ISSN: (Online):2456-9895

INTEGRATION OF UNIFIED POWER QUALITY CONDITIONER (UPQC) WITH SMART GRID

Anjali Gupta*[1], Vivek Rai*[2]

*1,2 Department of Electrical Engineering

LAKSHMI NARAIN COLLEGE OF TECHNOLOGY, BHOPAL, (M.P.) INDIA

ABSTRACT

The trustworthy power quality has always been a confront to smart gird system operation. It has been established that in spite of many solutions recommended the integration of unified power quality conditioner (UPQC) with smart grid is better option. In this paper, the approaches of UPQC integration are discussed. A model is also suggested in this concern. The proposed model was simulated in MATLAB and the results obtained are also discussed.

- **Keywords:** Smart Grid, unified power quality conditioner (UPQC), Power Quality, Distributed generation, Microgrid

---

I. INTRODUCTION

The term Smart Grid was created in the year -2005, when it gives the impression in the IEEE P&E Magazine in an article "Towards A Smart Grid" written by Amin and Wollenberg.
Somehow there is a common belief that the smart grid will revolutionize the electricity business and change the business model that has been in place for the past 75 years and more It is an automated widely distributed energy delivery network, Both direction flow of power and information with Monitoring and reacting to variations in everything from power plants to distinct consumer appliances. While universally agreed definition of Smart Grid is not obtainable and under evolution. the most commonly agreeable is –

"A smart grid is an electricity network that can cost efficiently integrate the behaviour and actions of all users connected to it, generators, consumers and those that do both, in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety."

1.1 Communication Architecture

The role and impact of ICT in smart grids is a key element in the way a smart grid architecture will be defined. In particular, a variety of communication technologies may potentially shape a very different role for the communication networks. The functional architecture above considers communication through specific subsystems such as the communications infrastructure subsystem (encompassing public and private networks) or the internet. Conversely, there are numerous communication networks involved: Home Area Networks (HAN), Neighbourhood Area Networks (NAN), Enterprise LAN, Powerline career Communication Networks, Wireline Access Networks, Wireless Access Networks, Core Network. It also deploys Local Network (LN) and Neighbourhood Networks (NN). There are a variety of underlying communication technologies: powerline career, cellular wireless, mesh wireless, etc. There are many potential connectivity setups between functional subsystems, commonly including only a division of the communication networks. Various communication technologies can be used at the different layers of the communication stack. The choice will depend on the specific requirements and business models. A further specific Communication Architecture can help understanding the impact of the communication standards on the organization of the subsystems. The description of a generic model may help the coherent definition of specific sub-models.

1.2. Characteristics of Smart Grid

- Renewable energy friendly
- Distributed generation friendly
- Bidirectional energy flow and data flow
- Communicate consumer home appliances
- Reliable :Fault detection and self healing
- Peak curtailment of ToD Pricing : DSM
- Sustainability
- Market enabling
- Smart transportation
- Reduction to carbon emission

1.3. Key Drivers of Smart Grid

1. Enabling Improved balance of supply-and-demand in real time
2. Poor Power Quality
3. Blackouts and power cuts
4. Poor efficiency and losses
5. Manual error in system operation

1.4. Key Components for Smart Grid

- Smart Energy Meters
- Energy Storage devices
- Distributed generation
- Renewable energy
- Energy efficiency appliances
- Home area networks
- IT infrastructure (hardware)
- IT Security system
- Integrated communications systems
- Smart home appliances

1.5. Power Quality challenges in Smart Grid operation:

Quality of power supply has become an imperative issue with the growing demand on smart grid or microgrid. The necessity for monitoring of desired power quality in transmission levels as well as in low voltage distribution levels are growing due to better consumer service demand, judiciously priced meters, operation, regulatory obligations telecommunication development and network planning, [1], which are also very important for the execution of a smart grid distribution network. According to the IEC [International Electrotechnical Commission] -

"The Smart Grid is an integrating the electrical and information technologies in between any point of Generation and any point of Consumption. Smart Grid is the concept of modernizing the electric grid." [2].

The National Institute of Standards and Technology (NIST) has also created the Smart Grid Conceptual Model, as shown in Figure 1, which presents a high-level framework for the smart grid that characterised seven notable factors: Operations, Bulk power Generation, Transmission, Distribution, Consumers, Service Providers and Markets [3] where power quality has been thought as notable factor in the Smart Grid Network, as shown in Table 1.

Smart Grid Components

Bulk Generation	Transmission	Distribution	Consumer	Communication
• Smart Generation	• Sub-station Automation & Protection • Power Quality & Power monitoring System • Energy Management System • Decision Support Systems • Power Electronics	• Asset Management System and Condition Monitoring • Distribution Automation & Protection • Power Quality • Distrtibution Management System • Smart Meter	• Smart Consumption • Local Production • Power Quality • Smart House • Building Automation	• Communication • Security

Table 1 - Smart Grid Components

Operation of Power Electronics Devices (PED) like IGBT based UPQC in microgrid or DG systems to improve the power quality provides better results and its usefulness is increasing [4-8].

International Journal of LNCT
Volume-4 Issue-20 October -2020

ISSN: (Online):2456-9895

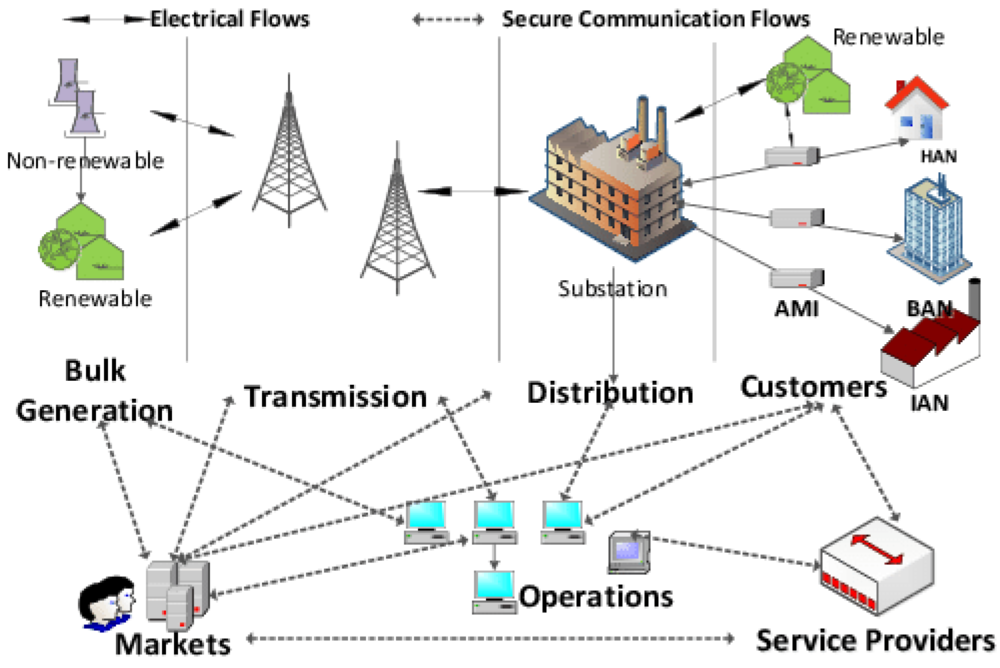
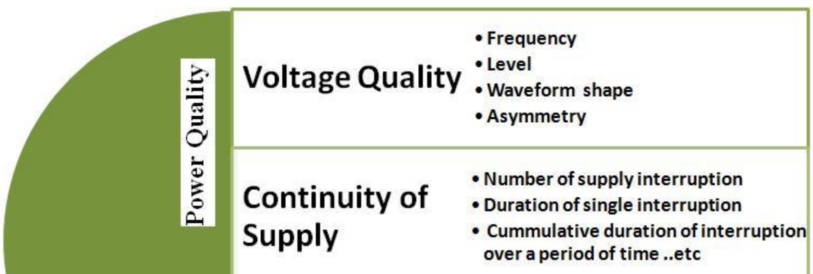


Figure 1 –NITS Smart Grid Conceptual model [3]

II. POWER QUALITY PROBLEMS IN SMART GRID - DG INTEGRATED

According to the Council of European Energy Regulators (CEER), the Electric power generation is the result of a production activity [9] as presented in Figure 2, the power quality of supply should encompass in three key fields, where the power quality leads to the voltage quality, commercial quality and continuity of supply. In addition to the Green House Gas (GHG) emission and the increasing Global Warming are the side outcomes of the traditional electric power production process. Therefore, developed countries are also trying to reduce their overall GHG emission by introducing and increasing the share of renewable energy into their electric grid system. Therefore, with the high implementation of DG systems, the quality of power supply has become most notable issue either linked to the micro-grid or smart grid. Considering wind, solar, micro-hydro are the most useful sources of DG systems therefore power quality problems related to these DG system along with diesel , which is one of the highest carbon dioxide gas emitter, have been pinpointed and displayed in Table 2.



International Journal of LNCT
Volume-4 Issue-20 October -2020

ISSN: (Online):2456-9895

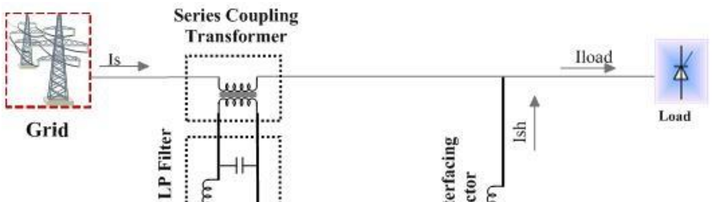
Figure 2 - Electric Power Supply Quality

Table 2 – Power quality problems related to DG systems

PQ Problems	Wind Energy	Solar Energy	Micro/ Small Hydro	Diesel
Voltage Sag/Swell	•		•	•
Over/Under Voltage	•			•
Voltage Unbalance		•		
Voltage Transient	•			
Voltage Harmonics	•	•	•	
Flicker	•	•		•
Current Harmonics	•	•	•	
Interruption	•	•		

III. OPERATING PRINCIPLE OF UPQC

The unified power quality conditioner connected back to back on the D.C. side, imparting a common D.C. shunt capacitor is the combination of series (APFse) and shunt (APFsh) active power filters [10] exhibits in Figure 3. For alleviating supply side disorders for example- voltage unbalance, voltage swells/sags, harmonics and flicker, the series component of the UPQC is accountable. It injects voltages in purpose of maintaining the load voltages of appropriate level with properly balanced and no distortion. The shunt part is accountable for alleviating the current quality problems produced by the consumer load, load harmonic currents, inferior power factor, high load unbalance etc. It injects currents in the A.C. system in manner the source currents develop balanced sinusoidal and remains in same phase with the source voltages. The complete purpose of UPQC primarily depends on the series and shunt APF controller. A basic functional block picture of a UPQC controller is shown in Figure 4. It is revealed that using hysteresis current controller, the shunt APF supress the harmonic and compensating reactive current and whereas the series APF employs PWM voltage controller in order to minimize the voltage disturbances.



ISSN: (Online):2456-9895

Figure 3 - UPQC – the Basic System Configuration

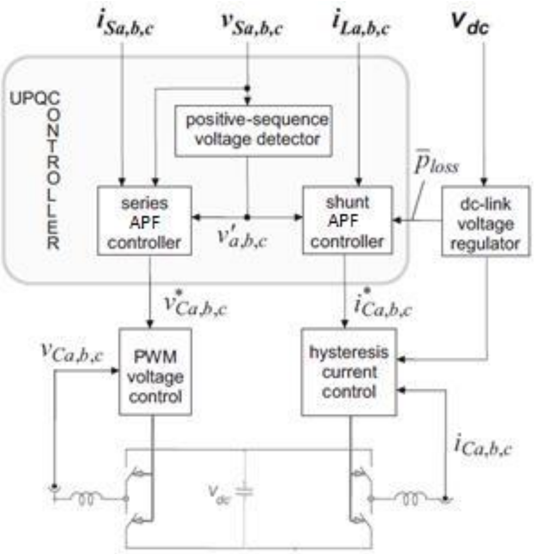


Figure 4 - UPQC controller - operational block diagram

IV. UPQC AND SMART GRID INTEGRATION

Latest research papers [4-8, 11, 12] implies that substantial research and development has been accomplish on the function of UPQC to DG integrated network. As the UPQC may compensate for mostly all prevailing power quality difficulties in the transmission and distribution powergrid. The installation of a UPQC in the distributed generation network may be versatile. Researches have been done on the subsequent two main practices- DC Linked and Separated DG UPQC systems in DG systems with installed UPQC.

A. DG – UPQC DC-linked

An arrangement has been projected in [4-7], as shown in Figure 5, where DG sources as an

ISSN: (Online):2456-9895

energy source are attached to a DC link in the UPQC. This formation operates both in islanded and interconnected mode (shown in Figure 6). In islanded mode, the DG (under power rating) provides power supply to the loads only, but in interconnected mode, DG provides power to the source and loads both. Moreover, UPQC employed with capability to inject power using DG to complex variable loads during interruption of main source voltage. Together with the other normal UPQC abilities, the benefit of this system is active power injection into the grid and to compensate voltage disruption. The grid operation may be effected during the voltage disruption situations, if the DG power ratings are not enough adequate. Economic operation of the system can also be achieved by proper monitoring and regulating of the active power transfer from the main supply and DG source and vice versa through a series APF [7]. It is found that if the UPQC and DG are worked individually the capital cost in the proposed system may also reduce by about one fifth only [8].

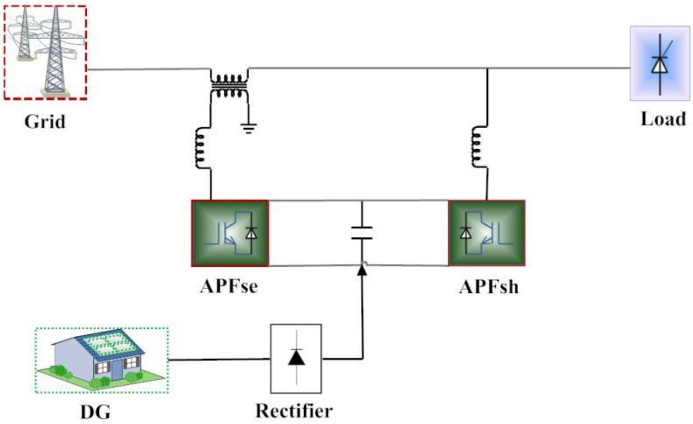


Figure 5 – UPQC with DG connected to the DC link

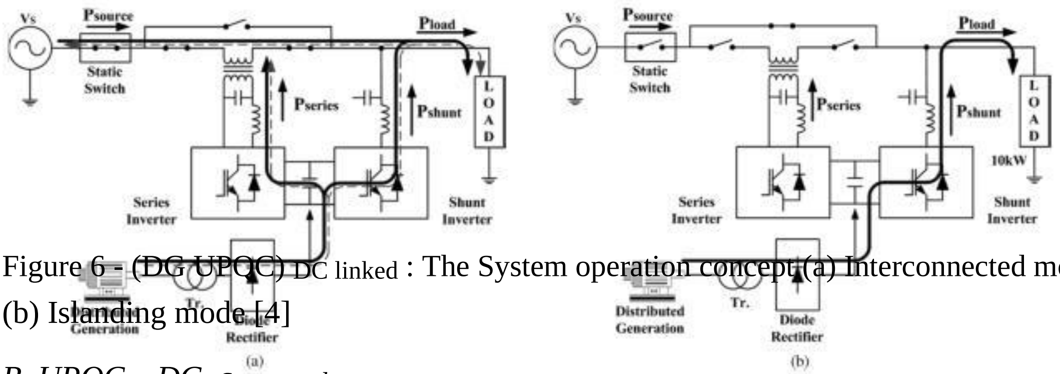


Figure 6 - (DG UPQC) DC linked : The System operation concept (a) Interconnected mode and (b) Islanding mode [4]

B. UPQC – DG Separated

Observations implies that normal application of a UPQC has the capacity to oppressed the grid integration challenges of the DG, such as the fixed speed induction generator (FSIG) as explained in [11] and presented in Figure 7. The outcomes show (Figure 8) that the UPQC is satisfactory devices for the integration of wind energy system to the grid. In the case of a wind farm connected to a weak grid, to mitigate voltage regulation problems UPQC can also

ISSN: (Online):2456-9895

be placed at the PCC [12]. The FSIG stops to stay connected to the grid if events of grid voltage sag or line fault due to excessive reactive power requirement occur. Over speeding of the turbine created by The fall in voltage, which results in under voltage protection relay trip. this fault-ride-through capability is achieved with the help of the UPQC, largely boosting the system stability. In these differently parted systems, the series APF of the UPQC is installed near the DG side by injecting the voltage in phase with PCC voltage, in order to overcome the voltage regulation. This type of UPQC is defined as left shunt UPQC [13]. Moreover with the normal functionality of UPQC, depending on the research study, some of the other advantages and disadvantages have been recognized for the methods which are shown in Table 3.

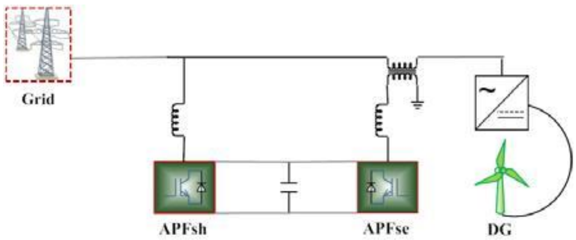


Figure 7 - Grid connected wind energy system with UPQC

V. PROPOSED MODEL

In the proposed model the UPQC is connected with smart grid as shown in figure 8 below

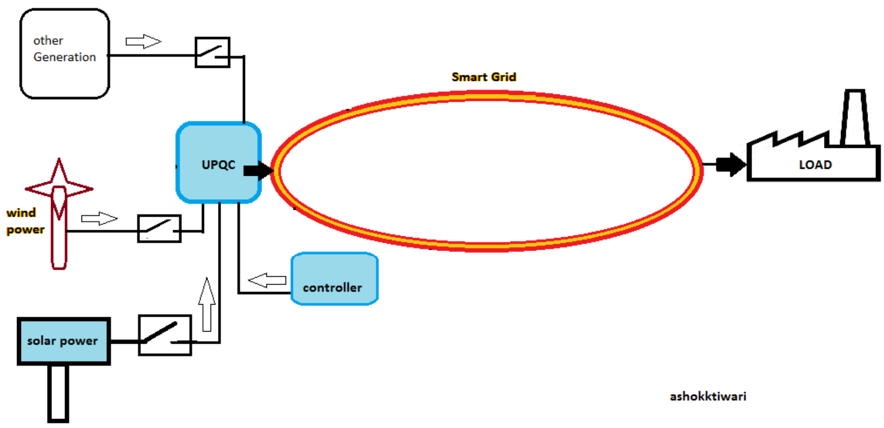


Figure 8 PROPOSED MODEL

Here input to UPQC are DG , solar power , wind power and other generating sources . The output is fed to other end of smart grid. The UPQC provides power to the load end of smart grid. The model is simulated in MATLAB and results were achieved in different fault conditions.

VI. SIMULATION RESULTS

	Without UPQC						WITH UPQC					
	Grid Voltage			Grid Current			Grid voltage			Grid current		
	R	Y	B	R	Y	B	R	Y	B	R	Y	B
NORMAL	11000	11000	11000	618	621	619	11000	11000	11000	450	450	450
R-G FAULT	0	11000	11000	6321	700	700	0	11000	11000	4088	551	549
R-Y FAULT	0	0	11000	5516	5534	700	0	0	11000	4114	4161	700
R-Y-G FAULT	0	0	11000	6105	6119	700	0	0	11000	4211	4189	700
R-Y-B FAULT	0	0	0	6022	6112	6210	0	0	0	4501	4488	4490
R-Y-B-G FAULT	0	0	0	6266	6401	6328	0	0	0	4717	4754	4737

VII. CONCLUSION

The simulation result shows that UPQC is able to improve the power quality of smart grid up to large extent. The harmonics are reduced up to 81%. The voltage sag and swell was also reduced up to 73%. It is also calculated that energy loss was reduced and saving in power cost was also obtained. This technique offers better results as compared to the conventional technique. The fall in %-THD was found to be more reasonable in this system using UPQC, which proves the usefulness of the proposed method. It was concluded that the compensation in the load current was also obtained up to 27% and fault current reduced up to 25%.

VIII. REFERENCES

[1] P Jarventausta, S Repo, A Rautianinen, J Partanen, "Smart grid power system control in distributed generation environment", Annual Reviews in Control 34, 2010, pp. 277 – 286
[2] IEC Smart Grid Standardization Roadmap, http://www.iec.ch/smartgrid/downloads/sg3_roadmap.pdf
[3] NIST Smart Grid Conceptual model framework, http://smartgrid.ieee.org/smart-grid-framework-diagram
[4] B Han, B Bae, H Kim, S Baek, "Combined Operation of Unified Power Quality Conditioner with Distributed Generation", IEEE Trans Power Delivery, vol. 21(1), 2006, pp. 330 – 338
[5] G S Reddy, "Feasibility analysis of DGSC-UPQC", Int Journal Research and Reviews in Applied Sciences, vol 4(1), 2010, pp. 32-47
[6] M Hosseinpour, Y M Rezapour, S Torabzade, "Combined operation of Unifier Power Quality Conditioner and Photovoltaic Array", Journal of Applied Sciences, vol 9(4), 2009, pp 680-688

[7] M A Emran, M Forghani, M Abedi, G B Gharehpetian, "Combined Operation of UPQC and Fuel Cell with Common DC Bus", Int Conf Renewable Energy and Power Quality, 2008

[8] M Hosseinpour, A Yazdian, M Hohamadian, J Kazempour, "Desing and Simulation of UPQC to Improve Power Quality and Transfer Wind Energy to Grid", Jour of Applied Sciences, 2008, vol. 8(21), pp. 3770 – 3782.

[9] Council of European Energy Regulators, Electricity Working Group Quality of Supply Task Force, Third Benchmarking Report on Quality of Electricity Supply, Final Version, 2005. Available: http://www.energy-regulators.eu.

[10] H Akagi and K Nabae, Control strategy of active power filters using multiple voltage source PWM converters, IEEE Trans. Ind. Appl. vol. l (3), 1985, pp. 460–466

[11] N G Jayanti, M Basu, M. F. Conlon and K. Gaughan "Rating requirements of the unified power quality conditioner to integrate the fixed speed induction generator-type wind generation to the grid", IET Renewable Power Generation, vol. 3(2), 2009, pp. 133-143

[12] M F Farias, P E Battaiotto, M G Cendoya, "Wind Farm to Weak-Grid connection using UPQC Custom Power Device", Int Conf on Industrial Technology, 2010, pp. 1745 – 1750

[13] A Ghosh and G Ledwich, "Power quality enhancement using custom power devices", Kluwer Academic, 2002.

[14] A Kumar, "A Ghosh, Interline Unified Power Quality Conditioner", IEEE Trans Power Delivery, Vol. 22(1), 2007, pp. 364-372.

[15] H R Mohammadi, A Y Varjani, "Multiconverter Unified Power-Quality Conditioning System: MC-UPQC", IEEE Trans Power Delivery, Vol. 24(3), 2009, pp. 1679-1686.

[16] J. Muñoz, J. Reyes, J. Espinoza, I. Rubilar, and L. Morán, "A novel multi-level three-phase UPQC topology based on full-bridge single-phase cells," in Proc. Conf. Rec. IEEE IECON, Nov. 2007, pp. 1787–1792.

[17] J A Munoz, J R Espinoza, "Design of a Modular UPQC Configuration Integrating a Components Economical Analysis", IEEE Trans Power Delivery, Vol. 24(4), 2009, pp. 1763-1772.

[18] J A Muñoz, J R Espinoza, C R A Morán, E Espinosa, P E Melín, D G Sbárbaro, "Design of a Discrete-Time Linear Control Strategy for a Multi-Cell UPQC", accepted for publication in IEEE Trans Ind Electr, 2011