VOLTAGE CONTROL AND DAMPING OF INTER AREA OSCILLATIONS USING HYBRID SCHEME

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Abstract- The recent power systems are highly complex and which are all interconnected together. So due to fault in any one place in system will affect the entire network because interconnection of transmission lines. So this will leads to transient instability in inter area mode of oscillation between different units. Here the hybrid connection of fixed capacitor and UPFC is introduced to damp out these oscillations and this combination will improve the transmission capability of transmission lines. The fixed capacitor will provide reactive power support to the system for reducing the line reactance and the way to increase the power transmission capability. The UPFC is one of the FACTS devices for controlling real and reactive power of transmission lines in independently. The UPFC can allow loading of transmission lines close to their thermal limits and forcing the power to flow through the desired paths. In three phase transmission lines the first two phases are compensated by fixed capacitor and third phase is compensated by combination of both fixed capacitor and UPFC. This combination will give better results in practical applications. The five bus system is tested by using MATLAB/SIMULINK under the fault condition.

Index Terms- inter area oscillation, transmission capability, hybrid connection, Unified Power Flow Controller (UPFC).

I. INTRODUCTION

In every day power demand is varied in gradually so to meet out this power demand operate generator in very sensitive manner and also we need to increase the power generation of power plants. Most of the time power demand is match with the power generation but the problem’s are arises in the transmission system. Because the generating stations are far away from the load centre and these are connected through the long transmission line. If there is any fault in any one these lines would make generator to oscillate. So these oscillations are related to one unit area swinging with respect to another area which is called inter-area oscillations [1]. These low frequency inter-area oscillations are due to connection of weak tie line between two buses in transmission network and these oscillations are controlled by placing appropriate FACT’s devices in transmission lines [3]. The FACT’s devices are having capable to control both real and reactive power in transmission line and also it will increase the transmission line capability [8]. In this paper UPFC is used as a FACT’s device and which is connected in series with capacitor. Series capacitive compensation method has been employed to remove significant portion of the reactive line impedance and hence to improve the amount of transmittable power during varies dynamic conditions [2]. The series capacitor will inject reactive power to transmission line when it is require but this has a one drawback of creating sub-synchronous resonance in system where electrical energy is transferred with generator shaft system in a growing manner which may result in generator-turbine shaft to mechanical damage. So that SSR is also one of important issue while series capacitors are placing in transmission line to control power flow [4]. In this proposed scheme hybrid compensation means in three phase transmission line the two phases are compensated by fixed capacitor and third phase is compensated by combination of fixed capacitor series with UPFC shown in fig. No.1.

![Fig.1 Schematic Diagram of Hybrid Scheme](image)

The supplementary control are used for enhance the power system oscillation damping. The phase balance is maintained by using the hybrid connection. The values of reactance are calculated by following.

1. At power frequency the reactance between two buses (X, Y) in figure are following

\[ X_a = X_b = \frac{1}{j\omega C} \] (1)

\[ X_c = \frac{1}{j\omega C_c} - jX_{UPFC} \] (2)

In here \((-jX_{UPFC})\) is the effective capacitive reactance created by UPFC at the power frequency such that \(X_a=X_b=X_c\). The transmission line 1 and 2 are has same reactance because these lines are connected only with fixed capacitor, the third line has a different reactance value which is due to connection of fixed capacitor and UPFC.
2. During any other frequency, \( f_c \)
\[
X_c = \frac{1}{j\omega_c C_c} - jX_{UPFC} - \Delta jX_{UPFC} \tag{3}
\]
The first term in (2)&(3) are different because they are different in frequency and third term in equation (3) is the effective capacitance due to their supplementary control action. The presented scheme is very economical in case of UPFC placed in all the three phases. The effectiveness on damping of power system oscillation and Sub-synchronous Resonance are presented in [5]. The system is modeled and simulated by using MATLAB/SIMULINK.

II. DESIGN OF SINGLE PHASE UPFC

A unified power flow controller (UPFC) is the most promising device in the FACTS concept. It has the ability to adjust the three control parameters such as the bus voltage, transmission line reactance, and phase angle between two buses, either simultaneously or independently. A UPFC performs this through the control of the in-phase voltage, quadrature voltage, and shunt compensation. UPFC can control the three control parameters either individually or in appropriate combinations at its series-connected output while maintaining reactive power support at its shunt-connected input. The mechanism of the three control methods of a UPFC can enhance power system damping. It was shown that a significant reduction in the transient swing can be obtained by using a simple proportional feedback of machine rotor angle deviation. It is generally accepted that the addition of a supplementary controller to the UPFC can significantly enhance power system damping [3].

The main function of the UPFC is to control the flow of real and reactive power by injecting of a voltage in series with the transmission line. Both the magnitude and the phase angle of the volt age can be varied independently. Real and reactive power flow control can allow for the power flow in prescribed routes, loading of transmission lines closer to their thermal limits and can be utilized for improving transient and small signal stability of the power system. The schematic of the UPFC is shown in Figure 2. In this model three level voltage source converter based on sinusoidal pulse width modulation technique is presented. Increasing in number of level the sinusoidal wave form will get accurate but it will increase the cost of circuit.

In this model the flow of power in series transformer is based on the UPFC inductive or capacitive mode of operation. Input line voltage and currents are measured by corresponding measurement system and based on that line control variables are produced. Here the injected voltage of one of the transmission line is adjusted by directly varying modulation index to change line reactance \( \frac{V_{UPFC}}{T_{LINE}} \) of UPFC. In the VSC device bidirectional MOSFET switch is used for bidirectional flow of power in the system. To control the MOSFET power electronics switches the proportional integral (PI) controller is used, based on the control signal from supplementary PI controller the switches will be operate. By properly tuning the MOSFET switches the problem of Sub-synchronous resonance can be minimized which is addressed by connecting series capacitor in transmission line. The series power transformer is used for converting low level voltage from converter side to high voltage level in transmission side.

III. TEST SYSTEM

To demonstrate the effectiveness of the supplementary control of hybrid scheme in power system damping, the system shown in fig.3 is adopted as a test system. The test system consists of three generator (G1, G2, G3) and the loads are (S1, S2) through 500Kv transmission lines. In that two double circuit transmission lines are connected, the first one is connected between generator 1(G1) to load 1(S1) and another one between generator 2 (G2) to load 2(S2). In that each double circuit transmission line connected by fixed series capacitor and UPFC and their compensation level is calculated by following formula it’s a ratio of \( \frac{X_c}{X_L} \ast 100 \% \) and the value of hybrid Compensation phase can be calculated by following \( \frac{X_{UPFC} + X_c}{X_L} \ast 100 \% \).

The maximum power generation capacity of all generators is 4500 MVA and peak load is 3800 MVA respectively. The load profile values is S1=1400+j200 MVA and S2=2400+j300 MVA. The test system is modeled and tested by using MATLAB/SIMULINK software.
IV. DAMPING OF POWER SWINGS

The damping of power swings can be achieved by modulating the UPFC reactance; here to modulate the reactance m-stage supplementary control is used. The supplementary control input signal are power flows (local signal) in transmission line by choosing the remote signal (like speed deviation of remote generator) it may have some problem due to communication error. In this paper input signal as line flow of line 1, line 2 and line 3 (PL1, PL2 and PL3) are selected as supplementary control input value.

V. SIMULATION AND RESULTS

The five bus test system is simulated by MATLAB/SIMULINK (MATrix LABoratory) software environment. In that to make a disturbance a balanced three phase fault is created at bus 4.

Case 1: NORMAL FIVE BUS SYSTEM

In this case there is no compensation device is connected to the system. The system has five buses which are used to connect different elements in power system network. The bus numbers one, two, three are connected to the synchronous generator their corresponding ratings are given in table [appendix]. Three phase loads are connected in bus number four and five. Three phase fault is created at near bus number four. The corresponding simulation figure and results are below.

By connecting series capacitor in transmission line it will reduce the line impedance by injecting capacitive effect in transmission line. Now the voltage magnitude reduced during fault condition compare to normal case figure no.5.

CASE 2: FIVE BUS SYSTEM WITH SERIES CAPACITOR

In this case, the series capacitance is connected to each of parallel transmission lines which are connected between bus number one to four and bus number two to five. This series capacitance is used to reduce line impedance effect.
CASE 3: FIVE BUS SYSTEM WITH HYBRID SCHEME

In this case the both series capacitor and unified power flow controller are connected in parallel transmission lines. The three phase fault is created at above mentioned time period. To control the line impedance by supplementary control of UPFC will modulate much more sensitive than series capacitor. The output of supplementary control signal is used control input firing pulse of MOSFET(Metal Oxide Semiconductor Field Effect Transistor) switches. This control of firing pulse to UPFC will reduce sub synchronous resonance (SSR) in power system. The SSR is occurred in the system while series capacitor is connected to transmission line.

These oscillations will affect the rotor shaft of generator. In next case fixed capacitor (blue line) is connected in line so the oscillations are damp out compare to normal case. In next case connection of fixed capacitance and hybrid (red line) shows oscillations are damp out mostly.

5.3 Voltage Waveform at Bus 1

The RMS voltage of system is measured in bus number 1. Three phase fault is created at 5 seconds and it’s cleared in 5.2 seconds. So during this period the voltage is reduced quickly and after fault clearing the voltage at bus 1 goes to steady state value faster than first two cases.

VI. GENERATOR SWING CURVES

The following figures shows output swing curve of each generator in before and after fault clearing in transmission line. The swing curve (Del) which is measured with respect to time.

A. FIRST GENERATOR SWING CURVE

In this fig.No.10 swing curve is obtained for under normal condition, with connection of fixed series capacitance in all lines and finally coordination of both fixed capacitor and UPFC is connected in one line. In this figure normal case (green line) has take more time to reach steady state value after fault clearing in system.

B. SECOND GENERATOR SWING CURVE

The following fig.no.11 shows the output swing curve for second generator. The green line shows rotor oscillation for normal case during and after fault clearing. The blue line shows the rotor oscillations for five bus system with series capacitor. The oscillations somewhat damped from normal case. The red line shows oscillations of rotor for test system with hybrid compensation scheme. In this case most of oscillations are damp out compare to normal case of system.

C. THIRD GENERATOR SWING CURVE

The following diagram shows the output swing curve of third generator. In this figure X axis is time in seconds and Y axis is Del in degree.
The green line shows normal case of test system has long period of oscillations and blue line shows test system with series capacitor has oscillation less than normal case. The third case is test system with hybrid scheme which has small oscillations then normal and second case. In the entire fault is occurred at 5 seconds and cleared at 5.2 seconds. From the above swing curve we can conclude by connecting series fixed capacitor will improve damping of power system oscillations and further connecting coordination of hybrid (fixed capacitor and UPFC) scheme will provide better results.

CONCLUSION

The ability and improvement of power system stability has been tested by using UPFC. Based on that for controlling the damping the power system oscillations and power transfer capability has been done by hybrid series combination of fixed capacitor and UPFC with the simple supplemental controller for the given five bus system. The presented compensation scheme is feasible, technically sound, and has industrial application potential.

REFERENCES