# Betterment In Voltage Stability In A High Voltage Grid Exerting A Unified Power Flow Controller

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***Abstract***- *The unified power flow controller (UPFC) realizes real-time control over power flow in transmission lines by adjusting the line parameters, including node voltages, phase angle, and line impedance, which cover all adjustable parameters of other FACTS. The UPFC protection system is designed to detect all the occasions when the UPFC system and equipment are endangered, as well as failure and abnormal operating conditions, and to change the control strategy or remove the least faulty units to minimize the negative effects. Therefore, the UPFC protection system should be controlled in a hierarchical system, in which protective sections should be overlapped to ensure that there is no dead zone. Each area or item of equipment should be configured with double main and double standby protection using the same principle or with one main protection and one standby protection using different principles. In addition, the protection system should configure redundancy to prevent fault clearing failure in a single protection system.*

***Keywords***- UPFC (Unified Power flow Controller),FACTS(flexible alternating current transmission system) AC(alternating current) etc.

## I. INTRODUCTION

Power systems in general are interconnected for economic, security and reliability reasons. Exchange of contracted amounts of real power has been in vogue for a long time for economic and security reasons. To control the power flow on tie lines connecting control areas, power flow control equipment such as phase shifters are installed. They direct real power between control areas. The interchange of real power is usually done on an hourly basis. On the other hand, reactive power flow control on tie lines is also very important. Reactive power flow control on transmission lines connecting different areas is necessary to regulate remote end voltages. Though local control actions within an area are the most effective during contingencies, occasions may arise when adjacent control areas may be called upon to provide reactive power to avoid low voltages and improve system security. Since the industrial revolution, man's demand for and consumption of energy has increased steadily. The invention of the induction motor by Nikola Tesla in 1888 signaled the growing importance of electrical energy in the industrial world as well as its use for artificial lighting. A major portion of the energy needs of a modern society is supplied in the form of electrical energy. Industrially developed societies need an ever-increasing supply of electrical power, and the demand of this world has been doubling every ten years.

Very complex power systems have been built to satisfy this increasing demand. The trend in electric power production is toward an interconnected network of transmission lines linking generators and loads into large integrated systems, some of which span entire continents. Indeed, in the United States and Canada, generators located thousands of miles apart operate in parallel. This vast enterprise of supplying electrical energy presents many engineering problems that provide the engineer with a variety of challenges. The planning, construction, and operation of such systems become exceedingly complex. Some of the 2 problems stimulate the engineer's managerial talents; others tax his knowledge and experience in system design. The entire design must be predicted on automatic control and not on the slow response of human operators. To be able to predict the performance of such complex systems, the engineer is forced to seek ever more powerful tools of analysis and synthesis.

This report is concerned with some aspects of the design problem, particularly the dynamic performance, of interconnected power systems. Characteristics of the various components of a power system during normal operating conditions and during disturbances will be examined, and effects on the overall system performance will be analyzed. Emphasis will be given to the transient behavior in which the system is described mathematically by ordinary differential equations.

## II. SYSTEM MODELLING

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 as to provide a voltage regulation at the connection point.

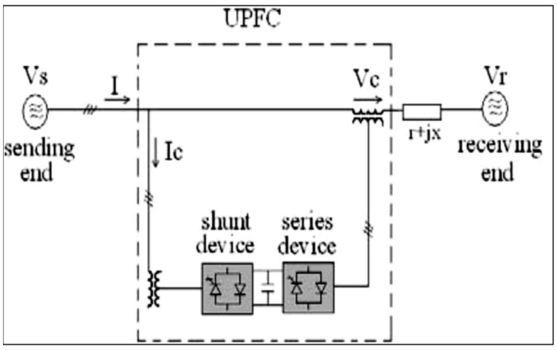


**Figure 1: Basic functional scheme of UPFC.**

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 flow on the transmission line.

### III. MATHEMATICAL MODEL OF UPFC

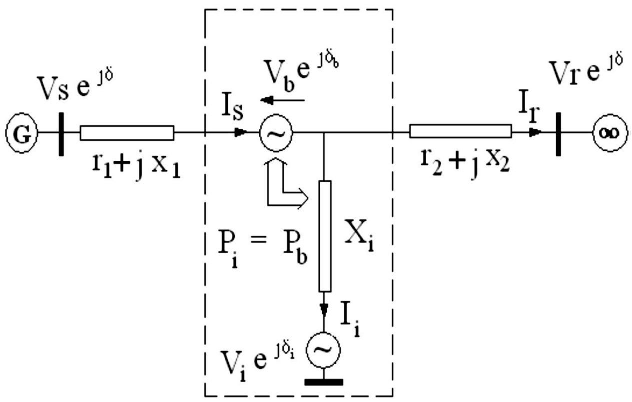


**Figure 2 : Mathematical model of UPFC**.

The single machine infinite bus (SMIB) has been taken initially to identify control parameters. As multi-machine dynamics is included in power network, other machine in the network can be viewed as representing the ac network at the next end, thus by increasing the dimensions of the state vector (additional Dd, Dx, DE0 q and DEFD) depending upon the number of machines can be included, thereby, existing state vector dimensions will be changed as [Ddm, Dxm, DE0 qm and DEFDm] where m = 1, . . . ,n represents the number of machines. By doing so the dynamics of each machine can be represented in state space framework and hence the dimension of state matrix will be changed accordingly and also any change in loading will be reflected in change in eigen values associated with the machines state vector.

While considering DC link, phase 'a' of transformer ET and the corresponding arm of VSCE. expression for voltage is given as:

$$\overline{V}_{Ea} = (m_e V_{dc}/2)\cos(\omega t - \delta_e)$$

Again DC link is considered, phase 'a' of transformer BT and the corresponding arm of VSCB then voltage expression is

$$\overline{V}_{Ba} = (m_b V_{dc}/2)\cos(\omega t - \delta_b)$$

the expression for voltage of phase 'b' and 'c' for VSC-E and VSC-B are similar but have phase shift of 2p/3 and 4p/3, respectively. The dynamics of DC link capacitor is

$$\frac{dV_{dc}}{dt} = \frac{1}{C_{dc}} i_{dc}$$

Where idc = iEdc _ iBdc.

On applying Park's transformation on three phase equations of the UPFC, the dynamic model of UPFC is [8]

$$\overline{V}_E = \frac{m_e V_{dc}}{2} e^{j\delta e}, \quad \overline{V}_B = \frac{m_b V_{dc}}{2} e^{j\delta b}$$
$$\frac{dV_{dc}}{dt} = \frac{3m_e}{4C_{dc}}[\cos\delta_e \quad \sin\delta_e]\begin{bmatrix} i_{Ed} \\ i_{Eq} \end{bmatrix} + \frac{3m_b}{4C_{dc}}[\cos\delta_b \quad \sin\delta_b]\begin{bmatrix} i_{Bd} \\ i_{Bq} \end{bmatrix}$$

From above following expressions can be written

$$\overline{V}_t = jX_{tE}\overline{I}_t + \overline{V}_{Et}$$
$$\overline{V}_{Et} = \overline{V}_{Bt} + jX_{Bv}\overline{I}_B + \overline{V}_b$$
$$\overline{V}_t = jE'_q - jI_d X'_d + I_q X_q$$

Using (4)–(8) d- and q-components of current IE and IB can be obtained. The non-linear differential equations from which Phillips– Heffron linear model of single machine infinite bus is derived [5–7] are

$$\dot{\delta} = \omega_0 \Delta\omega$$

$$\Delta\dot{\omega} = \frac{(P_m - P_e - D\Delta\omega)}{2H}$$

$$\dot{E}'_q = \frac{(-E_q + E_{qe})}{T'_{d0}}$$

$$\dot{E}_{qe} = \mathrm{Reg}(s)(V_{t0} - V_t) = \frac{K_A(V_{t0} - V_t)}{(1 + sT_A)}$$

Where,

$$P_e = \frac{E'_q V_b \sin\delta}{X'_{d\Sigma}} - \frac{V_b^2 (x_q - x'_d)\sin 2\delta}{2X'_{d\Sigma} X_{qE}}$$

$$E_q = \frac{X_{d\Sigma} E'_q}{X'_{d\Sigma}} - \frac{(x_d - x'_d) V_b \cos\delta}{X'_{d\Sigma}}$$

$$V_{td} = \frac{x_q V_b \sin\delta}{X_{q\Sigma}}; \quad V_{tq} = \frac{X_L E'_q}{X'_{d\Sigma}} + \frac{V_b x'_d \cos\delta}{X'_{d\Sigma}}$$

$$X'_{d\Sigma} = X'_d + X_L; \quad X_{q\Sigma} = X_q + X_L; \quad X_{d\Sigma} = X_d + X_L$$

where XL is the impedance of the transmission line, and the transfer function of the voltage regulator Reg(s) is assumed to be first-order linear loop. When a FACTS device is installed in system above Eqs. (9)–(12) must be modified in order to analyze the effect of device on the system performance.

## IV. PROPOSED WORK FOR IMPLEMENTATION & SIMULATION RESULT

- The UPFC is the most versatile FACTS controller developed so far, withall-encompassing capabilities of voltage regulation, series compensation, and phase shifting.
- It can independently and very rapidly control both real- and reactive power flows in a transmission.
- It is configured as shown in Fig 4.2.and comprises two VSCs coupled through a common dc terminal.

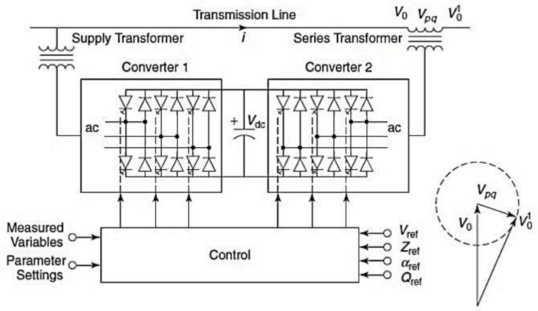


**Fig.3 Implementation of UPFC using two Back to Back VSCs**

One VSC converter 1 is connected in shunt with the line through a coupling transformer; the other VSC converter 2 is inserted in series with the transmission line through an interface transformer. The dc voltage for both converters is provided by a common capacitor bank. The series converter is controlled to inject a voltage phasor, Vpq, in series with the line, which can be varied from 0 to Vpq max. Moreover, the phase angle of Vpq can be independently varied from 00 to 3600. In this process, the series converter exchanges both real and reactive power with the transmission line. Although the reactive power is internally generated/ absorbed by the series converter, the real-power generation/ absorption is made feasible by the dcenergy–storage device that is, the capacitor. The shunt-connected converter 1 is used mainly to supply the real-power demand of converter 2, which it derives from the transmission line itself. The shunt converter maintains constant voltage of the dc bus.

- Thus the net real power drawn from the ac system is equal to the losses of the two converters and their coupling transformers.
- In addition, the shunt converter functions like a STATCOM and independently regulates the terminal voltage of the interconnected bus by generating/ absorbing a requisite amount of reactive power.

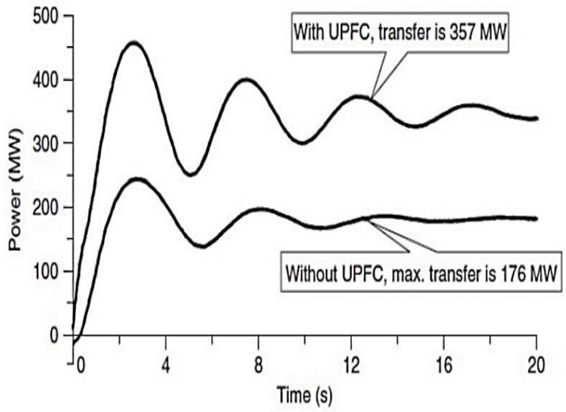


**Fig.4 Power Transfer Capability Curve with UPFC**

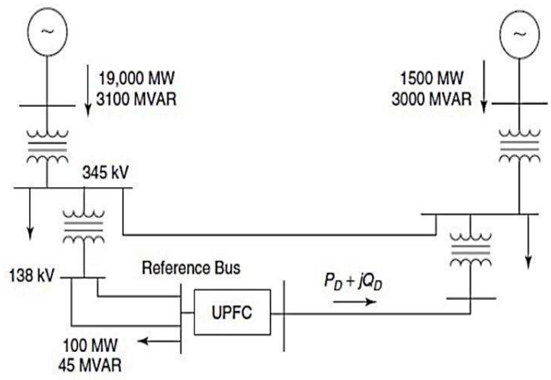


**Fig.5 UPFC Modelling**

In this model two voltage sources are used to represent the fundamental components of the PWM controlled output voltage waveform of the two branches in the UPFC.

- The impedance of the two coupling transformers is included in the proposed model and the losses of UPFC depicts the voltage source equivalent circuit of UPFC.
- The series injection branches a series injection voltage source and performs the main functions of controlling power flow whilst the shunt branch is used to provide real power demanded by the series branch and the losses in the UPFC.
- However, in the proposed model the function of reactive compensation of shunt branch is completely neglected.

## V. CONCLUSION

UPFC based controllers such as POD controller and d-q controller are effectively implemented on the power system to enhance protection. It supports good power compensation results.

- There is a marked improvement in the real and reactive power flow through the transmission line with UPFC when compared to the system without UPFC.
- The limitations in long transmission line caused by thermal capability which can be maximized using Unified Power Flow Controller.
- UPFC enhances the capability of Transmission line and hence the power system

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