Harmonics Reduction and Power Quality Improvement by using Multilevel DPFC

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***Abstract* - This paper presents on the utilization of DPFC with cascaded Multi-Level Inverter to improve the power quality in distribution systems. According to growth of electricity demand and the increased number of non-linear loads in power grids, providing a high quality electrical power should be considered. In this paper, Enhancement of power quality by using fuzzy based multilevel power flow controller (DPFC) is proposed. The DPFC is a new FACTS device, which its structure is similar to unified power flow controller (UPFC). In spite of UPFC, in DPFC the common dc-link between the shunt and series converters is eliminated and three-phase series converter is divided to several single-phase series distributed converters through the line. This eventually enables the DPFC to fully control all power system parameters. It, also, increases the reliability of the device and reduces its cost simultaneously. In recent years multi level inverters are used high power and high voltage applications. Application of Fuzzy Multilevel DPFC for reduction of Total Harmonic Distortion was presented. The simulation results show the improvement of power quality using DPFC with Fuzzy logic controller.**

***Index Terms* - DPFC, Multilevel Inverter,Fuzzy logic controller**

I. INTRODUCTION

In the last decade, the electrical power quality issue has been the main concern of the power companies. Power quality is defined as the index which both the delivery and consumption of electric power affect on the performance of electrical apparatus . From a customer point of view ,apower quality problem can be defined as any problem is manifested on voltage, current, or frequency deviation that results in power failure .The power electronics progressive ,especially in flexible alternating-current transmission system(FACTS) and custom power devices, affects power quality improvement. Generally, custom power devices, e.g., dynamic voltage restorer (DVR), are used in medium-to-low voltage levels to improve customer power quality . Mosserious threats for sensitive equipment in electrical grids are voltage sags (voltage dip) and swells (over voltage). These disturbances occur due to some events, *e.g.*, short circuit in the grid, inrush currents involved with the starting of large machines, or switching operations in the grid. The FACTS devices, such as unified power flow controller (UPFC) and synchronous static compensator (STAT-COM), are used to alleviate the disturbance and improve the power system quality and reliability. Fast power flow controlling devices based on power electronics (FACTS) are introduced but due to high prices are not widely used. Also, because of the reliability and the cost issues, the UPFC is not widely applied in current transmission network. The Distributed Power Flow Controller (DPFC) is a new device of D-FACTS family. The DPFC provides higher reliability than conventional UPFC at lower cost. In the UPFC to achieve there required reliability, the bypass circuits and redundant backups are needed which this increases the cost. In the DPFC to overcome these problems, multiple low rate series converters are used instead of one large series converter. Therefore, it causes not only the DPFC price will be less than UPFC but also increases its reliability. The DPFC eliminates the common dc link between the shunt and series converters. The active power exchanges between the shunt and the series converter through the transmission line at the third harmonic frequency.

Basically Inverter is a device that converts DC power to AC power at desired output voltage and frequency Demerits of inverter are less efficiency, high cost, and high switching losses. To overcome these demerits, we are going to multilevel inverter. But for complex systems, the simple linear control is difficultly adapt to the non-linear power system. The fuzzy control can overcome non-linear factors and does not require precise mathematical mode. For non linear systems, like the DPFC, fuzzy based control has been proved to work well. In this paper, a Fuzzy based Multilevel distributed power flow controller, is proposed, is used to improve power quality.

II. DPFC PRINCIPLE

In comparison with UPFC, the main advantage offered by DPFC is eliminating the huge DC-link and instate using 3rdharmonic current to active power exchange. from the UPFC structure that is included one shunt converter and several small independent series converters, as shown in Fig. 1. The DPFC has same capability as UPFC to balance. The line parameters, i.e., line impedance, transmission angle, and bus voltage magnitude In the following subsections, the DPFC basic concepts are explained.

Within the DPFC, the transmission line is used as aconnection between the DC terminal of shunt converter and the AC terminal of series converters, instead of direct connection using DC-link for power exchange between converters. The method of power exchange in DPFC is basedon power theory of non-sinusoidal components. Based on Fourier series, a non-sinusoidal voltage or current can be presented as the sum of sinusoidal components at different frequencies. The product of voltage and current components provides the active power. Since the integral of some terms with different frequencies are zero . Based on this fact, a shunt converter in DPFC can absorb the active power in one frequency and generates output power in another frequency. Assume a DPFC is placed in a transmission line of a two-bus system, as shown inFig.1.While the power supply generates the active power, the shunt converter has the capability to absorb power in fundamental frequency of current. Meanwhile, the third harmonic component is trapped in Y-Δ transformer. Output terminal of the shunt converter injects the third harmonic current into the neutral of Δ-Y transformer . Consequently, the harmonic current flows through the transmission line. This harmonic current controls the DC voltage of series capacitors.

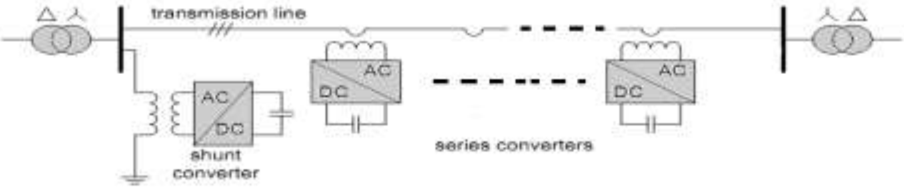


Fig.1: The DPFC Structure

Fig. 2 illustrates how the active power is exchanged between the shunt and series converters in the DPFC. The third harmonic is selected to exchange the active power in the DPFC and a high-pass filter is required to make a closed loop for the harmonic current. The third-harmonic current is trapped in Δ-winding of transformer. Hence, no need to use the high-pass filter at the receiving-end of the system. In other words, by using the third-harmonic, the high-pass filter can be replaced with a cable connected between Δ-winding of transformer and ground. This cable routes the harmonic current to ground.

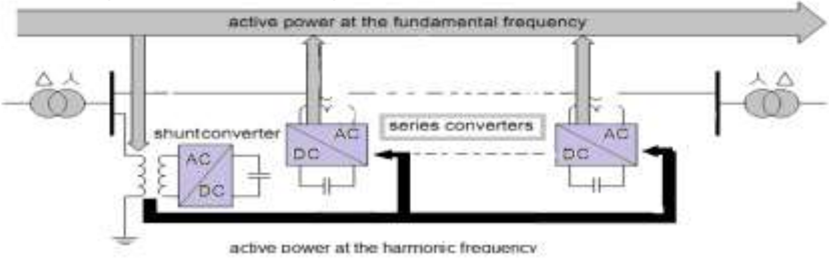


Fig.2: Active power exchange between DPFC converters

CASCADED MULTILEVEL INVERTER

A cascaded multilevel inverter made up of from series connected single full bridge inverter, each with their own isolated dc bus. This multilevel inverter can generate almost sinusoidal waveform voltage from several separate dc sources which may be obtained from solar cells, fuel cells, batteries ,ultra capacitors, etc. This type of converter does not need any transformer or clamping diodes or flying capacitors .Each level can generate five different voltage outputs +2Vdc, +Vdc,0 ,–2Vdc and –Vdc by connecting the dc sources to the ac output side by different combinations of the four switches. The output voltage of an M-level inverter is the sum of all the individual inverter outputs. Each of the H-Bridge’s active devices switches only at the fundamental frequency, and each H-bridge unit generates a quasi- square waveform by phase shifting its positive and negative phase legs switching timings. Further, each switching device always conducts for 180°(or half cycle)regardless of the pulse width of the quasi-square wave so that this switching method results in equalizing the current stress in each active device .This topology of inverter is suitable for high voltage and high power inversion because of its ability of synthesize waveforms with better harmonic spectrum and low switching frequency. Considering the simplicity of the circuit and advantages, Cascaded H-bridge topology is chosen for the presented work. A multilevel inverter has four main advantages over the conventional bipolar inverter. First, the voltage stress on each switch is decreased due to series connection of the switches. Therefore, the rated voltage and consequently the total power of the inverter could be safely increased. Second, the rate of change of voltage (dv/dt) is decreased due to the lower voltage swing of each switching cycle. Third, harmonic distortion is reduced due to more output levels. Fourth, lower acoustic noise and electromagnetic interference (EMI) is obtained.

FUZZY LOGIC CONTROLLER

Fuzzy set theory and fuzzy logic establish the rules of a nonlinear mapping. The use of fuzzy sets provides a basis for a systematic way for the application of uncertain and in definite models. Fuzzy control is based on a logical system called fuzzy logic. It is much closer in spirit to human thinking and natural language than classical logical systems. Nowadays, fuzzy logic is used in almost all sectors of
Industry and science.

Some of the main aspects of fuzzy controller design are choosing the right inputs and outputs and designing each of the four components of the fuzzy logic controller shown in Fig. 3. Each of these will be discussed in the subsections below: Also, the fuzzy controller is activated only during the transient period and once the value of the dc link voltage settles down, the controller gains are kept constant at the steady state value.

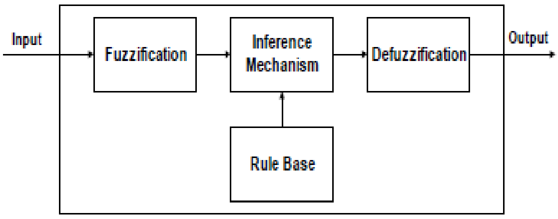


Fig.3: Active power exchange between DPFC converters

A. Fuzzification

The fuzzification interface modifies the inputs to a form in which they can be used by the inference mechanism. It takes in the crisp input signals and assigns a membership value to the membership function under whose range the input signal falls. Typical input membership functions are triangular trapezoidal or exponential. Seven triangular membership functions have been chosen: *NL* (Negative Large), *NM*(Negative Medium), *NS* (Negative Small), *Z* (Zero), *PS*(Positive Small), *PM* (Positive Medium) and *PL* (Positive Large) for both error (*err*) and change in error (*derr*) . The input membership functions are shown in Fig. 4. The tuning of the input membership function is done based on the requirement of the process. Each membership function has a membership value belonging to [0 1]. It can be observed that for any value of error or change in error, either one or two membership functions will be active for each.

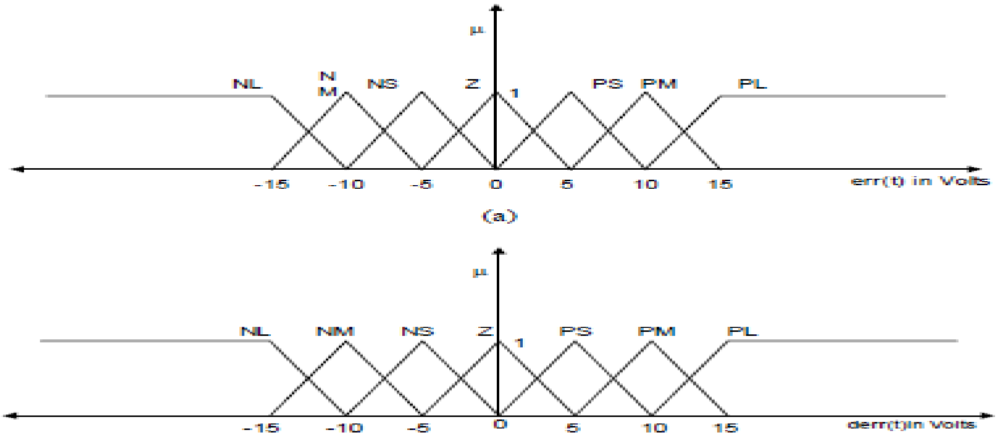


Fig.4: Membership functions for error input. (b) Membershipfunctions for change in error input

B. Inference Mechanism

The two main functions of the inference mechanism are:

a) Based on the active membership functions in error and the change in error inputs, the rules which apply for the current situation are determined.

b) Once the rules which are on are determined, the certainty of the control action is ascertained from the membership values .This is known as premise quantification. Thus at the end of this process, we shall have a set of rules each with a certain certainty of being valid. The database containing these rules is present in the rule base from which the control action is obtained. The rule base will be discussed in the next section .T he terms *PL* and *PM* are the membership functions for error and for change in error respectively.

C. The Rule Base

Designing the rule base is a vital part in designing the controller. It is important to understand how the rule base has been designed. The points involved in the design of the rule base is mainly depends on error. Fig. 5 gives an example of rule base matrix.

NM	L	L	M	S	S	Z	S
NS	L	M	S	S	Z	Z	Z
Z	M	Z	Z	Z	Z	Z	M
PS	Z	Z	Z	S	S	M	L
PM	S	Z	S	S	M	L	L
PL	Z	S	S	M	L	L	L

Fig.5: Rule base matrix

D. Defuzzification

The inference mechanism provides us with a set ofrules each with a $\mu_{premise}$. The defuzzification mechanism considers these rules and their respective $\mu_{premise}$ values, combines their effect and comes up with a crisp, numerical output. Thus, the fuzzy control action is transformed to a non fuzzy control action. The 'center of gravity' method has been used in this work for this. If we use this method, the resultant crisp output is sensitive to all of the active fuzzy outputs of the inference mechanism.

SIMULATION AND RESULTS

In this paper Fuzzy Logic Controller technique based distributed power flow controller (DPFC) with multilevel voltage source converter (VSC) is proposed. The purpose of the proposed intelligent power flow controller will be improved the power quality of the transmission line. The proposed fuzzy based Multilevel DPFC is evaluated by computer simulation as shown in fig's(6)-(23).

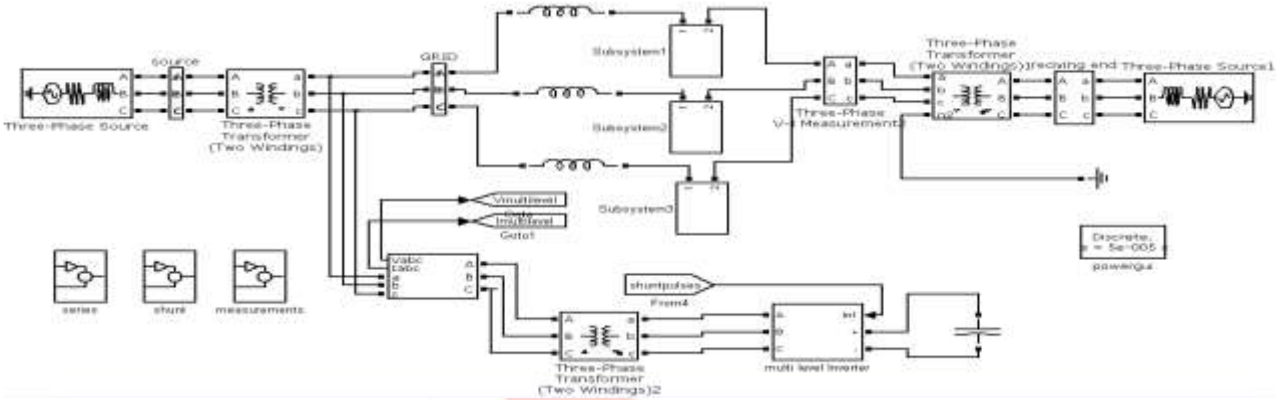
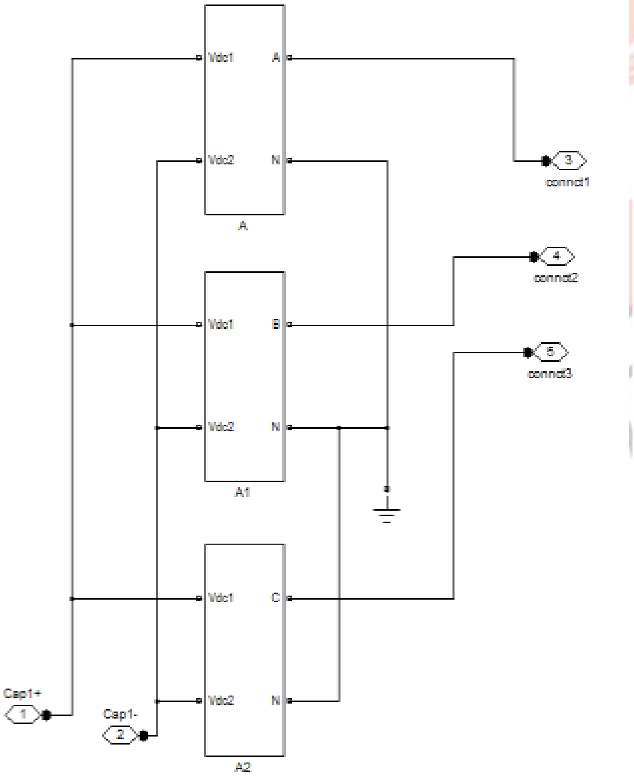


Fig.6: Simulation Model of proposed Fuzzy based Multilevel DPFC



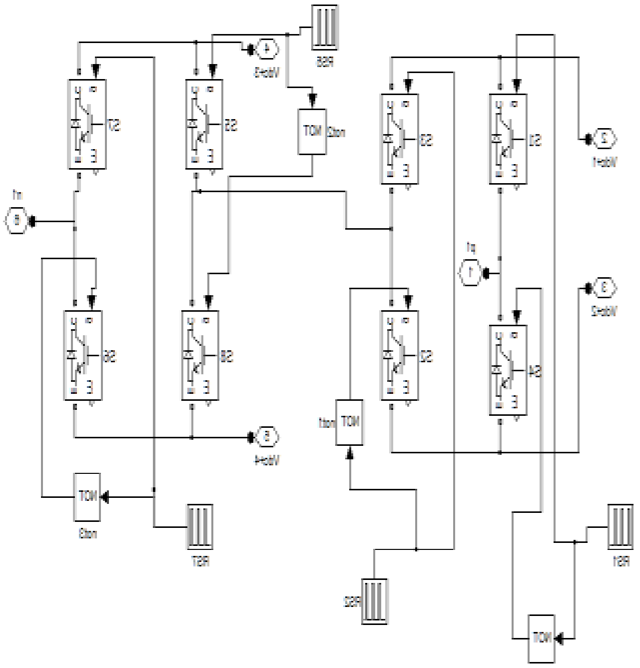


Fig.7: Three Phase Cascaded H-Bridge VSC

Fig.8: 5 Level Cascaded Multilevel Inverter

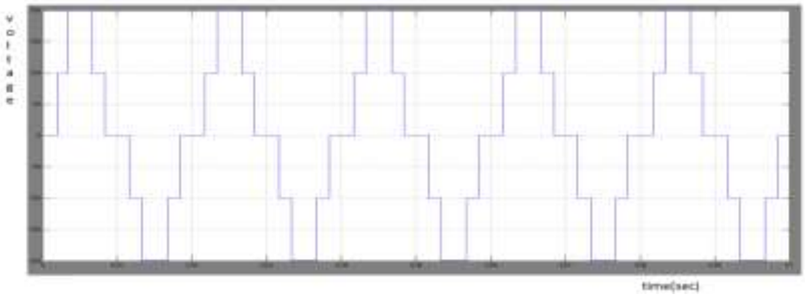


Fig.9: 5 Level Voltage Waveform

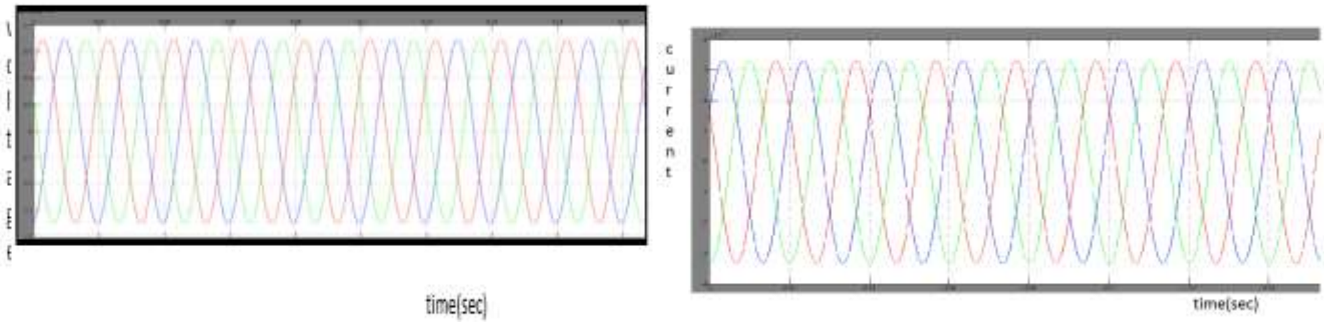


Fig.10: Three Phase output Voltage and Current Waveform

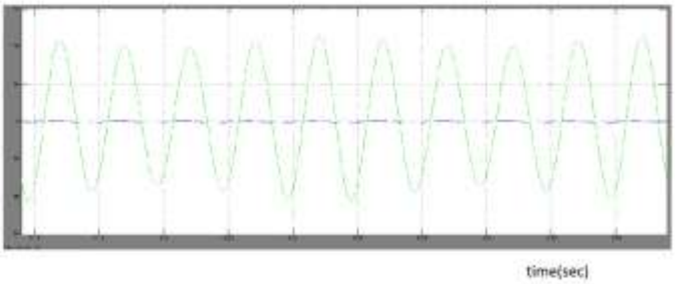


Fig.11: Supply Voltage and Current Waveform with unit PF

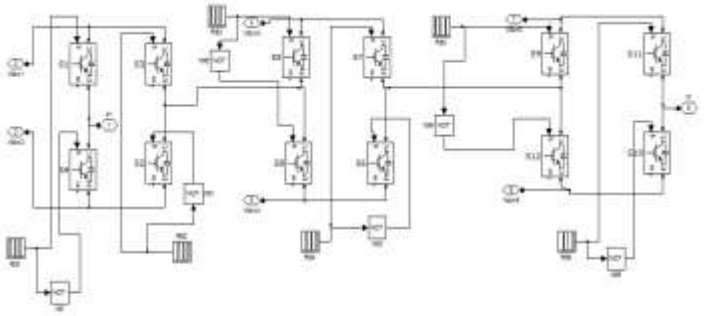


Fig.12: 7Level Cascaded Multilevel Inverter

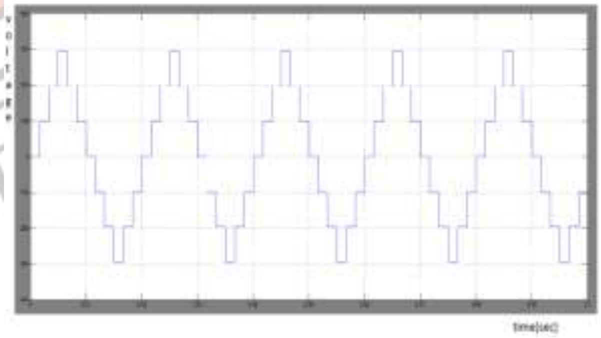


Fig.13: 7Level Voltage Waveform

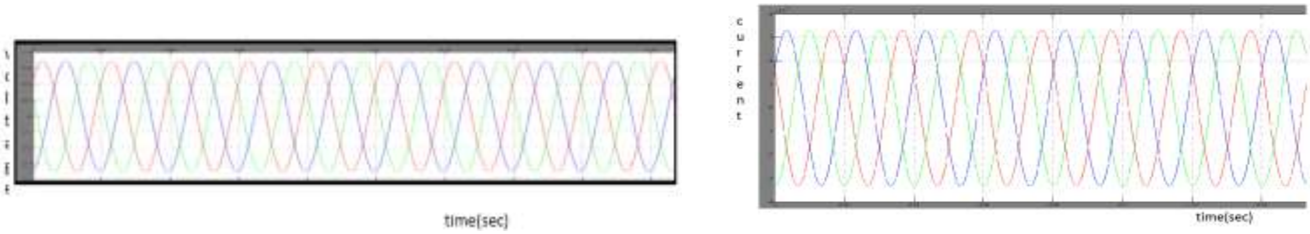


Fig.14: Three Phase output Voltage and Current Waveform

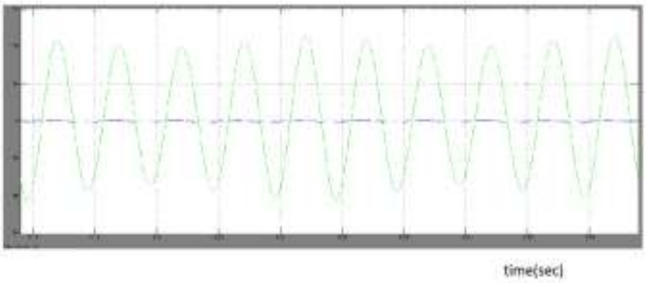


Fig.15: Supply Voltage and Current Waveform with unit PF

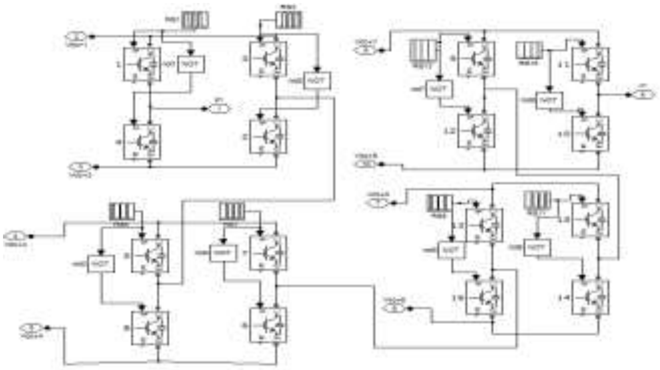


Fig.16: 9Level Cascaded Multilevel Inverter

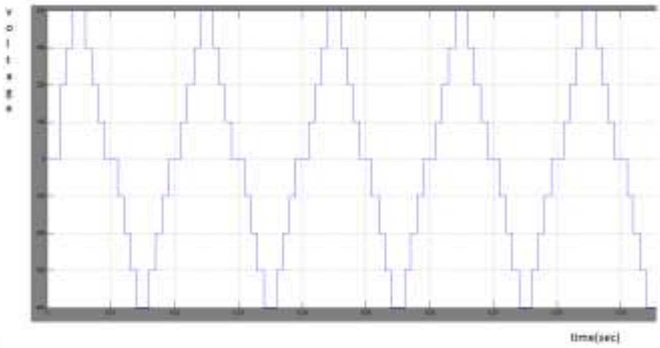


Fig.17: 9Level Voltage Waveform

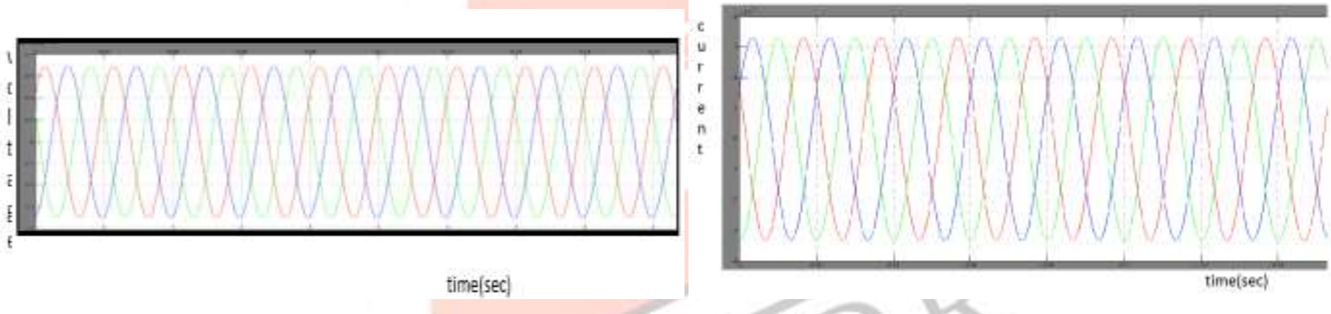


Fig.18: Three Phase output Voltage and Current Waveform

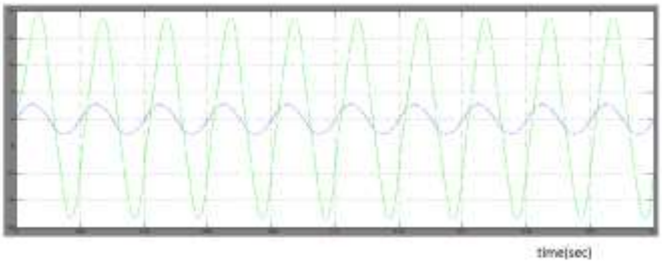
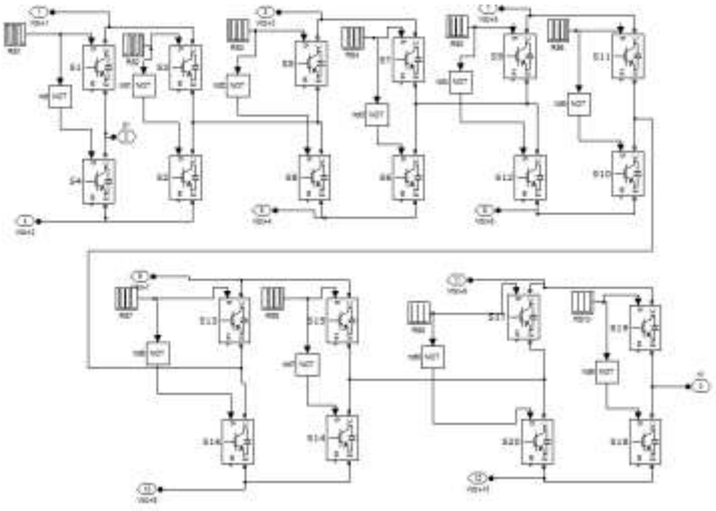


Fig.19: Supply Voltage and Current Waveform with unit PF



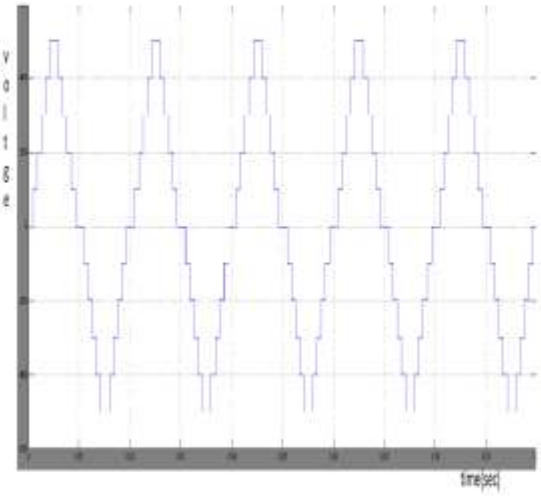


Fig.20: 11Level Cascaded Multilevel Inverter

Fig.21: 11 Level Voltage Waveform

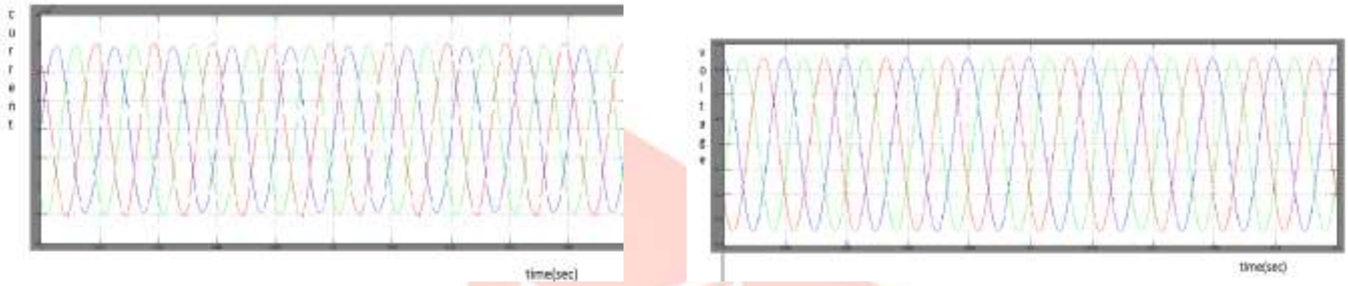


Fig.22: Three Phase output Voltage and Current Waveform

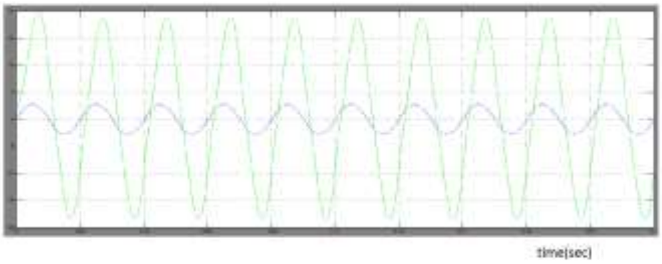
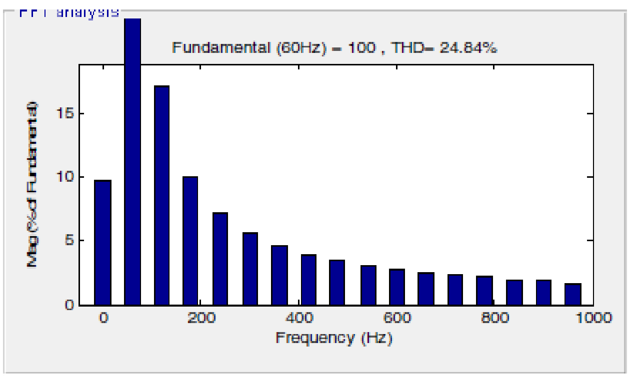


Fig.23: Supply Voltage and Current Waveform with unit PF



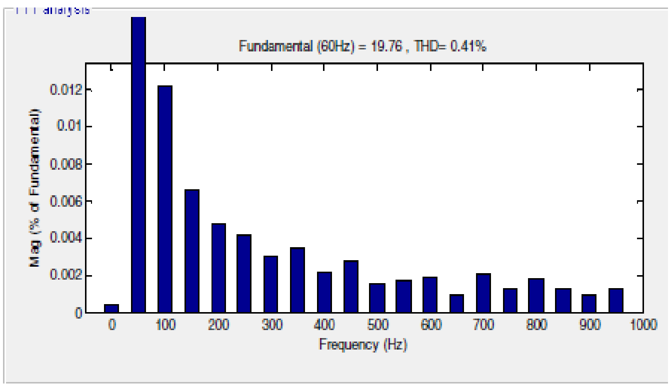


Fig 24: THD with out Fuzzy

Fig.25: THD with Fuzzy

Fig.6 shows the simulation Model of proposed fuzzy based Multilevel DPFC.Fig.7 shows Three Phase Cascaded H Bridge VSC. Fig.8 shows 5 Level Cascaded Multilevel Inverter Circuit. Fig.9 shows 5 Level Voltage Waveform.Fig.10 shows Three Phase output Voltage and Current Waveform. Fig.11 shows Supply Voltage and Current Waveform with unity Power Factor. Fig.12 shows 7 Level Cascaded Multilevel Inverter.Fig.13 shows 7 Level Voltage Waveform. Fig.14 shows Three Phase Output Voltage and Current Waveform. Fig.15 Shows supply Voltage and Current Waveform with unity Power Factor. Fig.16 Shows 9 Level Cascaded Multilevel Inverter. Fig.17 Shows 9 Level Voltage Waveform. Fig.18 Shows Three Phase output Voltage and Current Waveform. Fig.19 shows Supply Voltage and Current Waveform with unity Power Factor. Fig.20 shows 11 Level Cascaded Multilevel Inverter. Fig.21 Shows 11 Level Voltage Waveform. Fig.22 Shows Three Phase output Voltage and Current Waveform. Fig.23 shows Supply Voltage and Current Waveform with unity Power Factor. It is observed that Power Quality is improved in Supply Voltage and Current and Unity Power Factor is achieved.”

CONCLUSION

In this paper Fuzzy Logic Controller technique based distributed power flow controller (DPFC) with multilevel voltage source converter (VSC) is proposed. The presented DPFC control system can regulate active and reactive power flow of the transmission line. We are reducing the THD value from 24.84% to 0.41% by using this technique as shown in fig’s(24) & (25).The series converter of the DPFC employs the DFACTS concept, which uses multiple converters instead of one large-size converter. The reliability of the DPFC is greatly increased because of the redundancy of the series converters. The total cost of the DPFC is also much lower than the UPFC, because no high-voltage isolation is required at the series converter part and the rating of the components are low. Also results show the valid improvement in Power Quality using Fuzzy Logic based Multilevel DPFC.

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