2) and S5 is also closed (so that V1 = + *Vdc*/2), then the capacitor is charging (Ic = −I > 0 see Fig. 3 (c)) and V=V1+V2= 0. The case I < 0 is accomplished by simply reversing the switch positions of the I > 0 case for charge and consists of monitoring the output current and the capacitor voltage so that during periods of zero voltage output, either the switches S1, S4, and S6 are closed or the switches S2, S3, S5 are closed depending on whether it is necessary to charge or discharge the capacitor.

As Fig. 3 illustrates, this method of regulating the capacitor voltage depends on the voltage and current not being in phase. That means one needs positive (or negative) current when the voltage is passing through zero in order to charge or discharge the capacitor. Consequently, the amount of capacitor voltage the scheme can regulate depends on the phase angle difference of output voltage and current. It is noted that the above capacitor voltage regulation method is described using a fundamental frequency modulation scheme because it is easier to illustrate [7]. The PWM scheme uses the same method as described in the next section

III: MODULATION CONTROL SCHEME

The modulation control schemes for the multilevel inverter can be divided into two categories, fundamental switching frequency [1][4][8] and high switching frequency PWM [4][12-16] such as multilevel carrier based PWM, selective harmonic elimination and multilevel space vector PWM. Both PWM and fundamental frequency switching methods can be used for the hybrid multilevel inverter. Multi carrier based PWM strategies are the most popular method because they are easily implemented. Three major carrier-based techniques that are used in a conventional inverter can be applied in a multilevel inverter: sinusoidal PWM (SPWM), third harmonic injection PWM (THPWM), and space vector PWM (SVM). SPWM is a popular method in industrial applications. It uses several triangle carrier signals, one carrier for each level and one reference, or modulation, signal per phase. For an m-level inverter, the amplitude modulation index, Ma, is defined as

$$Ma = Am/(m-1)Ac$$

Where, Am is the peak-to-peak reference waveform amplitude, Ac is the peak-to-peak carrier waveform amplitude.

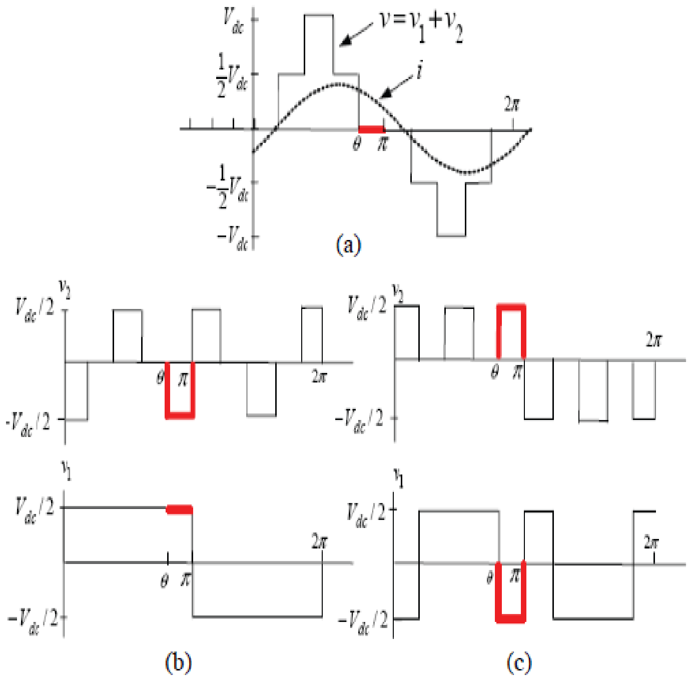

Fig.3 Capacitor voltage regulation

IV: MATLAB SIMULATION

In this paper the simulation model is developed for PWM method and Hybrid modulation Technique. Fig. 4 indicates the power circuit for PWM method. Fig.5 and Fig.6 are indicating the result and FFT analysis respectively. In Fig.6 it is observed that THD is 33% when Modulation Index is 1.Now second method is Hybrid Modulation Technique. In Hybrid Modulation Technique top H-bridge inverter is operated in PWM mode and Half bridge inverter is operated in square wave mode as depicted in Fig.7 Thereafter, the reference signal of sinusoidal PWM (SPWM) used for the H-bridge inverter is modified by using equation (1)-(4). The multiplexing signals from (3) and (4) are used to fabricate PWM signal by using logic diagram as shown in Table I. and Fig.8

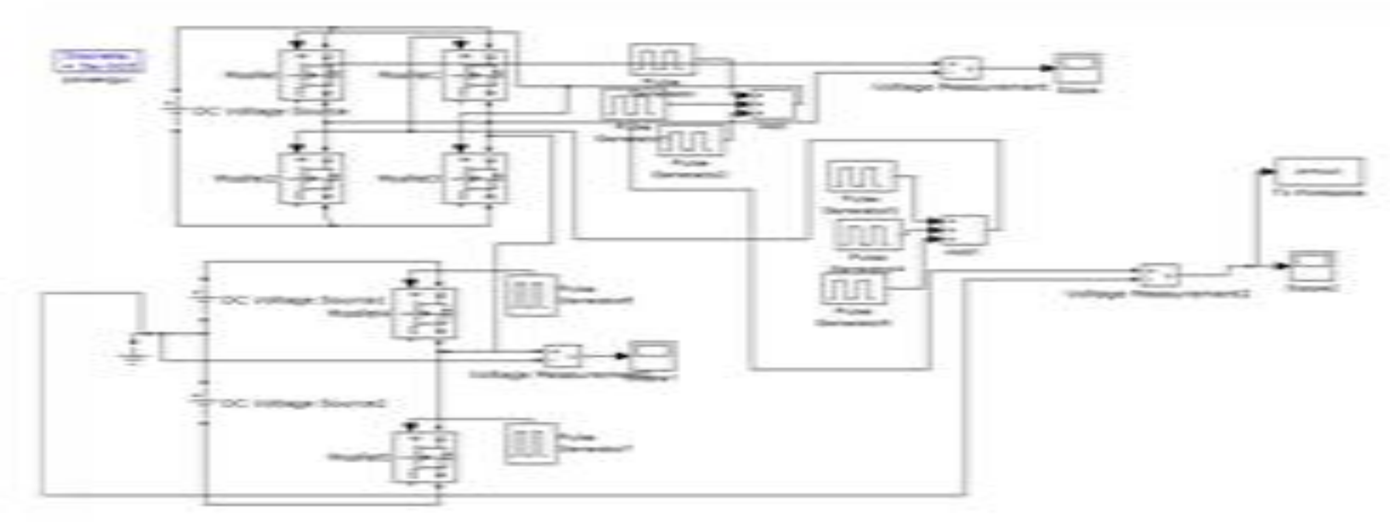

Fig.4 Simulation for PWM Method

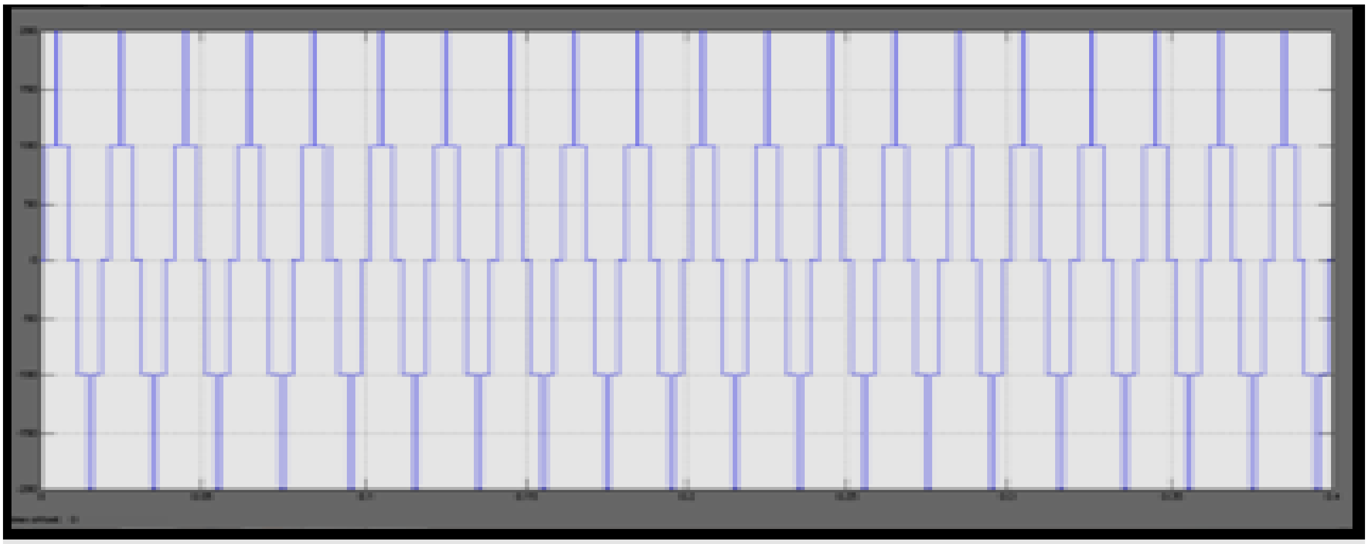

Fig.5 Result For PWM Method

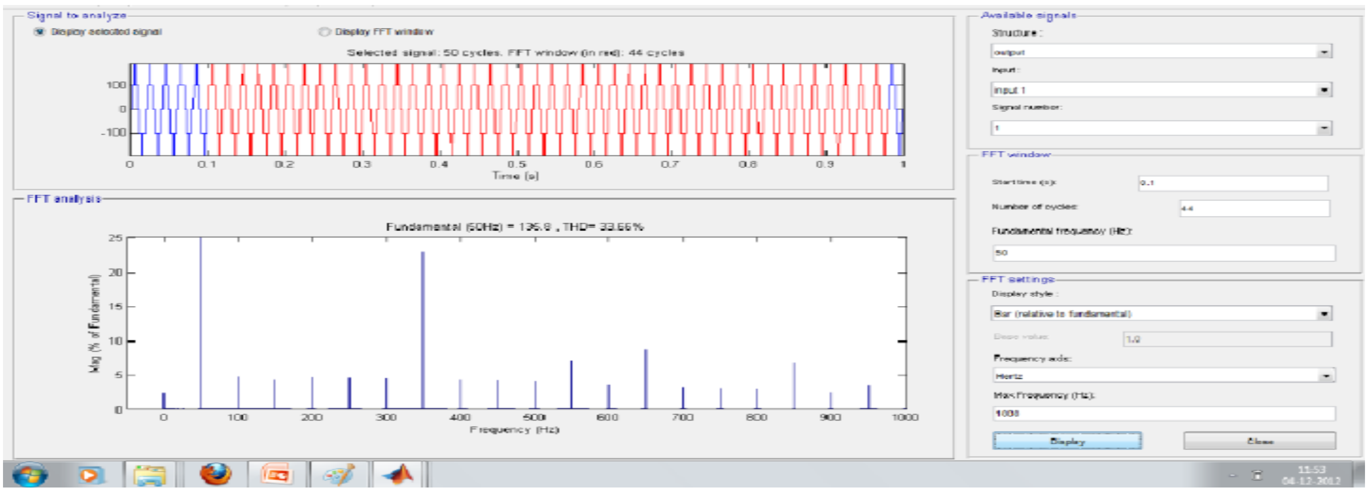

Fig.6 FFT Analysis of PWM Method

$$f(t) = m_a Sin(\omega t) \qquad (1)$$

$$\frac{T_P}{T_C} = \begin{cases} 2\left(f(t) - \frac{1}{2}\right); \frac{1}{2} \le f(t) \le 1 \\ 2\left(\frac{1}{2} - f(t)\right); 0 \le f(t) \le \frac{1}{2} \end{cases} \qquad (2)$$

$$A_1 = \begin{cases} 1 \ ; f(t) \ge 0 \\ 0 \ ; f(t) < 0 \end{cases} \qquad (3)$$

$$A_2 = \begin{cases} 1 \ ; |f(t)| \ge \frac{1}{2} \\ 0 \ ; |f(t)| < \frac{1}{2} \end{cases} \qquad (4)$$

when $f(t)$ is Reference signal,
m_a is Modulation Index (0-1.0),
A_1 is multiplexing signal #1,
A_2 is multiplexing signals #2,
$\frac{T_P}{T_C}$ is Pulse width of PWM (0–1).

Now Fig. 9 showed the Mat lab Simulation for Hybrid Modulation Technique. Fig. 10 showed result of the Hybrid Technique and Fig.11 showed FFT Analysis of the same.

TABLE I.
FABRICATED PWM SIGNAL FOR PROPOSED HYBRID MULTILEVEL INVERTER

S_n	Hybrid PWM mixing operator
S_{A1}	$A1$
S_{A2}	$\overline{A1}$
S_{A3}	$PWM \bullet ((A2 \bullet A1) + (\overline{A2} \bullet \overline{A1}))$
S_{A4}	$PWM' + \overline{((A2 \bullet A1) + (\overline{A2} \bullet \overline{A1}))}$
S_{A5}	$PWM \bullet \overline{((A2 \bullet A1) + (\overline{A2} \bullet \overline{A1}))}$
S_{A6}	$PWM' + ((A2 \bullet A1) + (\overline{A2} \bullet \overline{A1}))$

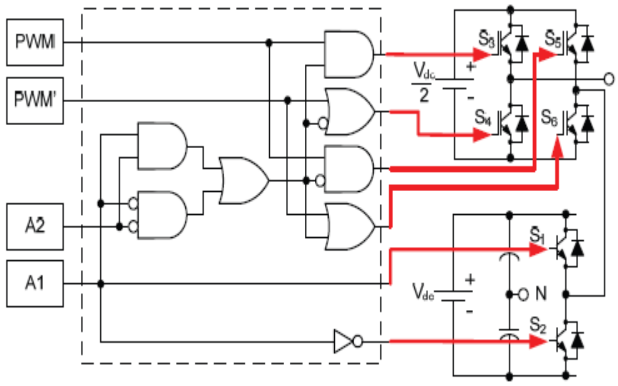

Fig.8 Logic Diagram

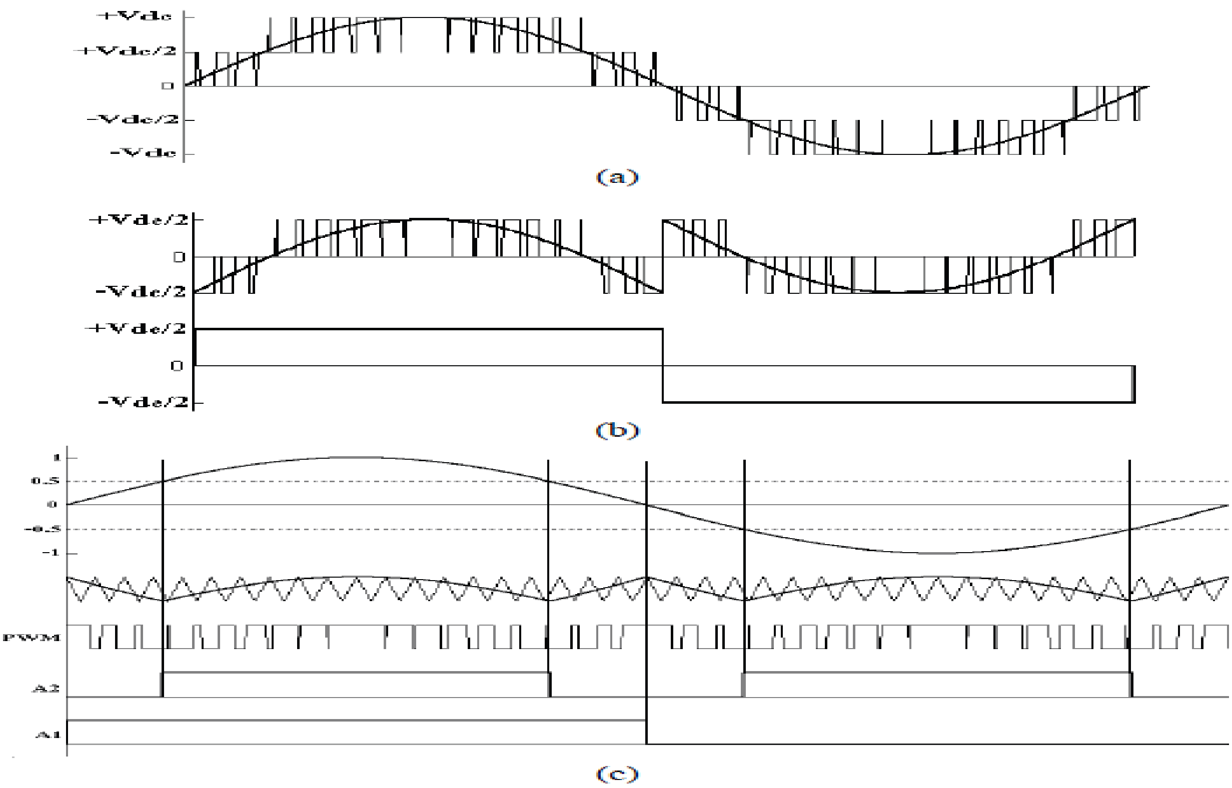

*Fig.*7 Proposed PWM paradigm (a) output phase voltage (b)Auxiliary and main inverter output voltages and (c) Modulation signals of both main and auxiliary inverter

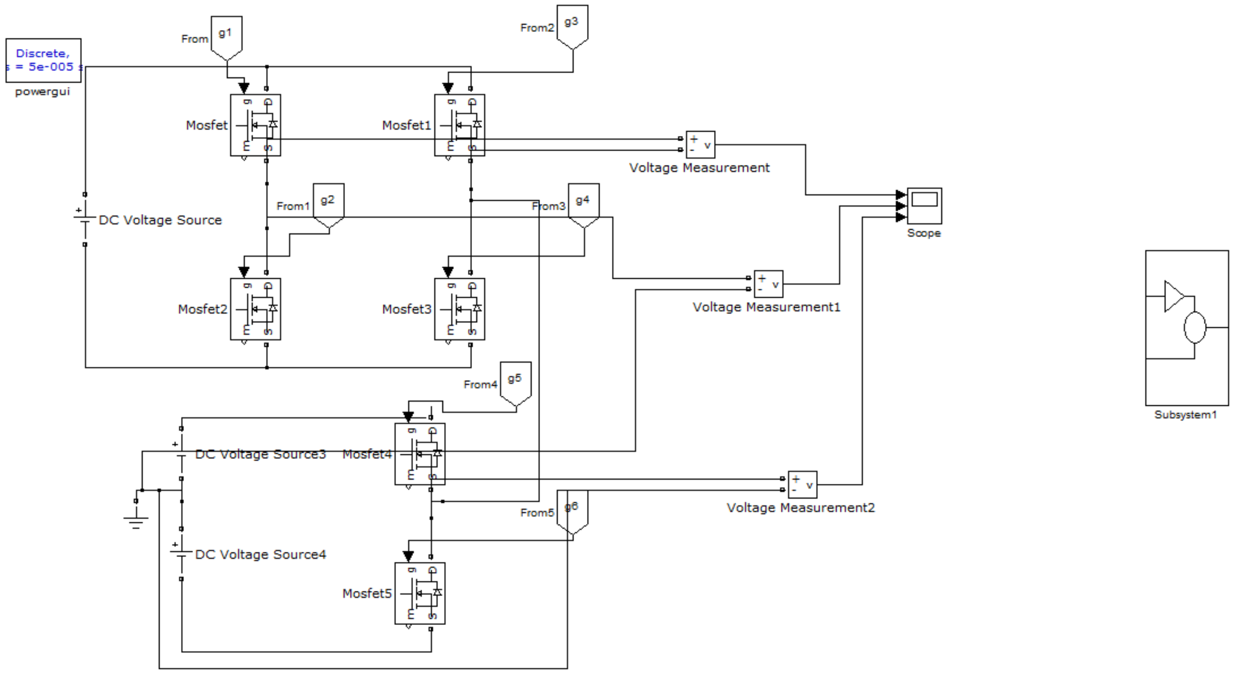

Fig.9 Simulation for Hybrid Modulation Tech

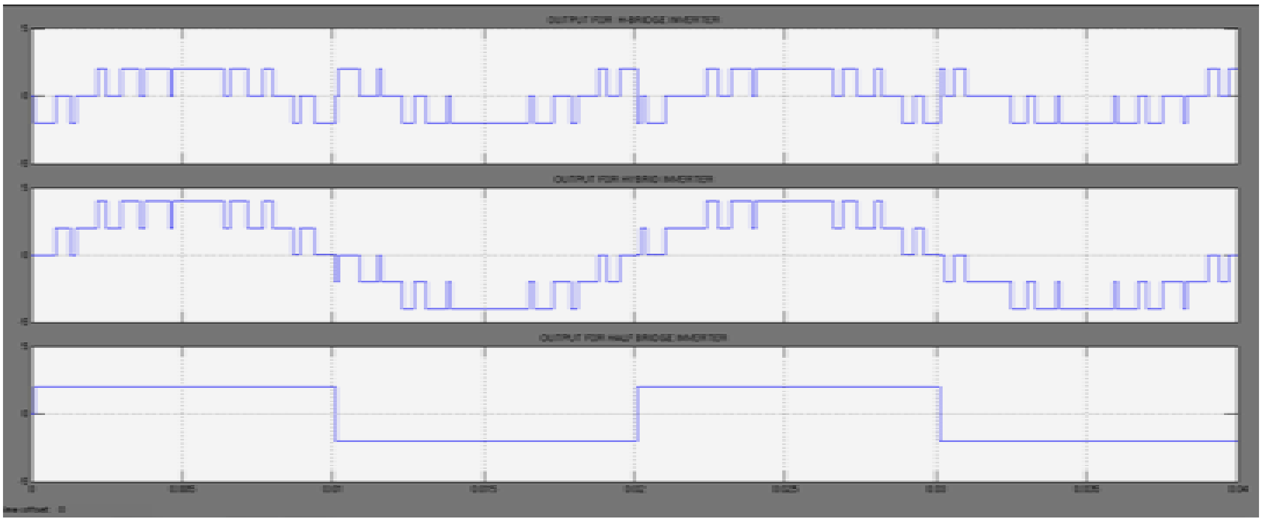

Fig.10 Result for Hybrid Modulation

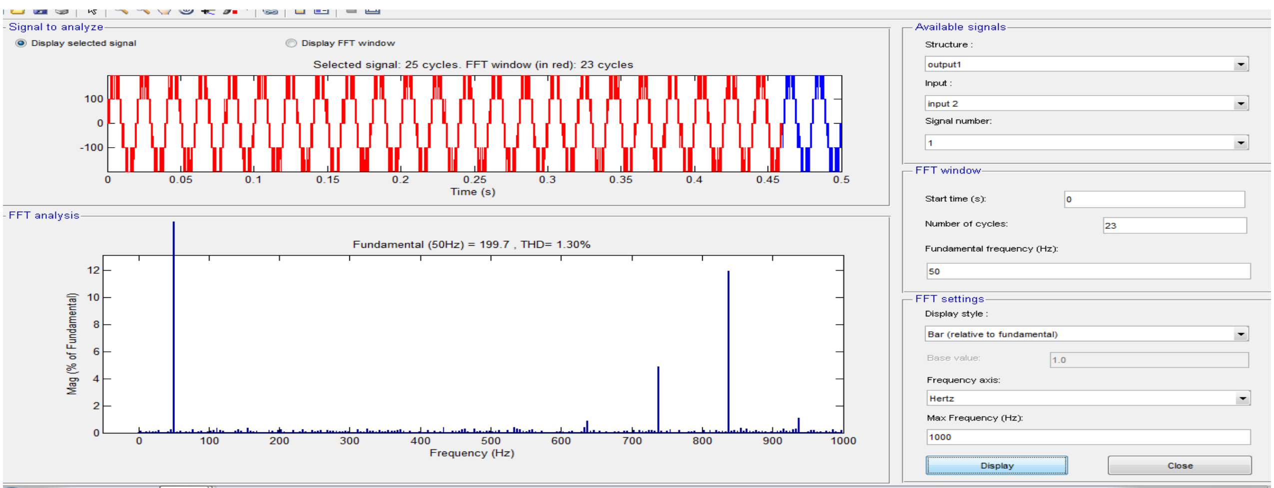

Fig.11FFT Analysis Of Hybrid Modulation Technique

V:CONCLUSION

Single phase Hybrid multi level inverter has been simulated and its results are observed. From the simulation of two different modulation techniques it can be concluded that hybrid modulation technique give better results. THD obtained from hybrid modulation technique(1.3%) is less as compared to PWM(33%). Thus, Matlab/Simulink model is developed and simulation results are presented.

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