Comparison of Simulation and Experimental Results of UPFC used for Power Quality Improvement

S. Muthukrishnan and Dr. A. Nirmal Kumar

Abstract— **This paper deals with digital simulation and implementation of power system using UPFC to improve the power quality. The UPFC is also capable of improving transient stability in a power system. It is the most complex power electronic system for controlling the power flow in an electrical power system. The real and reactive powers can be easily controlled in a power system with a UPFC. The circuit model is developed for UPFC using rectifier and inverter circuits. The control angle is varied to vary the real and reactive powers at the receiving end. The Matlab simulation results are presented to validate the model. The experimental results are compared with the simulation results.**

Index Terms— **UPFC, Power Quality, Statcom, Compensation and matlab simulink**

I. Introduction

The power-transfer capability of long transmission lines are usually limited by large signals ability. Economic factors, such as the high cost of long lines and revenue from the delivery of additional power, give strong incentives to explore all economically and technically feasible means of raising the stability limit. On the other hand, the development of effective ways to use transmission systems at their maximum thermal capability has caught much research attention in recent years. Fast progression in the field of power electronics has already started to influence the power industry. This is one direct outcome of the concept of flexible ac transmission systems (FACTS) aspects, which has become feasible due to the improvement realized in power-electronic devices. In principle, the FACTS devices could provide fast control of active and reactive power through a transmission line. The unified power-flow controller (UPFC) is a member of the FACTS family with very attractive features. This device can independently control many parameter, so it is the combination of the properties of a static synchronous compensator (STATCOM) and static synchronous series compensator (SSSC) [1].

These devices offer an alternative mean to mitigate power system oscillations. Thus, an important question is the selection of the input signals and the adopted control strategy for these devices in order to damp power oscillations in an effective and robust manner. Much research in this domain has been realized [2]-[4]. This research shows that UPFC is an effective device for this purpose.

The UPFC parameters can be controlled in order to achieve the maximal desired effect in solving first swing stability problem. This problem appears for bulky power systems with long transmission lines.

Various methods to reference identification of the series part, in order to improve the transient stability of the system based on: "optimal parameters"[2], "state variables"[3], and also "injection model" were studied. Finally, a new identification method based on "state variables" was proposed[4].

This paper is organized as follows. After this introduction, the principle and operation and of a UPFC connected to a network are presented. In section II, the control strategy for UPFC is introduced. Simulation results are presented in sections III. Section IV describes the conclusion.

II. UPFC System

A simplified scheme of a UPFC connected to an infinite bus via a transmission line is shown in Fig.1. UPFC consists of parallel and series branches, each one containing a transformer, power-electric converter with turn-off capable semiconductor devices and DC circuit. Inverter 2 is connected in series with the transmission line by series transformer. The real and reactive power in the transmission line can be quickly regulated by changing the magnitude (V_b) and phase angle (δ_b) of the injected voltage produced by inverter 2. The basic function of inverter 1 is to supply the real power demanded by inverter 2 through the common DC link. Inverter 1 can also generate or absorb controllable power [5],[6]. New method for improving transient stability is given in [7].

Application of UPFC in interconnected power system by presented in [8]. Enhancing transient stability using Fuzzy control is given in [9]. Comparison of field results and simulation results of VSI based facts controller is given in [10].

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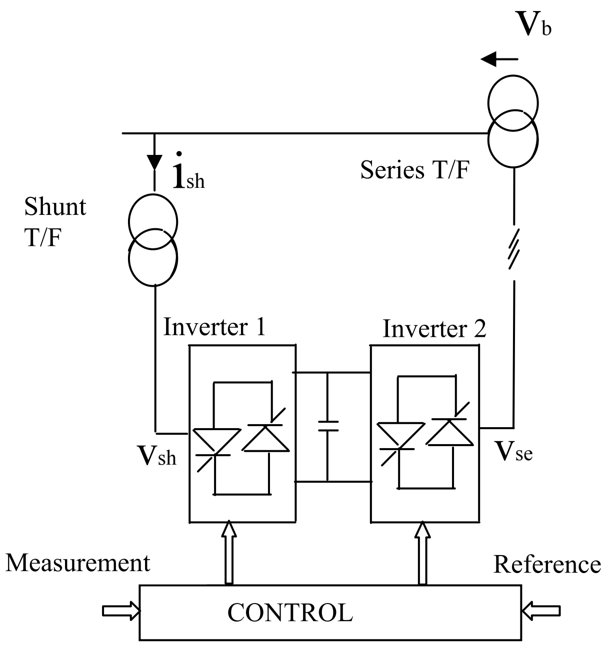

Fig1. UPFC Installed in a Transmission Line

Literature [1] to [12] does not deal with the embedded implementation of UPFC. Evaluation of shunt and serried power conditioning strategies for feeding sensitive loads is given [11]. Analysis of series compensation and DC link voltage control of DVR is given by [12]. An attempt is made in the present work to simulate and implement UPFC system.

III. Simulation Results

Two bus system without compensation is shown in Fig 2a. Sag is produced when an additional load is added. Voltage across loads 1 and 2 are shown in Fig 2b. The real power and reactive power waveforms are shown in Figures 2c and 2d respectively.

Two bus system with UPFC is shown in Fig 3a. UPFC is represented as a subsystem. The details of subsystem are shown in Fig 3b. Voltage across loads 1 and 2 are shown in Fig 3c. Real and reactive powers are shown in Figs 3d and 3e respectively. UPFC using voltage and current sources are shown in Fig4a. Converter 1 is represented as a shunt current source and converter 2 is represented as a series voltage source. Load voltage and current waveforms are shown in Fig 4b. Real and reactive powers are shown in Fig 4c. Variation of powers with the variation in the angle is given in table 1. The real and reactive powers increase with the increase in the angle of voltage injection.

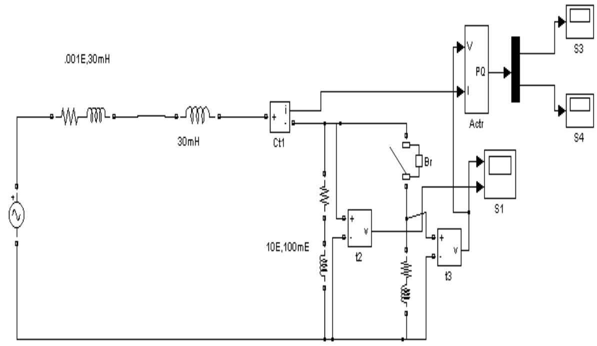

Fig. 2a. Line Model Without Compensation Circuit

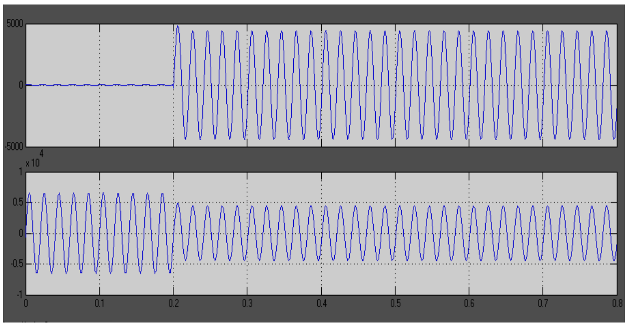

Fig. 2b. Voltage Across Load 2 and Load 1

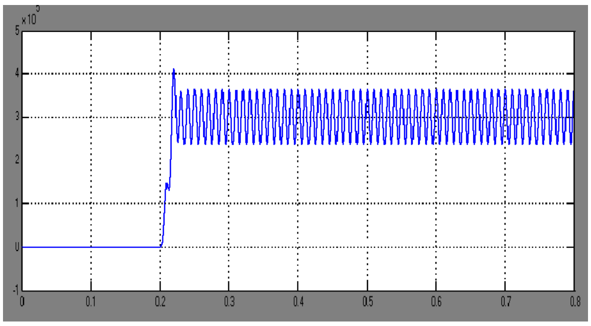

Fig. 2c. Real Power

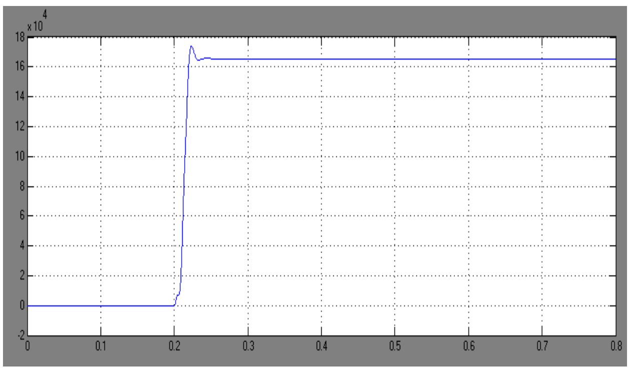

Fig. 2d. Reactive Power

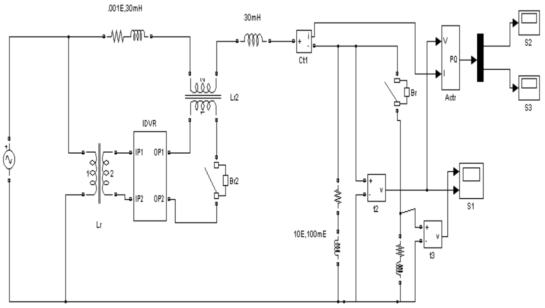

Fig. 3a. Two Bus System with UPFC

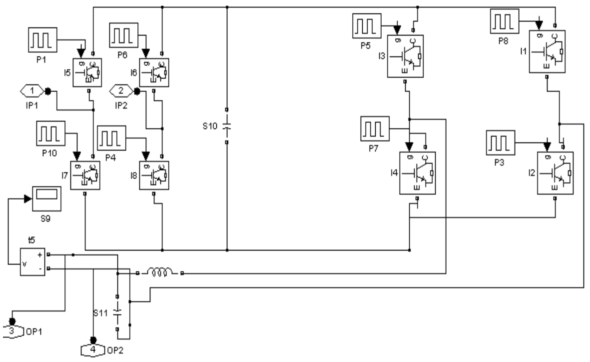

Fig. 3b. Rectifier Inverter System

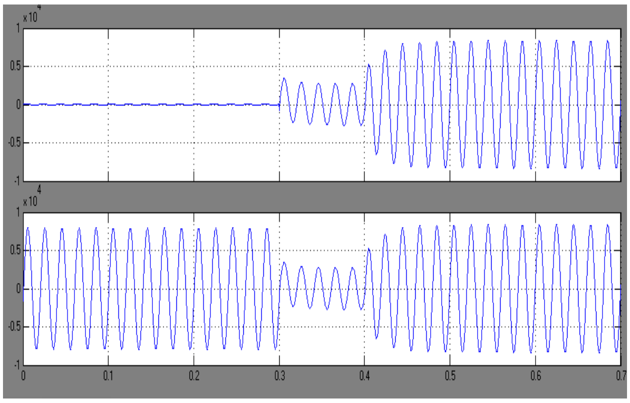

Fig. 3c. Voltage across Load 2 and Load 1

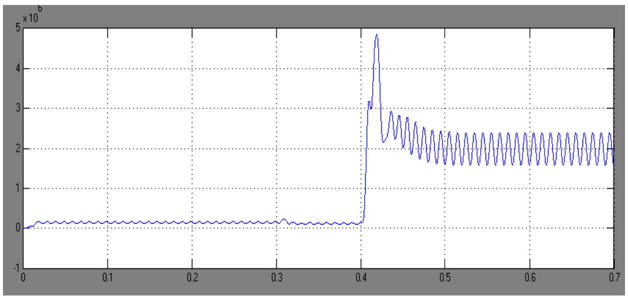

Fig. 3d. Real Power

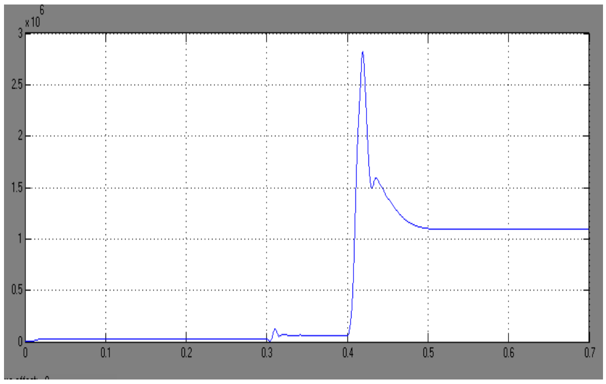

Fig. 3e. Reactive Power

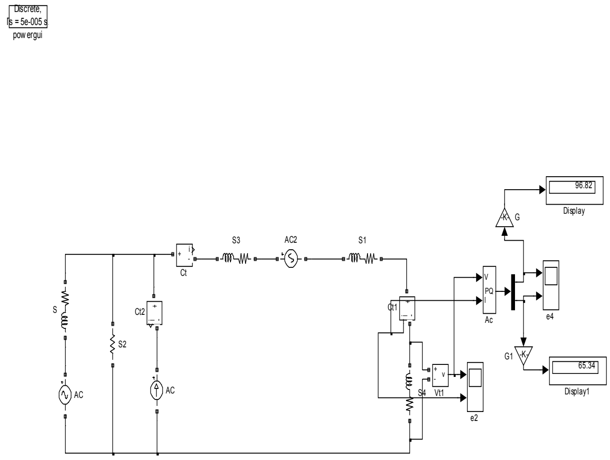

Fig. 4a. UPFC Circuit Model Using Shunt and Series Sources

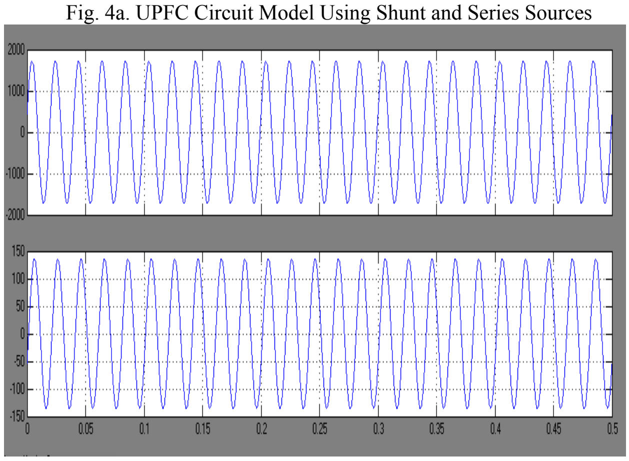

Fig. 4b. Load Voltgae and Current Waveform

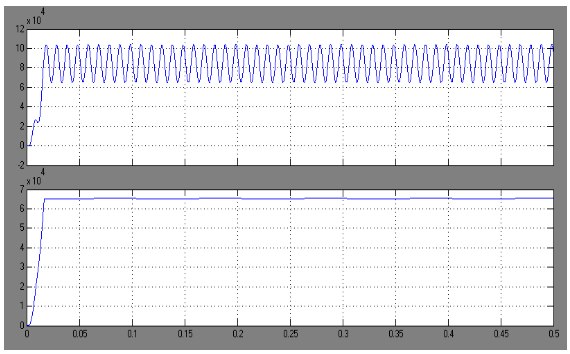

Fig. 4c. Real and Reactive Power

TABLE I VARIATION OF POWER WITH ANGLE OF INJECTION

S.NO	ANGLE OF INJECTED V2 VOLTAGE (DEG)	REAL POWE R (KW)	REACTIVE POWER(KVAR)
1	0	96.82	65.34
2	60	176.1	111.5
3	120	310.6	199.9
4	180	354.1	240.6

IV. EXPERIMENTAL RESULTS

Laboratory model of UPFC was designed and fabricated. It is tested in the laboratory to obtain the experimental results. Experimental set up is shown in Fig 5a. The hardware consists of control circuit and power circuit. The control board generates the pulses required by the MOSFETs. They are generated by the 8 bit microcontroller. They are amplified by using IR2110. The power circuit consists of rectifier and inverter system. AC input voltage is shown in Fig 5b. Rectifier output voltage is shown in Fig 5c. Driving pulses are shown in Fig 5d. Load voltage after compensation is shown in Fig 5e. From the figures 4b and 5e, it can be seen that the simulation results coincide with the experimental results.

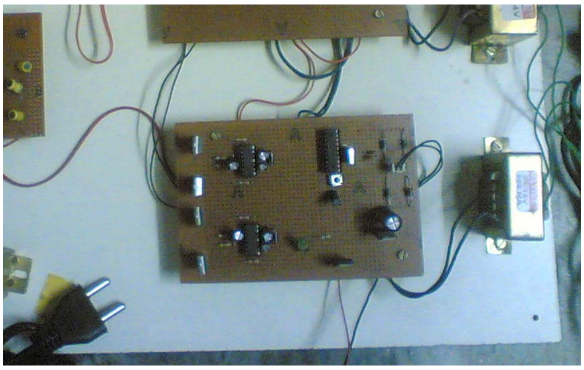

Fig. 5a. Experimental Setup

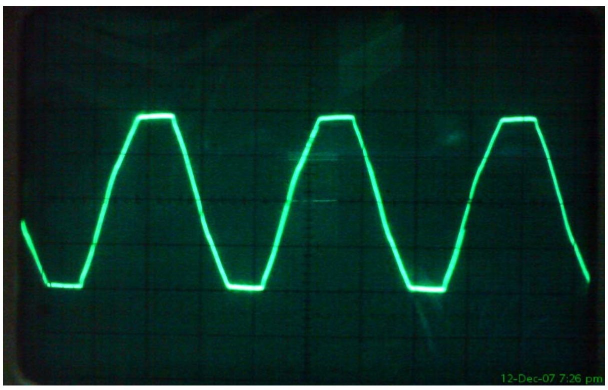

Fig. 5b. AC Input Voltage

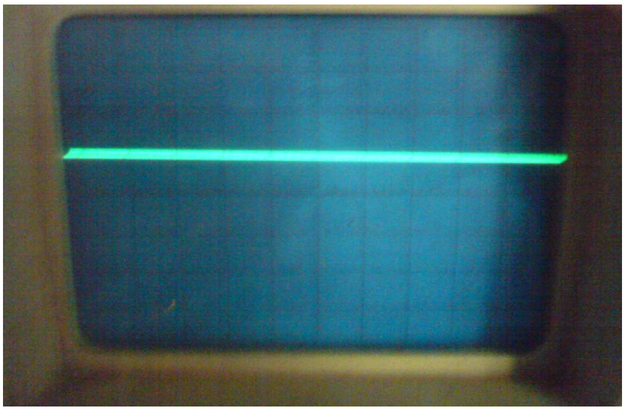

Fig. 5c. Rectifier output Voltage

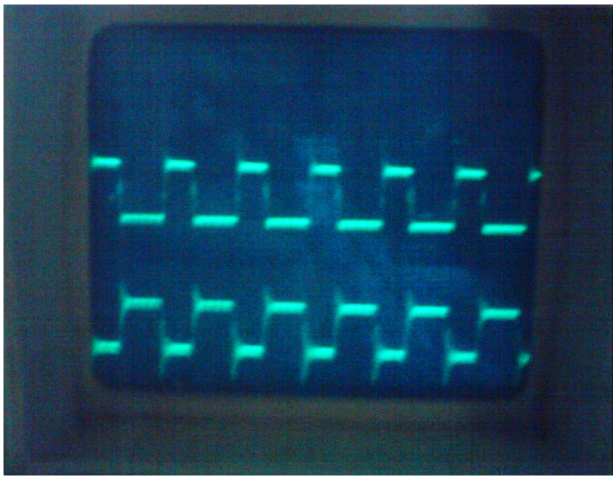

Fig. 5d. Driving Pulses for Inverter

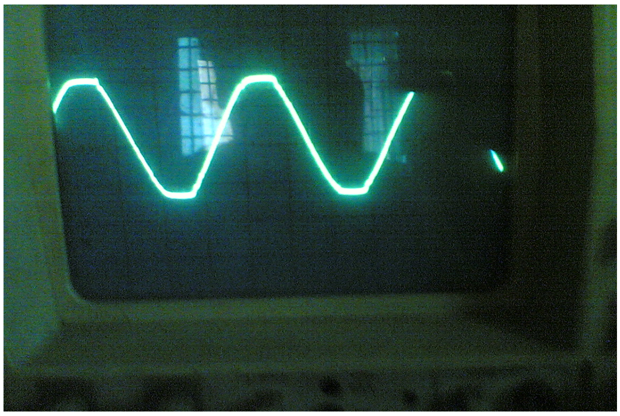

Fig. 5e. Load Voltage after Compensation

V. CONCLUSION

In the simulation study, matlab simulink enviroment is used to simulate the model of UPFC connected to a 3 phase system. This paper presents the control & performance of the UPFC used for power quality improvement. Voltage compensation using UPFC is studied. The real and reactive powers increase with the increase in angle of injection. Simulation results show the effectiveness of UPFC to control the real and reactive powers. It is found that there is an improvement in the real and reactive powers through the transmission line when UPFC is introduced. The UPFC system has the advantages like reduced maintanance and ability to control real and reactive powers. From Figures 3c and 5e, it can be seen that the experimental results matches with the simulation results. Thus experimental results closely agree with the simulation results.

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