To Improve Active Power Flow Capability by using Unified Power Flow Controller

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Abstract— This paper shows the capacity of a unified power flow controller on the electric power transmission network. The UPFC performance was investigated in controlling power flow over the transmission lines. 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. In this paper we see how the UPFC growing the transmission capacity and reduce the power congestion in the transmission line. This paper permits the output that we obtained by implementing a Transmission system in MATLAB model by using UPFC.

Key words: AC Transmission system, UPFC, Power Flow Control, Voltage Regulation

I. Introduction

Power system utility around the world has quickly evolved some changes in the technology along with improvement in power system structures and performance. The ongoing development in the technology, demand a more ideal and beneficial operation with respect to power systems. In the present condition, most of the power systems in the growing countries with large interconnected networks share the generation supply to increase the reliability of the power system. However, the increasing complex large interconnected networks had variation in reliability of power supply, which resulted in system instability, difficult to control the power flow and security problems that resulted large number blackouts in different regions of the world. The reasons behind the above fault may be due to the analytical errors in planning and operation, weak interconnection of the power system, absence of maintenance or due to overload of the network. In the late 1980's the Electric Power Research Institute (EPRI) introduced a concept of technology to improve the power flow, improve the system stability and reliability with the existing power systems. This technology of power electronic devices is termed as Flexible Alternating Current Transmission Systems (FACTS) technology. The two main objectives of FACTS are to increase the transmission capacity and control power flow over designated transmission routes. FACTS controllers are ability to control the network condition in a very rapid manner and this feature of FACTS can be apply to improve the voltage stability, and steady state and transient stabilities of a complex power system. The improvements in the field of power electronics had major impact on the development of facts controllers. These controllers are depending on voltage source converters and include devices such as Static Var Compensators (SVC), Static Synchronous Compensators (STATCOM), Thyristor Controlled Series Compensators (TCSC), the Static Synchronous Series Compensators (SSSC), and the Unified Power Flow Controller (UPFC).

II. Unified power flow controller

A. Characteristics of UPFC

The UPFC is a device which can able to control all parameters of line power flow that is line impedance, voltage and phase angle at the same time. Such "advanced" FACTS device combines together the property of two "old" FACTS devices: The Static Synchronous Compensator (STATCOM) and the Static Synchronous Series Compensator (SSSC). In common practices, two Voltage Source Inverters connected in shunt with 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 the storage capacitor. The shunt inverter is used to regulate the voltage at the point of connection injecting reactive power flow into the line and balance the real power flow interchanged between the series inverter and the transmission line. The series inverter can be used to control the real and reactive power flow inserting an appropriate voltage with controllable magnitude and phase in series with the transmission line. Thereby, the UPFC can satisfy functions of reactive shunt compensation, active and reactive series compensation and phase shifting. Besides, the UPFC enables a secondary but main function such as stability control to extinguish power system oscillations enhancing the transient stability of power system. As the needed flexible and fast power flow controllers, such as the UPFC 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 explore the impact of them on the performance of the power system.

B. Structure

The structure of the Unified power flow controller (UPFC) carry two voltage source converters using insulated gate bipolar transistor (IGBT) or Integrated Gate Commutated Thyristor (IGCT) with a common DC link (Fig. 1). First converter is connected as parallel and another converter as series with transmission line. The shunt converter is used to provides active power required by the series converter through a common DC link. The main function of series converter is injecting an AC voltage with controllable magnitude and phase angle. The transmission line current flows through series converter and therefore, it exchanges the active and reactive power with the AC system. Generally, this structure (Fig.2) allows voltage control by the shunt inverter and independent active and reactive power flow control by the series inverter.

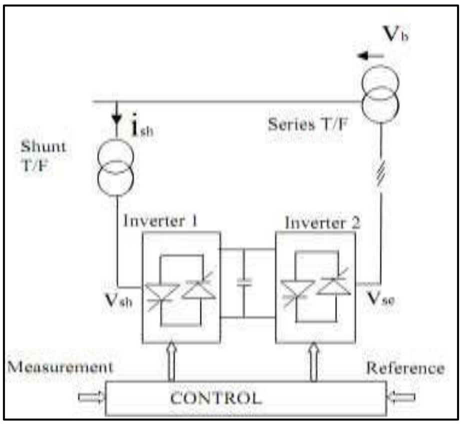

Fig. 1: UPFC installed in a transmission line.

In the parallel branch the active power is controlled by the phase angle of the converter output voltage. In the series branch the active and reactive power flows in the transmission line are influenced by the amplitude as well as the phase angle of the series injected voltage. Therefore, the active power controller can significantly affect the reactive power flow and vice versa.

C. Phasor Diagram Representation

Single phase circuit representation is given below with UPFC installed in the power system (Fig. 2). The voltages at the midpoint of transmission line is marked as VM, whereas the voltage injected by UPFC with controllable magnitude and phase is marked as Vc.

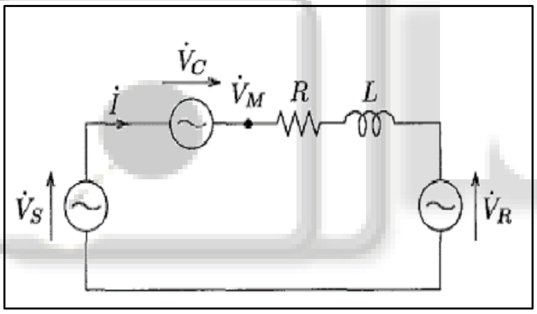

Fig. 2: UPFC installed in a transmission line.

The shunt inverter injects a controllable current into the transmission line. This controllable current consists of two components with respect to the line voltage:

1) real or direct component Id
2) reactive or quadrature component Iq .

the following phasor diagram (Fig. 3) is well describing the effect of direct and quadrature components.

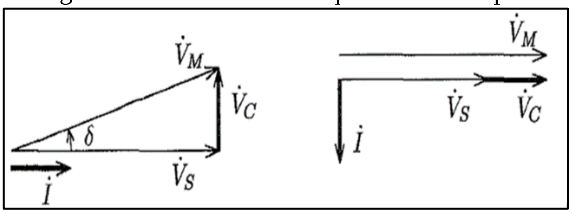

Fig. 3: (a) Active/Reactive Power Fig.3(b)Voltage regulation control

D. Operating Modes Of UPFC

1) VAR Control Mode:

The reference input is an inductive or capacitive reactive power the shunt inverter controls the reactive power reference into a corresponding shunt current request and the inverter to establish the desired current. Control mode of, a feedback signal representing the dc bus voltage, Vdc, is also required.

2) Automatic Voltage Control Mode:

The shunt inverter reactive current is control automatically for maintaining the transmission line voltage at the point of connection to a reference value. For automatic control mode, voltage feedback signals are obtained from the sending end bus feeding the shunt coupling transformer. The series inverter maintains 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.

4) Phase Angle Shifter Emulation mode:

The reference input is phase displacement between the sending end voltage and the receiving end voltage.

5) 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 SYSTEM

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. 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 contains 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.

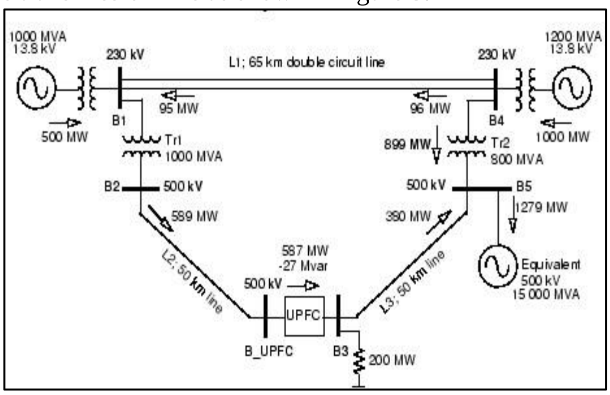

Fig. 4: Single line diagram system with UPFC

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:

1) Use of Bypass breaker – Used to connect or disconnect UPFC Block from Power System.
2) The reference power inputs [Pref, Qref] – Reference for power flow control.
3) 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 & RESULTS

A. Power Flow Control of System with and Without UPFC

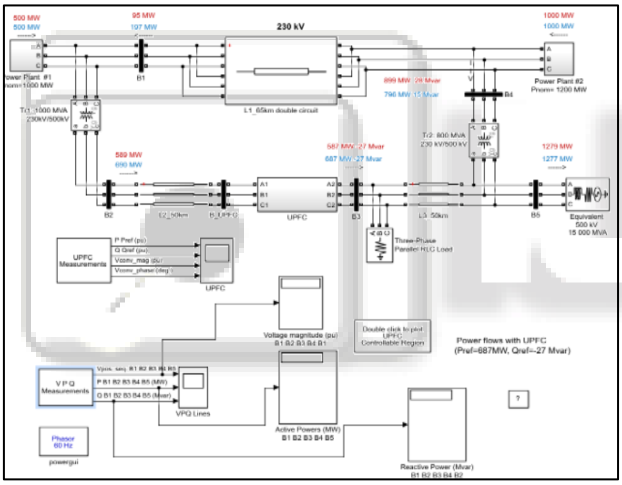

Fig. 5: MATLAB- SIMULINK Model of single line diagram with UPFC

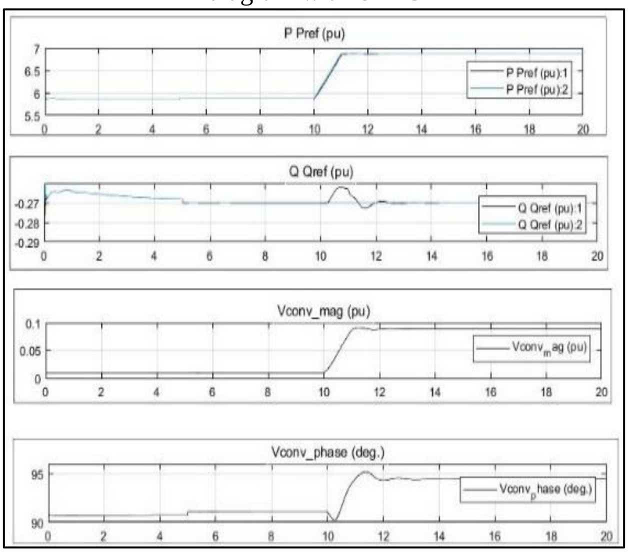

Fig 6.1: P Pref, Q Qref, Voltage Mag (p.u), Voltage phase (deg) of the UPFC

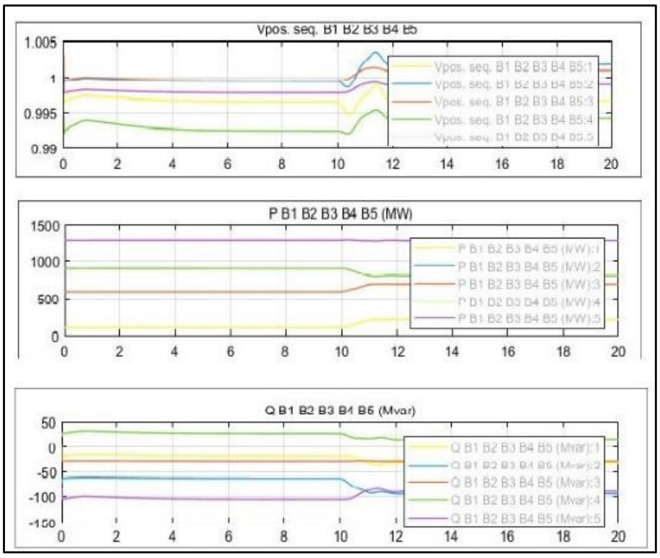

Fig 6.2: Voltage, Real Power and Reactive power at Bus

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 I: Bus Voltages and Power without 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

Table II: Bus Voltages and Power with UPFC

B. 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.

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 III: 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 IV: Bus Voltages and Power with UPFC with 5% 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 V: Bus Voltages and Power without 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

Table VI: Bus Voltages and Power with UPFC with 10% overloading

V. CONCLUSION & 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.

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