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Reactive Power Compensation and Voltage Fluctuation Mitigation Using Fuzzy Logic in Micro Grid

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ABSTRACT: To reduce the power quality issues, it is important to eliminate the harmonics in the power systems. The harmonic elimination through Shunt Active Power Filter .This work focus on design, modeling and analysis of FACTS device interconnected with grid during fault. These devices can be controlled by Synchronous Reference Frame theory. The performance is analyzed with the help of PI controller and Fuzzy logic technique. The simulation studies have demonstrated the effective influences of the SVC and STATCOM on the improvement of voltage using MATLAB simulink. It also shows that fuzzy logic controller gives better result when compared to PI controller.

KEYWORDS: Flexible AC Transmission System, Voltage Source Converter, Proportional Integral Controller, Fuzzy logic

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I.INTRODUCTION

Many domestic and industrial non-linear load share power electronic switching devices such as television, personal computers, business and office equipment namely copiers, printers, industrial equipment such as Programmable Logic Controllers (PLCs), Adjustable Speed Drives (ASDs), rectifiers, inverters, CNC tools. The power quality issues like interruptions, voltage sag, swell, harmonics, noise and switching transients are occurred in power system and introduces serious power pollution to the utility side. Among these power quality issues, the harmonics are the major contribution for polluting the power grid. Traditionally, passive LC filters have been used to avoid these effects [1].

The resonance, fixed compensation and huge size are the problems arising in passive filters. These problems are overcome by the introduction of active filters which addresses more than one harmonic at a time. Among the active filters, the SAPF is a power electronic converter that is connected in parallel and cancels the reactive and harmonic currents due to non-linear load [2]. Ideally, the SAPF needs to generate reactive and harmonic current to compensate the non-linear loads in the supply line. The SAPF is Voltage Source Inverter (VSI) with DC side capacitor (C_{dc}) and used to generate the filter current (i_f) and is injected into the utility power grid. This cancels the harmonic components by the non-linear load and keeps the utility line current (i_s) sinusoidal [3]. It has the advantage of carrying the compensation current and small amount of active fundamental current supplied to compensate for system losses.

The V_{dc} is regulated by using PI controller. This improves the system performance effectively. Several techniques are available to generate the switching current for the APF [4]-[6]. Bhim Singh et al proposed PI control algorithm for single phase SAPF [7]. In PI control strategy, reference current is calculated by sensing only line currents [8]. The PI controller requires accurate linear mathematical models, which fails to perform satisfactorily under non-linearity, load disturbances and parameter variations [9]. The conventional control requires mathematical analysis of the system so soft computing is an alternate solution to control the APF. Soft computing is a technology to extract information from the process signal by using expert knowledge. The Takagi Sugeno-FLC and mamdani FLC are compared in [16]. The FLC with different membership functions are compared in [7]-[8]. The conventional PI and FLC are compared in [9]-[10] based on PQ strategy

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II.DESIGN OF FUZZY LOGIC CONTROLLER

In order to keep C_{dc} voltage constant [20], the active power flowing into the filter needs to be controlled. If the active power flowing into the filter can be controlled, losses inside the filter get compensated. Then, the V_{dc} can be maintained at the desired value. The FLC is implemented to control the C_{dc} voltage based on processing of the V_{dc} error e(t) and its derivative Δe(t) is used to improve the dynamic of SAPF.

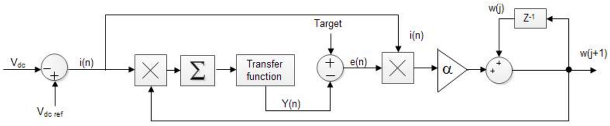


Fig.1. ADALINE is used to extract the amplitude of desired source current

A FLC consists of four stages: 1.Fuzzification 2.Knowledge base 3. Inference mechanisms 4.Defuzzification
The knowledge base is composed of a data base and rule base, and is deliberated to obtain good dynamic response under improbability in process parameters and peripheral turbulences. The data base, consisting of input and output membership functions, provides information for the suitable fuzzification operations, the inference technique and defuzzification. The inference technique uses a collection of linguistic rules to transform the input conditions into a fuzzified output. Finally, defuzzification is used to transform the fuzzy outputs into control signals [12]. Fig.1 shows a block diagram of the FLC for DC voltage control of SAPF.

A.Design of Control Rule

To propose the control rules of FLC, the formulation of rule set plays a key role in improvement of the system performance. In the case of the fuzzy logic based DC voltage control, the capacitor voltage deviation (e(t)) and its derivative (Δe(t)) are considered as the inputs of the FLC and the requirement for voltage regulation is taken as the output of the FLC. The input and output variables are transformed into linguistic variables as given in [17]. In this case, the knowledge of the systems behavior is put in the form of rules of inference. The rule table which is shown in Table I contains 49 rules. To convert crisp variables into fuzzy sets, the seven fuzzy sets are NL (Negative Large), NM (Negative Medium), NS (Negative Small), ZE (Zero), PS (Positive Small), PM (Positive Medium) and PL (Positive large) have been chosen. Normalized triangular membership functions are used for the input and output variables used here are shown in Fig.2.

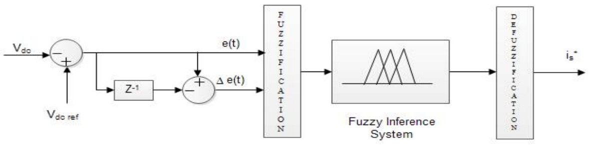


Fig.2. FLC for DC voltage control

III. APPLICATION AND RECENT DEVELOPMENTS

A. Applications

During the past several years, fuzzy logic has found numerous applications in fields ranging from finance to earthquake engineering . In particular, fuzzy control has emerged as one of the most active and fruitful areas for research in the application of fuzzy set theory. In many applications, the FLC-based systems have proved to be superior in performance to conventional systems. Notable applications of FLC include the heat exchange, warm water process , activated sludge process traffic junction , cement kiln, aircraft flight control , turning process robot control , model-car parking and automobile speed control, water purification process, elevator control , automobile transmission control , power systems and nuclear reactor control , fuzzy memory devices, and the fuzzy computer. In this connection, it should be noted that the first successful industrial application of the FLC was the cementkiln control system developed by the Danish cement plant manufacturer F.L.Smidth in 1979. An ingenious application is Sugeno’s fuzzy car, which has the capability of learning from examples. More recently, predictive fuzzy control systems have been proposed and successfully applied to automatic train operation systems and automatic container crane operation systems . In parallel with these developments, a great deal of progress has been made in the design of fuzzy hardware and its use in so-called fuzzy computers.

IV.SIMULATION RESULTS AND DISCUSSION

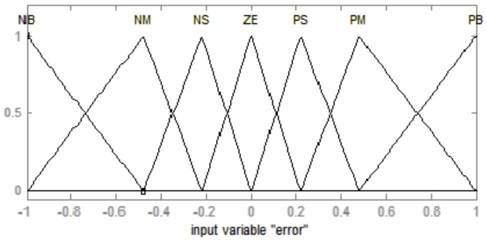
The Simulink model was developed using MATLAB SimPower Systems toolbox. The FLC is designed by using MATLAB fuzzy and neural toolbox. The performance of the FLC is detailed below.

a. Dynamic Performance of SAPF

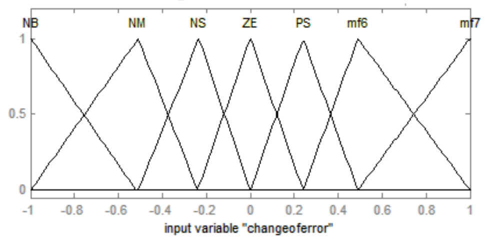
The balanced and sinusoidal three-phase input source voltages are considered. The diode bridge rectifier is considered as load for the system. The Total Harmonic Distortion (THD) before SAPF is 28.01%. The performance of SAPF with the proposed FLC, and conventional PI controller has been analysed for the following cases.

1. Switch-on response

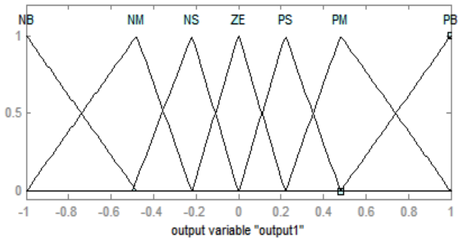
The SAPF is switched on at t=50ms. The concert of DC capacitor voltage of conventional PI controller and FLC controller is given in Fig. 3. The supply voltage (V_{sa}), supply current (I_{sa}), load current (I_{La}), filter current (I_{ca}) and V_{dc} related to phase-A of conventional PI controller and FLC controller are shown in Fig. 9 to Fig. 11 respectively. The capacitor voltage of PI settles at 18ms and FLC settles at 10ms.



(a) Input Variable Error



(b) Input variable change of Error



(c) Output Variable
Fig 3 Switch on Response

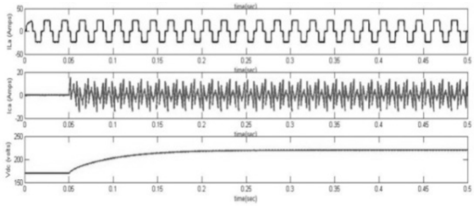


Fig.4.V_{sa}, I_{sa}, I_{La}, I_{ca} and V_{dc} of Conventional PI controller

In the fig 4 the conventional PI controller Performance factors like voltage and current values are shown.

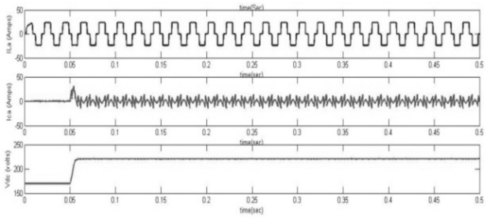


Fig.5. V_{sa}, I_{sa}, I_{La}, I_{ca} and $V_{dc}$of FLC

In the fig 5 shows the performance values with fuzzy logic controller for knowing the performance and system improvement while using fuzzy sets

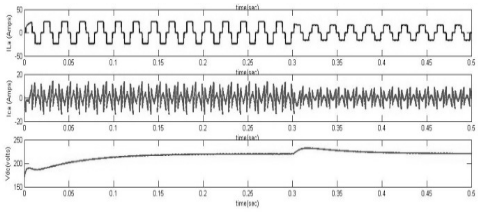


Fig.6. V_{sa}, I_{sa}, I_{La}, I_{ca} and V_{dc} of Conventional PI controller for varying R_L

Based upon the load resistance value the performance factors also change, in the fig 6 shows the variation of performance terms with PI controller

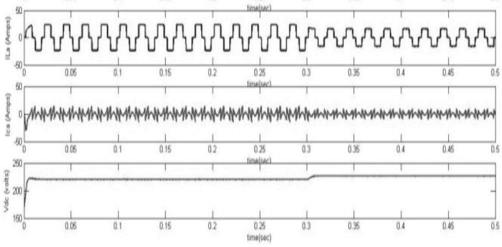


Fig.7. V_{sa}, I_{sa}, I_{La}, I_{ca} and V_{dc} of FLC for varying R_L

In the fig 7 shows the improvement values of voltage and current while using fuzzy sets .

The comparison of settling time, %THD and peak overshoot for Conventional PI, and FLC controllers is shown in Fig.8.

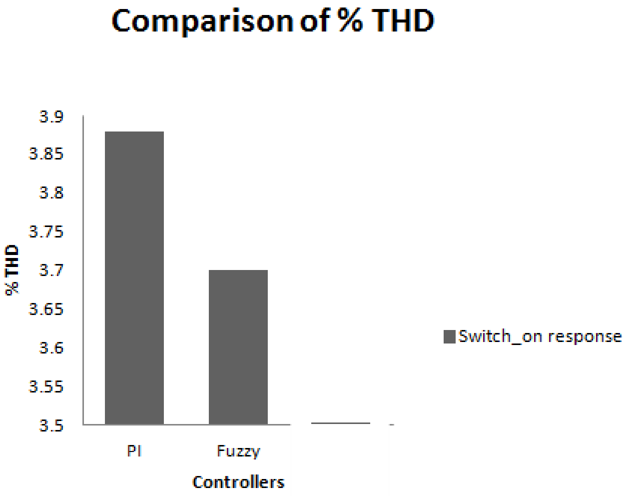


Fig 8 PI and FUZZY - % THD

The FLC controller settles at 6ms compared to PI controllers. The %THD is reduced in FLC compared to Conventional PI controllers. But the peak overshoot produced in FLC is larger compared to PI. Thus, the dynamic performance of FLC is compared with PI controller. The performance of FLC is improved conventional PI controller. The FLC has a settling time of 6ms, which is much better than the FLC and conventional PI controller

V. RESULT & DISCUSSION

In the below table 1 shows the variation of Grid, Source and Load voltage with respect to the different controllers like PI and FUZZY. While using the FUZZY Sets the system performance and load voltage values are quite improve comparing with the conventional controller.

S.no	Condition	Before Compensation		After Compensation	
		Gri d Voltage	Load Voltage	Source voltage	Load voltage
1	Without FUZZY (PI Controller)	230	205	230	223
2	With FUZZY	230	215	230	230

Table 1 Result

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OUTPUT WAVEFORM BEFORE COMPENSATION

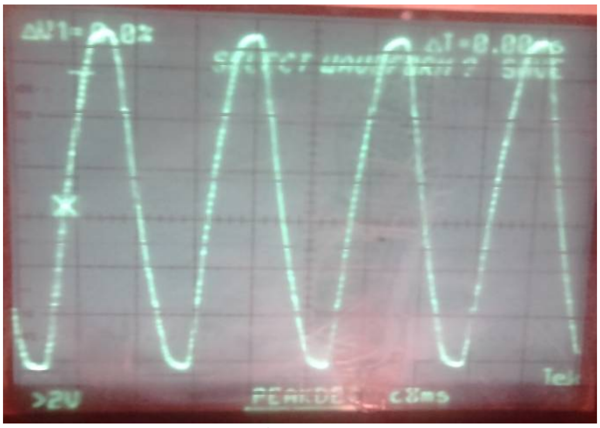

Fig 9 Output Waveform without compensator

The above figure shows that the output voltage marginally decreased with respect to the load. When the load increases the corresponding Voltage, Current and power value changed.

OUTPUT WAVEFORM AFTER COMPENSATION

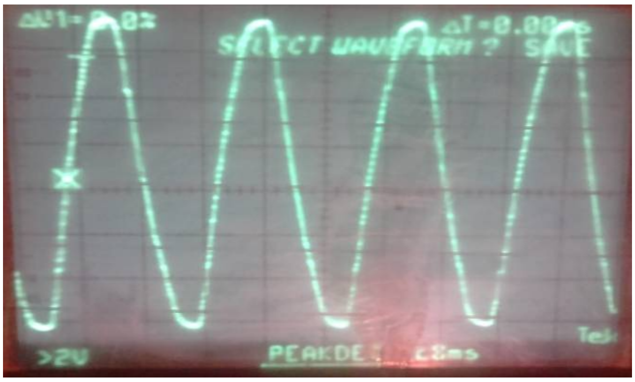

Fig 10 Output waveform with Compensator

The above figure shows that the output voltage is increased due to compensation.

V.CONCLUSION

In this paper, the Non model-based controllers are designed to achieve better utilization and reactive current compensation. The soft computing techniques were applied to control the switching of the SAPF. The LMS based ADALINE network is trained online to extract the fundamental load active current magnitude. The performance such as settling time, %THD of the FLC controller is better than conventional PI controllers and it is found to provide much better response under dynamic conditions.

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BIOGRAPHY

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