International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 05 Issue: 09 | Sept - 2021 ISSN: 2582-3930

Improvement of power flow in the power system network by using UPFC

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ABSTRACT:- In a power systems, power flows from the generating centre's to the load centres. In this process many things require investigation, such as the profile of the bus voltage, flow of active power (MW) and reactive power (MVar) in transmission lines, effect of rearranging circuits and installation of regulating devices etc., for different loading conditions. As modern power system has become more large and complex, these investigations should be done with some sort of simulation of the system. Hence in order to meet power demand in a very efficient and economical way, by incorporating Unified Power Flow Controller Device (UPFC) in the transmission system and by using Congestion Management which is used in this project and it makes possible to handle practically all power flow control and transmission line compensation problems, using Solid State Controllers, which provide functional flexibility. The Unified Power Flow Controller (UPFC) is a member of Flexible AC transmission system (FACTS) device, that utilizes the synchronous voltage sources (VSC) to provide comprehensive control of traditional power flow concepts, the UPFC able to control simultaneously or selectively, all the parameters such as voltage, Impedance, phase angle that affect the power flow in a transmission line. In other words it can provide functional capabilities of controlling both the active and reactive power independently. This project aims to present a reliable method to meet the requirements for control of power flow in transmission system by simulation method. A Mat lab program has been developed to calculate the control settings parameters of the UPFC after the load flow is converged.

Keywords: UPFC; FACTS; Statcom; Bus; Power flow; Matlab.

1. INTRODUCTION:- As the power systems are becoming more complex it requires careful design of the new devices for the operation of controlling the power flow in transmission system, which should be flexible enough to adapt to any momentary system conditions. The operation of an ac power transmission line, is generally constrained by limitations of one or more network parameters and operating variables By using FACTS technology such as STATCON (Static Condenser), Thyristor Controlled Series Capacitor (TCSC), Thyristor controlled Phase angle Regulator (TCPR), UPFC etc., the bus voltages, line impedances, and phase angles in the power system can be regulated rapidly and flexibly. FACTS do not indicate a particular controller but a host of controllers which the system planner can choose based on cost benefit analysis.

The UPFC is an advanced power system device capable of providing simultaneous control of voltage magnitude and active and reactive power flows in an adaptive fashion. Owing to its instantaneous speed of response and unrivalled functionality, it is well placed to solve most issues relating to power flow control in modern power systems. The UPFC can control voltage, line impedance and phase angles in the power system[1] which will enhance the power transfer capability and also decrease generation cost (and improve the security and stability) of the power system. UPFC can be used for power flow control, loop flow control, load sharing among parallel corridors In this paper UPFC is treated to operate in closed loop form and control parameters of UPFC are derived to meet the required power flow along the line.

2. UPFC model for power flow studies:

2.1 Principles of UPFC: The UPFC can provide simultaneous control of transmission voltage, impedance and phase angle of transmission line. It consists of two switching converters as shown in fig1. These converters are operated from a common d.c link provided by a d.c storage capacitor. Converter 2 provides the power flow control of UPFC by injecting an ac voltage with controllable magnitude and phase angle in series with the transmission line via a series transformer. Converter one is to absorb or supply the real power demand by the converter 2 at the common d.c link. It can also absorb or generate controllable reactive power and provide shunt reactive power compensation.

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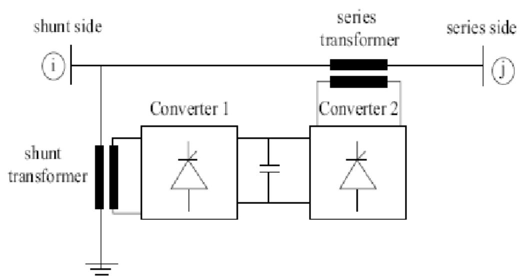


Fig.1 Implementation of the UPFC by back-to-back voltage source converters

The UPFC concept provides a powerful tool for cost effective utilization of individual transmission lines by facilitating the independent control of both the real and reactive power flow and thus the maximization of real power transfer at minimum losses in the line.

2.2 Power injection model of UPFC: The two voltage source model of UPFC is converted in to two power injections in polar form for power flow studies with approximate impedances as shown in fig 2. The advantage of power injection representation is does not destroy the symmetric characteristics of admittance matrix. When formulated in polar form, the power flow equations are quadratic. Some numerical advantages can be obtained from the form. The polar form also leads Naturally to the idea of an optimal power flow, this will be discussed in next section. The voltage sources can be represented by the relation- ship between the voltages and amplitude modulation ratios and phase shift of UPFC.In this model the shunt transformer impedance and the transmission line impedance including the series transformer impedance are assumed to be constant. No power loss is considered with the UPFC. However the proposed model and algorithm will give The solution of optimal power flow in the transmission lines this will be discussed in section 3.3.

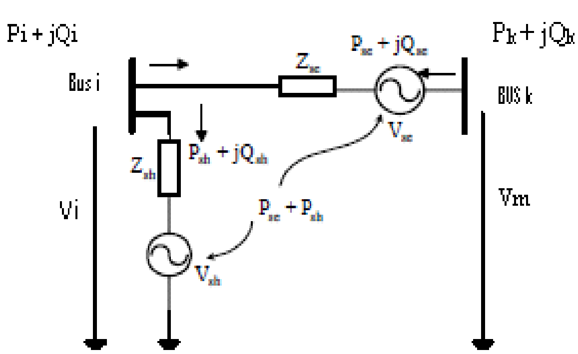


Fig.2. Two Voltage source model of UPFC

2.3 UPFC Injection Model for Load Flow Studies: The load flow studies are the backbone of the power system analysis and design. They are used for planning, operation, economic scheduling, exchange of power between utilities and stability analysis.

- The analysis of power flow is very important in planning stages of new networks or addition to existing ones like adding new generator sites, increase load demand and locating new transmission sites.
- Load flow solution gives the nodal voltages and phase angles and hence the power injection at all the buses and power flows through interconnecting power channels.
- The load flow is used to determine the best location as well as optimal capacity of proposed generating station, substation and new lines.
- It’s used to determine the voltage of the buses. The voltage level of the buses must be kept within the closed tolerances.
- To minimize the transmission line losses.
- Economic consideration with respect to fuel cost to generate all the power needed.
- To study about the stability of power system.

3. Bus Classification: In a power system a bus is a node at which one or many lines, one or many loads and generators are connected. Each node or bus is associated with 4 quantities, as magnitude of voltage, phage angle of voltage, true or active power and reactive power in load flow problem, out of these 4 quantities two are specified and remaining 2 are required to be determined through the solution of equation. Depending on these quantities that have been specified, the buses are can be classified into 3 categories. Buses are classified according to which two out of the four variables are specified as-

3.1 Slack Bus: A swing bus (or slack bus) is a generator bus with a generator controlling the terminal voltage, , and angle delta, δ, at the bus. It is also known as a reference bus. The terminal voltage angle would typically be set at 0° with the voltage set at 1 per unit (p.u.) voltage. The terminal voltage is kept constant by adjusting the field current in the generator. With and the angle delta being known parameters for this bus, the two unknown parameters are the real power P, and the reactive power Q. The slack bus makes up the difference between the scheduled loads and generated power that is caused by the losses in the networks. This machine swings or takes up the slack; hence it fits its name.

3.2 Generator Bus: A generator or PV bus in which a generator is connected with it .A synchronous generator controlling the terminal voltage and real power supplied to the bus. The terminal voltage is kept constant by adjusting the field current in the generator. At the same time, this also changes the reactive power supplied by the generator to the system.

The prime mover controls the power the generator supplies the system. The generator on this bus has a set amount of real power, P, it provides at or near its capacity. These generators work most efficiently at full capacity. Rest of the real power is picked up by the Swing Bus generator. The P and the are the two known parameters for this bus type. The reactive power Q, and the angle delta, δ are the two unknown parameters for this type of bus.

3.3 Load Bus: A load bus in which the real and reactive power are scheduled or connected. There are no generators are connected with them. The known parameters for this type bus are real power (P), and reactive power (Q). The unknown parameters are the voltage magnitude |V|, and angle delta δ.

4. MODEL OF UPFC

Equivalent model of UPFC is shown in Fig 3. In the Equivalent model of UPFC a voltage source is connected in series with the transmission line for representing series converter and a current source is connected in shunt for representing shunt converter. The waveforms of Active and reactive power is shown in figures 4.1, 4.2, 4.3.

From the waveforms obtained through simulation of equivalent model of UPFC, the results are shown in fig 4.1, 4.2, 4.3 [1]. From the observations, that the Active and reactive power of the power system can be control by controlling the phase angle of series injected voltage.

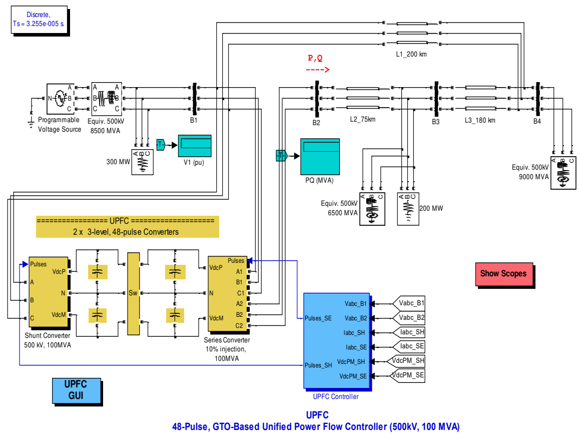


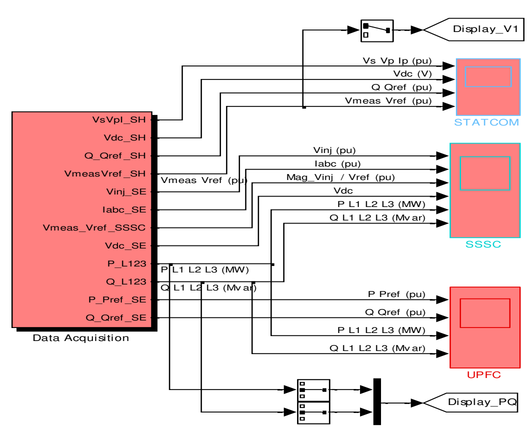
Fig. 3 Equivalent model of UPFC

4.1 Model Description

A Unified Power Flow Controller (UPFC) is used to control the power flow in a 500 kV transmission system. The UPFC located at the left end of the 75-km line L2, between the 500 kV buses B1 and B2, is used to control the active and reactive powers flowing through bus B2 while controlling voltage at bus B1. It consists of two 100-MVA, three-level, 48-pulse

GTO-based converters, one connected in shunt at bus B1 and one connected in series between buses B1 and B2. The shunt and series converters can exchange power through a DC bus. The series converter can inject a maximum of 10% of nominal line-to-ground voltage (28.87 kV) in series with line L2.

This pair of converters can be operated in three modes:



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Volume: 05 Issue: 09 | Sept - 2021 ISSN: 2582-3930

Fig. 4 Pair of converters of UPFC in three modes

Unified Power Flow Controller (UPFC) mode, when the shunt and series converters are interconnected through the DC bus. When the disconnect switches between the DC buses of the shunt and series converter are opened, two additional modes are available:Shunt converter operating as a Static Synchronous Compensator (STATCOM) controlling voltage at bus B1Series converter operating as a Static Synchronous Series Capacitor (SSSC) controlling injected voltage, while keeping injected voltage in qudrature with current.

The mode of operation as well as the reference voltage and reference power values can be changed by means of the “UPFC GUI” block.

When the two converters are operated in UPFC mode, the shunt converter operates as a STATCOM. It controls the bus B1 voltage by controlling the absorbed or generated reactive power while also allowing active power transfer to the series converter through the DC bus. The reactive power variation is obtained by varying the DC bus voltage. The four three-level shunt converters operate at a constant conduction angle (Sigma= 180-7.5 = 172.5 degrees), thus generating a quasi-sinusoidal 48-step voltage waveform. The first significant harmonics are the 47th and the 49th.

When operating in UPFC mode, the magnitude of the series injected voltage is varied by varying the Sigma conduction angle, therefore generating higher harmonic contents than the shunt converter. As illustrated in this demo, when the series converter operates in SSSC mode it generates a “true” 48-pulse waveform.

The natural power flow through bus B2 when zero voltage is generated by the series converter (zero voltage on converter side of the four converter transformers) is P=+870 MW and Q=-70 Mvar. In UPFC mode, both the magnitude and phase angle and the series injected voltage can be varied, thus allowing control of P and Q. The UPFC controllable region is obtained by keeping the injected voltage to its maximum value (0.1 pu) and varying its phase angle from zero to 360 degrees. To see the resulting P-Q trajectory, double click the “Show UPFC Controllable Region”. Any point located inside the PQ elliptic region can be obtained in UPFC mode.

4.2 Demonstration:

1. Power control in UPFC mode

Open the UPFC GUI block menu. The GUI allows you to choose the operation mode (UPFC, STATCOM or SSSC) as well as the Pref/Qref reference powers and/or Vref reference voltage settings . Also, in order to observe the dynamic response of the control system, the GUI allows you to specify a step change of any reference value at a specific time.

Make sure that the operation mode is set to “UPFC (Power Flow Control)”. The reference active and reactive powers are specified in the last two lines of the GUI menu. Initially, Pref= +8.7 pu/100MVA (+870 MW) and Qref=-0.6 pu/100MVA (-60 Mvar). At t=0.25 sec Pref is changed to +10 pu (+1000MW). Then, at t=0.5 sec, Qref is changed to +0.7 pu (+70 Mvar). The reference voltage of the shunt converter (specified in the 2nd line of the GUI) will be kept constant at Vref=1 pu during the whole simulation (Step Time=0.3*100> Simulation stop time (0.8 sec). When the UPFC is in power control mode, the changes in STATCOM reference reactive power and in SSSC injected voltage as are not used.

Run the simulation for 0.8 sec. Open the “Show Scopes” subsystem. Observe on traces 1 and 2 of the UPFC scope the variations of P and Q. After a transient period lasting approximately 0.15 sec, the steady state is reached (P=+8.7 pu; Q=-0.6 pu). Then P and Q are ramped to the new settings (P=+10 pu Q=+0.7 pu). Observe on traces 3 and 4 the resulting changes in P Q on the three transmission lines. The performance of the shunt and series converters can be observed respectively on the STATCOM and SSSC scopes. If you zoom on the first trace of the STATCOM scope, you can observe the 48-step voltage waveform Vs generated on the secondary side of the shunt converter transformers (yellow trace) superimposed with the primary voltage V_p and the primary current I_p. The dc bus voltage (trace 2) varies in the 19kV-21kV range. If you zoom on the first trace of the SSSC scope, you can observe the injected voltage waveforms V_{inj} measured between buses B1 and B2.

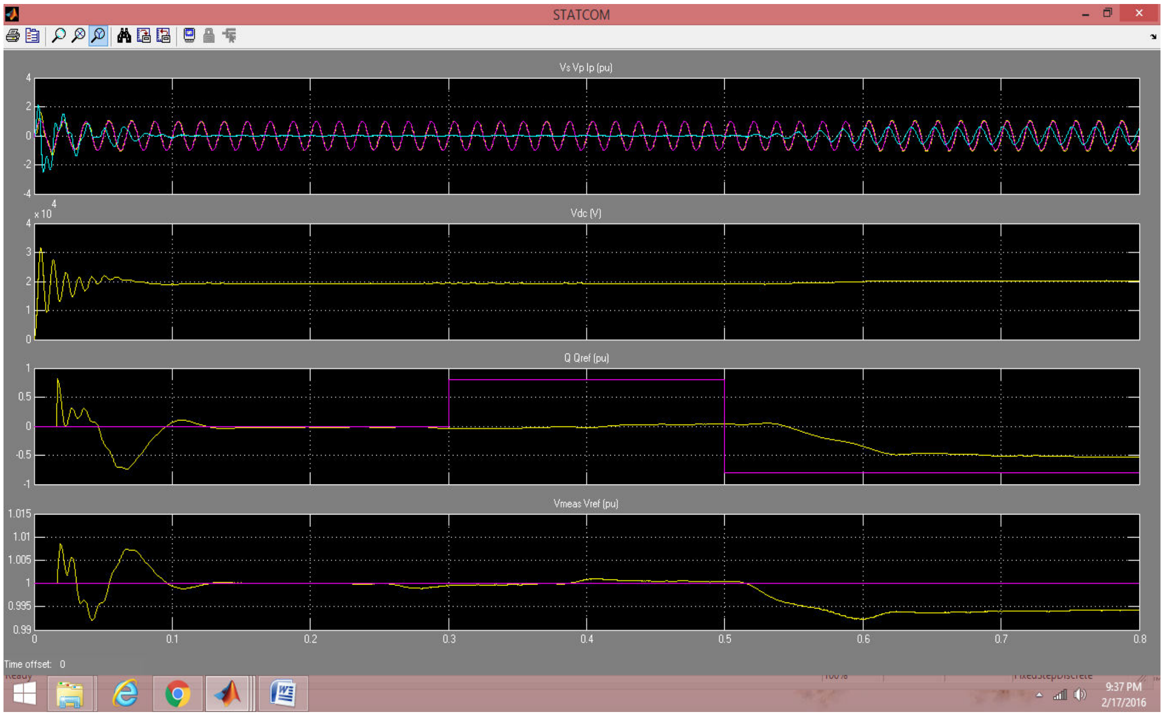

Fig 5 Var control in STATCOM mode

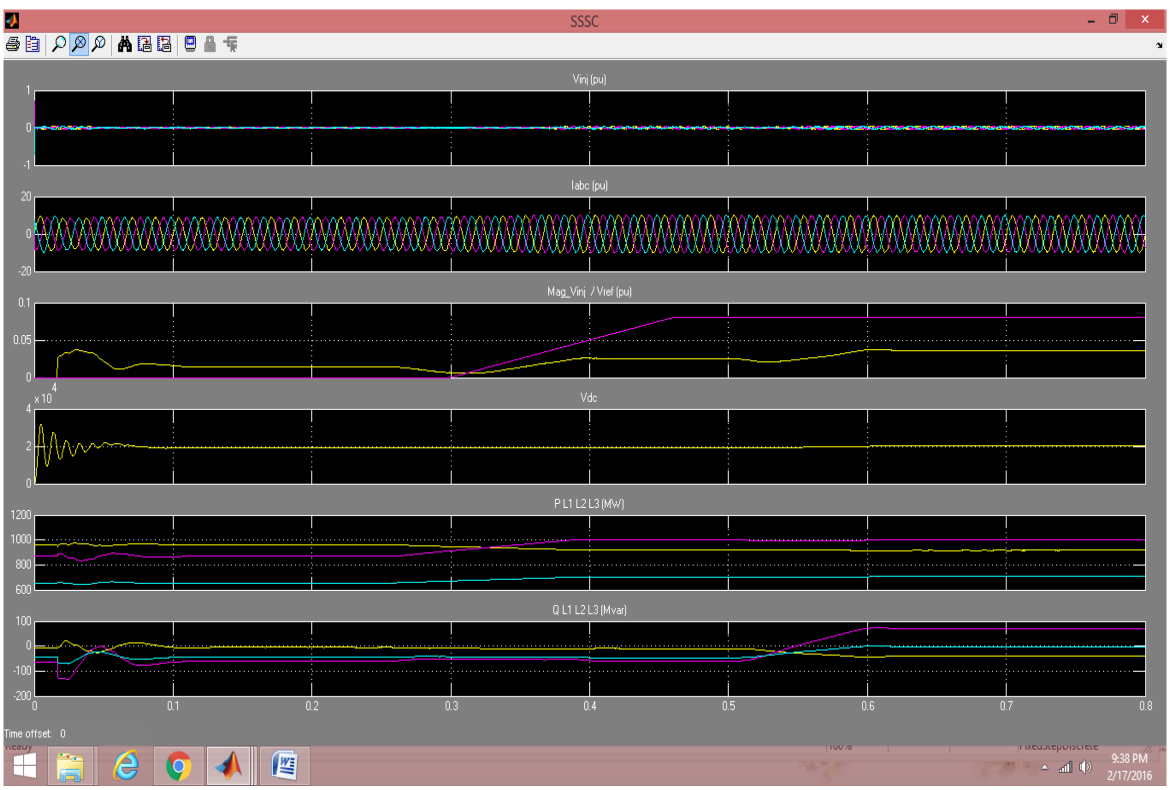

Fig.6 Series voltage injection in SSSC mode

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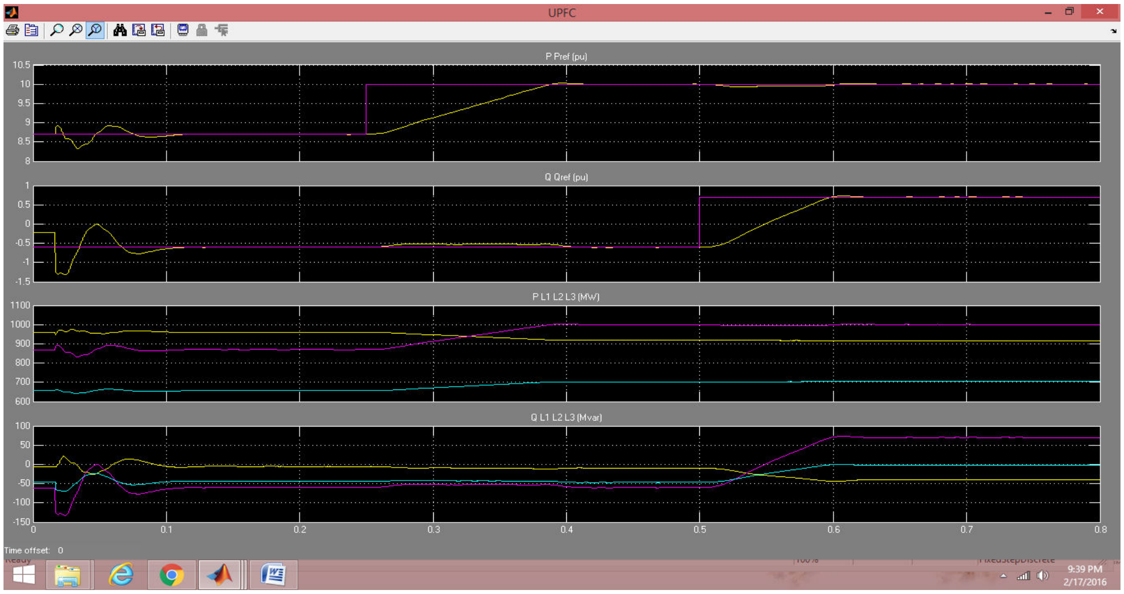

Fig 7 Power control in UPFC mode

5. CONCLUSION:

The unified power flow controller provides simultaneous or individual controls of basic system parameters like Transmission voltage, impedance and phase angle, thereby controlling transmitted power. Load flow studies were conducted on given system to find the nodal voltages, and power flow between the nodes. The MATLAB program is run with and without incorporation of UPFC. UPFC is incorporated between any of two buses, to improve the power flow between the lines to a Pre-specified value. From the results it has been observed that the power flow between the lines is improved to a pre-specified value. The real power losses between the lines were decreased after the incorporation of UPFC. So, it can be concluded that after the incorporation of UPFC the voltage profile and power flow between the lines improves.

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