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Fuzzy Controller based MPFC for Power Quality Enhancement in an Electric Grid

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Abstract: *This paper presents a new idea for smart electric grid stabilization and to improve the power quality for efficient utilization of electric power using modulated power filter compensator (MPFC). The MPFC is controlled by a novel tri-loop dynamic error driven inter coupled fuzzy controller. The Fuzzy logic controller based on fuzzy logic provides a means of converting a linguistic control strategy based on expert knowledge into automatic control strategy. This paper presents a Digital validation conducted for normal load operating case using the Mat lab/Simlink/Sim-Power software environment with the modified power Filter Compensator scheme for effective voltage stabilization, power factor correction and harmonic reduction.*

Keywords: *FACTS, Dynamic Voltage Stabilization, Modified power filter compensator fuzzy controller, Smart Grid, Stabilization, Efficient Utilization.*

1. INTRODUCTION

A power quality problem is defined as any variation in voltage, current or frequency that may lead to an equipment failure or malfunction. In a modern electrical distribution system, there has been a sudden increase of nonlinear loads, such as power supplies, rectifier equipment used in telecommunication networks, domestic appliances, adjustable speed drives, etc. Due to their non-linearity, the loads are simultaneously the major causes and the major victims of power quality problems [1]. Harmonics, voltage sag/swell and persistent quasi steady state harmonics and dynamic switching excursions can result in electric equipment failure, malfunction, hot neutral, ground potential use, fire and shock hazard in addition to poor power factor and inefficient utilization of electric energy manifested in increase reactive power supply to the hybrid load, poor power factor and severely distorted voltage and current waveforms. To improve the efficiency, capacitors are employed which also leads to the improvement of power factor of the mains [2]. Passive filters are traditionally used to absorb harmonic currents because of low cost and simple robust structure. But they provide fixed compensation and create system resonance [3, 4]. The shunt active filters are used for providing compensate ion of harmonics, reactive power and/or neutral current in ac networks, regulation of terminal voltage, suppression of the voltage flicker, and to improve voltage balance in three- phase system [5, 6]. Hybrid filters effectively mitigate the problems of both passive filters and pure active filter solutions and provide cost effective and practical harmonic compensation approach, particularly for high power nonlinear loads. The combination of low cost passive filters and control capability of small rating active filter effectively improve the compensation characteristics of passive filters and hence reduce the rating of the active filters, compared to pure shunt or series active filter solutions [7-9]. Many power filter compensation configurations are proposed in literature to enhance power quality and to improve power factor [10-12]. Fuzzy logic is a convenient way to map an input space to an output space. Mapping input to output is the starting point for everything. **F**uzzy-Rule-Based modeling has become an active research field in recent years because of its unique merits in solving complex nonlinear system identification and control problems.[15] Primary advantages of this approach include the facility for the explicit knowledge representation in the form of If–Then rules, the mechanism of reasoning in human understandable terms, the capacity of taking linguistic information from human experts and combining it with numerical information, and the ability of approximating complicated nonlinear functions with simpler models. Unlike conventional modeling, where a single model is used to describe the global behavior of a system, fuzzy rule-based modeling[16] is essentially a *multimodel* approach in which individual rules (where each rule acts like a ―local model‖) are combined to describe the global behavior of the system[17- 18]. The paper validated a novel modulated power filter compensator (MPFC) scheme, to improve the power quality and utilization in smart grid application. The proposed

FACTS based system utilizes the tri-loop dynamic error driven fuzzy controller to control the MPFC by using mamdani rule base. The proposed scheme proved success in improving the power quality, enhancing power factor, reduce harmonic distortion and limit transient over voltage and inrush current conditions.

This paper is organized as below. In Section II, the description of proposed system is presented. The Tri loop error driven PID controller is explained in section III. The Tri loop error driven fuzzy controller is explained in Section IV. The proposed test system is explained in section V. The description of results is presented in section VI Finally, the conclusion of this paper is presented in Section VII.

A. Abbreviationss

- MPFC–Modified Power Filter Compensator
- PWM–Pulse Width Modulation

2. PROPOSED SYSTEM

The low cost modulated dynamic series-shunt power filter and compensator is a switched type filter, used to provide measured filtering in addition to reactive Compensation. The modulated power filter and compensator is controlled by the on-off timing sequence of the Pulse Width Modulation (PWM) switching pulses that are generated by the dynamic tri loop error driven fuzzy controller. The fuzzy controller is equipped with a error and error-sequenced compensation loop for fast effective dynamic response in addition to modified PID activation. This scheme of MPFC structure comprises a aeries fixed capacitor bank and two shunt fixed capacitor banks are connected to a modulated PWM switched tuned arm filter through six pulse uncontrolled rectifier. The mat lab model of this scheme Structure is shown in Fig. 1

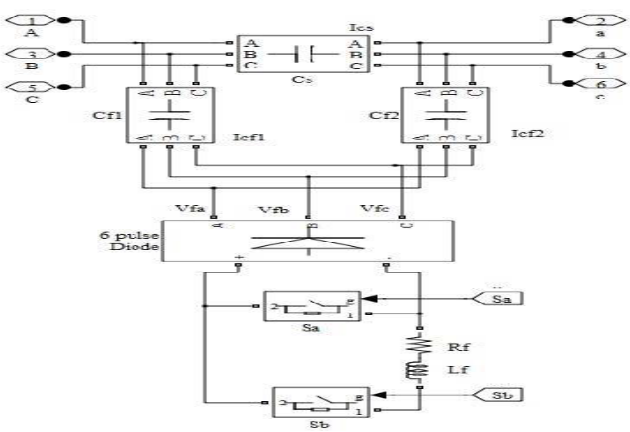

Fig. 1: Modified Power Filter Compensator

3. TRI LOOP ERROR DRIVEN PID CONTROLLER

The tri-loop error-driven dynamic controller is a novel dual action control used to modulate the power filter compensator [17, 18]. The global error signal is an input to the modified PID controller to regulate the modulating control signal to the PWM switching block as shown in Figs. 2. The modified PID includes an error sequential activation supplementary loop to ensure fast dynamic response and affective damping of large excursion, in addition to conventional PID structure.

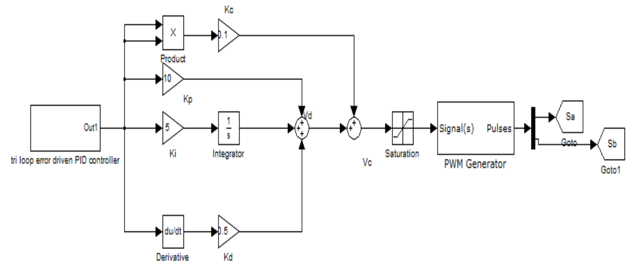

Fig. 2: Modified tri loop error driven PID controller

4. TRI LOOP ERROR DRIVEN FUZZY CONTROLLER

The tri-loop error-driven dynamic controller is a novel dual action control used to modulate the power filter compensator. The global error signal is an input to the fuzzy controller to regulate the modulating control signal to the PWM switching block as shown in Figs.3a&3b. The fuzzy controller includes an error sequential activation supplementary loop to ensure fast dynamic response and affective damping of large excursion, in addition to modified PID structure.

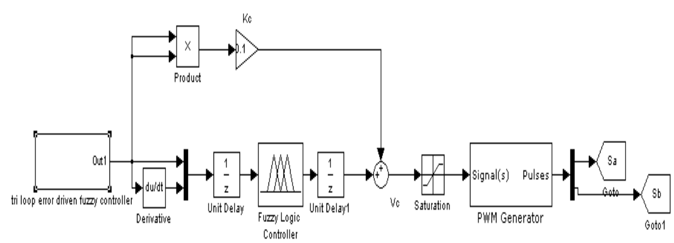

Fig. 3a: Modified tri loop error driven fuzzy controller

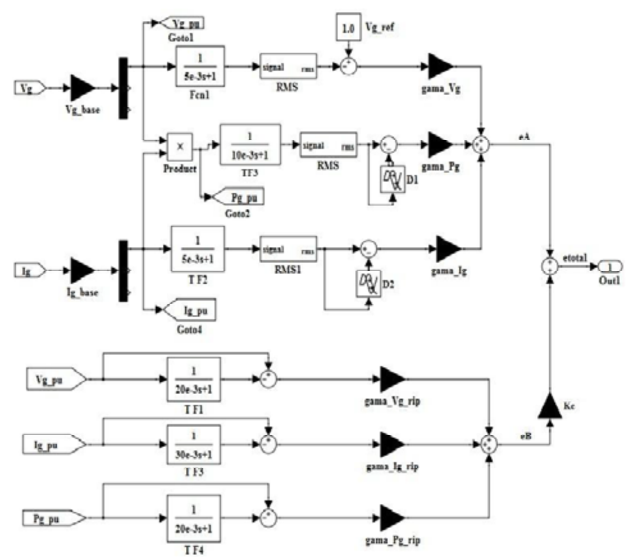

Fig. 3b: Matlab functional model of the Inter-coupled tri loop error driven fuzzy controller

5. AC STUDY SYSTEM

The sample study AC grid network is shown in Fig. 4. It comprises a synchronous generator (driven by steam turbine) delivers the power to a local hybrid load (linear, non-linear and induction motor load) and is connected to an infinite bus through 300 km transmission line. The system, compensator parameters are given in the Appendix.

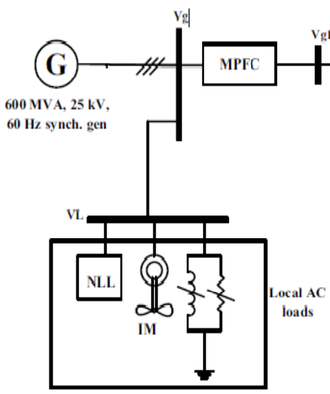

Fig. 4: The single line diagram of the unified EHV study AC system

6. DIGITAL SIMULATION RESULTS

The Mat lab digital simulation results using MATLAB/ SIMULINK/ Sim-power Software Environment for proposed MPFC Scheme under normal operation.

The dynamic responses of voltage, current and power factor at the generator bus and load bus obtained from the both PID and fuzzy controlled MPFC techniques are presented and compared in the below figures as shown in figures 6 to 11. The stable voltage signal of synchronous generator power system stabilization (PSS) is depicted in Fig. 12.

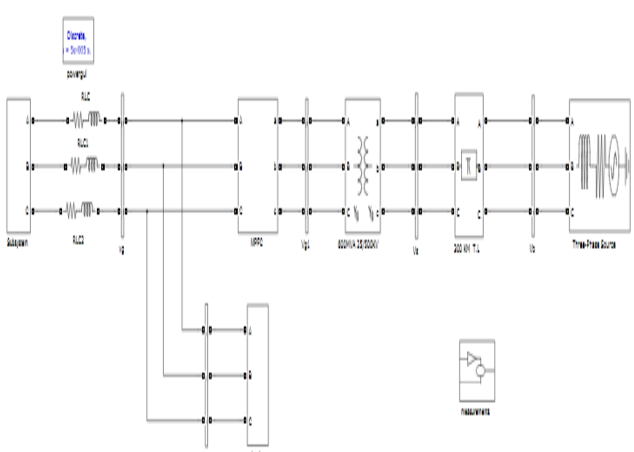

Fig. 5 Simulation model

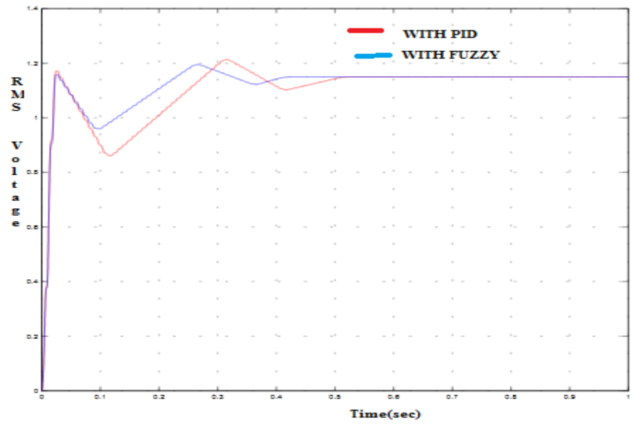

Fig. 6:The RMS voltage at AC buses under normal operation for Generator bus

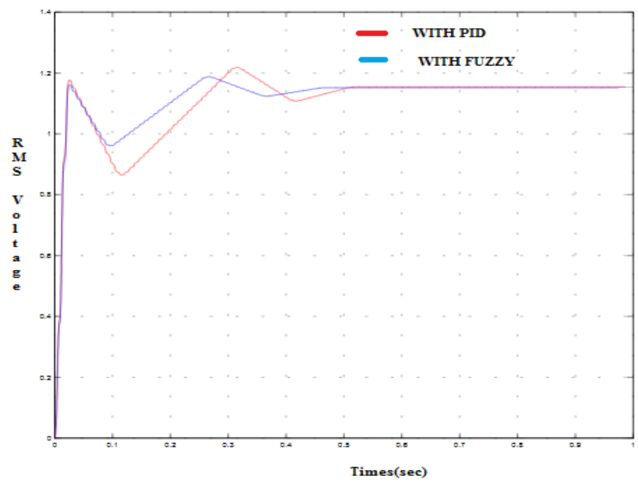

Fig. 7: The RMS voltage at AC buses under normal operation for Load bus

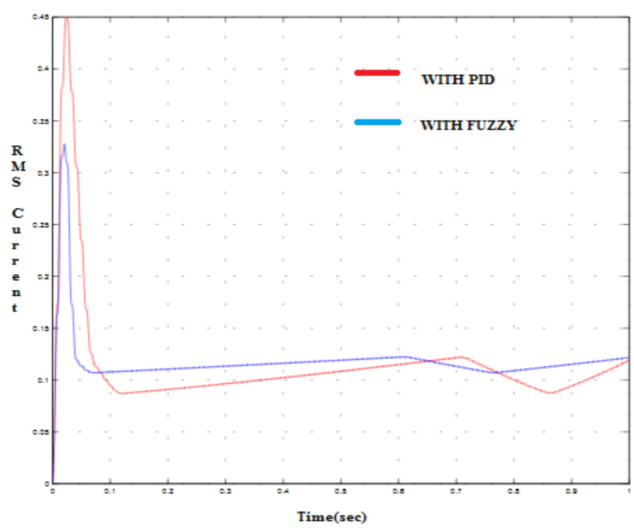

Fig. 8: The RMS current at AC buses under normal operation for generator bus

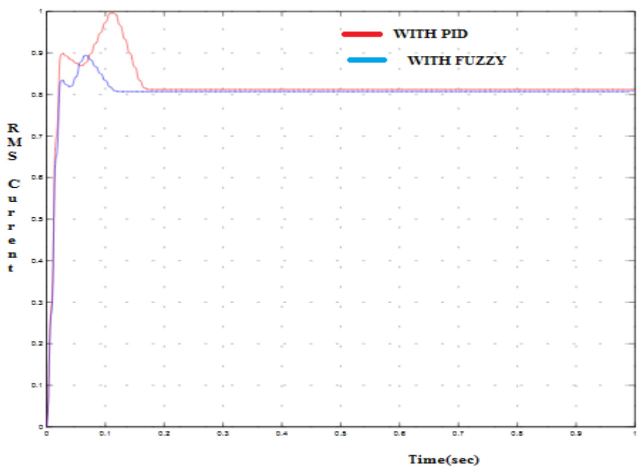

Fig. 9: The RMS current at AC buses under normal operation for Load bus

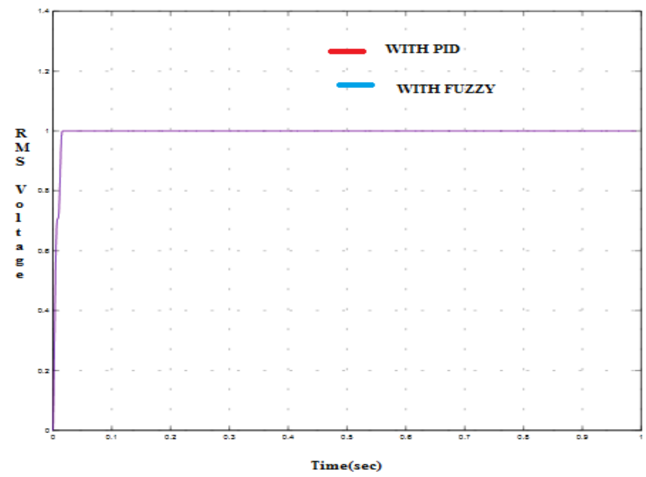

Fig. 10: The RMS voltage at the infinite bus under normal operation

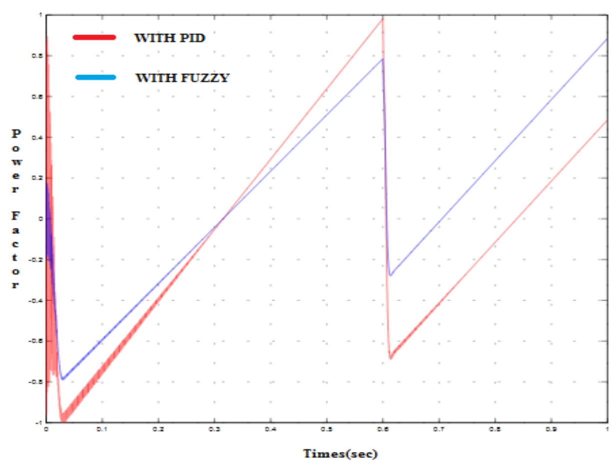

Fig. 9: The power factor at AC buses under normal operation for generator bus

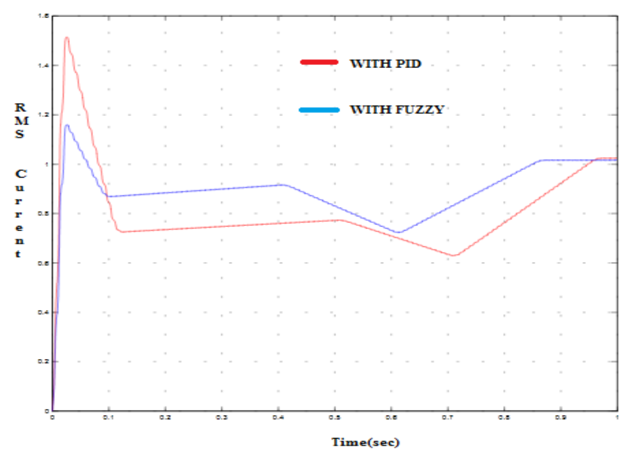

Fig. 11: The RMS Current at the infinite bus under normal operation

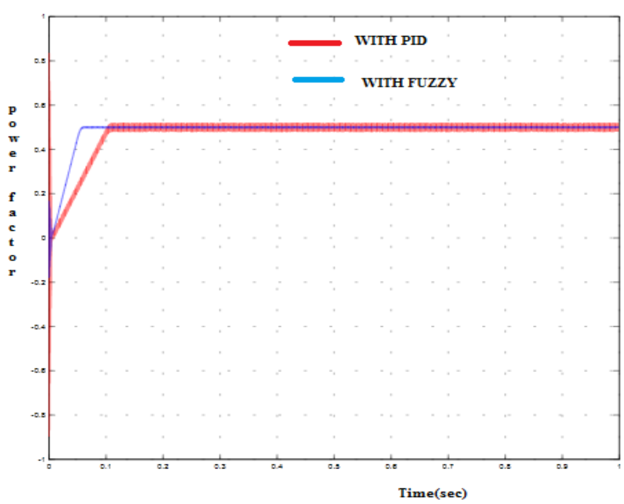

Fig. 9: The power factor at AC buses under normal operation for Load bus

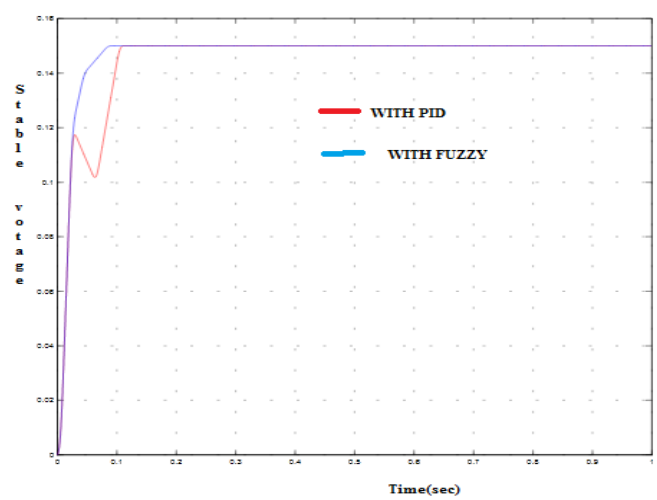

Fig. 12: Power System Stabilization voltage signal

From the above results, it is concluded that each response obtained with Fuzzy controller is more stable compared to the responses by PID controller.

B. Comparison of PID and Fuzzy Controllers in terms of THD

The Total Harmonic Distortion in voltage and current waveforms at the load bus and infinite bus is reduced in the case of Fuzzy controller compared to PID controller.

The obtained THD values by the both controlling techniques are presented and compared in the table I.

Table I: Comparison of THD Values

Type of bus	Parameter	Total Harmonic Distortion (in %)	
		With PID	With Fuzzy
Load Bus	Voltage	9.41	6.27
	Current	15.51	10.57
Generator Bus	Voltage	0.06	0.03
	Current	18.06	12.37

7. CONCLUSION

In this paper,a novel modulated switched power filter compensator (MPFC) scheme is controlled by a dynamic tri loop dynamic error driven fuzzy controller. The proposed FACTS based scheme can be extended to other distributed/dispersed renewable energy interface and utilization systems and can be easily modified for other specific compensation requirements, voltage stabilization and efficient utilization. The proposed MPFC scheme has been validated for effective power quality improvement, voltage stabilization, and power factor correction when the system is extensively simulated in MATLAB/SIMULINK

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