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Harmonic Analysis of Fuzzy Controlled Based on Digital Active Power Filter Controller for current compensation in a Power System

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Abstract

In this paper a digital active power filter is introduced into a grid system with non-linear load for elimination of harmonics in the source current. Nonlinear loads are essential part of power system. With the advancement in power electronics, switching elements have major share in electrical load. The active filter has a voltage source converter (VSC) which works in back-to-back configuration with a DC coupling capacitor. Power is injected by the VCS at the point of common coupling (PCC). The reference current is generated using instantaneous power theory. The instantaneous power theory or PQ theory is updated with FIS control system for better DC voltage generation across the DC link capacitor. The fuzzy system replacing the PI controller has (7x7) 49 rule base structure for generation of error signal.

Keywords: *Active Power Filter, Instantaneous Power Theory, Harmonics, Non-Linear Load, MATLAB Simulink and FFT analysis tool*

1. Introduction

Early technology was built to tolerate disturbances like lightning, short circuits, and abrupt overloads without incurring additional costs. If current power electronics (PE) equipment was constructed with the same resilience, prices would be significantly higher. Nonlinear loads such as transformers and saturation coils have polluted power systems, but the rate of disturbance has never reached the current levels.[1] PE is responsible for the majority of pollution problems due to its nonlinear properties and rapid switching. The nonlinear properties and quick switching of PE are responsible for the majority of environmental problems. PE processes around 10% to 20% of today's energy; this percentage is expected to rise to 50% to 60% by 2010, owing to the rapid increase of PE capability. On the one side, there is a race between rising PE pollution & sensitivity, while on the other hand, there is a race among innovative PE-based corrective devices that can mitigate the concerns caused by PE.

Increased non-linearity results in a variety of unfavourable characteristics, including low system efficiency and a low power factor. It also creates annoyance to other customers and communication network interference in the area. Within the next few years, the impact of such non-linearity could be significant. As a result, overcoming these negative characteristics is critical.

Shunt passive filters, which are made up of tuned LC filters and/or high passive filters, are traditionally used to eliminate harmonics and power capacitors are used to enhance power factor. However, they have fixed compensation, are huge in bulk, and can cause resonance situations. [2]

To compensate for harmonics as well as reactive power requirements of non-linear loads, active power filters are now viewed as a feasible alternative to traditional passive filters. The goal of active filter is to alleviate these issues by integrating it with significantly reduced ratings of the required passive filters.

However, the conventional PI controller was used for the generation of a reference current template. The PI controller requires precise linear mathematical models, which are difficult to obtain and fails to perform satisfactorily under parameter variations, nonlinearity, load disturbance, etc. [3]

Fuzzy logic controllers (FLCs) have recently sparked a lot of interest in a wide range of applications. FLCs have several advantages over conventional controllers, including the fact that they really do not require a perfect mathematical formula that they can work with imprecise inputs, that they can manage lion-linearity, and they're far more robust than typical nonlinear controllers. The flow of harmonic and reactive currents adversely affects the power system by lowering the power factor and deteriorating the voltage quality. These harmful effects are becoming increasingly more important for the following reasons: [4]

While the power demand is growing, public concerns over environmental impacts of transmission lines and right of way costs are making it more difficult for utility companies to build new transmission lines. The need to build new lines is reduced if the current carrying capacity of the existing transmission facilities is fully utilized by improving the power factor.

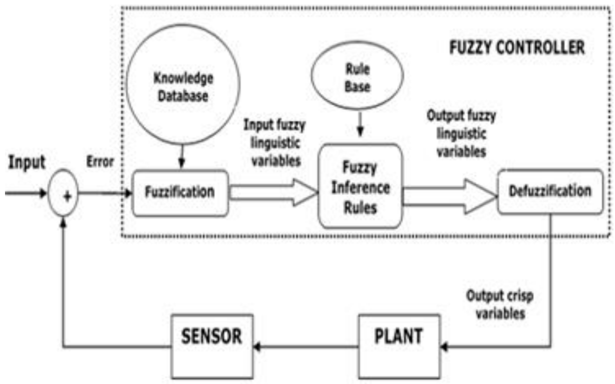

Fig.**Error! No text of specified style in document.** Fuzzy Logic Control System

Deregulation of the power industry is putting additional pressure on the utility companies to remain competitive by improving the voltage quality and by reducing the costly system losses.

Addition of harmonic generating loads such as power electronic equipment by consumers is increasing the level of harmonic current flow in power systems

This paper implements a PI and fuzzy logic-controlled shunt active power filter for harmonics as well as reactive power correction of a nonlinear load. The control scheme is based on sensing line currents only; an approach different from convention ones, which are based on sensing harmonics and reactive volt-ampere requirements of the nonlinear load. [5]

2. Methodology

In pursuit of the objective a detail review of literature is carried out to understand the principles, working and other subsystems of APF. The circuit and control parameters are designed based on the problem and the specification. An elaborated simulation is carried out in MATLAB/SIMULINK to validate the designed parameters are in accord with the required specification. Then different criteria's affecting the performance of APF is figured out and suitable solutions are used to enhance the compensation performance.[18]

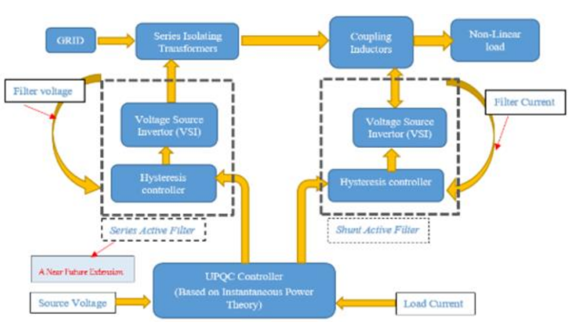

Figure 2 Block diagram of complete procedure

2.1UPQC Controller

FACTS have emerged as a solution to several PQ issues in recent years. A new generation of compensating devices has arisen from the application of FACTS concepts in distribution networks. A UPQC is a distribution-level expansion of the UPFC concept.

UPQC is the combination of two active power filters, Series APF and Shunt APF, which are coupled back-to-back on the dc side and share a common DC capacitor. The UPQC's series component is in charge of reducing supply-side disturbances such as voltage sags/swells, flicker, voltage imbalance, as well as harmonic. It introduces voltages to keep the load voltages balanced and distortion-free at a set level. The shunt component is in charge of reducing current quality issues generated by the consumer, such as low power factor, load harmonic currents, and load unbalance. It infuses currents into the ac system to make the source currents balanced and also in phase with the source voltages.

3. Fuzzy Logic Controller

The fuzzy controller is made up of four primary parts: The knowledge in the form of a collection of rules outlining the optimal way to manage a system is stored in the rule-base. To measure knowledge, membership functions are being used. The inference system determines which control rules are applicable at this time and then determines which plant input must be activated. The inputs are modified by the fuzzification interface so that they may be understood and matched to the rules in the rule-base. The defuzzification interface converts the plant's inputs into the conclusions derived by the inference engine. A circuit illustration of a fuzzy logic controller is shown in fig.

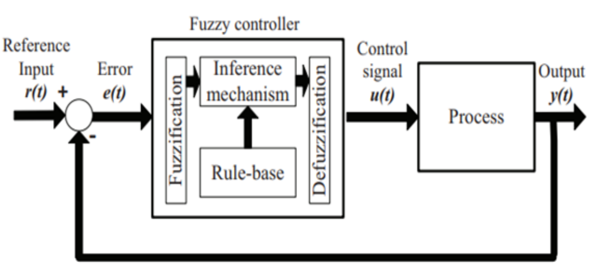

Figure 3 Scheme of a fuzzy logic controller

A. Description of fuzzy logic tools

Unlike Boolean or crisp logic, fuzzy logic deals with situations that are unclear, uncertain, or imprecise, and employs membership functions with values ranging from 0 to 1. A graphical block diagram of a fuzzy inference system or fuzzy controller is shown in Figure.

It is made up of the following working blocks.

- Fuzzification Interface

- Knowledge base
- Decision making logic
- Defuzzification

A fuzzy controller should have proportional integral control effects because it is a two-dimensional fuzzy control. To get the best performance in a practical situation, an entire action is usually required.

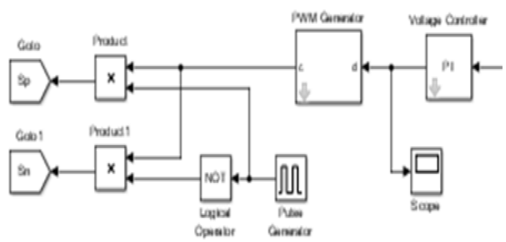

Figure 4 PWM pulse generator

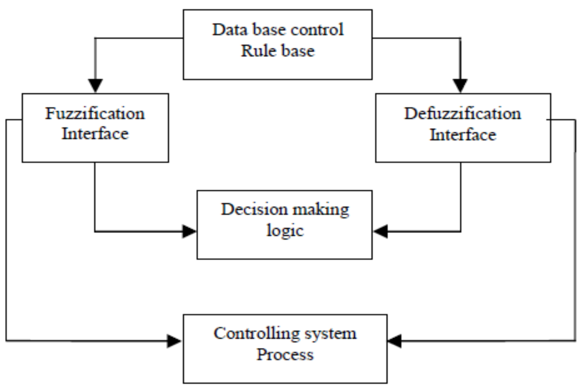

Figure 5 Fuzzy Inference Systems

When compared to the PI controller, the Mamdani kind of fuzzy controller used for APF control produces superior results, but it has the disadvantage of having a larger number of fuzzy sets and rules. Furthermore, all of the coefficients must be improved in order to outperform a traditional PI controller. When compared to the PI control system, the fuzzy control takes less time to settle. As a consequence, the results show that for constant power SEIG systems, the fuzzy logic controller-based system outperforms the PI control-based system as a voltage regulator.

4. Results and Discussion

A simulation study is done using MATLAB/SIMULINK to study the performance of shunt active filter based on d-q transformation and SRF theory. As seen in the above modelling the grid is connected to non-linear load as diode bridge rectifier connected RL load. This load generates harmonics in the system and the source currents get disrupted. A digital active power filter with six switches and DC link capacitor is connected at PCC to mitigate harmonics in the system which is controlled by PQ theory. The modelling of the PQ theory can be seen below.

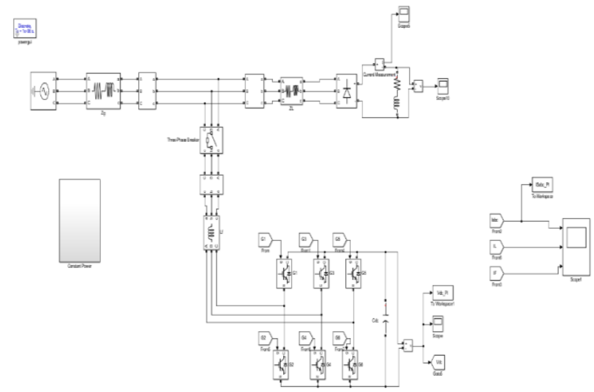

Figure 6 Proposed grid system with non-linear load connected to digital active power filter at PCC

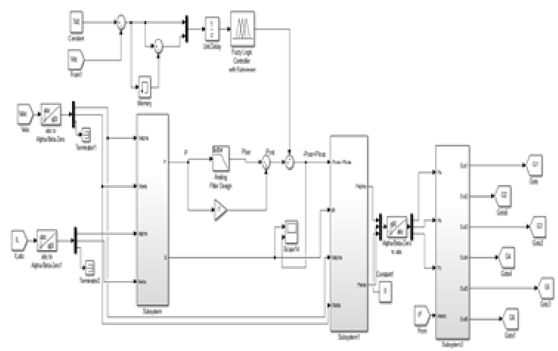

Figure 7 PQ theory control structure with FIS controller of digital active power filter

The PQ theory is further updated with FIS controller at the DC link comparison and the simulations are carried out with 0.5sec simulation time. From 0-0.2sec there is no digital active power filter connected, and at 0.2sec the device is connected and from 0.2-0.5sec the system is with digital active power filter. The results of system currents and DC link voltages are given below.

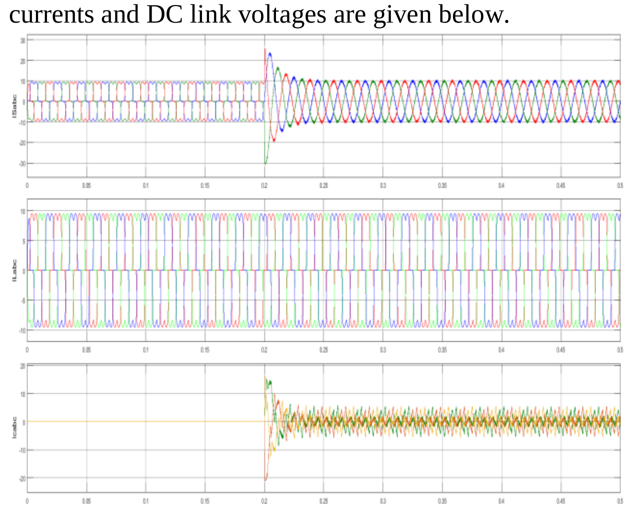

Figure 8 Source currents, Load currents and compensating current before and after digital active power filter

The above are the source currents, load currents and compensation currents from the digital active power filter comparison before and after the device connected at 0.2sec.

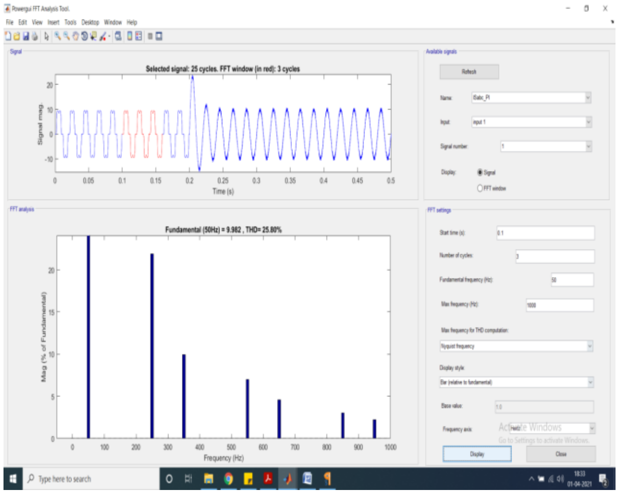

Figure 9 THD of source current without digital active power filter

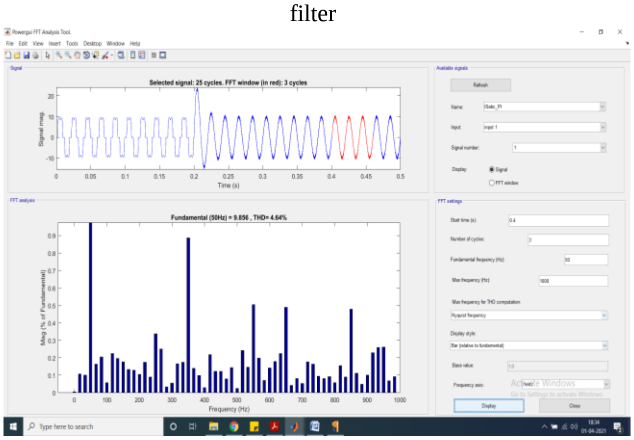

Figure 10 THD of source current with PI controller digital active power filter

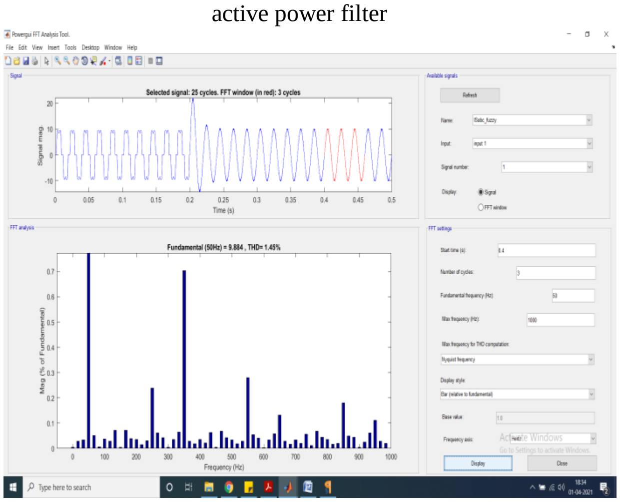

Figure 11 THD of source current with FIS controller digital active power filter

5. Conclusion

As seen in the above graphs the harmonics mitigation is achieved when the grid system with non-linear load is connected with digital active power filter. Here, the combination of Park's transformation and digital PI controller, this varying PWM signal is generated. These PWM signals are control signals to a voltage source inverter (VSI) which injects the harmonics of same magnitude at 180-degree shift to cancel the effect of harmonics or distortion in power line. The DC link voltage with FIS controller is more accurate with 740V generation at DC link as compared PI controller. Therefore, the performance of the digital active power filter is improving when the controller s updated with FIS module. The THDs of the source current without and with digital active power filter by PI and FIS are shown above.

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