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Three Phases Fault Analysis in Transmission Line Using UPFC

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ABSTRACT

In this paper analyse well regulated power flow between the Bus systems so as to maximize the power quality by minimizing the losses and improving the power transfer capability of system by use of FACTS devices. Regulating flow of active and reactive power and hence power factor of line allows the system to be utilized to full potential. It is often observed that due to losses in power systems there is an underutilization of available resources, and to overcome those drawbacks compensators are used such as Series and Shunt compensators. Series and shunt compensation although have good performance on their relevant conditions but have certain drawbacks with the regulation of power flow and also the size, so by combining the features of series compensator and shunt compensator a novel approach is developed named UPFC which allows the power exchange between the compensators via DC link. Which is further discussed in the paper .The entire system is designed and analysed using **MATLAB/SIMULINK.**

Key words: *FACTS, UPFC, Series and Shunt compensators.*

INTRODUCTION

If we go a few years back it was so difficult to operate and control power flow in transmission line, also there was increase in stress over transmission system, along with insecurity due to unscheduled power flow and losses because of growth in demand of electricity and limit to increase in transmission line. But now due to technological advancement there has been huge transformation in power transmission scenario with the inclusion of better power flow control devices and equipment and also the awareness towards stable operation has led to greater stability in grid. The magnitude of sending end voltage and receiving end voltage, phase angle between the voltage at both ends, impedance of the line are the major factors contributing to transfer of power in the AC transmission system. It can also be explained with mathematical expression:-

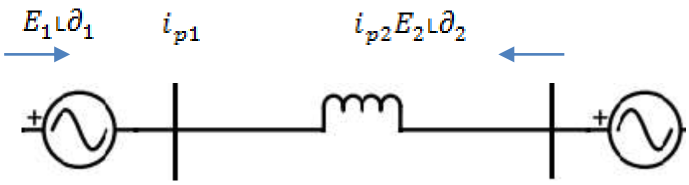

Figure 1 Single line Diagram of Simple Two Machine System

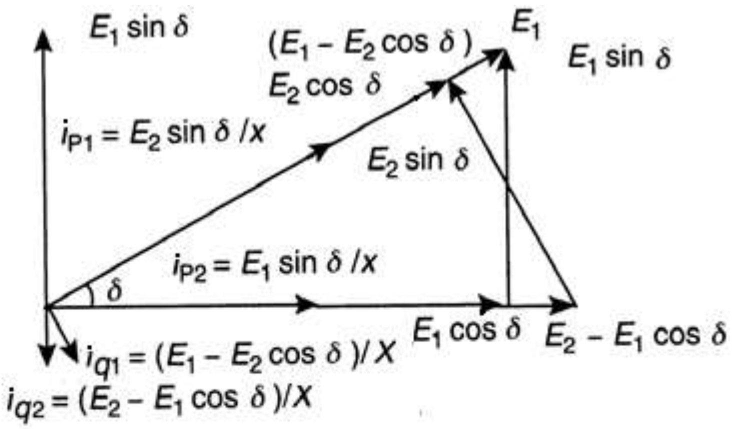

Figure 2 Power flow diagram.

Current flow at E_1 : $i_{p1} = \frac{(E_2 Sin\partial)}{x}$

$i_{q1} = \frac{(E_1 - E_2 \ Cos \ \partial)}{x}$

Power at E_1: $P_1 = \frac{E_1 \ (E_2 Sin\partial)}{x}$

$Q_1 = \frac{E_1 \ (E_1 - E_2 Sin\partial)}{x}$

Current flow at E_2 $i_{p2} = \frac{(E_1 Sin\partial)}{x}$

$i_{q2} = \frac{(E_2 - E_1 Cos\partial)}{x}$

Power at E_2: $P_2 = \frac{E_2 \ (E_1 Sin\partial)}{x}$

$Q_2 = \frac{E_2 \ (E_2 - E_1 Sin\partial)}{x}$

Hence we can see from the equation that P_1 and $P_2$are equivalent.Thus with variation in ‘x’ P, Q_1 and Q_2 can be varied. [2]

It’s a common practice to use reactive power compensation to control the power flow in transmission system. Fixed or mechanically-switched capacitors and reactors are used for these type of controlling purpose.

With the recent studies, research and experimentations new fast switching devices have been introduced to meet the energy requirement and achieve greater stability these devices can switch between reactive compensation by drawing power from circuit and feeding voltage to the circuit.

Power exportation and power importation in the sense of grid is interconnection of individual power carrying transmission system to flow power from power deficient system to power abundant system and the interconnecting transmitting system will play only as a wheeling partner for the flow of power, however the traditional system of transmission were not equipped with the such control of power flow hence the power which depends on impedance of line cannot be restricted to desired power corridors resulting in development of power flow loop causing overloading of line.

Due to this an electrical body involved in research and development of power control devices EPRI (Electrical power research institute) has devised FACTS (Flexible AC Transmission System).Flexible AC Transmission System (FACTS) was introduced [9] as a family of power electronic equipmentwhich have emerged for controlling and optimizing flow of electrical power in the transmission line.

The type of FACTS devices are differentiated based on their property to draw reactive power from the circuit of feed power to the circuit. The basic type of FACTS controllers are:-

1. Series controller: - These type of controllers are basically used for series injection of voltage into the circuit their by compensating the inductance (inductive loss) of the line. Along with phase quadrature relationship as any other phase relation could also draw active power exchange.
2. Shunt controller: - these type of controller are basically used for injection of current in the circuit their by compensating capacitance (capacitiveloss) of the line keeping in mind the phase quadrature relationship as any other phase may draw dealing with active power of the circuit.
3. Shunt-series controller: - these type of controllers are hybrid type controllers by providing series as well as shunt compensation shunt compensator provide for voltage and series provide for current in the circuit.
4. Series-series controller: - these type of controllers are basically two series controllers each providing for voltage compensation along with real power exchange with line.

Depending on the power electronic device used FACTS devices can be classified as:

1. Variable impedance type
2. Voltage source convertor (VSC) based.

UPFC (UNIFIED POWER FLOW CONTROL):

UPFC is a combination of two VOLTAGE SOURCE CONVERTOR one shunt connected other series connected, connected by DC link. [6] One is STATCOM and other is SSSC. Each SSSC provide the reactive power compensation to the individual line where it is connected and also it is capable of transmitting the real power from underutilized line to the overloaded line these concepts was explained in [8] .The SSSC which is a voltage source inverter injects an almost sinusoidal voltage in series with the transmission line. This injected voltage is almost in quadrature with the line current, thereby emulating an inductive or a reactive capacitance in series with line.[11] UPFC improves the voltage profile of the system and thus increase the load ability margin of the power system.[7].

This power flow controller proposed by Gyugyi is the most versatile power flow controller. Comparison between conventional thyristor-controlled and unified power-flow controllers [1] has been drawn by Gyugyi in 1992, in which it is stated that conventional thyrister controlled circuit required complex design arrangements and two different devices for simultaneous control series compensation and phase angle control which increases the size of compensator, which not in case of UPFC.

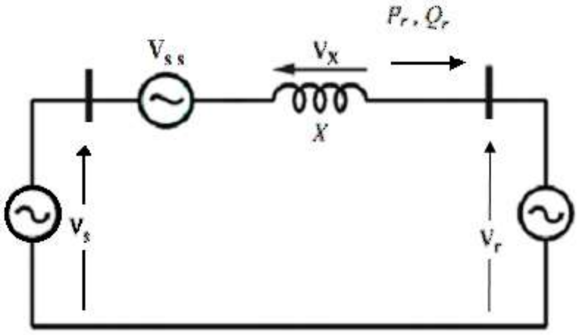

Figure 3 Representation of basic power transmission system.

The power exchange relation between the two SSSC via DC link ($P_{exc□}, Q_{exc□}$) is generalised by the mathematical expression by Kalyan K sen and Mey ling sen [3] is

For negative compensating voltage can be represented in dq variables as with Ø as phase angle between current and compensating voltage

$$-V_{ss} = V_{dq}$$

Active power: $P_{exc□} = V_{dq} I cos Ø$

And reactive power: $Q_{exc□} = V_{dq} I sin Ø$

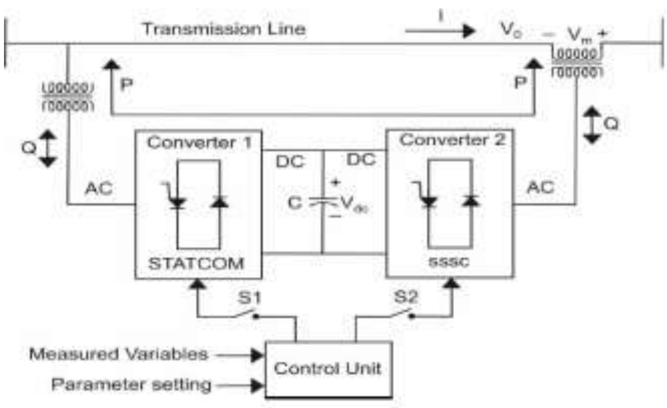

Figure 4 General representation of UPFC

UPFC can work in 3 modes:

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1. Shunt- series mode providing two way compensation (bi directional).
2. Shunt compensation when dc link is open acting as STATCOM controlling bus
3. Voltage by injection of current into the circuit.
4. Series compensation when shunt compensator is disconnected providing voltage source.

However UPFC cannot control real power in steady state except during losses, the STATCOM (Static synchronous Compensator) maintains constant bus voltage thereby providing energy for DC link of SSSC and also maintain voltage of capacitor at the DC link. SSSC with controllable injection of voltage controls the active and reactive power flow into the circuit.And impedance compensation controller can compensate for the transmission line resistance if an SSSC is operated with an energy storage system [10].The operation of UPFC if compared to conventional compensator can simultaneously provide reactive shunt compensation, series compensation and phase shifting. The UPFC will dynamically decouple the sending end and receiving end buses so as to maintain the stable condition, in essence if preferred the UPFC can be commanded to force an appropriately varying power level that will effectively damp the power oscillation in the line [4]. For further modification of line error with reference various controllers are used.

CONTROL UNIT:

A controller is one which compares the controlled value with reference value and has a function to correct the deviation produced.

There are two important conditions that needs to be fulfilled while choosing the type of control unit required:

1. Deviation should not be large, it means there should be less deviation between the input and output.
2. Deviation should not be sudden.

PI controller: Proportional integral controller is used for performance checking of UPFC [5].It modifies the error signal produced with respect to the reference signal.

It is the combination of proportional and integral controller which gives an output (actuating signal, A(t)) is summation of proportional and integral of error signal (E(t)). Analysing the PI controller mathematically:

$$A(t) \propto \int_0^t E(t)dt + E(t)$$

Removing the proportionality we have

$$A(t) = K_i \int_0^t E(t)dt + K_p E(t)$$

Here $K_p and K_i$ are proportionality constants.

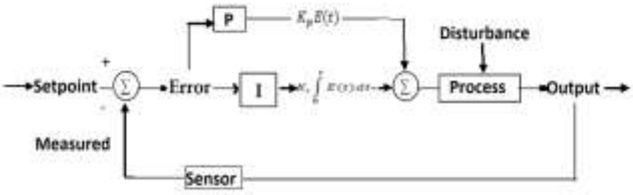

Figure 5 PI controller

Series Controller

The series inverter controller as shown in Fig 6. The fundamental magnitude of line voltage can be found by using fundamental magnitude calculator. They can be processed by the phase lock loop for producing the required phase angle. The frequency can be locked for fundamental value. The real power Pline is compared with Pref and is processed through a PI controller is added with which produces the angle.

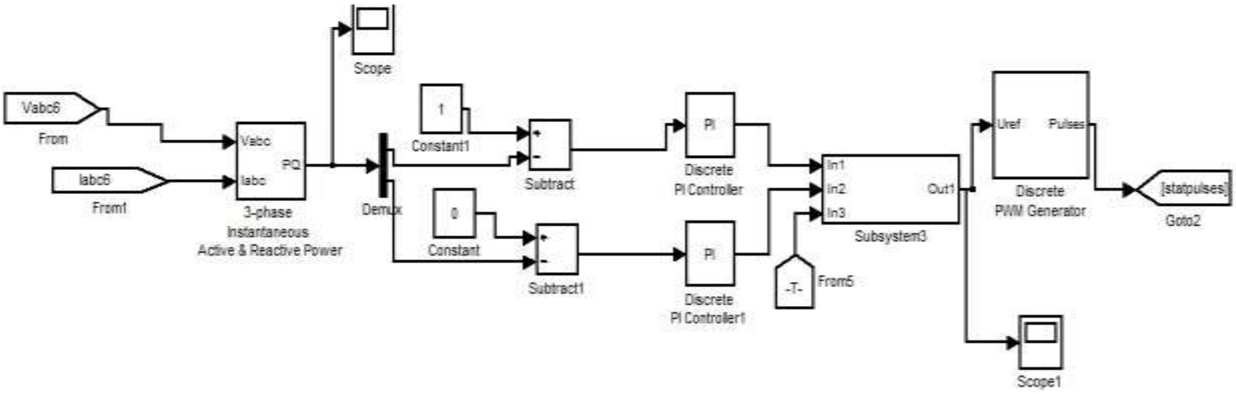

Figure 6 simulation diagram of series converter controller

The reactive power flow Qline is compared with the Qref and is processed through a PI controller.

The output of the PI controller is added with the modulation index (m) and producing the required values. Using the pulse width modulation controller and (mse) are computed with triangular wave, thus the gating pulse of thyristeris produced.

Shunt Controller:

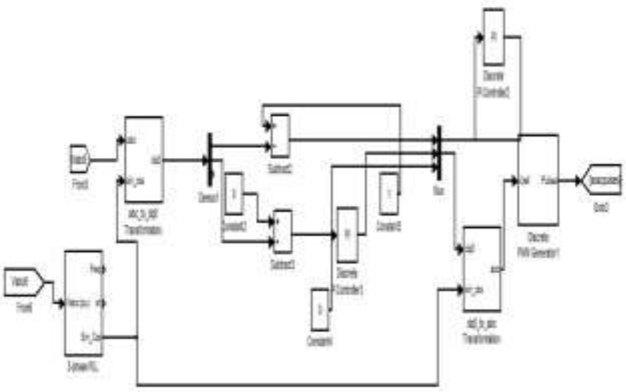

Figure 7 simulation diagram of shunt convertor controller

The shunt converter control structure as shown in Fig 7.The fundamental magnitude of line voltage can be found by using fundamental magnitude calculator can be processed by the phase locked loop for producingthe required phase angle. The frequency can be locked for fundamental value. The line voltage can be compared with reference voltage and it's processed through PI controller. The output of the PI controller is added with the modulation index (m) and producing the required value. The DC voltage is compared with reference to DC voltage and it is processed through another PI controller. The delay angle is produced by DC voltage controller and it is added with (θ) and Produces shunt delay angle (θsh). Using the pulse width modulation controller (θsh) and (Msh) are computed with triangular wave, thus the gating pulses of Thyrister are produced.

Modeling of UPFC:

This modeling is done with Simulink block set and simulation is carried out in MATLAB environment as shown in Fig.8. The system is modeled with a three phase source connected to a load. The source is connected to load through transmission line. The UPFC is incorporated between bus 5 and 6 of transmission line.The inductive and capacitive loads are connected for dynamic performance analysis. To obtain the transient analysis the fault can be connected near the load. The simulation model of UPFC is modeled with a three phase voltage source inverter connected to different loads. Each transmission line bus has the bus measurement block to measure the real power, reactive power, voltage and the current. The shunt and series device of UPFC consists of three phase bridge thyrister.

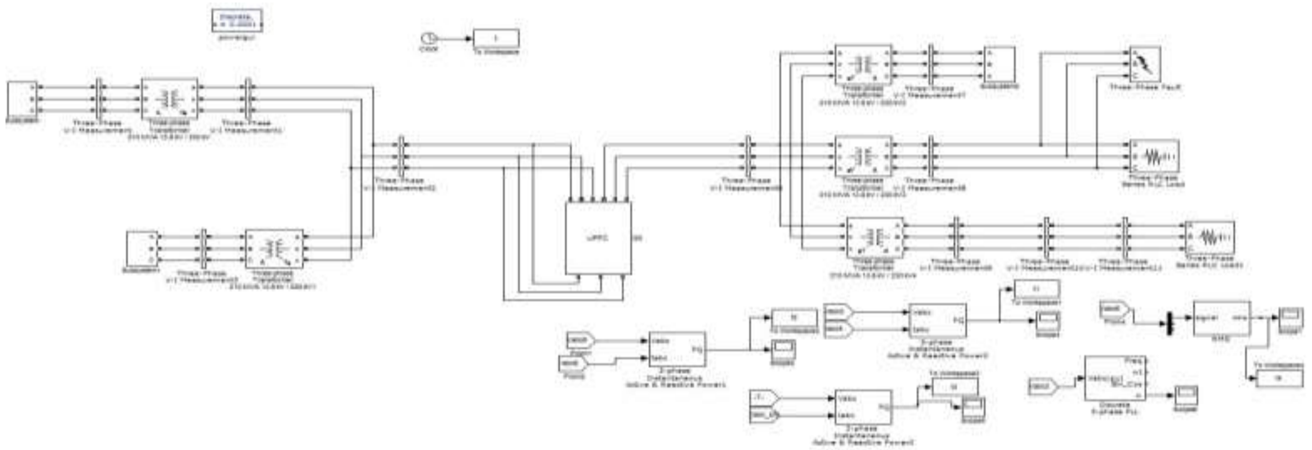

Figure 8 Simulation model of UPFC.

The shunt converter is connected to the transmission line in parallel through a three phase transformer. The system model is used as it is described above. The active and reactive components of loads have constant current characteristics (α = β = 1). The UPFC is installed between bus 5 and bus 6, according to Figure 8. A 3 phase fault occurs in the system at point F. The fault duration is from 0.2 to 0.3 sec.

RESULTS

The results are drawn based on the type of fault, magnitude of fault and fault duration. Here we analyse the flow of power, Figure 9 and 10 illustrates the active and reactive power flow at bus 5, in that case, for the system with and without the UPFC. It can be observed that with the inclusion of UPFC there is an improvement in control over active and reactive power flow if compared between the figure 9 and 10, which gives out an obvious result as improvements in damping of the oscillations and hence improved power stability at the busses. Voltage profile is also observed with the figure 11 with UPFC in the circuit the fault duration from 0.2 to 0.3 sec is shown, this is the injected voltage into the circuit to compensate the voltage dip via series injection to maintain the stability of the system. The magnitude of the voltage will depend on the fault characteristics.

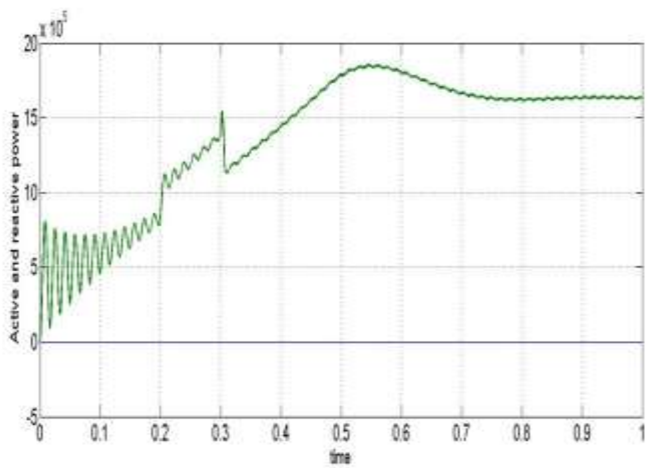

Figure 9 effect on P & Q at bus 5 without UPFC

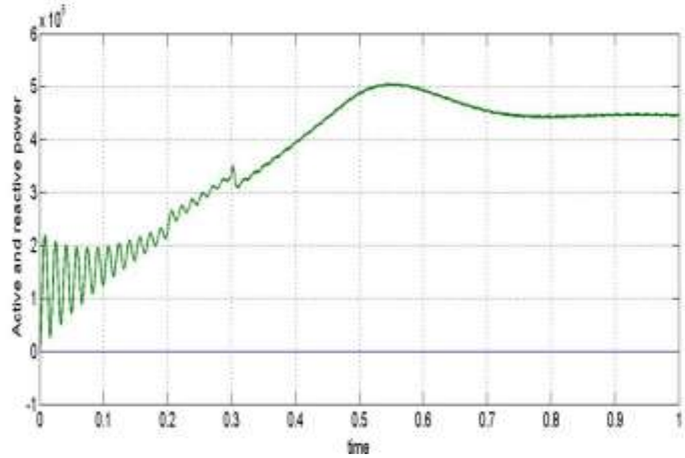

Figure 10 effect on P & Q at bus 5 with UPFC

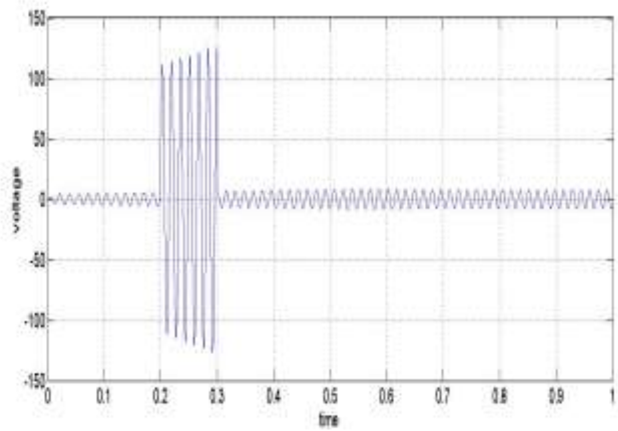

Figure 11 Effect on voltage profile due to fault with UPFC.

CONCLUSION

The main advantage of the UPFC is to control the active and reactive power flows in the transmission line. If there are any disturbances or faults in the source side, the UPFC will not work. The UPFC operates only under balanced sine wave source. The controllable parameters of the UPFC are reactance in the line, phase angle and voltage. Damped oscillation and PF improvement and power flow regulation can be achieved by this method as by using these FACTS devices the impedance seen by line is substantially reduced. Moreover oscillation damping rate is steeper as compared to others. To supply shunt compensation no additional capacitor is needed to be connected, which reduces the size substantially. Reactive power is fed by shunt compensator which it absorbs via dc link from series compensator and vice versa. By drawing conclusion from observation it easy to imply that UPFC is better than other FACTS devices for regulation of power. The model can be further tuned to achieve improved pf and power transfer capability.

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