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Performance Analysis of Shunt Active Power Filter Using Fuzzy Controller

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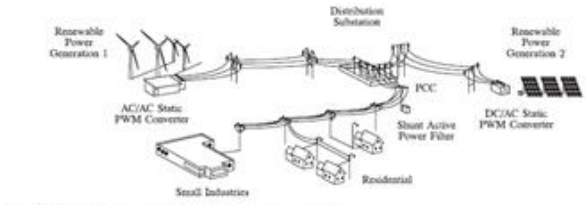
Abstract:
In this paper, Performance of Shunt active power filter (SAPF) is analyzed for various types of non linear loads. Among the various control schemes available for SAPF, indirect current control scheme is used here. PI controller and fuzzy logic controller are used to analyze its performance for various types of nonlinear loads the output parameters are Total Harmonic Distortion (THD) and power factor. The results are obtained with the conventional PI controller and fuzzy controller. The proposed method offer an efficient control method under the various load conditions results in power factor improvement and THD reduction. Simulation of the proposed controller (PI and fuzzy logic controller) of a shunt active power filter has been carried out in MATLAB/SIMULINK and the aim is to reduce the THD.

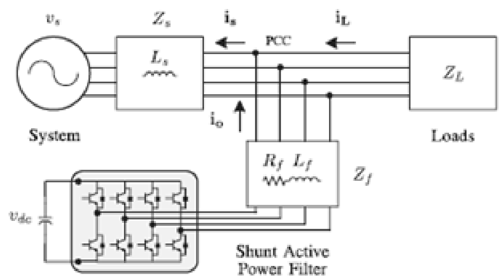
Keywords:
Active power filter, current control, four-leg converters, predictive control.

INTRODUCTION:
Renewable generation affects power quality due to its Non linearity, since solar generation plants and wind power generators must be connected to the grid through high-power static PWM converters [1]. The non uniform nature of power generation directly affects voltage regulation and creates voltage distortion in power systems. This new scenario in power distribution systems will require more sophisticated compensation techniques. Although active.

This paper presents the mathematical model of the 4L-VSI and the principles of operation of the proposed predictive control scheme, including the design procedure. The complete description of the selected current reference generator implemented in the active power filter is also presented. Finally, the proposed active power filter and the effectiveness of the associated



tand-alone hybrid power generation system with a shunt active power filter.



. 2. Three-phase equivalent circuit of the proposed shunt active power r.

It consists of various types of power generation units and different types of loads. Renewable sources, such as wind and sunlight, are typically used to generate electricity for residential users and small industries. Both types of power generation use ac/ac and dc/ac static PWM converters for voltage conversion and battery banks for long term energy storage. These converters perform maximum power point tracking to extract the maximum energy possible from wind and sun.

The electrical energy consumption behavior is random and unpredictable, and therefore, it may be single- or three-phase, balanced or unbalanced, and linear or nonlinear. An active power filter is connected in parallel at the point of common coupling to compensate current harmonics, current unbalance, and reactive power. It is composed by an electrolytic capacitor, a four-leg PWM converter, and a first-order output ripple filter, as shown in Fig. 2. This circuit considers the power system equivalent impedance Zs , the converter output ripple filter impedance Zf , and the load impedance ZL .

Active Filters:

There are basically two types of active filters: the shunt type and the series type. It is possible to find active filters combined with passive filters as well as active filters of both types acting together. Fig. 4 presents the electrical scheme of a shunt active filter for a three-phase power system with neutral wire, which is able to compensate for both current harmonics and power factor. Furthermore, it allows load balancing, eliminating the current in the neutral wire. The power stage is, basically, a voltage-source inverter controlled in a way that it acts like a current-source.It is the dual of the shunt active filter, and is able to compensate for distortion in the power line voltages, making the voltages applied to the load sinusoidal (compensating for voltage harmonics). The filter consists of a voltage-source inverter (behaving as a controlled voltage source) and requires 3 single-phase transformers to interface with the power system.

FUZZY LOGIC CONTROLLER:
INTRODUCTION:

This is the first in a series of six articles intended to share information and experience in the realm of fuzzy logic (FL) and its application. This article will introduce FL. Through the course of this article series, a simple implementation will be explained in detail. Each article will include additional outside resource references for interested readers.

WHAT IS FUZZY LOGIC CONTROLLER?

In this context, FL is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.

WHY USE FAZZY LOGIC CONTROLLER:

FL offers several unique features that make it a particularly good choice for many control problems.

1) It is inherently robust since it does not require precise, noise-free inputs and can be programmed to fail safely if a feedback sensor quits or is destroyed. The output control is a smooth control function despite a wide range of input variations.

2) Since the FL controller processes user-defined rules governing the target control system, it can be modified and tweaked easily to improve or drastically alter system performance. New sensors can easily be incorporated into the system simply by generating appropriate governing rules.

3) FL is not limited to a few feedback inputs and one or two control outputs, nor is it necessary to measure or compute rate-of-change parameters in order for it to be implemented. Any sensor data that provides some indication of a system's actions and reactions is sufficient. This allows the sensors to be inexpensive and imprecise thus keeping the overall system cost and complexity low.

The operation of fuzzy controller:

In a fuzzy logic controller, the control action is determined from the evaluation of „a' set of simple linguistic rules.

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The development of the rules requires „a' thorough understanding of the process to be controlled, but it does not require a mathematical model of the system. The design of a fuzzy logic controller requires the choice of membership functions. The membership functions should be chosen such that they cover the whole universe of discourse. It should be taken care that the membership functions overlap each other. This is done in order to avoid any kind of discontinuity with respect to the minor changes in the inputs. To achieve finer control, the membership functions near the zero regions should be made narrow. Wider membership functions are away from the zero regions provides faster response to the system. Hence, the membership functions should be adjusted accordingly. After the appropriate membership functions are chosen, a rule base should be created. It consists of a number of Fuzzy If-Then rules that completely define the behavior of the system. These rules very much resemble the human thought process, thereby providing artificial intelligence to the system. The error and change of error are used numerical variables from the real system. To convert these numerical variables into linguistic variables, the following seven fuzzy levels or sets are chosen as:

NB (negative big)
NM (negative medium)
NS (negative small)
ZE (zero)
PS (positive small)
PM (positive medium)
PB (positive big) and presented in input and output normalized membership functions.

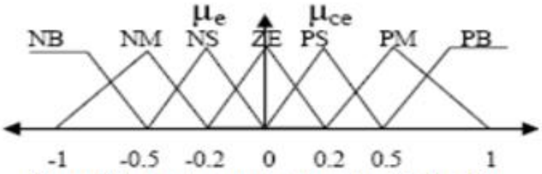
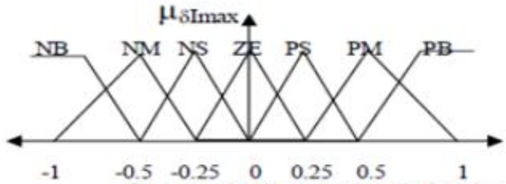


Figure 5(a): Input normalized membership function.



Output normalized membership function.

The fuzzy controller is characterized as follows:
(i) Seven fizzy sets for each input and output.
(ii) Triangular membership functions for simplicity.
(iii) Fuzzification using continuous universe of discourse.
(iv) Implication using Mamdani"s 'min' operator
(v) Defiizzification using the 'centroid' method.

Fuzzification:

The term fuzzification means to fuzzify the data. This is done by converting the classical set to fuzzy set. For this process we need different fuzzifiers such as Triangular, Trapezoidal, Singleton and Gaussian. With the help of these fuzzifiers we assign some membership function to each and every input and convert it into fuzzy set.

Membership function:

It is a graph between input and the membership value, which varies from 0 to 1. The membership function provides impreciseness to the fuzzy logic. There are various types of membership functions:

i.Trapezoidal
ii.Triangular
iii.Gaussian
iv.Sigmoid
v.Piecewise linear
Fuzzy Inference Engine:
It consists of knowledge base, in which the rules are framed.

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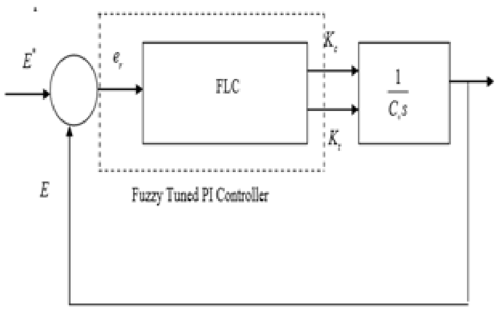
Fuzzy inference engine can be broadly categorized into two types of methods:

i.Mamdani method
ii.Sugeno method

Deffuzification:

It is a process of converting a fuzzy set into classical set. It is the inverse process of fuzzification. It is of much importance as by deffuzification process we convert the fuzzy values back into the classical or crisp values. There are different methods for deffuzification such as the centroid method, bisector method, largest of maximum, middle of maximum and finally the smallest of maximum. Among all of this the most efficiently used defuzzification method is the centroid method. A fuzzy controller can operate in a broad range of operations along with the variation of the parameters and load existence as compared to PI controllers. Depending on the control requirements and operational conditions of the DFIG, a fuzzy PI control strategy is designed. Input to the fuzzy PI controller is the error, which is continuously tracked and automatically corrected by the Kc and Kt controllers so as to achieve a dynamic performance.



Block diagram of Fuzzy Tuned PI controller

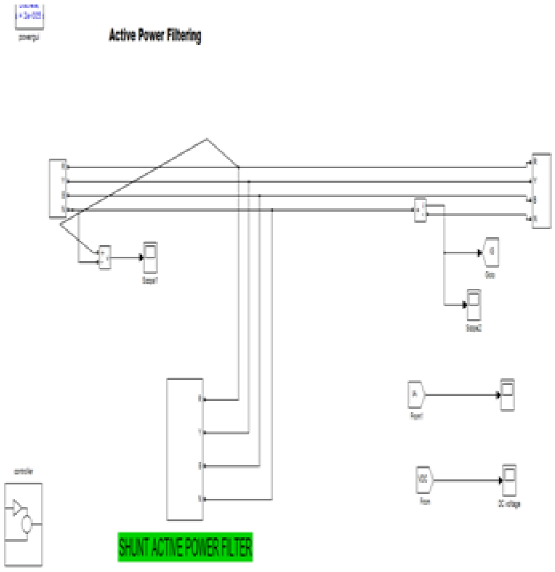
Kc = Proportional Gain, Kt = Integral Gain

The input signal consists of nine membership functions and the two output"s each consisting of five membership functions.

SIMULATION RESULTS:

A simulation model for the three-phase four-leg PWM converter with the parameters shown in Table I has been developed Using MATLAB Simulink. The objective is to verify the current harmonic compensation effectiveness of the proposed control scheme under different operating conditions. A six-pulse rectifier was used as a nonlinear load. The proposed predictive control algorithm was programmed using an S-function block that allows simulation of a discrete model that can be easily implemented in a real-time interface (RTI) on the dSPACE DS1103 R&D control board. Simulations were performed considering a20 [μs] of sample time.

Main Power Circuit



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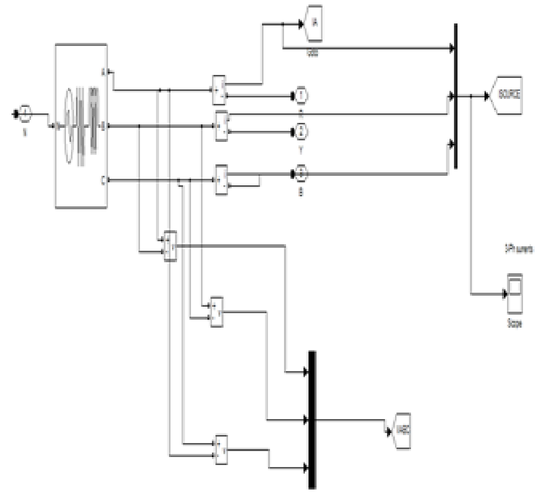
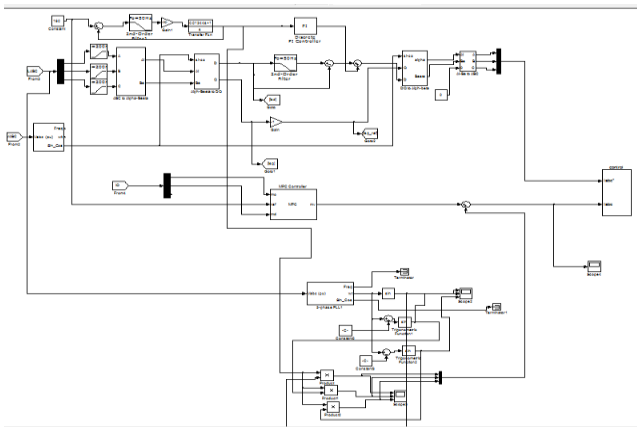
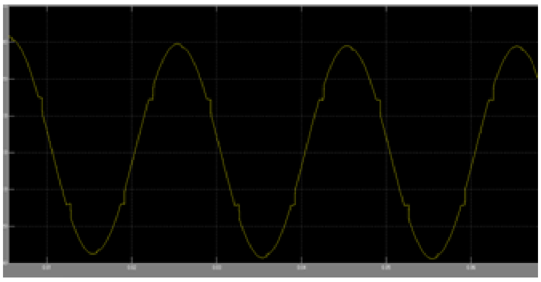
3-PH source



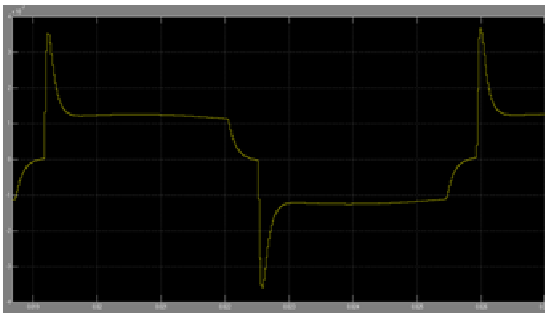
Controller



Source wave forms
L-N voltage

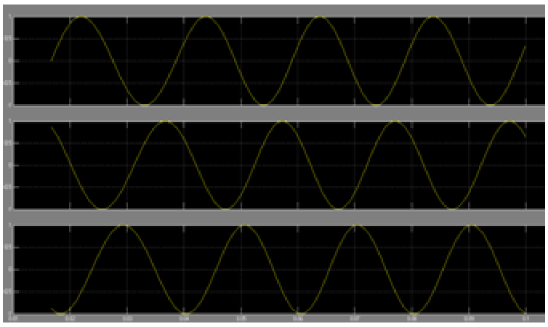


Neutral current

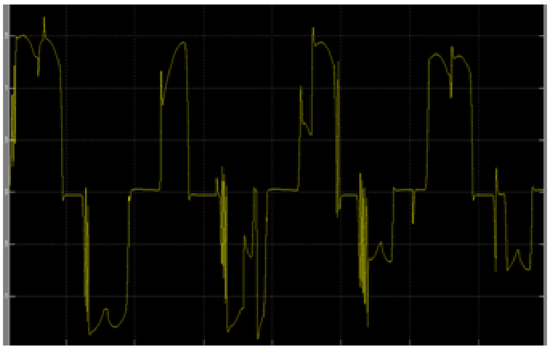


DC current

3-Ph Reference current generation



Nonlinear load currents



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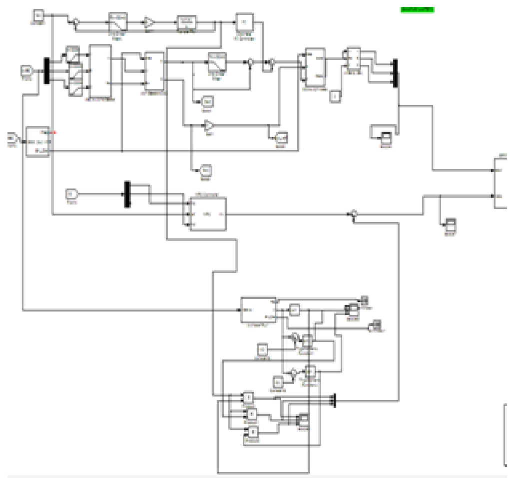
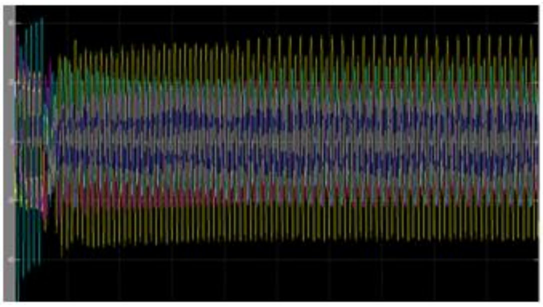
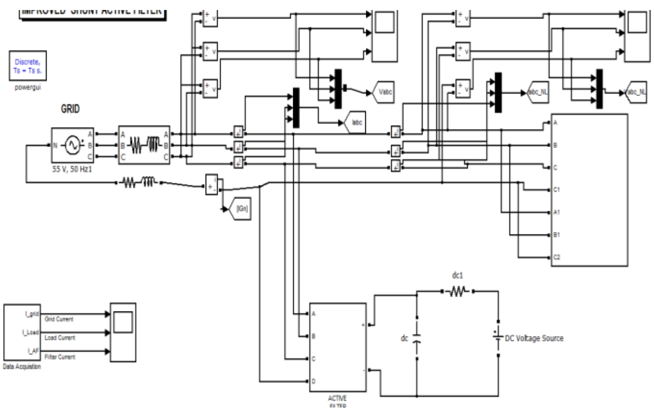
CONTROL CIRCUIT:



SOURCE CUREENT

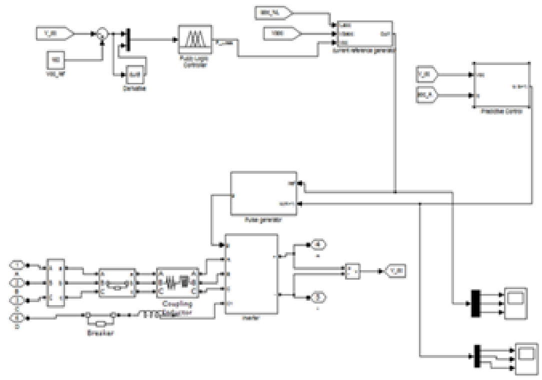


EXTENSION SIMULATION RESULTS

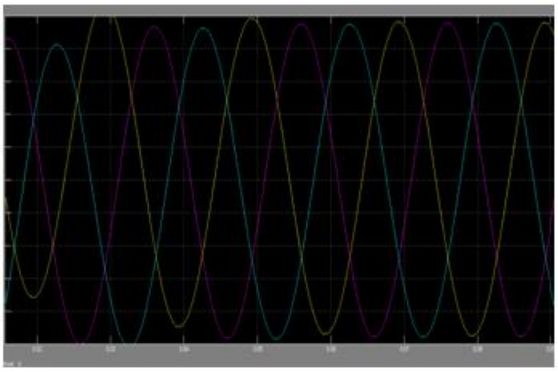


simulink model diagram

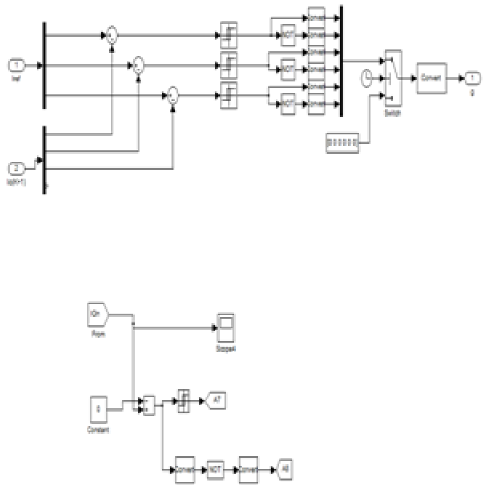
With Fuzzy Controller



Source wave forms:



Pulse generator



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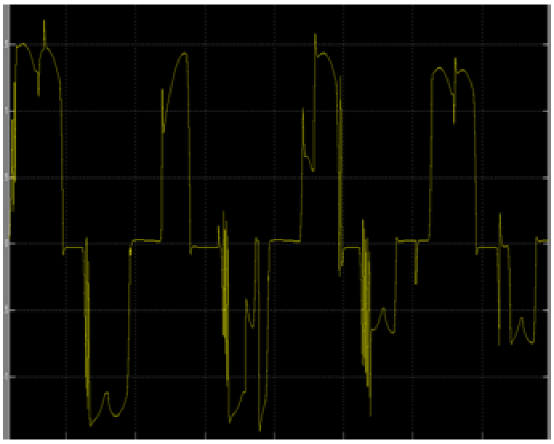
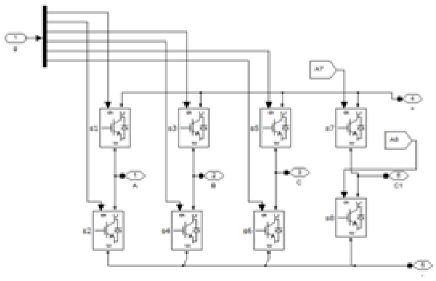
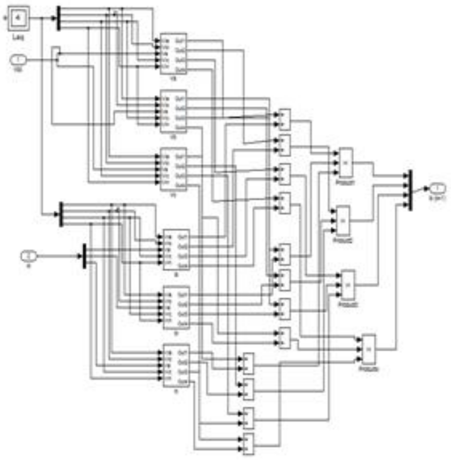


Active filter/Inverter



Simulation of Predictive Control



CONCLUSION

Improved dynamic current harmonics and a reactive power compensation scheme for power distribution systems with generation from renewable sources has been proposed to improve the current quality of the distribution system.

Advantages of the proposed scheme are related to its simplicity, modeling, and implementation. The use of a predictive control algorithm for the converter current loop proved to be an effective solution for active power filter applications, improving current tracking capability, and transient response. Simulated and experimental results have proved that the proposed predictive control algorithm is a good alternative to classical linear control methods. The predictive current control algorithm is a stable and robust solution. Simulated and experimental results have shown the compensation effectiveness of the proposed active power filter.

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