INVESTIGATIONS ON DAMPING TORSIONAL OSCILLATIONS IN POWER SYSTEM USING FACTS CONTROLLERS

Thesis

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ABSTRACT

The competition, cost, and customer choice are becoming the facets in which soon to be deregulated and unbundled electrical energy utilities would be working. In the present pace of power system, transmission systems are being restructured to provide increased power transfer capability to accommodate a much wider range of possible generation patterns. The utility companies would need to meet the growing demand of electrical power in an open transmission access scenario with minimal environmental impact. The optimization of transmission corridor for power transfer has become of great importance. The power transfer in the integrated power system is impeded by transient stability, voltage stability, and small signal stability. These constraints limit a full utilization of available transmission corridor. The fast acting power electronic converters with the generic name Flexible AC Transmission System (FACTS) devices with their equally fast and efficient controlling capabilities are becoming the pillars of support of such a highly integrated power systems. FACTS devices are very effective and capable for increasing loadability, reducing system loss, improved stability of network and reduced cost of production. These converters give precise and flexible control to an electric power system. A number of power electronic devices have been proposed for dynamic compensation, improving system stability, directing power flows, etc. One of the power electronic devices used for reactive power compensation is a Static VAR Compensator (SVC). Such a system when connected in shunt with a power system is referred to as a static VAR System.

Series compensation has been widely used to enhance the power transfer capability. However, series compensation gives rise to dynamic instability and sub synchronous resonance (S.S.R.). Damping of low frequency oscillations is one of the most important and challenging task in power industry as the stability of these oscillations is a pre-requisite for secure and stable operation of power system. To address the dynamic instability problems in series compensated lines, many preventive measures have been reported in literature [1, 2, 3, 4, 5]. It is observed from the literature that thyristor controlled (FACTS) devices such as SVS, STATCOM, SSSC and controlled series capacitors (CSC) are finding increasing application in the modern power system. Off these the application of SVS controller has become popular in recent years due to its capability to work as Var generation and absorption systems. Besides, voltage control and

improvement of transmission capability, SVS in coordination with auxiliary signals can be used for damping of power system oscillations effectively.

An effective SVS controller needs to be developed in order to achieve satisfactory performance over a wide operating range and under large disturbance conditions. To study the system dynamics accurately over a wide operating range a detailed system model is required to be developed and used. The omission of the line dynamics for series compensation line can lead to erroneous predictions especially when the transmission network eigenvalues are close to those of electromechanical system.

Different types of SVS auxiliary signals and their combination are to be tried to find out the most effective auxiliary signals or their combination for enhancement of dynamic and transient stability over a wide operating range. The different auxiliary signals that have been tried to modulate SVS bus voltage are the deviation in active power, reactive power, angular speed, voltage angle, combined reactive power and frequency signals and their combinations such as combined active power and reactive power, voltage angle and reactive power and derivative of reactive power and derivative of active power are tried in this presentation to enhance the dynamic and transient stability of a series compensated power system.

The major objectives and scope of the thesis are described below:

1) To develop an effective detailed model of the system that can reflect the dynamics of each component of power system accurately.
2) To study the comparative performance of SVS auxiliary controller in coordination with Induction machine damping unit for dynamic stability enhancement of series compensated power system over a wide operating range and to determine the most effective scheme.
3) To study the damping of sub-synchronous resonance using voltage angle and reactive power (VARP) auxiliary signal combined active power and reactive power (CARP) auxiliary signal and derivative of reactive power and derivative of active power

(DRDAP) auxiliary signal and their comparative performances and thus selecting the most effective auxiliary signal for SVS controller.

A detailed system model has been developed for the dynamic and transient performance study of the system. The study system consists of two generators 555 MW each equivalent to 1110 MW generator supplying power to an infinite bus over a long series compensated transmission line. The model is similar to the IEEE I bench mark model. Data for the study is considered from [7, 9, 10]. In the detailed machine model, stator is represented by a dependent current source in parallel with an inductance. The rotor flux linkages are expressed in terms of currents, which are defined with respect to machine reference frame. To have a common axis of representation with network and SVS, these flux linkages are transferred to synchronously rotating D-Q frame of reference by applying Kron’s transformation [8]. The Generator model includes field winding and a damper winding along d-axis and two damper windings along q-axis. The all modes model is utilized for studies in the present chapter. In this multi resonant model the turbo generator mechanical system is represented as a linear multi mass spring dash pot system. Each major rotating element is modeled as a lumped mass representing by its inertia while every shunt element is modeled as mass less rotational spring with its stiffness expressed by spring constant. Viscous damping of each mass and shaft segment is represented by a dash pot damping. The natural damping of these masses is considered to be zero. IEEE type-1 excitation system is considered for the generator. The SVS of (SC-TCR) type provides dynamic voltage support at the mid point of line. The detailed SVS model has been used which incorporates TCR transients. The Network is represented by a lumped parameter T circuit. The SVS and series compensation are located at the center of transmission line.

The property of induction machine to act as a generator or motor is utilized to absorb the mechanical power when there is excess and to release it when there is a deficiency. Optimal location i.e. middle of transmission line of series compensation and SVS is selected, also the optimal location of IMDU along T-G shaft is determined for most effective damping [10] of torsional modes in a series compensated power system for wide operating range using eigenvalue study.

A number of SVS auxiliary controllers are developed and then comparative performance is evaluated for enhancement of dynamic stability of a series compensated power system by computing the eigenvalues of linearized system model. The combined active power and reactive power SVS auxiliary controller in coordination with induction machine damping unit is found to be most effective for system damping over a wide operating range. The proposed scheme is simple, economical and easy to implement. Performance of the above scheme is examined for sub-synchronous resonance damping in a series compensated power system over a wide operating range. Digital simulation is carried out to evaluate the damping performance of various schemes for torsional modes and other power system oscillating modes under large disturbance conditions. The results of digital simulation study correlates with that of eigenvalue study.

Comparative analysis has been performed on the combined voltage angle and reactive power (VARP), combined active power and reactive power auxiliary controller (CARP) and derivative of reactive power and derivative of active power auxiliary controller (DRDAP) for effective control of SVS and CARP auxiliary signal controlled SVS has been found to be best.

The eigenvalues have been computed for the system with and without auxiliary controller incorporated in the SVS control system in co-ordination with induction machine damping using T circuit model of AC network.

The following SVS auxiliary controllers have been used in respect of then ability to stabilize the unstable system modes.

- Line reactive power auxiliary controller
- Bus frequency auxiliary controller
- Voltage angle auxiliary controller
- Combined active power and bus frequency (CAPF) auxiliary controller.
- Derivative of reactive power auxiliary controller.
- Derivative of active power (DAP) auxiliary controller.
- Combined active power and reactive power (CARP) auxiliary Controller
- Combined Voltage and reactive power (VARP) auxiliary controller

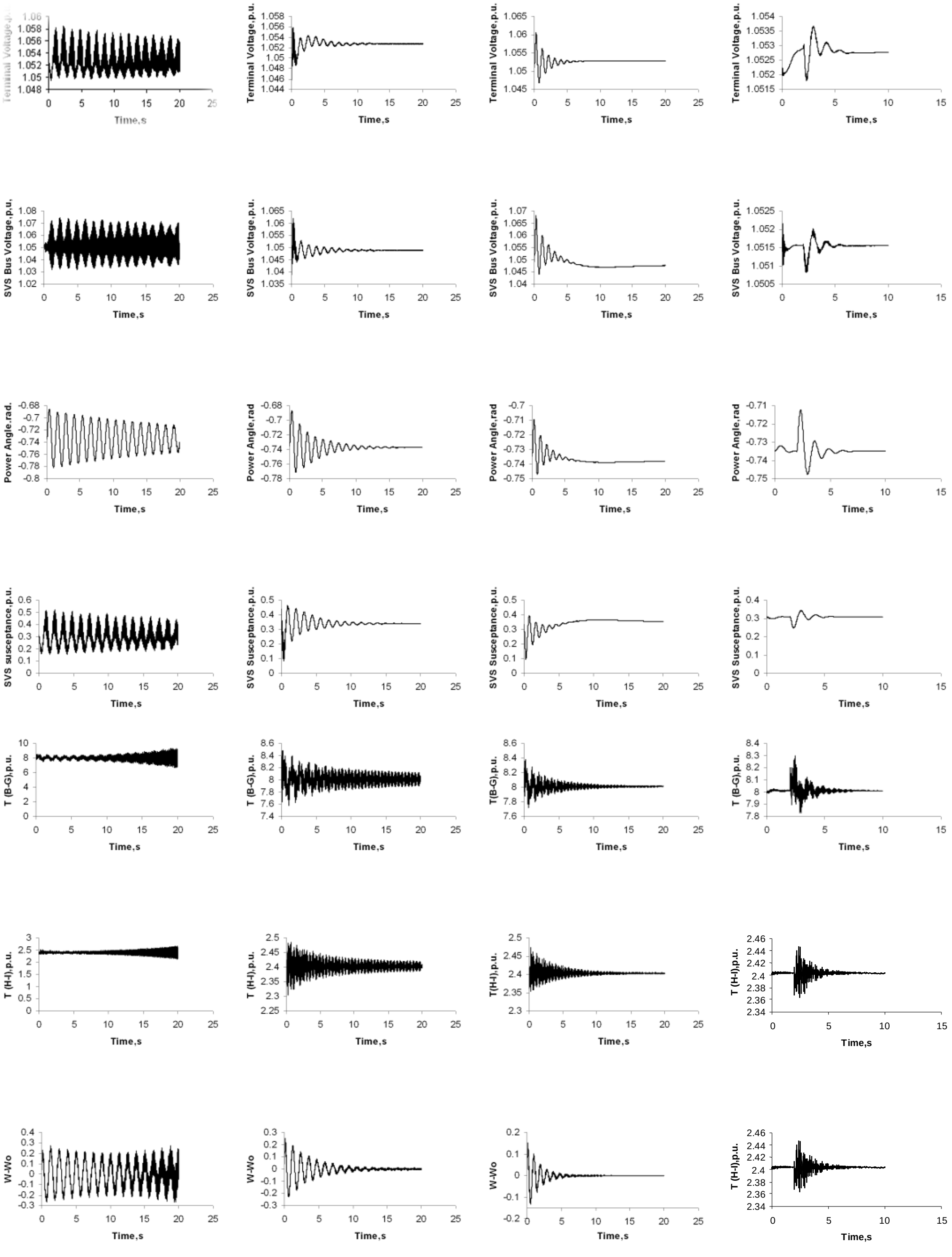
- Combined derivative of reactive power and derivative of active power (DRDAP)) auxiliary controller only CARP, VARP and DRDAP auxiliary controller has been able to stabilize all the mechanical modes.

Dynamic performance has been evaluated using eigenvalue analysis All the above auxiliary signals have stabilized all the electrical modes but not all low frequency modes i.e. mechanical modes .All mechanical modes have been stabilized by CARP,VARP and DRDAP auxiliary signals. All the low frequency modes have been listed in the table.

Digital time domain analysis for the system under large disturbance has been curried on the basis of non linear differential equations with all non-linearities and limits. A fourth order Runge Kutta method has been used for solving the differential equations. Disturbance is created by a 30% sudden increase in input torque for 0.1 s at time t = 0. The simulation study has been carried out at Pg = 800 MW using T-circuit representations of AC network. For this simulation study all self and mutual damping constants of the turbine generator shaft system have been assumed to be zero to represent the worst damping conditions. 40% series compensation has been used at the center of transmission line. The response of the system namely terminal voltage, SVS bus voltage, power angle, SVS Susceptance, torsional torques and deviation in angular speed without and with the VARP, CARP and DRDAP auxiliary controllers are plotted. It can be readily seen that these auxiliary controllers present the better damping characteristics and effectively damp out the various oscillations whereas the response curves exhibit growing oscillations when no auxiliary controller is used in the SVS control system. The torsional oscillations are stabilized effectively with these auxiliary controllers and these attain a significant improvement in the transient performance of the series compensated power system.

Eigenvalues of CARP, VARP and DRDAP auxiliary controller showing mechanical modes

		Pg = 200 MW	Pg = 500 MW	Pg = 800MW
Without any auxiliary Controller	Mode 5	-.0000±j298.1006	-.0000±j298.1006	-.0001±j298.1006
	Mode 4	-.0593±j202.7368	-.0681±j202.7265	-.1118±202.7264
	Mode 3	-.0111±j160.5519	.0050±j160.5464	.0089±j160.5241
	Mode 2	.0008±j126.9794	.0017 ± j126.9764	.0032±j126.9691
	Mode 1	.0167±j98.8784	.0090 ±j98.8318	.0100±j98.7327
	Mode 0	-.3969±j4.7451	.1985±j5.0264	.0153+j4.9871
With VARP Auxiliary controller	Mode 5	-0.002 ± j 298.10	-0.002±j 298.10	-0.0021±j298.100
	Mode 4	-0.015 ±j 202.89	-0.001 ±j 202.89	-0.015±j202.89
	Mode 3	-0.015±j160.52	-0.012 ± j160.52	-0.012 ±j160.525
	Mode 2	-0.0002±j126.98	-0.0001±j126.98	-0.00013±j126.98
	Mode 1	-0.018±j98.981	-0.0188 ±j98.98	-0.019±j98.984
	Mode 0	-0.49±j6.66	-0.327±j6.81	-0.326± j 6.82
With CARP Auxiliary controller	Mode 5	-0.002 ± j 298.10	-0.002±j 298.10	-0.0021±j298.100
	Mode 4	-0.015 ±j 202.89	-0.001 ±j 202.89	-0.015±j202.89
	Mode 3	-0.015±j160.52	-0.012 ± j160.52	-0.012 ±j160.525
	Mode 2	-0.0002±j126.98	-0.0001±j126.98	-0.00013±j126.98
	Mode 1	-0.018±j98.981	-0.0188 ±j98.98	-0.019±j98.984
	Mode 0	-0.49±j6.66	-0.327±j6.81	-0.326± j 6.82
With DRDAP Auxiliary controller	Mode 5	-.0000±j298.1006	-.0000±j298.1006	-.0001±j298.1006
	Mode 4	-.0593±j202.7368	-.0681±j202.7265	-.1118±202.7264
	Mode 3	-.0111±j160.5519	-.0050±j160.5464	-.0089±j160.5241
	Mode 2	-.0008±j126.9794	-.0017 ± j126.9764	-.0032±j126.9691
	Mode 1	-.0167±j98.8784	-.0090 ±j98.8318	-.0100±j98.7327
	Mode 0	-.3969±j4.7451	-.1985±j5.0264	-.0153+j4.9871



(A) (B) (C) (D)

Fig. . Simulation results showing response curves without auxiliary controller (A), with CARP auxiliary Controller (B), with VARP auxiliary controller (C), and with DRDAP auxiliary controller (D)

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