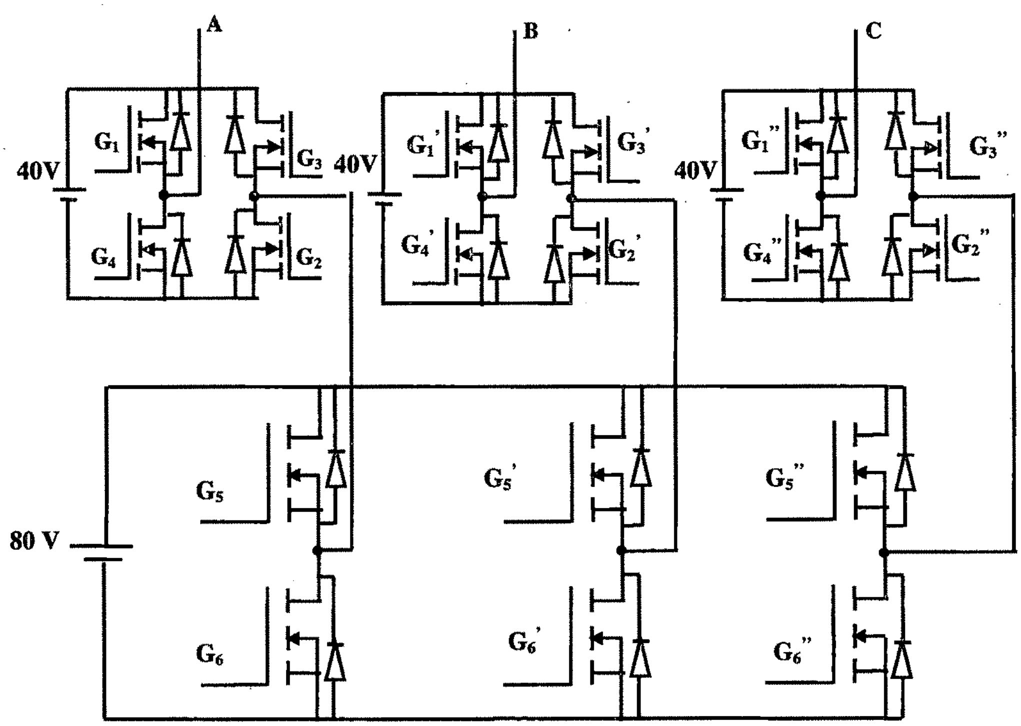
CHAPTER 5

SIMULATIONS RESULTS for SELECTED HYBIRD MULTILEVEL INVERTER

Circuit topology selected for the hardware implementation is as shown below. Circuit selection was done from many available HMLI topologies at the time of registration. As per norms registered topology cannot be changed hence it was implemented but hardware was done for the proposed topology only.

In this chapter MATLAB simulations done for selected configuration of hybrid multilevel inverter are described and analyzed. Simulations are carried out for single phase and three phase. Different modulation techniques implemented are PD, POD, APOD, PS, inverted sine and hybrid modulation technique which are described in chapter 3. Modulation index is taken either 0.9 or 1 specified with respective output figures while frequency modulation index is 21. For better visualization figures are resolved, but simulations and THD measurement are done as per the values specified and not for the resolved one.

Further sections describe MATLAB simulations for selected configuration of single phase and three phase HMLI.



Schematic for power circuit

5.1 SIMULATIONS FOR SINGLE PHASE HYBRID MULTILEVEL INVERTER

Fig. 5.1 is simulation block for selected single phase HMLI for which simulations are done in MATLAB and hardware is also implemented which is described in further chapters. Simulations are done for different modulation techniques. Working principle for this HMLI is explained in chapter 2. Solver ode23tb is used as suggested by MATLAB Help.

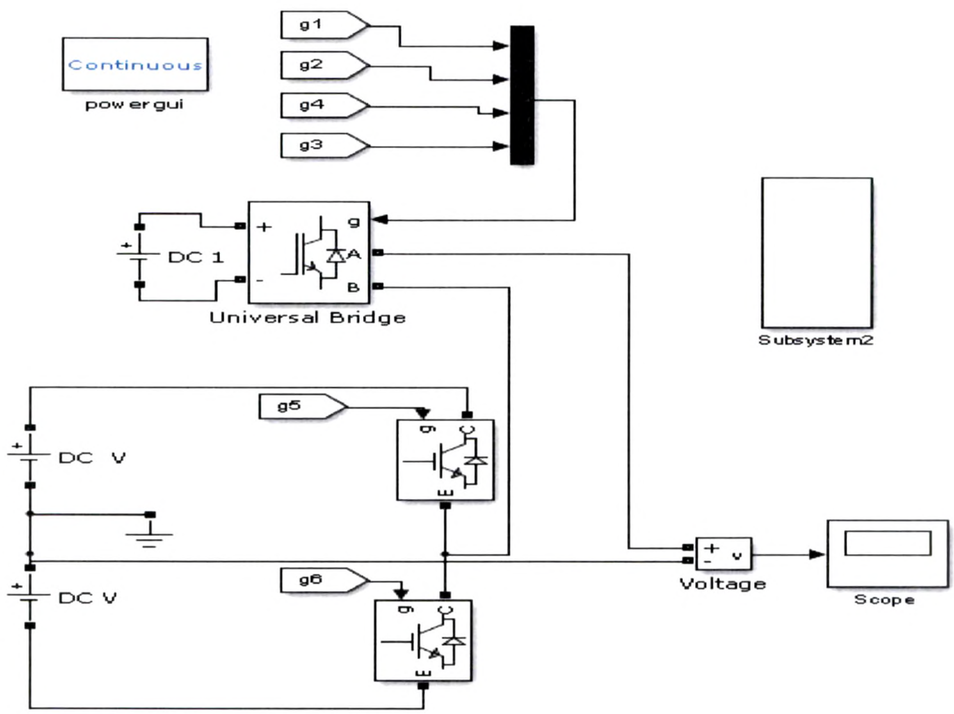


Fig. 5.1 Simulink block for single phase HMLI

5.1.1 SIMULATIONS FOR HMLI WITH PD MODULATION TECHNIQUE

Fig. 5.2 shows the output for single phase HMLI with phase disposition modulation technique and equal DC sources which are equal to 20V. Thus five level output is obtained. While Fig. 5.3 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as mentioned in previous chapter.

For all simulation results on Y-axis voltage in volts is taken and on X-axis time is taken in seconds.

modulation technique and equal DC sources which are equal to 20V. Thus five level output is obtained. While Fig. 5.3 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as mentioned in previous chapter.

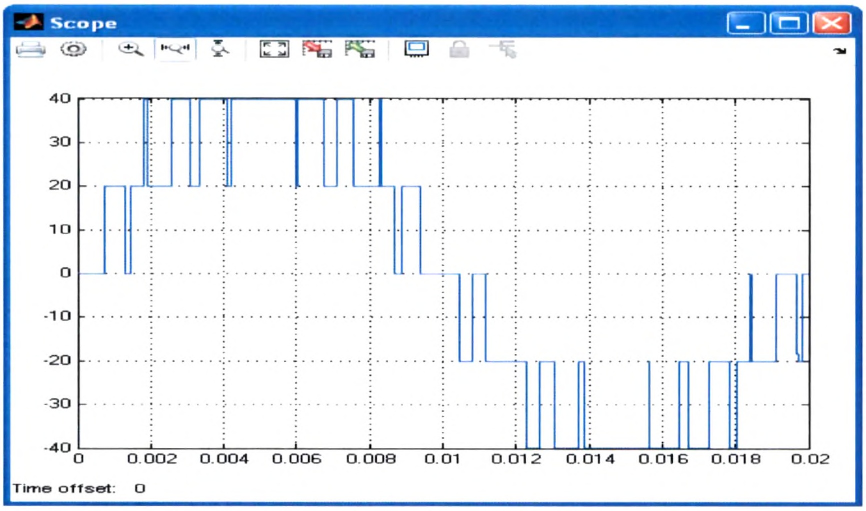


Fig. 5.2 Simulink output for single phase HMLI with PD modulation technique

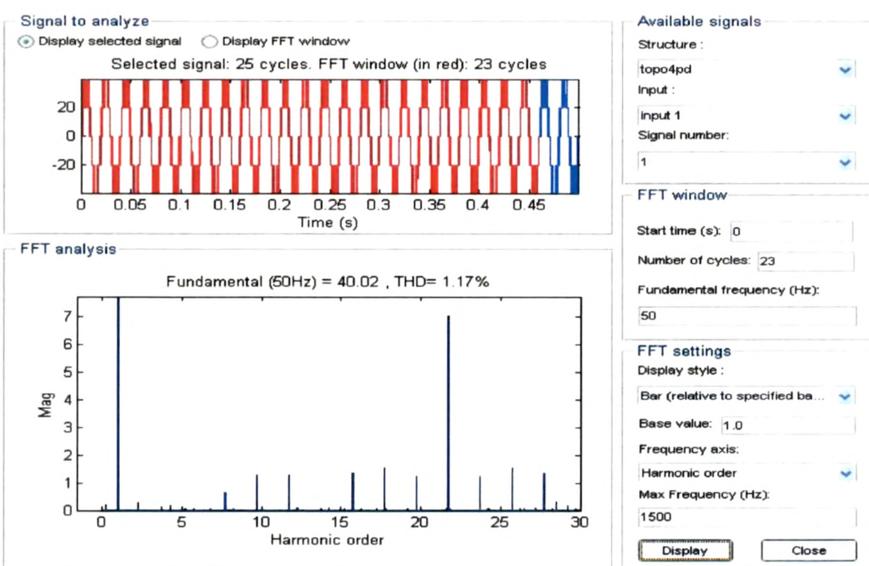


Fig. 5.3 FFT analysis and THD for single phase HMLI with PD modulation technique

5.1.2 SIMULATIONS FOR HMLI WITH POD MODULATION TECHNIQUE

Fig. 5.4 shows the output for single phase HMLI with phase opposition disposition modulation technique and equal DC sources which are equal to 20V. Thus five level output is obtained. While Fig. 5.5 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as mentioned in previous chapter.

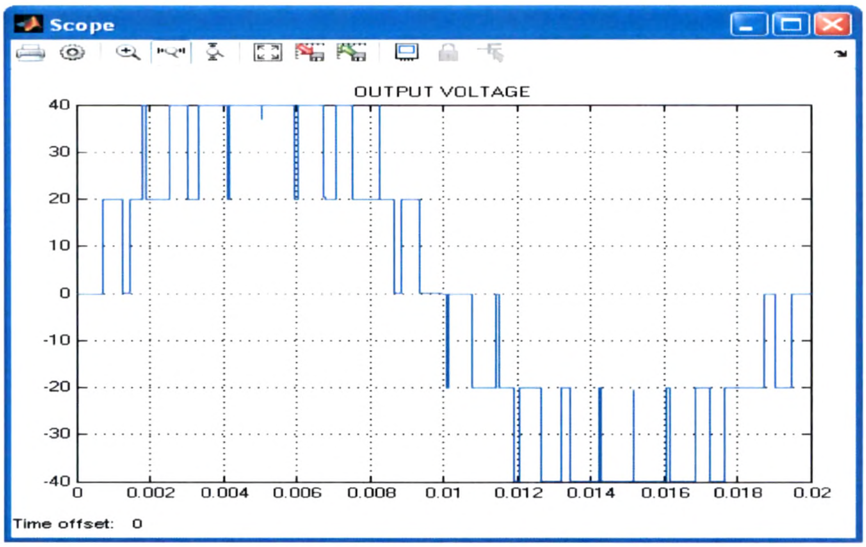


Fig. 5.4 Simulink output for single phase HMLI with POD modulation technique

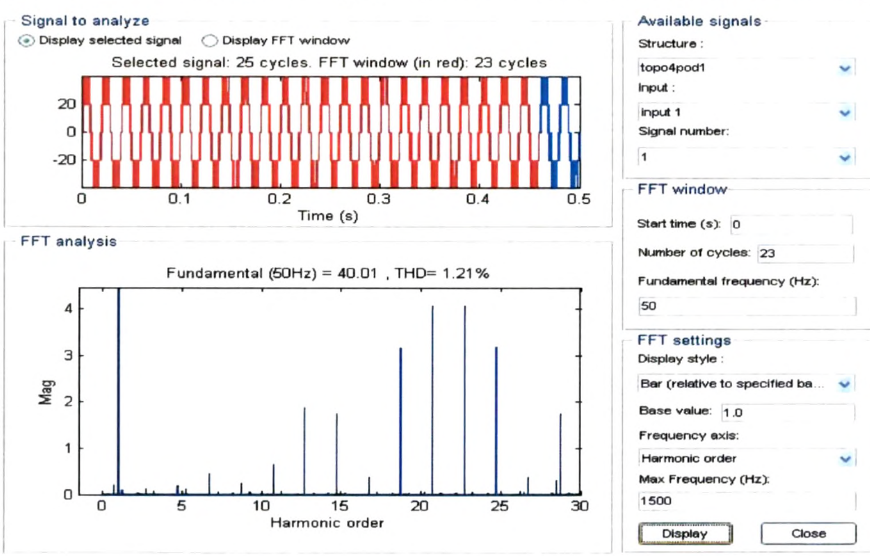


Fig. 5.5 FFT analysis and THD for single phase HMLI with POD modulation technique

5.1.3 SIMULATIONS FOR HMLI WITH APOD MODULATION TECHNIQUE

Fig. 5.6 shows the output for single phase HMLI with alternative phase opposition disposition modulation technique and equal DC sources which are equal to 20V. Thus five level output is obtained. While Fig. 5.7 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as mentioned in previous chapter.

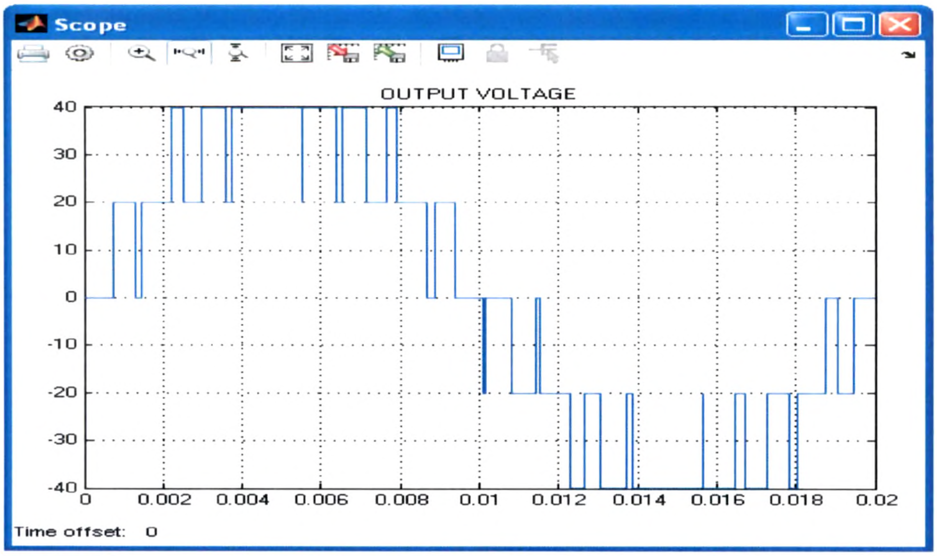


Fig. 5.6 Simulink output for single phase HMLI with APOD modulation technique

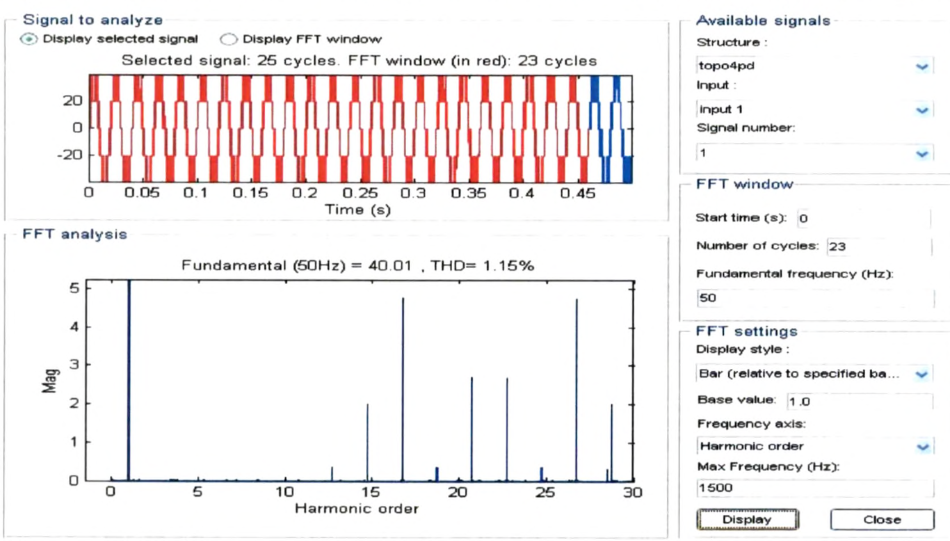


Fig. 5.7 FFT analysis and THD for single phase HMLI with APOD modulation technique

5.1.4 SIMULATIONS FOR HMLI WITH PS MODULATION TECHNIQUE

Fig. 5.8 shows the output for single phase HMLI with phase shifted modulation technique and equal DC sources which are equal to 20V. Thus five level output is obtained. While Fig. 5.9 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency.

Other parameters remain same as mentioned in previous chapter.

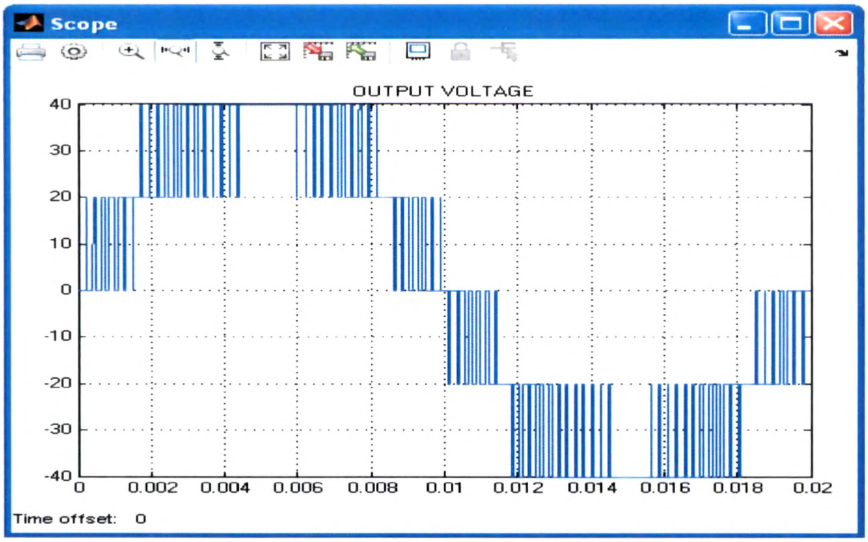


Fig. 5.8 Simulink output for single phase HMLI with PS modulation technique

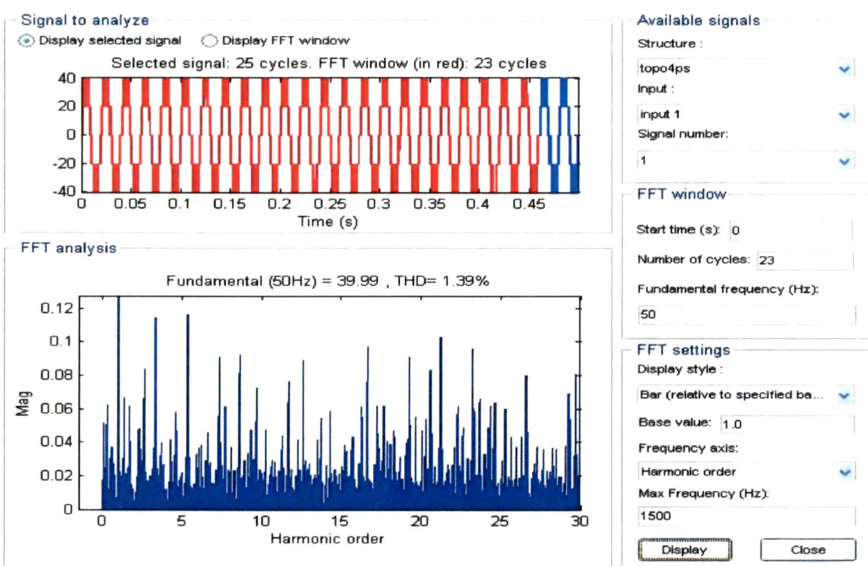


Fig. 5.9 FFT analysis and THD for single phase HMLI with PS modulation technique

5.1.5 SIMULATIONS FOR HMLI WITH HYBRID MODULATION TECHNIQUE

Fig. 5.10 shows the output for single phase HMLI with hybrid modulation technique and equal DC sources which are equal to 20V. Thus five level output is obtained. While Fig. 5.11 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

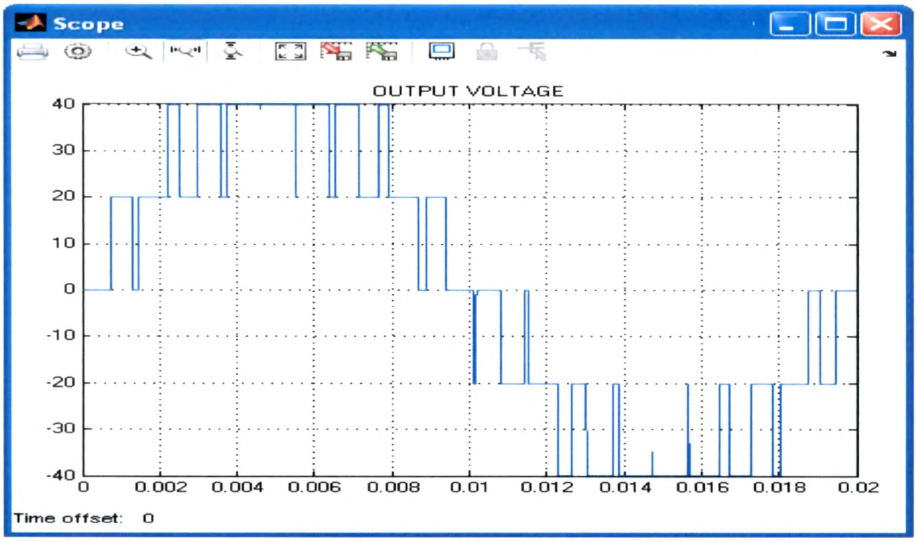


Fig. 5.10 Simulink output for single phase HMLI with hybrid modulation technique

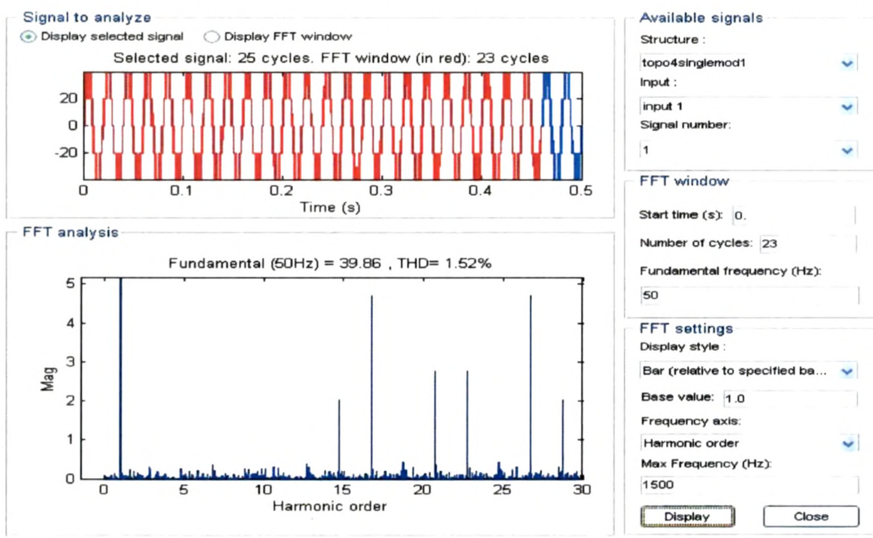


Fig. 5.11 FFT analysis and THD for single phase HMLI with hybrid modulation technique

5.1.6 SIMULATIONS FOR HMLI WITH THIRD HARMONIC INJECTION MODULATION TECHNIQUE

Fig. 5.12 shows control block for single phase HMLI with third harmonic injection modulation technique. Fig. 5.13 shows the output for single phase HMLI with third harmonic injection modulation technique and equal DC sources which is equal to 20V. Thus five level output is obtained. While Fig. 5.14 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. As explained in chapter

3 this modulation technique is applicable for three phase system due to addition of third harmonic in each reference hence THD obtained is high for single phase HMLI.

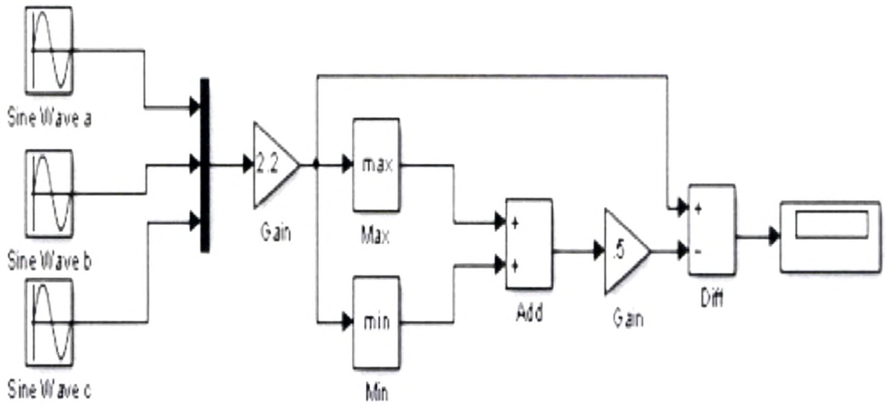


Fig. 5.12 Control block for HMLI with third harmonic injection modulation technique

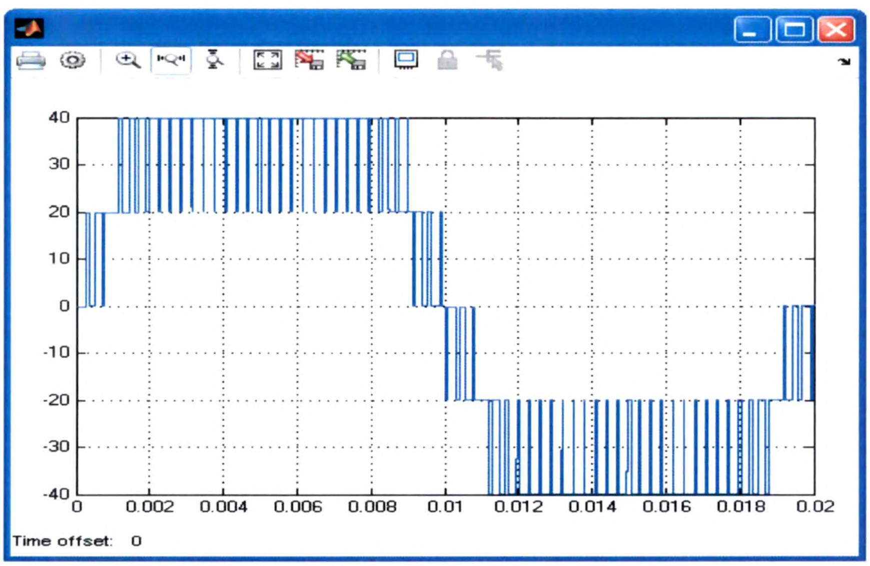


Fig. 5.13 Simulink output for single phase HMLI with third harmonic injection modulation technique

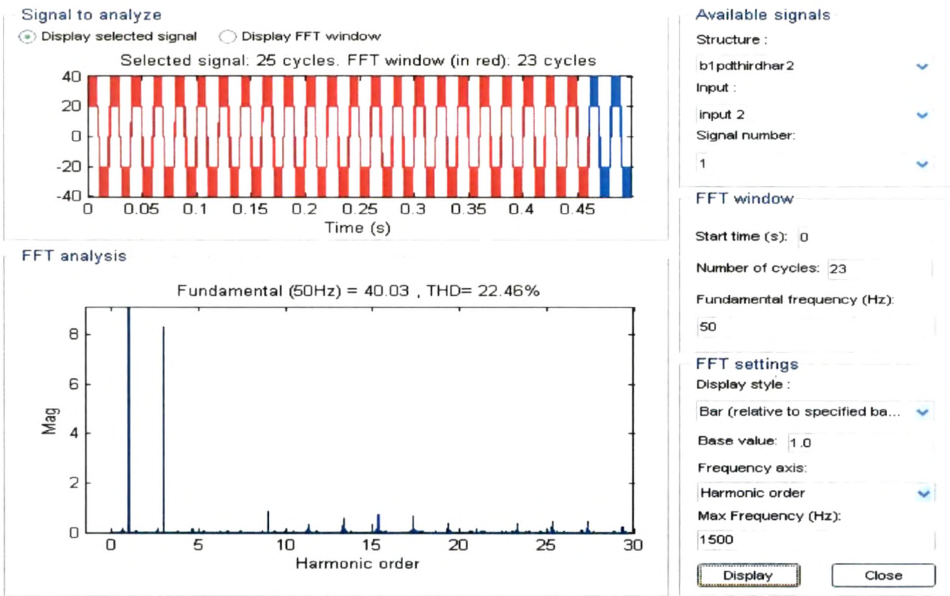


Fig. 5.14 FFT analysis and THD for single phase HMLI with third harmonic injection modulation technique

5.1.7 SIMULATIONS FOR HMLI WITH ISPWM TECHNIQUE

Fig. 5.15 shows the control block for single phase HMLI with ISPWM technique.

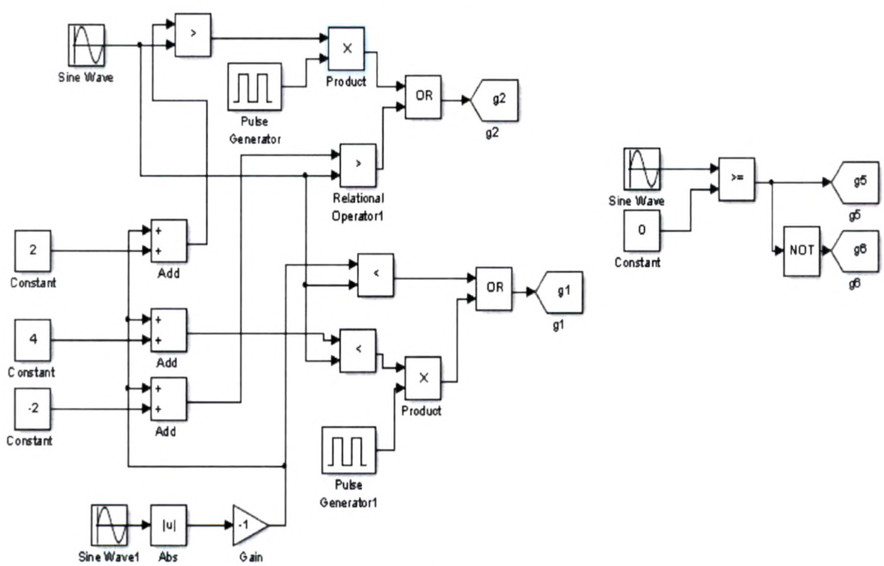


Fig. 5.15 Control block for HMLI with ISPWM technique

Fig. 5.16 shows the output for single phase HMLI with ISPWM technique and equal DC sources which is equal to 20V. Thus five level output is obtained. While Fig. 5.17 corresponds to FFT analysis giving THD at 1st cycle with 1500 Hz as maximum frequency. It was observed that for increased number of cycles THD remains unchanged. For ISPWM carrier frequency is 1 kHz. Output is not half wave symmetrical thus even harmonics are also present hence THD is more.

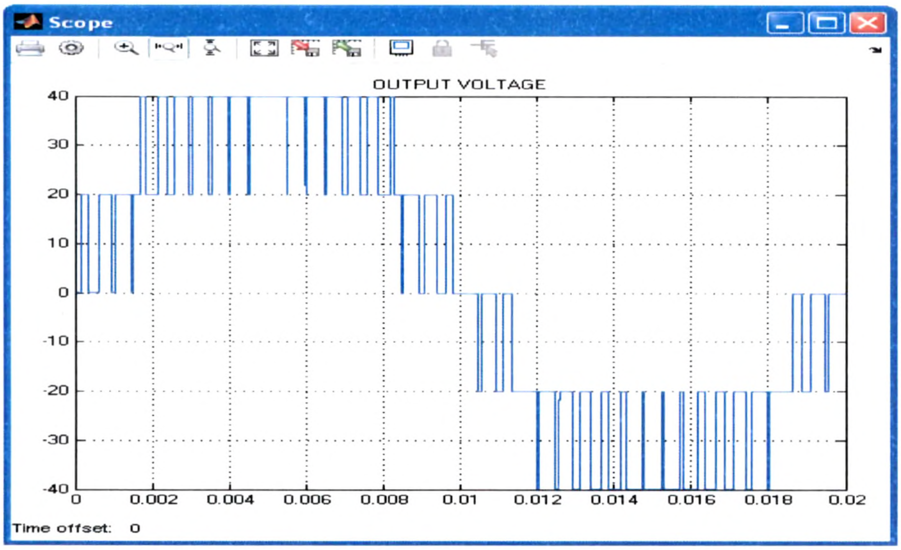


Fig. 5.16 Simulink output for single phase HMLI with inverted sine modulation technique

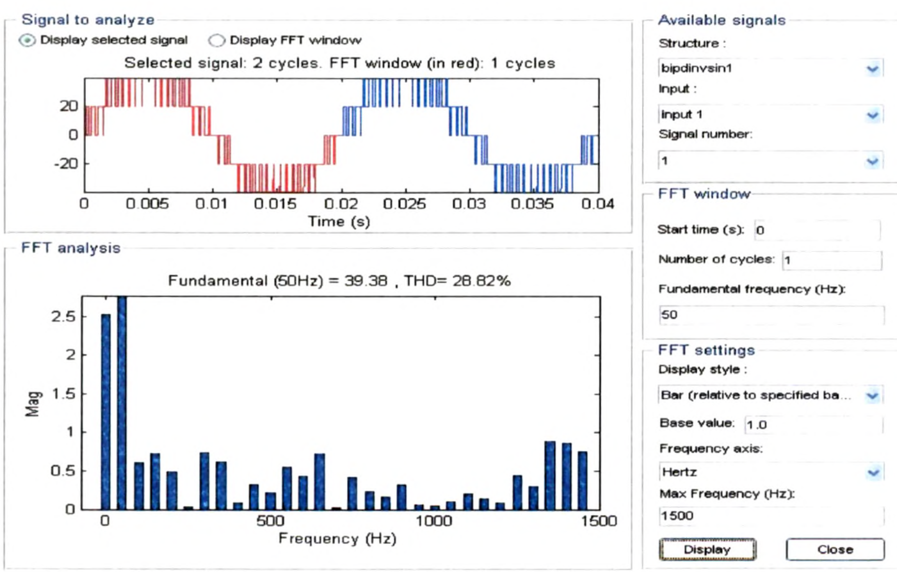


Fig. 5.17 FFT analysis and THD for single phase HMLI with inverted sine modulation technique

5.2 SIMULATIONS FOR THREE PHASE HYBRID MULTILEVEL INVERTER

Fig. 5.18 is simulation block for selected three phase HMLI for which simulations are done in MATLAB and hardware is also implemented which is described in further chapters. Simulations are done for different modulation techniques. Working principle for this HMLI is explained in chapter 2.

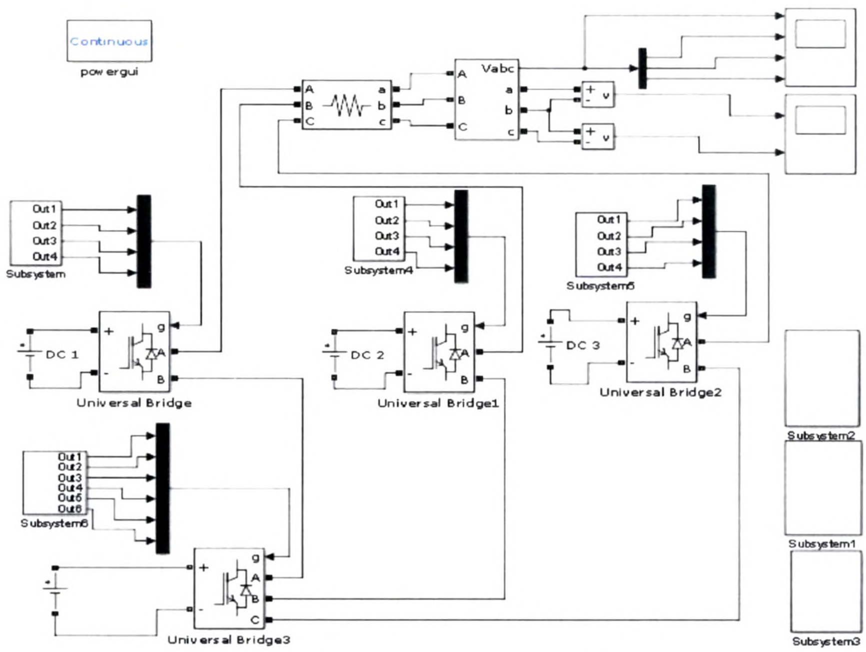


Fig. 5.18 Simulink block for three phase HMLI

5.2.1 SIMULATIONS FOR THREE PHASE HMLI WITH PD MODULATION TECHNIQUE

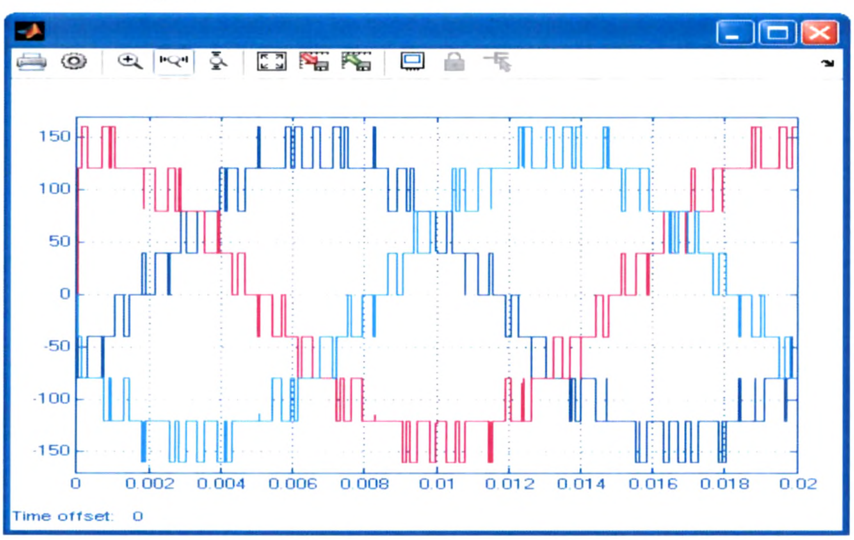


Fig. 5.19 Simulink output for three phase HMLI with PD modulation technique

Fig. 5.19 shows the output for three phase HMLI with phase disposition modulation technique.

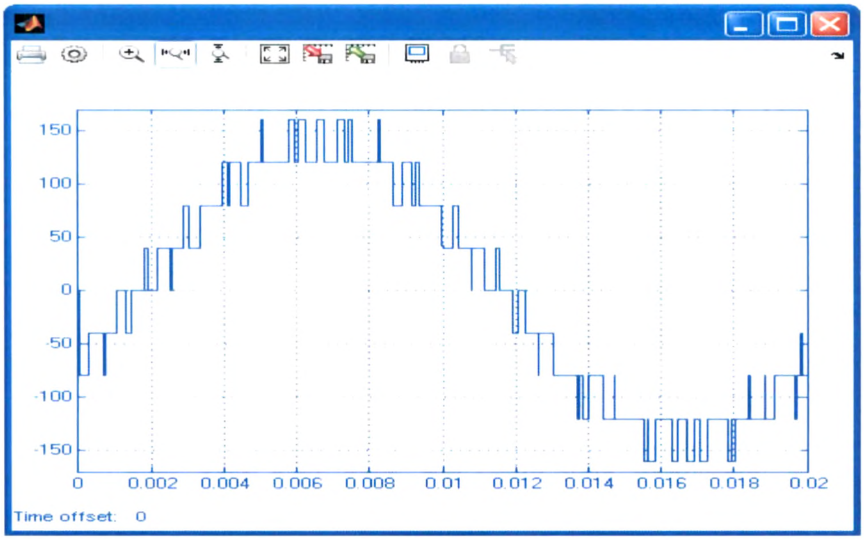


Fig. 5.20 One phase output from three phase HMLI PD modulation technique

DC source is 80V for three phase inverter and 40V for single phase 3 H bridges. Thus nine level output is obtained. While Fig. 5.21 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

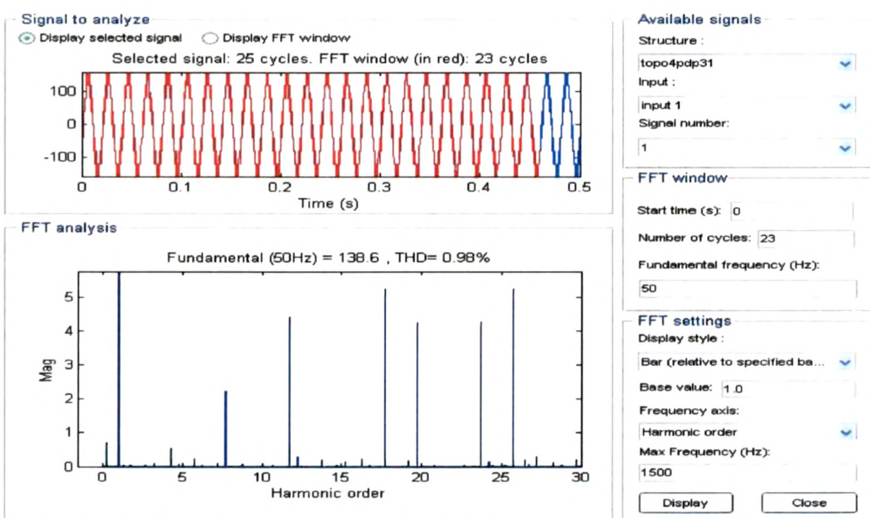


Fig. 5.21 FFT analysis and THD for HMLI with PD modulation technique

5.2.2 SIMULATIONS FOR THREE PHASE HMLI WITH POD MODULATION TECHNIQUE

Fig. 5.22 shows the output for three phase HMLI with phase opposition disposition modulation technique.

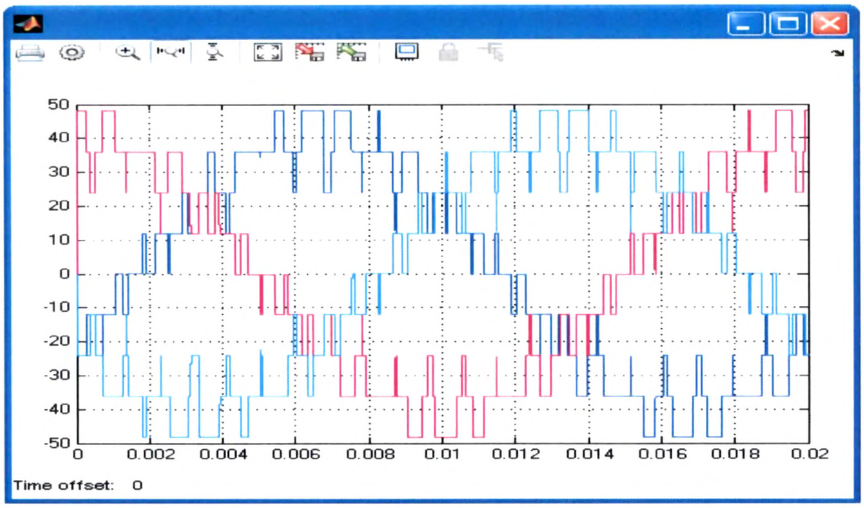


Fig. 5.22 Simulink output for three phase HMLI with POD modulation technique

DC source is 24V for three phase inverter and 12V for single phase 3 H bridges. Thus nine level output is obtained. While Fig. 5.24 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

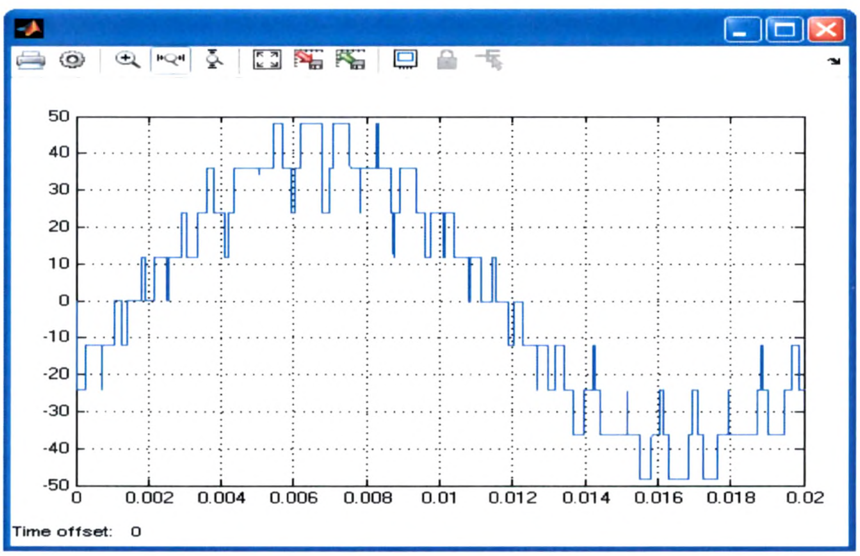


Fig. 5.23 One phase output from three phase HMLI POD modulation technique

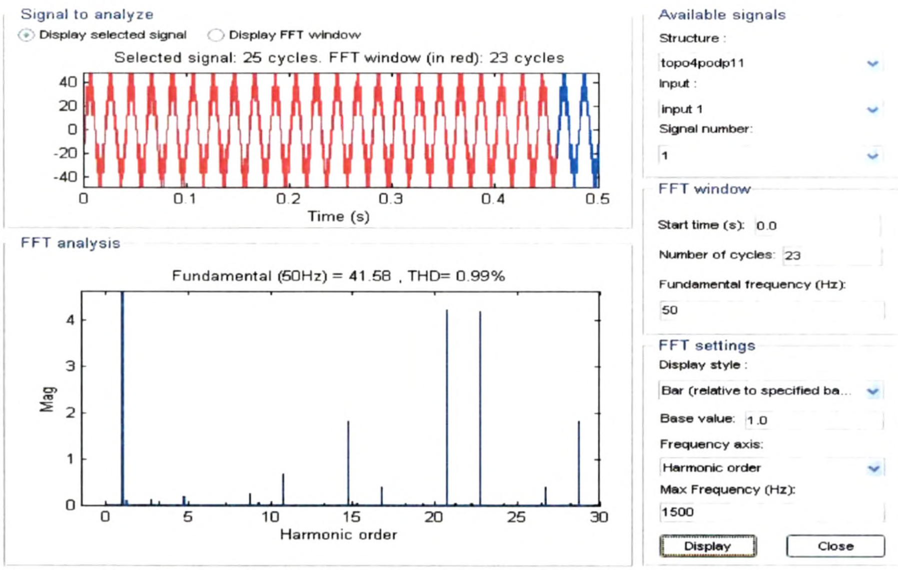


Fig. 5.24 FFT analysis and THD for HMLI with POD modulation technique

5.2.3 SIMULATIONS FOR THREE PHASE HMLI WITH APOD MODULATION TECHNIQUE

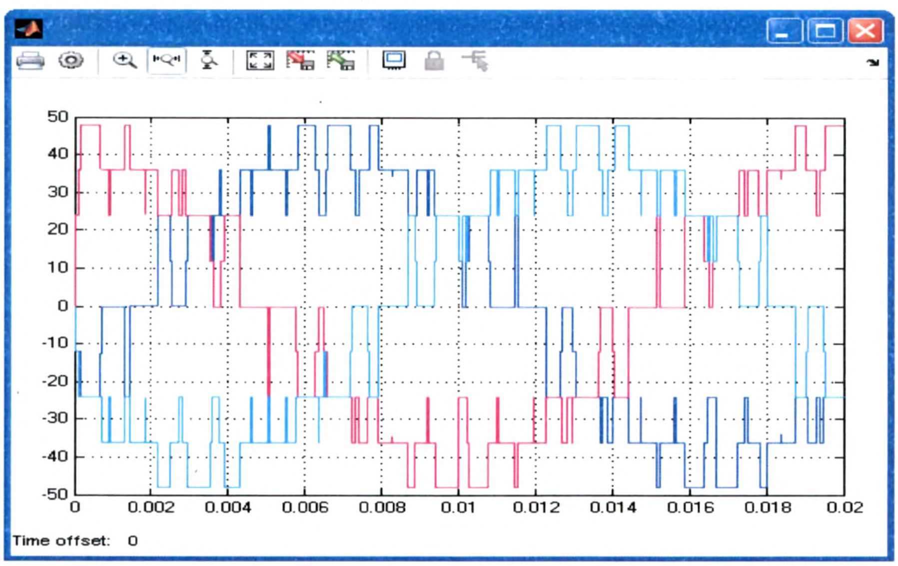


Fig. 5.25 Simulink output for three phase HMLI with APOD modulation technique

Fig. 5.25 shows the output for three phase HMLI with alternative phase opposition disposition modulation technique. DC source is 24V for three phase inverter and 12V for single phase 3 H bridges. Thus nine level output is obtained. While Fig. 5.27 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

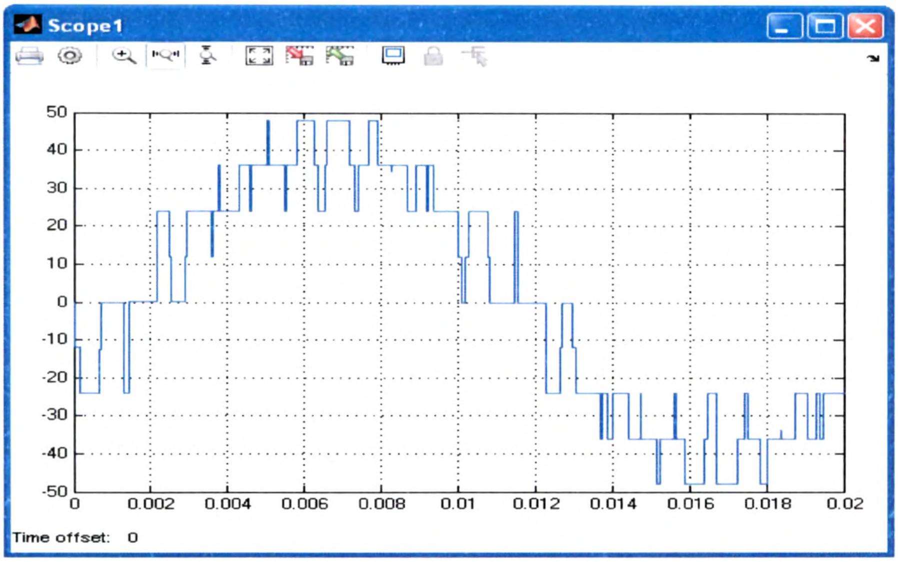


Fig. 5.26 One phase output from three phase HMLI APOD modulation technique

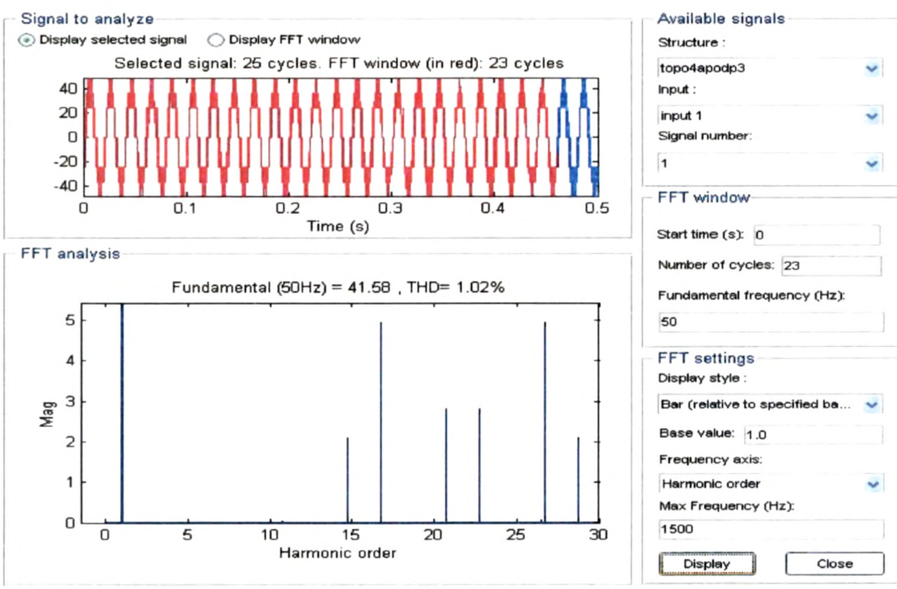


Fig. 5.27 FFT analysis and THD for HMLI with APOD modulation technique

5.2.4 SIMULATIONS FOR THREE PHASE HMLI WITH PS MODULATION TECHNIQUE

Fig. 5.28 shows the output for three phase HMLI with phase shifted modulation technique. DC source is 40 V for three phase inverter and 20 V for single phase 3 H bridges. Thus nine level output is obtained. While Fig. 5.30 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

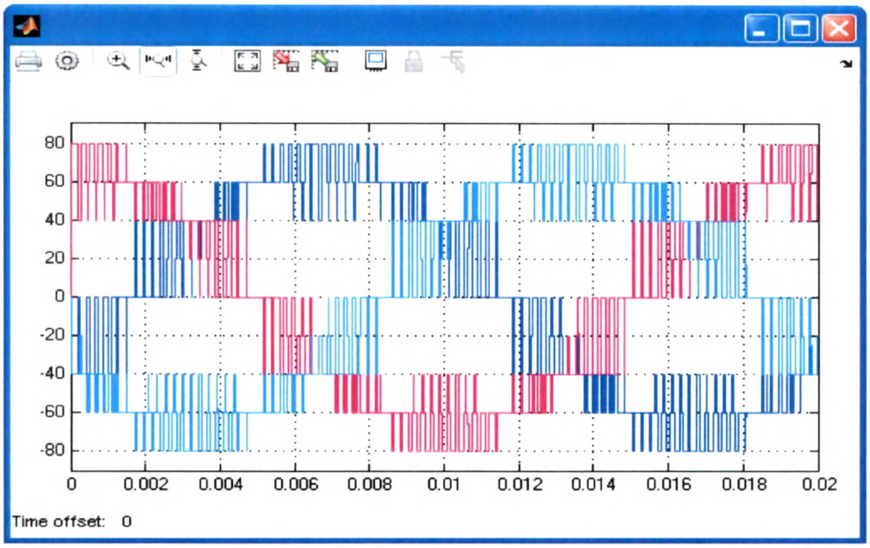


Fig. 5.28 Simulink output for three phase HMLI with PS modulation technique

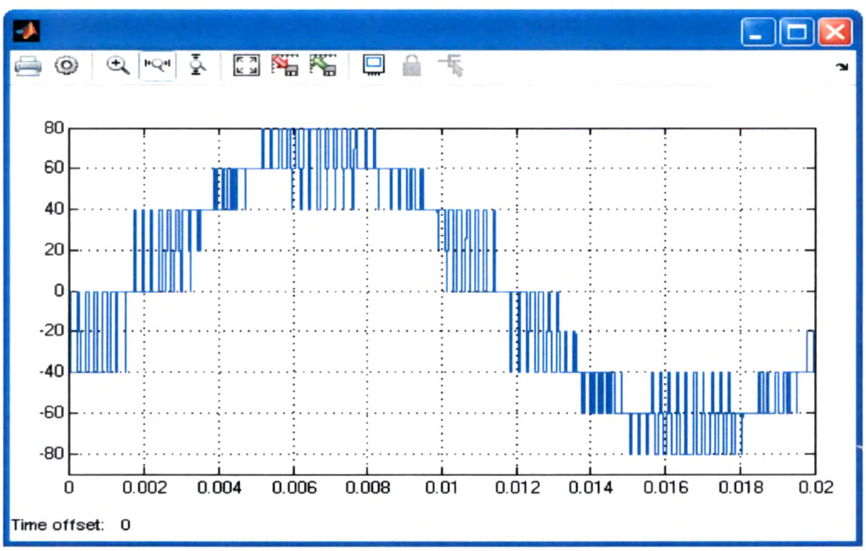


Fig. 5.29 One phase output from three phase HMLI PS modulation technique

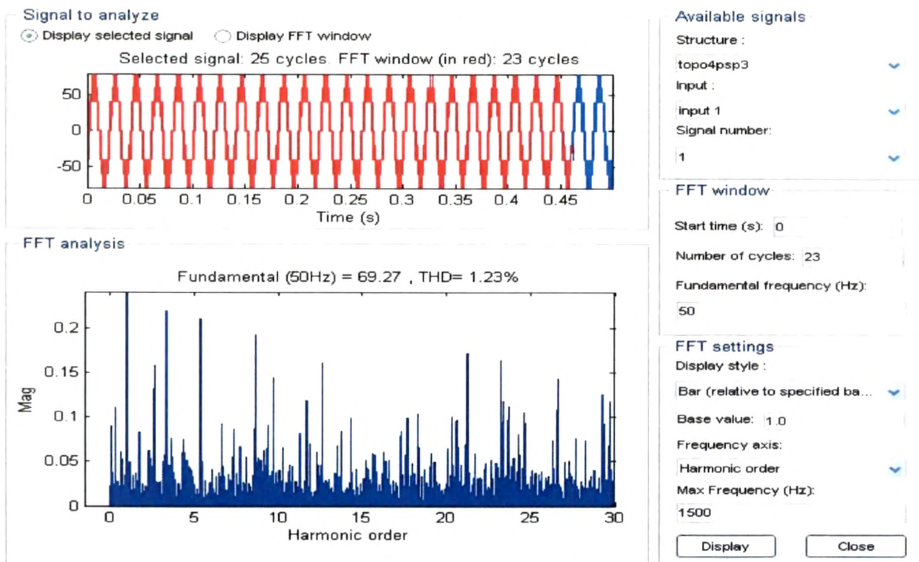


Fig. 5.30 FFT analysis and THD for HMLI with PS modulation technique

5.2.5 SIMULATIONS FOR THREE PHASE HMLI WITH HYBRID MODULATION TECHNIQUE

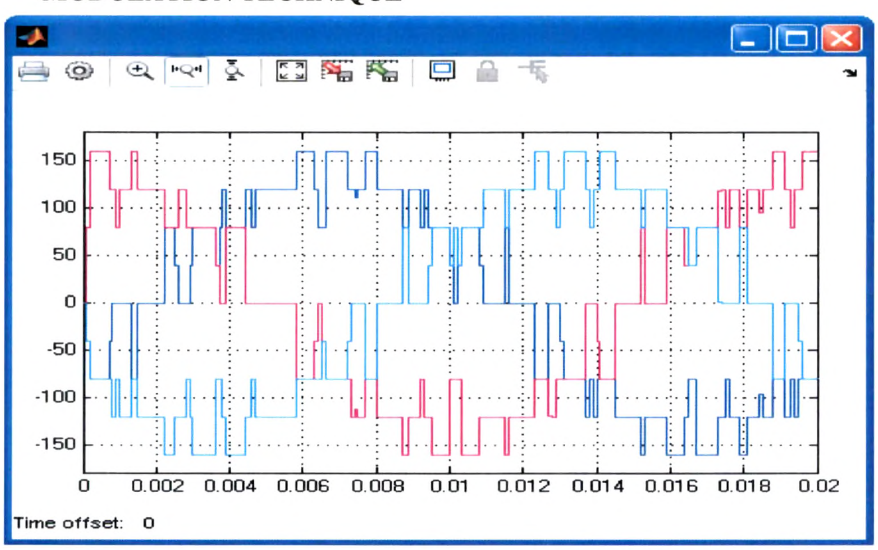


Fig. 5.31 Simulink output for three phase HMLI with hybrid modulation technique

Fig. 5.29 shows the output for three phase HMLI with hybrid modulation technique. DC source is 80 V for three phase inverter and 40 V for single phase 3 H bridges. Thus nine level output is obtained. While Fig. 5.31 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

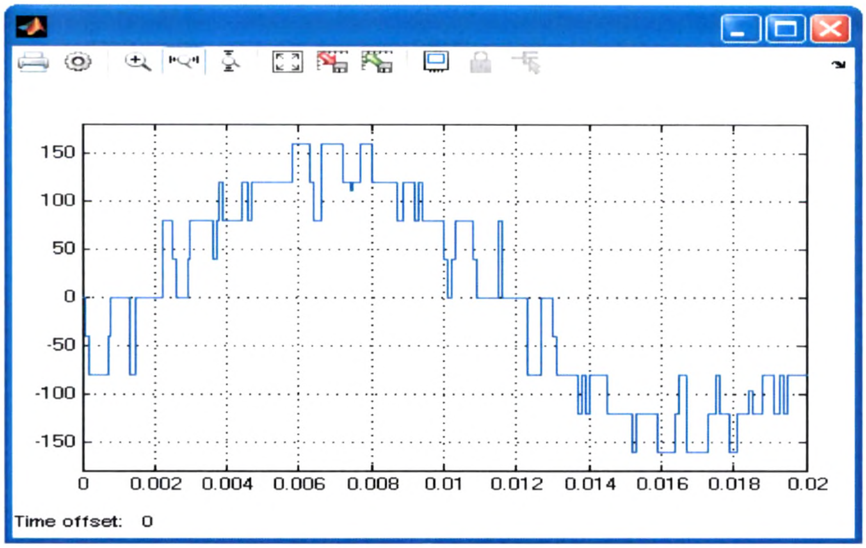


Fig. 5.32 One phase output from three phase HMLI hybrid modulation technique

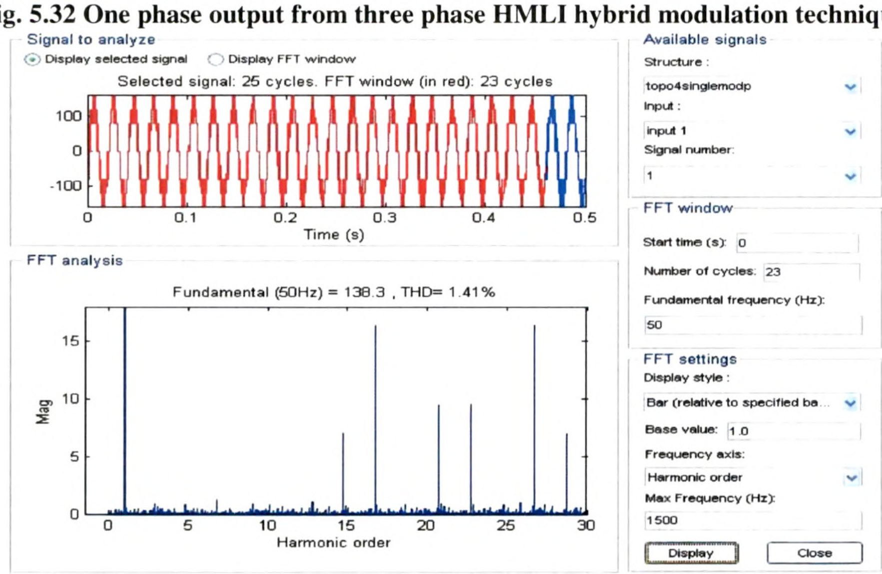


Fig. 5.33 FFT analysis and THD for HMLI with hybrid modulation technique

5.2.6 SIMULATIONS FOR HMLI WITH THIRD HARMONIC INJECTION MODULATION TECHNIQUE

Fig. 5.32 shows the output for three phase HMLI with phase shifted modulation technique. DC source is 80 V for three phase inverter and 40 V for single phase 3 H bridges. Thus nine level output is obtained. While Fig. 5.34 corresponds to FFT analysis giving THD at 23rd cycle with 1500 Hz as maximum frequency. Other parameters remain same as previous chapter.

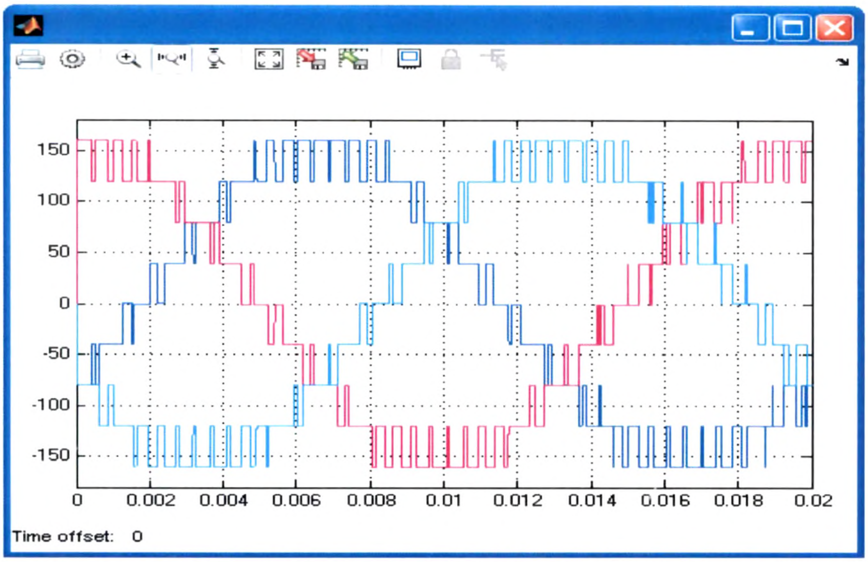


Fig. 5.34 Simulink output for three phase HMLI with third harmonic injection modulation technique

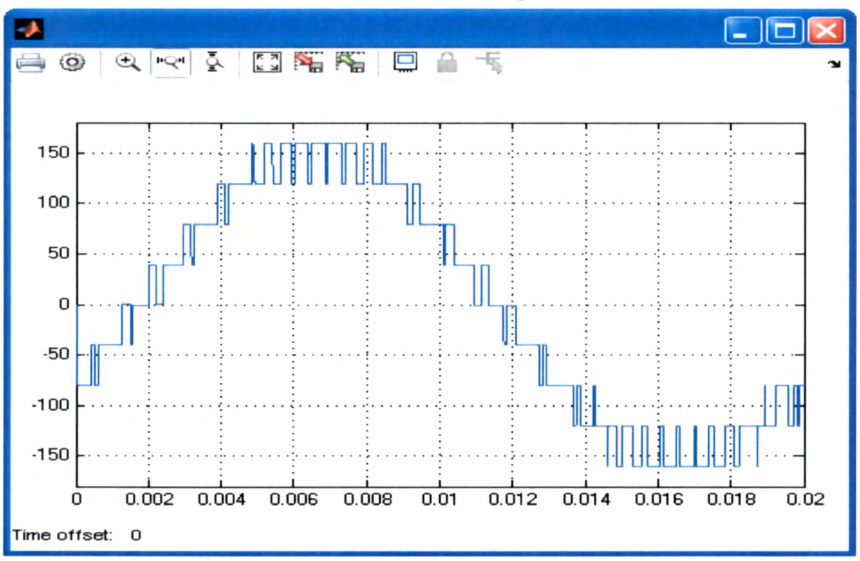


Fig. 5.35 One phase output from three phase HMLI third harmonic injection modulation technique

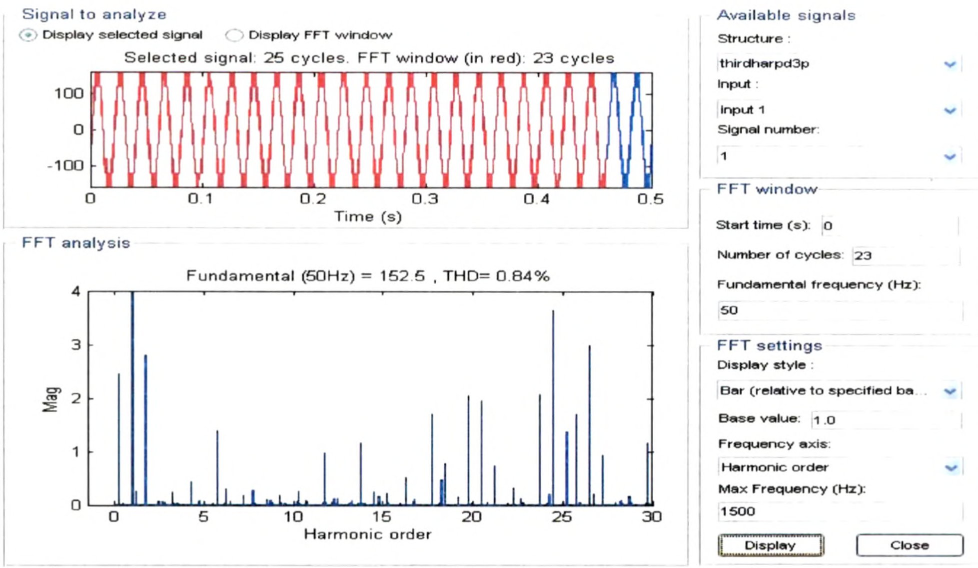


Fig. 5.36 FFT analysis and THD for HMLI with third harmonic injection modulation technique

Table 5.1 MATLAB simulation summary for HMLI

Phase	Modulation Technique	Output Levels	THD
Single	PD	5	1.17
	POD	5	1.21
	APOD	5	1.15
	PS	5	1.39
	HYBRID	5	1.52
	THIRD HARMONIC INJECTION	5	22.46
	ISPWM	5	28.82
Three	PD	9	0.98
	POD	9	.99
	APOD	9	1.02
	PS	9	1.23
	HYBRID	9	1.41
	THIRD HARMONIC INJECTION	9	0.84

5.3 SUMMARY

Different MATLAB simulations are done for selected hybrid multilevel inverter. Comparison is done on basis of THD. Results are summarized in Table 5.1. It is observed that for particular modulation index THD does not vary much with change in modulation technique. Number of stages, number of switches, number of sources, number of capacitors, overall cost etc. are the selection criteria for given application.