CONTROL OF REAL & REACTIVE POWER BY MULTILEVEL UPFC

[1]PALLAVI SHRIVASTAVA,[2] ALKA THAKUR

[1] *Student, Electrical Enggineering,SSSIST,SEHORE ,M.P,INDIA*

[2] *ASSISTSNT PROFESSOR,Electrical Enggineering,SSSIST,SEHORE ,M.P,INDIA*

ABSTRACT

High-voltage and power capability of multilevel converters better used for unified power-flow controller (UPFC application). The three-level neutral-point-clamped (NPC) converter allows back-to-back connection as the UPFC shunt and series converters than other multilevel topologies. In place of the pulse width-modulated (PWM) multilevel control schemes, constant dc-link voltage and balanced voltages in the NPC multilevel dc capacitors is necessary for UPFCs. The proposed work provides three main contributions to increase the performance of the system of multilevel UPFCs as this can be operated in STATCOM, SSSC and exactly in the UPFC mode with the double balancing of dc capacitor voltages under line faults, overall enhancing the UPFC ride-through capability.NPC series and shunt converters keep the dc-link voltage steady, results the effectiveness of the real-time PWM generation and dc-link capacitor voltages balancing. Transients are the causes of fault in power system, Power System Stabilizer (PSS) and Automatic Voltage Regulator (AVR) are used to stabilize the response. Mostly to analyze the transients introduced in the system due to the occurrence of faults load flow analysis is used. The UPFC are becoming important and effective in suppressing power system oscillations, improving system damping and control the active and reactive power. This proposed work investigating the performance of UPFC with respect to the ideal and actual response of the system to achieve stability and it is seen and verified by the results. The effectiveness of the proposed dc link switch based UPFC in suppressing power system oscillation is investigated by analyzing line injection voltage, real and reactive power, dc link voltage and current. A proportional integral (PI) controller has been use in the UPFC to control the voltage source converters (VSC) current, voltage and phase of the transmission lines.

Keyword - *Pulse Width-Modulated, Unified Power-Flow Controller, Automatic Voltage Regulator, Power System Stabilizer, Voltage Source Converters, Proportional Integral, MATLAB. ….*

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1. INTRODUCTION

In power networks highly use of power electronicdevices because of their multiple functions:compensation, protection and interface for generators. It makes possible the insertion in the power network of renewable sources of energy and independent generators by transforming and adapting the electric energy.However, the current and voltage harmonics will generate by switching components, power electronic converters which may cause measurements, stability and control problems. A good knowledge on the harmonic **generation and propagation is necessary, to avoid that kind of harmonic disturbances.**

FACTS technology is a collection of controllers that aresituated separately or coordination with other devices to control one or more interconnected power system suchas shunt impedance, series impedance, current, voltage and damping oscillations. This concept is known as FACTS Controllers [5].

1.1 BACKGROUND

In 1990s introduced designed based on the concept ofcombined series-shunt FACTS Controller having the.It capability of improve the power flow control with stability and reliability and also. The ability tosimultaneously control all the transmission parameters without affecting the power flow of transmission line i.e.voltage, line impedance and phase angle, this is known as Unified Power Flow Controller (UPFC) [2].

1.2 PROBLEM

Now a day, in developing countries large number ofinterconnected networks, the generation reserves to increase the reliability of the power system. However,fluctuations in reliability of power supply increase with interconnection complex system, it is very difficult to control the power flow and security problems due to large number of blackouts in world. To reduce these consequences and to provide better power flow along with line which makes system stability and reliability required to new transmission linesinstallations. But new installation is limited for some factor like environment related issues, economic cost.

2. METHODS & MATERIAL

Flexible Alternating Current Transmission Systems (Facts)

Model based on facts devicesGeneration of FACTS Controllers:There are four generation in FACT controllers:In generation of FACTS device controllers are fallowed:

First Generation of FACTS Controllers:

- Static Var Compensator (SVC)
- Thyristor Control Series Compensator (TCSC).

Second Generation of FACTS Controllers:

- Static Synchronous Series Compensator (SSSC),
- Static Synchronous Compensator (STATCOM).

Third Generation of FACTS Controllers:

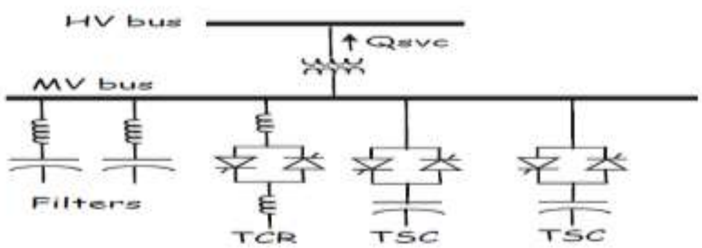
- Unified Power Flow Controller (UPFC)
- Interline Power Flow Controller (IPFC) and

Fourth Generation of FACTS Controllers:

- Generalized Power Flow Controller (GUPFC)

2.1 Types of FACTS controller

***Static Var Compensator (SVC):*This is the first device of FACTS controller, it providefast-acting reactive power compensation in transmission system.**



CIRCUIT DIAGRAM OF SVC

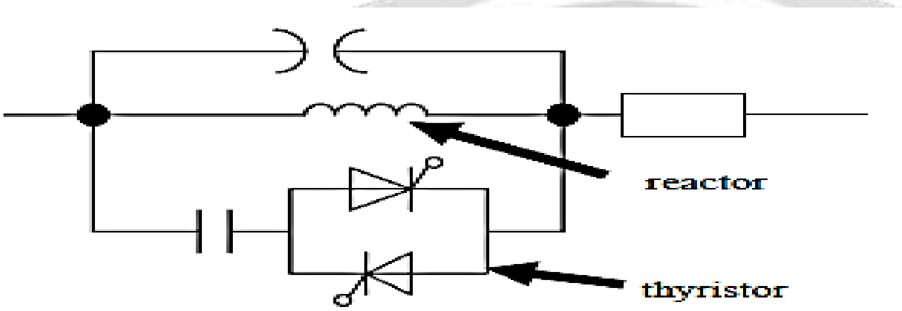
Characteristics of SVC:

The SVC provide, improve of power flow control, increase the damping power oscillations and also provide a dynamic voltage control to increase the transient stability in power transmission system.The SVC is mostly control the reactive power, reduced the voltage level due to non-linear level, improves the power factor, power quality and reduces the energy consumption. [14].

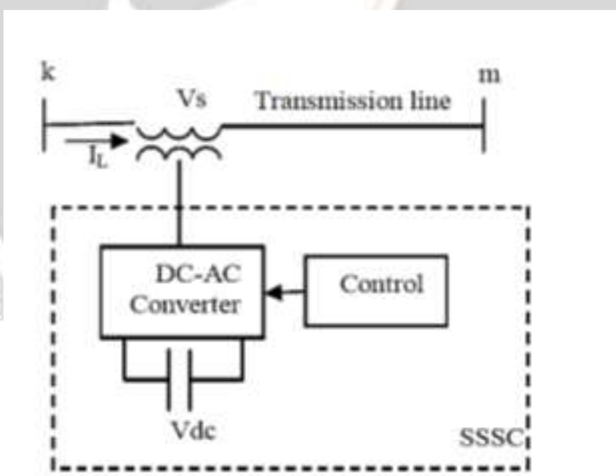
Advantages:

- To maintain bus voltage near to constant level.
- To improve transient stability.

Thyristor Controlled Series Compensator (TCSC): The TCSC is thyristor control based FACTS technology having ability to control the line impedance which is installed series with thyristor-controlled capacitor in transmission line. In TCSC a series capacitor installed to reduce the total series impedance to enhance the transmission line capability thus additional power will be transferred [7].

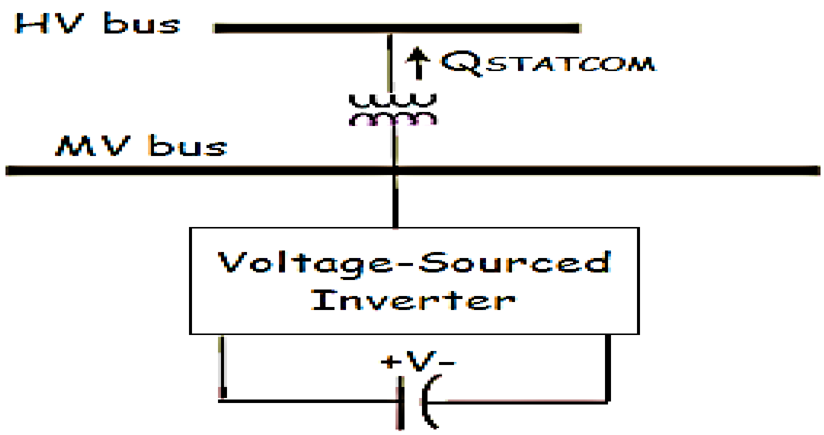


Static Synchronous Series Compensator (SSSC*):* In Static Synchronous Series Compensator it is based on solid-state voltage source converter, having generates the voltage magnitude independent from line current.



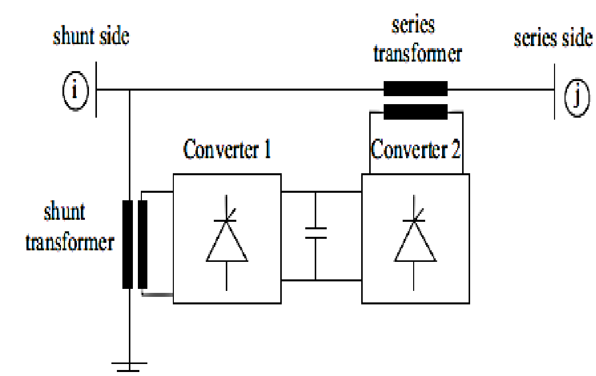
CIRCUIT DIAGRAM OF SSSC

Static Synchronous Compensator (STATCOM): The STATCOM is designed based on Voltage source converter (VSC) power electronic device with Gate turn off and dc capacitor linked with step down transformer installed in transmission line.



CIRCUIT DIAGRAM OF STATCOM

Unified Power Flow Controller (UPFC): The UPFC is a grouping of series compensator (SSSC) and shunt compensator (STATCOM) link with common DC capacitor. It has ability to simultaneously control every parameter of the transmission systems, like voltage, phase angle and impedance.

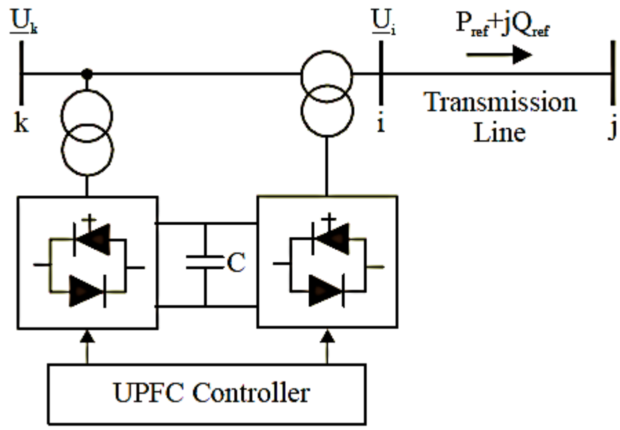


CIRCUIT DIAGRAM OF UPFC

4.MATHEMATICAL MODELLING

4.1The Unified Power Flow Controller

In 1991 Gyugiy was introduced the Unified Power Flow Controller. The UPFC is a member of third generation FACTS controller proposed to control voltage and power flow in systems It consist of combining features of Series Synchronous Compensator (SSSC) and Static Synchronous Compensator (STATCOM). It has to ability to control active and reactive power in transmission line as well as transmission parameters like voltage, impedance and phase angle.



This figure 4.1 consist of two voltage source converter, first converter is connected at sending end in shunt as shunt converter and second converter is connected between sending and receiving end bus in series as series converter, One end of converters is connected to transformer and other end is connected with common DC capacitor link.

4.2 Operation of UPFC-

This ideal AC to DC converter in which real power flow between AC terminal of two converters and each converter are ability to generate or absorb reactive power of AC output terminal. The UPFC provide by shunt converter given an AC voltage as synchronous AC voltage source with controlled phase angle and magnitude in series with line

Unified Power Flow Controller (UPFC):In 500 KV transmissions systems the control of power flow by the using of Unified Power Flow Controller (UPFC). The UPFC is located at receiving end of 75km line L2, the buses B1 and B2 of 500 KV line, Bus B1 is used for voltage control and Bus B2 is used to control active and reactive powers. It consists two set of 100-MVA, three-level, 48-pulse GTO-based converters, the first one is connected in shunt with bus B1 and second one is connected series between buses B1 and B2. Through DC bus series and shunt converters can changes power maximum power of 10% of nominal line-to-ground voltage (28.87 kV) is injected by series converter in series with line L2.

4.3Control modeling

In an open loop, the phase θ and magnitude M of modulating signal is used for calculation the Fourier coefficients of switching function which is invariable and identified. In the close loop these two parameters are used to control state variables of magnitudes converter, in ac current. Because of that reason this is not fixed, it is depend on real and reference values of controlled state variables.

By calculating the phase and magnitude of the modulating signal its control the input systems. By replacing the state variable converter of reference values, the fundamental frequency and the fundamental switch function is obtained in Equation (13). The modulating signal parameters are obtained by fundamental of switching function. Taken into a account by knowing M and θ the real switching function obtained.

The state variables converters and switching functions are symmetrical, only fundamental component is considered:

$$\begin{cases} i_1 = i \\ i_2 = ie^{-j\frac{2\pi}{3}} \\ i_3 = ie^{j\frac{2\pi}{3}} \end{cases} \qquad \begin{cases} V_1 = V \\ V_2 = Ve^{-j\frac{2\pi}{3}} \\ V_3 = Ve^{j\frac{2\pi}{3}} \end{cases} \qquad \begin{cases} u_1 = u \\ u_2 = ue^{-j\frac{2\pi}{3}} \\ u_3 = ue^{j\frac{2\pi}{3}} \end{cases}$$

The passive elements are considered as equal in three phases:

$$\begin{cases} L_1 = L_2 = L_3 = L_k \\ R_1 = R_2 = R_3 = R_k \end{cases}$$

Equation (20) and (21), only one phase converter is considered. Then, Eq. (13) is written as:

$$\begin{cases} L_k \dfrac{di}{dt} = V - u\dfrac{V_{dc}}{6} - R_k i \\ C\dfrac{dV_{dc}}{dt} = \dfrac{3}{2}ui - \dfrac{V_{dc}}{R} \end{cases}$$

The switching function and converter variables are transformed in dq0 structure as a constant:

$$\begin{cases} i = i_d + ji_q \\ V = V_d + jV_q \\ u = u_d + ju_q \end{cases} \tag{23}$$

Equations (22) transformed in dq0 structure convert:

$$\begin{cases} L\dfrac{di_d}{dt} = \omega L_k i_q - R_k i_d + V - \dfrac{1}{2}u_d V_{dc} \\ L_k \dfrac{di_q}{dt} = -\omega L_k i_d - R_k i_q - \dfrac{1}{2}u_q V_{dc} \\ C\dfrac{dV_{dc}}{dt} = \dfrac{3}{2}\left(u_d i_d + u_q i_q\right) - \dfrac{V_{dc}}{R} \end{cases}$$

In the dq0 structure the magnitudes of the state variables are constant, so that derivative is equal to zero:

$$\frac{di_d}{dt} = 0 \qquad \frac{di_q}{dt} = 0 \qquad \frac{dV_{dc}}{dt} = 0$$

By considering the ac current equal to reference value (PI controllers are ideal), then d and q components of switching functions is.

$$\begin{cases} V_{dc} = \sqrt{\frac{3}{2} R\left(i_{dref}\left(\omega L_k i_{qref} - R_k i_{dref} - V\right) + i_{qref}\left(-\omega L_k i_{dref} - R_k i_{qref}\right)\right)} \\ u_d = \frac{2}{V_{dc}}\left(\omega L_k i_{qref} - R_k i_{dref} - V\right) \\ u_q = \frac{2}{V_{dc}}\left(-\omega L_k i_{dref} - R_k i_{qref}\right) \end{cases}.$$

The values of u_d and u_q, the fundamental magnitude and phase of switching function are calculated:

$$\begin{cases} M = \sqrt{u_d^2 + u_q^2} \\ \theta_0 = -\arctan\left(\frac{u_q}{u_d}\right) \end{cases}$$

4.4 Application of the method to the whole converter structure

The resistor of Fig.4.2 is changed by DC/AC converter. This equation is utilize to entire system. A resistor is used as load and converter system is connected into the grid. The frequency of PWM is 2kHz.

4.5Equivalent Circuit Operation of UPFC

In Fig 5.2, the two-voltage source converters is changes as two ideal voltage sources, one is connected in series and another is shunt between the two buses. The output of series voltage magnitude V_{se} is controlled between $V_{se\max} \le V_{se} \le V_{se\min}$ and the angle θ_{se} between $0 \le \theta_{se} \le 2\Pi$ respectively. And shunt voltage magnitude V_{sh} controlled between $V_{sh\max} \le V_{sh} \le V_{sh\min}$ and angle between $0 \le \theta_{sh} \le 2\Pi$. Where Z_{se} and Z_{sh} is impedances of two transformers which is connected series and shunt between line and UPFC [11].

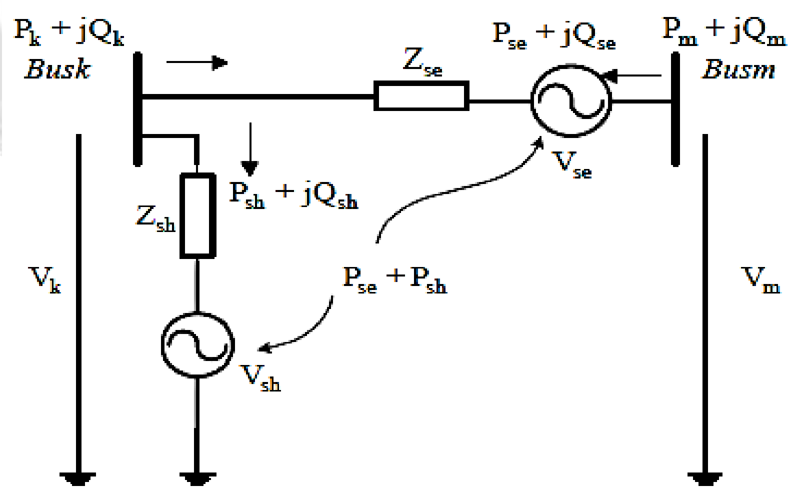


Figure 0-1 Equivalent circuit of UPFC

Voltage source and ideal series from Fig 5.2 is obtained

$$V_{se} = V_{se}(\cos\theta_{se} + j\sin\theta_{se}) \tag{1}$$

$$V_{sh} = V_{sh}(\cos\theta_{sh} + j\sin\theta_{sh}) \tag{2}$$

The magnitude and angle of converter output voltage used to control of power flow mode and voltage mode is follows:

1) The magnitude of bus voltage is control by series voltage V_{se} in phase or off-phase.

2) Series reactive compensation is control by series voltage V'_{se} in quadrature with line correct.

3) Phase shifter is controlled by magnitude of voltage V''_{se} in quadrature to node voltage θ_m [2].

5.**WORKING & SIMULATION-**

5.1Proposed circuit

The Matlab/Simulink model is used to simulate the power flow control in the 500 kV transmission line.

5.1.2 Study system model in Matlab/Simulink with UPFC

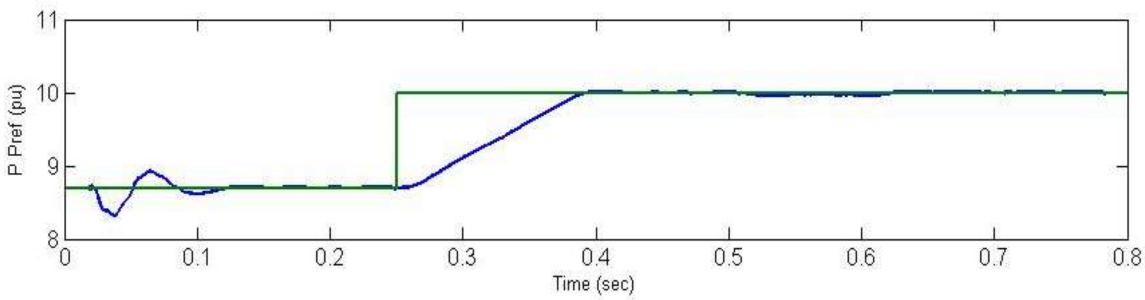
The Unified Power Flow Controllers are used to control 500 kV power flow in transmitting line. The Unified Power Flow Controller is installed in between the 500 kV buses B1 and buses B2 to simulate at installed in GENCO-1(generating station) of 75km, in transmission line. This installed Controller simulation is used to control the reactive and active power flow through the bus B2 and controlling voltage at bus B1. And this Controller consists of two 100-MVA, three-level, 48-pulse GTO-based converters, the first one is connected in shunt with bus B1 and the second one is connected in series between buses B1 and B2. The shunt converters and series converters are change our power through a DC link bus. The series converter is injecting a maximum number of 10% of nominal voltage {28.87 kV} in series with line bus B1 and B2. The Matlab/Simulink model is used to simulate the power flow control in the 500 kV transmission line.

5.2Power control in UPFC mode

To start the UPFC GUI block from menu. The GUI gives the option of operating mode i.e. UPFC, STATCOM and SSSC and also the P_{ref}/Q_{ref} reference powers and V_{ref} reference voltage settings. To observe the dynamic response of control system, a step change of any reference value at specific time in GUI block menu to specify it.The operating mode is set into "UPFC Power Flow Control" mode. In the GUI menu the reference active and reactive powers are specified in last two lines. At starting, P_{ref}= +8.7 pu/100MVA which is +870 MW and Q_{ref} = - 0.6 pu/100MVA which is -60 Mvar. At t=0.25 sec P_{ref} is becomes to +10 pu (+1000MW). And, at t=0.5 sec, Q_{ref} is becomes to +0.7 pu (+70 Mvar). The V_{ref}=1 pu (reference voltage) of shunt converter (2nd line of GUI) will be constant whole simulation (Step Time=0.3*100> Simulation stop time (0.8 sec). In power control mode, the changes in STATCOM reference reactive power and SSSC injected voltage is not used ($1^{st}$and 3^{rd} line of GUI).

5.3UPFC Response

A. The steady state of active power is reached (P=+8.7 pu) behind the transient period approx. 0.15 sec. After new settings of P (P=+10 pu)is ramped to by changing the reference value t=0.25 second. In fig 7.12.



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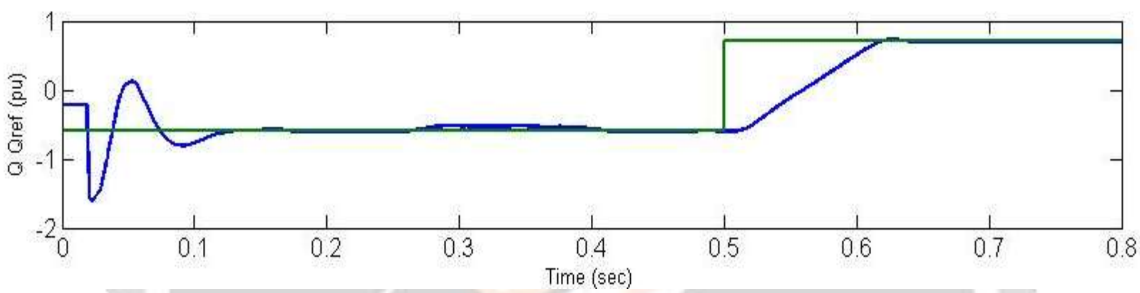
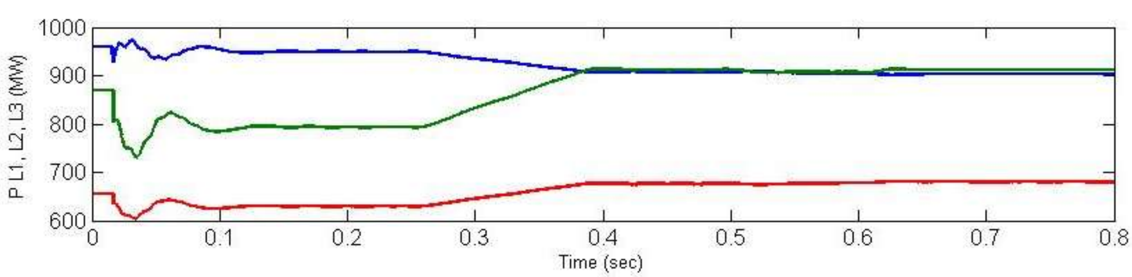
UPFC responses active power changing

B. The reference value of the reactive power is changed at point t = 0.5 sec, to 0.7 pu and the reactive power occurred a new value after 0.15 sec. in fig 7.13.



UPFC responses reactive power changing

C. The P (L1, L2, L3) is the active power shown in fig. 7.14. And it is observe that resulting changes in active power flow in the 3 transmission lines. The blue line shows the UPFC response.



Active power response in 3 transmission line

D. The Q (L1, L2, L3) is the reactive power shown in fig. 7.15. And it is observe that resulting changes in reactive power flow in the 3 transmission lines. The blue line shows the UPFC response.

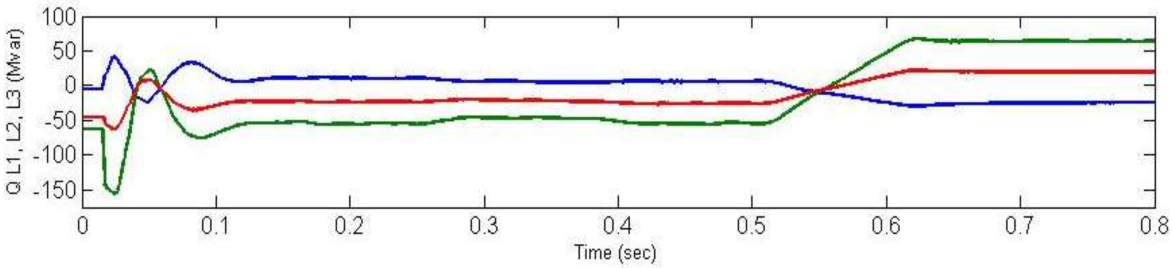


Figure 0-1 Reactive power response in 3 transmission line

6. CONCLUSION AND FUTURE SCOPE

The stability of power system using FACTS devices like UPFC is compared and discussed, with the major disturbance the dynamics of the system is compared with the presence of STATCOM & UPFC in the system. Improvement in stability is compared by the reference work which has been before now done, by using the STATCOM. The simulation results show that significant enhancement in the system performance by the use of UPFC as system stabilization and the harmonics in the line voltage.The proposed high power multilevel UPFC control strategy includes dc-link voltage control gains with low sensitivity to dc link current and the balancing of the dc-link capacitor voltages using both multilevel converters.

The dc-link capacitor voltages are balanced using both series and shunt multilevel converters in spite of only one of the multilevel converters. The main improvement is to reduce the harmonics by .16% of the line voltage and stabilisation of the system. This gives the effectiveness of the proposed work to operate in three different modes as per the requirement compared to the works which have been already implemented.

The proposed thought is modelled and designed in MATLAB Simulink and the results verify the effectiveness of the model. Transients and THD are the major cause in the power system related to power quality issues. This is useful to in the high power transmission lines for the stabilisation of the system and also to maintain the line voltage as per the demand with good power quality aspects. Here as the dc-link capacitor is introduced between two converters known as series and shunt converters maintain the level of it.

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