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PERFORMANCE ANALYSIS OF 3 BUS - HYBRID POWER SYSTEM INTEGRATED WITH TWO LEVEL AND VARIOUS TYPES OF MULTI- LEVEL INVERTERS

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Abstract: The depletion of natural resources has called for development of Hybrid power system. The present day hybrid power system has various sources ofRenewable and Non-Renewable types.The renewable energy sources are solar, wind, ocean, and geothermal. The advancement in technology has made Waste-To-Energy also feasible. The output of the renewable energy sources is DC. But most loads are AC. Hence, it is required to interface the renewable energy source to the grid through an inverter. The paper proposes to study the performance of 2-Level, and various types of multi-level inverters and also the performance of the 3-Bus hybrid power system integrated with the inverters, Solar energy is taken as the renewable source in the hybrid power system under study.It has been observed that the performance of 3-Level inverters is better than 2-Level inverter.Also, the hybrid power system integrated with inverters is satisfying the load balance equation, and therefore we are able to achieve stable performance of the hybrid power system.

Keywords: Inverters, Hybrid Power System, Renewable Source, Solar, Wind, Ocean, Geothermal, Waste-To-Energy.

1.0 INTRODUCTION

Multilevel Inverters (MLI) [1] are gaining importance because of the wide areas of their applications. They are used in small to large areas as: micro-grid, distribution systems, adjustable speed drives, static reactive power compensation, conveyors, and transportation applications as electric vehicle drives [2]. Several configurations of multi-level inverters have

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been developed and research is being done for development of further simpler configurations and switching techniques [3] to improve their performance.

The depletion of natural resources and the increase in power demand at various locations for various new developed electronic devices and areas, has called for development of new power sources, which has resulted in the conceiving of renewable energy sources. Hybrid renewable energy is becoming more flexible and attractive to fulfill the load demand both in standalone and grid connected mode [4] [5].Renewable energy generated from almost all energy sources is about DC and at different voltage levels. If the load is DC the renewable energy source output can be directly given to it, if the voltage levels match. If the loads are AC then they need to be interfaced through an inverter [6].

An inverter converts the DC electricity from renewable energy sources such as solar, wind to AC electricity. The electricity can be at any required voltage; in particular it can operate AC equipment designed for mains operation, or rectified to produce DC at any desired voltage.Multilevel inverters provide several advantages, including reduced voltage stress, higher output voltage quality, and increased power rating[7].Multilevel converters are been actively employed in the industrial sector and are the subject of substantial research and development.Since multilevel has been introduced, several switching methods are proposed which can be used for various multilevel inverters to increase efficiency and improve the inverters output waveform.

The paper has been organized as Section 1.0 Introduction, Section 2.0 Inverters, Section 3.0 Three bus hybrid power system, Section 4.0 Performance Simulation of Inverters, Section 5.0 Performance of Three Bus Hybrid Power System Integrated with Inverters, Section 6.0 Conclusion.

2.0 INVERTERS

2.1 TWO-LEVEL INVERTER

An inverter is a device that changes DC power into AC power at the right voltage and frequency. When the inverter gets its power from a strong and steady DC source, like a battery, it's called a Voltage Source Inverter (VSI),Figure 1.0.However, a 2-level VSI can sometimes produce AC output that's not perfectly smooth; it can have sharp changes in voltage, which is called high total harmonic distortion (THD). To improve the quality of the AC output and reduce THD, additional filtering components like inductors and capacitors are often added to the circuit.

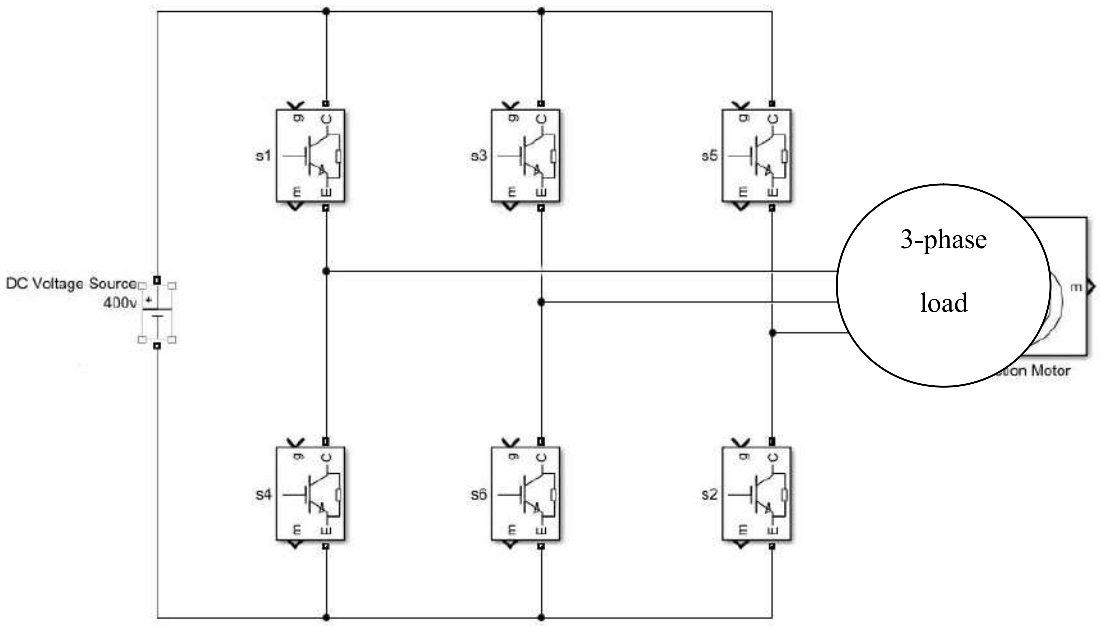

Fig 1.0: 2-Level Voltage Source Inverter

2.2 MULTI-LEVEL INVERTERS (MLI)

Voltage Source Inverters (VSIs) are commonly employed for the speed and torque control of Induction Motors (IMs). Traditional two-level VSIs have been widely used, but they exhibit drawbacks such as high Total Harmonic Distortion (THD) in their output voltage and increased stress on the switching components, potentially leading to VSI failures.To overcome these limitations, Multilevel Inverters (MLIs) have gained popularity due to their numerous advantages, including reduced switch stress, lower switching losses, diminished filtering requirements.

MLIs are being deployed in power systems [8] for their ability to meet the demand in power quality and power type AS DC/AC, as well as their reduced level of harmonic distortion and electromagnetic interference. There are several advantages of an MLI over the traditional two-level inverters where high switching frequency PWM is used [**9**, **10**]. MLIs are currently being considered as an industrial solution for high power quality and dynamic performance demanding systems [**11**].

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In this paper studies have been conducted on two types of multi-level inverters:

i. 3-Level H-Bridge Inverter and ii. 3-L Neutral Point Clamped Inverter

2.2.1 THREE LEVEL H-BRIDGE INVERTER

A 3-level H-bridge inverter, Figure 2.0 is an advanced power electronic device used to convert direct current (DC) power into alternating current (AC) power with higher efficiency and improved output waveform quality compared to traditional inverters. It's designed to provide three distinct voltage levels for generating a smoother AC waveform.

In this inverter configuration, there are three output voltage levels[**12**]: positive, negative, and zero. This is achieved by using multiple switches to create the different voltage levels. The inclusion of the zero voltage level helps reduce harmonic distortion in the AC output, leading to better overall power quality.

The 3-level H-bridge inverter surpasses the 2-level inverter in terms of output quality, reduced harmonic distortion, and improved efficiency. While 2-level inverters have their applications, the 3-level H-bridge configuration shines in scenarios where clean and precise AC power is essential.

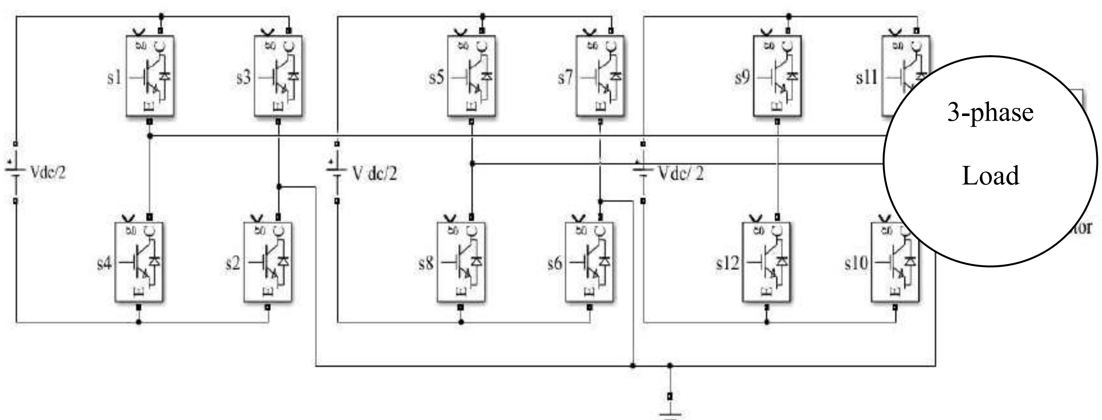

Fig 2.0: 3-L H-Bridge Inverter

2.2.2 3-L NEUTRAL POINT CLAMPED(NPC) INVERTER

The key feature of the NPC inverter, Figure 3.0 is the inclusion of a neutral point, which is a midpoint voltage reference between the positive and negative voltage levels. This neutral point

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helps distribute the voltage stress across the switches more evenly, reducing the stress on individual components.

The 3-level configuration consists of three voltage levels above the neutral point, three voltage levels below the neutral point, and one zero voltage level at the midpoint. This design allows for more precise control over the output voltage waveform, resulting in reduced harmonic content compared to traditional inverters.

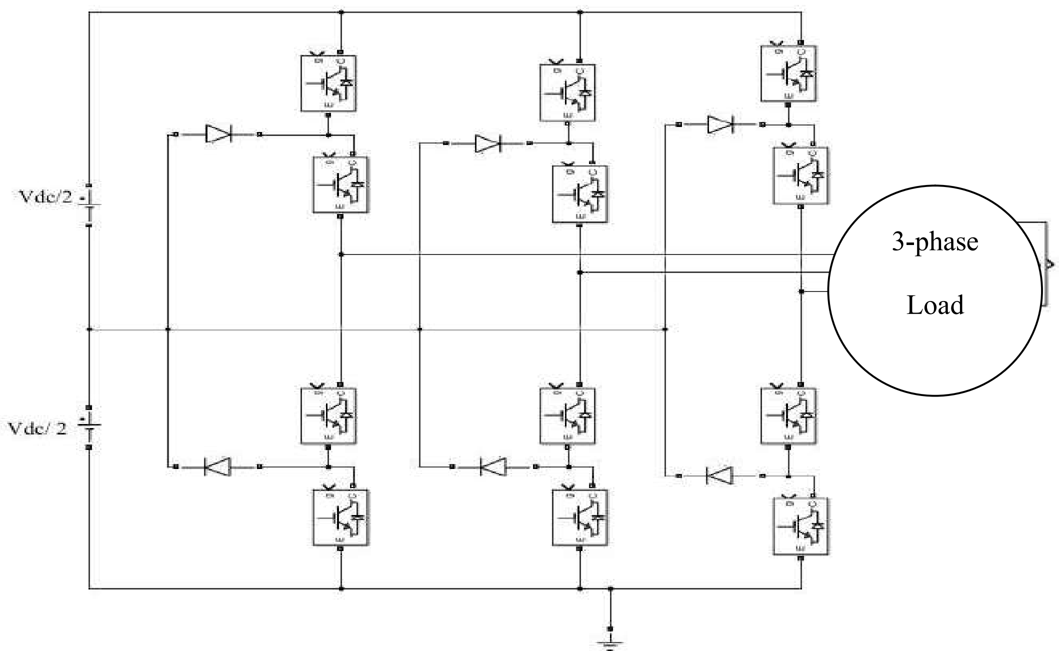

Fig 3.0: 3-L Neutral Point Clamped

3.0 THREE BUS HYBRID POWER SYSTEM

A 3-bus power system, Figure 4.0 consists of 3 interconnected buses representing generation, transmission and consumption points. Each bus has voltage magnitude, phase angle, and load characteristics that determine power flow and system stability. The first bus called slack bus, sets the reference voltage and angle and absorbs or injects any mismatches to maintain system balance.

3 level inverters are commonly used in renewable energy systems, such as PV systems and wind turbines[**13**]. Integrating these inverters with 3-bus power system can provide the smooth integration of renewable energy sources into the grid by providing controlled and high quality AC power injection.

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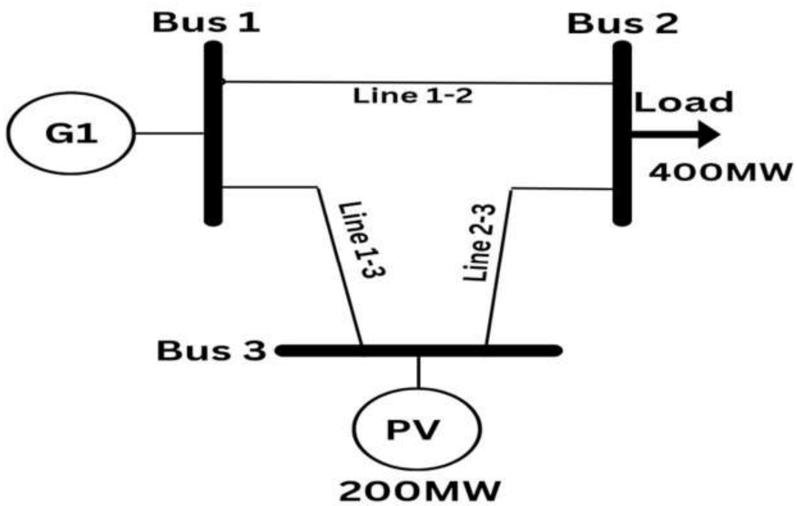

Fig 4.0: Three-Bus Hybrid Power System

4.0 PERFORMANCE SIMULATION OF INVERTERS

Performance of 2L-VSI,3L-CHB inverter and 3L-NPC inverter fed IMD was simulated at different torques[**14**].. For all the cases the parameters: Voltage THD, Current THD, Efficiency of Induction Motor were observed and tabulated.

4.1TWO-LEVEL INVERTER

Figure 5.0 is the Matlab simulation of 2L-VSI fed induction motor drive. Figure 6.0 is the FFT Analysis of the system, showing the Line Voltage and THD of the system.

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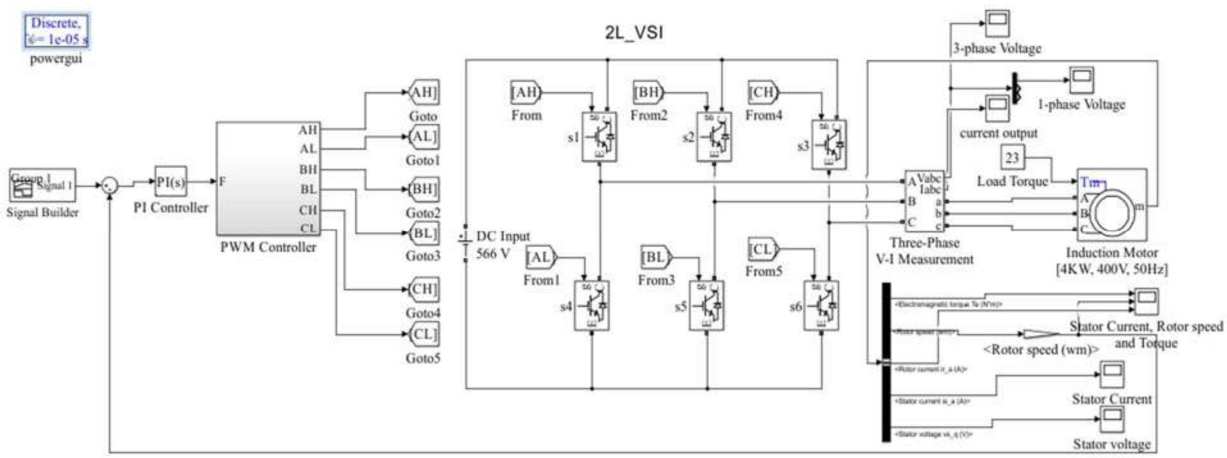

Fig. 5.0:Matlab simulation model of 2L-VSI fed induction motor drive

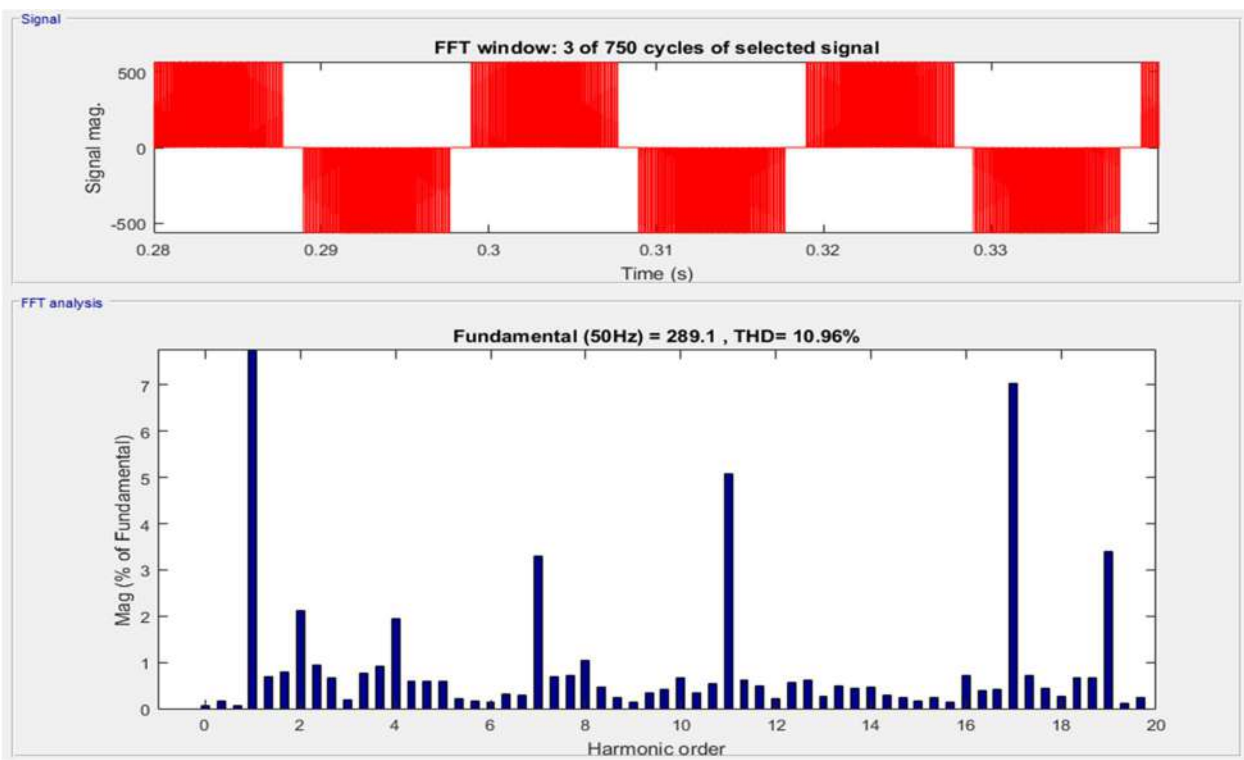

Fig. 6.0:FFT Analysis 2L-VSI

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4.2 THREE LEVEL HB

Figure 7.0 is the Matlab simulation of 3L-HB fed induction motor drive. Figure 8.0 is the FFT Analysis of the system, showing the Line Voltage and THD of the system.

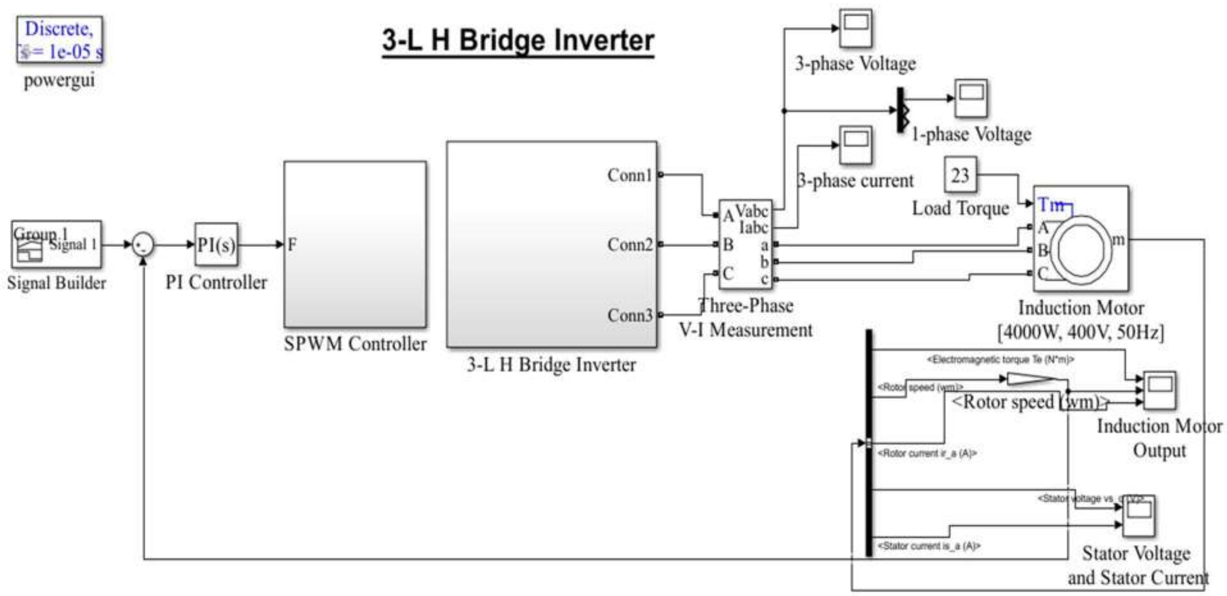

Fig. 7.0:Matlab simulation model of 3L-HB fed induction motor drive

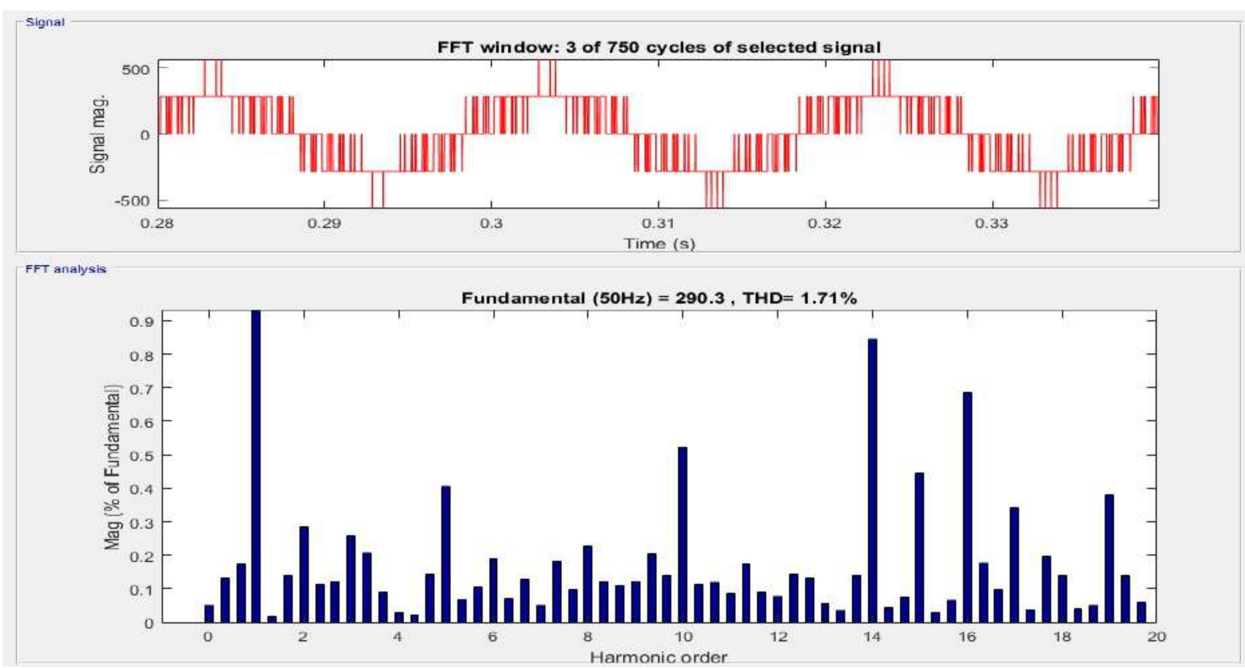

Fig. 8.0: FFT Analysis 3L-HB

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4.3 THREE LEVEL NPC

Figure 9.0 is the Matlab simulation of 3L-NPC fed induction motor drive. Figure 10.0 is the FFT Analysis of the system, showing the Line Voltage and THD of the system.

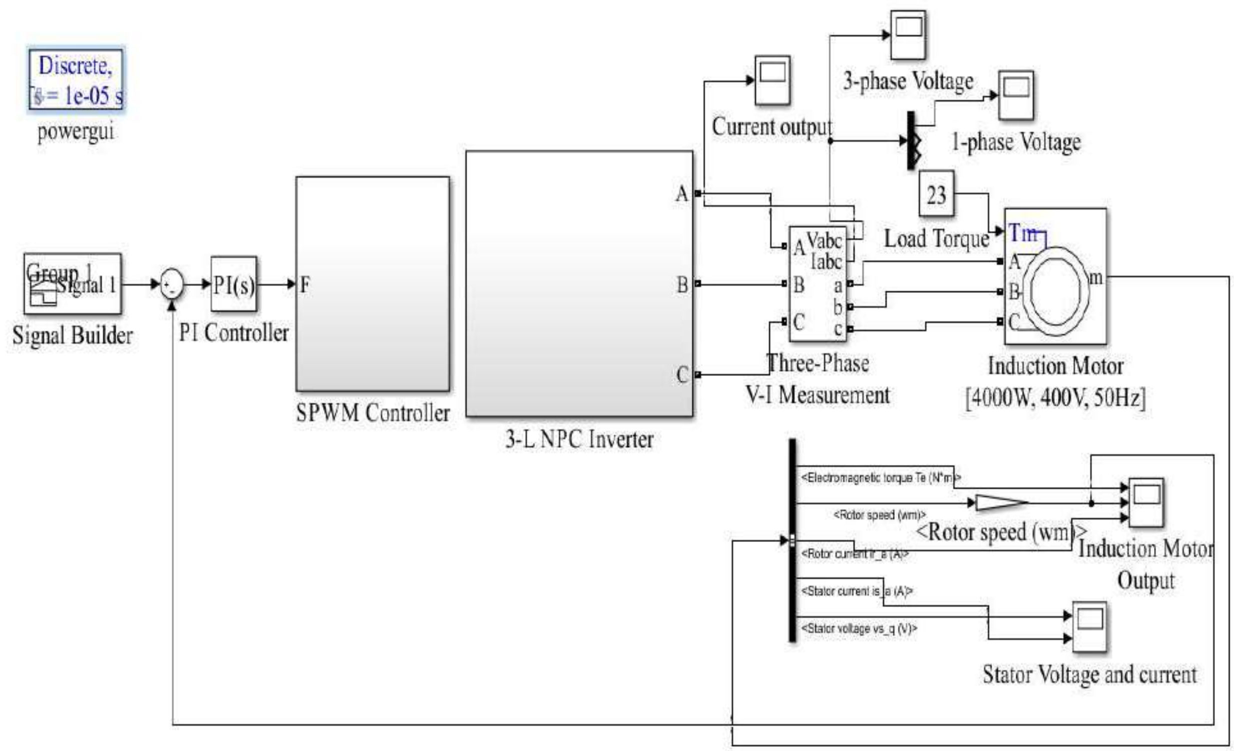

Fig. 9.0:Matlab simulation model of 3L-NPC fed induction motor drive

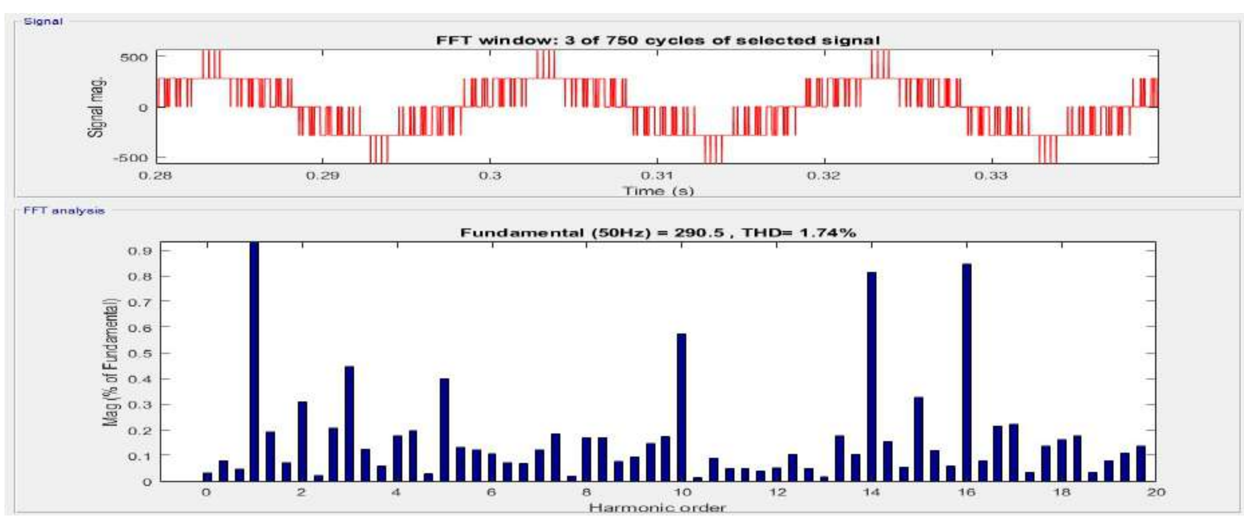

Fig. 10.0:FFT Analysis 3L-NPC

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4.4 Comparision of Various Simulated Inverters fed IMD – Performance

The Volatge and Current THD of 2L-VSI,3L-CHB inverter and 3L-NPC inverter fed IMD for different load torques is presented in Table I.

Table-I

Load Torque N-m	2-L Inverter		3-L HB Inverter		3-L NPC Inverter	
	Voltage THD%	Current THD%	Voltage THD%	Current THD%	Voltage THD%	Current THD%
23 N-m	10.96%	3.70%	1.71%	0.80%	1.74%	0.88%
18 N-m	12.14%	4.02%	1.90%	0.86%	2.00%	0.92%
13 N-m	15.53%	4.65%	2.24%	0.88%	2.37%	1.12%
8 N-m	16.35%	4.95%	2.59%	1.22%	2.46%	1.54%

The efficinecy of the induction motor fed with 2L-VSI,3L-HB and 3L-NPC Inverters is presented in Figure 11.0.

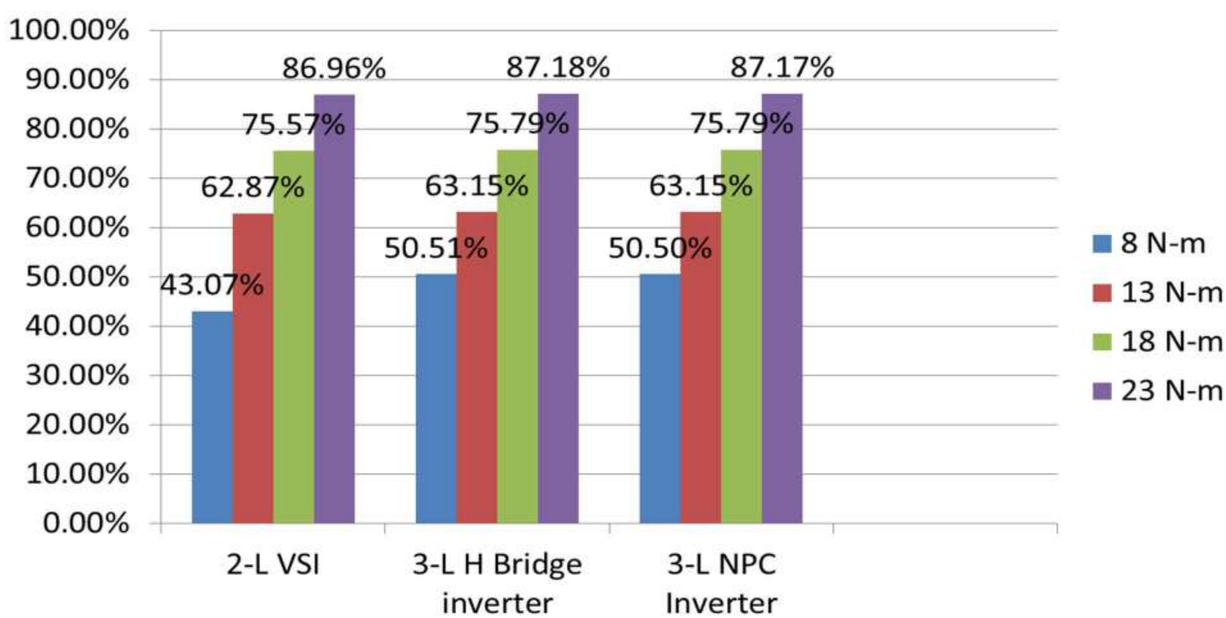

Fig.11.0 Efficiency of Induction Motor fed with 2L-VSI,3L-HB and 3L-NPCInverters

4.5 Discussion of Results

From figures 6.0,8.0,10.0,11.0 and Table I we can observe that the Voltage THD, Current THD and efficiency of the induction motor is better with 3L-NPC inverter.

5.0 THREE BUS HYBRID SYSTEM INTEGRATED WITH INVERTYERS

To study the effect of inverters in a power system, a three bus hybrid power system was selected. PV system was simulated for the renewable energy source. The one line disgram of the system has been presented in figure 4.0. The Matlab simulation diagram with 3L-HB inverter is presented in figure 12.0. Matlab models of the three bus hybrid power sytem for all the three types of inverters under study – 2l,3 L-HB and 3L-NPC have been developed and executed for load flow studies[**15**].

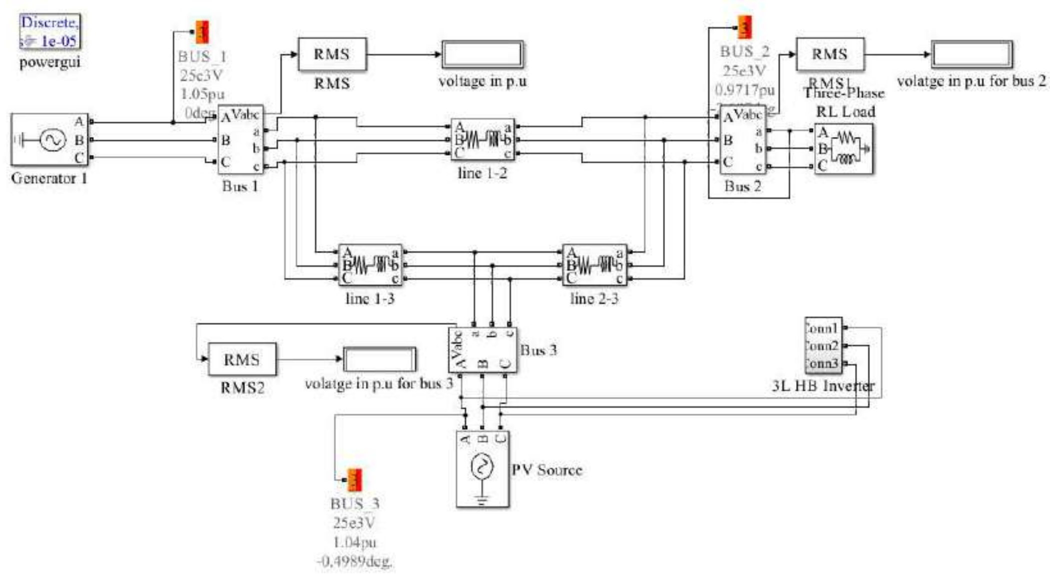

Fig. 12.0: Matlab simulation model of 3 Bus Hybrid Power system integrated with 3L-HB

5.1 Results and Discussion of 3-Bus Hybrid Power System

On conducting load flow studies, in was onserved the the three bus power system with every type of inverter has satisfied the load-balance equation:

Total Generated Power = (Total Load Demand – Total Loses)---- eq.(1)

For this three bus system under study,the load balance equation is:

G1+G2 = [D-{L1+L2+L3)] ------- eq.2

Where

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G1 = Power generated by grid source in MW

G2= Power generated by PV source in MW

D = Load Demand in MW

L1,L2,L3 = Line Losses of the three transmission lines in MW

The generation,load demand and line losses data is presented in line Table II.

Table-II

	Base Case (MW & Mvar)	**With 2L Inverter (MW & Mvar)**	**With 3L H B Inverter (MW & Mvar)**
Generation G1	218.42+j140.85	218.44+j140.85	218.45+j140.85
Generation G2 (PV)	200+j146.18	200+j146.18	200+j146.18
Load Demand (D)	400+j250	400+j250	400+250
Line losses 1-2 (L1)	8.39+j16.79	8.25+j16.63	8.06+j16.24
Line losses 2-3 (L2)	9.85+j19.69	9.56+j19.42	9.32+j19.37
Line losses 3-1 (L3)	0.18+j16.79	0.18+j16.79	0.18+j16.79

6.0 CONCLUSION

The performance of 2-Level invereter, 3L-HB and 3L-NPC multi-level inverters have been studied, after simulating the Matlab models. The performance of the 3-Bus hybrid power system integrated with the inverters, Solar energy taken as the renewable source in the hybrid power system has been studied. It has been observed that the performance of 3-Level inverters is better than 2-Level inverter. Also, the hybrid power system integrated with inverters is satisfying the

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load balance equation, and therefore we are able to achieve stable performance of the hybrid power system.

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