Power Quality Enhancement in Wind Integrated Three Phase System using Fuzzy- UPQC Controller

Y. Ragava Rao[1] P.Yedukondaku[2] V. Hari Babu[3]
[1]PG Scholar [2]Associate Professor [3]Associate Professor& Head of Department
[1,2,3]Department of Electronics & Electrical Engineering
[1,2,3]Prakasam Engineering College, Kandukur, AP, India

Abstract—In this paper a fuzzy based unified power quality controller (UPQC) is proposed to eliminate power quality issues in wind integrated three phase grid system. Increasing population and global warming concerns leads to renewable source integration to the grid. Here a wind system is integrated to deliver the demanded power. Integrated wind system and nonlinear loads causes harmonics, voltage disturbance and reactive power demand on line. For suppressing harmonics in source current, reactive power compensation and voltage disturbances like sag/ swell UPQC is proposed. Performance of proposed UPQC is studied in MATLAB/SIMULINK environment.
Keywords—Wind Energy System, Power Quality, FACTS, PI Controller, Fuzzy Controller

I. Introduction

One of the most important problems facing by the growing world is providing the power demanded. Increasing living standards of people and growing industrialization leads to increase in power demand. Providing the demanded power has to consider environmental challenges like global warming and pollution. The existing nonrrenewable sources doesn't meet the present requirement. This leads to drastic development in Renewable energy based power Generating Systems, which are clean and abundant availability of Renewable Sources like Wind, Solar Energy etc.

In this paper, a renewable energy unit (Wind Energy Unit) is integrated to Grid at distribution side for providing the power demanded by the load. Due to integration of WEU at distribution side, it affects the system power quality in wide aspects. WEU's suffers with unavailability of constant input. The connected nonlinear loads also impose many effects on the overall system power quality [1]. This deterioration of system power quality can be improved by using effective power switching devices and efficient control technique .This paper presents a novel technique based on Neural Network control Scheme for Synchronous Reference Frame(SRF) to compensate the harmonics and reactive power requirement. The Non Linear Loads and wind energy unit (WEU) places requirement of reactive power and injects harmonics into the Grid connected system lines [2]. This diminishes power factor, and causes, current and voltage variations .The proposed shunt connected SRF injects the required Reactive power and absorbs the excess reactive power at the CCL and injects the currents to cancel out the harmonic currents in the line (CCL) [3]. The proposed SRF uses Energy Storage unit (ESU) which is as shown in Fig.1 for real and reactive power support.

For the alleviation of both voltage sag and current harmonics, custom power technology comes into picture. The widely exercised custom power device by plentiful researchers for relieving voltage related problems is Dynamic Voltage Restorer (DVR). Due to its excellent dynamic capabilities, DVR is well suited to protect sensitive loads from short duration voltage dips or swells [4,5]. But DVR doesn't take care of load current harmonics, which when untreated, results in low power factor, leads to voltage notch and reduced consumption of the distribution system. The device STATCOM is widely used for the eradication of load current harmonics in addition to the contribution of reactive power control [6], but it doesn't take care of voltage related problems. UPQC is the only device widely used for the mitigation of both voltage sag and load current harmonics, thus replacing the functions of two devices DVR and STATCOM [7-10].

The choice of suitable controller plays a vital role to improve the performance of UPQC. In conventional PI controller, proportional and integral gains are chosen heuristically and also requires precise linear mathematical model of the system, which is difficult to obtain under parameter variations and non-linear load disturbances. To overcome this problem the fuzzy logic controller is proposed which is best suited for nonlinear loads, as it works with linguistic variables and it doesn't need any mathematical modeling [11-15]. In the proposed work, the PQ problems voltage sag and current harmonics are simulated and analyzed in the grid connected wind power system. To enhance PQ, the proposed FLC based UPQC is implemented for effective and efficient mitigation of both voltage sag and current harmonics. The performance of the proposed system is validated by comparing the simulation results with conventional PI controlled UPQC.

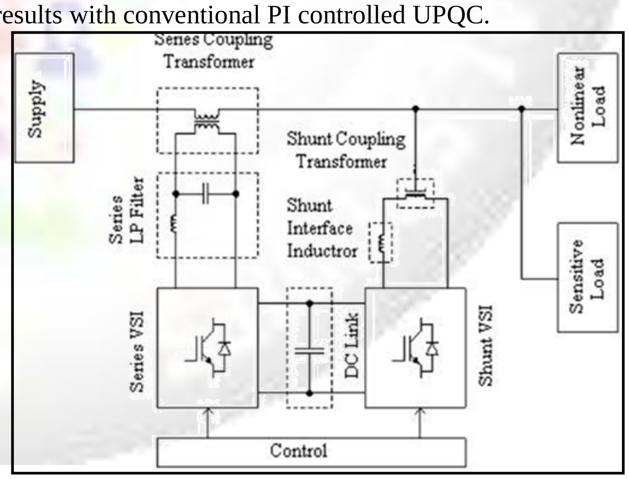

Fig.1: Proposed UPQC System

II. Proposed system description

The schematic diagram of interconnection of Grid with SFIG based wind power system is shown in Fig.1. The stator of SFIG is used to supply power directly to the grid, while the rotor supplies power to the grid via power electronic converter. As the back to back converter is connected only to the rotor, the converter costs only 25% of the total system power which improves entire system efficiency to a greater extent.

While integrating electric grid with wind power system, owing to the stochastic nature of the wind, the quality of power from the generator output gets affected. If a huge proportion of the grid load is supplied by wind turbines, the output deviations owing to wind speed alternations incorporate voltage variations, harmonics and flicker.

The origin of voltage variations such as voltage sag and swell is due to wind velocity, generator torque and switching of wind turbine generator. Harmonics is one of the severe problems in grid connected wind power system. As the consequences faced by voltage sag and harmonics are dominant and leads to degradation of PQ at the consumer's terminal, this paper concentrates on alleviating these two PQ problems.

The foremost impacts of the PQ problems are

1) Malfunction of equipments such as adjustable speed drives, microprocessor based control system and Programmable Logic Controller.
2) Tripping of protection devices.
3) Stoppage and damage of sensitive equipments like personal computers, industrial drives etc.

The Standards provided by IEEE for individual customers and utilities for improving PQ is shown below:

1) IEEE Standard 519 issued in 1981, suggests voltage distortion < 5% on power lines below 69 kV.
2) ANSI/IEEE Standard C57.12.00 and C57.12.01 confines the current distortion to 5% at full load in supply transformer.

In order to keep PQ within bounds, there is a need PQ Enhancement. For this custom power devices plays a vital role for the purpose of supplying required level of PQ thus make the grid connected wind power system free from PQ problems.

UPQC is responsible for mitigating both current and voltage related issues and also has the subsequent facilities:

- It eradicates the harmonics in the supply current, thus enlarging utility current quality for nonlinear loads.
- UPQC also supports VAR requirement of the load, so that the supply voltage and current are forever in phase. As a consequence no additional power factor correction equipment is essential.
- UPQC maintains load end voltage at the rated value even in the existence of supply side disturbances.
- The voltage injected by UPQC to keep the load voltage at the desired value is taken from the same dc link, thus no extra dc link voltage support is involved for the series compensator.

A. Wind Energy Unit

The wind energy unit consists of wind turbine and generator. Here induction generator is used due to its effective operation, which does not require separate field circuit and has natural short circuit protection. The power available at WEU is given by eqn. (1).

$$P_{wind}=\frac{1}{2}\rho\pi R^2 V^3_{wind} \qquad (1)$$

Here ρ - Air Density, R - radius of rotor, V_{wind} - speed of the wind.

The relation between wind and mechanical power is given by eqn. (2).

$$P_{mech} = C_P P_{wind} \qquad (2)$$

Here P_{mech} is the mechanical power produced by wind turbine given by eqn.(3)

$$P_{mech}=\frac{1}{2}\rho\pi R^2 V^3_{win} C_P \qquad (3)$$

The mechanical-torque is given by in (4)

$$T_{mech} = P_{mech}/\omega_{mech} \qquad (4)$$

B. Shunt Control Scheme

The reactive power requirement and harmonics developed by the nonlinear loads and wind systems will be cancelled out using SRF controlled byFuzzy controller .The utilized control scheme is clearly described by the fig. 2 .Inthe control scheme , the difference b/w dc line voltage andreferencecapacitor voltage is applied to Fuzzy.The effective Fuzzy reshapes the difference signal and applied to Neural Network Controller .This improved control voltage signal from Fuzzy is further tuned by Neural Network Controller .The combined Neural Network outcome andsource voltage unit vectors generates the reference current.

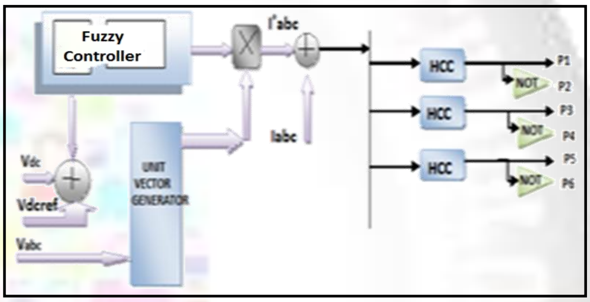

Fig.2: Shunt APF Control Scheme

Now the difference of the source current taken at common connecting line and reference current signal is applied to hysteresis current controller which limits the current within the hysteresis band (HB = 0.08).Finally the required firing angles are developed and applied to SRF, which consists a 3 leg inverter. The controlling signals for IGBT of inverter are derived from hysteresis controller [16].The phase–a switching function S_A of phase 'a' is given by eqn. (5)

$$HB < (I_a^* - I_a) \rightarrow S_A=0 \text{ and}$$
$$HB > (I_a^* - I_a) \rightarrow S_A=1 \qquad (5)$$

The SRF injects the currents to cancel out the harmonics in the Source currents at PCC. It also provides the required reactive power to the line and makes the common connecting line power factor as unity. The inductors are used to limits the harmonics developed from the inverter of SRF .The energy storage unit maintains the dc link voltage at constant level.

C. Series Controller

In series APF, the faulted sag voltage is compared with the reference voltage. The error voltage is processed through PI controller and its output is converted to three phase through unit vector generation, then it is fed into Pulse Width Modulation (PWM) generator to provide gate pulses to Series APF such that this can be able to inject the required voltage for the mitigation of voltage sag. Fig. 3 shows Series APF controller.

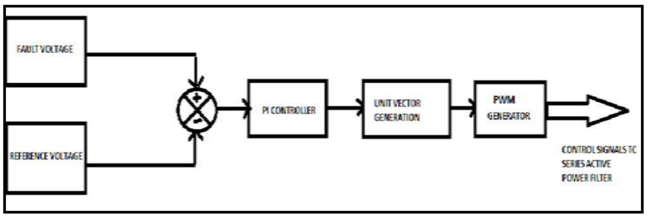

Fig.3: Series APF Control Scheme

D. *Fuzzy Logic Controller*

FLC[17] is one of the most successful operations of fuzzy set theory. Its chief aspects are the exploitation of linguistic variables rather than numerical variables. FL control technique relies on human potential to figure out the systems behavior and is constructed on quality control rules. FL affords a simple way to arrive at a definite conclusion based upon blurred, ambiguous, imprecise, noisy, or missing input data. The basic rules of an FLC is represented in Table I.

- A Fuzzification interface alters input data into suitable linguistic values.
- A Knowledge Base which comprises of a data base along with the essential linguistic definitions and control rule set.
- A Decision Making Logic which collects the fuzzy control action from the information of the control rules and the linguistic variable descriptions.
- A Defuzzification interface which surrenders a non-fuzzy control action from an inferred fuzzy control action.

dee	HN	MN	SN	ZE	SP	MP	HP
HN	HN	HN	HN	HN	MN	SN	ZE
MN	HN	HN	MN	MN	SN	ZE	SP
SN	HN	MN	SN	SN	ZE	SP	MP
ZE	MN	MN	SN	ZE	SP	MP	HP
SP	MN	SN	ZE	SP	SP	MP	HP
MP	SN	ZE	SP	MP	MP	HP	HP
HP	ZE	SP	MP	HP	HP	HP	HP

Table 1: Fuzzy Rules

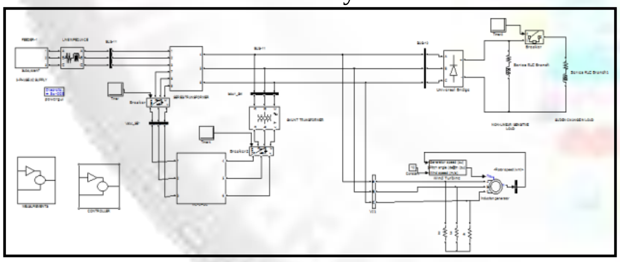

Fig.4: Simulink Diagram of Proposed Wind Integrated Threee Phase System with UPQC

III. Simulation Results

The proposed model is simulated in MATLAB/SIMUNLINK environment. The proposed Fuzzy- UPQC system are modeled in SIMULINK shown in Fig. 4. The parameters for proposed system are given in Table II.

S.No	Parameters	Ratings
1	Source voltage	3-phase415v,50HZ
2	Wind generator	150kw,12m/s
3	DC link voltage	Vc = 800V C = 100µF
4	Solar energy unit	800V
5	Load	8ohms,12mH
6	Source inductance	0.05mH

Table 2: Parameters of the System

The Fig. 4 clearly shows the pulse generating from the proposed control scheme to maintain the power quality at the CCL. It also shows the WEU connected at common coupling line (CCL).

A. *Steady State Analysis of the System*

The harmonics in the grid current are injected by the nonlinear loads. To suppress these harmonic components in the current equivalent opposite current has to be injected such that the current is free from harmonics. Fig.5 shows the various currents developed at CCL.

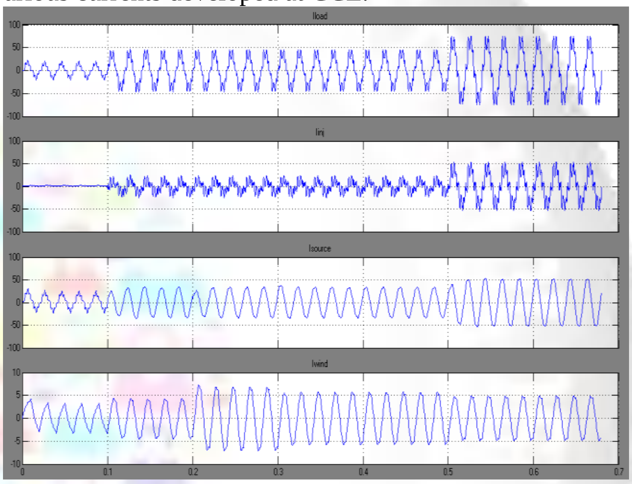

Fig.5: System Currents withFuzzy UPQC a) Load Current b) Injected Current c) Grid Inverter Current d) Wind Current

Similarly sag is created between 0.1sec to 0.2 sec. Swell is created between 0.2sec to 0.3 sec. Series APF compensates the sag and swell in load voltage, which is shown in Fig. 6. DC link voltage is also presented in Fig 6.

B. *Power Quality at CCL*

The power quality is analyzed in three different cases without UPQC, with PI - UPQC and withFuzzy- UPQC.

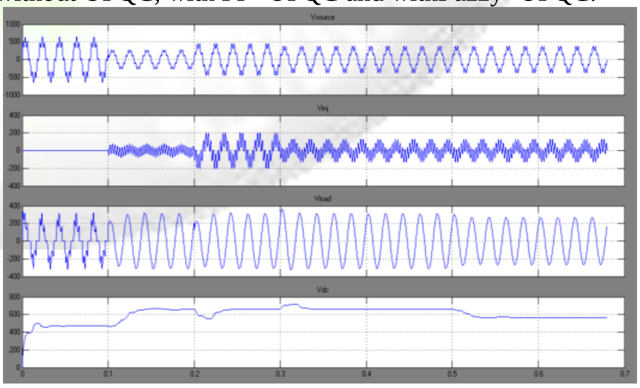

Fig. 6: System Voltages withFuzzy- UPQC a) grid Voltage b) Injected Voltage c) Load Voltage d) DC Link Voltage

1) Case1: The % THD of the currents without SRF are as shown in Fig. 7

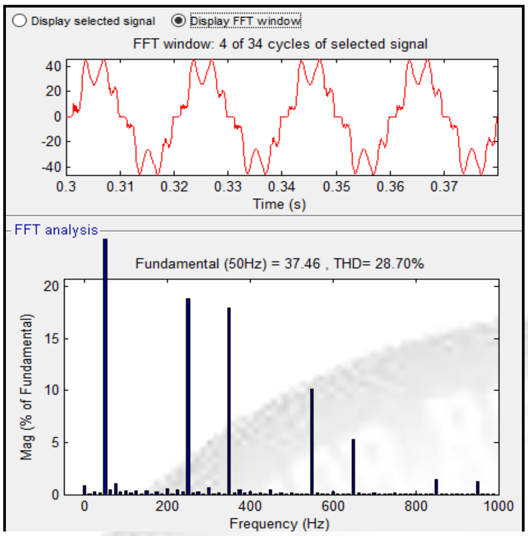

Fig. 7: %THD of Grid Current without UPQC

2) Case2: UPQC is connected to the line at T=0.1. After T=0.1 the % THD of the currents with PI controlled UPQC is as shown in Fig.8
3) Case3: The % THD of the currents with Fuzzy UPQC is as shown in Fig.9.

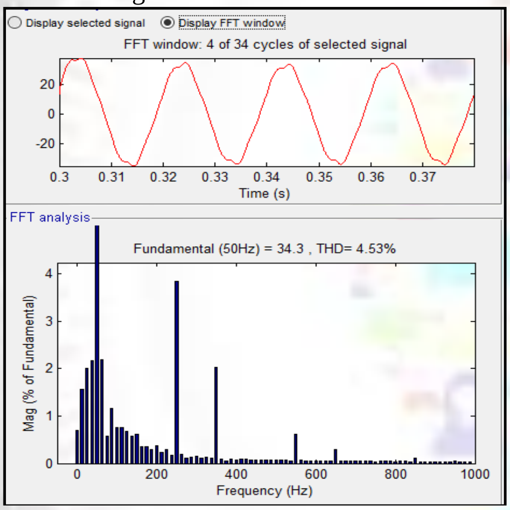

Fig. 8: %THD of Grid Current with PI- UPQC

From the Table –III it is clear that the Fuzzy Neural Network controlled SRF effectively reduces the Harmonics at Grid common connecting line from 4.06% to 0.38% THD

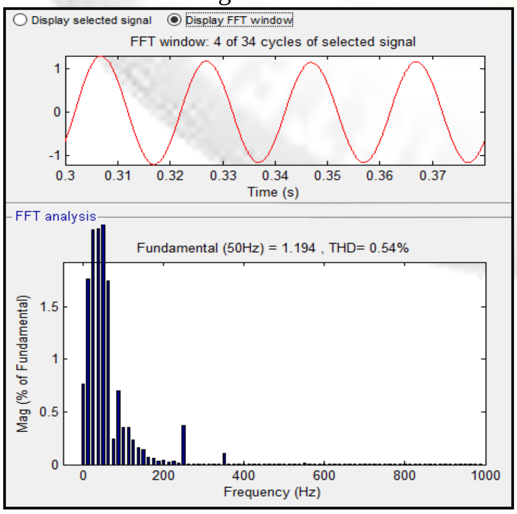

Fig. 7: %THD of Grid Current with Fuzzy-UPQC

Parameters	Without UPQC	With PI based UPQC	With Fuzzy- UPQC
	%THD		
Source current	28.07	4.53	0.54

Table 3: Comparison of % THD for Various Currents and Power Factor for the Three Cases

IV. Conclusion

Here, the Paper presents Fuzzy-SRF based control strategy for UPQC which improves the power quality of the WIND integrated tree phase System. The control Strategy keeps the source current in phase with the Source voltage. It also compensates the Load current harmonics and reactive power at PCC. It also provides the reactive power required by the Wind unit. Here, the control strategy improves the %THD of Currents by injecting the currents to cancel out the harmonic current.Series APf compensates the voltage sag and swell in load voltage by injecting compensating voltage. The simulated result compares the various currents %THD without UPQC, with PI-UPQC and with FUZZY- UPQC control techniques.

References

[1] DusanGraovac,VladimirA.Katic,AlfredRufer , “Power quality problems compensation with universal power quality conditioning system,” IEEE Trans. on Power Delivery, vol. 22, no. 2, pp. 968-97, April 2007
[2] J. H. R. Enslin and P. J. M. Heskes, “Harmonic interaction between a large number of distributed power inverters and the distribution network,”IEEE Trans. Power Electron., vol. 19, no. 6, pp. 1586–1593, Nov. 2004.
[3] P. Jintakosonwit, H. Fujita, H. Akagi, and S. Ogasawara, “Implementation and performance of cooperative control of shunt active filters for harmonic damping throughout a power distribution system,” IEEE Trans. Ind. Appl., vol. 39, no. 2, pp. 556–564, Mar./Apr. 2003
[4] S Kasa, SudhaRamasamy “Photovoltaic Fed Dynamic Voltage Restorer with Voltage Disturbance Mitigation Capability Using ANFIS Controller” International Journal of Renewable Energy Research, vol.6, No.3, pp-825-832, 2016.
[5] S Kasa, SudhaRamasamy “Mitigating Voltage Imperfections with Photovoltaic fed ANFIS based ZSI-DVR in Three Phase System” International Journal of Renewable Energy Research, Vol.7, No.4, pp-2103-2110, 2017.
[6] S. Heier, Grid Integration of Wind Energy Conversions. Hoboken, NJ: Wiley, 2007, pp. 256–259.
[7] S kasa, SudhaRamasamy, PrabhuRamanathan, “Hybrid Fuzzy-ZN PID control based Grid Interfaced distribution level Renewable Energy Source with Power Quality" ICCPCT,IEEE, pp.1-7, Mar 2015.
[8] Kasa S, SudhaRamasamy, PrabhuRamanathan ,DP Kothari "Effective Grid Interfaced Renewable Sources with Power Quality Improvement using Dynamic Active Power Filter", Journal of Electrical Power & Energy Systems, Elsevier, Vol. 82, pp. 150-160, 2016
[9] S Kasa, SudhaRamasamy “Mitigation of Current Harmonics in Renewable Source Integrated Grid

Topology with Fuzzy based Dynamic Shunt Active Filter" IPACT, IEEE Conference, pp.1-6,Mar 2017,

[10] S Kasa, SudhaRamasamy "Enhancement of Power Quality in Multi Feeder Three Phase System with Photovoltaic fed ANFIS-Unified Multi Converter Controller"International Journal of Green Engineering , Vol.8 Issue.1, Pages:71-88, 2018.

[11] D. L. Yao, S. S. Choi, K. J. Tseng, and T. T. Lie, "A statistical approach to the design of a dispatchable wind power—Battery energy storage system," IEEE Trans. Energy Conv., vol. 24, no. 4, Dec. 2009.

[12] M. I. Milands, E. R. Cadavai, and F. B. Gonzalez, "Comparison of control strategies for shunt active power filters in three phase four wire system," IEEE Trans. Power Electron., vol. 22, no. 1, pp. 229–236, Jan.2007.

[13] S. W. Mohod and M. V. Aware, "Power quality issues & it's mitigation technique in wind energy conversion," in Proc. of IEEE Int. Conf. Quality Power & Harmonic, Wollongong, Australia, 2008

[14] Sharad W. Mohod,, and Mohan V. Aware" A STATCOM - Control Scheme for Grid ConnectedWind Energy System for Power Quality Improvement" IEEE systems journal, vol. 4, no. 3, Sep. 2010.

[15] Shiny K. George, and Fossy Marry Checko "Comparison of Different Control Strategies of STATCOM for Power Quality Improvement of Grid Connected Wind Energy System" IEEE Conference, ISBN: 978-1-4673-5089-1, pp.650-655, March 2013.

[16] S Kasa, "Pi Based Power Quality Enhancement Of Grid Connected Wind Energy System For Dc – Link Energy Storage System" International Journal of Science Engineering and Advance Technology (IJSEAT), Vol. 2, Issue 10, October – 2014 (ISSN: 2321-6905).

[17] S Kasa, "Neuro Fuzzy Control Single Stage Single Phase AC-DC Converter for High Power factor" International Journal of Engineering Research & Technology (IJERT) 2013 (ISSN: 2278-0181).