# To Improve Power Flow Capability by Using Unified Power Flow Controller

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***ABSTRACT:*** **-**Now-a-days the Flexible AC Transmission Systems (FACTS) is very popular and essential device in power systems. After introducing the FACTS technology, power flow along the transmission lines becomes more flexible and controllable. Several FACTS-devices have been introduced for various applications in power system. Among a variety of FACTS controllers, Unified Power Flow Controller (UPFC) is the most powerful and versatile device. The UPFC is a device which can control the flow of real and reactive power by injection of a voltage in series with the transmission line. Both the magnitude and the phase angle of the voltage can be control independently. This topic is focused on to improve the bus voltage and control the active and reactive power flow in transmission system. Voltage source model study the operation of the UPFC in controlling the active power, reactive power, voltage profile of the system. In this direction series devices are used for voltage regulation and the shunt device are help in improve power transfer capability of the line by supply VARs to the system. The UPFC growing the transmission capacity and reduce the power congestion in the transmission line.

***Keywords:*** *-FACTS devices, UPFC, Active and Reactive power, AC transmission system, shunt and series converter*

## I. INTRODUCTION: -

In complex power systemsthere is a great need to improve utilization, while still maintaining reliability and security. While, some transmission lines are charged up to the thermal limitthe others may have been overloaded, which have an effect on the values of voltage and reduce system stability and security. For this reason, it is very important to control the power flows along transmission lines to meet transfer of power needs. The Electric Power Research Institute (EPRI), introduced a new approach to solve the problem of designing and operating power systems; the proposed concept is known as Flexible AC Transmission Systems (FACTS). The main objectives of FACTS are to enhance the power transfer the capability, facilitate the power flow control and improve the security and stability of the power system. FACTS controllers can be divided into four categories – Series, Shunt, Series-series, and Series-shunt Some of the Series-series, series-shunt controllers are known as unified due to the fact that the DC link are connected together to provide real power transfer, for instance the interline power flow controller (IPFC) and unified power flow controller (UPFC). Usually the DC connection has a minimum storage and can be added an extra source of energy like a battery or a super conducting magnet to replace this link storage device. For a voltage source converter, a unidirectional DC voltage of DC link capacitor, is presented to the AC side as AC voltage through sequential switching of devices. Throughout appropriate converter and modulation topology it is possible to vary the AC output voltage in magnitude and in any phase. The power reversal involves reversal of current, not the voltage. In our research work, the voltage source converters are used for all control strategies.

## II.UNIFIED POWER FLOW CONTROLLER: -

### A. Characteristics of UPFC: -

The Unified power flow controller is a device which can control simultaneously all parameters of line power flow (line impedance, voltage and phase angle). Such "new" FACTS device combines together the features of two "old" FACTS devices: The Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC).In practiceVoltage Source Converters connected respectivelyinshuntwith the transmission line through a shunt transformer and in series with the transmission line through a series transformer, connected to each other by a common dc link with a storage capacitor. The shunt converter is used for voltage regulation at the point of connection injecting an opportune reactive power flow into the line and to balance the real power flow exchanged between the series converter and the transmission line. The series converter can be used to control the real and reactive line power flow inserting an opportune voltage with controllable magnitude and phase in series with the transmission line. Thereby, the UPFC can fulfill functions of reactive shunt compensation, active and reactive series compensation and phase shifting. Besides, the UPFC allows a secondary but important function such as stability control to suppress power system oscillations increase the transient stability of power system. As the need for flexible and fast power flow controllers, such as the Unified power flow controller, is expected to grow in the future due to the changes in the electricity markets, there is a corresponding need for reliable and realistic models of these controllers to investigate the impact of them on the performance of the power system.

### B. Operation of UPFC

The basic components of the Unified power flow controller are two voltage source converters sharing a common dc storage capacitor and connected to the power system through coupling transformers. One Voltage source converter is connected in shunt to the transmission system via a shunt transformer, while the other one is connected in series through a series transformer. A basic UPFC functional scheme is shown in fig.1.

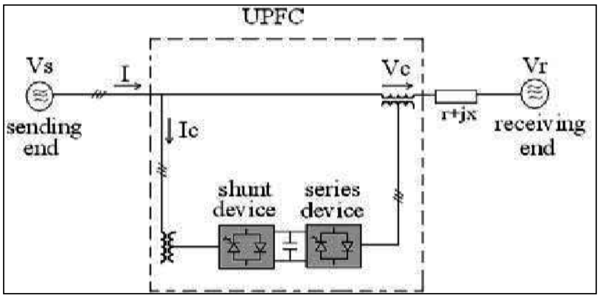


**Figure 1: Basic UPFC functional scheme**

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, thisconverter will exchange active and reactive power with the line. The reactive power is provided by the series converter, and the active power is transmitted to the dc terminals. The shunt converter is operated in such a way as to demand this dc terminal powerfrom the line keeping the voltage across the storage capacitor Vdcconstant.The shunt converter is operating as a STATCOM (Static Synchronous Compensators) that generates or absorbs reactive power to regulate the voltage magnitude at the connection point. Instead, the series converter is operating as SSSC (Static Synchronous series compensators) that generates or absorbs reactive power to regulate the current flow, and hence the power flows on the transmission line.

### C. Operating modes of UPFC

The Unified power flow controller has many operating modes. In particular, the shunt converter is operating in such a way to inject a controllable current, into the transmission line. This current consists of two components with respect to the line voltage: the real or direct component, which is in phase or in opposite phase with the line voltage, and the reactive or quadrature component, which is in quadrature. The direct component is automatically determined by the requirement to balance the real power of the series converter. The quadrature component, instead, can be independently set to any desired reference level (inductive or capacitive) within the capability of the converter, to absorb or generate respectively reactive power from the line. The shunt converter can be controlled in two different modes:

**1.VAR Control Mode**: The reference input is an inductive or capacitive VAR request. The shunt converter control translates the Var reference into a corresponding shunt current request and adjusts gating of the converter to establish the desired current. For this mode of control, a feedback signal representing the dc bus voltage, Vdc, is also required.

**2.Automatic Voltage Control Mode**: The shunt converter reactive current is automatically regulated to maintain the transmission line voltage at the point of connection to a reference value. For this mode of control, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series converter controls the magnitude and angle of the voltage injected in series with the line to influence the power flow on the line. The actual value of the injected voltage can be obtained in several ways.

**3.Direct Voltage Injection Mode**: The reference inputs are directly the magnitude and phase angle of the series voltage. Phase Angle Shifter Emulation mode: The reference input is phase displacement between the sending end voltage and the receiving end voltage.

4. **Line Impedance Emulation mode**: The reference input is an impedance value to insert in series with the line impedance Automatic Power Flow Control Mode: The reference inputs are values of P and Q to maintain on the transmission line despite system.

## III. MODELLING OF UPFC ON TRANSMISSION LINE: -

In a 500 kV /230 kV transmission system, which is connected in a loop configuration as shown in the figure 4 consists essentially of five buses (B1to B5) interconnected through three transmission lines (L1, L2,L3) and two 500 kV/230 kV transformer banks Tr1 and Tr2. Two power plants located on the 230kV system generate a total of 1500 MW which is transmitted to a 500 kV, 15000 MVA equivalent connected at bus B5 and to a 200 MW load connected at bus B3. The plant model includes a speed regulator, an excitation system as well as a power system stabilizer (PSS). In normal operation, most of the 1200 MW generation capacity of power plant #2 is exported to the 500 kV equivalents through two 400 MVA transformers connected between buses B4 and B5. For this illustration we consider a case where only two transformers out of three are available (Tr2= 2*400 MVA = 800 MVA). The simulation shows that most of the power generated by plant #2 is transmitted through the 800 MVA transformer bank (901 MW out of 1000 MW) and that 92.58 MW is circulating in the loop. Transformer Tr2 is therefore overloaded by 101 MVA. This power congestion can be relieved by placing the UPFC in the transmission line as shown in figure 3.

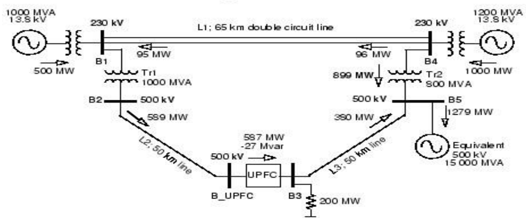


**Figure 2: Single line diagram system with UPFC**

### A. Parameters of the UPFC:

The series converter is rated 100 MVA with a maximum voltage injection of 0.1 pu. The shunt converter is also rated 100 MVA. The DC link nominal voltage (Vdc) is 40KV and DC link total equivalent capacitance(C) is 750μF.

The UPFC located at the right end of line L2 as shown in figure 4.4 is used to control the active and reactive powers at the 500 KV bus B3, as well as the voltage at bus B_UPFC. The UPFC consists of two 100 MVA, IGBT-based, converters (one shunt converter and one series converter interconnected through a DC bus).The important keys to note in the block diagram are:

- Use of Bypass breaker – Used to connect or disconnect UPFC Block from Power System.
- The reference power inputs [Pref, Qref] – Reference for power flow control.
- The reference voltage Vdqref – Reference for voltage injection

The series converter of UPFC can inject a maximum of 10% of nominal line-to-ground voltage (28.87 KV) in series with line L2.

## IV. SIMULATIONS AND RESULTS: -

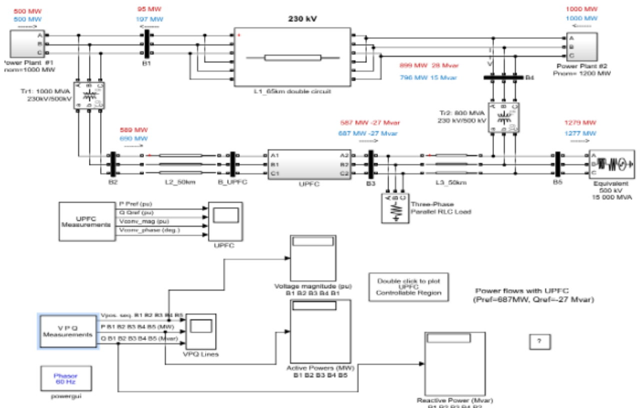


**Figure 3:MATLAB- SIMULINK Model of single line diagram with UPFC**

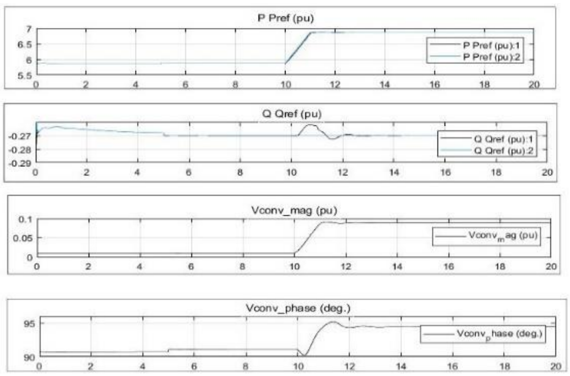


**Figure 4.1 P Pref, Q Qref, Voltage Mag (p.u), Voltage phase (deg) of the UPFC**

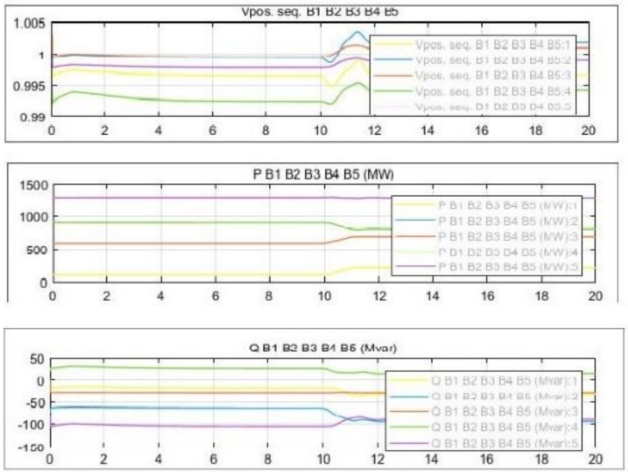


**Figure4.2Voltage, Real Power and Reactive power at Bus**

**Table 1.: Bus Voltages and Power withoutUPFC**

| Bus No | Bus voltage (pu) | 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.:Bus Voltages and Powerwith UPFC**

| Bus No | Bus voltage (pu) | 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 |
| | | | |

- Power Flow Control of system with 5% and 10% overloading condition

From above result it shows that with the help of UPFC power congestion problem will be overcome and power transfer capability will be increase.so we take 5% and 10% overloading condition.so we get result as mentioned below.

**Table 3.: Bus Voltages and Power without UPFC with 5% overloading**

| Bus No | Bus voltage (pu) | Active power (Mw) | Reactive Power(Mvar) |
|---|---|---|---|
| 1 | 0.9964 | 103.9 | -16.8 |
| 2 | 0.999 | 597.5 | -63.77 |
| 3 | 0.9923 | 595 | -29.05 |
| 4 | 0.9927 | 889.9 | 25.37 |
| 5 | 0.9979 | 1184 | -101.9 |

**Table 4.:Bus Voltages and Power without UPFC with 5% overloading**

| Bus No | Bus voltage (pu) | Active power (Mw) | Reactive Power (Mvar) |
|---|---|---|---|
| 1 | 0.9965 | 196.9 | -29.27 |
| 2 | 1.001 | 689.7 | -91.6 |
| 3 | 1.001 | 687 | -27 |
| 4 | 0.9942 | 796 | 14.54 |
| 5 | 0.9991 | 1181 | -84.42 |

**Table 5.:Bus Voltages and Power Without UPFC with 10% overloading**

| Bus No | Bus voltage (pu) | Active power (Mw) | Reactive Power (Mvar) |
|---|---|---|---|
| 1 | 0.9963 | 196.9 | -28.71 |
| 2 | 1.001 | 689.9 | -89.71 |
| 3 | 1.001 | 687 | -27 |
| 4 | 0.9942 | 796 | 14 |
| 5 | 0.9992 | 1106 | -81.25 |

**Table 6.: Bus Voltages and Power with UPFC with 10% overloading**

| Bus No | Bus voltage (pu) | Active power (Mw) | Reactive Power (Mvar) |
|---|---|---|---|
| 1 | 0.9962 | 110.7 | -17.16 |
| 2 | 0.9988 | 604.2 | -63.95 |
| 3 | 0.9991 | 602.4 | -29.84 |
| 4 | 0.9928 | 883 | 24.38 |
| 5 | 0.998 | 1184 | -98.96 |

## IV. CONCLUSION AND FUTURE SCOPE: -

Maintain the voltage magnitude, phase angle and line impedance of the transmission system the (UPFC) simulation study, MATLAB Simulink is used to simulate the model of UPFC connected to a 3phase transmission system the control & performance of the UPFC used for power quality improvement. The active and reactive powers increase with the increase in angle of injection. Simulation results show the effectiveness of UPFC to control the real and reactive powers. It is found that there is an improvement in the real and reactive powers through the transmission line when UPFC is introduced. After overloading with 5% and 10% results show the effectiveness of UPFC to control the real and reactive powers.

The UPFC model can be enhanced and enriched to terminate the power quality problems in a power system. The various ways for doing that: -

- We create different fault on system and check the result that UPFC recover that drop-in voltage.
- Placement of optimal location of UPFC in a transmission system.

We can try this method for hybrid power system also

## REFERENCES: -

[1] Parvej Khan,2.Himmat Singh .“Power flow control in a transmission line through UPFC." International Journal of Emerging Technology and advanced Engineering. Volume 2, Issue 12, December 2012.

[2] Vibhor Gupta “study and Effects of UPFC and its Control System for Power Flow Control and Voltage Injection in a Power System” International Journal of Engineering Science and Technology Vol. 2(7), 2010, 2558-2566.

[3] Noroozian “Use of UPFC for optimal power flow control” IEEE Transactions on Power Delivery, Vol. 12, No. 4, October 1997.

[4] Hingorani, N.g., “High power Electronics and Flexible AC Transmission System”, IEEE Power Eng. REV., july 1988.

[5] Phasor Model of UPFC control, MATLAB v 7.6, „help‟- UPFC power flow control.

[6] Control Block of UPFC - M. Toufan, U.D.Annakkage, “Simulation of The Unified Power Flow Controller performance Using PSCAD/EMTDC,” Electrical Power System Research Vol. 46, 1998, pp 67-75

[7] A. J. F. Keri, X. Lombard, A. A. Edris, “Unified Power Flow Controller (UPFC): Modelling and Analysis”, IEEE Trans. On Power Delivery, Vol. 14, No. 2, April 1999, pp. 648-654.

[8] L. Xu and V.G. Agelidis, “Flying Capacitor Multilevel PWM Converter Based UPFC‟, IEE Proc. Of Electronic Power Application Vol. 149, No. 4, July 2003. Page(s) 304-310.

[9] Narain G. Hingorani, Laszlo Gyugyi, “Understanding FACTS: Concepts and technology of Flexible AC Transmission Systems, ”IEEE Press Marketing, 1999, pp.297-352,pp.407-424.

[10]C.D.Schauder, D.M. Hamai, A. Edris,“Operation of the Unified Power Controller (UPFC) under practical constraints”, IEEE transaction on Power Delivery, vol. 13, No. 2, April 1998.