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SIMULATION OF UPFC AND DPFC FATCS DEVICES FOR OSCILLATION DAMPING IN THE POWER SYSTEM

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Abstract: The electricity is considered as the backbone for industrial revolution. Today the demand and consumption of electrical energy has increased steadily. To meet this increasing demand very complex interconnected power systems are built. These complex networks are subjected to power oscillations. This paper presents a concept of a distributed power flow controller (DPFC) and Unified Power Flow Controller (UPFC) for damping oscillation in Power System. The DPFC is derived from the unified power flow controller (UPFC). The DPFC can be seen as a UPFC with an eliminated common DC link. The cost of the DPFC is also much lower than the UPFC because no high-voltage isolation is required at the series converter part and the rating of the components of is low. This paper proposes a new control scheme to improve the stability of a system by optimal design of distributed power flow controller (DPFC) based stabilizer. The purpose of the work is to design an oscillation damping controller for DPFC to damp low frequency electromechanical oscillations. The shunt and series converters in the DPFC can exchange active power at the third-harmonic frequency, and the series converters are able to inject controllable active and reactive power at the fundamental frequency. The proposed system is simulated by using MATLAB/SIMULINK.

I. INTRODUCTION

There is a high demand for power flow control in power systems of the future, and combined FACTS devices are the most suitable devices. To get a new power flow controlling device that has combined performances of FACTS devices, acceptable cost of electric utilities and reliability of power systems. DPFC is a connected FACTS device, which has taken a UFPC at its beginning phase. The DPFC has control capability as same as that of UPFC, independent adjustment of the line impedance, the transmission angle, and the bus voltage. The DPFC eliminates the common DC link that is used to plug in the shunt and series converter back-to-back within the UPFC. By employing the DFACTS concept as the series converter of the DPFC, the cost is greatly reduced due to the small rating of the components in the series converters. Equally well, the reliability of the DPFC is improved because of the redundancy offered by the multiple series converters. In a power scheme, there is a great desire for a fast and reliable control of the power flow controller because of the growing requirement of energy, the aging of network flow and distributed generations. UPFC is the most powerful device within the FACTS family. It can simultaneously check all the parameters of the system: the line resistance, the transmission angle, and the bus voltage magnitude. The Distributed Power Flow Controller (DPFC) recently represented in [3], is a new device within the family of FACTS devices. The DPFC provides a higher reliability than conventional FACTS devices at a lower cost. It is inferred from the UPFC and has the same capability to correct all the parameters of the power system [4] simultaneously. The common DC link between the shunt and series converters is eliminated in DPFC concept, which offers flexibility for independent assignment of series and shunt converter. The DPFC uses the transmission line to exchange active power between converters at the 3rd harmonic frequency [4]. Likewise, series converter distribution reduces cost because no high voltage isolation and high power rating components are required at the series part. By using the two approaches eliminating the common DC link and passing around the series converter, the UPFC is further developed into a new combined FACTS device. Fig.1 shows the Distributed Power Flow Controller (DPFC). This paper introduces a concept of distributed power flow controller (DPFC) that is derived from the UPFC. The same as the UPFC, the DPFC can control all system parameters. The DPFC eliminates the common DC link between the shunt and series converters. The series converter of the DPFC works the distributed FACTS (D-FACTS) concept. Equating with the UPFC, the DPFC have two major benefits:-

- low cost because of the low-voltage isolation and the low component rating of the series converter and
- High reliability because of the redundancy of the series converters.

This paper begins with presenting the principle of the DPFC, followed by its steady-state analysis.

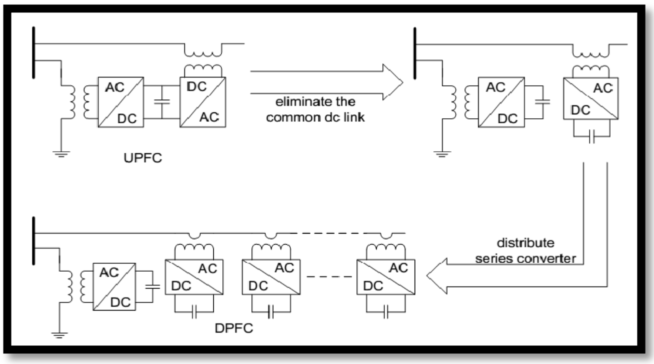

Fig.1: Schematic representation from UPFC to DPFC

II. UPFC WORKING

Unified power flow controller (UPFC) is a series shunt FACTS device. It consists of a combination of SSSC in series and STATCOM in shunt with the transmission line. These two voltage source converters are connected by a common d.c. link capacitor. Fig.3.1 shows the schematic diagram of UPFC. The series part injects the voltage of controllable magnitude in the transmission line to control the real and reactive power of the power system. The shunt part is used to maintain the voltage across the d.c. link capacitor and the bus voltage where it is connected by injecting the current of controllable magnitude in the system. Each voltage source converter can control the magnitude and phase angle of the output voltages of series and shunt converters by controlling the amplitude of modulation index (Mb,Me) and phase-angle (δb,δe) of series and shunt respectively.

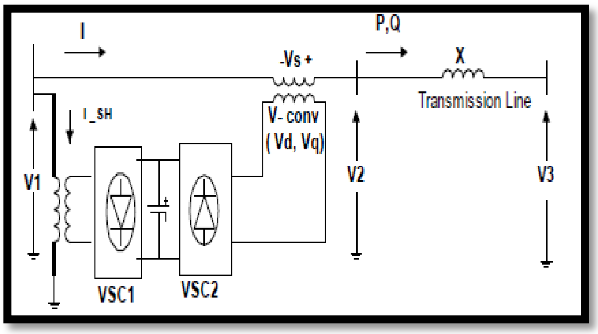

Fig.2-Schematic diagram of UPFC

III. CONTROL CONCEPT OF UPFC

The classical connection of UPFC with transmission line shown on the figure-2. The UPFC uses a two back-to back VSCs, operated from a common dc link. The converter 2 injects the controllable voltage both magnitude and phase angle to the connected line via series transformer. The converter 1 called STATCOM supplies or absorbed the real power demand by the converter 2 via dc link which then support the real power exchange between them. Conceptually the UPFC can automatically control all the system parameter that affect the power flow in a line, namely, voltage, impedance, and phase angle, hence, the name suggested “unified”. The UPFC provides complete control over power flow in the line. A circuit equivalent diagram of the UPFC is show in the fig.3.

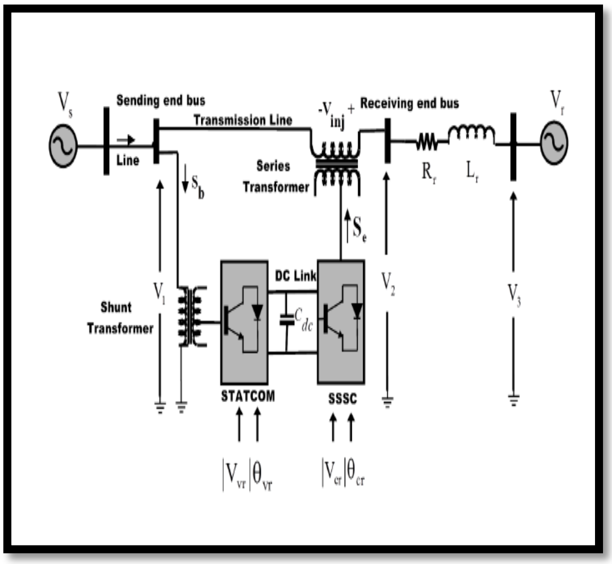

Fig.2. Connection diagram of UPFC with transmission line

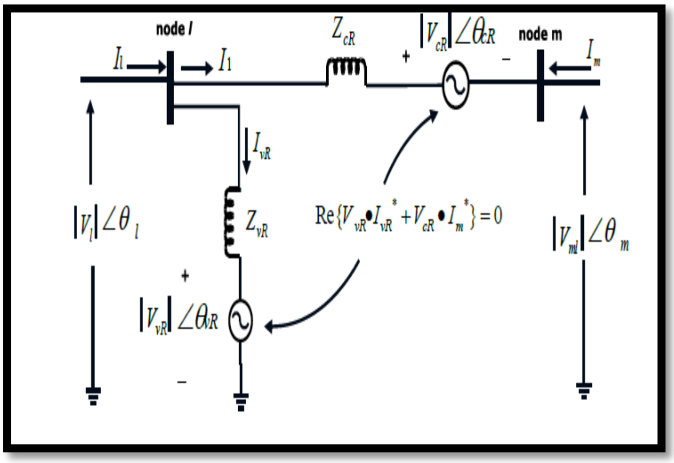

Fig.3 a general circuit equivalent of UPFC

IV. OVERVIEW OF DPFC

By introducing removal of the common DC link and distribution of the series converter into the UPFC, the DPFC is accomplished. Similar as the UPFC, the DPFC consists of shunt and series connected converters. The shunt converter is similar as an STATCOM while the series converter employs the DSSC concept, which is to use multiple single-phase converters as a replacement for one three-phase converter. Each converter within the DPFC is independent and delivers its DC capacitor to supply the required DC voltage. The form of the DPFC is shown in Fig.4.

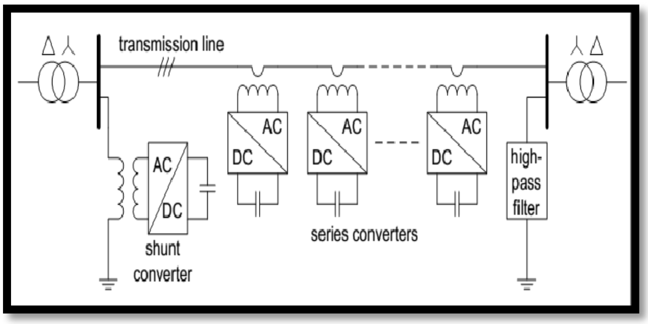

Fig.4- DPFC configuration

The exclusive control capability of the UPFC is given by the back-to-back construction between the shunt and series converters, which allows the active power to easily exchange. To ensure the DPFC has the same control capability as the UPFC, a method that allows active power exchange between converters with an eliminated DC link be needed.

V. SYSTEM MODEL FOR THE DPFC

The topology of the DPFC gives two means for controlling the line power. Either, the settings of the PST may be changed, the tasks that require speed of control like power oscillation damping, transient stability improvement, and voltage stability improvement are performed by the TSSC/TSSR. When the fast control tasks are considered, the PST is assumed to be a device contributing with its constant electrical characteristics to the grid environment surrounding the TSSC/TSSR. This is the basis for construction of the system model for the DPFC control which is aimed at controlling the dynamic TSSC/TSSR part of the device. The control of the internal PST of the DPFC has not been considered in detail in this project. However, one aim of this controller may for instance be to minimize the overall grid losses by power flow control. These are tasks performed by the Transmission System Operator (TSO) at the system level where a large amount of grid data and remote system information must be considered. Another aim of the PST controller may be to ensure that the setting of the internal TSSC of the DPFC is such that it can provide a sufficient amount of series compensation in case of a fault threatening the system stability.

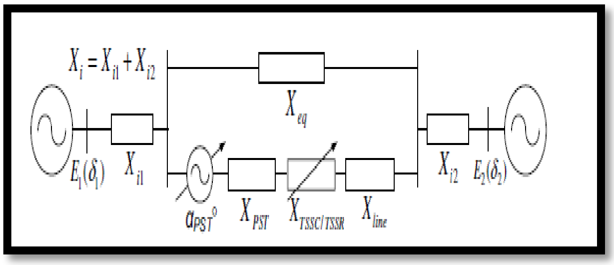

Figure 5: Generic system model for control of DPFC

The system model for control of the dynamic part of the DPFC is based on the system model developed for control of CSC utilizing the same basic assumptions. A simple model for the PST consisting of a controllable voltage angle shift in series with a tap-dependent series reactance is included in the original model yielding a basic model illustrated in Fig. 4.2. Here, two additional known parameters are introduced, the tap-dependent series reactance of the PST, XPST , and the phase angle shift introduced by the PST, α. The series reactance of the uncompensated DPFC line is given as Xline and the variable reactance inserted by the dynamic part of the DPFC is denoted XTSSC/TSSR. The damping of the oscillatory mode is given by the damping exponent σ and the frequency of the mode as ωosc (or fosc expressed in Hz). The unknown grid parameters Xi and Xeq remain the same as in the CSC system model.

VI. CONTROL OF DPFC

To control multiple converters, a DPFC contains three types of controllers: central control, shunt control, and series control, as exhibited in Fig.6. The shunt and series control are localized controllers and are in authority for maintaining their converters and its parameters. The central control takes care of the DPFC functions at the power system level.

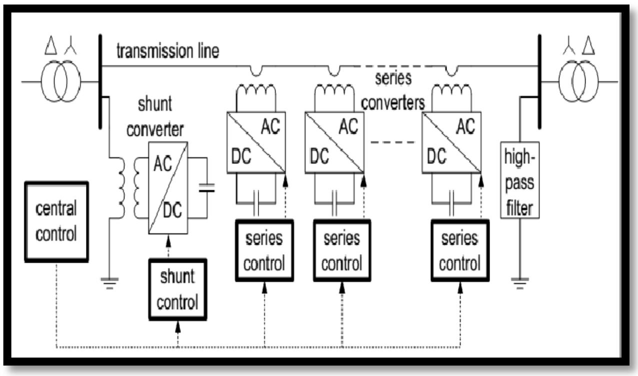

Fig.6- DPFC control blocks diagram

Central control

The central control produces the reference signals for both the shunt and series converters of the DPFC. Its control function depends on the specifics of the DPFC application at the power system level, such as power flow control, low-frequency power oscillation damping, and balancing of asymmetrical components.

Series control

Each series converter has its series control. The controller is used to maintain the capacitor DC voltage of its converter, by using third harmonic frequency components, in addition to generating a series voltage at the fundamental frequency is necessary by the central control.

Shunt control

The aim of the shunt control is to inject a constant third harmonic current into the line to supply active power for the series converters. At the same time, it prevents the capacitor DC voltage of the shunt converter at a constant value by taking up active power from the electrical system at the fundamental frequency and injecting the required reactive current at the fundamental frequency into the power system. The shunt controls involves injecting a constant third harmonic current into the communication channel to supply active power for series converters, retain the capacitor DC voltage of the shunt converter by absorbing active power from the grid at the central frequency and inject a reactive voltage at the central frequency of the power system as prescribed by the central command.

VII. MODELLING AND SIMULATION OF DPFC DEVICE

The DPFC device which is already discussed in the earlier chapter is used for oscillation damping includes two converter one is series converter which is distributed and connected in the three phase system in each phase which is shown in the fig.7 below. The shunt converter in the DPFC is connected at the sending end in the system which is used for the power quality problems mitigation at source side in the three phase system.

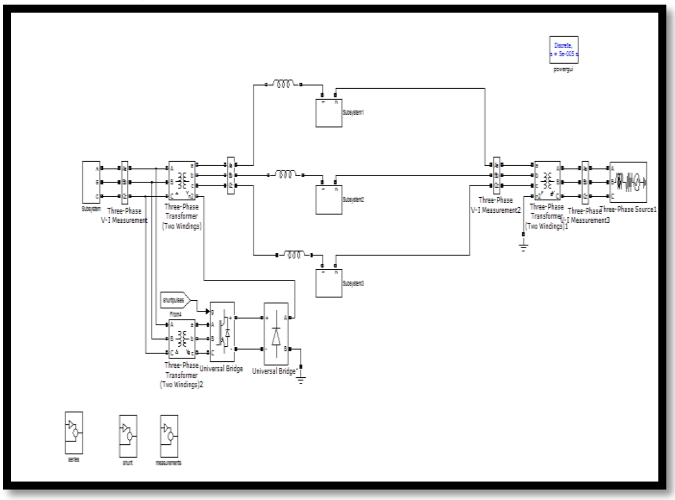

Fig 7-The Simulink model of DPFC device with 3-phase system

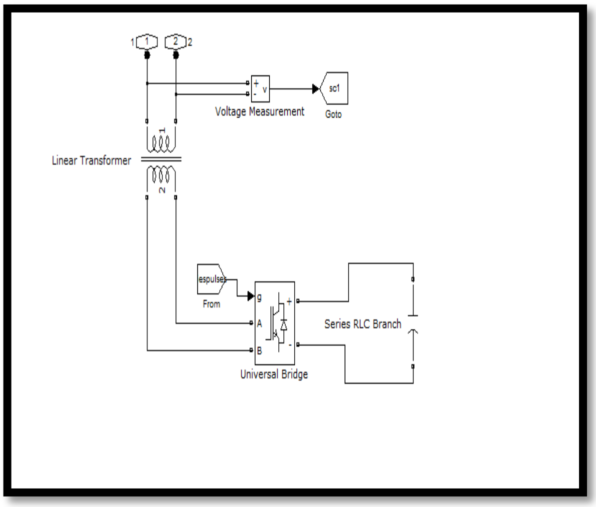

Fig.8 – The subsystem of series converter in the DPFC

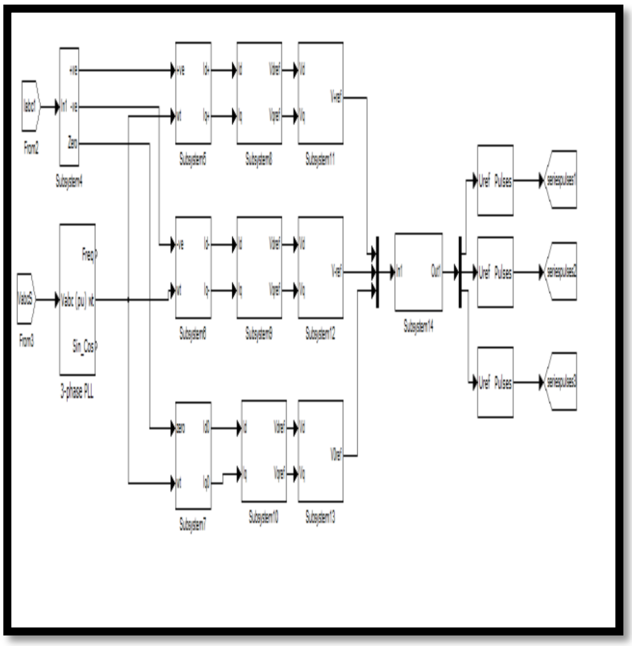

Fig.9- Control strategy for series converter

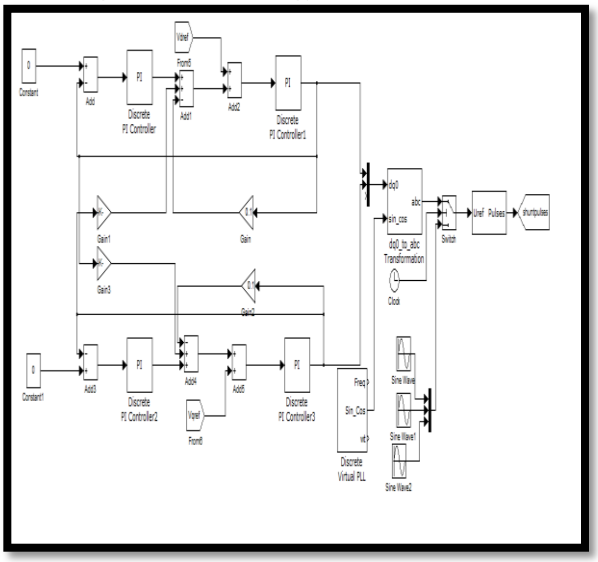

Fig.10- Control strategy for shunt converter at sending end

The control strategy for series and shunt converter of DPFC has shown in the above fig.9 and fig.10 which is working with the PLL and PI controller with triggering pulses for constant voltage and current management in the 3-phase system. Now the simulation results of DPFC for oscillation damping and mitigation of phase displacement is shown in the below sections.

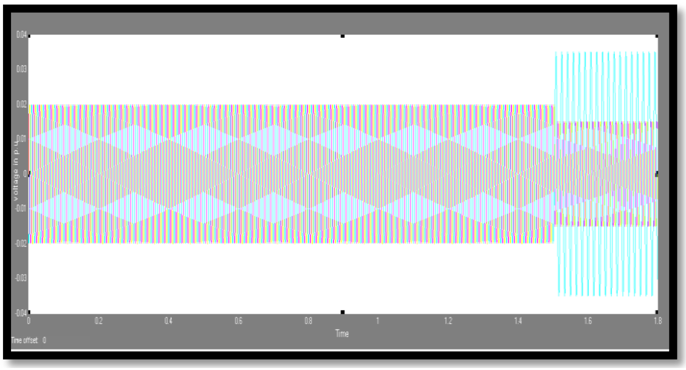

Fig.11- Voltage Unbalancing in three phase system

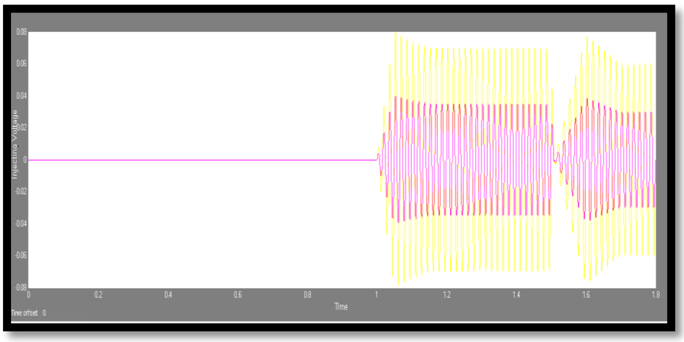

Fig.12- Injecting voltage by DPFC in the system

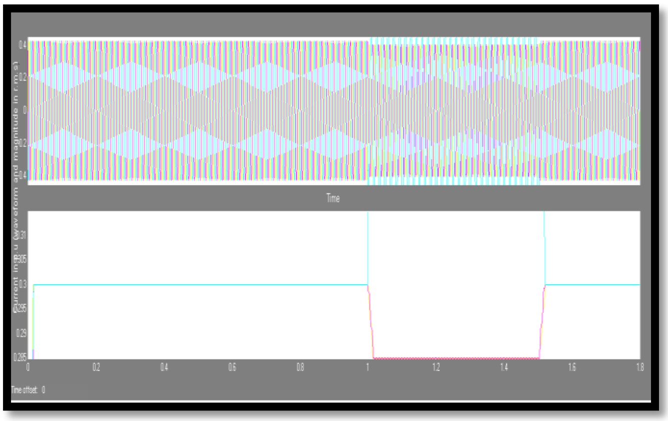

Fig.13-Three phase balanced voltage after DPFC

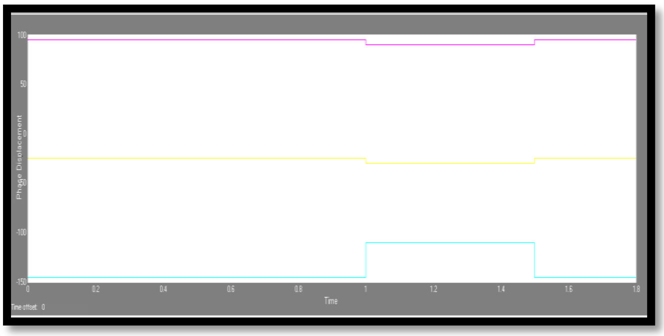

Fig.14- Three phase displacement in the system

VIII. CONCLUSION

This paper showcasing the application of UPFC and DPFC for damping power system oscillations. The two area power system was used to analyze the role of UPFC for damping the oscillations. The study shows that the DPFC is derived from the unified power flow controller (UPFC). The DPFC can be seen as a UPFC with an eliminated common DC link. It was observed that the results of three phase unbalanced condition system with non linear and D.C load have the distorted waveform of voltage and current and at other side the active and reactive power also unstable. The simulation of UPFC for oscillation damping is shows in Matlab Simulink software. The Matlab simulation of DPFC is also done in this project for voltage balancing and oscillation damping.

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