ANALYSIS OF DAMPING POWER SYSTEM OSCILLATION

USING UPFC

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**Abstract**

*This paper shows that the UPFC is able to*

*control both the real and reactive power flow. Now-a-days, electrical consumption has increased rapidly. So it must be supplied to all the consumers with high reliability and quality. Since the load is unpredicted but only estimated the generation must be equal to load all the times. But due to variations in load there is effect on the power system whether the load is switched on or off suddenly which causes low frequencyoscillations in the entire system.*

*Low frequency electromechanical oscillations are inevitable characteristics of power systems and they greatly affect the transmission line transfer capability and power system stability. Power system stabilizers (PSS) along with FACTS devices can help in damping these low frequency oscillations. The objective of this report is to design an advanced PSS and UPFC damping controller using Swing equation.*

Keywords: FACTS Devices, PSS, UPFC.

1. INTRODUCTION

Successful operation of any power system depends largely on the engineer’s ability to provide reliable & uninterrupted service to load. With increase in power demand there has been an increase in order for power plants which has given rise to an increase in interconnections studies to ensure that these plants are integrated into power system.

The modelling & controlling of UPFC have come into intensive investigation in recent year due to its attractive features. The UPFC which was proposed in year 1991 is one of the most complex FACTS device control method is used, it devices in power system today in power system today [7]

A unified power flow controller (UPFC) consists of an advanceshuntand seriescompensator

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with a common DC link. The energy storing capacity of the dc capacitor is generally small. Therefore, the active power drawn (generated) by the shunt converter should be active power generated (drawn) by the series converter [8].

**2. OPERATIONAL PRINICIPLES OF UPFC**

**2.1 PRINCIPLE OF SHUNT COMPENSATION:**

The ultimate compensation in a transmission system is to objective of applying shunt supply reactive power to increase the transmittable power and to make it more compatible with the prevailing load demand. Thus, the shunt compensator should be able to minimize the line overvoltage under light load condition, and maintain voltage levels under heavy load condition. An ideal shunt compensator is connected at the mid-point of the transmission line, as shown in figure 2.1(a) The compensator voltage that is in phase with the midpoint voltage vm has amplitude of v identical to that of the sending-and receiving-end voltages that is ,vm= vs=vr=v. the midpoint compensator in effect segments the transmission lie into two independent parts :( 1) the first segment, with an impedance of jx/2, carries power and ( 2 ) the second from the sending –end to the midpoint, segment, also with an impedance of jx/2 ,carries power from the midpoint to the receving end.

An ideal compensator is lossless. That is, the active power is the same at the sending end, midpoint and receiving end. Using the pharos diagram as shown figure 2.1b, we get the magnitudes of the voltage component and the current component as in

*Ism = Imr = I =*



Fig 2.1 Ideal shunt compensated line, (a) a simple two machine system (b) related voltage phasors,(c)real and reactive power versus transmission angle, (d) sending-end/receiving-end reactive power versus transmission real power.[4]

The transmitted active *Pp* for shunt compensation is given by

*Pp = Ism = Vmr I mr = Vm Ism = VI*

Thus, pp becomes the maximum pp (max)=2v2/x at d=1800 and Qp becomes the maximum QP( MAX) =4V2/X AT δ=1800. The plots of the receptive power Pp and the reactive power Qp against the angle δ are shown in figure 4.1c. the maximum transmitted power Pp( max) is increased significantly to twice the uncompensated value Pmax for δ= 900, but at the expense of increasing reactive power demand Qp(max)on the shunt compensator and also on the end terminals.

It should be noted that the midpoint of the transmission line is the best location for the shunt compensator .this is because the voltage sag (or drop) along the uncompensated transmission line is the largest at the midpoint. Also, the compensation at the midpoint breaks the transmission line into two equal segments for each of which the maximum transmittable power is the same. for unequal segment ,the transmittable power of the longer segment would clearly determine the overall transmission limit.[10]

**2.2 PRINCIPLE OF SERIES COMPENSATION:**

A voltage in series with the transmission line can be introduced to control the current flow and thereby the power transmission from the sending end to the receiving end an ideal series compensator, represented by the Voltage source, is connected in the middle of a transmission line, the current flowing through the transmission line is given by:

If the series applied voltage Vc is in quadrature with respect to the line current, the series compensator cannot supply or absorb active power. That is, the power at the source VC terminals can be only reactive. This means that capacitive or inductive equivalent impedance may replace the voltage source Vc. The transmission line equivalent impedance is given by:

where,

and r is the degree of series compensation, 0 < r < Xcomp is the series equivalent compensation reactance, which is positive if it is capacitive and negative if it is inductive.

The magnitude of the Current through the line is given by

If the source Vc is compensating only capacitive reactive power, the line current is leading the voltage Vc by 900. For inductive compensation, the line current is lagging the voltage VC by 900. The inductive compensation may be used when it is necessary to decrease the power flowing in the line. In both capacitive and inductive compensation, no active power is absorbed or generated by the source VC. The capacitive compensation, is, however, more commonly used.

Series capacitive impedance can decrease the overall effective series transmission impedance from the sending end to the receiving end, and thereby increase the transmittable power. A series capacitor compensated line with two identical segments in shown. Assuming that the magnitudes of the terminal voltage remain constant and equal to *V.* For *Vs*= *Vr*= *V,* the corresponding voltage and current phasors are shown in Figure 2.1b. Assuming the same end voltages, the magnitude of the total voltage across the series line inductance *Vx* = 2*Vx/2* is increased by the magnitude of the opposite voltage across the series capacitor –*Vc*.This result in an increase in the line current.

**2.3 PRINCIPLE OF PHASE-ANGLE COMPENSATION:**

Phase-angle compensation is a special case of the series compensator. The power flow is controlled by phase angle. The phase compensator is inserted between the sending-end generator and the transmission line. This compensator is an ac voltage source with controllable amplitude and phase angle. The compensator controls the phase difference between the two ac systems and thereby can control the power exchanged between the two ac systems. The effective sending-end voltage is the sum of sending-end voltage **V***s* and the compensator voltage **V***s* and **V**o-, as shown in the pharos diagram in Figure 2.1b. The angle o- between **V**s and **V**o- can be varied in such a way that the angle o- change does not result in a magnitude change. That is,

**V**seff **= V**s **+ Vo-**

⎮**V***seff*⎮=⎮**V**s⎮=*Vseff* = *Vs = V*

By controlling the angle o- independently, it is possible to keep the transmitted power at the desire level, independent of the transmission angle δ.Thus, for example, the. Power can be kept at its peak value after angle δ exceeds the peak power angle π/2 by controlling the amplitude of compensation voltage so that the effective phase angle phasor diagram, the transmitted power with phase compensation is given by

)

The transmitted reactive power with phase compensation is given by

*Qa =*)]

Unlike other shunt and series compensators, the angle compensator needs to be able to handle both active and reactive power [10].

**3. CONSTRUCTION AND WORKING OF UPFC:**

UPFC consists of two voltage source converter connected through common dc bus which includes a dc capacitor four ripple control. Shunt voltage source converter provides voltage support to the connected bus and series voltage source converter has ability to control power flow in transmission line. Two converters are connected in parallel to the transmission line which share common dc bus. Converter one absorbs or supply real power by converter two at common dc link. Converter two injects the voltage with controllable magnitude of transmission line voltage and phase angle [8].

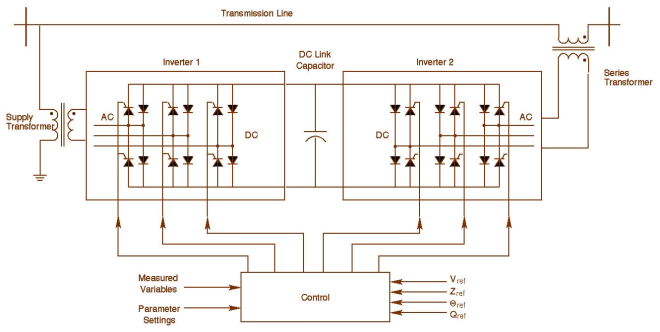
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Fig.3.1 Implementation of UPFC by back- to- back voltage-source converter

Fig.3.2 Two machine system with UPFC [4]

From conceptual viewpoint, the upfc is a generalized synchronous voltage source (svs), represented at the fundamental (power system) frequency by voltage pharos Vpq with controllable magnitude Vpq (0<Vpq<Vpqmax) and angle p(0<p<360deg) in series with transmission line as illustrated for usual elementary two machine system. In this functionally unrestricted operation which clearly includes voltage and angle regulation the svs generally exchanges both reactive and real power with transmission system.svs is able to generate only the reactive power exchanged the real power must be supplied to it or absorbed from it by suitable power supply or sink.in the upfc arrangement the real power exchanged is provided by one of the end bus [8].

Convereter 2 provides the main function of the upfc by injecting voltage Vpq with controllable magnitude Vpq and phase angle p in series with line via insertion transformer. This injected voltage acts essentially as a synchronous ac voltage source. The transmission line current flows through this voltage source resulting in reactive and real power exchange between it and ac system .the reactive power exchange at ac terminal is generated internally by the converter. Real power exchange at ac terminal is converted into dc power which appears at dc link as a positive or negative real power demand.

The basic function of Converter 1 is to supply or absorb the real power demanded by Converter 2 at the common dc link to support the real power exchange resulting from the series voltage injection. This dc link power demand of Converter 2 is converted back to ac by Converter 1 and coupled to the transmission line bus via a shunt-connected transformer. Thus converter 1 can be operated at a unity power factor there can be no reactive power through upfc dc link.

**4. SYSTEM INVESTIGATED:**

Fig.4.1 System Diagram without UPFC

Fig. 4.2 System Diagram with UPFC

**5. SYSTEM MODEL:**

In a 500 kV/230 kV transmission system which is connected in a loop configuration, consists essentially of eleven buses (B1 to B11) interconnected through transmission lines (L1, L2, L3, L4 and L5) and six 500 kV/230 kV transformer banks Tr1 to Tr6. Four power plants located on the 230-kV system generate a total of 4000 MW which is transmitted to a 500- kV 15000-MVA equivalent and to a 200-MW load connected at bus B3 and 800-MW load connected between bus9 and bus11. The plantmodels include a speed regulator, an excitation to bus bar. Three line of 100 KM each is connected in the transmission network system as well as a power system stabilizer (PSS). In normal operation, most of the 1000-MW generation capacity of power plant #2 is exported to the 200MW connected between buses B4 and B5 and 800Mw between B9 and B11.The equipments ratings are as follows:

Four Generators of 13/8 KV, 1000 MVA, rotor

type: main network star / star fashion with 230

KV / 500 KV respectively.

Line l1, l2, l3, l4, l5 each of 100 km.

Three phase VI measurement blocks B1 to B11 of

base voltage of 230 KV, and base power of 100

MVA respectively.

Three phase voltage source in series with R-L

branch having phase to phase rms voltage of 500

KV and X/R ratio of 10.

Three phase parallel RLC load of voltage 500 KV

and power of 200 MW at B3 and 500MW at B11

and B9.

.

The four dynamic generators are connected to

two transformers which in turn connected [1].



Fig-5: Multimachine system installed with

UPFC

**6. STUDY FOR UPFC APPLICATION IN THE POWER SYSTEM OF THE WESTERN AREA POWER ADMINSTRATION:**

The western area power adminstration is responsible for a transmission system that consists of more than 16,500 miles of line over an area of some 1.3 million square miles. Major power and var control facilities presently used by western include conventional phase angle regulator, static var compensator, series capacitor, and HVDC interties. The realisation of a practical UPFC has several logistic and operational advantage based upon western diversity in power system facilities and equipment. With the UPFC being able to control all three line parameters, the concept of having one ststic piece of equipment in lieu of several disyributed equipment installation has the potential for not only improved system performance, but reduced maintanence, lwss overall property for facilities, and simplified operation for dispatchers.

In the past, western has studied the UPFC using small test cases to simulate system trasients and dynamic response. The present full sized planning system study examines whether the UPFC could provide multi power flow and dyanamic compensation functions in a major application like the Mead-Pheonix project.

The above application study shows that a single UPFC could replace the combination of phase angle regulator, series capacitor and ststic var compensator and provide steady state and superior dyanamic performance. Further studies are planned which will focus on finding an effective combination of the UPFC and conventional equipment, and on the application of improved control algorithns in order ti overcome up with the best trade off between cost and performance.

**8. CONCLUSION:**

A systematic approach for designing UPFC based controllers for damping power system oscillations has been presented. The Combination of

Power System Stabilizer and UPFC not only reduces the system oscillation but also reduces the oscillation present in the real & Reactive power & phase voltage i.e. it maintains the constant power flow after the occurrence of the fault This paper focuses on PSS and UPFC damping controller design and their contributions in damping the system oscillations during adverse conditions. Here during the simulation studies the position of UPFC is kept constant. The simulation studies revealed that oscillations present after occurrence of fault are greatly reduced after PSS and UPFC combination.

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