Indian Journal of Science and Technology, *Vol 9(11), DOI: 10.17485/ijst/2016/v9i11/89296, March 2016*
ISSN (Print) : 0974-6846
ISSN (Online) : 0974-5645

Influence of Advanced Multi-Carrier Modulation Scheme for 15-Level Multilevel Inverter using ANFIS Controller

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Abstract

The main objective of this concept is attaining optimal harmonic resolution, unity power factor, DC bus voltage regulation, incredible efficiency, and low switch stress. The proposed technique employs a co-generation based micro-grid system via zeta methodology of neuro-fuzzy controller for optimal performance of asymmetrical 15-level inverter. This proposed asymmetrical converter requires only 7 switches over 10 switches for improved 15-level voltage provides a pure sinusoidal current which is in phase with improved grid voltage. ANFIS controller predicts the optimal modulation index & switching angles for an improved output voltage then prevents the sudden variations coming from the grid/DC bus. The proposed concept is so perfect compare to several test system based classical pi, fuzzy controllers. A simulink model is designed to validate the performance evaluation of this proposed work by using matlab/simulink platform and results are conferred. The major findings in this work is getting around 100/400 V with input voltage of 10/40 V within a single module compared to low voltage gain conversion schemes. The type of conversion schemes is mostly preferred in micro-grid applications, irrigation applications and etc.

Keywords: Advanced Multi-Carrier Modulation Schemes, Adaptive Neuro-Fuzzy Inference System Controller, Asymmetrical Inverter Topology, Co-Generation Scheme, Total Harmonic Distortion

1. Introduction

The evolutions of economic value and environment crisis have forced them to greatly explores the prevail technologies. In recognition of renewable energy sources, this holds the superior advantages[1], ability to paw the micro-grid system with naive connectivity[2]. Acquiring the clean, safe, eco-friendly specifications, the photo-voltaic (PV) & fuel cell (FC) are effectively used as primary power producers look up as a co-generation system. A co-generation scheme extends the attainable flexibility & splendid scalability for excellence of incredible energy management. It is the acceptable system for power generation & mostly utilized in remote-area applications. Classical string type inverters uses cascaded connections with several modules to obtain greater DC link voltage to the grid through a DC-AC inverter. However, this scheme is more useful in terms of repair, partial shading, mismatch module, system monitoring, diminished energy system yields[1-4]. The AC module, which has been recommended to enhance these issues, comprises of a multiple units of regular micro inverter & input sources. The eminent power density is

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attained by intermittent formation of PV/FC have good dynamic stability, the fast step load changes will be minimized by support of co-generation system[4].

The power conditioning units are required for floating the outcome power from input power with continuing the stable performance. There are two flavors such as; (i) high step up DC/DC converter, (ii) DC-AC inverter module, DC/DC converter strengthen the PF/FC stack voltage at DC bus & DC-AC inverter act as the barrier in between the DC bus & grid system. Amelioration of voltage quality & efficiency is enhanced by eradicating the utmost stress of active switches with help of multi-level structure[5]. The multi-level technology has been researched few years ago and obtaining the superior advantages such as greater voltage quality, counteracts the harmonics, low harmonic distortion, incredible efficiency, EMI loss is low and low dv/dt stress by increased number of voltage levels by administering the advanced topologies[6]. The basic fundamental characteristics of formal multilevel inverter structures are diode-clamped module[7], flying capacitor module[8], cascaded H-bridge module[9], these are regular vital topologies by so many literatures, but these are useless due to several disadvantages. Diode clamped & flying capacitor modules requires additional switching components and difficult to generate asymmetrical voltages.

Asymmetrical voltage technique is mostly used in cascaded H-bridge module, but it requires more devices. The main affection while using Asymmetrical inverter, it provides high number of levels with low number of switches by consisting of unequal DC sources, the space requirement, cost of an asymmetrical module is very low. Several unique MLI structures have been explored[5-9]. In this paper, a novel asymmetrical smart multi-level inverter topology has been investigated by advanced modulation schemes for micro grid applications with imperative ANFIS controller. The adaptive neuro-fuzzy inference system is a class of artificial neural scheme that is established on Takagi sugeno fuzzy inference system. It incorporates the both fuzzy logic & neural network essentials; it has more potentiality to express of both in a unique architecture. The main characteristic of intelligent control system is that they constitutes as symbolic path of inference system along proficiency knowledge.

This model requires several inputs such as grid voltage & change in voltage, controlled target voltage, by means of these things proposed controller produces the optimal rules & tuned effectively for attaining the enhanced quality voltage at grid, greater transient stability. In that, adaptive neuro-fuzzy inference system (ANFIS) are designed for closed loop control action of proposed 15-level inverter to eradicate the harmonic content, improve transient stability, by acquiring the qualitated RMS voltage. Several comparisons are made for different control objectives with classical over proposed intelligent controllers. Finally, the validation of the proposed module for micro grid system with intelligent controllers is evaluated by using Matlab/Simulink platform & results are conferred.

2. Proposed Co-Generation Scheme

The overall structure of illustrated co-generation system with adaptive neuro fuzzy inference system (ANFIS) based control objective for micro grid system via modern asymmetrical 15-level inverter is depicted in Figure 1. The power conversion activity of PV/FC outcome power into unique self-reliant voltage sources with myriad relationships which are interfaced to the power inverter module via high step up DC-DC converter to maintain DC link voltage as a constant. The turn's ratio of the coupled inductor is magnified by the voltage gain & the secondary winding of the coupled inductor is cascaded with respect to a switched capacitor for getting the enhanced voltage. The Zeta converter is aligned from a M1 coupled inductor with streamed active switch Sa. The N1 primary winding of a coupled inductor M1 is akin to the source inductor of the classical boost regulator, barring the diode D1 & capacitor C1. The secondary winding N2 is append with alternate pair of diode D2 & capacitor C2, all these components are series with N1. The D3 rectified diode interfaces to its outcome capacitor C3 & DC bus. The characteristics of the Zeta converter are; 1) recycling the coupled inductor's leakage inductor, voltage spikes has been restrained on the active switch; high voltage gain, low stress components, incredible efficiency, low cost, the active switch isolates the co-generation power during non-working conditions, thus prevents the electric hazards to facilities/human beings.

The proposed asymmetrical modern multilevel inverter comprises of three sources, three balanced diodes & seven switches, the voltage sources are Vdc-100v, 2Vdc-200v, 4Vdc-400v generates the 7-level DC voltage by sub-multi cell module, which is shown in

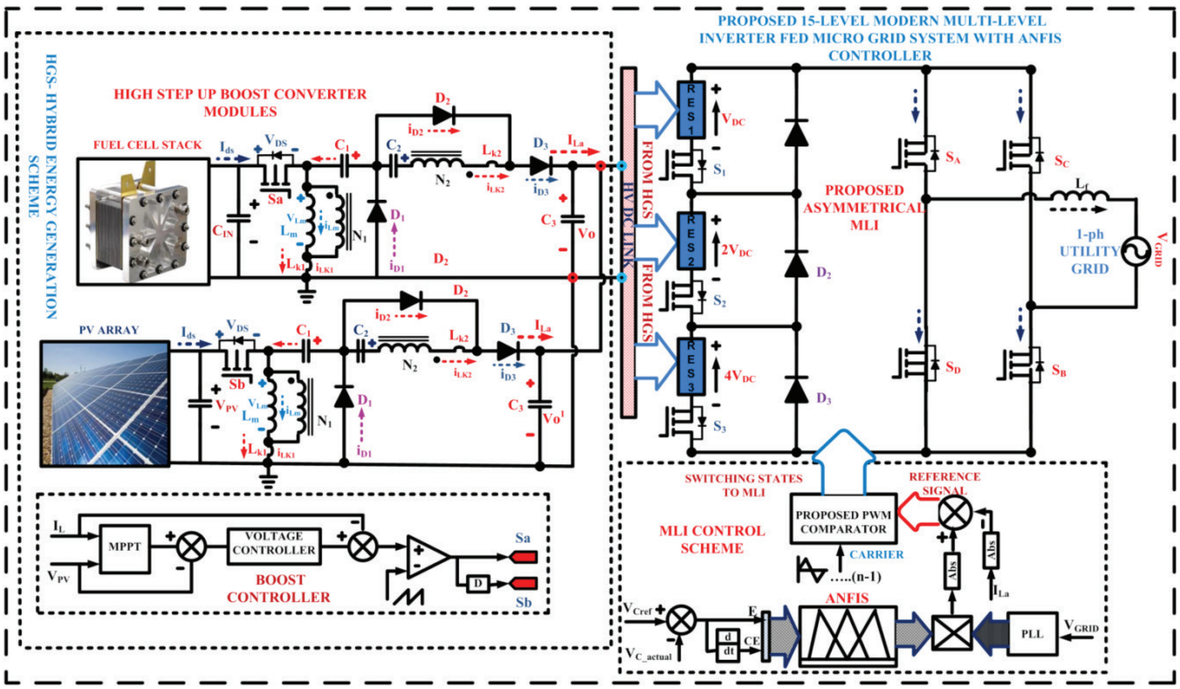


Figure 1. Overall Structure of Proposed Co-Generation System with ANFIS Controller for Micro Grid System via Reduced Switch Type-Modern Asymmetrical 15-Level Inverter.

Figure 1. The inclusive 15-level outcome voltage is V(t)=Vdc+2Vdc+4Vdc, which are reify by turn ON/OFF of S1, S2, S3 switches. The basic unit of asymmetrical MLI structure consists of three switches (level generation), three diodes, three active sources besides with a full-bridge inverter module (polarity generation). The respective voltage levels are acquired by acceptable switching between the other switches and produce the zero, negative & positive voltage levels.

This full bridge converter converts the 7-level DC voltage into 15 levels AC voltage by using polarity generation concept and that is interfaced with utility voltage through filter inductors. In this process, the proposed system generates a sinusoidal outcome of both voltage/currents, these are in-phase with each other & related to grid voltage, then interfaced to utility grid. This converter requires only 7 switches for generating 15-levels, so as to simply the conversion structure which have many advantages like as compact integrated device, low complexity, low switching stress, low cost device, incredible efficiency, called as a smart inverter. In this scheme, the fewer switches are casted-off to define 15 levels & fabricate the user friendly module with low switching loss by minimized number of switches. Requirement of specific power electronic devices & maximum outcome voltage levels for proposed module is contrived as;

$$V_{O\max} = (2^k - 1) * Vdc \tag{1}$$

$$N_{IGBT's} = (n + 4) \tag{2}$$

$$N_{Level's} = 2^{(k+1)} - 1 \tag{3}$$

Where k represents the requirement of voltage sources used in proposed inverter module. The detailed switching scheme is depicted in Table 1 & 2. The voltage at grid is recognized by a voltage detected circuit & sends to PLL circuit in order to generate the unified amplitude with a sine frame. The voltage at capacitor is recognized & then compared over the desired voltage, the error & change in error values are integrated to ANFIS controller. The PLL circuit output & the ANFIS output are combined to produce a reference signal using multiplier circuit, while the current of the 15-level inverter is recognized by a current detection circuit. The reference signals coming from the comparison are proceed to integrate with proposed PWM generation circuits for production of switching states for 15-level inverter topology according to characteristic table.

Table 1. Switching Pattern for Level Generation Scheme for Proposed Inverter Module

Vo	S_1	S_2	S_3
7Vs	H	H	H
6Vs	L	H	H
5Vs	H	L	H
4Vs	L	L	H
3Vs	H	H	L
2Vs	L	H	L
Vs	H	L	L

Table 2. Switching Pattern Level Generation Scheme for Proposed Inverter Module

Vo	S_A	S_B	S_C	S_D
Zero State	L	H	L	H
Positive State	H	H	L	L
Negative State	L	L	H	H

3. Advanced Modulation Scheme

Advanced multi-carrier modulation schemes are acquired for multilevel inverters, the most encouraged near to the pure sinusoidal outcome voltage with less harmonic profile, low switch stress, reduced loss component compared to formal PWM strategies without help of large size filter. Effective modulation techniques are implemented in several applications can be categorized as phase & level shifting multi-carrier modulation technique is proposed[10], based on these techniques author implements a contemporary modulation scheme which have good results over classical methods. The traditional variable switching frequency is proposed[11]; this technique regards mainly definite carrier frequency ranges with respect to multiplication factor as proposed by authors. The carrier frequencies of several carriers are 3050 Hz, 5050 Hz, 7050 Hz are relating to the reference signal coming from the ANFIS controller as depicted in Figure 2. The proposed multi-carrier modulation scheme is nothing but merging of both phase & level shifted PWM techniques to trounce the problem regards to switching action of shifting

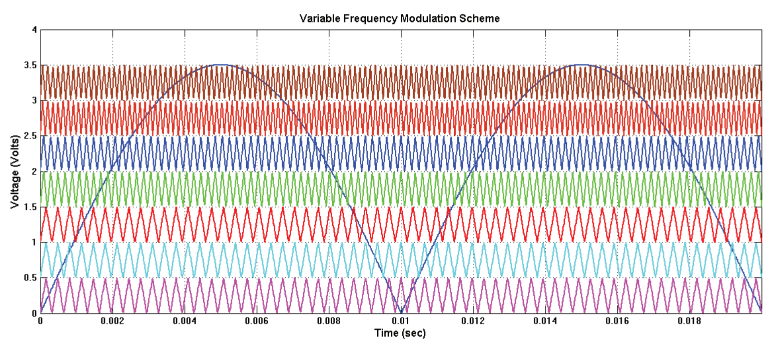


Figure 2. Modulation Scheme of Variable Frequency Switching Strategy.

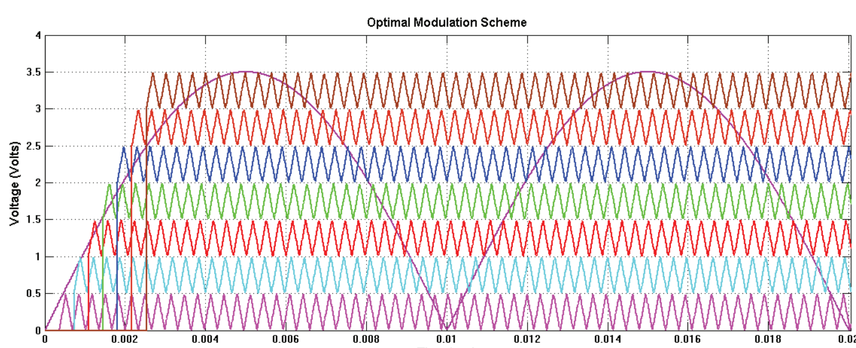


Figure 3. Switching Strategy for Optimal Modulation Scheme.

technique each other & overcome the phase imbalance condition. In this scheme all carriers have equal frequency as well as peak amplitude is un-equal, which are vertically disposed. The optimal modulation scheme for 15-level proposed multilevel inverter as depicted in Figure 3.

$$MI_a = \frac{V_{ref}}{V_{cr(q-1)}} \tag{4}$$

$$\varnothing_{sh} = \frac{360°}{4(n-1)} \tag{5}$$

For this optimal scheme, (n-1) carriers are required and are defined based on requirement & essentially disposed vertically by measurable angle. Where V_{ref} constitutes the reference signal coming from ANFIS controller, V_{cr} constitutes the carrier signal, MI_a constitutes the modulation index & constitutes the disposed phase angle. As, Table 1 shows the switching states for proposed asymmetrical 15 Level multi-level inverter for production of DC voltage levels & Table 2 shows the switching pulses for 15 Level MLI for production of polarities, in that "L" specifies the switch is at OFF state & "H" specifies the switch is at ON state.

4. Adaptive Neuro-Fuzzy Inference System

Artificial intelligence has become a soft computed tool for solving concerns having un-known solution. It is a soft computed formation of hybrid model by a neuron-fuzzy developing system in which fuzzy inference system is effectively trained by a neural learning characterization. Although, it has the ability to adapt & divide these arranged groups as an optimal membership function that can clustered by achieving the outcome within a reduced epochs[12]. There is a possibility of perfect tuning for fuzzy inference system by a new learning process for specified input-output information (Table 3). Mostly the parameters are tuned by using either a back propagation or hybrid method algorithm[13-15]. Figure 4 shows the membership function for error (e(x)) & change in error (Δe(x)) is defined with rules as follows;

$$e(x) = Vcref - Vcactual \tag{6}$$

$$\Delta e(x) = e(k) - e(k-1) \tag{7}$$

Table 3. Rules for ANFIS Structure

e(x)/ Δe(x)	**NB**	**NS**	**Z**	**PS**	**PB**
NB	R1	R2	R3	R4	R5
NS	R6	R7	R8	R9	R10
Z	R11	R12	R13	R14	R15
PS	R16	R17	R18	R19	R20
PB	R21	R22	R23	R24	R25

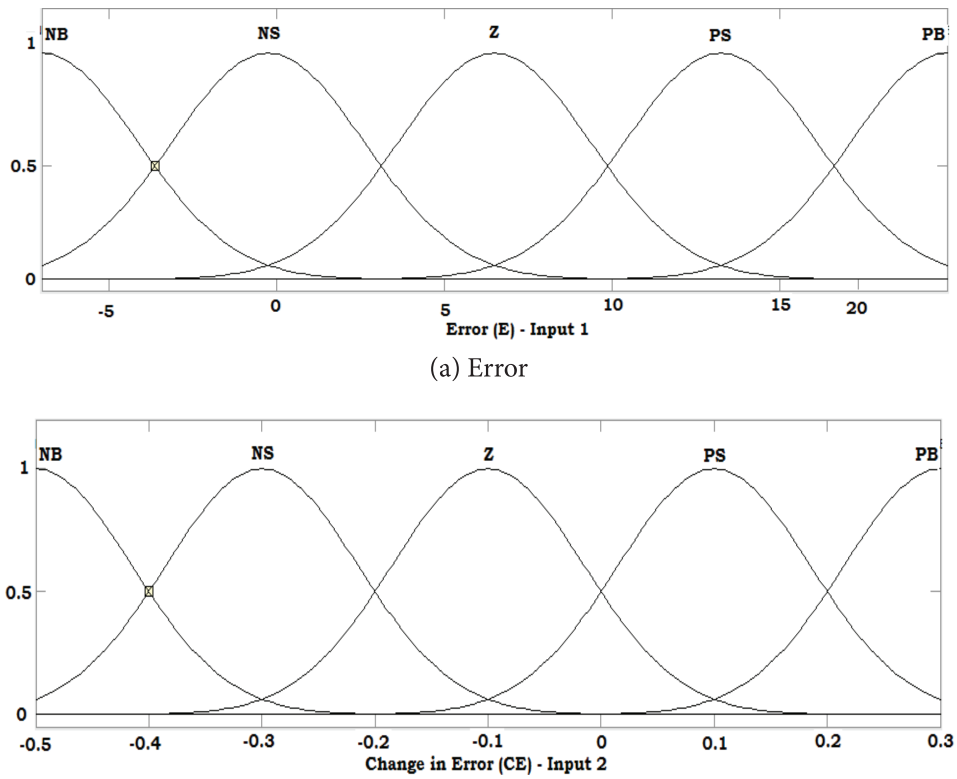
Where the Vc ref/ Vc actual is the reference/actual voltage of the DC link capacitor, specifies the error value & is change in error value. These inputs variables are converter into the several linguistic variables. In this paper, author prefer five membership functions such as; positive big (PB), positive small (PS), zero (Z), negative small (NS), negative big (NB).

5. Matlab/Simulink Results

Implementation of proposed PV/FC co-generation system by using a computer simulation tool & designed with several control objectives. The parameters for this configuration are illustrated in Table 4; it is merely suitable for proposed grid interfaced system with a 700V, 50 Hz supply. (Figure 5)

6. Conclusion

The contemporary approach of the intended co-generation energy system with ANFIS controller includes managing the PV/FC energy for applications to micro-grid system using asymmetrical Zeta type multi-level inverter form as a single unit with several modulation schemes. The main features of proposed scheme include high power density, fast steady state response, THD reduction. The several conclusions are updated from the evaluation of proposed 15-level MLI has requires only 7 switching devices, low space requirement, low cost, high comfort. As number of levels increases, automatically THD components approximate near to IEEE standards, common mode voltage also decreases, stress is low, minimizes the load side filter. THD comparison is takes place in Table 5, in that variable switching frequency modulation technique



(a) Error

(b) Change in Error

Figure 4. Membership Function for Error (e(x)) & Change in Error (Δe(x)).

Table 4. Operating Parameters for Proposed 15-Level Inverter for Grid System

S.No	Operating Parameters	Values
1	PV Source	10-40 V
2	Fuel Cell Stacks	10-20 V
3	Boost Inductor (L)	1 mH
4	Capacitors (C)	C1/C2=47 μF; C3=100 μF
5	Filter Inductor (Lf)	1.5 mH
6	Switching Frequency	3050 Hz to 7050 Hz
7	PI Controller	Kp-0.7, Ki-0.05

with ANFIS controller has better THD % reduction over classical controllers. The simulation results validates the proposed concept is very attractive for micro-grid system and attains quality power, meticulously manages the co-energy.

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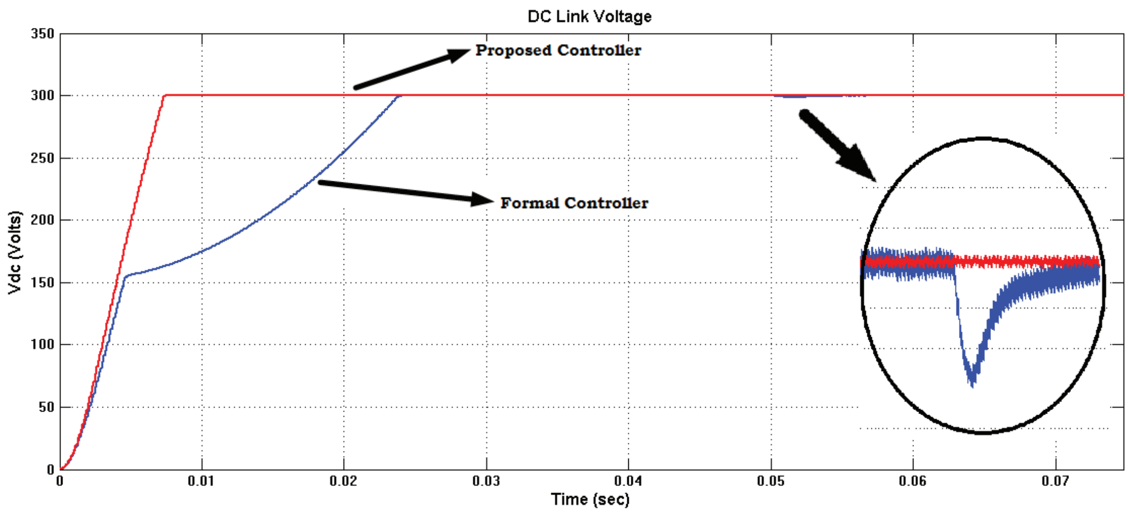
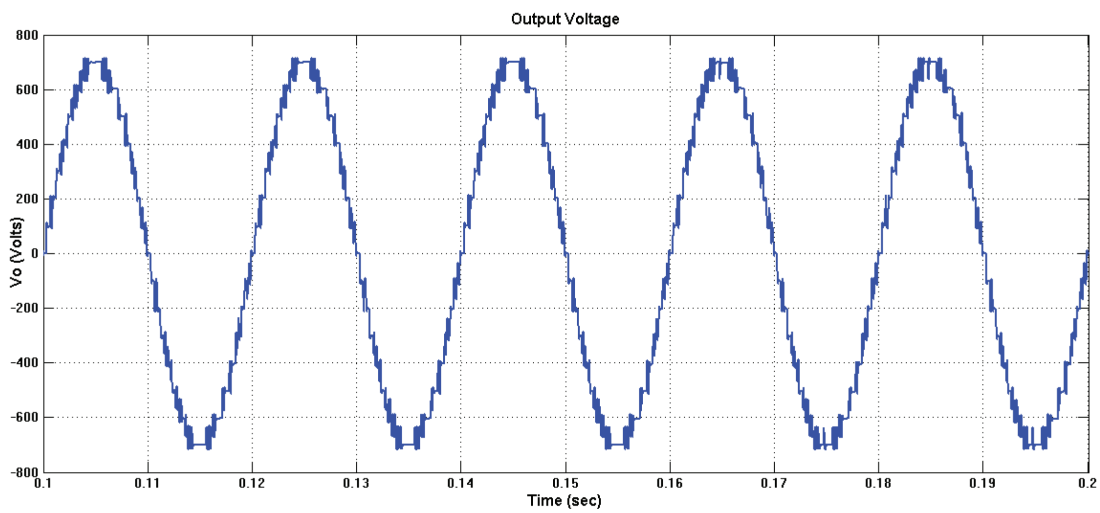
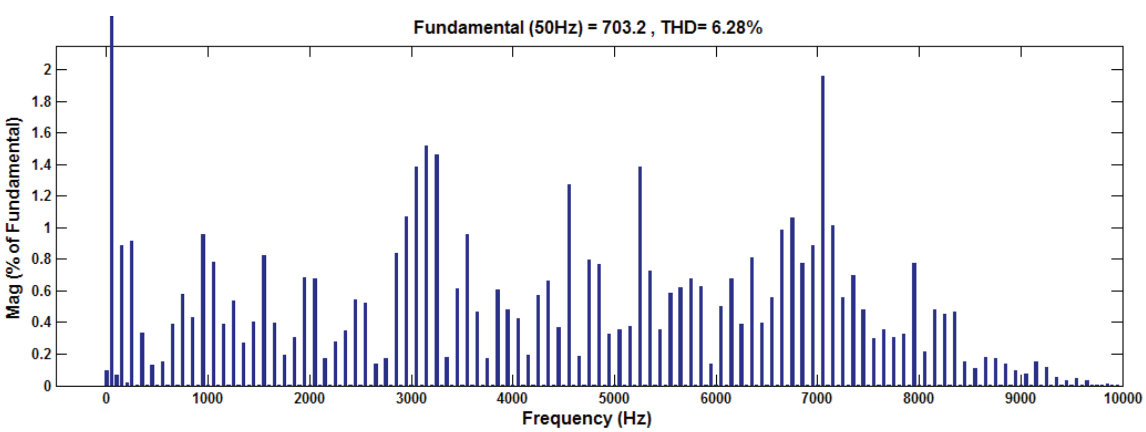


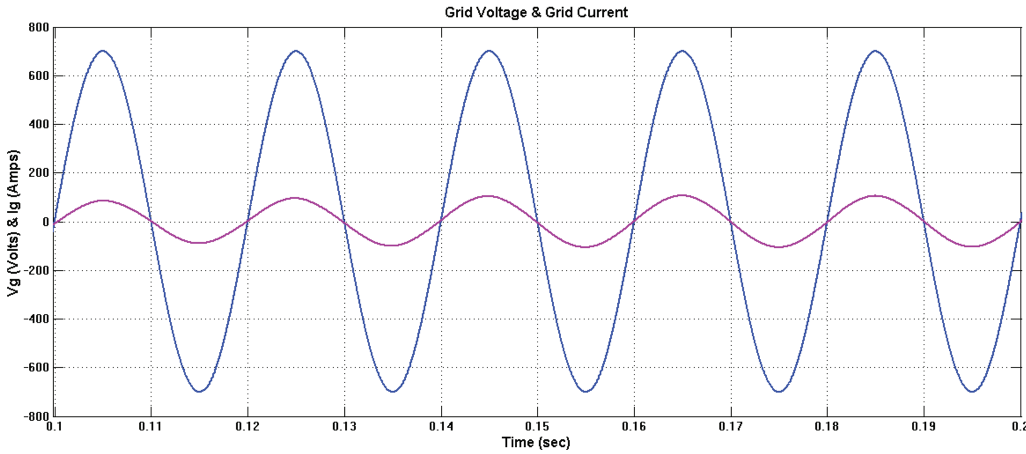
(a) DC Link Voltage



(b) 15-Level Output Voltage



(c) Grid Voltage & Current



(d) THD of 15-Level Output Voltage

Figure 5. Several Simulations of Proposed 15-Level MLI topology for Grid Integrated System via ANFIS Controller.

Table 5. Comparison of FFT Analysis of Outcome Voltage with Proposed Controller over Classical Controllers

Type of Controller	Regular PWM			Variable Frequency PWM Scheme			Optimal PWM Scheme		
	PD	POD	APOD	PD	POD	APOD	PD	POD	APOD
PI Controller	7.75%	7.76%	7.76%	7.65%	7.67%	7.67%	7.68%	7.60%	7.71%
Fuzzy Controller	5.86%	5.96%	5.95%	4.99%	5.03%	5.03%	6.06%	6.10%	6.12%
ANFIS Controller	4.44%	4.56%	4.57%	3.68%	3.62%	3.62%	4.67%	4.69%	4.73%

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