Power Quality Improvement Using Multilevel UPQC with Fuzzy Technique

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Abstract - The power generation and transmission capacity have not increased proportionally to meet the global demand. FACTS devices becomes more popular in improving the existing transmission network capacity. Fuzzy logic based UPFC control have several limitations such as distortions in the output voltage and current waveforms. Therefore, in this work multilevel UPQC with fuzzy technique is proposed. The multilevel unified power quality conditioner is a custom power device, which mitigates voltage, and current related power quality (PQ) issues in distribution systems. Hence results in reduction of harmonics in the input voltage and current waveforms, which enhances the quality of power under various operating conditions. Unified power quality conditioner (M-UPQC) that consist of shunt and series voltage source converters connected back to back and deals with load current and supply voltage imperfections. This proposed topology also has voltage source converters consisting of shunt and series feeder lines to compensate supply voltage and load current imperfection on other feeders. The proposed fuzzy logic controller multilevel UPQC is designed and implemented in MATLAB/Simulink environment.

Keywords: Power Quality, Unified Power Quality Conditioner, Voltage Source Converter, Fuzzy Logic Controller

I. INTRODUCTION

The widespread use of non-linear loads is leading to a variety of undesirable phenomena in the operation of power systems. The harmonic components in current and voltage waveforms are the most important among these. Conventionally, passive filters have been used to eliminate line current harmonics. However, they introduce resonance in the power system and tend to be bulky. So, active power line conditioners have become more popular than passive filters as it compensates the harmonics and reactive power simultaneously.

Therefore, the active power filters such as series, shunt and combinations of both can be used to mitigate the hormonics. Shunt active filter is more popular than series active filter because most of the industrial applications require current harmonic compensation. Different types of active filters are proposed to increase the electric system quality. Few authors have proposed different types of active filters to increase the electric system quality. The harmonic interaction between a large number of distributed power inverters and the distribution network is proposed [1]. The authors in [2] mainly focus on solving the problem that arises when two converters connected in parallel with harmonic compensation. The authors [3] proposed cooperative control of multiple active filters based on voltage detection for harmonic damping throughout a power distribution system. The Decoupled double synchronous reference frame PLL for power converters control algorithm presented in [4] has their own merits and demerits. Single-phase grid-connected inverters for photovoltaic modules are proposed [5]-[7], which is mainly focus on inverter technologies for connecting photovoltaic (PV) modules to a single-phase grid. The authors in [8]-[11] presented about distributed energy resource, is increasingly being pursued as a supplement and an alternative to large conventional central power stations.

One of the most common problems when connecting small renewable energy systems to the electric grid concerns the interface unit between the power sources and the grid, beds based on the power electronic elements introduced serious perturbation problems in the electric power distribution grids [12]. The flow of harmonic currents in the electric grids can also cause voltage harmonics and disturbance. These harmonic currents can interact adversely with a wide range of power system equipment, control systems, protection circuits and other harmonic sensible loads [13]-[15]. The energy distributors like consumers were concerned by imposing some regulation protection against the expansion of harmonic problems.

The main objective of this work is to incorporate the features of APF in the conventional inverter interfacing i.e., four leg voltage source inverter which interfaces the renewable energy sources (RES) such as wind energy and the photovoltaic cell at the distributed grid, without any additional hardware cost. In order to evaluate the performance of the proposed approach, a model of the AC grid, non-linear load, multilevel inverter and renewable energy source is developed in MATLAB/Simulink environment.

II. PROPOSED SYSTEM CONFIGURATION

The main cause of harmonics is the injection of harmonic currents by the non-linear loads. The bridges of diodes are the non-linear loads present in the power applications because they do not need a control and they have long life duration with low cost. The feeding of non-linear loads generates harmonic currents, which spread into the electrical grid. The spread of current harmonics into the feeding impedances (transformers and grid) creates harmonic voltages in these feeders. Few authors presented in literature for the elimination of electric grid harmonics in order to defeat the disadvantages of the traditional methods like passive filters. Active filters are relatively new types of devices for eliminating harmonics. The active filters are power electronic based devices and are much more expensive than passive filters. They have the distinct advantage that they do not resonate with the power system and they work independently with respect to the system impedance characteristics. They are used in difficult circumstances where passive filters do not operate successfully because of resonance problems and they do not have any interference with other elements installed anywhere in the power system.

Fig. 1 illustrates the hybrid APF parallel and series UPQC. This structure combines the advantages of the two APF type's series and parallel. Therefore, it allows simultaneously achieving sinusoidal source current and voltage. The main objective of this work is to incorporate the features of APF in the conventional inverter interfacing i.e., four leg voltage source inverter which interfaces the renewable energy sources such as wind energy and the photovoltaic cell at the distributed grid, without any additional hardware cost. Here the grid interfacing inverter is maximum utilized to perform following important functions: to inject maximum available power of renewable energy resources to the AC grid. To provide load active power and o compensate, load reactive power and current harmonics at PCC. In order to evaluate the performance of the proposed approach, a model of the AC grid, non-linear load, multilevel inverter and renewable energy source in MATLAB/Simulink environment.

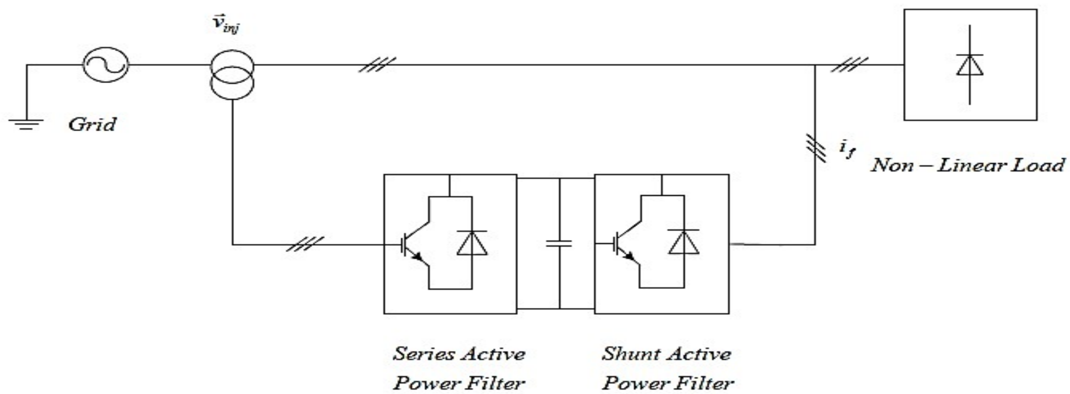


Figure 1. Proposed hybrid unified power quality conditioner's diagram

III. PROPOSED CONTROL TECHNIQUE

In recent years, the number and variety of applications of fuzzy logic (FL) have increased significantly. The applications range from consumer products such as cameras, camcorders, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems, and portfolio selection. The basic concept in FL, which plays a central role in most of its applications, is that of a fuzzy if-then rule or, simply, fuzzy rule. Although rule-based systems have a long history of use in Artificial Intelligence (AI), what is missing in such systems is a mechanism for dealing with fuzzy consequents and fuzzy antecedents. In fuzzy logic, the calculus of fuzzy rules provides this mechanism. The calculus of fuzzy rules serves as a basis for the fuzzy dependency and command language (FDCL). A trend that is growing in visibility relates to the use of fuzzy logic in combination with neuro computing and genetic algorithms. More generally, fuzzy logic, neuro-computing, and genetic algorithms may be viewed as the principal constituents of what might be called soft computing. Unlike the traditional, hard computing, soft computing accommodates the imprecision of the real world.

To determine the appropriate amount of tip requires mapping inputs to the appropriate outputs. Between the input and the output, the preceding figure shows a black box that can contain any number of things: fuzzy systems, linear systems, expert systems, neural networks, differential equations, interpolated multidimensional lookup tables, or even a spiritual advisor, just to name a few of the possible options. The knowledge-base module contains knowledge about all the input and output fuzzy partitions. It will include the term set and the corresponding membership functions defining the input variables to the fuzzy rule-base system and the output variables, or control actions, to the plant under control. Fig.2 illustrates simple fuzzy logic control system. The proposed fuzzy rules are illustrated in Table.1

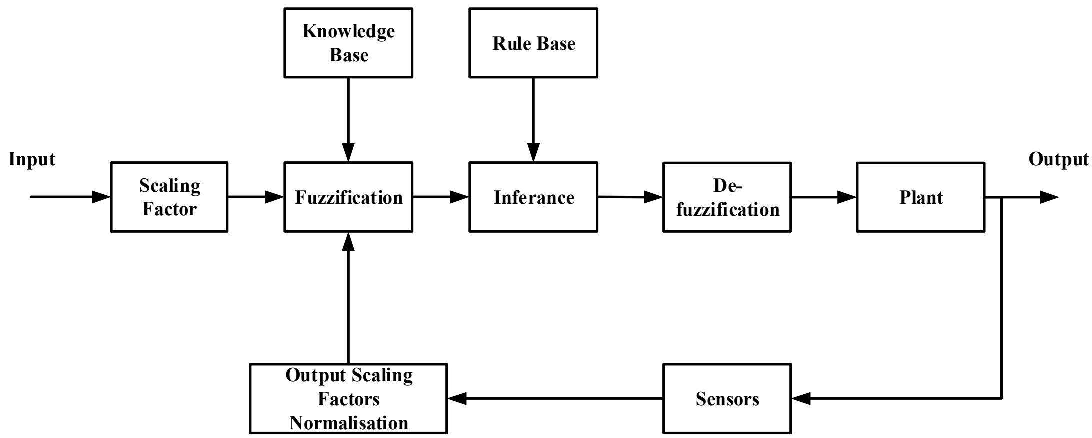


Figure 2. A Simple fuzzy logic control system

Table 1. Fuzzy Rule

ε\εΔ	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	**NB**	NM	NM	NS	ZE	PS
NS	NB	NM	NS	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PS	PM	PB
PM	NS	ZE	PS	PM	PM	PB	PB
PS	ZE	PS	PM	PB	PB	PB	PB

IV. SIMULATION RESULTS AND ANALYSIS

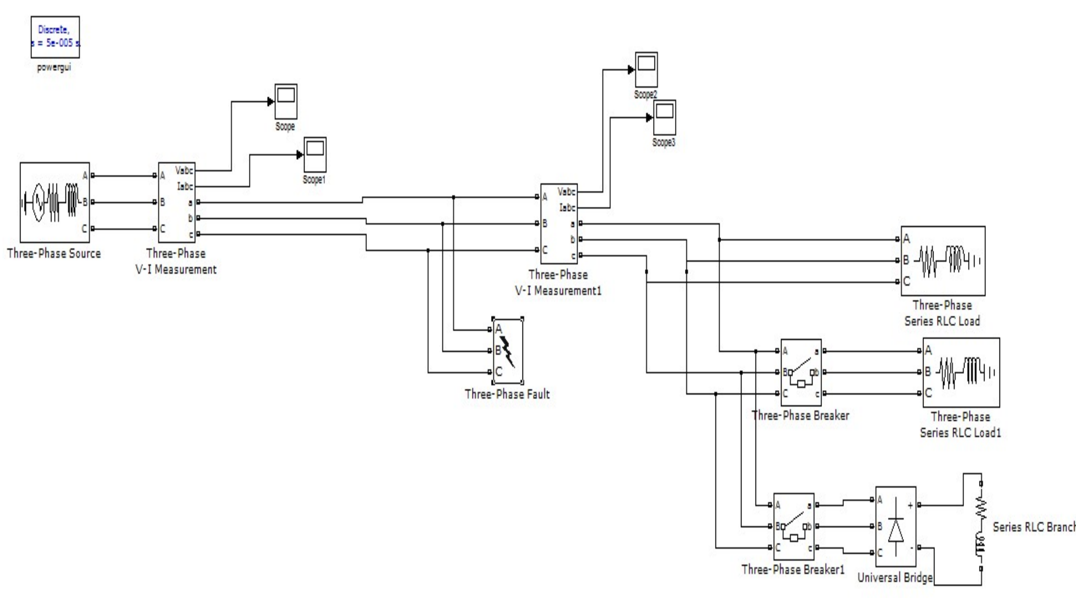
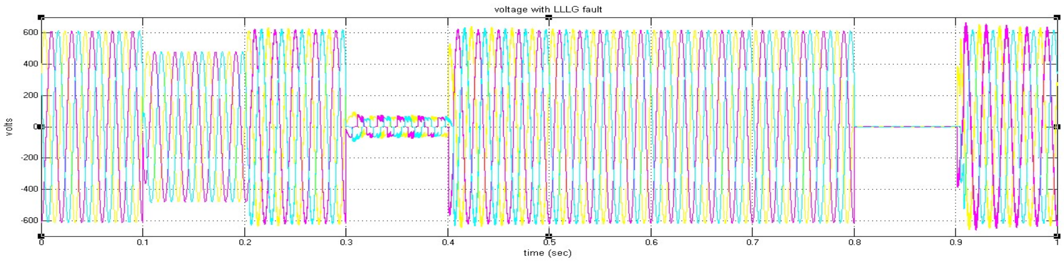
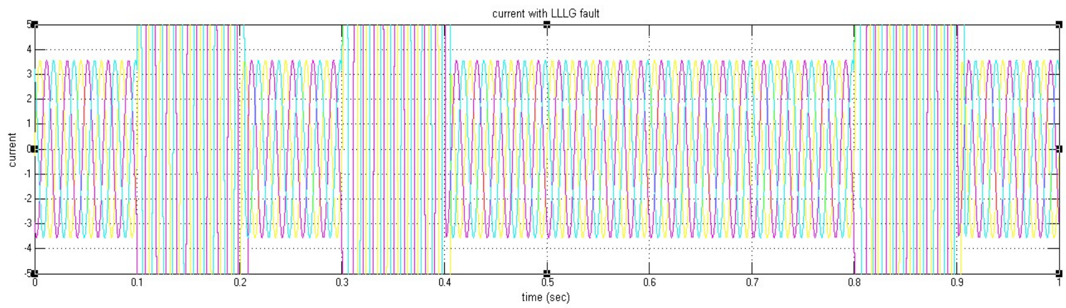


Figure .3 Simulation model of proposed work without UPQC

In order validate the effectiveness of proposed work; the proposed work has implemented in simulation in three cases, without PQC, with UPQC and hybrid controller for parallel line. Fig.3 illustrates the simulation model of proposed work without UPQC. The simulation waveforms of output voltage and output current of proposed work without unified power conditioner are shown in fig.4. From fig.4 (a), it clearly indicates that the system without UPQC experiences a voltage disturbance when a LLLG fault occurred this effects the system power quality. From fig.4 (b), it clearly shows a high current is observed under LLLG fault condition to the circuit with PI controller. This increases the system loses and affects the quality of power supply.



(a)



(b)

Figure 4. Simulation waveforms without unified power conditioner; (a) Voltage Waveform, (b) Current Waveforms

The current waveform and total harmonic distortion of proposed work without UPQC is shown in fig.5. From fig.5 it clearly indicates that the total harmonic distortion of proposed work without UPQC is 6.02%. The simulation model of proposed work with UPQC is illustrated in fig.6. The simulation waveforms of output voltage and output current of proposed work with unified power conditioner are shown in fig.7. From fig.7 (a) it clearly indicates that the system with UPQC has generated a stabilized output voltage waveform without any distortions maintained during the LLLG fault condition. From fig.7 (b), it clearly shows the current waveform still have some distortions under LLLG fault condition with UPQC controller.

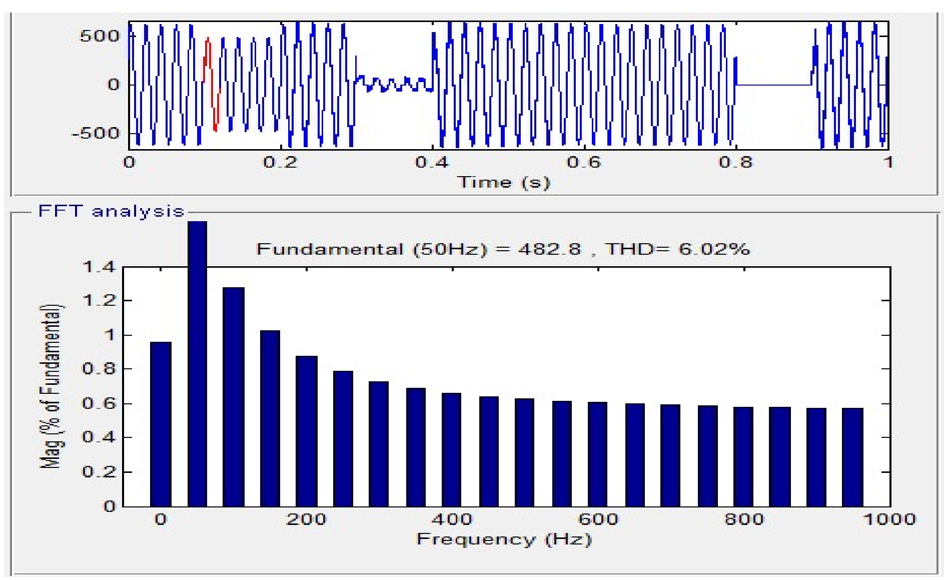


Figure 5. Simulation waveform of THD without unified power conditioner.

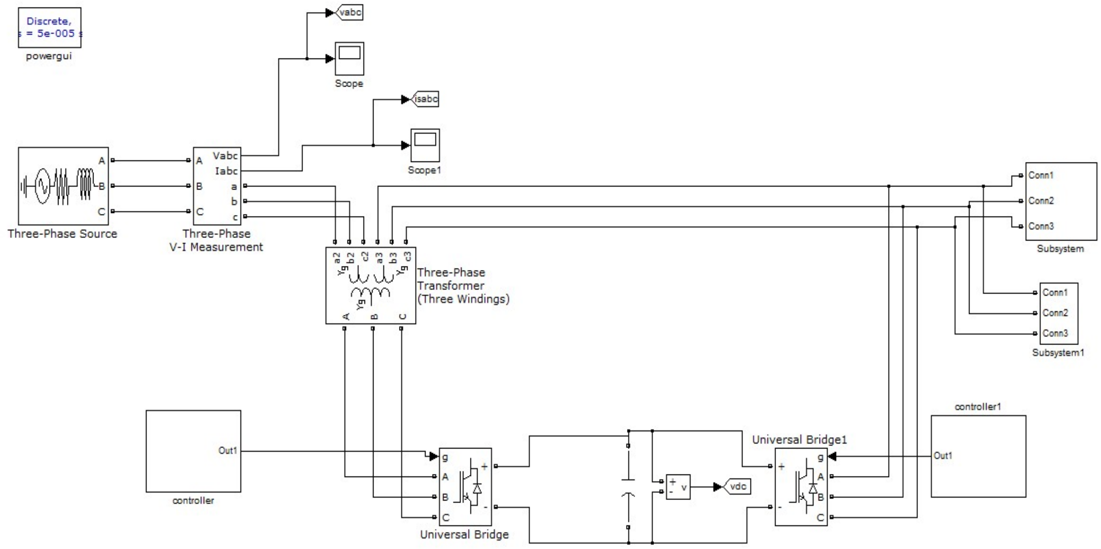
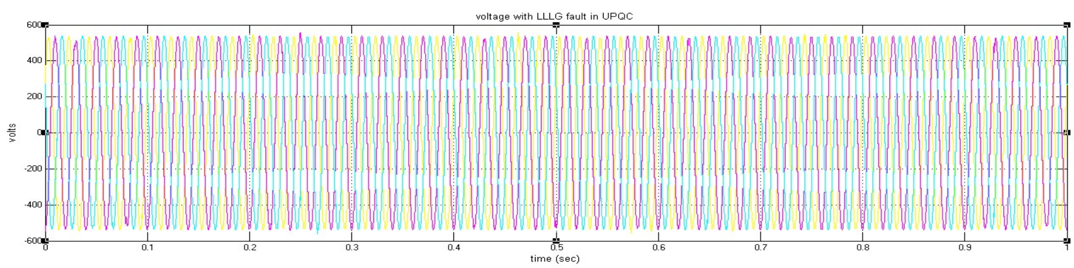
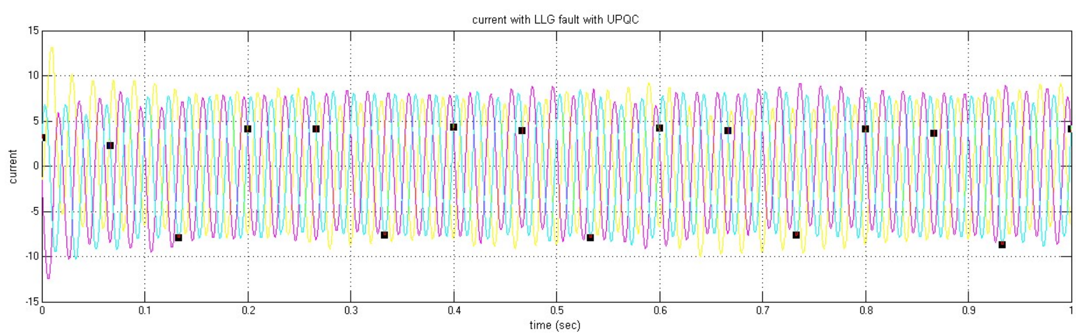


Figure 6. Simulation model of proposed work out UPQC



(a)



(b)

Figure 7. Simulation waveforms with unified power conditioner; (a) Voltage Waveform, (b) Current Waveforms

The current waveform and total harmonic distortion of proposed work with UPQC is shown in fig.8. From fig.8, it clearly indicates that the total harmonic distortion of proposed work with UPQC is 2.74%. The THD of the system with UPQC controller has reduced from 6.02% to 2.74%.

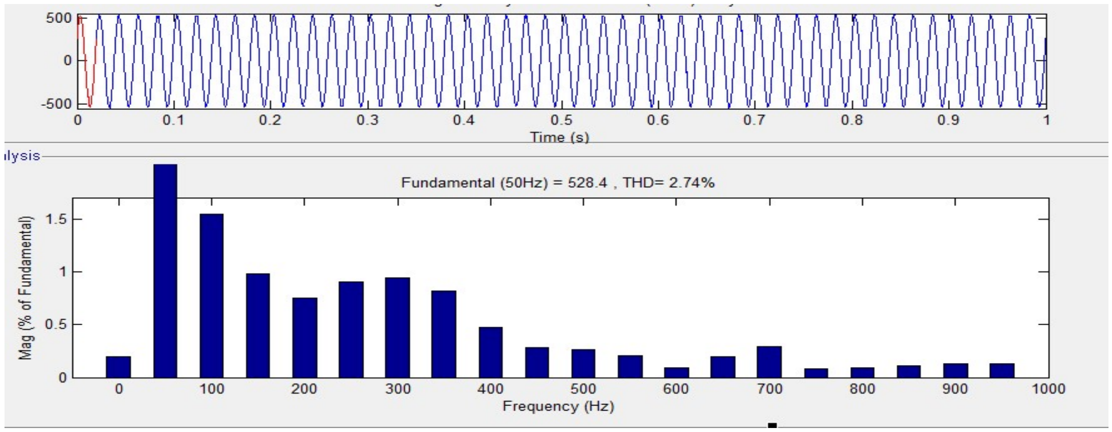


Figure 8. Simulation waveform of THD with unified power conditioner

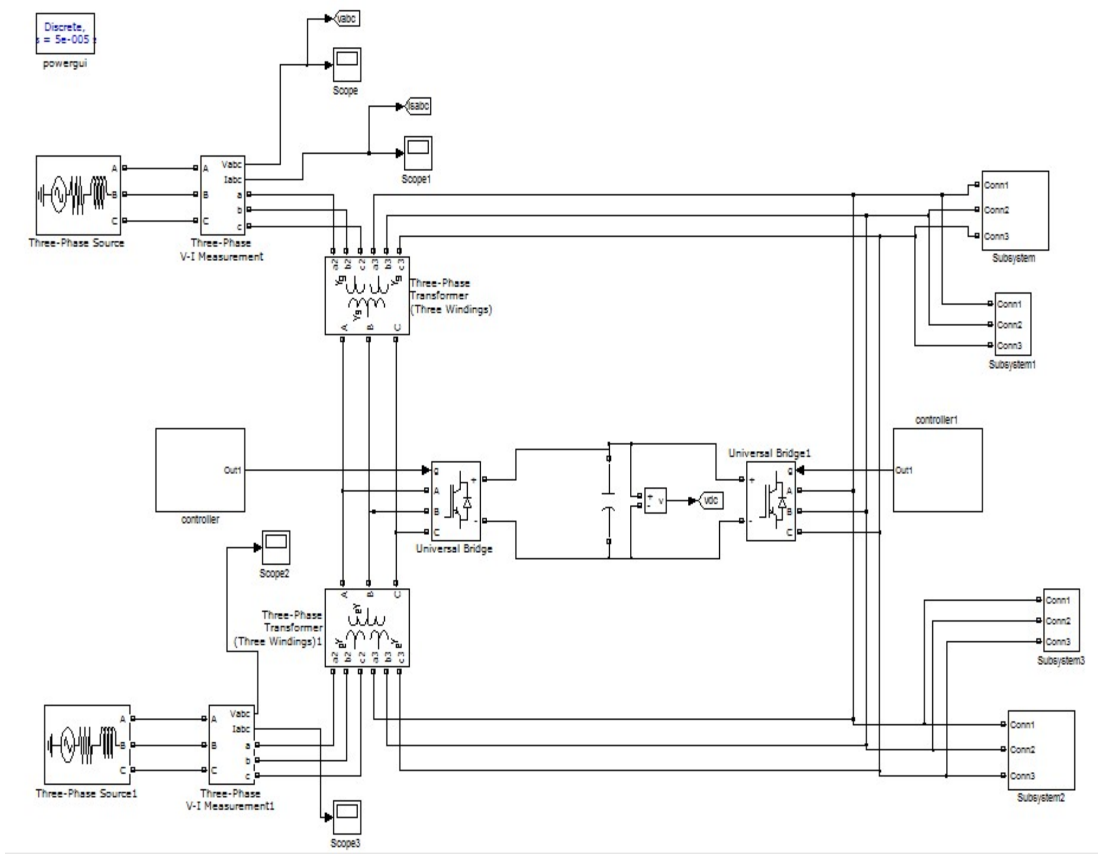
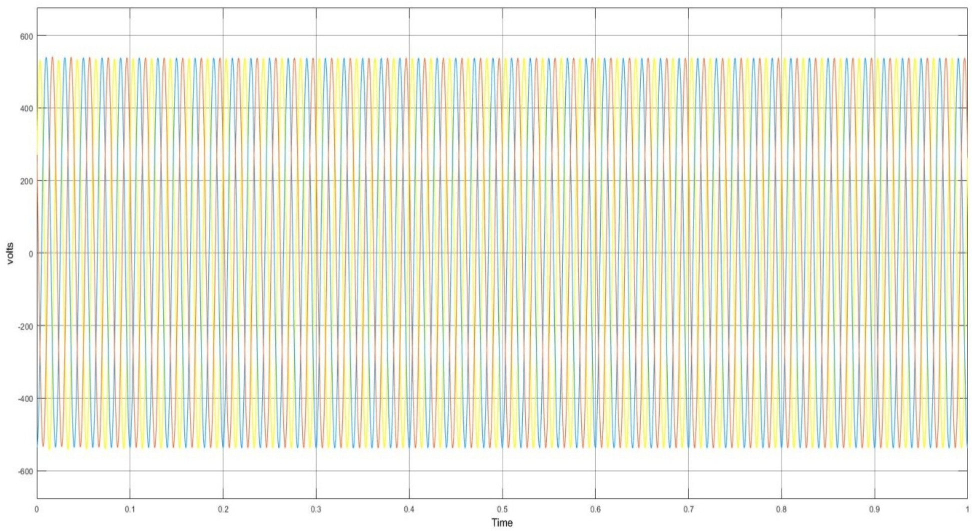
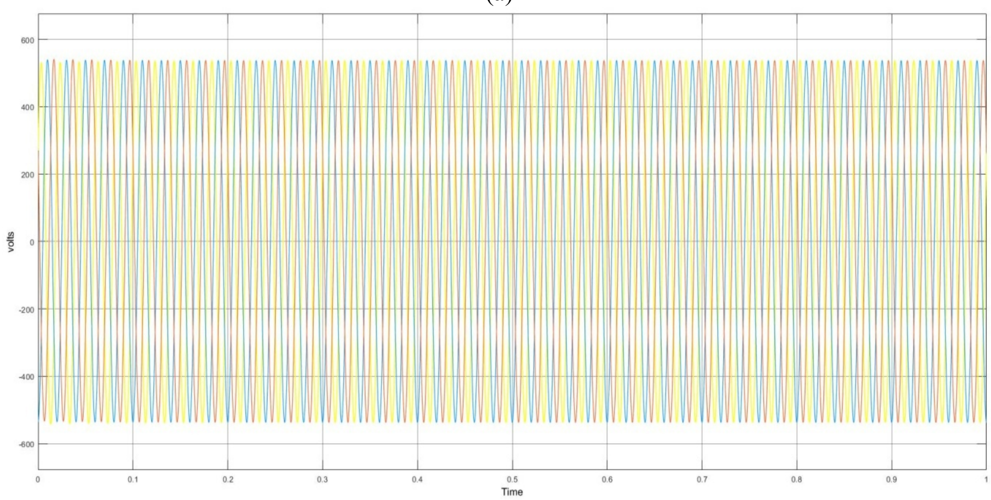


Figure 9. Simulation model of proposed work with hybrid controller

Fig.9 illustrates the simulation model of proposed work with hybrid controller for parallel line. Fig.10 illustrates the simulation waveforms of output voltage and output current of proposed work using the hybrid control technique for a parallel line. By using the hybrid control technique for a parallel line system the output voltage in line 1 and in line 2 are maintained constant without any fluctuations are shown in fig.10 (a). From fig.10 (b), it clearly indicates that the hybrid control technique to UPQC the current harmonics is completely reduced and maintained constant under any fault condition.



(a)



(b)

Figure 10. Simulation waveforms with hybrid controller; (a) Voltage Waveform, (b) Current Waveforms

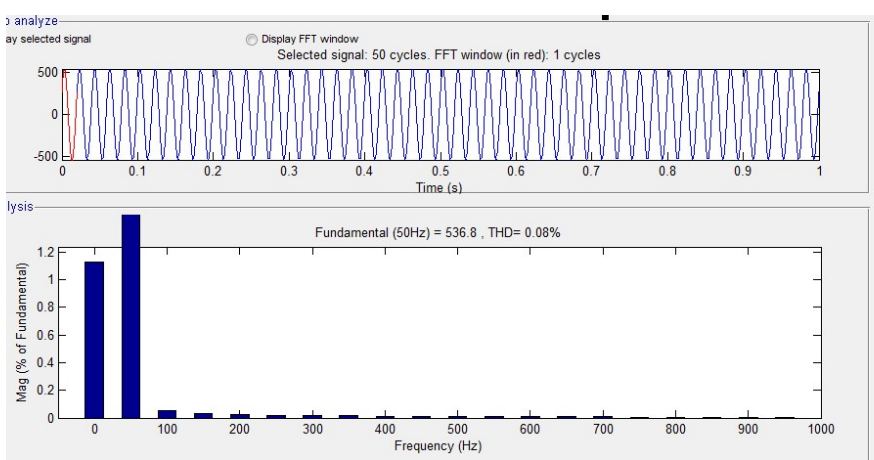


Figure11. Simulation waveform of THD with hybrid controller

Table.2 illustrates the comparisons of all the methods of proposed work. From Table.2, it clearly describes the simulation model without UPQC, voltage is unbalanced for different types of faults and maximum currents are obtained, then the THD of the system is 6.02%. By using the PI controller with UPQC then the voltages under any fault, conditions are balanced but some distortions are still identified in current values and the overall THD is reduced to 2.74%. In proposed hybrid, controller with UPQC for parallel lines the voltages and currents are balanced under any fault condition and the overall THD is reduced to 0.08%. This clearly shows that proposed system gives better results when compared to without and with PI models.

S.No	Type of control	Fault duration time	Type of fault	Voltage (V)	Current (A)	%THD
1	Without	0.8-0.9	LG	380	90	6.02%
			LLG	380	90	
			LLLG	0	90	
2	With PI controller	0.8-0.9	LG	580	9	2.74%
			LLG	580	9	
			LLLG	580	9	
3	With Hybrid controller	0.8-0.9	LG	550	7.5	0.08%
			LLG	550	7.5	
			LLLG	550	7.5	

V. CONCLUSIONS

In this work, UPFC is developed in MATLAB/Simulink to reduce control cost and power grid resilience. In the existing system of fuzzy logic based UPFC control still we observe some distortions in the output voltage and high distortions in the current wave forms. The proposed UPFC controller model, which is connected parallel to the DC link capacitor in the three-phase micro grid system reduced the Total Harmonic Distortion to less than 5% when compared with fuzzy logic control model and also voltage and current waveforms are obtained without any distortion. The proposed fuel cell based UPFC configuration can be extended to parallel bus system.

REFERENCES

[1] Ellabban, O., Abu-Rub, H., Blaabjerg, F.: ‘Renewable energy resources: current status, future prospects and technology’, Renew. Sustain. Energy Rev., 2014, 39, pp. 748–764
[2] Bull, S.R.: ‘Renewable energy today and tomorrow’, Proc. IEEE, 2001, 89, (8), pp. 1216–1226
[3] Malik, S.M., Ai, X., Sun, Y., et al.: ‘Voltage and frequency control strategies of hybrid AC/DC microgrid: a review’, IET Renew. Power Gener., 2017, 11, (2), pp. 303–313
[4] Kusakana, K.: ‘Optimal scheduled power flow for distributed photovoltaic/ wind/diesel generators with battery storage system’, IET Renew. Power Gener., 2015, 9, (8), pp.916–924
[5] Askarzadeh, A.: ‘Solution for sizing a PV/diesel HPGS for isolated sites’, IET Renew. Power Gener., 2017, 11, (1), pp.143–151
[6] Kant, K., Jain, C., Singh, B.: ‘A hybrid diesel-wind-PV based energy generation system with brushless generators’, IEEE Trans. Ind. Inf., 2017, 99, pp. 1–1
[7] John, T., Ping Lam, S.: ‘Voltage and frequency control during microgrid islandinginamulti-areamulti-microgridsystem’, IET Gener Transm.Distrib., 2017, 11, (6), pp. 1502–1512
[8] Philip, J., Jain, C., Kant, K., et al.: ‘Control and implementation of a standalone solar photo-voltaic hybrid system’, IEEE Trans. Ind. Appl., 2016, 52, (4), pp. 3472–3479
[9] Kwon, M., Choi, S.: ‘Control scheme for autonomous and seamless mode switching of bidirectional DC–DC converters in a DC microgrid’, IEEE Trans. Power Electron., 2017, early access
[10] Merabet, A., Tawfique Ahmed, K., Ibrahim, H., et al.: ‘Energy management and control system for laboratory scale micro grid based wind-PV-battery’, IEEE Trans. Sustain. Energy, 2017, 8, (1), pp. 145–154
[11] Prakash, S.L., Arutchelvi, M., Jesudaiyan, A.S.: ‘Autonomous PV-array excited wind-driven induction generator for off-grid application inIndia’, IEEE J. Emerg. Sel. Top. Power Electron., 2016, 4, (4), pp. 1259–1269
[12] Reddy, U.R., and Narasimharaju, B.L. (2016) Improved efficiency coupled inductor-buck ac-dc light emitting diode (led) driver,. IEICE Electronics Express,, 13 (16),.
[13] Reddy, U.R., and Narasimharaju, B.L. (2017) High step-down dual output light emitting diode driver,. International Journal of Renewable Energy Research,, 7 (1), pp.157–169,.
[14] Serban, I., Marinescu, C.: ‘Control strategy of three-phase battery energy storage systems for frequency support in microgrids and with uninterrupted supply of local loads’, IEEE Trans. Power Electron., 2014, 29, (9), pp. 5010– 5020
[15] Reddy, U.R., and Narasimharaju, B.L. (2015) Unity power factor buck-boost led driver for wide range of input voltage application,. IEEE India Conference (INDICON), pp. 1-6, New Delhi.