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Power Flow Control of Deregulated System using Facts Devices

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Abstract:
This paper deals with the power flow control of deregulated power system. Deregulated power system scenario has been setup to achieve economy & better services for consumers. As this deregulation introduces competition which brings many challenges & technical issues to the operation of this power system, like stability problem, voltage collapse, decrease in power transfer capacity, etc. To overcome such problems, we are going to control active and reactive power flow with the help of FACTS (Flexible AC Transmission System) devices. The main objective is to enhance power transfer capacity by controlling the active and reactive power and to achieve stability of the system using FACTS devices. The UPFC (Unified Power Flow Controller) integrates of both shunt and series compensations, and can effectively alter power system parameters in a way that used to manage the congestion in deregulated system.

Keywords: FACTS Device, Deregulated System, UPFC, VSC, Voltage profile, MATLAB Simulink

I. INTRODUCTION

In recent decades, great demands have been placed in power system and it will continue because of heightened competition among utilities themselves. This issues in power industries has arises the less security & reduced quality of supply. So in electric power system, FACTS technology is essential to reduce severity of some problems [1]. From last two decades, many power electric companies worldwide have been restructure their rules & change their way of operation for driving their power electric companies for open market which can be described as Deregulation. Deregulation can be called as global trend where improve of efficiency in operation & opening up to large competition. Such restructured system means that there will be restructure of the rules of transmission lines drive by open market. This will require availability & flexibility of power system which respond to all those challenges with the help of FACTS technology [1, 13]. Considering all FACTS devices from any generation and type, UPFC (Unified Power Flow Controller) can be regard as most versatile for stability improvement. UPFC with combination of SSSC (Static Synchronous Series Compensator) and STATCOM (Static Synchronous Compensator) that can control all three factors i.e. Phase Angle, Impedance and Voltage on which power flow is dependent [2]. Due to such features it can be regard as most expensive & most sophisticated power flow controller at present. As mention earlier, it consists of series & shunt converter which is connected by dc link. As a result it can control active & reactive power flow of transmission line [6]. Other than that UPFC in power system is use to reduce losses & improve the voltage profile [4].

II. OVERVIEW OF UPFC

UPFC concept was first proposed by GyuGyi in 1991. The UPFC was invented for dynamic compensation & control of real time of ac transmission systems. It provides multifunctional flexibility for solving many of the issues which are faced by power delivery industries. UPFC is able to control all the parameters i.e. voltage, phase angle, and impedance which affects power flow in the power system network. Thus this unique capability is known by the "unified". The main reason for wide spreads of UPFC is its ability to power flow directionally. Also it maintains well regulated DC voltage, workability in the wide range of operating conditions. UPFC is the second or latest generation of FACTS technology. UPFC consists of combined features of two other FACTS devices "STATCOM" & "SSSC". Basically these FACTS devices are voltage source converters (VSC's). UPFC is a generally synchronous voltage source (SVS). The SVS usually exchange both reactive and real power with the transmission system [8]. As in the Figure 1 shows us UPFC which consist of two voltage source convertors named as VSC1 and VSC2 are operated by a DC link provided with dc storage capacitor. These arrangements operate as an ideal ac to ac converter in which the real power can freely flow in any direction between the ac terminals of the both converters. Each converter has capability of generate or absorb reactive power independently as its own ac output terminal [8]. In Figure 1, the UPFC consist of two voltage source convertors. Both convertors are named as VSC1 & VSC2. They are operated from DC link provided by dc storage capacitor. One VSC is connected in shunt to the transmission line through a shunt transformer and another one is connected in series through a series transformer. As DC terminal of two VSCs is coupled. This creates a path for active power exchange between both converters. VSC provide the main function of UPFC by injecting a voltage with controllable magnitude & phase angle in series with the line. This injected voltage act as a synchronous ac voltage source. The transmission line current flows through this VSC results in reactive and active power exchange between it and the ac system. The reactive power exchanged between dc terminals is generated internally by the converter. The real power exchanged between ac terminals is converted to dc power which appears as a real power demand at dc link. VSC1 is to supply or absorb the real power demanded by VSC2 at the common dc link to support real power exchange resulting from the series voltage injection. This dc link power demand of VSC2 is converted back to ac by VSC1 and coupled to the transmission line bus with shunt connected transformer. Also note that VSC1 can also generate or absorb controllable reactive power and thereby provide independent shunt reactive compensation for the line. Thus VSC1 can be operated at a unity power factor or to be controlled to have a reactive power exchange with the line independent of the reactive power exchanged by VSC1 [8, 9].

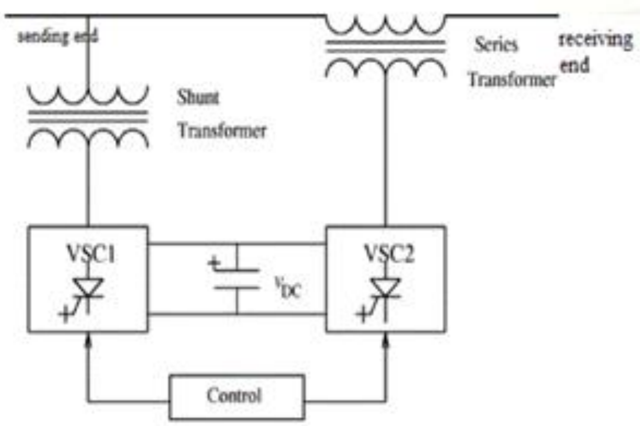

Figure.1. Basic Circuit Arrangement of UPFC [8]

III. OPERATING PRINCIPLE OF UPFC

The UPFC is the most versatile and complex of the FACTS devices having combining features of the both, STATCOM and the SSSC. The basic components of the UPFC are two voltage source converters (VSCs) sharing a common dc storage capacitor, and connected to the power system through coupling transformers. One VSC is connected to in shunt to the transmission system through shunt transformer, while the other one is connected in series via series transformer. The DC terminals of the two VSCs are coupled and this creates a path for active power exchange between the converters as shown in Figure 1 [8, 9]. The UPFC can be used to control the flow of active and reactive power via the transmission line and to control the amount of reactive power that has to be supplied to the transmission line at the point of installation. The series converter is controlled to inject a symmetrical three phase voltage system of controllable magnitude and phase angle in series with the line to control active and reactive power flows on the transmission line. So, this can 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 constant. So, the net active power absorbed from the line by the UPFC is equal only to the losses of the converters and their transformers. The remaining capacity of the shunt converter can be used to exchange reactive power with the line so to provide a voltage regulation at the connection point [9].

The two VSCs 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 SSSC that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line. The UPFC can also provide simultaneous control of all basic power system parameters, viz., transmission voltage, impedance and phase angle. The UPFC has many possible operating modes: Var control mode, automatic voltage control mode, direct voltage injection mode, phase angle shifter emulation mode, line impedance emulation mode and automatic power flow control mode.

IV. CONTROL OF UPFC

As the UPFC consists of two convertors, so study of control of each convertor (Series & Shunt) should be studied.

1. Operating of Shunt Converter in UPFC

The shunt converter draws a controlled current from system. One component of this current is “Ip” which is automatically determined by the requirement to balance the real power which is supplied to the series converter from DC link. By regulating the DC capacitor voltage by feedback control, the power balance is enforced [8]. The other component of the shunt converter current is the reactive current (Ir) which can be controlled in a similarly way as in a STATCOM. There are two control modes for a shunt converter. These are:

1. VAR control mode
2. Automatic voltage control mode

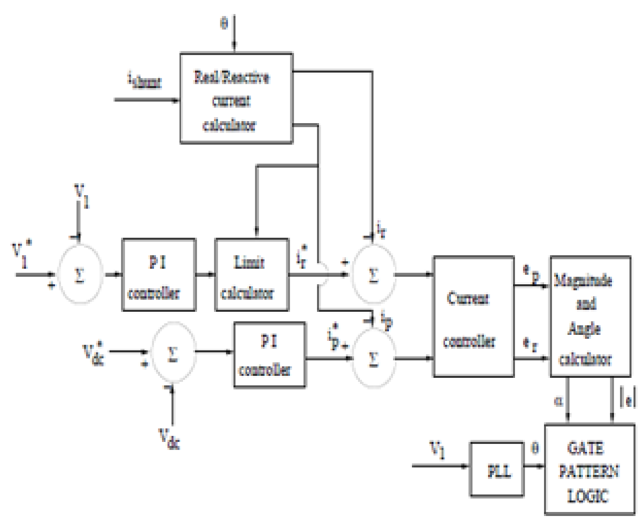

Figure.2. Block Diagram of Shunt Controller [8]

2. Operating of Series Converter in UPFC

In this control mode, the series injected voltage is determined by a vector control system to ensure the flow of the desired current which is maintained even during system disturbances. Although the normal conditions dictate the regulation of the complex power flow in the line, the contingency conditions require the controller to contribute to system stability by damping power oscillations [8].

The different control modes of series convertor are:

1. Direct voltage injection mode
2. Phase angle shifter emulation mode
3. Line impedance emulation mode
4. Automatic power flow control mode

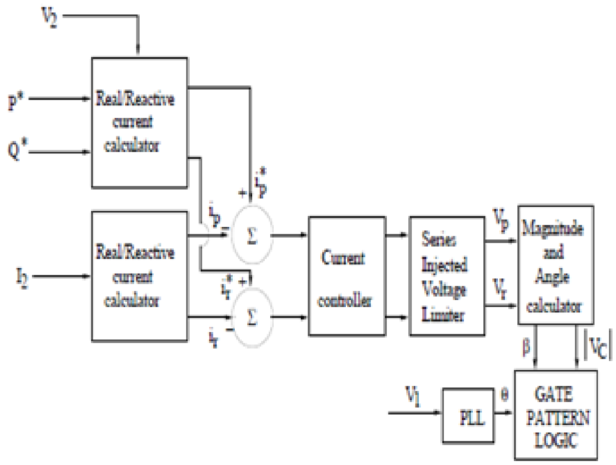

Figure.3. Block Diagram of Series Controller [8]

V. SIMULATION RESULTS & ANALYSIS

The UPFC is commonly used for maintaining voltage profile and control active & reactive power at the point of connection. The main MATLAB simulation circuit for power enhancement for UPFC of 6 bus system is shown in Figure 5.5. Here we have considered two cases to analysis the problem: (i) Line without UPFC & (ii) Line with UPFC.

1. Line without UPFC

Initially, we had taken the line without UPFC connected to it. The parameters like voltage, active power & reactive power are analyzed and there waveforms are recorded so that it can be compared with line including UPFC.

Source

Base Voltage = 500kV
Rating = 15000 MVA

Transformers

Step up transformers (Y-Y)
230kV/500kV
Rating = 1000MVA & 800 MVA

Power Plant

Nominal Voltage = 13.8kV
Power Delivered = 1000MW & 1200MW

UPFC

Nominal Voltage = 500kV
Shunt converter rating = 100MVA
Shunt converter impedance = [0.22/30, 0.22] (Rpu, Lpu)
Series converter rating = 100MVA
Shunt converter impedance = [0.16/30, 0.16] (Rpu, Lpu)
DC link nominal voltage = 40kV
DC link equivalent capacitance = 750microF
Maximum injected voltage = 0.1 (pu)

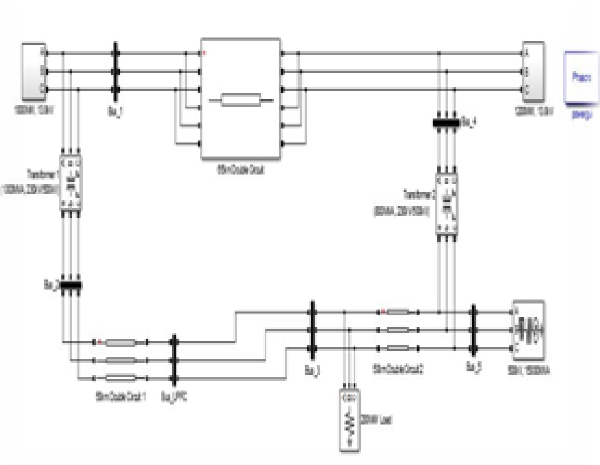

Figure.4. MATLAB Model without UPFC in Line

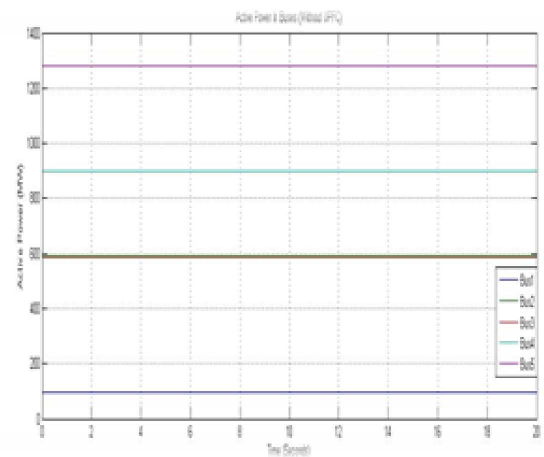

Figure.5. Output of Active Power at Buses without UPFC

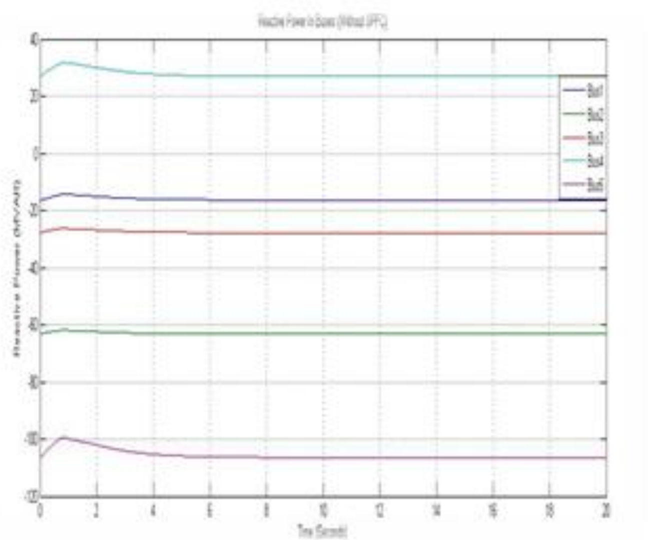

Figure.6. Output of Reactive Power at Buses without UPFC

2. Line with UPFC

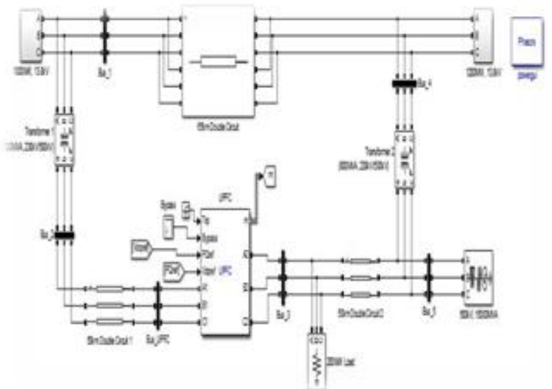

Figure.7. MATLAB Model with UPFC in Line

A UPFC is used to control the power flow in a 500 kV /230 kV transmission system. The system, connected in a loop configuration, consists essentially of five buses (B1 to B5) interconnected through transmission lines (L1, L2, L3) and two 500 kV/230 kV transformer banks Tr1 and Tr2. Two power plants located on the 230-kV system generate a total of 1500 MW which is transmitted to a 500-kV 15000-MVA equivalent and to a 200-MW load connected at bus B3. The UPFC located at the right end of line L2 is used to control the active and reactive powers at the 500-kV bus B3, as well as the voltage at bus B_UPFC. It consists of a phasor model of two 100-MVA, IGBT-based, converters (one connected in shunt and one connected in series and both interconnected through a DC bus on the DC side and to the AC power system, through coupling reactors and transformers). Parameters of the UPFC power components are mention in section 5.1. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.

Bus 1 & 4

Nominal Voltage = 230kV

Base Power = 100MVA

Bus 2,3 & 5

Nominal Voltage = 500kV

Base Power = 100MVA

Double Circuit

No. of phases = 6 (65km)

No. of phases = 3 (50km)

Load

Rating = 200 MW

Nominal voltage = 500kV

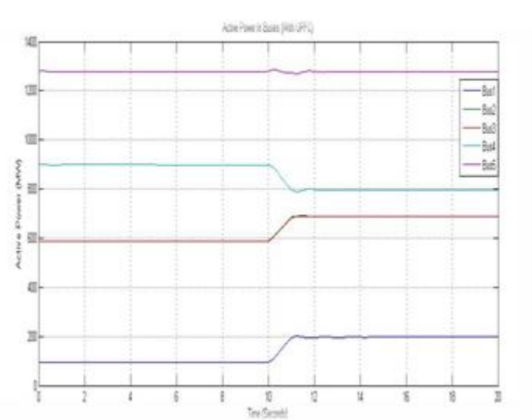

Figure.8. Output of Active Power at Buses with UPFC

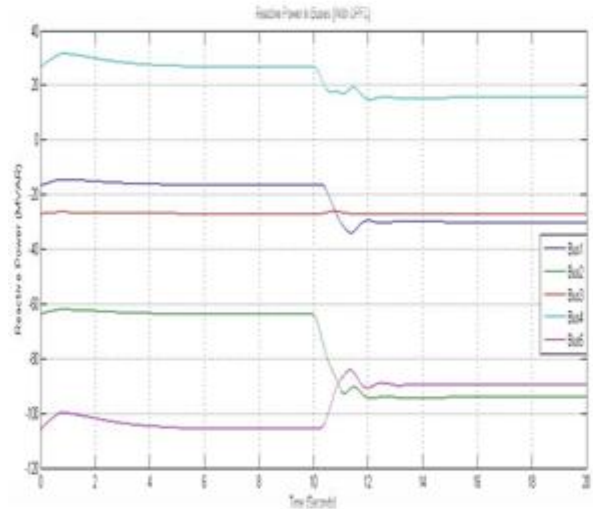

Figure.9. Output of Reactive Power at Buses with UPFC

3. RESULTS

Table.1. Output Parameters of Line without UPFC

Bus No.	Voltage (V)	Active Power (MW)	Reactive Power (MVAR)
1	0.9965	95.16	-16.34
2	0.9993	588.8	-63.27
3	0.9995	587	-27.79
4	0.9925	898.7	26.89
5	0.9977	1279	-106.4

Table.2. Output Parameters of Line with UPFC

Bus No.	Voltage (V)	Active Power (MW)	Reactive Power (MVAR)
1	0.9967	196.6	-30.06
2	1.002	689.7	-94.05
3	1.001	687	-27
4	0.9942	796	15.57
5	0.9989	1277	-89.32

VI. CONCLUSION

This paper deals with maintaining a voltage profile of power network by controlling power of system. For such purposes, FACTS technology is most suitable as it maintains system's stability and parameters like voltage magnitude, phase angle & line reactance which will consequently control power flow. So by comparing different FACTS devices, UPFC was opted because of its versatility of controlling both Active & Reactive power. In this project, 6 bus systems are designed with MATLAB Simulink & achieved results are compared (With UPFC & Without UPFC). Due to UPFC in system, issue like transient stability is improved due to which congestion is less and stability of system is improved. Other than that power transfer capability of deregulated is system is enhanced. As a result, it can be conclude that Voltage collapsing is decreased & security and reliability is maintained with voltage profile of deregulated system.

VII. FUTURE SCOPE

In this paper, our purposed method was tested for 6 bus system and it is concluded from our results that our method has enhance the power transfer capability by maintaining voltage profile &reducing power losses. This method can be tested for 9 bus systems & 12 bus systems in future. The present work can be extended with generalized TCSC and IPFC for same bus system. FACTS-based controllers could be designed in presence of different types of distributed generations for improving the stability of system.

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