Reactive Power Compensation using Unified Power Flow Controller

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Abstract - *In power system, stability is one of the important factor for reliable power supply, and reactive power compensation can be achieved by using Flexible AC Transmission Systems devices, which provides good flexibility to control the active and reactive power flow and bus voltages in the power system. In this paper a five bus system is considered with two cases namely without UPFC and UPFC device at lake bus, using Mi-Power software. It is also observed that the power factor and the bus loading is also improved using FACTS devices and power oscillations are reduced to make system more stable.*

Key Words: UPFC, Mi Power, Reactive Power Compensation

1. INTRODUCTION

The UPFC is recently introduced FACTS controller, it is having the capability to control all the four transmission parameters. UPFC performs the functions of different FACTS devices like STATCOM, TCSC, and the phase angle regulator and it also provides additional flexibility by combining some of the functions of these controllers. It control voltage stability and active and reactive power flow in power system transmission lines, so that secure loading can be done, thus it also increases and stabilizes the stability in the power systems. UPFC consists of two voltage-sourced converters (VSCs) which are connected to each other with a common dc link. Its series converter inserts controllable magnitude and controllable phase angle of ac voltage in series with our transmission lines. Demand of the series controller of Active power can be injected or it can be absorb with the help of shunt controller by using a dc link through which active power can be easily transferred in both the direction as per demand between two ac terminals. The required reactive power which is exchanged (either generated of absorbed) by each converter at its points locally, and there is no as such flow of reactive power in the UPFC through the help of dc link fixed in between, and thus reactive power compensation is done.[1]

2. UNIFIED POWER FLOW CONTROLLER

The UPFC is a device which can control simultaneously all three parameters of line power flow (line impedance, voltage and phase angle) .It is a one of the FACTS family that used to optimum power flow in transmission. [8] The UPFC is a combination of static synchronous compensator (STATCOM) and static synchronous compensator (SSSC)[6].Both converters are operated from a common dc link with a dc storage capacitor. The real power can freely flow in either direction between the two-ac branches. Each converter can independently generate or absorb reactive power at the ac output terminals. The controller provides the gating signals to the converter valves to provide the desired series voltages and simultaneously drawing the necessary shunt currents, In order to provide the required series injected voltage, the inverter requires a dc source with regenerative capabilities [2]. The possible solution is to use the shunt inverter to support the dc bus voltage The UPFC is the most versatile and complex of the FACTS devices, combining the features of the STATCOM and the SSSC. The main reasons behind the wide spreads of UPFC are its ability to pass the real power flow bi-directionally, maintaining well-regulated DC voltage, workability in the wide range of operating conditions etc .The basic components of the UPFC are two voltage source inverters (VSIs)[3], 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. The DC terminals of the two VSCs are coupled and this creates a path for active power exchange between the converters. Thus the active supplied to the line by the series converter can be supplied by the shunt converter as shown in fig. Therefore, a different range of control options is available compared to STATCOM or SSSC.[12][13] The UPFC can be used to control the flow of active and reactive power through the transmission line and to control the amount of reactive power supplied to the transmission line at the point of installation.[7]The series inverter 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 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 V_{dc} 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.[4][5]

The two VSIs 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. Configuration of UPFC is shown in fig.1.

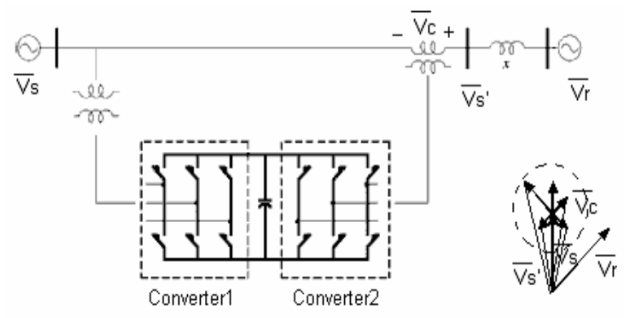

Fig.1.Configuration of UPFC

3. MATHEMATICAL MODEL

3.1. Modeling of series converter

To develop the series converter model, Kirchhoff's voltage equations (KVL) for the phase 'a' of the series branch can be written as

$$Lse\frac{di_{a1}}{dt}+i_{a1}r_{se}=(Vta-Vra+Vca)$$

Similarly the KVL equations can be written for phases 'b' and 'c'. The KVL equations for three phases in matrix form can be written as follows.[9]

$$\frac{d}{dt}\begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{c1} \end{bmatrix} = \begin{bmatrix} \frac{-r_{se}}{L_{se}} & 0 & 0 \\ 0 & \frac{-r_{se}}{L_{se}} & 0 \\ 0 & 0 & \frac{r_{se}}{L_{se}} \end{bmatrix} \begin{bmatrix} i_{a1} \\ i_{b1} \\ i_{cl} \end{bmatrix} + \frac{1}{L_{se}} \begin{bmatrix} V_{ta}-V_{ra}+V_{ca} \\ V_{tb}-V_{rb}+V_{cb} \\ V_{tc}-V_{rc}+V_{cc} \end{bmatrix}$$

Equation (2) pertains to a-b-c reference frame. To ease the complexity, these equations are transformed from a-b-c reference frame to synchronous d-q reference frame keeping Vt as reference (Vtd=Vt, Vtq=0). The differential equations for d-q components of series branch current can be written as

$$\frac{di_{d1}}{dt}=\frac{-r_{se}}{L_{se}}i_{d1}+\omega i_{q1}+\frac{1}{L_{se}}(V_{td}-V_{rd}+V_{cd})$$

$$\frac{di_{q1}}{dt}=\frac{-r_{se}}{L_{se}}i_{q2}-\omega i_{q1}+\frac{1}{L_{se}}(V_{td}-V_{rq}+V_{cq})$$

3.2. Modeling of shunt converter

Proceeding in a similar way, the differential equations for the shunt converter currents are given by

$$\frac{di_{d2}}{dt}=\frac{-r_{sh}}{L_{sh}}i_{d2}-\omega i_{q2}+\frac{1}{L_{sh}}(V_{pd}-V_{td})$$

$$\frac{di_{q2}}{dt}=\frac{-r_{sh}}{L_{sh}}i_{q2}-\omega i_{d2}+\frac{1}{L_{sh}}(V_{pq}-V_{tq})$$

3.3. Modeling of DC link capacitor voltage

The performance of UPFC depends on the stability of the dc link voltage between the series and shunt converters. In the case of ideal converters, the shunt converter must be capable of handling the amount of real power which is exchanged between the series converter and the line.[10] Thus the UPFC as a whole exchanges zero real power with the transmission line. However, during dynamic conditions, the input power to the shunt converter should be equal to the sum of series injected power and the rate of change of stored energy in the capacitor on an instantaneous basis. Thus, by power balance we obtain the equation below.

$$P=\frac{3}{2}\left[-V_{pd}i_{d2}-V_{pq}i_{q2}-V_{cd}i_{d1}-V_{cq}i_{q1}\right]$$

$$=CV_{dc}\frac{dV_{dc}}{dt}+\frac{V_{dc}^{2}}{R_{dc}}$$

$$V_{dc}=\frac{3}{2CV_{dc}}\left[-V_{pd}i_{d2}-V_{pq}i_{q2}-V_{cd}i_{d1}-V_{cq}i_{q1}\right]-\frac{V_{dc}}{CR_{dc}}$$ Th

and hence above equation governs the dc-link capacitor voltage of UPFC. The dc voltage level is controlled by regulating the real power flow from the ac system into the common dc-link via the shunt converter.[10]

4. SIMULATION AND RESULTS

The proposed work to identify the effect of UPFC for transmission network has been implemented using Mi-Power on the IEEE 5 bus system. In this paper two cases has been discussed, one is without UPFC and other is UPFC at lake bus.

4.1. IEEE 5 bus system without UPFC

In this case, IEEE5 bus system shown in figure 1 is simulated using Mi-Power power system software. Load flow calculation using Newton Raphson method is performed

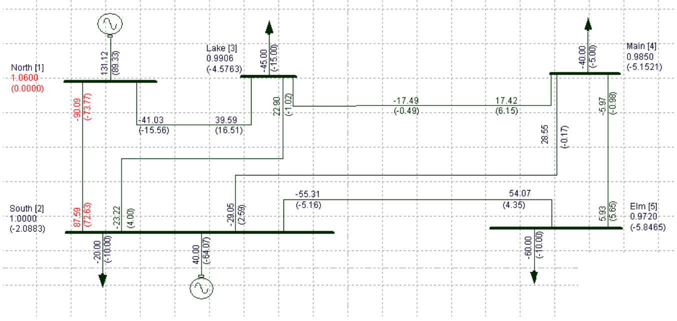

Fig-2. IEEE 5 bus system without UPFC

4.2. IEEE 5 bus system with UPFC at lake bus

In this method, UPFC is installed at the lake bus as shown in fig.3 and the simulations are done using MiPower power system software. Here, to install UPFC a dummy bus by the name of bus 6 has also been introduced.

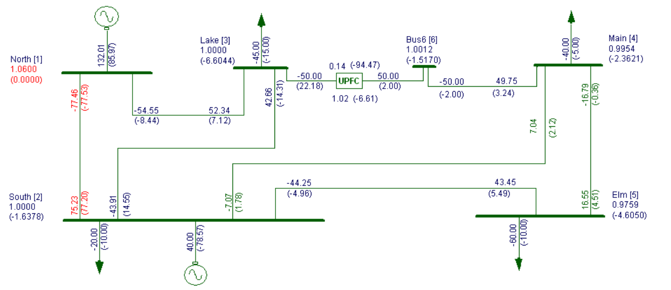

Fig-3. IEEE 5 bus system with UPFC **at lake bus** bus

Results in the power ocillations can be easilty observed in the Fig.4. and thus we can conclude that with using UPFC, Power is more stable.[11]

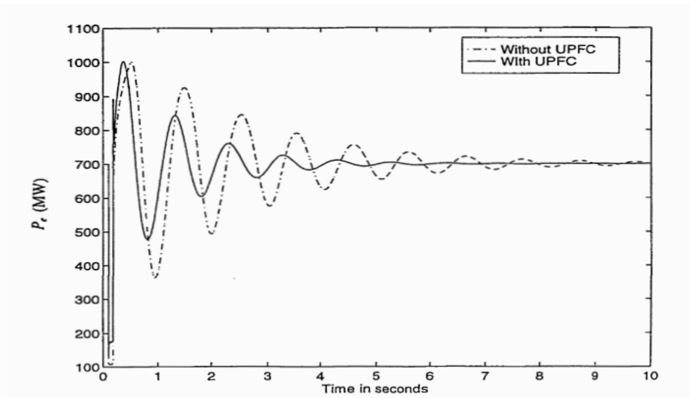

Fig-4. Power Oscillation with and without UPFC

3. CONCLUSIONS

In this work the power flow analysis with the inclusion of UPFC reactive power compensation of 25.5478 MVar has been analyzed. Newton Raphson method used in polar coordinates is effectively utilized to solve the power flow equation of IEEE 5bus system, and power oscillations can be reduced by using UPFC.

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