Simulation Modeling & Analysis of Generalized Unified Power Flow Controller (GUPFC) for Power Profile Improvement

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Abstract

The FACTS (Flexible AC Transmission Systems) is a modern technology based on power electronic device controllers introduce by Dr. N.G. Hingorani in 1970s which has been used in power systems for enhancing the existing transmission capabilities and improvement in dynamic performance of electrical power system in order to make the transmission line system more flexible and efficient in operation. This paper deals with the simulation and analysis of Generalized Unified Power Flow Controller (GUPFC) or multi-line Unified Power Flow Controller (UPFC) which is the novel concept for controlling the bus voltage and power flows of more than one line or even a sub-network. In this paper Generalized Unified Power Flow Controller (GUPFC) has been analysed for both open loop and close loop configuration. For this a Single Machine Infinite Bus (SMIB) system is simulated. Sine Pulse Width Modulation (SPWM) control strategy has been used for open loop system configuration and PI controller is used for close loop system configuration. The simulation results have been compared for both uncompensated system and GUPFC in open loop and close loop system configuration which demonstrate the performance after compensating the system. It gives the clear observation of performance improvement in power profile of the power system in given network. For analysing the THD (Total Harmonic Distortion) level of the system the FFT (Fast Fourier Transform) analysis for GUPFC in open loop and close loop has been done. All simulations and analysis has been carried out in MATLAB12a/SIMULINK environment.

Index Terms— FACTS, SMIB System, GUPFC, FFT Analysis, Reactive power compensation

1. Introduction

In Modern complex power system, better power quality is necessary to fulfil the increased demand. Due to the advanced technologies being used for improving power system security, reliability and profitability the power quality is need to be improved. For this it is essential to improve the power profile of the transmission network.

Since the reactive power is very precious in keeping the voltage of power system stable the reactive power flow control in the network is essential to achieve optimum performance of power system. Because of new transmission line networks and power stations, variety of loads and transformers the problem of system operation as well as the voltage collapse occurs in power system when system is faulted, heavily loaded and there is a sudden increase in the demand of reactive power. When voltage fluctuations are there the system is unable to meet the reactive power demand and the loading of long transmission lines increased which causes voltage instability & reactive power imbalance in power system.

So, there was a greater need of the alternative technology made of solid state devices with fast response characteristics because of slow responses of traditional conventional devices which is not being able to achieve desired performance effectively.

With the invention of semiconductor device like thyristor switch the door for the development of power electronics devices known as Flexible AC Transmission Systems (FACTS) controllers opened. FACTS device are power electronic based semiconductor device which can inject or absorb reactive power in a system as per requirement and one of the most important reactive power sources.

2. Introduction of Generalized Unified Power Flow Controller (GUPFC)

An innovative approach of utilization of complex FACTS controllers providing a multifunctional power flow management device was proposed in [1] and [2]. There are several possibilities of operating configurations by combing two or more converter blocks with flexibility. Among them, there is a novel operating configuration, namely the Generalized Unified Power Flow Controller (GUPFC) which is significantly extended to control power flows of multi-lines or a sub-network rather than control power flow of single line by a Unified Power Flow Controller (UPFC) or Static Synchronous Series Compensator (SSSC) [4].

A fundamental model of the GUPFC consisting of one shunt converter and two series converters which can be increase if needed as shown in fig.2.1.

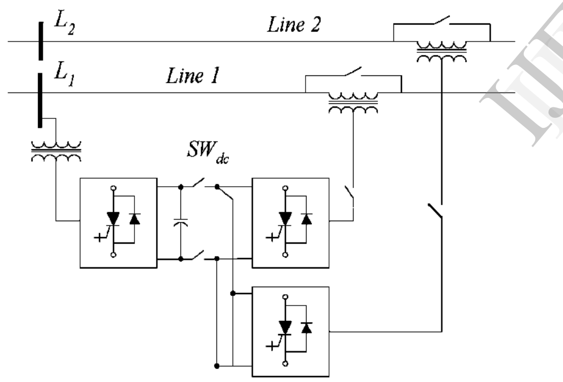

Fig.2.1 Generalized Unified Power Flow Controller (GUPFC)

The topology shown in the figure consist one shunt connected VSC and two series connected VSC. Here also the shunt converter STATCOM (Static Synchronous Compensator) is used to provide reactive power to the ac system and it will provide the dc supply required for both series connected VSC. The series connected VSCs are SSSC (Series converter or Static Synchronous Series Compensator) which are used to add controlled voltage magnitude and phase angle in series with the both line. With injection of a voltage in series with its host lines the primary function of the GUPFC is power-flow control in transmission network. The GUPFC controls the magnitude and phase angle of the injected voltages in each line, resulting in four degrees of freedom. Hence, they have the capability to precisely control power flow in two different transmission lines.

3. Simulation & performance analysis of Uncompensated System Model

The simulated model of basic uncompensated double conductor transmission line is shown below in Single Machine Infinite Bus (SMIB) system in Fig. 3.1.

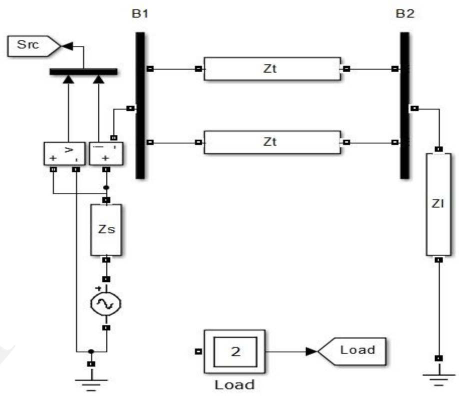

Fig.3.1 Uncompensated System Model

Here 440 V, 50 Hz transmission line is shown where the source impedance Zs is (0.01 + j0.001) Ω and the transmission line impedances Zt for line1 and line2 (0.1 + j1.57) Ω are considered. The load rating is (20 + j6.28) Ω considered. These ratings are kept constant for all analysis.

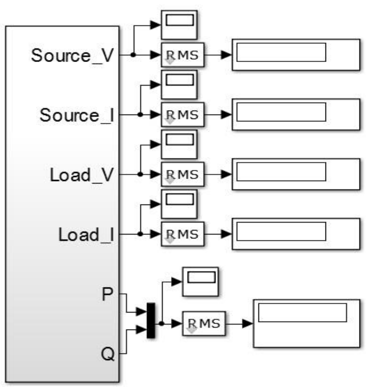

Fig.3.2 Signal Measurement subsystem

Fig.3.2 shows the signal Measurement system in which the voltage & current measurement block is used to measure source and load instantaneous voltage & current flowing in the transmission line. The active & reactive Power measurement block is used to measure the real power and reactive power in the load which is shown in Fig.3.3. Scope displays the signal generated during a simulation.

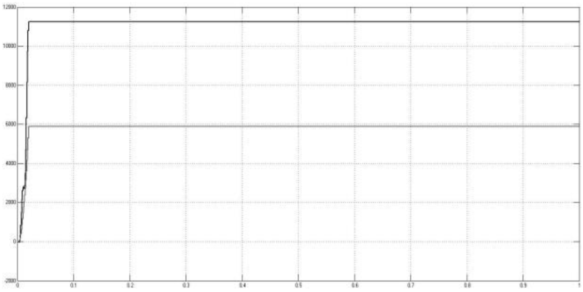

Fig.3.3 Active and Reactive Power

Here real and reactive power flow is obtained without any compensation. Here the active power (P) is 11.23 Kw and reactive power (Q) is 5.88 Kvar for uncompensated system model. For both compensated system models, generated waveforms are taken and calculations are done for the common parameters capacitor (C) 2000µF, sampling time 25e-3 sec. and load rating of (20 + j6.28) Ω constant for open loop and close loop configuration respectively. Here device is inserted at 0.1sec in the transmission system model.

4. Simulation & performance analysis of GUPFC compensated System Model

The simulated model of GUPFC with source voltage of 440V, 50Hz is shown below in Fig. 4.1. Here mid-point compensation is done at both lines.

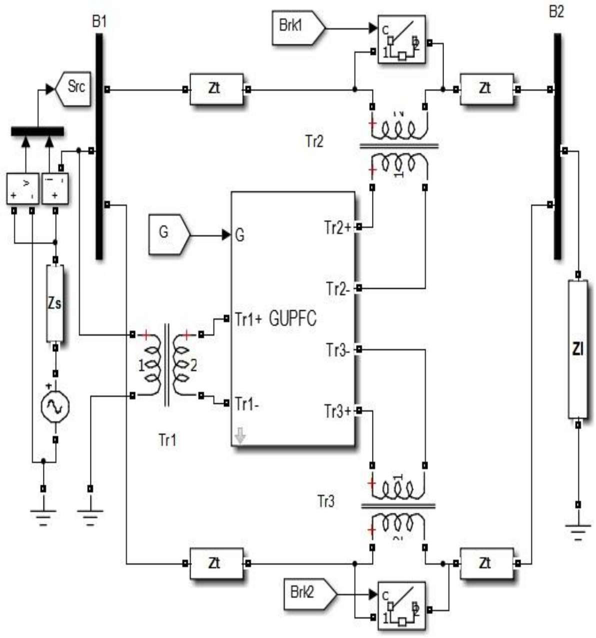

Fig.4.1 GUPFC compensated System Model

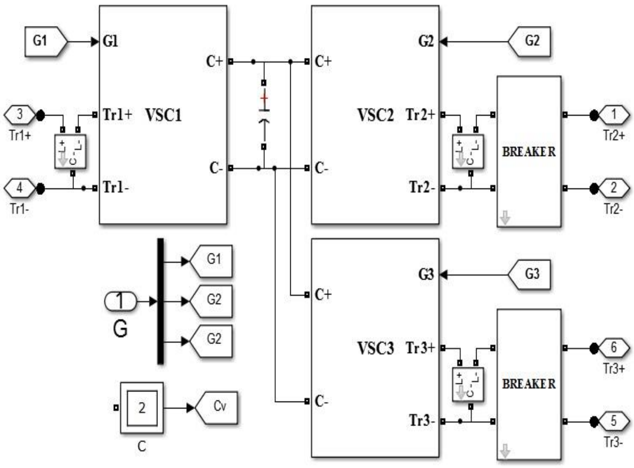

Fig.4.2 GUPFC Subsystem Model

Fig.4.2 shows the GUPFC device subsystem where three VSCs are shown. Here LC filters are used to reduce harmonics from the system and breakers are used to insert device in transmission system.

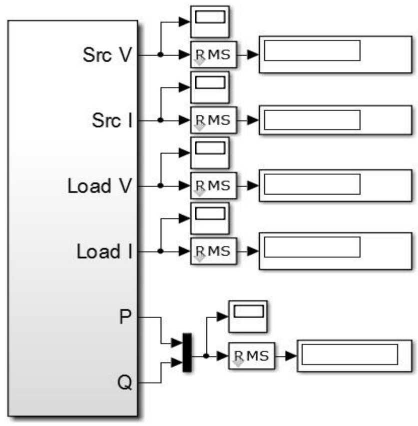

Fig.4.3 GUPFC Signal Measurement system 1

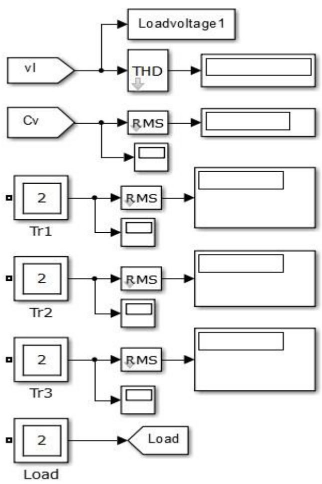

Fig.4.4 GUPFC Signal Measurement system 2

Fig.4.3 and 4.4 shows the signal measurement system which measures source and load voltage & current, all transformers and capacitor voltage and current. Also the THD (Total Harmonic Distortion) block is used to measure the THD level of the system. Here the GUPFC compensated system model analysis is done in both open loop and close loop system.

4.1 Open loop GUPFC

In open loop system configuration for achieving the desired system performance SPWM (Sine Pulse Width Modulation) control strategy is used. For this the sine waveform of 625 v (440 rms) , 50Hz is given to the discrete PWM block with the sampling frequency of 2 KHz for generating the pulses continuously which feds as the gate signals for GUPFC as shown in Fig. 4.1.1.

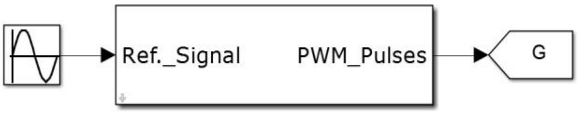

Fig.4.1.1 SPWM pulse generator for open loop GUPFC

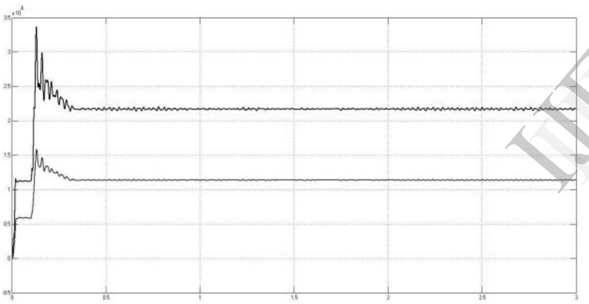

Fig.4.1.2 Active and Reactive power for open loop GUPFC

Fig.4.1.2 shows the active & reactive power of the system measured by the scope. Here the active power (P) is 21.72 Kw and reactive power (Q) is 11.37 Kvar for open loop GUPFC system model.

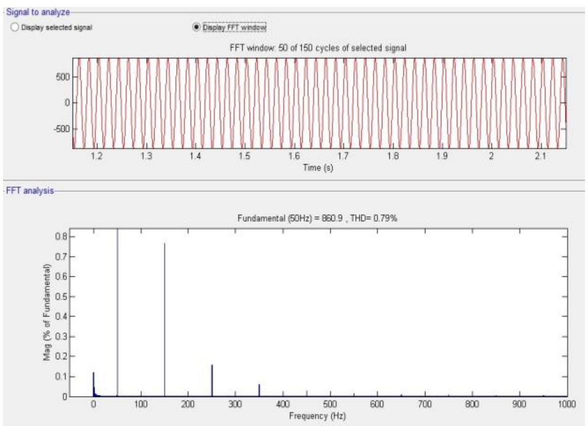

Fig.4.1.3 Voltage THD (FFT analysis) for open loop GUPFC

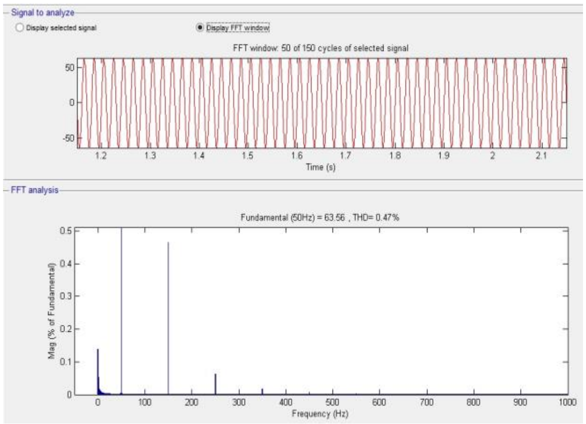

Fig.4.1.4 Current THD (FFT analysis) for open loop GUPFC

The FFT (fast fourier transform) analysis of this system shows 0.79% of voltage THD level and 0.47% of current THD level as shown in fig. 4.1.3 and 4.1.3.

4.2 Close loop GUPFC

For close loop system PI controller as shown in fig.4.2.1 is used in a reference tracking mode for achieving the desired system performance. Here for controlling the load voltage in a specific range the measured load voltage is given to the PI controller. Also the reference sine wave controlled by gain which is adaptive in nature is given for tracking purpose. The PI controller generates PWM pulses for GUPFC according to the parameters of system voltage.

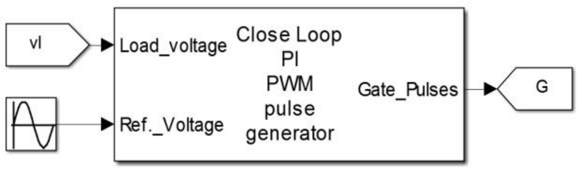

Fig.4.2.1 PI PWM pulse generator for close loop GUPFC

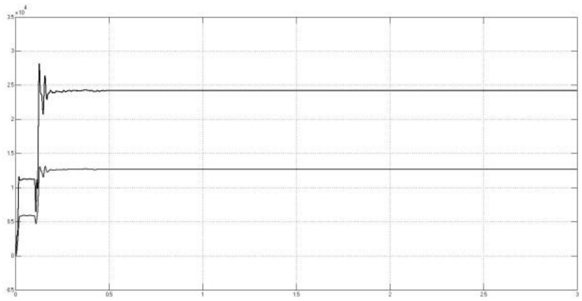

Fig.4.2.2 Active and Reactive power for close loop GUPFC

Fig.4.2.2 shows the active & reactive power of the system measured by the scope. Here the active power (P) is 24.23 Kw and reactive power (Q) is 12.69 Kvar for close loop GUPFC system model.

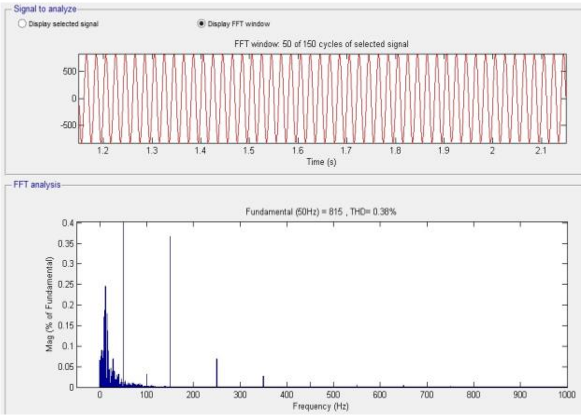

Fig.4.2.3 Voltage THD (FFT analysis) for close loop GUPFC

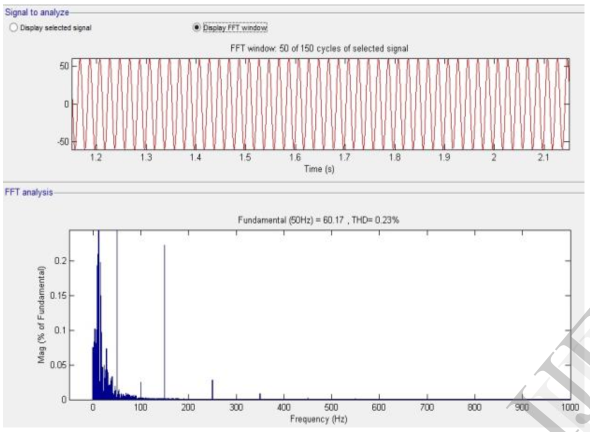

Fig.4.2.4 Current THD (FFT analysis) for close loop GUPFC

The FFT (fast fourier transform) analysis of this system shows 0.38% of voltage THD level and 0.23% of current THD level as shown in fig. 4.2.3 and 4.2.4.

5. Result

Here for the uncompensated system model and both compensated system models the comparisons are done for the common parameters as mentioned above. The results are tabulated below.

FACTS Device	Open loop System		Close loop System	
	Active power (P) Kw	*Reactive power (Q) Kvar*	*Active power (P) Kw*	*Reactive power (Q) Kvar*
GUPFC	21.72	11.37	24.23	12.69

Table 5.1 Active and Reactive power of GUPFC

Here table 5.1 shows the comparative values of active and reactive power for GUPFC in open loop and close loop system.

Fig.5.1 shows graphical comparison of Active power (P) Kw and Reactive power (Q) Kvar between uncompensated transmission line and Generalized Unified Power Flow Controller (GUPFC).Also fig.5.2 shows comparison of inverter output voltage and load voltage graphically.

Fig.5.3 contains the FFT analysis for device in both open loop and close loop which shows THD level of the system. The figure shows voltage THD and current THD level for both configuration of GUPFC.

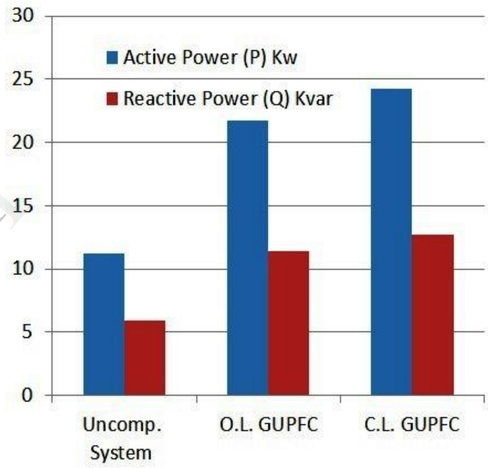

Fig.5.1 Comparison of Active and Reactive power

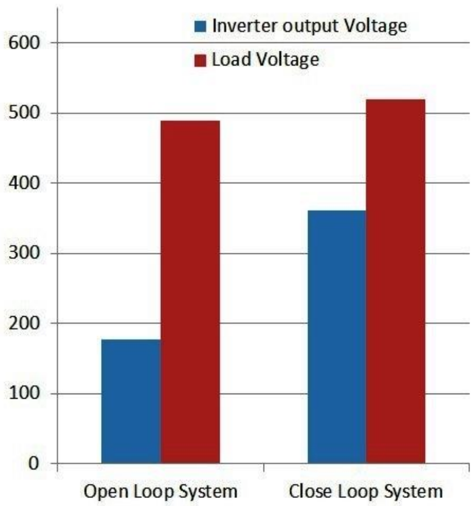

Fig.5.2 Comparison of Voltage level

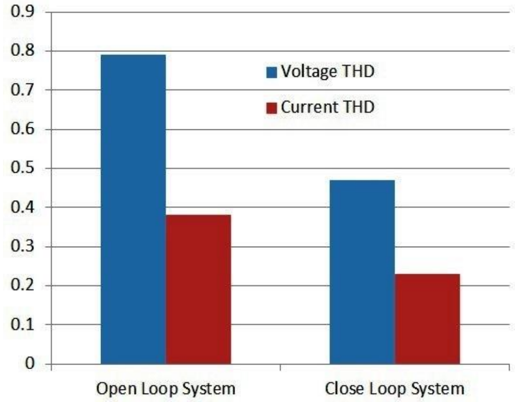

Fig.5.3 Comparison of %THD levels

Form all results shown above it is clearly shown that after introducing GUPFC in the system it is improving the active and reactive power of the network, hence improving the power profile of the system. It is also shown from the results for both open loop and close loop system that the performance of PI control strategy is improved from SPWM control strategy and better performance achieved. The THD (fast fourier transform) analysis of the load in network for both voltage and current also shows the improved performance analysis in case of close loop system.

6. References

[1] Rishabh shah, Sarafraz Gandhi, Bhavin Trivedi "Simulation and Performance Evaluation of UPFC and IPFC for Power System Performance Enhancement",International Journal Of Engineering Development And Research 2013, ISSN: 2321-9939

[2] Rishabh Shah, Nehal Patel "Simulation Modeling & Comparison of Various FACTS Devices for Reactive Power Control In Power System", Emerging vistas of technology in 21st century 2013, ISBN 978-93-82880-34-9

[3] S.Muthukrishnan, A.Nirmalkumar,"Comparison and Simulation of Open Loop System and Closed Loop System Based UPFC used for Power Quality Improvement" International Journal of Soft Computing and Engineering (IJSCE) ISSN: 2231-2307,Volume-1, Issue-6, January 2012

[4] Xiao-Ping Zhang, "Modeling of the Generalized Unified Power Flow Controller (GUPFC) in a Nonlinear Interior Point OPF", IEEE Transactions On Power Systems, Vol. 16, No. 3, August 2001, ISBN 0885–8950/01

[5] R. Mohan Mathur, Rajiv K. Varma, " Thyristor-Based Facts Controllers For Electrical transmission Systems" IEEE Press, John Wiley & Sons, Inc. Publication, ISBN 0-471-20643-1

[6] N. G Hingorani & Laszlo Gyugyi, "Understanding FACTS: concepts and technology of flexible AC transmission System", IEEE Press, New York (2000).