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Comparison study of Controllers implemented in STATCOM for mitigation of Voltage fluctuations in Microgrid

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***Abstract*— Microgrid has been receiving increased popularity these days in latest Power system trends due to its unique features such as Standalone, Distributed/Decentralized energy production and also effectively incorporates various sources of distributed generation sources predominantly Renewable energy sources thus making it more economical and eco friendly. The Controller of Power electronic devices utilized in Microgrid play a major role in mitigating power quality issues present in Microgrid. A comparison study of two controllers used in STATCOM in mitigating Voltage sag and swell that occur in Microgrid powered by Renewable energy (Solar Energy) and proposed the best controller among them by simulating each of them under Standard operating condition. The main controllers that have been considered are PI controller and Fuzzy logic, the latter which has been found out to be the best among them. The Controllers are chosen by studying almost all of the important controllers which are currently used in power system and thus studying of these both controller simulations and comparing their THD values helps in determining the best among them. The reliability and effectiveness of each controller considered is demonstrated by base Microgrid example with standard specifications.**

Keywords : Microgrid,Voltage Sag and Swell, PI controller, Fuzzy logic, STATCOM, THD

I INTRODUCTION

In this project we have done a comparison study of controllers which are implemented in STATCOM for reactive power compensation in Microgrid [1]. A microgrid is a group of interconnected loads and distributed energy resources within clearly defined electrical boundaries that acts as a single controllable entity with respect to the grid. A microgrid can connect and disconnect from the grid to enable it to operate in both grid-connected or island-mode [2].Real-time power is most expensive at times of greatest demand when the grid is most stressed or there is congestion in the local power distribution zone. By generating power and minimizing demand on the grid during peak times, microgrids can help reduce the requirement for additional utility generation, transmission and distribution assets – costs that are passed on to the ratepayers.A microgrid strategy that integrates local wind or solar resources can provide redundancy for essential services and make the main grid less susceptible to localized disaster.By joining together with smart grid deployments, excess energy can be sold back to local microgrids to create revenue in addition to providing resilience and capacity to local electrical grids.

Irrespective of their numerous advantages, implementing microgrids faces serious challenges such as Power Quality issues and Synchronisation with main grid. The major issue in Microgrid is that unlike the conventional grid where the generation side is constant and load side is variable, in microgrid both are variable due to Renewable energy sources. Due to this Microgrids are more susceptible to voltage fluctuations which results poor voltage regulation and power quality. STATCOM is a FACTS device which act either as source or sink of reactive AC power when connected to the grid [3]. It is a shunt device and is commonly used for improving voltage regulation and power factor of the grid. Compared to SVC, STATCOM has faster response time and better transient stability [7]. By connecting STATCOM to the PCC we mitigate the voltage fluctuations that occur in the microgrid. The controllers implemented in STATCOM play a major role in the operation of STATCOM. By utilizing an Apt Controller we can improve the Robustness, Flexibility, Response time and System Stability drastically. There are many controllers used in power system such as PI, Fuzzy logic, Hysteresis, dead beat, bang-bang controller etc. Among all of these controllers we have chosen PI and Fuzzy

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Logic controller for comparison due to their reliability, robustness, simplicity and practical feasibility.

II SYSTEM CONFIGURATION

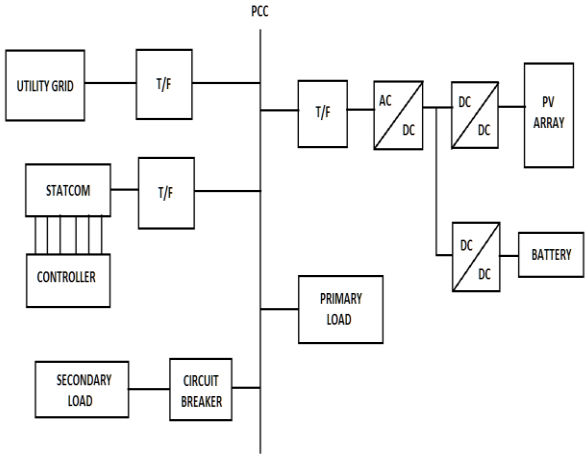


Fig. 1 Simplified Block diagram

The above figure shows the microgrid model we have considered for implementation of the two controllers and to perform the comparison study. A three phase AC source of 11KV (Utility grid) is stepped down to 400V by a 11KV/400V step down three phase transformer and connected to the microgrid at PCC. The microgrid consists of Solar array whose boosted DC output voltage is 72V. This DC voltage is converted to AC output voltage through inverter and stepped up as 400V AC voltage. A Battery energy storage system of capacity 40Ah is used to store energy from PV array and discharge during peak demand. A primary load of resistance 250 ohms which is connected to the system all the time. To create an artificial Voltage sag for a short period of time 0.1 second, a secondary load of resistance 70 ohms is connected for 0.1 seconds and then disconnected by a circuit breaker. Therefore by connecting STATCOM at the PCC, voltage regulation at the bus are accomplished. The STATCOM consist of three leg voltage source inverter using six IGBTs thyristor switches with interface inductor (Lf), dc link capacitor. The switching transients which occur when STATCOM is switched, can be controlled by connecting a three phase capacitor ripple filter (Cf). The modulated control switching signals to the VSI STATCOM is obtained by applying ABC to DQ transformation and inverse after performing controller operation.

III PI CONTROLLER

The Proportional-Integral (PI) controller computes and transmits a controller output (CO) signal every sample time T, to the final control element. The computed CO from the PI algorithm is influenced by the controller tuning parameters and the controller error, e(t).PI controllers have two tuning parameters to adjust.Integral action enables PI controllers to eliminate offset, a major weakness of a P-only controller. Thus, PI controllers provide a balance of complexity and capability that makes them by far the most widely used controller in process control applications.

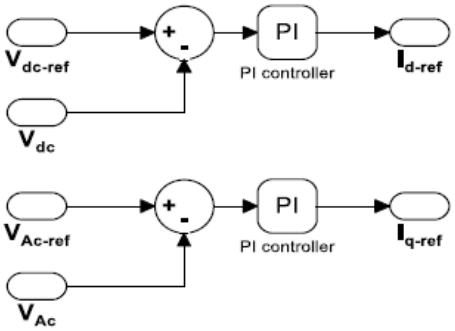


Fig. 2 PI Control scheme

The above PI control scheme is used to generate Id and Iq reference value which is once again fed to two more PI controllers [4]. The outputof those two controllers are converted back to ABC frame by DQ to ABC transformation technique. Finally firing pulses are generated by Hysteresis current controller.

IV FUZZY LOGIC CONTROLLER

Fuzzy logic is a method of easily representing analog processes on a digital computer. Fuzzy models or sets are mathematical means of representing vagueness and imprecise information, hence the term fuzzy. These models have the capability of recognizing, representing, manipulating, interpreting, and utilizing data and information that are vague and lack certainty. The input values are converted in fuzzified inputs based on rules set in the system. These inputs are further processed based on the rules defined by us and the output is once again defuzzified to numerical values.

The below diagrams show the membership function of two input parameter change in error and error input along with membership function of output parameter. NL : Negative Large, NM : Negative Medium, NS : Negative Small, Z : Zero, PS : Positive Large, PM : Positive Medium and PL : Positive Large. Membership function represents the degree of truth in fuzzy logic. Membership functions are represented by graphical forms. There are six types of Fuzzy membership function. They are triangular, trapezoidal, Z shape, S shape, Sigmoid and Gaussian. The membership function we have chosen here is triangular. Each fuzzy set overlap one another which in turn gives the controller smooth and stable surface. The overlap can be in the range of 10 to 50 percent of

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neighouring space and the total sum of vertical points in an overlap must ne less than 1[6].

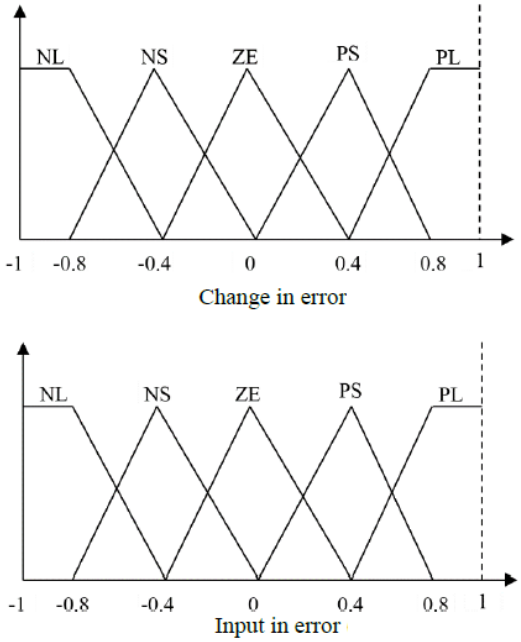


Fig. 3 & 4 Fuzzy Input Parameters

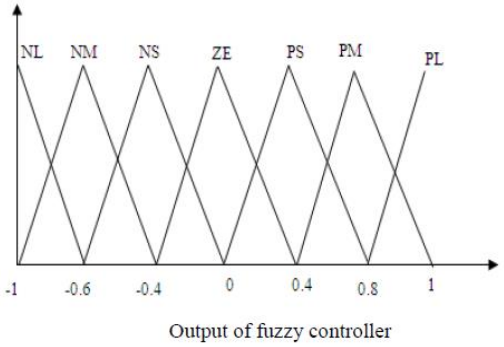


Fig. 5 Fuzzy Output Parameter

The below table shows the fuzzy rules of the proposed system [5].This fuzzy rules generated based on the error (d/de). In the table d is indicated as error and de indicated as change in error.

de / d	NL	NS	Z	PS	PL
NL	NL	NL	NM	NS	Z
NS	NL	NM	NS	Z	PS
Z	NM	NS	Z	PS	PM
PS	NS	Z	PS	PM	PL
PL	Z	PS	PM	PL	PL

Fig. 6 Fuzzy rules for the proposed system

Similar to PI Controller the output of fuzzy logic controller is converted back to ABC frame before Firing pulses are generated.

V ANALYSIS

The simulink model of system is simulated with each controller implemented at a time. The moment the load is connected and a voltage sag is detected both the controllers produce firing angles and maintain the voltage stability. To determine the best controller among two we compare the simulation results of Load voltage and THD values of load voltage and load current under two controllers.

VI SIMULATION RESULTS AND DISCUSSIONS

The proposed system for comparison study is run using MATLAB/SIMULINK using synchronous reference frame control algorithm under both PI and Fuzzy logic controller. The model is used for voltage regulation at PCC and observed under two different controllers.

Without compensation:

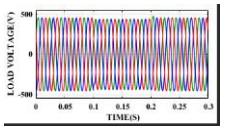


Fig. 7 Voltage Sag at Load voltage

The above simulation diagram represents the voltage sag that occur in Load voltage form the interval period of 0.1 to 0.2 seconds.

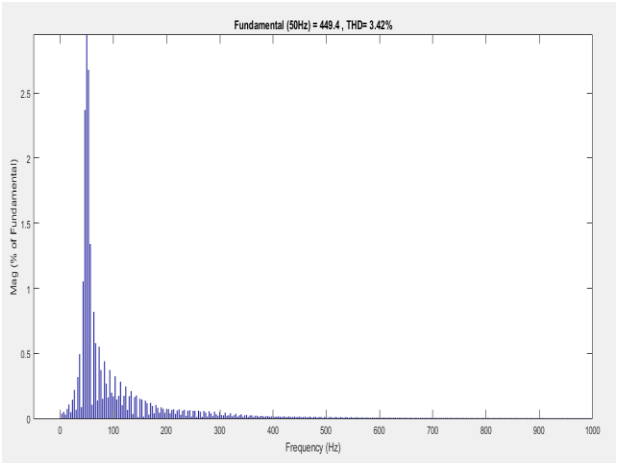


Fig. 8 THD value of Load voltage

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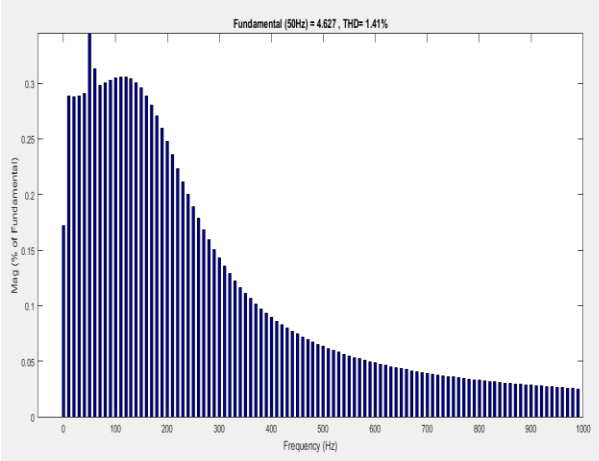


Fig.9 THD value of Load current

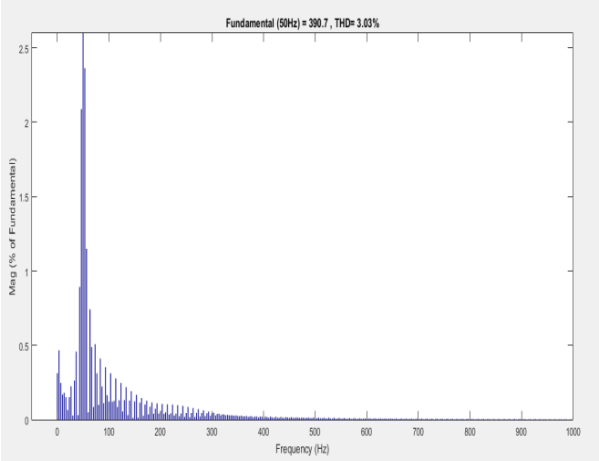


Fig. 12 THD value of Load voltage

With PI Controller :

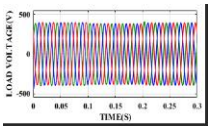


Fig. 10 Load Voltage with PI implemented

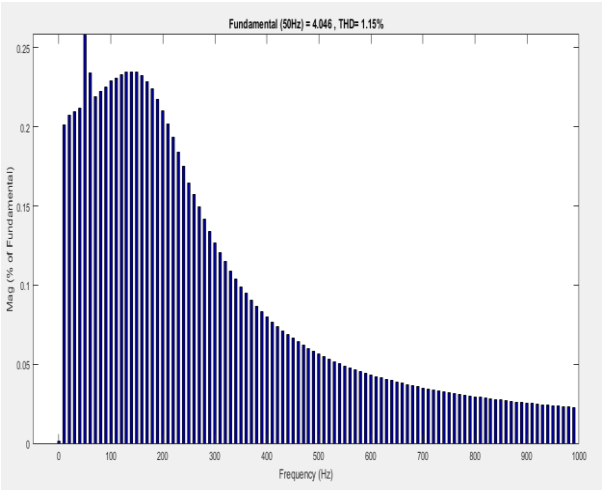


Fig. 13 THD value of Load current

With Fuzzy Logic controller:

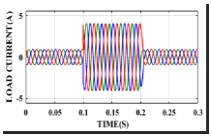


Fig. 11 Load current with PI implemented

The above two simulations represent the compensated smooth voltage and current at Load side due to compensation provided by STATCOM with PI Controller implemented. During interval of 0.1 to 0.2 seconds due to sudden increase in load there is a increase in magnitude of the Load current during that interval. The below two diagrams represent the THD values measured in both Voltage and current by FFT analysis in MATLAB.

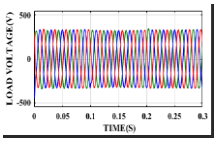


Fig. 14 Load voltage with Fuzzy implemented

Similarly these two simulations represent the compensation provided by STATCOM with Fuzzy Logic Controller implemented. The other two diagrams represent the THD values measured in both Voltage and current.

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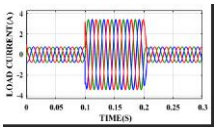


Fig. 15 Load current with Fuzzy implemented

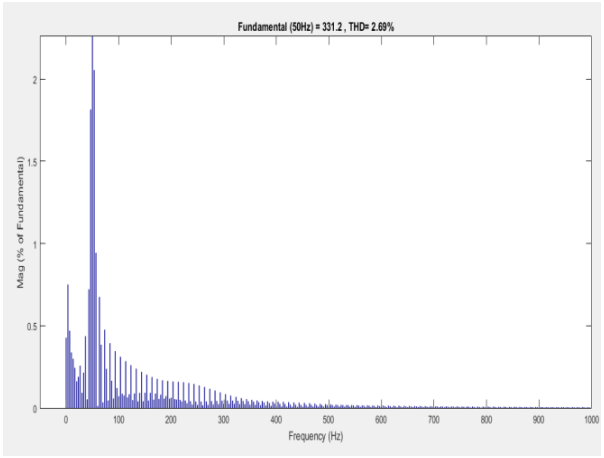


Fig. 16 THD value of Load voltage

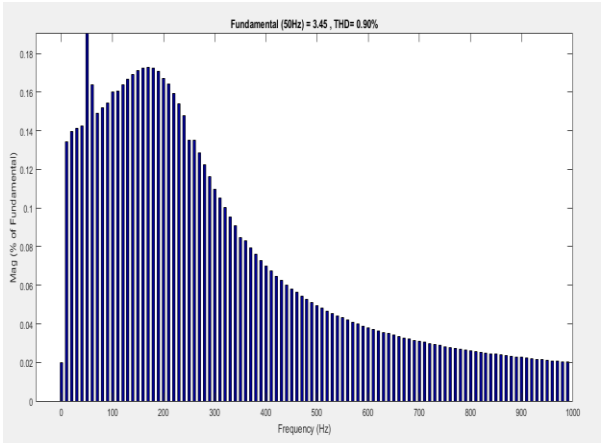


Fig 17. THD value of Load current

Table 1

Parameters	Controllers		
	Without Compensation	With PI	With Fuzzy Logic
Voltage THD	3.42%	3.03%	2.69%
Current THD	1.41%	1.15%	0.90%

VII CONCLUSION

In this paper, the performance of VSI based STATCOM has been analyzed using the synchronous reference frame control algorithm for the compensation of reactive power, harmonic and voltage regulation in a Microgrid. The simulation results for the proposed system is analyzed and compared separately with PI and FUZZY logic controller. The PCC bus voltage is maintained constant during voltage fluctuations for both controllers. Both the controllers have provided good compensation, but fuzzy logic controller has superior performance. The simulation results obtained and the comparison in THD values show Fuzzy logic controller having better response to voltage fluctuations hence produce quality power output.

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