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Unified Power Flow Controller for Power Quality Improvement

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***Abstract: — The Unified Power Flow Controller (UPFC) is a typical FACTS (Flexible AC Transmission Systems) device that is the most sophisticated and complex power electronic equipment and has emerged for the control and optimization of power flow and also to regulate the voltage in electrical power transmission system. This project propose the real, reactive power and voltage control through a transmission line by placing UPFC at the sending end using computer simulation. The control scheme has the fast dynamic response and hence is adequate for improving transient behavior of power system after transient conditions. When no UPFC is installed, real and reactive power through the transmission line cannot be controlled. A control system which enables the UPFC to follow the changes in reference values like AC voltage, DC voltage and angle order of the series voltage source converter is simulated. In this control system, a generalized pulse width modulation technique is used to generate firing pulses for both the converters. Simulations will be carried out using MATLAB/PSCAD software to check the performance of UPFC*.**

Keywords: - UPFC, FACTS, Power Quality, Transient, Control.

I. INTRODUCTION

The technology of power system utilities around the world has rapidly evolved with considerable changes in the technology along with improvements in power system structures and operation. The ongoing expansions and growth in the technology, demand a more optimal and profitable operation of a power system with respect to generation, transmission and distribution systems. Power quality is an issue that is becoming increasingly important to electricity consumers at all levels of usage. Sensitive equipment and non-linear loads are commonplace in both the industrial and the domestic environment; because of this a heightened awareness of power quality is developing [2]. The sources of problems that can disturb the power quality are: power electronic devices, arcing devices, load switching, large motor starting, embedded generation, sensitive equipment, storm and environment related damage, network equipment and design. The solution to improve the energy quality (PQ-Power Quality) at the load side is of great important when the production processes get more complicated and require a bigger liability level, which includes aims like to provide energy without interruption, without harmonic distortion and with tension regulation between very narrow margins [3].

In the present scenario, most of the power systems in the developing countries with large interconnected networks share the generation reserves to increase the reliability of the power system.

However, the increasing complexities of large interconnected networks had fluctuations in reliability of power supply, which resulted in system instability, difficult to control the power flow and security problems that resulted large number blackouts in different parts of the world. The reasons behind the above fault sequences may be due to the systematical errors in planning and operation, weak interconnection of the power system, lack of maintenance or due to overload of the network.

In order to overcome these consequences and to provide the desired power flow along with system stability and reliability, installations of new transmission lines are required. However, installation of new transmission lines with the large interconnected power system are limited to some of the factors like economic cost, environment related issues. These complexities in installing new transmission lines in a power system challenges the power engineers to research on the ways to increase the power flow with the existing transmission line without reduction in system stability and security.

In this research process, in the late 1980’s the Electric Power Research Institute (EPRI) introduced a concept of technology to improve the power flow, improve the system stability and reliability with the existing power systems. This technology of power electronic devices is termed as Flexible Alternating Current Transmission Systems (FACTS) technology. It provides the ability to increase the controllability and to improve the transmission system operation in terms of power flow, stability limits with advanced control technologies in the existing power systems [4].

II. FACTS CONTROLLERS

FACTS controllers are used for the dynamic control of voltage, impedance and phase angle of high voltage AC transmission lines. FACTS controllers can be divided into four categories:

1. Series controllers.
2. Shunt controllers.
3. Combined series-series controllers.
4. Combined series-shunt controllers.

2.1 SERIES CONTROLLERS

Series controllers inject voltage in series with the line. As long as the voltage is in phase quadrature with the line current, the series controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well.

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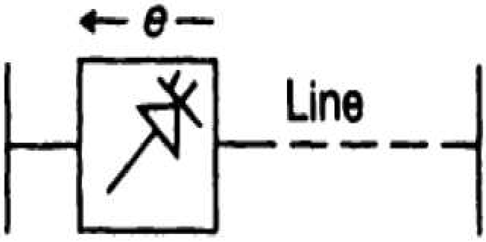

Figure 2.1 Static Synchronous Series Compensator (SSSC) is one such series controller.

2.2 SHUNT CONTROLLERS

All shunt controllers inject current into the system at the point of connection. As long as the injected current is in phase quadrature with the line voltage, the shunt controller only supplies or consumes variable reactive power. Any other phase relationship will involve handling of real power as well.

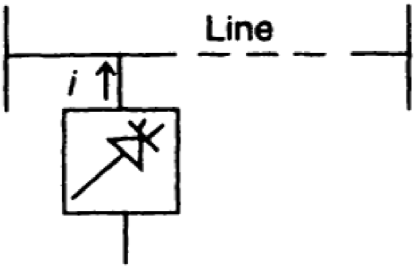

Figure 2.2 Static Synchronous Compensator (STATCOM) is one such controller

2.3 COMBINED SERIES-SERIES CONTROLLERS

This could be a series combination of separate series controllers, which are controlled in a coordinated manner, in a multilane transmission system. Or it could be a unified controller, in which series controllers provide independent series reactive compensation for each line but also transfer real power among the lines via the power link.

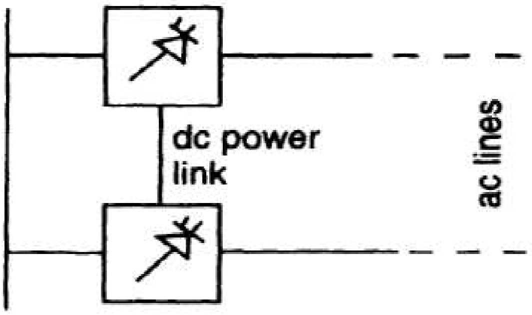

Figure 2.3 Interline Power Flow Controller comes in this category.

2.4 COMBINED SERIES-SHUNT CONTROLLERS

This could be a combination of separate shunt and series controllers, which are controlled in a coordinated manner, or a unified power flow controller with series and shunt elements. In principle, combined shunt and series controllers inject current into the system with shunt part of the controller voltage in series in the line with the series part of the controller. However, when the shunt and series controllers are unified, there can be a real power exchange between the series and shunt controllers via the power link.

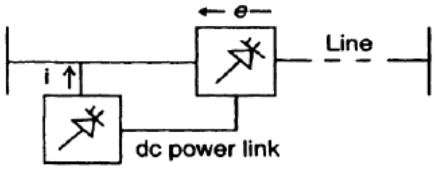

Figure 2.4 Interline Power Flow Controller comes in this category.

III. THE PROPOSED SYSTEM FOR POWER QUALITY USING UNIFIED POWER FLOW CONTROLLER (UPFC)

3.1 The Operating Principal of UPFC

The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSI is connected to in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer.

A basic UPFC functional scheme is shown in fig.3.1.

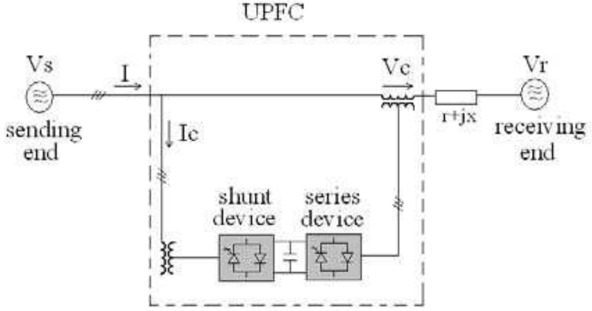

Fig3.1 Basic functional scheme of UPFC

The series inverter is controlled to inject a symmetrical three phase voltage system (Vse), of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this inverter will exchange active and reactive power with the line. The reactive power is electronically provided by the series inverter, and the active power is transmitted to the dc terminals. The shunt inverter is operated in such a way as to demand this dc terminal power (positive or negative) from the line keeping the voltage across the storage capacitor Vdc constant. So, the net real power absorbed from the line by the UPFC is equal only to the losses of the inverters and their transformers. The remaining capacity of the shunt inverter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point.

The two VSI's can work independently of each other by separating the dc side. So in that case, the shunt inverter is operating as a STATCOM that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series inverter is operating as SSSCregulate the current flow, and hence the powers flow on the transmission line.

The UPFC has many possible operating modes. In particular, the shunt inverter is operating in such a way to inject a controllable current, ish into the transmission line. The shunt inverter can be controlled in two different modes:

3.1.1 VAR Control Mode

The reference input is an inductive or capacitive VAR request. The shunt inverter control translates the var reference into a corresponding shunt current request and adjusts gating of the inverter to establish the desired current. For this mode of control a feedback signal representing the dc bus voltage, V_{dc}, is also required.

3.1.2 Automatic Voltage Control Mode

The shunt inverter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways

Direct Voltage Injection Mode: The reference inputs are directly the magnitude and phase angle of the series voltage.

Phase Angle Shifter Emulation mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.

Line Impedance Emulation mode: The reference input is an impedance value to insert in series with the line impedance.

Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system changes.

3.2 UPFC Construction

The UPFC consists of two voltage source converters; series and shunt converter, which are connected to each other with a common dc link. Series converter or Static Synchronous Series Compensator (SSSC) is used to add controlled voltage magnitude and phase angle in series with the line, while shunt converter or Static Synchronous Compensator (STATCOM) is used to provide reactive power to the ac system, beside that, it will provide the dc power required for both inverter. Each of the branches consists of a transformer and power electronic converter. These two voltage source converters shared a common dc capacitor [5]. The energy storing capacity of this dc capacitor is generally small. Therefore, active power drawn by the shunt converter should be equal to the active power generated by the series converter. The reactive power in the shunt or series converter can be chosen independently, giving greater flexibility to the power flow control. The coupling transformer is used to connect the device to the system. Figure3.2.1 shows the schematic diagram of the three phase UPFC connected to the transmission line.

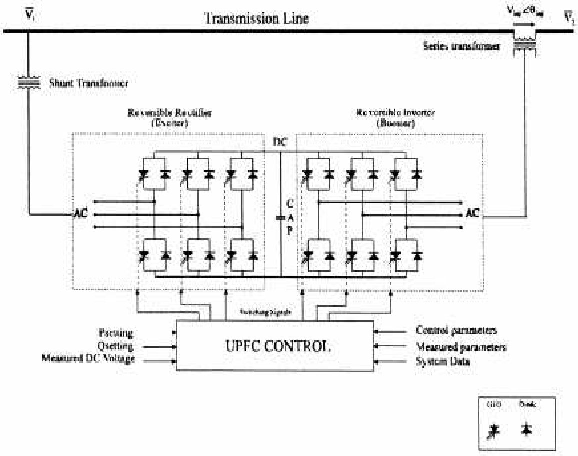

Figure 3.2.1: Schematic diagram of three phase UPFC connected to a transmission line [2] Control.

Control of power flow is achieved by adding the series voltage, VS with a certain amplitude, VS and phase shift, φ to V1. This will gives a new line voltage V2 with different magnitude and phase shift. As the angle φ varies, the phase shift δ between V2 and V3 also varies. Figure 2 shows the single line diagram of the UPFC and phasor diagram of voltage and current.

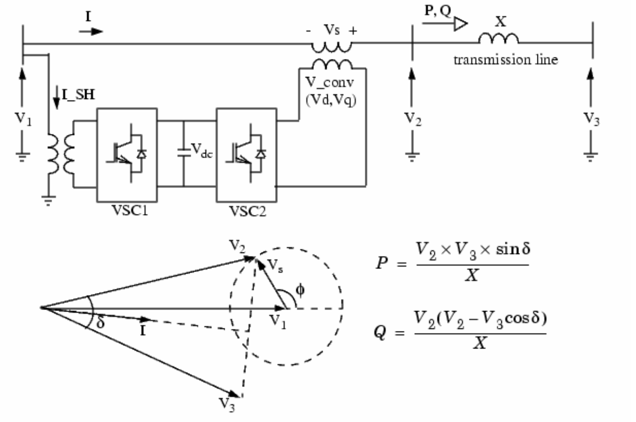

Figure 3.2.2: Single line diagram of UPFC and phasor diagram of voltage and current

IV. EXPERIMENTS CARRIED OF 22KV TRANSMISSION LINE SYSTEM WITH UPFC DEVICE.

With the development of power systems especially the opening of electric energy markets, it becomes more and more important to control the power flow along the transmission line, thus to meet the need of power transfer. On the other hand the fast development of power electronic technology has made UPFC a promising part for future power system needs. This device is an advance power system device capable of providing simultaneous control of voltage magnitude, active and reactive power flows in an adaptive fashion [10]. The following section is discussing the testing of transmission line with UPFC device with MATLAB / SIMULINK model environment [11-12].

A. Simulink model of 22 kV Transmission Line

The simulation model of Single line transmission system of 22kV Line is shown in Fig .4.1. The model is simulated and corresponding results of voltage magnitude, real and reactive power flows in line are shown in Fig’s 4.2 and 4.3 respectively.

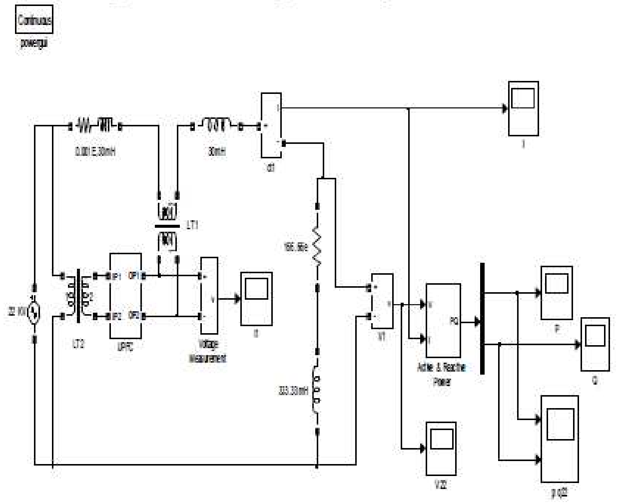

Fig.4.1. Simulink Model of 22 k V Transmission Line.

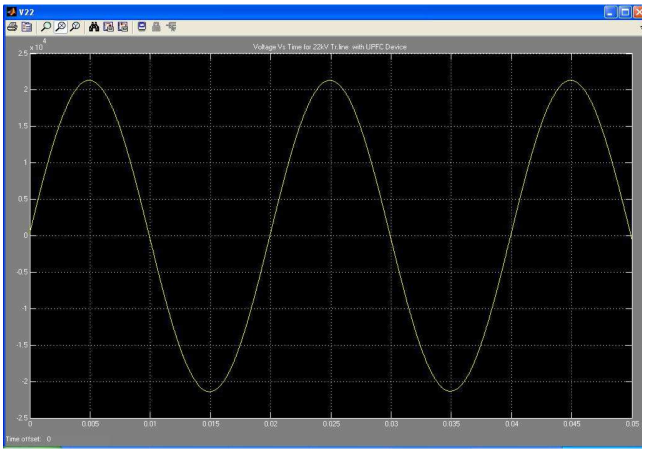

Fig.4.2. Voltage magnitude of 22 kV Transmission Line.

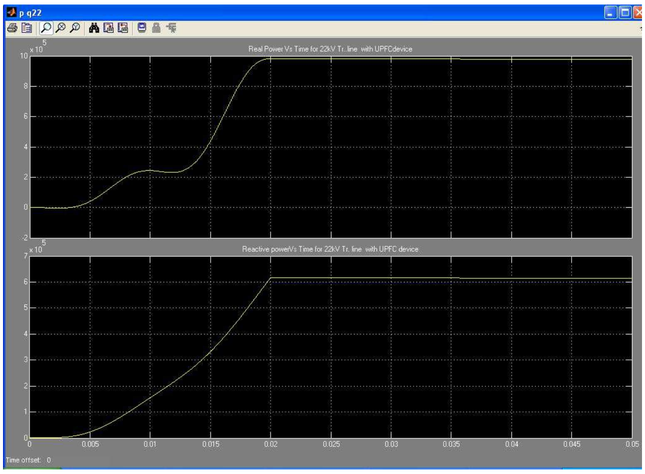

Fig.4.3. Real and Reactive power flows of 22 kV Line.

By observing the above wave forms, at steady state time t = 0.02sec the voltage magnitude is 21.23kV, the real power is 98.15MW and the reactive power is 61.64 MVAr

V. CONCLUSIONS

In the simulation study, Matlab Simulink environment is used to simulate the model of UPFC connected to a 3 phase system. The modelling of UPFC and analysis of power systems embedded with UPFC has been presented, which is capable of solving large power networks very reliably with the UPFC. The investigations related to the variation of control parameters and performance of the UPFC on power quality results are carried out. In 22 kv study, the MATLAB environment using phasor model of UPFC connected to a three phase-three wire transmission system. This paper presents control and performance of UPFC intended for installation on a transmission line. Simulation results show the effectiveness of UPFC in controlling real and reactive power through the line.

VI. FUTURE SCOPE

The UPFC model can be reduce the harmonics and ability to control real and reactive powers. The heating in the transformers is reducing by using multilevel response. This is due to the reduction in the harmonics. So That the simulation results are inline with the predictions .They are used for power quality too.

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