JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1562 - 1568
https://publishoa.com
ISSN: 1309-3452

Mathematical Modelling of Fuzzy Controlled Multilevel Inverter for Unified Power Quality Conditioner

[1]Dr.Baskar Srinivasan, [2]Nageswara Rao Gotivada,

[1]Professor, [2]Post Graduate scholar Dept.of Electrical & Electronics Engineering,
Vel Tech Rangarajan Dr.Sagunthala R&D Institute of Science and Technology, Avadi, Chennai. India. drbaskar@veltech.edu.in

ABSTRACT

The Unified Power Quality Conditioner can help reduce grid harmonics caused by nonlinear loads linked in transmission lines (UPQC). The Fuzzy Logic Controller is said to be used by the proposed Multilevel Inverter (MLI) to alleviate concerns with power quality on the load side, according to UPQC. The fuzzy logic controller is more reliable and accurate than the proportional integer (PI) controller. H bridge MLI suppresses harmonics in grid, whereas UPQC controls voltage drop and rise on transmission lines to enhance power quality (grid). MATLAB-Simulink is used to determine how the load maintains a steady voltage and how much electricity is delivered.

INDEX TERMS: Multilevel Inverters (MLI), Power Quality, Unified Power Quality Conditioner (UPQC), Fuzzy Logic Controller.

I. INTRODUCTION

Fundamentally, energy is the building block of all living things. Electricity is one of the most important sources of energy on the planet. It enables a more adaptable way of life, and the demand for this type of energy is increasing as a result. One of the key goals of today's electric power systems is to improve the quality of the electricity that they provide. Customers in the industrial, commercial, and residential sectors have all seen a decrease in power quality as a result of the increase in non-linear loads linked to the electric grid in the last several years. The quality of electric power required for critical loads has decreased as a result of voltage sags, swells, and unbalances, among other factors. There have been several methods established to cope with power quality issues, such as Unified Power Quality Conditioners (UPQCs) systems, that have been developed. The usage of active power filters (APFs), including shunt, series, and hybrid active power filters (APFs), as well as dynamic voltage restorers, has been shown to improve power quality (PQ). The usage of APFs as a non-sinusoidal current source in single-phase or three-phase topologies is in parallel with the use of nonlinear loads. This type of compensation can only be utilised in three-phase systems, and it can only be used to adjust for harmonic currents, load unbalances, and reactive power created by the loads themselves.

When used in conjunction with series APF filters, which are non-sinusoidal voltage or current sources positioned between the utility grid and the load, it is possible to compensate for harmonic currents, load imbalances, and reactive power while maintaining load voltage control. The authors describe a UPQC system with a lower DC-link voltage than is often used. When using a shunt active filter, its interface inductor is connected in series with a capacitor, as shown in this diagram. The series capacitor reduces the DC-link voltage requirement of the shunt active filter while at the same time compensating for the reactive power of the load in order to maintain unity power factor without degrading performance of the filter. In this work, the multilayer inverter with PI and fuzzy controllers that was proposed was a completely new concept. As defined by the Electrical Engineering Dictionary, a multi-level converter is a device that transforms low voltage components into high voltage waveforms. Multilevel inverters are found in a variety of configurations across the world. In this configuration, a cascaded multi-level inverter is employed. For the purpose of computing an error signal, the P.I. Controller takes the system output from the multilayer inverter and subtracts it from the system output of the error signal. It is necessary to use a fuzzy logic controller in order to increase the performance of the cascaded multilevel inverter. It was the MATLAB/SIMULINK application that was used to generate the simulation outcomes.

II. SYSTEM CONSTRUCTION

Figure 1 shows the PV-BESS-UPQC construction. The PV-BESS-UPQC model is three-phase system compatible. In the PV-BESS-UPQC, a DC-link split capacitor couples a series and shunt APF compensator. The shunt compensator, on the other hand, reduces the load's current harmonics. Interfacing inductors link the series and shunt APF compensators.

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1562 - 1568
https://publishoa.com
ISSN: 1309-3452

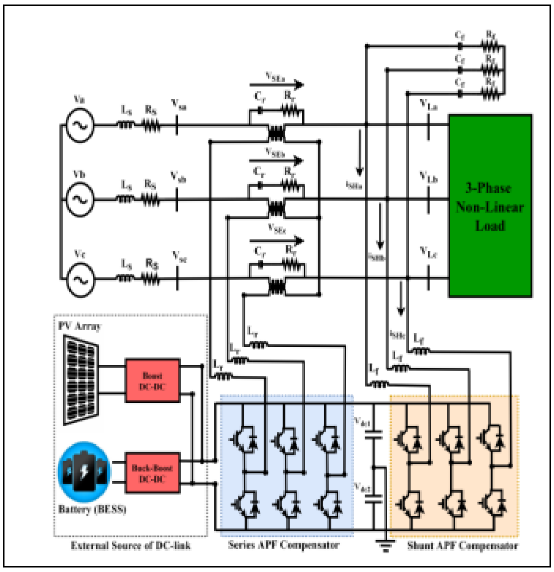


Fig.1. UPQC system configuration

Harmonics are generated during the converter switching process, which are filtered using a ripple filter. The series compensator injects electricity into the grid using a series injection transformer. The three-phase non-linear load is being used in this model.

A. UPQC DESIGN

1) DC-LINK VOLTAGE MAGNITUDE

Vdc,min,- Minimum DC-link voltage is determined by the system's phase voltage. The size of the DC-voltage link should be double that of the supply's phase voltage peak value. The Vd,min equation is as follows:

$$V_{dc,min} = \frac{2\sqrt{2}(V_{u,rms})}{\sqrt{3}(m)} \qquad (1)$$

Where VLL,rms is the grid's phase voltage, as defined by the Malaysian Energy Commission in accordance with IEC standards, and m is the modulation depth index, which is set to 1.

DC-LINK CAPACITOR ALUE

The following is the equation for the capacitor used in the DC-link:

$$\frac{3V_{ph}\ i_{sh}a_f\ k_e t}{1/2\ (V_{dc,set^2} - V_{dc,min^2}\ )} \qquad (2)$$

It is measured in amperes in APF phase current. It is also measured in time in system stability time (t) and dynamic energy fluctuation (ke) in APF phase current. The DC-minimum connection necessitates the use of Vdc,min, whereas the reference voltage necessitates the use of Vdc,set.

2) INDUCTOR RIPPLE FILTER FOR SHUNT APF

The ripple current and DC-link voltage are represented by the variables FSH, Icr,pp, and Vdc,set, respectively. An interfaced inductor is represented by the following equation:

$$\boldsymbol{L_{f,min} = \frac{(\sqrt{3})(m)(V_{dc,set})}{12(a_f)(f_{SH})(I_{cr,pp})}} \qquad \textbf{(3)}$$

3) SERIES INJECTION THREE-PHASE ISOLATION TRANSFORMER

This is the highest value of the injection transformer's turns ratio for the APF series:

$$\boldsymbol{K_{SE} = \frac{V_{urms}}{\sqrt{3}(V_{SE})}} \qquad \textbf{(4)}$$

$$\boldsymbol{S_{SE} = 3(V_{SE})(i_{SE(under\ sag)})} \qquad \textbf{(5)}$$

The series APF is able to supply the same amount of current as the grid. When the voltage sag is 0.6 pu, the supply current is 36 A. Because of this, the injection transformer's VA rating has been increased to 15 kVA.

INDUCTOR RIPPLE FILTER FOR SERIES APF

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1562 - 1568
https://publishoa.com
ISSN: 1309-3452

The series APF, as the name implies, is a passive filter that connects to the network through an inductor and makes use of the DC-link voltage, ripple current, and switching frequency to filter the signal. An interfaced inductor is represented by the following equation:

$$L_{r,min} = \frac{(\sqrt{3})(m)(V_{dc,set})(K_{SE})}{12(a_f)(f_{SH})(I_r)} \qquad (6)$$

It is defined as 20 percent of the Series APF rms phase current, where is the maximum per-unit overload value and is the maximum inductor ripple current. It is possible to express the switching frequency in terms of the acronym fSE. It was discovered that the measured inductance value is 3.6 microhenries (mH) when the following parameters are used: m=1, af=1.5, fSE=10 thousand hertz, 20 percent ripple current, and Vdc,set = 700 volts. It was discovered that the measured inductance value is 3.6 microhenries (mH) when the following parameters are used: m=1, af=1.5, fSE=10 thousand hertz, 20 percent ripple current, and Vdc,set = 700 volts.

B. DESIGN OF UPQC CONNECTING WITH PV-BESS AS EXTERNAL SUPPORT OF DC-LINK

The proposed model, seen in Fig. 2, includes a BESS, boost converters, buck-boost converters, and a controller, among other components. Buck-boost converters increase the stability of the UPQC and are capable of dealing with power quality issues. The entire power flow represented by the model is expressed by the formula (7). Table I contains the technical characteristics for the PV system and Li-ion battery used in this investigation.

$$P_{total} = P_{pv} + P_{BESS} - P_{LoadDC-link} \qquad (7)$$

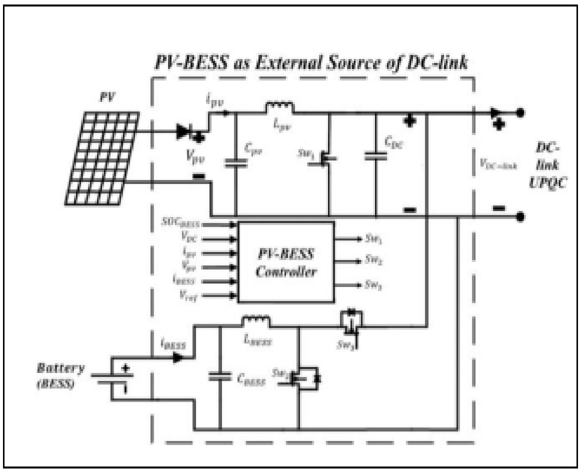


Fig.2. Source configuration

i.Multi-level converters with PI controller:

Multilevel converters are a concept that has been around since 1975. The three-level converter gave rise to the word "multilevel." As a result, numerous topologies for multilayer converters have been developed.

a) Cascaded H Bridge Inverters

The single-phase cascaded inverters depicted in the picture below are an example of this type of inverter. An H-bridge inverter is a single-phase inverter that is totally bridged since it uses a separate direct current source (SDCS). Inverter levels 1, 2, 3, and 4 may be achieved by using the switch combinations S1, S2, S3, and S4. Each of the four inverter levels can be achieved by using the switch combinations S1, S2, S3, and S4. Both Switches 1 and 4 are activated, and both Switches 2 and 3 are deactivated. When all four switches are triggered at the same time, a zero output voltage is created. Full-bridge inverter levels provide alternating current outputs that are equal to the sum of all of the synthesised voltage waveforms produced by them. For a cascade inverter, the number of output phase voltage levels m is equal to 2s+1, where s is the number of independent dc sources and m is the number of output phase voltage levels. The sum of the phase voltage vans in the first figure (Va1 + Va2 + Va3 + Va4 & v A5) is equal to the sum of the phase voltage vans in the second figure. The Fourier Transform of an s-step waveform is represented as follows, using Figure (b) as an illustration. follows:

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1562 - 1568
https://publishoa.com
ISSN: 1309-3452

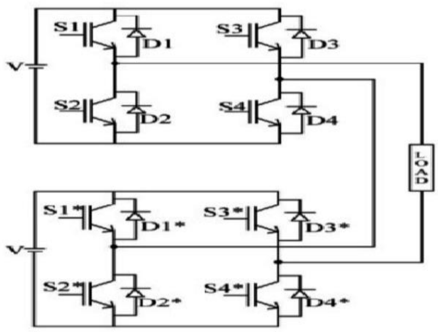


Fig.3Structure of a single-phase H-bridge inverter with many levels of cascaded H-bridges

ii.MLI with Fuzzy Logic controller:

Complex simulated issues with a large number of input and output variables can be solved using fuzzy logic, a complex mathematical technique. As a result, it's critical to distinguish between fuzzy logic and more well-known logics like Boolean algebra. The basics of fuzzy logic are presented in this book as an introduction.

Control systems are often described with the use of stochastic models, mathematical logic-derived models, or models that follow physical principles in mathematics. Making the transition from a real-world situation to an appropriate mathematical model is the most challenging part of employing this methodology. In spite of the fact that sophisticated computer technology now makes this possible, running these kinds of systems is still prohibitively complex. The graphic below depicts the Fuzzy Logic Control/Analysis Method in its entirety.

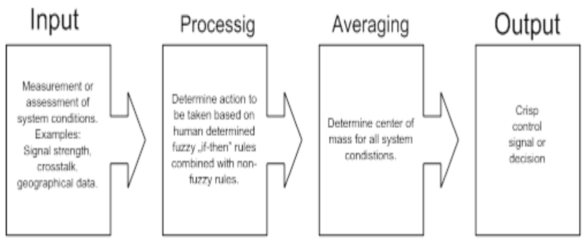


Fig.4. The FUZZY logic Control-Analysis method

FIGURE 2 depicts a schematic representation of all of the components required for a fuzzy logic control system (fuzzification, fuzzy inference, fuzzy rule matrix, and defuzzification).

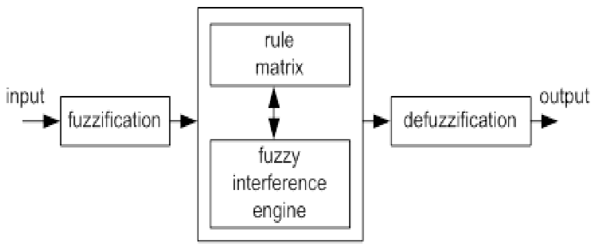


Fig.5. Fuzzy logic controller

The below figure will tells us about the membership functions of Fuzzy Logic Controller. There two inputs are considered i.e., error in figure (11) and change in error in figure (12) and the membership function of output is shown in figure (13)

JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1562 - 1568
https://publishoa.com
ISSN: 1309-3452

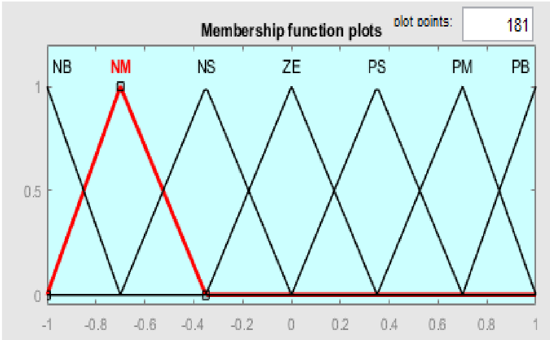


Fig.6.Fuzzy logic controller output

Table 2: Rules of FLC

e / Δe	NB	NM	NS	ZE	PS	PM	PB
NB	NB	NB	NB	NB	NM	NS	ZE
NM	NB	NB	NB	NM	NS	ZE	PS
NS	NB	NB	NM	NS	ZE	PS	PM
ZE	NB	NM	NS	ZE	PS	PM	PB
PS	NM	NS	ZE	PS	PM	PB	PB
PM	NS	ZE	PS	PM	PB	PB	PB
PB	ZE	PS	PM	PB	PB	PB	PB

The above table consists of the 7x7=49 rules, whereas

NB= Negative Big; NM= Negative Medium; NS= Negative Small; Z= Zero Medium;

PS= Positive Small; PM= Positive Medium; PB= Positive Big.

III. SIMULATION RESULTS:

Multilevel Inverter with Fuzzy Logic Controller: Case-1:

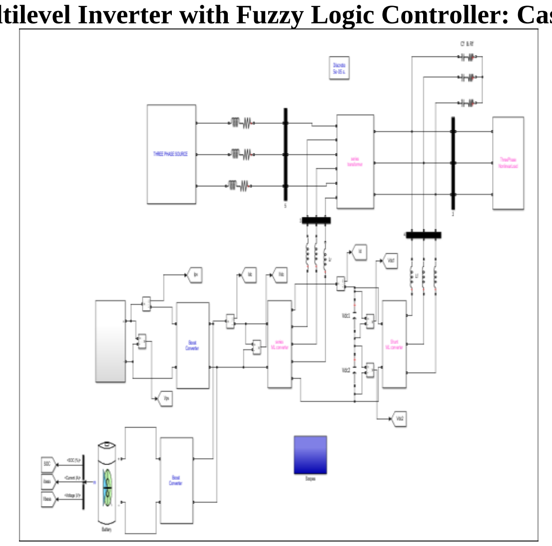


Fig .7. simulation model of case-1

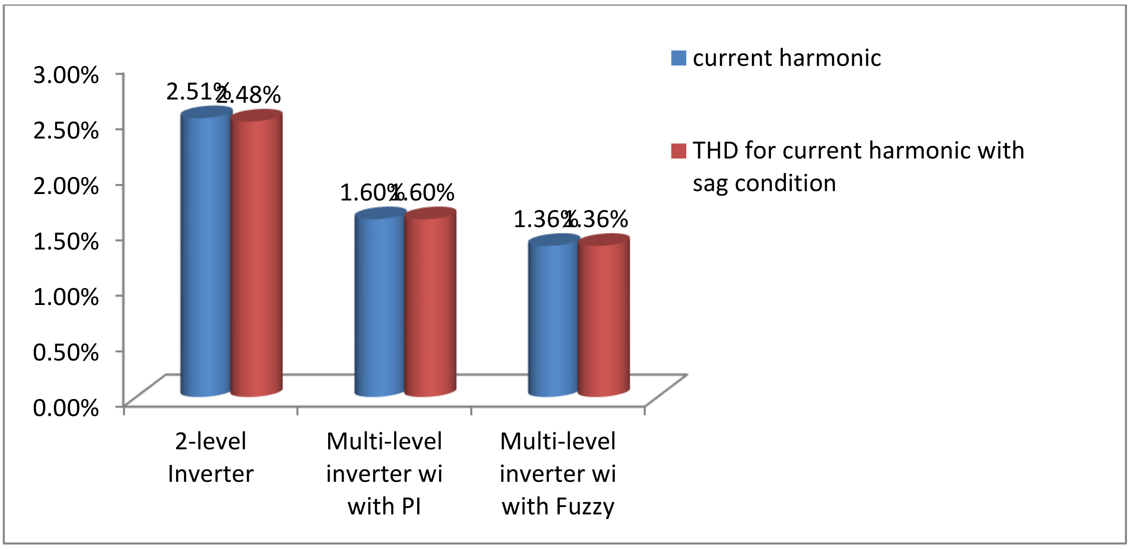
The above figure depicts the performance of UPQC which is constructed by using Multi-level inverter with fuzzy logic controller. From the above figure we can conclude that the simulation is done by considering the Time Vs voltages of Source and Load. We can also observe that how the waves are formulated when it is undergone into the operation.

Comparison Table of Total Harmonic Distortion for PI and Fuzzy Logic Controllers:

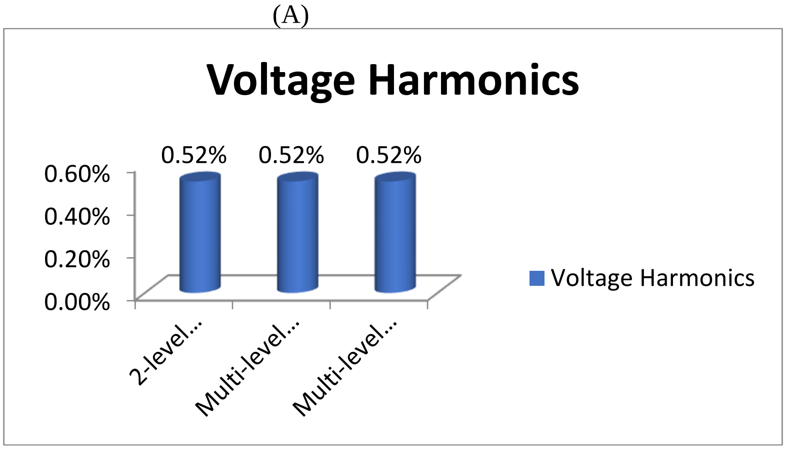
JOURNAL OF ALGEBRAIC STATISTICS
Volume 13, No. 2, 2022, p. 1562 - 1568
https://publishoa.com
ISSN: 1309-3452

Case study-1

Parameter	**2-level Inverter**	**Multi-level inverter with PI**	**Multi-level inverter with Fuzzy Logic**
current harmonic	2.51%	1.60%	1.36%
THD for current harmonic with sag condition	2.48%	1.60%	1.36%
Voltage Harmonics	0.52%	0.52%	0.52%



(A)



(B)

Fig 8.(A) current harmonic (B) Voltage harmonic

Using the current under voltage harmonic situation, the 2-level inverter has 2.51 percent THD, the multilayer inverter with PI controller has 1.60 percent THD, and the multilevel inverter with Fuzzy controller has 1.36 percent THD. 2.48 percent THD in 2-level inverter, 1.60 percent in multilevel with PI controller, whereas the multilevel with Fuzzy controller has 1.36 percent THD under voltage harmonic situation. All of the THD numbers in this study are the same, however, in terms of voltage: 0.52 percent.

CONCLUSION:

In grid settings, harmonics, voltage swells and sags, and voltage interruption necessitated research into the design of a three-phase UPQC. Both PI and Fuzzy controllers are used in the Series and Shunt Controllers in the proposed system to improve the system's performance. The simulation results, the Total Harmonic Distortion Values are compared. In this paper, simulations for multilevel inverters with PI controllers and multilevel inverters with fuzzy logic controllers are performed in order to recover the magnified power quality. The Fuzzy Logic Controller produces the better results in all aspects, and voltage distortions are reduced. The simulation results were verified using the MATLAB/SIMULINK software.

REFERENCES

[1] R. A. Modesto, S. A. O. Silva, and A. A. Oliveira Jr., “Power quality improvement using a dual unified power quality conditioner/ uninterruptible power supply in three-phase four-wire systems,” IET Power Electron., vol. 8, no. 9, pp. 1595-1605, Aug. 2015.
[2] R. A. Modesto, S. A. O. Silva, A. A. Oliveira Jr., and V. D. Bacon, “A versatile unified power quality conditioner applied to three-phase fourwire distribution systems using a dual control strategy,” IEEE Trans. Power Electron., vol. 31, no. 8, pp. 5503-5514, Aug. 2016.
[3] N. L. Díaz, J. C. Vasquez, and J. M. Guerrero, “A communication-less distributed control architecture for islanded microgrids with renewable generation and storage,” IEEE Trans. Power Electron., vol. 33, no. 3, pp. 1922-1939, Mar. 2018.
[4] D. Somayajula and M.L. Crow, "An Integrated Dynamic Voltage Restorer-Ultracapacitor Design for Improving Power Quality of the Distribution Grid," Sustainable Energy, IEEE Trans., vol. 6, April 2015, pp. 616-624.
[5] J.G. Nielsen and F. Blaabjerg, "A detailed comparison of system topologies for dynamic voltage restorers," Industry Applications, IEEE Trans., vol. 41, Sept. 2005, pp. 1272-1280.
[6] A.M. Rauf and V. Khadkikar, "An Enhanced Voltage Sag Compensation Scheme for Dynamic Voltage Restorer," Industrial Electronics, IEEE Trans., vol. 62, Oct. 2015, pp. 2683-2692.
[7] M. B. Latran, A. Teke, and Y. Yoldaş, "Mitigation of power quality problems using distribution static synchronous compensator: a comprehensive review," IET Power Electronics, vol. 8, pp. 1312-1328, 2015.
[8] A. Sannino, J. Svensson, and T. Larsson, "Power-electronic solutions to power quality problems," Electric Power Systems Research, vol. 66, pp. 71-82, 2003.
[9] M. Shafie, H. Singh, and M. A. Rahman, "Harmonic and neutral to ground voltage reduction using isolation transformer," in Power and Energy (PECon), 2010 IEEE International Conference on, 2010, pp. 561-566.
[10] K. Tada, A. Umemura, R. Takahashi, J. Tamura, Y. Matsumura, D. Yamaguchi, et al., "Frequency control of power system with solar and wind power stations installed by flow control of HVDC interconnection line," in Electrical Machines and Systems (ICEMS), 2017 20th International Conference on, 2017, pp. 1-5.
[11] S. Sasitharan and M. Mishra, “Design of passive filter components for switching band controlled DVR,” in TENCON 2008 - 2008 IEEE Region 10 Conference, Nov. 2008, pp. 1 –6.
[12] Y. Pal, A. Swarup, and B. Singh, “A comparative analysis of threephase four-wire UPQC topologies,” in Power Electronics, Drives and Energy Systems (PEDES) 2010 Power India, 2010 Joint International Conference on, Dec. 2010, pp. 1 –6.
[13] muhammad alif mansor , kamrul hasan , muhammad murtadha othman, (Member, IEEE), Construction and Performance Investigation of Three-Phase Solar PV and Battery Energy Storage System Integrated UPQC) at Sriharikota Range in the Nellore District of Andhra Pradesh (SHAR).