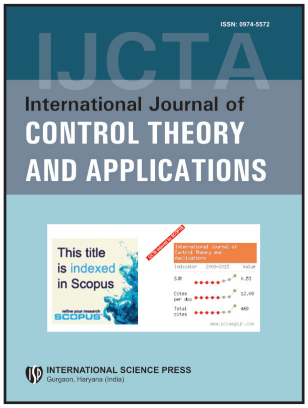

International Journal of Control Theory and Applications

ISSN : 0974-5572

Volume 10 • Number 16 • 2017

ANFIS Based SVPWM Technique for H-Bridge Multilevel Matrix Converter in Wind Energy Conversion System Employing DFIG

G. Pandu Ranga Reddy[a] and M. Vijaya Kumar[b]

[a]*Associate Professor, Department of Electrical and Electronics Engineering, G.P.C.E.T, Kurnool, A.P, India. Email: gprreee@gmail.com*

[b]*Professor, Department of Electrical and Electronics Engineering, J.N.T.U C.E, Anantapur, A.P, India. Email: mvk_2004@rediffmail.com*

Abstract: The demand for electrical energy is continuously increasing and the world's fossil fuels are getting depleted drastically which are not sufficient enough to meet the energy requirements for the next few decades. Hence, to meet the energy requirement, alternative or renewable sources of energy are being used. Alternative energy sources are under extensive research aiming to provide the world's ever increasing energy demands. Wind energy, with a global annual increasing growth rate ranging between 20-30%, is highly opted for renewable power generation than other resources. The power electronic converter plays a major role in controlling the power generated in a Wind plant. Over past three decades, Matrix Converters and Multilevel Converter Topologies gained an outstanding attention among the power electronic converters**.** The combination of Matrix Converter and Multilevel Converter is named as Multilevel Matrix Converter and is useful in many industrial and commercial applications. In this paper, H-Bridge Multilevel Matrix Converter is developed for operating a Double Fed Induction Generator. An Adaptive Neuro Fuzzy Inference System based Space Vector Pulse Width Modulation technique is implemented for controlling the switching sequence of the converter. This entire converter configuration is integrated to an electric grid and the performance of the system is analyzed. The simulations are carried out by using MATLAB/SIMULINK software and results are discussed.

Keywords: Adaptive Neuro Fuzzy Inference System (ANFIS), Double Fed Induction Generator (DFIG), Fuzzy Inference System (FIS), H-Bridge Multilevel Matrix Converter, SVPWM technique, Wind Energy Conversion System (WECS).

1. INTRODUCTION

The generation of electrical power from variable speed machines in Wind Energy Conversion System mainly requires power electronic converters as a part of power conversion. Since last 30 years, with the advancement of semiconductor devices and Micro Processor technology, the applications of power electronics increased rapidly**.** But these power electronic devices impose some major problems on the quality of power. Hence it is necessary to design the power converters that provide good quality of power by reducing the Total Harmonic Distortion (THD) injected into the power system. The major elements in wind plant are wind turbine, generator and power electronic converters [1]. The Wind Energy Conversion System employing DFIG having AC – DC – AC converter (Back to Back converter) connected to the grid as shown in Figure 1(a). This type of power conversion denotes indirect power conversion.

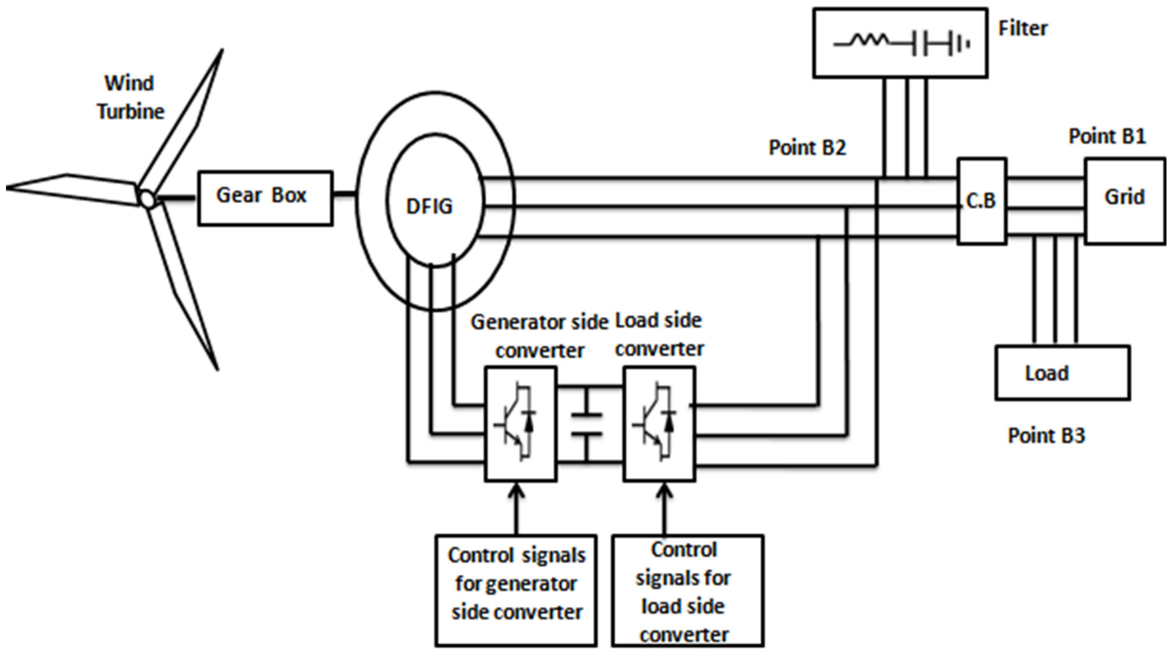

Figure 1: (a) Grid connected WECS employing DFIG with Back to Back converter

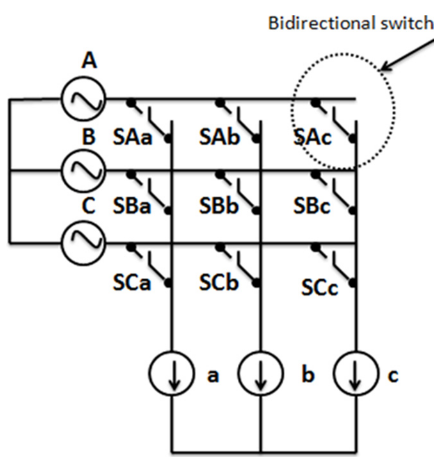

Figure 1: (b) Conventional 3×3Matrix Converter

Another approach for converting AC-DC-AC is, by using Matrix Converter. Power conversion takes place in a single stage process using this converter. Hence it is called Direct AC/AC Power Converter. Figure 1(b) shows the basic Matrix Converter containing nine bidirectional switches. The utilization of Matrix Converter is restricted to low and medium voltage applications. For medium and high voltages, multilevel concepts are incorporated in the basic Matrix Converter. This hybrid combination gives the Multilevel Matrix Converter. Multilevel Converters are basically classified into three types.

Diode Clamped Multilevel Converter was invited by A. Nabae, I. Takahashi and H. Akagi. The Capacitor Clamped Multilevel Converter was proposed by T.A. Meynard and H. Foch and H-Bridge Multilevel Converter was introduced by R. H. Baker and L.H. Bannister [2]. In this paper the modeling of H-Bridge Multilevel Matrix Converter is discussed. An Adaptive Neuro Fuzzy Inference System (ANFIS) based SVPWM technique is designed for controlling the switching sequence of the proposed Converter in Wind Energy Conversion System employing DFIG.

2. MODELING OF H-BRIDGE MULTILEVEL MATRIX CONVERTER

The Hybrid Bridge Multilevel Matrix Converter is similar to conventional 3×3 Matrix Converter. It can be obtained by replacing switches in the conventional 3×3 Matrix Converter with H-Bridges [3]. The H-Bridge contains four IGBT switches with diodes that are connected in anti-parallel to bypass the circulating currents. The schematic diagram of proposed converter shown in Figure. 2 (a). Each module in the converter consists of a capacitor act as a DC link which stabilizes the output voltage of the H-Bridge. The operation of proposed converter is dependent on the working of single H-Bridge module. The operation of each module in the converter is as follows [4].

It gives the three levels of voltages of $+V_c$, 0, $-V_c$, where V_c is the voltage across capacitor in each H-Bridge module. If

1. Sw_1, Sw_4 are turned on and Sw_2, Sw_3 are turned off then $V_{xy} = +V_c$.
2. Sw_2, Sw_3 are turned on and Sw_1, Sw_4 are turned off then $V_{xy} = -V_c$.
3. Sw_1, Sw_3 are turned on and Sw_2, Sw_4 are turned off / Sw_2, Sw_4 are turned on and Sw_1, Sw_3 are turned off then $V_{xy} = 0$.
4. Sw_1, Sw_2, Sw_3 and Sw_4 all are turned off then V_{xy} is clamped by other branches, $-V_c \leq V_{xy} \leq V_c$.

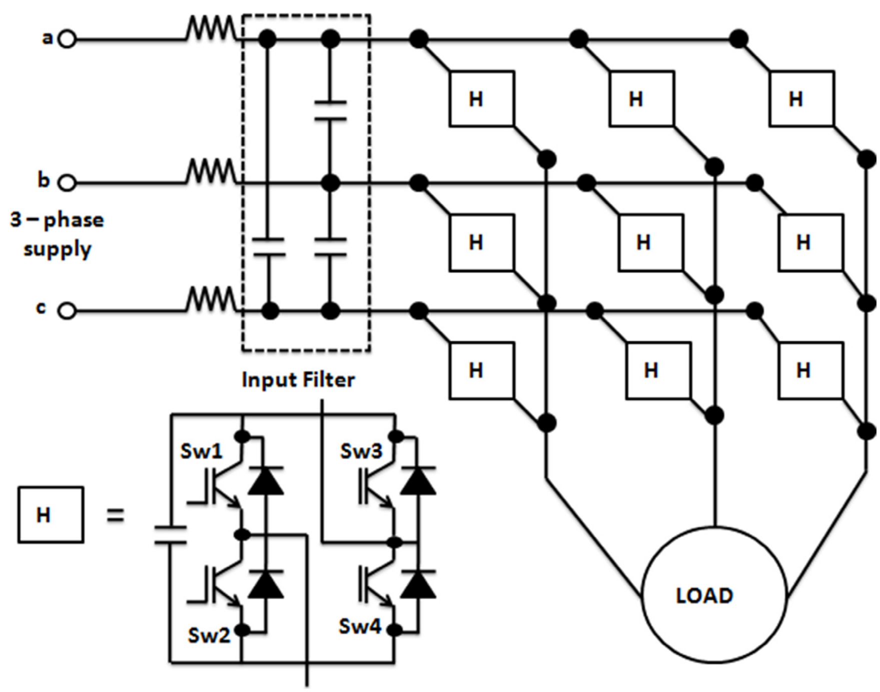

Figure 2: (a) Schematic diagram of Cascade H-Bridge Multilevel Matrix Converter

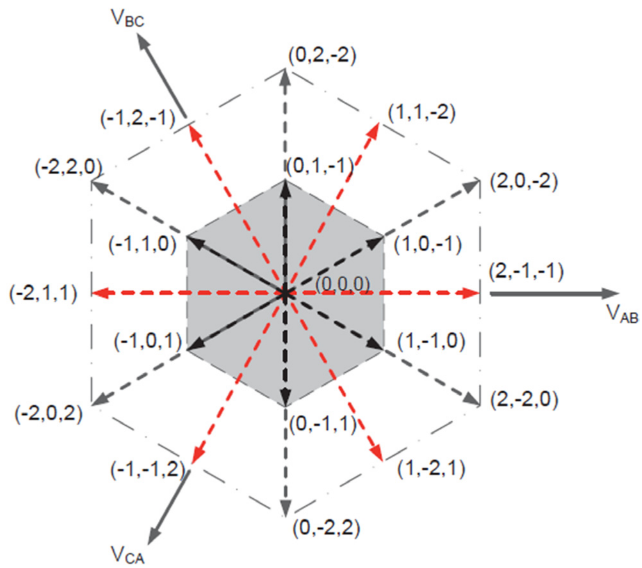

Figure 2: (b) Space Vector Trajectory of Cascade H-Bridge Multilevel Matrix Converter

3. IMPLEMENTATION OF CONTROL CIRCUIT

For development of ANFIS based SVPWM technique, first SVPWM technique is implemented for determining switching sequence required for the operation of the proposed converter. After acquiring the necessary data, ANFIS concept is incorporated into SVPWM technique. Then the performance of the proposed converter is analyzed.

3.1. Development of SVPWM Technique

SVPWM technique is first discussed for single H-Bridge converter. By considering the instantaneous input voltages (line – to – line), the output voltages are expressed in terms of DC voltage that exists across capacitor (V_c) of H-Bridge module, as $+2V_c$, $+V_c$, 0V, $-V_c$, $-2V_c$. The control architecture of H-Bridge Multilevel Matrix Converter [8] can be split into three groups. That is source side control, load side control and constant voltage control. The source side and load side control schemes are similar to that of two stage converter topologies. The source side control scheme controls the power factors of the source current and voltage, and assures that the complete energy stored in Hybrid bridge capacitors of the H-Bridge [8] module is steady. The load side control scheme regulates the load voltage in accordance with the variation of several load demands. From the following equation the source side line voltages are converted into $\alpha - \beta$ axis variables [5], [8].

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_{ab} \\ V_{bc} \\ V_{ca} \end{bmatrix} \quad (1)$$

The space vectors of reference input is expressed as a resultant of three adjacent vectors

$$\vec{V}_{ref\_in} = D_{1\_in}\vec{V}_1 + D_{2\_in}\vec{V}_2 + D_{0\_in}\vec{V}_0 \quad (2)$$

Similarly the space vector of output is expressed as a resultant of three adjacent vectors.

$$\vec{V}_{ref\_out} = D_{1\_out}\vec{V}_1 + D_{2\_out}\vec{V}_2 + D_{0\_out}\vec{V}_0 \quad (3)$$

The Figure. 2 (b) shows the trajectory of space vector for the proposed converter [8]. The vectors in the trajectory created by the rectifier symmetric sequence and inverter symmetric sequence are fed to the logical gates 'AND' and 'OR' for production of required output.

4. DESIGNING OF ANFIS BASED SVPWM TECHNIQUE

The following are the steps to be followed for designing the converter control circuit [7].

Step 1: Load the training data obtained from conventional SVPWM technique into ANFIS controller.

Step 2: Evaluate the ANFIS output.

Step 3: Import the FIS data from ANFIS controller.

Step 4: Export FIS data to Fuzzy Logic Controller which is used in the proposed converter control circuit.

The ANFIS is a Sugenoe Tsukamoto Fuzzy model and is a combination of both ANN and Fuzzy Logic. Its architecture is similar to Neural-Network constructed from Fuzzy Reasoning [6]. The ANN has good learning capabilities. Fuzzy logic is efficient in combining expert's knowledge and has an ability to interpret the data efficiently. This can improve estimation accuracy and hence good performance is achieved with ANFIS controller. Figure 3 displays the network structure containing five interconnected network layers l_1 to l_5.

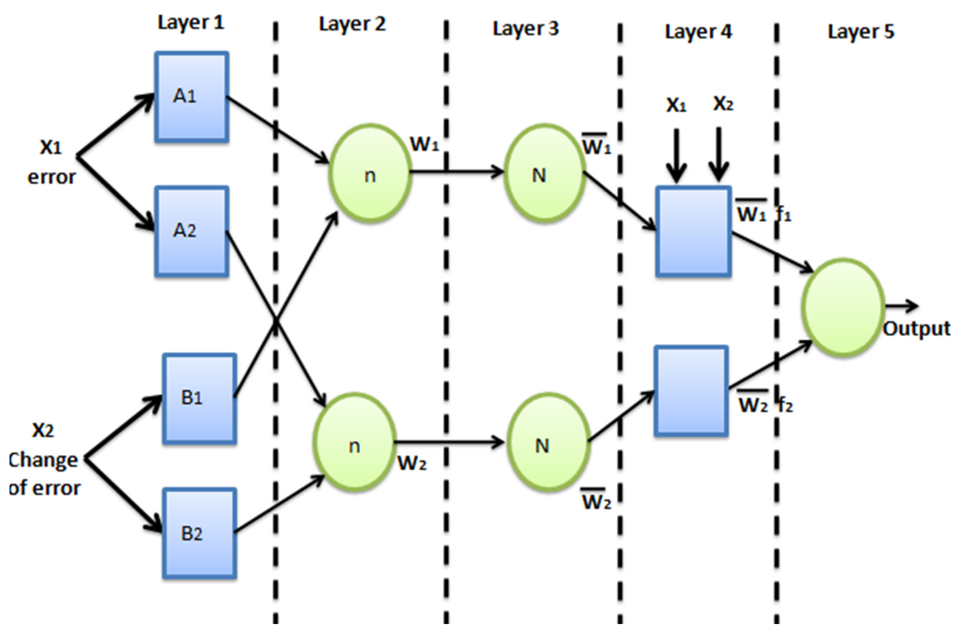

Figure 3: Two input – One output ANFIS Structure

Layer 1: The inputs termed as X_1, X_2, are present in this layer. These are expressed as Membership Functions (MF). Triangular MF and Bell-Shaped MF are generally chosen.

Layer 2: This layer is also termed as Membership Layer. It determines the weights of MF. The inputs x_i emerging from the former layer are accepted and combined with the corresponding weights. The resultants thus obtained serve as membership functions for representing the fuzzy sets of the corresponding inputs.

Layer 3: This layer is termed as Rule Layer. It is assumed that the number of layers is equivalent to the fuzzy rule count. Based on this assumption, fuzzy rule matching is carried out and the activation level of respective rule is computed. The normalized weights are computed at each node.

Layer 4: Defuzzification Layer is the other name given to Layer 4. The outputs *y*, obtained in this layer result from the deductions of fuzzy rules. One more set of Neuro-Fuzzy parameters are obtained by Fuzzy Singletons. These parameters are indicated by weighted connections between Rule Layer and Defuzzification Layer.

Layer 5: This is the Output Layer of the network. Outputs of Layer 4 serve as inputs to Output Layer. In this layer, the inputs are summed up and the outcomes obtained from Fuzzy classification are transformed into crisp.

5. SIMULATION RESULTS

In this paper ANFIS based SVPWM controller is designed for H-Bridge MMC in WECS employing DFIG. The model is designed and analyzed using MATLAB/SIMULINK Software. Up to $t = 0.2$sec, WECS does not get connected to the grid. After t = 0.2sec, WECS employing DFIG with H-Bridge MMC is connected to the grid.

The THD values at various points in Figure. 1 are determined by FFT analysis. Figure 4, Figure 5 represent the voltage and current harmonic distortion spectrums at point B1, Figure 6, Figure 7 represent the voltage and current harmonic distortion spectrums at point B2 and Figure 8, Figure 9 represent the voltage and current harmonic distortion spectrums at point B3 respectively.

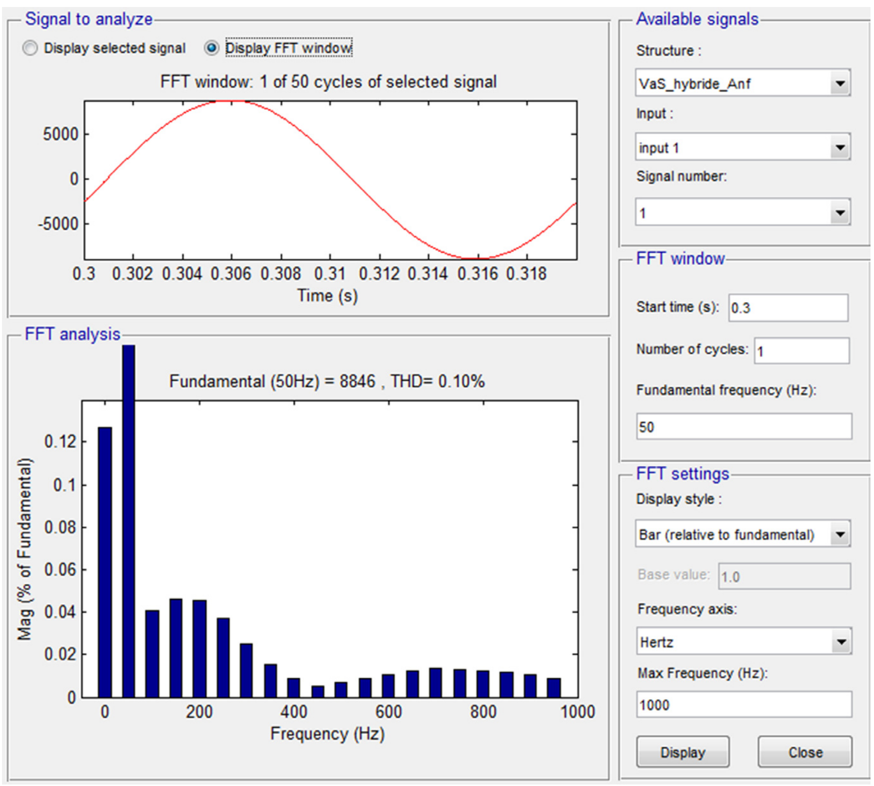

Figure 4: Voltage Harmonic Spectrum at point B1

6. CONCLUSIONS

This paper discusses the novel concept of simulation design of H-Bridge MMC in Wind Energy Conversion System employing DFIG. The H-Bridge Multilevel Converter provides better quality of power and gives less distorted voltage and current waveforms, when compared to other Multilevel Converters. The proposed Converter topology is based on H-Bridge Multilevel Converter. From the result analysis, it is observed that, proposed Multilevel Matrix Converter provides better quality of power to the grid. The similar H-Bridge units of Multilevel Matrix Converter topology are advantageous in isolating faulty units quickly and without difficulty.

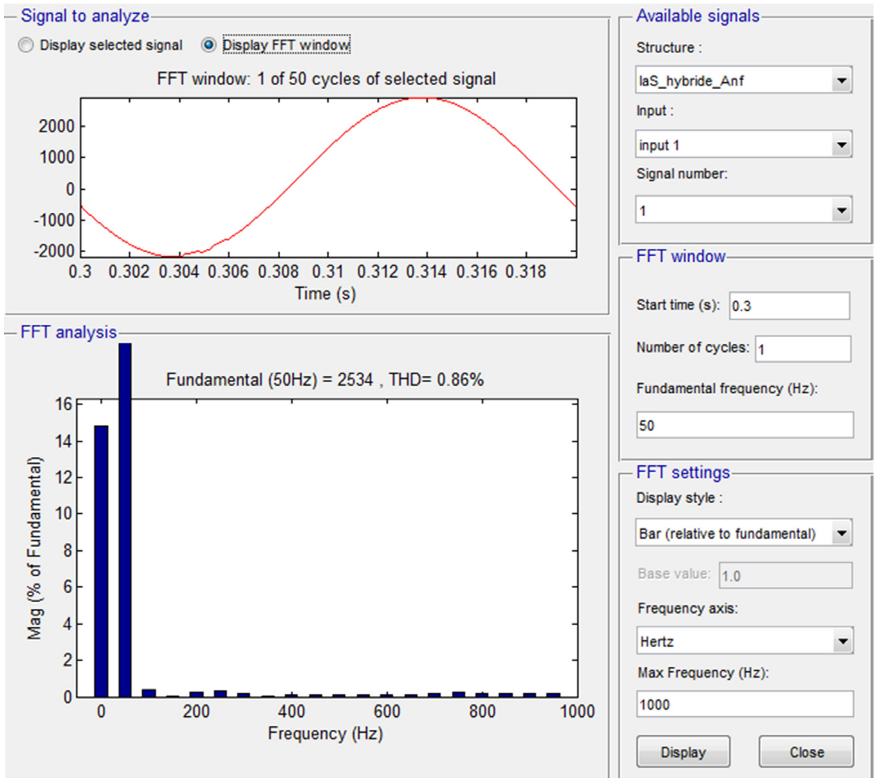

Figure 5: Current Harmonic Spectrum at point B1

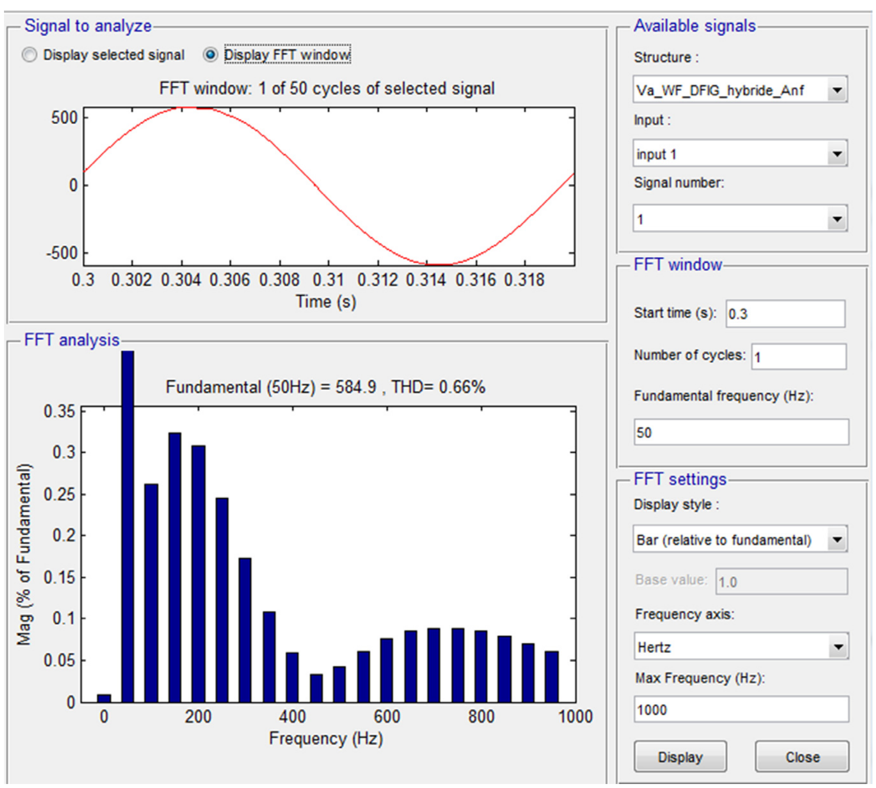

Figure 6: Voltage Harmonic Spectrum at point B2

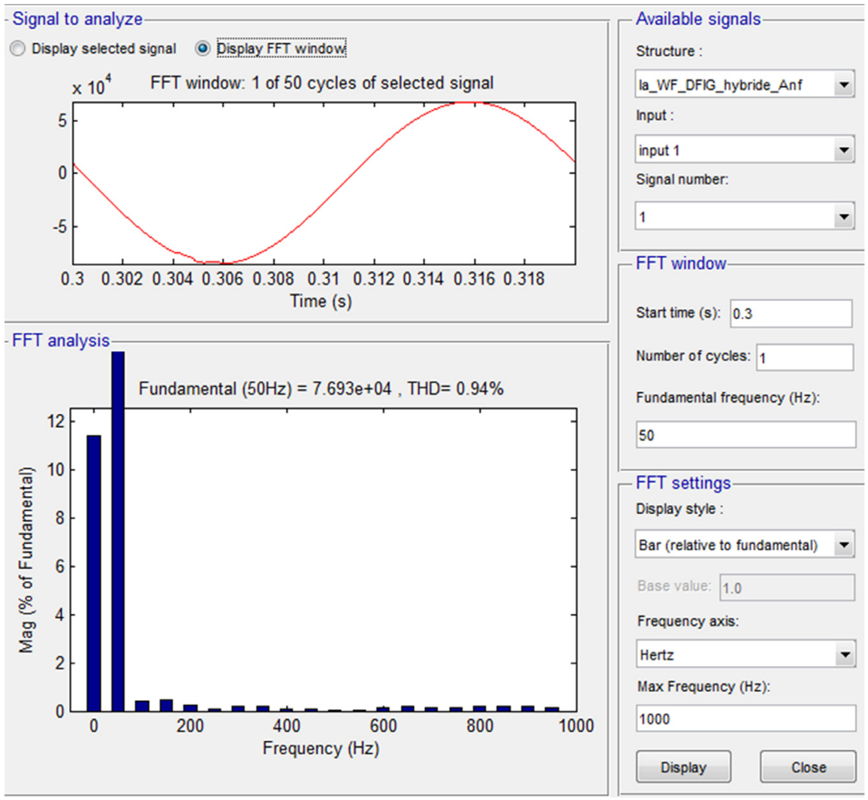

Figure 7: Current Harmonic Spectrum at point B2

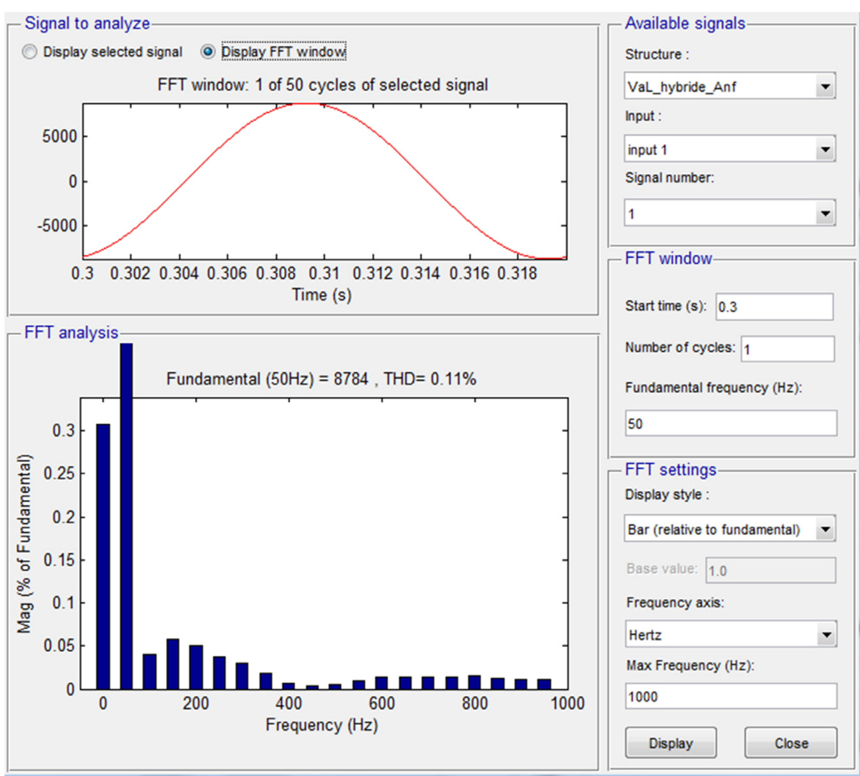

Figure 8: Voltage Harmonic Spectrum at point B3

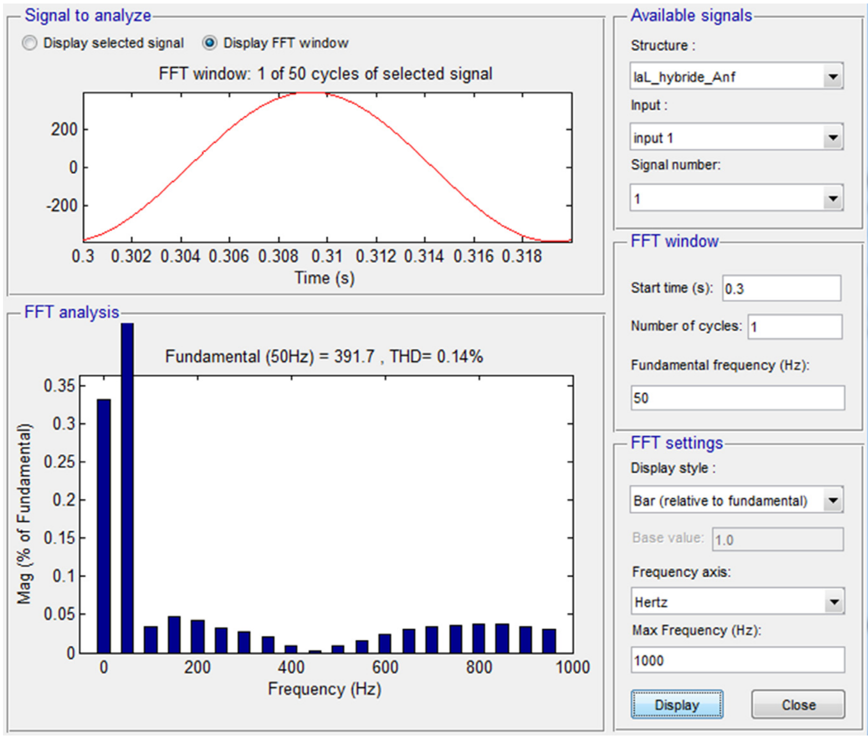

Figure 9: Current Harmonic Spectrum at point B3

ANFIS based SVPWM technique is employed for operating the converter. The design and analysis of proposed converter is simulated on MATLAB/SIMULINK platform and THDs of voltage and current waveforms are determined using FFT analysis.

REFERENCES

[1] Zhe Chen, Josep M. Guerrero, and FredeBlaabjerg, A Review of the State of the Art of Power Electronics for Wind Turbines, IEEE Transactions on Power Electronics, Vol. 24, No. 8, August 2009.

[2] Patrick Wheeler, Xu Lie, MengYeong Lee, Lee Empringham, Christian KIumpner, Jon Clare, A Review of Multi-level Matrix Converter Topologies, Power Electronics, Machines and Control Group, University of Nottingham.

[3] Kartick Chandra Jana, Sujit Kumar Biswas, A Simple and Generalized SVPWM Control of Cascaded H-Bridge Multilevel Inverters, Journal of Electrical Engineering.

[4] Yao, LI, Lie, XU, Yongdong, LI, Control of the Cascaded H-bridge Multilevel Matrix Converter, PCIM Europe 2014, 20 –0 22 May 2014, Nuremberg, Germany.

[5] MengYeong Lee, Patrick Wheeler, and Christian Klumpner, Space-Vector Modulated Multilevel Matrix Converter, IEEE Transactions on Industrial Electronics, Vol. 57, No. 10, October 2010.

[6] A. Albakkar, and O.P. Malik, Adaptive Neuro-Fuzzy Controller Based on Simplified ANFIS Network, 978-1-4673-2729-9/12/$31.00©2012 IEEE.

[7] Abdur Rosyid, Mohanad Alata and Mohamed ElMadany "Adaptive Neuro-Fuzzy Inference System Controller for Vibration Control of Reduced-order Finite Element Model of Rotor-Bearing-Support System" International Letters of Chemistry, Physics and Astronomy ISSN: 2299-3843, Vol. 55, pp 1-11.

[8] Yao Li,, Lie Xu, and Yongdong Li. "Control strategy of the modular Multilevel Matrix Converter", 2014 IEEE Conference and Expo Transportation Electrification Asia-Pacific (ITEC Asia-Pacific), 2014.