



Article Title: Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

Ashi Vimal J¹, Christal Saji K², Cinu S. Robin³

¹ PG Student, ashivimal97@gmail.com

² Professor, sajidennis@gmail.com

³ Assistant Professor, Department of Electrical and Electronics Engineering, Bethlahem Institute of Engineering, Karungal, India

ABSTRACT

Distributed Energy Generation is one of the solution to meet the growing energy demand. Distributed energy generation mostly involve renewable energy sources such as solar and wind. These renewable energy resources uses technologies that are clean and green and also reduce the use of fossil fuels that are depleting at a faster rate. The Renewable Energy Sources (RES) are connected to the grid using grid interfacing inverters. The use of power electronic devices and also nonlinear loads has lead to power quality issues. In this paper the control for grid interfacing inverter is done using PI and Fuzzy logic controller. The inverter acts as multifunction device by transferring the power generated from Renewable energy Sources to the grid also as a shunt active power filter to mitigate Harmonics. Simulations are done using MATLAB/ SIMULINK Software.

Keywords: Distributed Generation, Fuzzy Logic Controller, Power Quality, Renewable Energy Sources, Shunt Active Power Filter

1 Introduction

Distributed Generation based on renewable energy sources has an important role to meet today's rising energy demand. In Centralized power generation systems burning of fuel had lead to CO₂ emissions. Therefore, in order to meet the growing energy demand Distributed Generation is given much importance. Distributed energy generation mostly involve renewable energy sources such as solar and wind. With the integration of renewable energy sources to the grid, reliability in electric energy transmission is improved and CO₂ emissions has been reduced. Most of the Renewable energy sources are interfaced to the grid using power electronic converters [1]. However, because of the high frequency switching of inverters it injects further harmonics to the system creating power quality issues. There are different types of filters such as series Active Filters, Shunt active filters and Hybrid filters to compensate the power quality problems [2]. The power quality issues such as Voltage sag and swell can be compensated by Dynamic Voltage Restorer [3, 4]. Non-linear loads like rectifiers, cycloconverters, variable speed drives and arc furnaces, etc. will cause high disturbances in the



Article Title: Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

power system. Harmonics not only increases the losses but also causes disturbances in the power system. So in order to mitigate the harmonics generated, Shunt active power filters are used as a compensating devices [5-7]. In this paper a four leg Voltage source inverter is used as an interfacing device. The fourth leg is to compensate the neutral current [8]. The inverter acts a multifunction device by mitigating current harmonics, transfer of active power and reactive power compensation [9,10]. The paper is arranged as follows: Section II describes the System description and the controller for DC link voltage. A simulation study is presented in Section III. Results are discussed in Section IV and Section V concludes the paper.

2 System Description

The proposed system consists of a four leg voltage source inverter which functions as a Shunt Active Power Filter (SAPF) capable of simultaneously compensating for problems such as current imbalance, the current harmonics and also injecting the energy generated by RES [11]. The shunt active filter is a voltage source inverter (VSI) connected in parallel with the load. Shunt active power filter compensate current harmonics generated by nonlinear loads by injecting equal-but-opposite harmonic compensating current. In this case the shunt active power filter injects the harmonic components generated by the load but phase shifted by 180 degree.

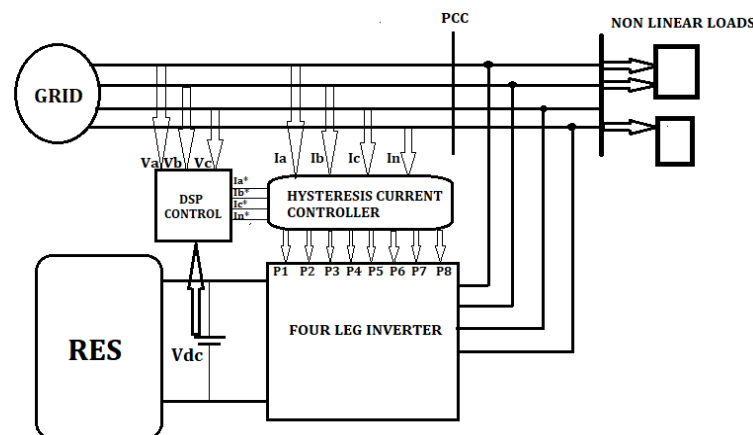


Figure 1: Schematic for the proposed system

Here the Shunt active power filter consists of a four leg inverter. The shunt active power filter is connected at the PCC through the interface inductor.

2.1 Control of Grid interfacing inverter Using Hysteresis current controller

There are different control strategies to control the Grid interfacing inverter. Hysteresis current control (HCC) is the simplest control method to control the voltage source inverter for



Article Title: Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

compensating the current harmonics. The control signals for the voltage source inverter are generated from the hysteresis current controller. The current controller is implemented with closed loop control system where an error signal is used to control the switching in a voltage source inverter. The error signal is the difference between the desired current and the current being injected by the inverter. The upper switch of the inverter arm is turned OFF when the error exceeds the upper limit of the hysteresis band. At this instant, the lower switch is turned ON. The lower switch of the inverter arm is turned OFF when the error exceeds the defined lower limit. At the same time the upper switch is turned ON. The minimum and maximum values of the error signal are e_{min} and e_{max} respectively and the range of the error signal $e_{max} - e_{min}$ directly controls the amount of ripple in the output current from the VSI.

Dc-link voltage regulation carries data about active power exchange between renewable source and grid. Thus the output of dc link voltage regulator is active current (I_m). Reference grid currents (I_a^* , I_b^* and I_c^*) are generated by multiplying active current component with unity grid voltage vector templates (U_a , U_b and U_c). The reference grid neutral current (I_n^*) is set as zero.

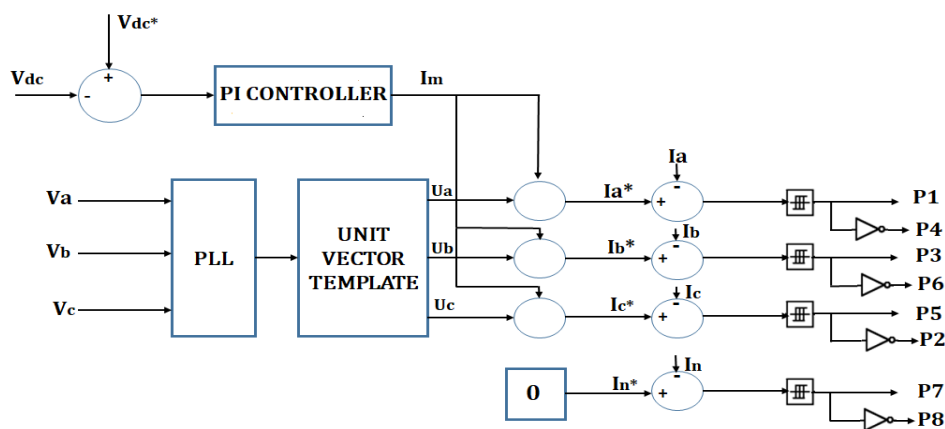


Figure 2: Control for grid interfacing inverter using PI Controller

2.2 Control of DC link voltage using Fuzzy Logic Controller

The DC link voltage can be controlled effectively by the use of fuzzy logic controller. In order to implement the fuzzy logic control algorithm of an active power filter in a closed loop, the dc-bus capacitor voltage is sensed and then compared with the desired reference value. The error signal $e(n)$ and change of error signal $ce(n)$ are used as inputs for fuzzy processing. These controllers are becoming popular because it is cheaper, Robust, Efficient and Reliable. The major components of FLC are Fuzzifier, Fuzzy Knowledge Base, Fuzzy rule base, Inference Engine and Defuzzifier. IF-THEN rules are used in designing the controller.



Article Title: **Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems**

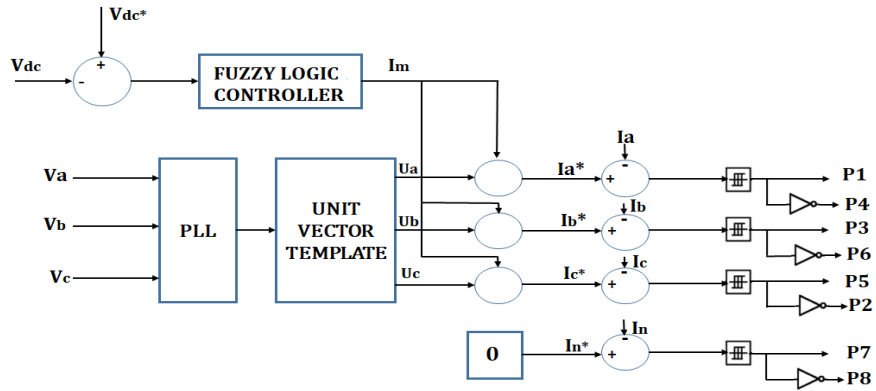


Figure 3: Control for grid interfacing inverter using Fuzzy Logic Controller

The 49-rules used in this proposed controller are shown in table 1.

Table 1: Fuzzy Logic Controller Rules

$\begin{matrix} e \\ \backslash \\ de \end{matrix}$	NL	NM	NS	ZE	PS	PM	PL
NL	NL	NL	NL	NL	NM	NS	ZE
NM	NL	NL	NL	NM	NS	ZE	PS
NS	NL	NL	NM	NS	ZE	PS	PM
ZE	NL	NM	NS	ZE	PS	PM	PL
PS	NM	NS	ZE	PS	PM	PL	PL
PM	NS	ZE	PS	PM	PL	PL	PL
PL	NL	NM	NS	ZE	PS	PM	PL

3 Simulation Results and Analysis

This section presents the details of the simulation results carried out to demonstrate the effectiveness of the proposed control strategy for the active filter to reduce the harmonics.

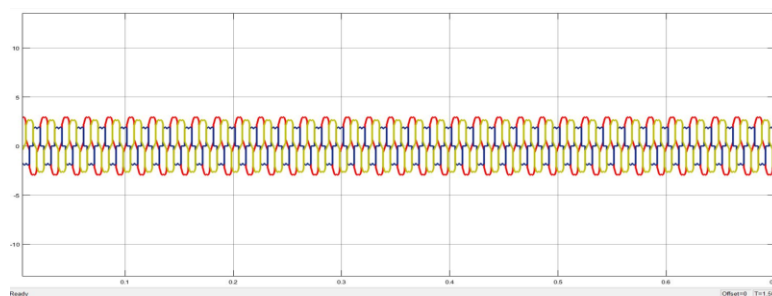


Figure 4: Grid current before connecting the SAPF



Article Title: Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

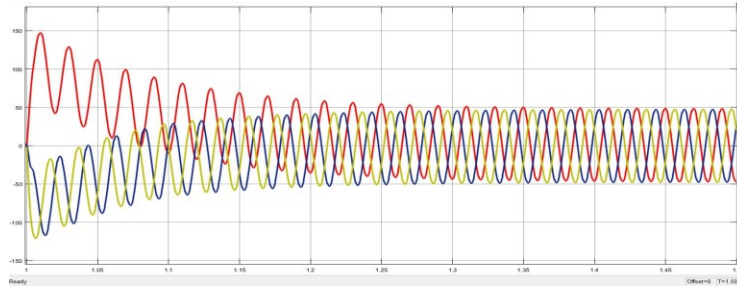


Figure 5: Grid current after connecting the SAPF

3.1 FFT Analysis

The THD for different cases are shown in figures 8- 10.

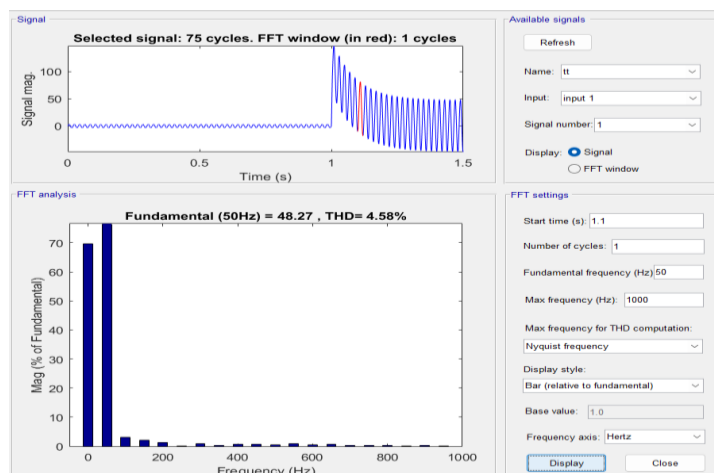


Figure 6: FFT Analysis (control of DC link Voltage using PI Controller)

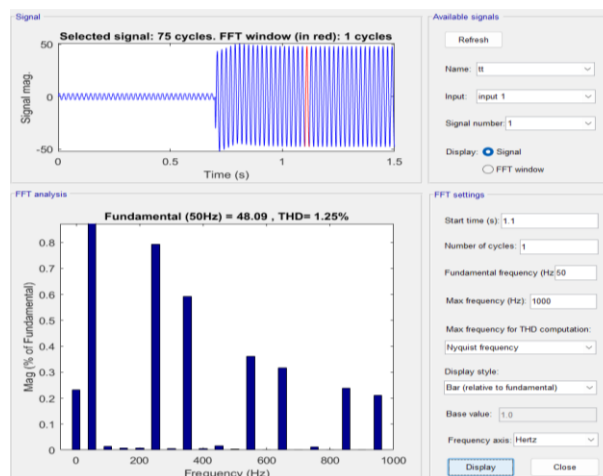


Figure 7: FFT Analysis (Control of DC link voltage using Fuzzy Logic Controller)



Article Title: Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

4 Conclusion

This paper has presented a comparative analysis of PI and Fuzzy logic based power quality improvement in grid connected systems. In figures 6 Total Harmonic Distortion has been reduced from 20.08% to 4.58% by using PI controller to control the DC link Voltage. In figure 7 FFT Analysis shows that the THD after connecting the shunt active power filter using Fuzzy Logic Controller is 1.25%. It was observed that the power quality can be effectively improved by Fuzzy logic controller than the conventional PI controller.

References

1. Mukhtiar Singh; Vinod Khadkikar; Ambrish Chandra; Rajiv K. Varma, Year: 2011, "Grid Interconnection of Renewable Energy Sources at the Distribution Level with Power-Quality Improvement Features", IEEE Transactions on Power Delivery, Vol: 26, no: 1.
2. Wajahat Ullah Tareen; Saad Mekhilef; Mehdi Seyedmahmoudian; Ben Horan, Year: 2017, "Active power filter (APF) for mitigation of power quality issues in grid integration of wind and photovoltaic energy conversion system", Renewable and Sustainable Energy Reviews, Vol: 70, no: 6, pp. 635 – 655.
3. Adil M. Al-Zamil; David A. Torrey, Year: 2001, "A Passive Series, Active Shunt Filter for High Power Applications", IEEE Transactions on Power Electronics, Vol: 16, no: 1.
4. B. Ferdi; C. Benachaiba; S. Dib; R. Dehini, Year: 2010, "Adaptive PI Control of Dynamic Voltage Restorer Using Fuzzy Logic", Journal of Electrical Engineering: Theory and Application, Vol: 1, no: 3, pp. 165 – 173.
5. Ritesh Dash; Sarat Chandra Swain, Year: 2018, "Effective power Quality Improvement using Dynamic Activate Compensation system with Renewable grid interfaced Sources", Ain Shams Engineering Journal, Vol: 9, pp. 2897 – 2905
6. Sudheer Kasa; Prabhu Ramanathan; Sudha Ramasamy; D.P. Kothari, Year: 2016, "Effective grid interfaced renewable sources with power quality improvement using dynamic active power filter", Electrical Power and Energy Systems, Vol: 82, pp. 150 – 160.
7. Foad H. Gandoman; Abdollah Ahmadi; Adel M. Sharaf; Pierluigi Siano; Josep Pou; Branislav Hredzak; Vassilios G. Agelidis, Year: 2018, "Review of FACTS technologies and applications for power quality in smart Grids with renewable energy systems", Renewable and Sustainable Energy Reviews, Vol: 82, pp. 502 – 514.
8. Ruben Lliuyacc; Juan M. Mauricio; Antonio Gomez-Exposito; Mehdi Savaghebi; Josep M. Guerrero, Year: 2017, "Grid-forming VSC control in four-wire systems with unbalanced nonlinear loads", Electric Power Systems Research, Vol: 152, pp. 249 – 256.



Article Title: Comparative Analysis of PI Controller and Fuzzy Logic Controller Based Power Quality Improvement in Grid Connected Distributed Energy Systems

9. K. Ilango; A. Bhargav; A. Trivikram; P. S. Kavya; G. Mounika; N. Vivek; G. Nair Manjula, Year: 2012, “STATCOM Interface for Power Quality Improvement. Conference on power and energy systems”, AASRI Procedia, Vol: 2, pp. 69 – 74.

10. Huajun Yu; Junmin Pan; An Xiang, Year: 2005, “A multi-function grid-connected PV system with reactive power compensation for the grid”, Solar Energy, Vol: 79, pp. 101 – 106.