International Journal of Applied Power Engineering (IJAPE)
Vol. 13, No. 3, September 2024, pp. 539~545
ISSN: 2252-8792, DOI: 10.11591/ijape.v13.i3.pp539-545

Implementation of fuzzy controller based active filter for harmonic mitigation of grid-connected PV-system

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Article Info

Article history:

Received Jul 12, 2023
Revised Feb 20, 2024
Accepted Mar 11, 2024

Keywords:

Active power
Fuzzy-controller
Grid integration
Harmonics
Shunt active filter

ABSTRACT

Incorporating photovoltaic (PV) systems to grids have developed into an obvious alternative for many countries, those results in harmonics issues for the utility operators. Harmonics arises due to extensive utilization of power-electronic components during incorporation of PV to grid. Harmonic deformation has traditionally been taken care of by the relevance of passive filter. Active filters have come up as an alternative choice over passive ones for reduction of harmonic due to existence of several advantages in comparison to previous filter. The application of controllers is the most significant aspect of using an active filter. Various investigations are beneath development to progress performance of the filters. Control of capacitor voltage is among the major regulation requirement for the filter. Here, regulation of voltage is carried on by fuzzy-controller. The article represents compensation of harmonic currents of a grid integrated PV-system by application of fuzzy-controller placed active filter. One of the important control requirements of filter is the regulation of DC link up capacitor voltage. Here the voltage supervision of capacitor is being done using PI controller. The paper shows current harmonics compensation of PV grid connected system using PI controller based active filter. Simulating results are revealed that shows the harmonics are contained inside IEEE limits.

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1. INTRODUCTION

Harmonics are the main power-quality issue while using photovoltaic system as the system uses different power electronic equipments [1]–[3]. In addition, non-linear loads prove to be the main source of harmonics. Nonlinear loads alter the sinusoidal property of current that results in the drift of distorted current waveform in power system. Harmonics are not visible or usually not reckonable through an indicator, but are exposed to damage power-distribution network [4], [5]. If not diminished, the harmonics can deteriorate the system performance. Current harmonics flows across the network impedances, originates voltage deformations [6]. The deformed voltage wave begins drawn of current harmonics by loads attached at point of common coupling (PCC). The presence of harmonics current in the system give rise to losses in system, reduce the pf furthermore damages the equipments [7].

The conventional techniques to reduce harmonic currents involve application of passive-LC filters. Though, passive-filters consist of various pitfalls for instance huge size, along with possibility of resonance issues [8]–[11]. The augmented seriousness of harmonics contamination in systems has fascinated the concentration of engineers for development of vibrant and flexible solution to this problem. A foresaid device, usually termed as active filter (AF) [12]–[15], is widely utilized for compensation of harmonics. An AF improves the power-quality by injecting equal but opposite current or voltage distortion into the network thereby calling-off the result of actual distortion. The filter when connected in shunt to the load is termed as “shunt active filter” (SAF) which is applied commonly for the reparation of current harmonics.

A SAF is a type of power electronic device used to mitigate harmonics and improve the power quality in electrical systems. The centre of SAF is the controller part. The controller of a shunt active filter plays a crucial role in ensuring that the filter operates effectively. The strategies applied to SAF plays a vital role in improving the functioning and steadiness of filter. Voltage supervision of capacitor, production of reference currents and production of gating signal are core worry whilst operating SAF. Diverse controllers are being used and still beneath research for curb of aforesaid aspects of SAF [16]–[18]. The capability of fuzzy-controller (FC) to control random and uneven real-time information make it appropriate for a huge range of operations, specially, while the systems are very difficult to be analysed. This article focuses on the voltage regulation of DC linked-up capacitor of SAF utilizing fuzzy-controller in such a manner so as to diminish the current harmonics. A fuzzy controller-based shunt active filter is a control system that uses fuzzy logic to regulate the operation of a shunt active filter in an electrical system. Fuzzy logic is a computational approach that can handle imprecise or uncertain information, making it suitable for control systems where the rules are not well-defined or where the system's behavior is complex. In the context of a shunt active filter, a fuzzy controller can be used to improve the filter's performance in mitigating harmonics. Fuzzy controller-based shunt active filters are particularly useful in situations where the electrical system's characteristics are nonlinear, time-varying, or difficult to model precisely. They provide a flexible and adaptive approach to control that can help maintain power quality and reduce harmonic distortion in a wide range of applications. Simulation by MATLAB/Simulink is conducted to justify functioning of the projected controller. Harmonic extraction time domain method used is synchronous reference frame theory. Also the Hysteresis current controller is applied to produce pulses [19]–[21].

2. SAF COMPOSITION

For the composition of SAF, a pulsewidth-modulated (PWM) dependent voltage source inverter (VSI) as illustrated in Figure 1 is utilized, which functions in current-control manner [22]. The compensation of currents is carried in time sphere for rapid reaction. The aim is to set up compensating current at PCC so as to make source current sinusoid, as the SAF is utilized to cancel harmonic currents. Fuzzy controllers are particularly useful when dealing with systems that have uncertain, ambiguous, or nonlinear behavior [23]–[25]. Fuzzy logic provides a way to incorporate human-like decision-making into SAF.

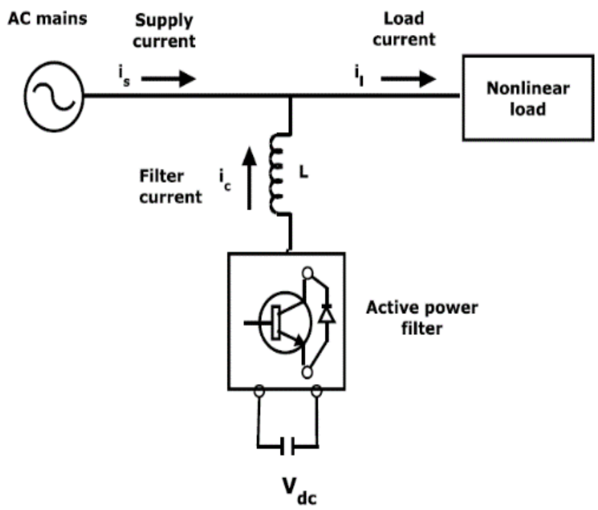

Figure 1. Simple drawing of SAF

3. FUZZY-CONTROLLER APPLIED TO SAF

While condition of load alters, real-power equilibrium among main supply and load gets troubled. This difference of real-power needs to get remunerated via means of linked DC-capacitor. As a result the voltage of DC-capacitor gets apart through the set reference value. So as to achieve the adequate functioning of SAF, FC has been designed to regulate the DC linkup voltage.

Figure 2 shows the FC designed for SAF. The reference voltage is set at a reference voltage, and the actual voltage is observed. The difference in voltages becomes the error. This error and the change in error is supplied as input to FC. Figures 3 and 4 show the membership function (MF) plot of two inputs "error" and "change in error". The type of MF used in both inputs is trimf. The output is given by FC using the rule base illustrated in Figure 5.

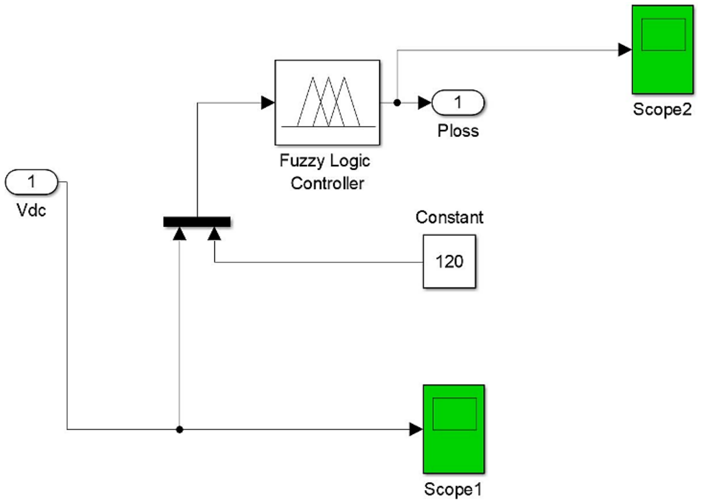

Figure 2. Fuzzy-controller design

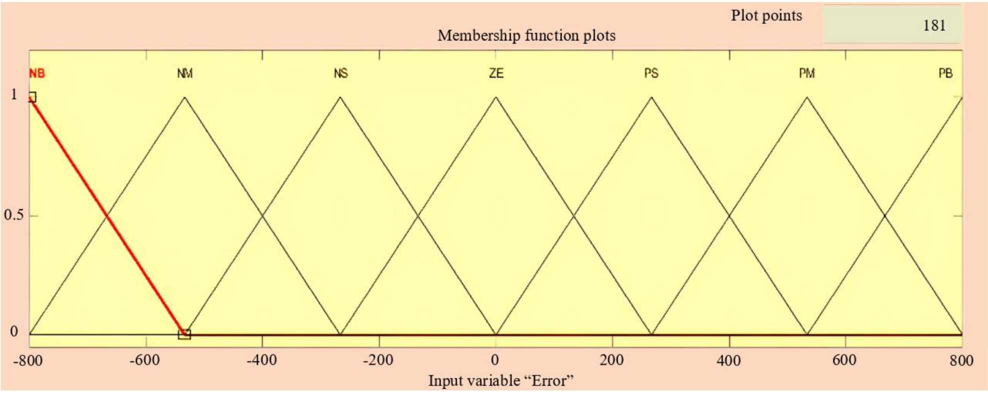

Figure 3. MF plot of i/p "error"

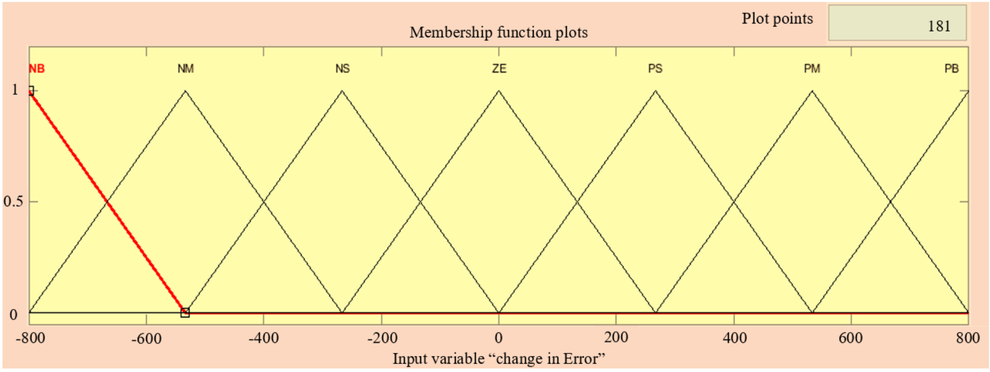

Figure 4. MF plot of i/p "change in error"

Δe / e	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	MN	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

Figure 5. Rule-base table

4. SIMULINK RESULTS

Simulations are conducted by means of MATLAB/Simulink 2018. Figure 6, displays the Simulink design of FC based SAF to mitigate current harmonics of a PV grid-connected PV-scheme. Figures 7 and 8 show current total harmonic distortion (THD) next to PCC without SAF and amid SAF respectively. As shown in diagrams, by applying fuzzy-controller dependent SAF, the current-THD is diminished to 2.91% as of 28.38%. Figure 8 demonstrates the THD for current harmonics at PCC, as evident the harmonics has been reduced to 2.91%. Furthermore it's evident through Figures 9 and 10 that harmonic contents are at lowest which provides nearly sinusoid wave of current at PCC when compared to twisted waveform amid harmonic. Also, when looking at the 3-phase current waveform at PCC as shown in Figure 10, it's been observed to be approximate sinusoidal.

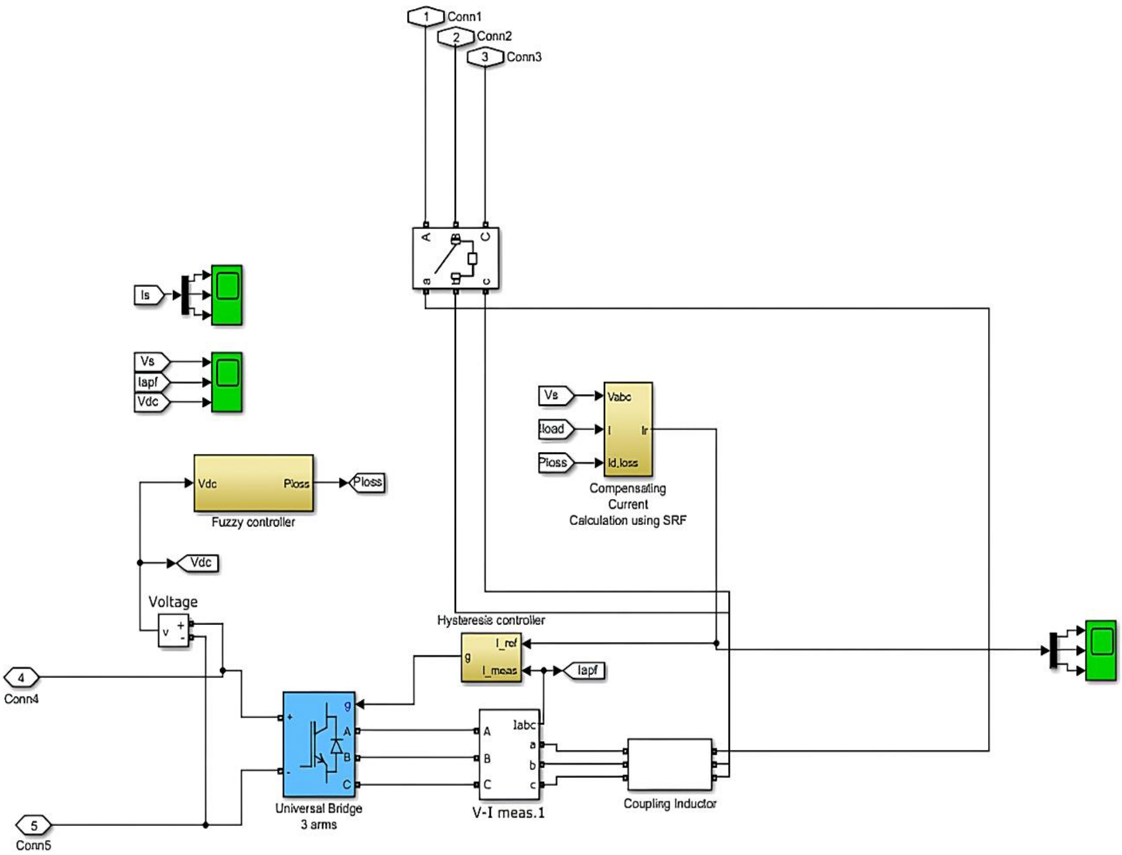

Figure 6. FC based SAF design

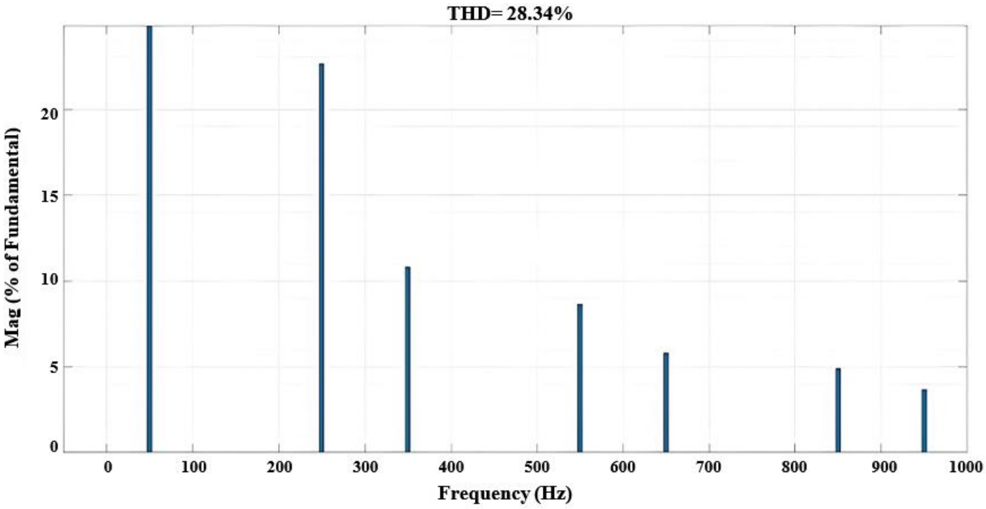

Figure 7. THD_i at PCC

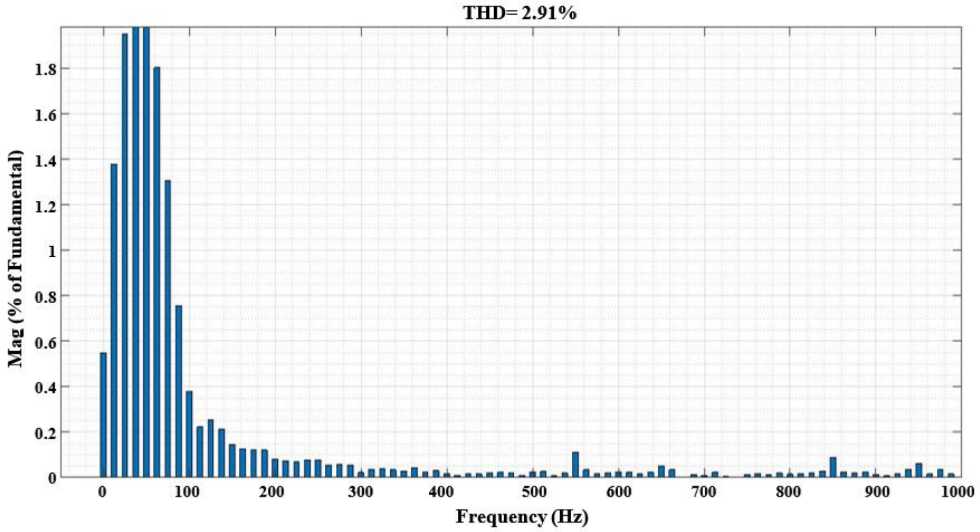

Figure 8. THD_i at PCC using fuzzy based SAF

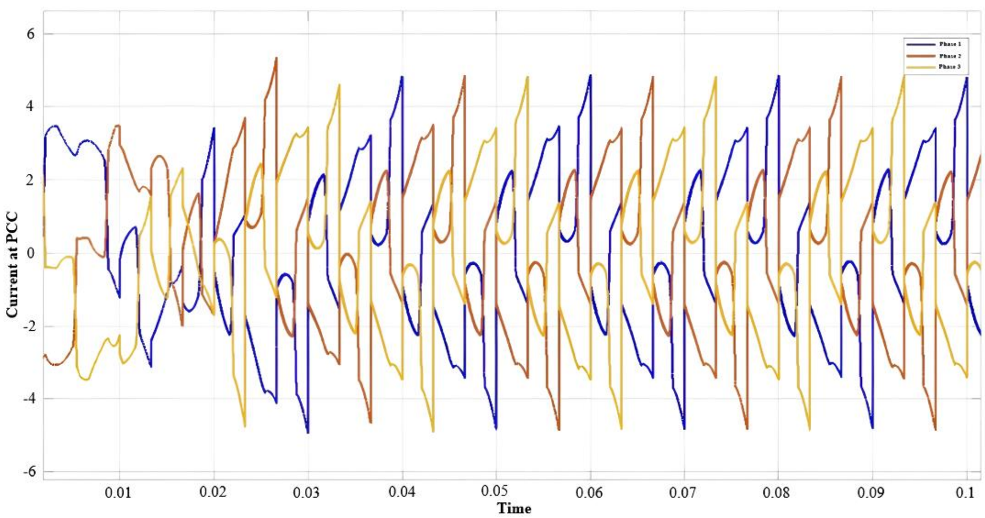

Figure 9. Current-wave at PCC

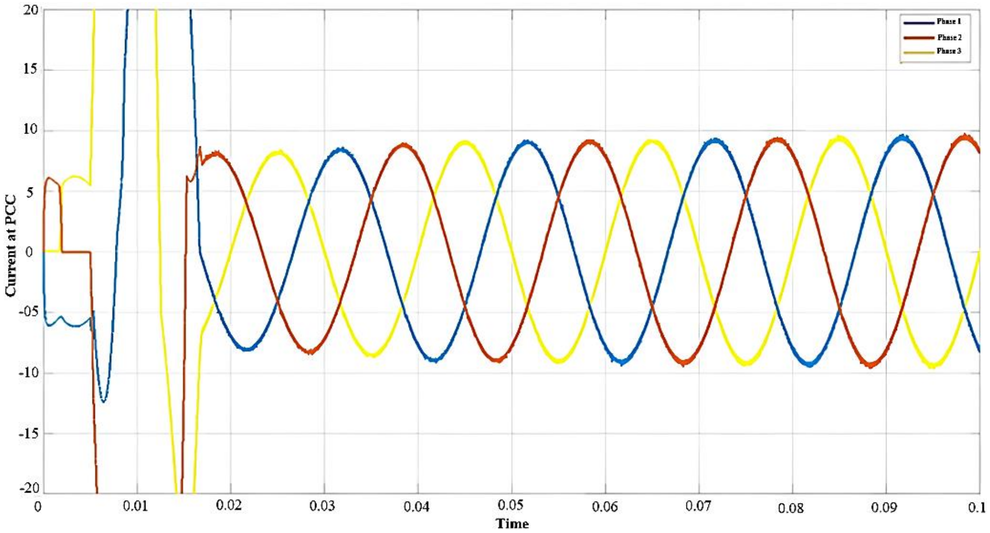

Figure 10. The 3-phase current-wave at PCC using fuzzy-SAF

5. CONCLUSION

An arrangement dependent on fuzzy-controller for SAF is modelled and the outcomes are represented. FC is competent in diminishing current harmonics in source and also maintains the linkup voltage to be steady. The current harmonics has been reduced to a great extent using SAF. It's observed that current THD for source is beneath IEEE519 boundaries. Current harmonics substance may additionally be diminished further by introducing appropriate interventions. The efficacy of this kind of curb technique can be probed further beneath unbalanced supply situations. The specific design and features of the controller can vary depending on the manufacturer and the application requirements. The goal of the controller is to ensure that the shunt active filter operates effectively in reducing harmonics, improving power factor, and maintaining overall power quality in the electrical system.

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