Power System Stability Enhancement using Interline Power Flow Controller

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Abstract: - FACTS technology improves the power system stability by providing the necessary compensation to transmission lines. Interline Power Flow Controller (IPFC) is one such unique concept for exchange of power flow in case of interconnected systems. In this paper, an IPFC is proposed to improve the voltage stability of a given power system network consisting of three transmission lines. The gate triggering pulses to the power electronic based IPFC are provided by a neural network based intelligent controller. The entire system is simulated using MATLAB/Simulink. Simulation results show that this power electronic based FACTS controller provides faster dynamic response along with enhanced stability limits.

Keywords: - Power system stability, power system operation and control, FACTS

1 Introduction

Rapid development of power electronics has facilitated implementation of highly advanced FACTS based controllers. The main objective of these FACTS based controllers is to achieve flexible control over one or more transmission line parameters namely voltage, line impedance and power angle in order to enhance power flow and stability limits [1] – [3]. A Unified Power Flow Controller (UPFC) provides selective or simultaneous control over the basic transmission line parameters for one transmission line at a time [4], [5]. UPFC uses shunt and series connected power electronic based voltage source converters (VSC) fed from a common dc link to provide the necessary real and reactive power support.

Interline Power Flow Controller (IPFC) is an extension of the UPFC, which can be efficiently used to control the transmission line parameters in case of interconnected systems [6]. Enhanced power flow and hence better stability is ensured by real power exchange between under utilized and over loaded transmission lines and by providing the necessary reactive power support.

In this paper, attempt is made to enhance the stability of a given power system by using a generalized IPFC. The entire power system network is simulated using power system blockset present in MATLAB/Simulink.

2 Problem Formulation

Power system stability is governed by bus voltage magnitudes, phase angle, real and reactive power support provided at the load bus. This mainly depends on the amount of transmitted real power, which is effectively restricted by the line impedance and thermal limits of the transmission lines. This leads to over loading and/or under utilization of various transmission lines in case of an interconnected system. A generalized IPFC is hence proposed to facilitate exchange of real and reactive power between the transmission lines. Due to improved power flow, better stability limits can be realized.

3 The Interline Power Flow Controller

3.1 Basic Structure of IPFC

The IPFC consists of one shunt and number of series connected (same as the number of transmission lines) VSCs supplied by a common dc link. The structure of an elementary IPFC consisting of two VSCs is shown in Fig.1. The bidirectional dc link represents bidirectional active power exchange between the two voltage sources. By controlling the dc link voltage, reactive power can be exchanged between the transmission line and the shunt converter. Series converter injects a voltage of controllable magnitude and phase angle, thus providing real power exchange between the transmission lines.

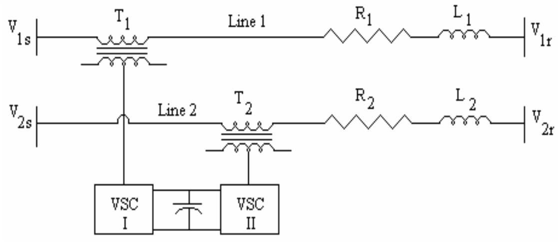

Fig. 1. Basic Structure of IPFC

3.2 Operation of IPFC

The operation of IPFC can be considered as an extension of Static Synchronous Series Condenser (SSSC), where the series injected voltage must always be in quadrature with the line current to ensure zero real power at the common dc link. This implies that only the magnitude of injected voltage can be controlled. In case of IPFC, there will be atleast two series compensated lines coupled to the dc buses of the VSCs. Therefore, both the injected voltage magnitude and phase angle can be controlled [7], [8]. This facilitates real power extraction from one line and injection into the other in addition to reactive power exchange.

For the simple configuration shown in Fig. 2, the variables available for control are the series injected voltage magnitudes and phase angles. Thus we have four variables namely $?V_1$, $?V_2$, $?_1$ and $?_2$. ($?_1$ and $?_2$ represent the phase angles) The dc link has no real power source and its voltage must be held constant. Therefore, the real power injected in one line by the VSC must be equal to the real power extracted from the other line. This constraint on the power flow means that only three out of the four available variables can be independently controlled. Hence, the line with two controllable variables is termed as the primary (master) line while the other line with only one controllable variable acts as the secondary (slave) line.

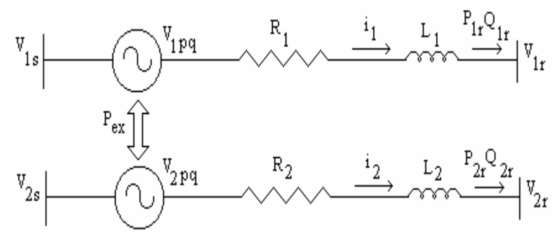

Fig. 2. Equivalent Circuit of IPFC

4 Power System Details

In this paper, a generalized IPFC consisting of three buses and two transmission lines is considered. The two transmission lines are fed by shunt and series voltage source converters that are fed from a common dc link. The transmission line is fed from a 200 MVA, 13.8 kV, 50 Hz synchronous generator. The transmission line voltage is further stepped up to 230 kV using a 13.8/230 kV, 200 MVA transformer. Base voltage is taken as 230 kV while base MVA is taken as 200 MVA. A 75 km transmission line is considered.

5 Simulation Results

The entire system is simulated using power system toolbox of MATLAB/Simulink. A three phase fault is introduced at 40 ms and the fault is cleared at 50 ms. During this time interval, the voltage magnitude at the load bus falls to 1.6 pu from 1.9 pu. However, without IPFC the bus voltage would fall to zero until fault clears. These results can be observed from fig. 3.

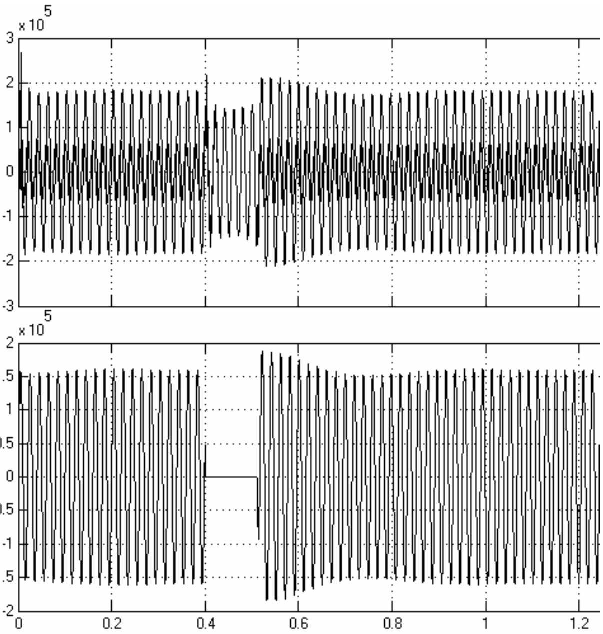

Fig. 3. Voltage waveform at load and fault bus

The current magnitude would become zero and continue to remain at zero until the fault is cleared. This can be observed from Fig. 4.

In addition to this, real and reactive power waveforms are also shown in Fig. 5. Simulation results clearly show that voltage magnitude is maintained at a satisfactory level due to the addition of IPFC.

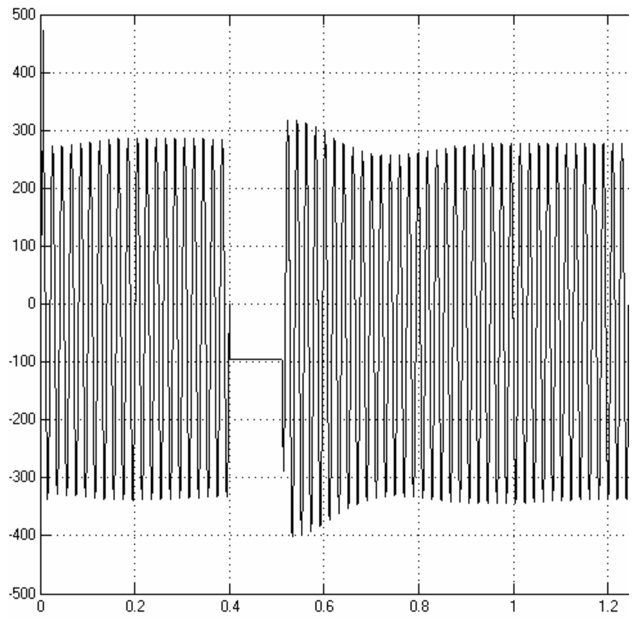

Fig. 4. Current waveform at fault bus

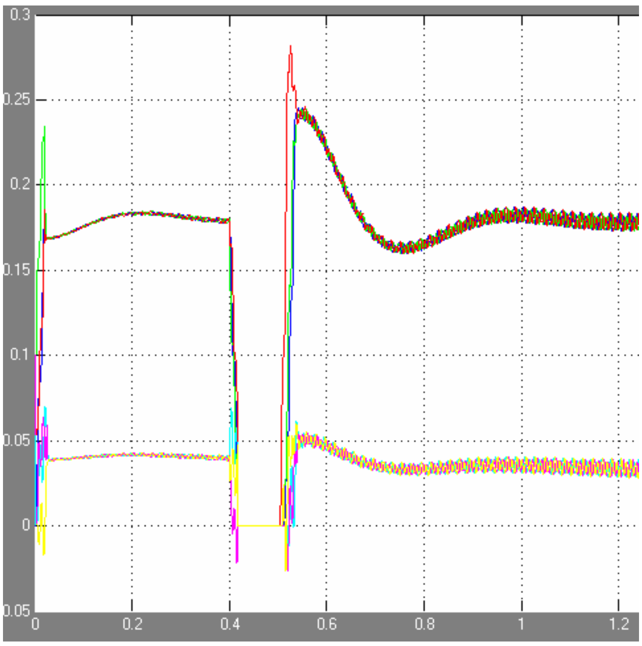

Fig. 5. Real and reactive power waveforms

6 Conclusion

In this paper, a generalized IPFC was proposed to enhance the voltage stability limits by properly utilizing the available real and reactive power. This was made possible by power electronics based FACTS controllers, which operated from a common DC link and provided the necessary real and reactive power exchange. Simulation results show that voltage stability limits have considerably increased due to the addition of IPFC.

7 References

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