International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252

Power Flow Control in Transmission System with the use of UPFC

Manish Navlakha, Anil Choudhary, Jigyasa Jangid , Meenakshi Meena, Harsha Khandelwal, Lovish Bansal

Department of Electrical Engineering SKIT,Jaipur
Department of Electrical Engineering SKIT,Jaipur
Department of Electrical Engineering SKIT,Jaipur
Department of Electrical Engineering SKIT,Jaipur

Submitted: 01-08-2021 Revised: 14-08-2021 Accepted: 17-08-2021

ABSTRACT— Transmission lines of existing power system are used near to their thermal and stability limit. FACTS technology [1] opens up new opportunities for controlling power and enhancing the usable capacity of present, as well as new and upgraded lines. The UPFC (Unified Power flow Controller) is a second-generation FACTS device which enables independent control of active power and reactive power besides improving reliability and quality of the supply. This paper presents a performance analysis of a 3-machine transmission system with and without the use of UPFC in case of contingency. This paper examine the effectiveness of UPFC and simulation result shows a comparable performance.

Keywords—Transmission system, Unified power flow controller, FACTS.

I. INTRODUCTION

Modern transmission system has many limitations when power is transferred between the different systems or within the single area. Increasing transmission capacities is always a difficult task. The secure operation of power system has become an important and critical issue in today's large, complex, and load increasing systems. Security constraints such as thermal limits of transmission lines and bus voltage limits must be satisfied under all system operation conditions. FACTS controllers (Flexible AC Transmission Systems) have been used as an alternative method to increase existing transmission line transmission capacities [2]. Flexible AC Transmission Systems (FACTS) devices first introduced in 1970 and since then there are many FACTS devices have been invented according to the need and their applications in industries and power systems and their dynamic performance is continuously getting improved day by day. FACTS technology is integrated technology which is based on the power electronics devices such as Thyristor, GTO and other power electronics converters for the improvement of power system effective utilization, power transferring capability of system, stability of system, reliability of interconnected system and quality of transferred power. Power system depends on certain variables, which can be controlled to control the power flow in power system. FACTS devices can reduce the flows of heavily loaded lines, maintain the bus voltages at desired levels, and improve the stability of the power network. Consequently, they can improve the power system security under contingency situations. Unified power flow controller (UPFC) is a versatile FACTS's device which can independently or simultaneously control the active power, the reactive power, and the bus voltage to which it is connected[3].

- basic scheme of the upfc

UPFC is combination of STATCOM (Static synchronous compensator) and SSSC(Static synchronous series compensator). Active power requirement of SSSC is provided by STATCOM through the line itself. The basic components of the UPFC are two voltage source inverters (VSIs) sharing a common dc storage capacitor [4], 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. A basic UPFC functional scheme is shown in fig.1. The series inverter is controlled to inject a symmetrical three phase voltage system (Vc), 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 to provide a voltage regulation at the connection point.

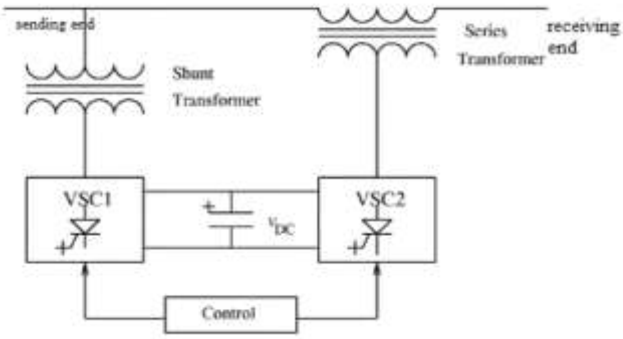


Figure 1:UPFC link in Transmission Line

The two VSI's can work independently of each other by separating the dc side. 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.

- operation of the upfc

The UPFC operates in different modes. In particular, the shunt inverter 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 inverter. The quadrature component, instead, can be independently set to any desired reference level (inductive or capacitive) within the capability of the inverter, to absorb or generate respectively reactive power from the line. The shunt inverter can be controlled in two different modes[5]. At normal power flow, when UPFC is absent, then zero voltage is injected through by the series converter, where as in the presence of UPFC, both magnitude & phase of the voltage injected in series can be varied as a result, the real and reactive power can be controlled. The injected voltage can be varied from 0 to 1 p.u. and the phase angle is varied from 0 to 360 degree based on which different modes are defined.

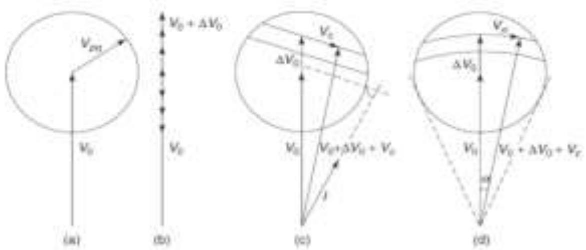


Figure 2: the phase diagram illustrating the series voltage injection and attainable power flow control functions

The figure 2 shows four basic operating modes of UPFC which are (a) series voltage injection (b) terminal voltage regulation (c) terminal voltage and line impedance regulation and (d) terminal voltage and phase angle regulation

- control of the upfc

In order to understand the UPFC Control System the phasor diagram in the figure 3 and figure 4 given below is system.

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252

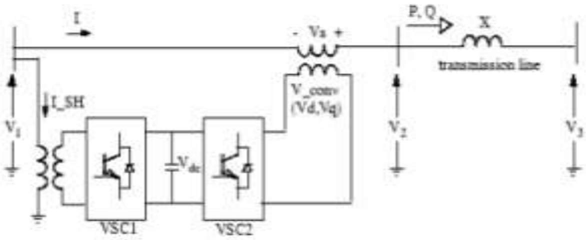
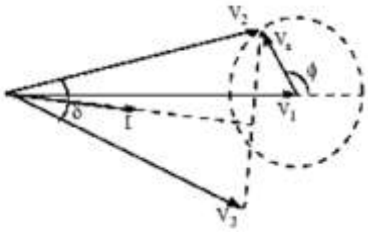


Figure 3: UPFC connected in transmission line



$$P = \frac{V_2 \times V_3 \times \sin\delta}{X}$$

$$Q = \frac{V_2(V_2 - V_3\cos\delta)}{X}$$

Figure 4: Phasor Diagram of Voltages and Currents

This FACTS topology provides much more flexibility than the SSSC for controlling the line active and reactive power because active power can now be transferred from the shunt converter to the series converter, through the DC bus. Contrary to the SSSC where the injected voltage Vs is constrained to stay in quadrature with line current I, the injected voltage Vs can now have any angle with respect to line current. If the magnitude of injected voltage Vs is kept constant and if its phase angle with respect to V1 is varied from 0 to 360 degrees, the locus described by the end of vector V2 (V2=V1+Vs) is a circle as shown on the phasor diagram. As is varying, the phase shift δ between voltages V2 and V3 at the two line ends also varies. It follows that both the active power P and the reactive power Q transmitted at one line end can be controlled [6].

The shunt converter operates as a STATCOM. In summary, the shunt converter controls the AC voltage at its terminals and the voltage of the DC bus. It uses a dual voltage regulation loop: an inner current control loop and an outer loop regulating AC and DC voltages. Control of the series branch is different from the SSSC. In a SSSC the two degrees of freedom of the series converter are used to control the DC voltage and the reactive power. In case of a UPFC the two degrees of freedom are used to control the active power and the reactive power[7,8]. The series converter can operate either in power flow control (automatic mode) or in manual voltage injection mode. In power control mode, the measured active power and reactive power are compared with reference values to produce P and Q errors. The P error and the Q error are used by two PI regulators to compute respectively the Vq and Vd components of voltage to be synthesized by the VSC. (Vq in quadrature with V1 controls active power and Vd in phase with V1 controls reactive power). In manual voltage injection mode, regulators are not used. The reference values of injected voltage Vdref and Vqref are used to synthesize the converter voltage.

- modelling of transmission system with upfc

A transmission line of a power system is taken to implement the use of UPFC. The two modes i.e. the power flow control and the voltage injection mode are simulated in SIMULINK to see the effect of UPFC on a power system[9]. Study is carried out to verify the utility of FACT device. The figure 5 below illustrates application study the steady-state and dynamic performance of a unified power flow controller (UPFC) used to relieve power congestion in a transmission system.

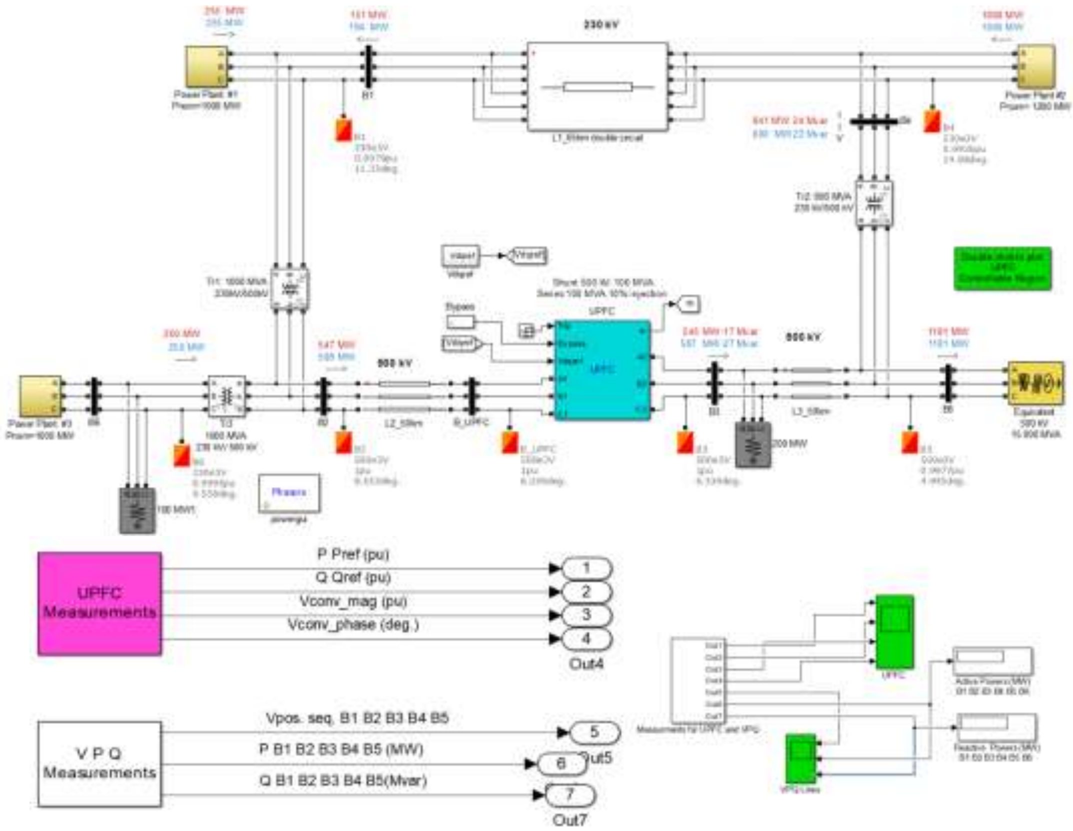
- Explanation of the model

UPFC is used to control the power flow in a 500 kV /230 kV transmission system. The system, connected in a loop configuration, consists essentially of six buses (B1 to B6) interconnected through transmission lines (L1, L2, L3) and three 500 kV/230 kV transformer banks Tr1,Tr2 and Tr3. Three power plants located on the 230-kV system generate a total of 1505 MW which is transmitted to a 100W,200W and 500-kV 15000-MVA equivalent load connected at bus B6,B3 and B5 respectively The plant models include a speed regulator, an excitation system as well as a power system stabilizer (PSS)[10]. In normal operation, most of the 1200-MW generation capacity of

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252

power plant #2 is exported to the 500-kV equivalent through three 400-MVA transformers connected between buses B4 and B5. We are considering a contingency case where only two transformers out of three are available (Tr2= 2*400 MVA = 800 MVA). Using the load flow option of the power gui block, the model has been initialized with plants #1 ,#2, #3 generating respectively 255MW, 250MW and 1000 MW and the UPFC out of service (Bypass breaker closed). The resulting power flow obtained at buses B1 to B6 is indicated by red numbers on the circuit diagram. The load flow shows that most of the power generated by plant #2 is transmitted through the 800-MVA transformer bank (841 MW out of 1000 MW), the rest (159 MW), circulating in the loop. Transformer Tr2 is therefore overloaded by 41 MVA. The model illustrates how the UPFC can relieve this power congestion.

The UPFC located at the right end of line L2 is used to control the active and reactive powers at the 500-kV bus B3, as well as the voltage at bus B-UPFC. It consists of a phasor model of two 100-MVA, IGBT-based, converters (one connected in shunt and one connected in series and both interconnected through a DC bus on the DC side and to the AC power system, through coupling reactors and transformers). Parameters of the UPFC power components are given in the dialog box. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.



- Simulation of the model

The UPFC reference active and reactive powers are set in the blocks labelled "Pref(pu)" and "Qref(pu)". Initially the Bypass breaker is closed and the resulting natural power flow at bus B3 is 545 MW and -17 Mvar. The Pref block is programmed with an initial active power of 5.45 pu corresponding to the natural flow. Then, at t=5s, Pref is increased by .42 pu (42 MW), from 5.45 pu to 5.87 pu, while Qref is kept at -0.27 pu.

Running the simulation and examining on the UPFC Scope how P and Q measured at bus B3 follow the reference values. At t=5 s, when the Bypass breaker is opened the natural power is diverted from the Bypass breaker to the UPFC series branch without noticeable transient. At t=5 s, the power increases at a rate of .42 pu/s. It takes one second for the power to increase to 587 MW. This increase of active power at bus B3 is achieved by injecting a series voltage of 0.042 pu with an angle of 94 degrees. This results in an approximate

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252

41 MW decrease in the active power flowing through Tr2 (from 841 MW to 800 MW), which now carries an acceptable load.

- simulation outcomes

In the UPFC dialog box Control parameters (series converter) we can select the mode of operation of UPFC (voltage injection mode or power flow control mode). For the first five seconds the Bypass breaker stays closed, so that the PQ trajectory stays at the (-17Mvar, 545 MW) point. Then when the breaker opens, the magnitude of the injected series voltage is ramped. At 10 s, the angle of the injected voltage starts varying at a rate of 45 deg/s.

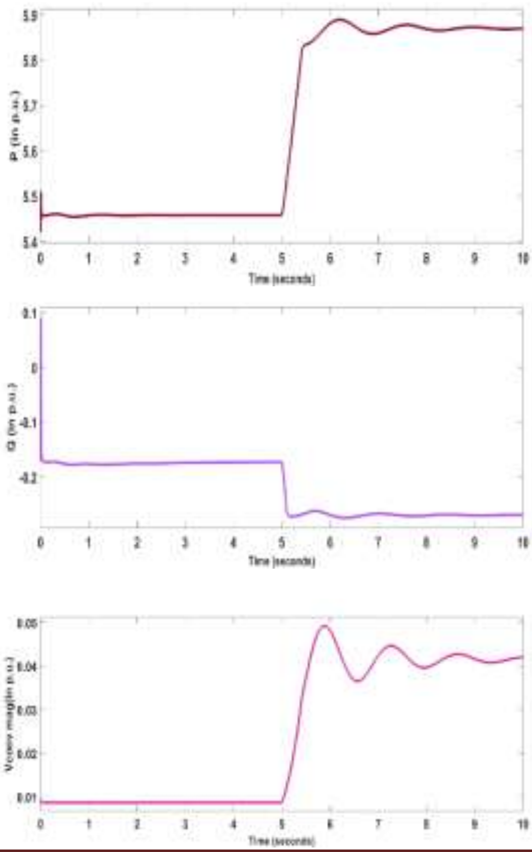
- Active and reactive power at buses without compensation

Bus no.	Active power	Reactive Power
1	151.6	-27
2	547.5	-55.92
3	545.8	-17.34
4	841.6	24.85
5	1182	-76.64
6	247.8	-8.058

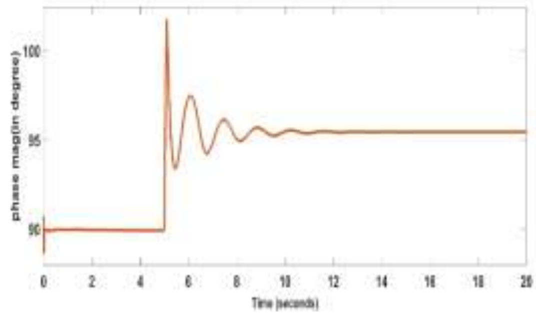
- Active and reactive power at buses with compensation

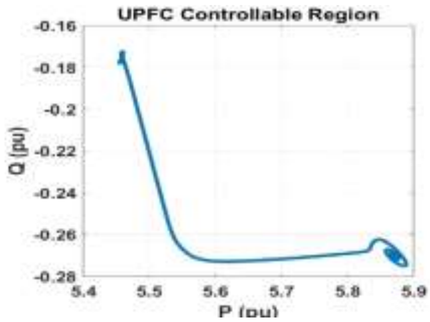
Bus no.	Active Power	Reactive Power
1	193.4	-34.37
2	589	-73.57
3	587	-27
4	799.3	21.59
5	1181	-78.49
6	247.8	-13.01

- Power flow Control with the UPFC

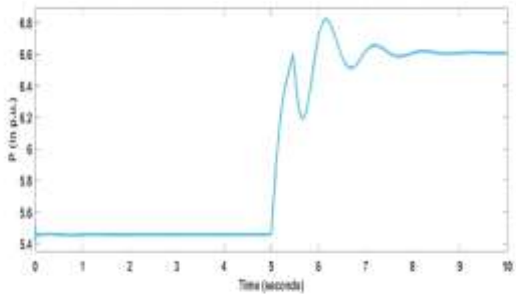


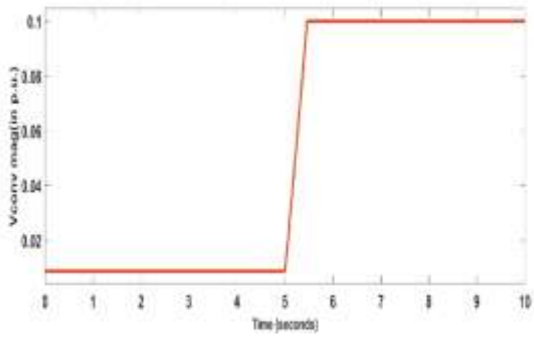
International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252



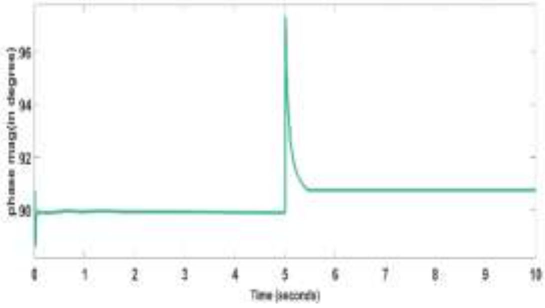


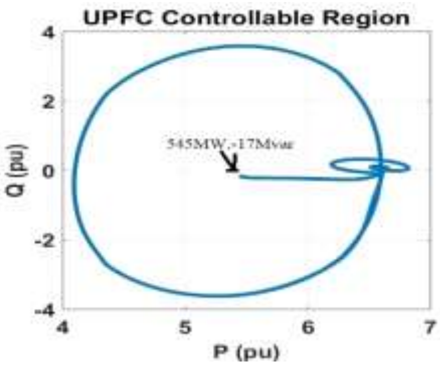
- Manual Voltage Injection mode





International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252





II. RESULT

The results are in compliance with the UPFC characteristics. 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 bypass breaker is closed, power flow (active and reactive) changes through the buses therefore reducing the overload on transformer 2. The variation in active and reactive power can be seen in the plots given above also showing the oscillations in power as breaker is closed. The main concern lies at the UPFC controllable region. The region defined in the graph such that the UPFC can only act under these conditions else the UPFC behaves like open to transmission link.

III. CONCLUSION

In the simulation study, MATLAB Simulink environment is used to simulate the model of UPFC connected to a 3-machine transmission system. This paper presents the control & performance of the UPFC used for power flow improvement. The real 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. The UPFC system has the advantages like reduced maintenance and ability to control real and reactive powers. Therefore, we can conclude by the use of UPFC we can achieve power flow control , transient stability , faster Steady State achievement and improved voltage profile

REFERENCES

[1]. Hingorani, Narain G. "FACTS technology-state of the art, current challenges and the future prospects." IEEE Power Engineering Society General Meeting. Vol. 2. 2007.
[2]. Sen, Kalyan K., and Eric J. Stacey. "UPFC-unified power flow controller: theory, modeling, and applications." IEEE transactions on Power Delivery 13.4 (1998): 1453-1460.
[3]. Gyugyi, Laszlo, et al. "The unified power flow controller: a new approach to power transmission control." IEEE Transactions on power delivery 10.2 (1995): 1085-1097.
[4]. Papic, I., et al. "Basic control of unified power flow controller." IEEE Transactions on Power systems 12.4 (1997): 1734-1739.
[5]. Schauder, C. D., et al. "Operation of the unified power flow controller (UPFC) under practical constraints." IEEE transactions on power delivery 13.2 (1998): 630-639.
[6]. Gupta, Vibhor. "Study and effects of UPFC and its control system for power flow control and voltage injection in a power system." International journal of engineering

International Journal of Advances in Engineering and Management (IJAEM)
Volume 3, Issue 8 Aug 2021, pp: 1165-1172 www.ijaem.net ISSN: 2395-5252

science and technology 2.7 (2010): 2558-2566.
[7]. Geethalakshmi, B., and P. Dananjayan. "Investigation of performance of UPFC without DC link capacitor." Electric Power Systems Research 78.4 (2008): 736-746.
[8]. Gholipour, Eskandar, and Shahrokh Saadate. "Improving of transient stability of power systems using UPFC." IEEE Transactions on power delivery 20.2 (2005): 1677-1682.
[9]. Wang, H. F. "Applications of modelling UPFC into multi-machine power systems." IEE Proceedings-Generation, Transmission and Distribution 146.3 (1999): 306-312.
[10]. Koo, K. L. "Modeling and cosimulation of AC generator excitation and governor systems using simulink interfaced to PSS/E." IEEE PES Power Systems Conference and Exposition, 2004.. IEEE, 2004.