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Unified Power Flow Controller to Improve the Transfer Capability of a Power System Using ATC Method

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Abstract:

Open access to the transmission system places an emphasis on the intensive use of the interconnected network reliably, which requires knowledge of the network capability. Fast, accurate algorithms to compute network capabilities are indispensable for transfer-based electricity markets. Available Transfer Capability (ATC) is a measure of the remaining power transfer capability of the transmission network for further transactions. Transmission System Operators (TSOs) are encouraged to use the existing facilities more efficiently. Most transfer studies involve contingencies and multipattern scenarios that often can only be performed in reasonable time with the use of reactive methods. One of the limitations of reactive ATC is the error produced by neglecting the effect of reactive power flows in line loading.This paper presents the determination of shunt reactive power compensation with Flexible AC Transmission System (FACTS) devices, the Unified Power Flow Controller(UPFC) to improve the transfer capability of a power system incorporating the reactive power flows in ATC calculations. By redistributing the power flow, the ATC is improved. Studies on a sample 5-bus compensation along with line flow control

Keywords:
Reactive Method, ATC, PTDF, UPFC.

I. INTRODUCTION:

Over the years, it has become clear that the maximum safe operating capacity of the transmission system is often based on voltage and angular stability rather than on its physical limitations. And also In the recent years ecological concerns and high installation costs have put constraints over construction of new plants and overhead lines in many countries, thereby forcing existing system to be used more efficiently rather than constructing new lines, industry has tended towards the development of technologies or devices that increase transmission network capacity while maintaining or even improving grid stability. Our main objective is to meet the electric load demand reliably while simultaneously satisfying certain quality constraints imposed on the power supply. Generally, this specified level of system reliability and quality is insured in terms of the capacity of the system to meet the aggregate load demand and the ability of the system to withstand the impact of disturbance.

An increase of the unplanned power exchanges causes some lines located on particular paths may get overloaded, which causes a phenomenon called congestion, and thus full capacity of the transmission interconnections may not be fully utilized. Therefore, it became effective to have a way of permitting a more efficient use of the transmission lines by controlling the power flows.

Until a few years ago, the only means of carrying out this function were electromechanical devices such as switched inductors or capacitor banks and phase shifting transformers, however, specific problems related to these devices make them not very efficient in some situations they are not only relatively slow, but they also cannot be switched frequently, because they tend to wear out quickly.

II. POWER TRANSFER DISTRIBUTION FACTORS (PTDF):

We calculate the Linearized Power Transfer Distribution Factors for a line with respect to a transfer , where is the size of the transfer in per unit, and T is a vector of participation factors of size were is number of buses.

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$$T = T_s + T_b = \begin{bmatrix} PF_{s1} \\ PF_{s2} \\ : \\ : \\ PF_{sn} \end{bmatrix} + \begin{bmatrix} PF_{b1} \\ PF_{b2} \\ : \\ : \\ PF_{bn} \end{bmatrix} \qquad (2.1)$$

And

$$\sum_{k=1}^{n} PF_{s,k} = 1 \qquad (2.2)$$

$$\sum_{k=1}^{n} PF_{b,k} = -1 \qquad (2.3)$$

Eqn (2.2) participation factor in case of [3]
Eqn (2.3) participation factor incase of [3]
The distribution factor is calculated as

$$\rho_{ij,s-b} = \frac{\partial P_{ij}}{\partial P} = \frac{\partial P_{ij}}{\partial \delta_i}\frac{\partial \delta_i}{\partial P} + \frac{\partial P_{ij}}{\partial \delta_j}\frac{\partial \delta_j}{\partial P} + \frac{\partial P_{ij}}{\partial V_i}\frac{\partial V_i}{\partial P} + \frac{\partial P_{ij}}{\partial V_j}\frac{\partial V_j}{\partial P}$$

Where the derivatives with respect to the state variables can be determined explicitly from the active and reactive power flow equations (Eqn (2.4), (2.5)), and the derivatives with respect to are determined from the Jacobian inverse matrix. For any state variable the derivative with respect to is computed as in the following equation

$$\frac{\partial \delta_i}{\partial P} = \sum_{k \neq Slack}^{n} \left[PF_{sk} \frac{\partial \delta_i}{\partial P_k} \right] + \sum_{k \neq Slack}^{n} \left[PF_{bk} \frac{\partial \delta_i}{\partial P_k} \right] \qquad (2.5)$$

$$\frac{\partial \delta_j}{\partial P} = \sum_{k \neq Slack}^{n} \left[PF_{s,k} \frac{\partial \delta_j}{\partial P_k} \right] + \sum_{k \neq Slack}^{n} \left[PF_{b,k} \frac{\partial \delta_j}{\partial P_k} \right] \qquad (2.6)$$

$$P_{ij} = V_i^2 G_{ij} - V_i V_j Y_{ij} \cos(\delta_i - \delta_j - \theta_{ij}) \qquad (2.7)$$

Let us consider the small system as shown in Fig (2.1) and the lines are loss less. Thus $G_{ij} = 0$ and $\theta_{ij} = -90$ Then Eqn (2.7)

$$P_{ij} = V_i V_j Y_{ij} \sin(\delta_i - \delta_j) \qquad (2.8)$$

The derivatives with respect to the state variables in (2.8) are

$$\frac{\partial P_{ij}}{\partial \delta_i} = V_i V_j Y_{ij} \cos(\delta_i - \delta_j) \qquad (2.9a)$$

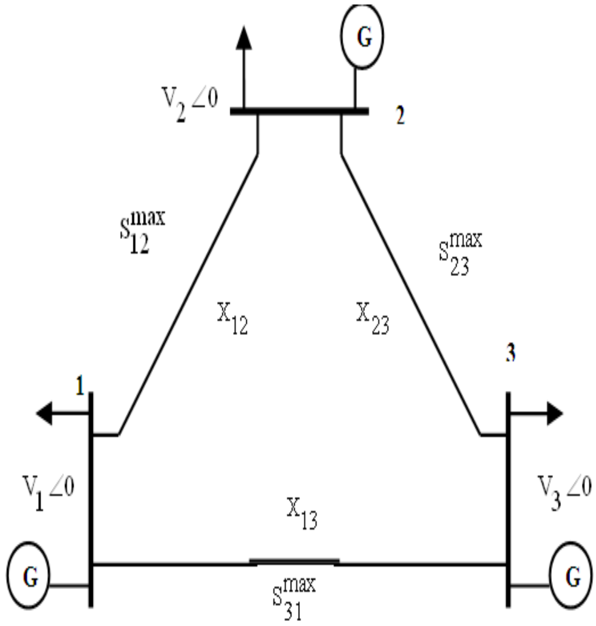

Figure 2.1: 3-Bus System

$$\frac{\partial P_{ij}}{\partial \delta_j} = -V_i V_j Y_{ij} \cos(\delta_i - \delta_j) \qquad (2.9b)$$

$$\frac{\partial P_{ij}}{\partial V_j} = 0 \qquad (2.9c)$$

$$\frac{\partial P_{ij}}{\partial V_i} = 0 \qquad (2.9d)$$

III. POWER FLOW CONTROL WITH UPFC:

Better utilization of existing power system capacities by installing new power electronic controllers such as FACTS has become imperative. FACTS controllers are able to change, in a fast and effective way, the network parameters in order to achieve better system performance. FACTS controllers, such as phase shifter, shunt, or series compensation and the most recent developed converter-based power electronic controllers, make it possible to control circuit impedance, voltage angle, and power flow for optimal operation performance of power systems, facilitate the development of competitive electric energy markets, stimulate the unbundling the power generation from transmission and mandate open access to transmission services, etc. With the practical applications of the converter based FACTS controllers—STATCOM, SSSC, TCSC, and UPFC in power systems, computer modeling of these is of great

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concern for the planning, operation planning, and control analysis of the FACTS controllers.

IV. THE UNIFIED POWER FLOW CONTROLLERS (UPFC):

The Unified Power Flow Controller (UPFC) is a member of this latter family of compensators and power flow controllers which utilize the synchronous voltage source (SVS) concept of controllers for providing a uniquely comprehensive capability for transmission system control.

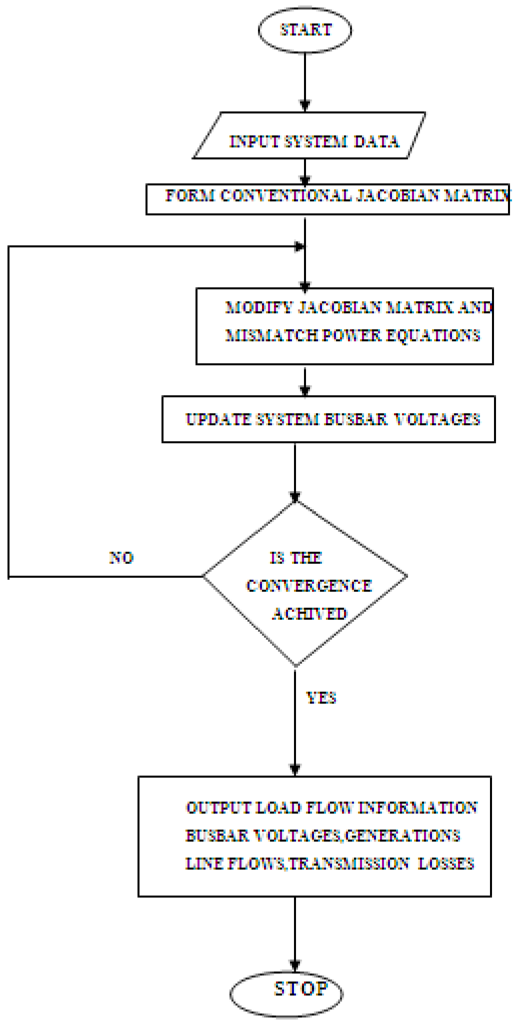
Within the framework of traditional power transmission concepts, the UPFC is able to control, simultaneously or selectively, all the parameters affecting power flow in the transmission line (i.e., voltage impedance, and phase angle). Alternatively, it can provide the unique functional capability of independently controlling both the real and reactive power flow in the line. These basic capabilities make the most powerful device presently available for transmission system control.

4.1 Modeling of UPFC:

A UPFC can be represented in the steady-state by two voltage sources representing fundamental components of output voltage waveforms of the two converters and impedance being leakage reactance's of two coupling transformers. the figure shows the two voltage-source model of UPFC.

The voltage at the bus i is taken as reference (all other angles are taken wrt this bus angle) Vi=|V|0And voltage upto UPFC is Vi'=Vi+Vse. The voltage sources,Vse and Vsh,are controllable in both magnitude and phase angles. the values of and r are defined with in the limits as

$0 \le r \le r\,max \qquad 0 \le \gamma \le 2$□□□



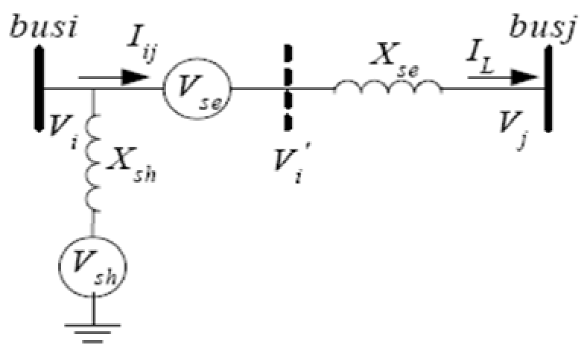


Figure 4.1: Two voltage-source model of UPFC

Vse is defined in terms of reference bus voltage (i.e) ,Vi.
Vse= r*Vi *e^(j)

V. AVAILABLE TRANSFER CAPABILITY:

The ATC of a transmission network has been defined as the unutilized transfer capability of the transmission network for the transfer of power for further commercial activity, over and above already committed usage.

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Power transactions between a specific seller bus/area can be committed only when sufficient ATC is available for that interface. Thus, such transfer capability can be used for reserving transmission services, scheduling firm and non-firm transactions and for arranging emergency transfers between seller bus/areas or buyer bus/areas of an interconnected power system network. ATC among areas of an interconnected power system network and also for critical transmission paths between areas are required to be continuously computed, updated and posted to Open Access Same time Information System (OASIS) following any change in the system conditions.

VI. SIMULATION RESULTS:

A.Simulation of a 5-Bus system:

Another sample 5-bus system is considered to illustrate the implementation of UPFC for ATC enhancement. The system consists of two generator buses, 3 load buses (3,4 and 5) , and 8 transmission lines. The UPFC is located in the line connected between 3 and 4. The real and reactive power settings of the UPFC are 40 MW and 2 MVAR. The results of the 5-bus system are given in Table.

Transfer Direction	Limiting Line		NR Reactive ATC		With UPFC Reactive ATC	
	NR	UPFC	PTDF	ΔP_{ij}	PTDF	ΔP_{ij}
1-2	2-1	2-1	0.8533	1.4241	0.8778	1.3844
1-3	3-1	3-6	0.4132	1.3287	0.9779	0.9995
2-3	2-3	3-6	0.4191	1.1821	1.2224	0.8093
2-4	4-3	5-2	0.4381	1.8101	1.3333	0.7419
2-5	2-5	3-6	0.7396	1.3375	0.7778	1.2719
3-4	3-4	4-6	0.9143	1.0931	1.0000	0.8136
4-5	5-2	3-6	0.5206	1.0937	0.8889	0.9153

From the Table, it can be seen that control of line flows by UPFC the ATC capability of from the system is improved and bus voltages are also improved significantly. The magnitudes of real power line flows are also redistributed significantly from high values to low values.

CONCLUSION:

Improving of ATC is an important issue in the current deregulation environment of power systems. ATC can be limited usually by heavily loaded circuits and buses with relatively low voltages.

It is well known that FACTS technology can control voltage magnitude, phase angle and circuit reactance. Using these devices may redistribute the load flow regulating bus voltage. Therefore, it is worthwhile to investigate the effect of FACTS controller on the ATC. The paper has presented the application of a new generation FACTS device, the UPFC in determination of ATC along with the line flow control using the reactive method.

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