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DAMPING OF SUBSYNCHRONOUS MODES OF OSCILLATIONS

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Abstract

The IEEE bench mark model 2 series compensated system is considered for analysis. It consists of single machine supplying power to infinite bus through two parallel lines one of which is series compensated. The mechanical system considered consists of six mass, viz, high pressure turbine, intermediate pressure turbine, two low pressure turbines, generator and an exciter. The excitation system considered is IEEE type 1 with saturation. The auxiliary controls considered to damp the unstable subsynchronous modes of oscillations are Power System Stabilizer (PSS) and Static var Compensator (SVC). The different cases of power system stabilizer and reactive power controls are adapted to study the effectiveness of damping these unstable subsynchronous modes of oscillations.

Keywords: Power system stabilizer, Static var compensator, Subsynchronous modes of oscillations.

1. Introduction

Series compensation is widely used in modern power system to increase the power capability of transmission lines. There is a possibility of self excited electrical oscillations when series capacitors are employed in these lines. Due to these oscillations subsynchronous resonance (SSR) and torsional interaction between the

Nomenclatures

R,X	Transformer resistance and reactance [Ω]
R_l,X_l	Line resistance and reactance [Ω]
X_c	Series capacitor reactance [Ω]
V_t	Generator terminal voltage [V]
V_0	Infinite bus bar voltage [V]
δ_i	Angular deviation of rotor i [rad]
ω_i	Velocity of mass i [rad/sec]
ω_{mi}	Modal velocity corresponding to mode i [rad/sec]
T_{mi}	Mechanical torque applied to mass i [N.m]
T_u	Electrical torque [N.m]
T_p	PSS time constant [sec]
K_{PS}	PSS gain for generator speed deviation signal input
K_{PSi}	PSS gain for modal speed deviation input corresponding to mode i
K_P	Proportional control gain
K_D	Derivative control gain
K_I	Integral control gain

electrical network and the rotating mechanical system may occur leading to shaft failures [2]. The analysis of subsynchronous oscillations for the IEEE bench mark model 2 system is carried out using Eigen value technique [1]. PSS are auxiliary controllers which receive a feed back signal from shaft speed, frequency or accelerating power and inject a transient stabilizing signal on the normal voltage error signal [4]. The PSS described here is designed to damp the torsional oscillations. Reactive power control is also one of the effective methods of suppressing torsional oscillations [3]. The SVC described here is designed to damp the torsional oscillations.

2. System Model

The IEEE bench mark model 2 system is considered for analysis. It consists of single generator supplying power to infinite bus through two parallel lines of which one is series compensated as shown in Fig. 1. The Mechanical system considered consists of six mass, viz, high pressure turbine, intermediate pressure turbine, two low pressure turbines, generator and an exciter as shown in Fig. 2. The basic system is modelled in state space form. The state variables chosen for basic system are machine currents, voltage across series capacitor, angular displacements and angular speeds. The system equations are linearized around an operating point and expressed in state space form. The IEEE type 1 excitation system with saturation is considered. The linearized equations around an operating point are expressed in state variable form.

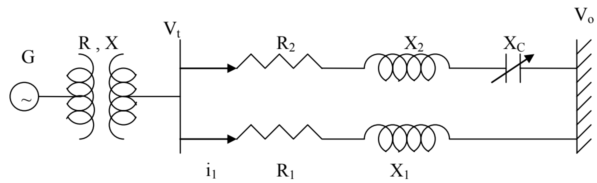

Fig.1. Electrical system.

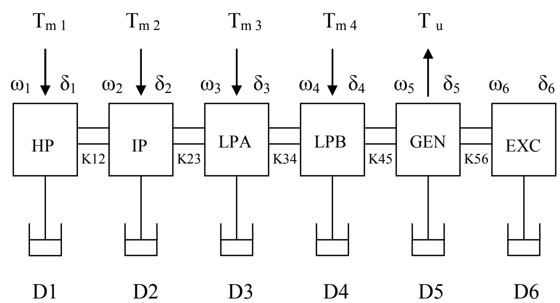

Fig.2. Tandem compound steam generator set.

3. Proposed Control Schemes

3.1 Power system stabilizer (PSS)

One PSS with generator speed deviation signal input, One PSS with modal speed deviation signal input and Two PSS with modal speed deviation signal input as shown in Fig. 3 (a), (b) and (c) is considered for damping the subsynchronous modes of oscillations. The state equations that describe PSS for small disturbance analysis are obtained from the transfer function. The modal speeds can be obtained in terms of the actual speeds using torsional monitory device.

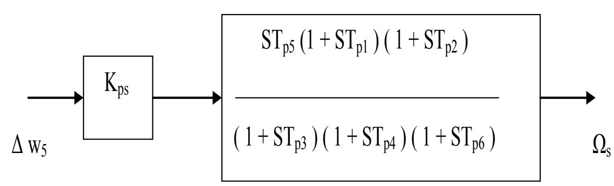

Fig.3. (a) One PSS with generator speed deviation signal input.

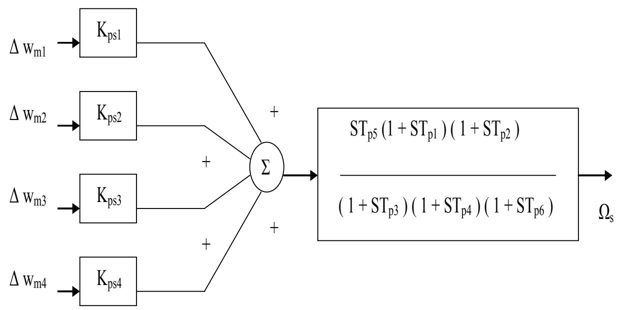

Fig.3. (b) One PSS with Modal speed deviation signal input.

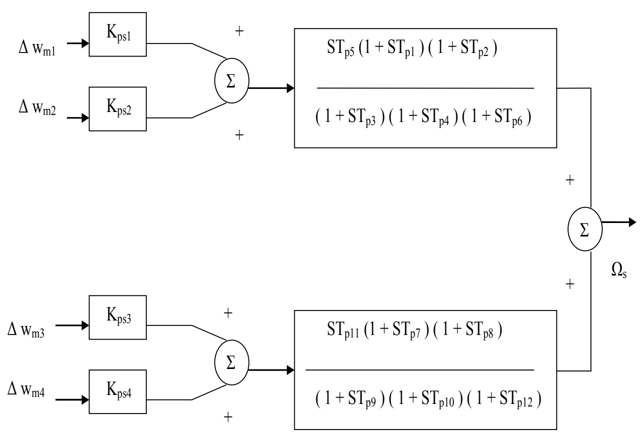

Fig.3. (c) Two PSS with modal speed deviation signal input.

3.2 Static var compensator (SVC)

SVC with complete controls which consists of a voltage control and auxiliary controls of proportional with filter, PD with filter and PID with filter as shown in Fig. 4 (a) and (b) is considered for damping of subsynchronous modes of oscillations. The linearized equations in state variable form are obtained and these equations are included to electromechanical system of equations.

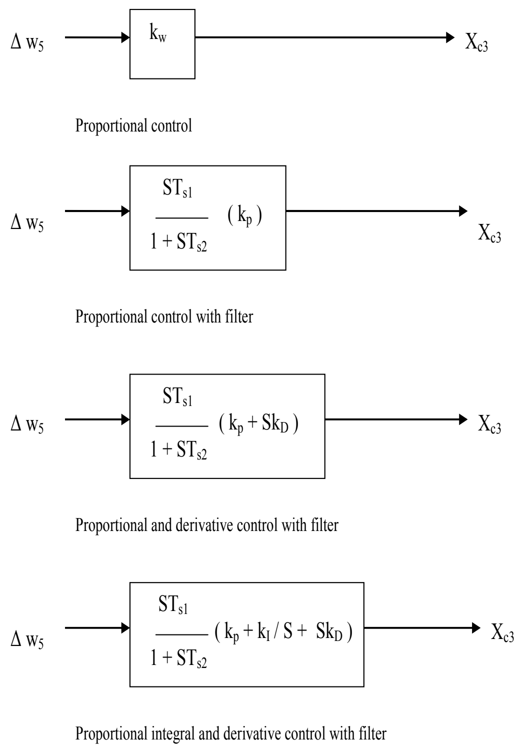

Fig.4. (a) SVC auxiliary controllers.

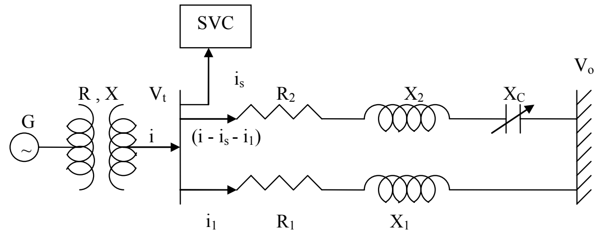

Fig.4. (b) Electrical network with SVC.

4. Results and Analysis

Damping of torsional modes by PSS and SVC with complete controls at specified operating point is investigated. The main objective of this investigation is the performance study of the PSS and SVC control strategies to damp the subsynchronous modes of oscillations.

4.1 One PSS with Generator Speed Deviation Feed Back

The plot of decrement factor vs. percentage compensation is shown in Fig.5. From this study it is observed that one PSS with generator speed deviation signal cannot provide effective damping to all torsional modes.

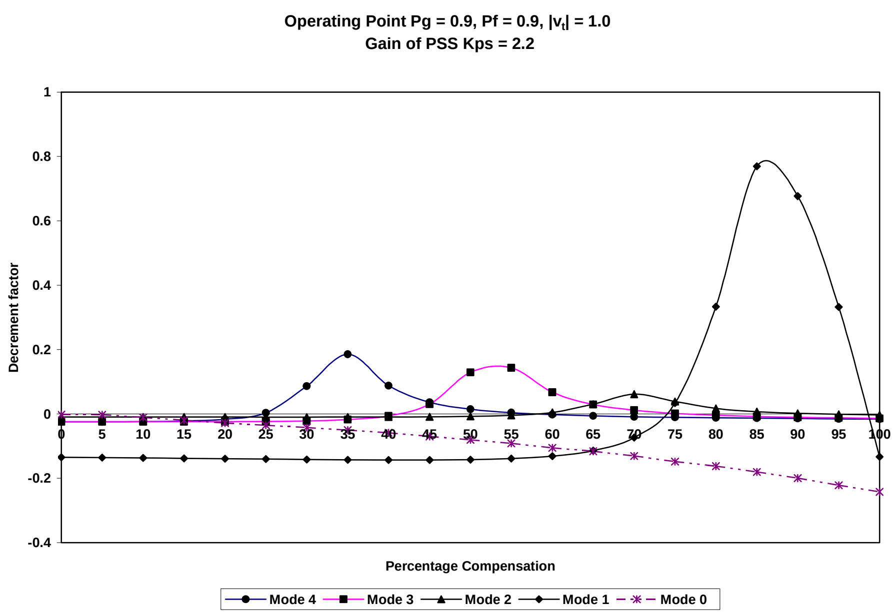

Fig.5. Type of control: One PSS with generator speed deviation input.

4.2 One PSS with Modal Speed Deviation Feed Back

The plot of decrement factor vs. percentage compensation is shown in Fig.6. From this study it is observed that one PSS with modal speed deviation feed back provides effective damping to all torsional modes.

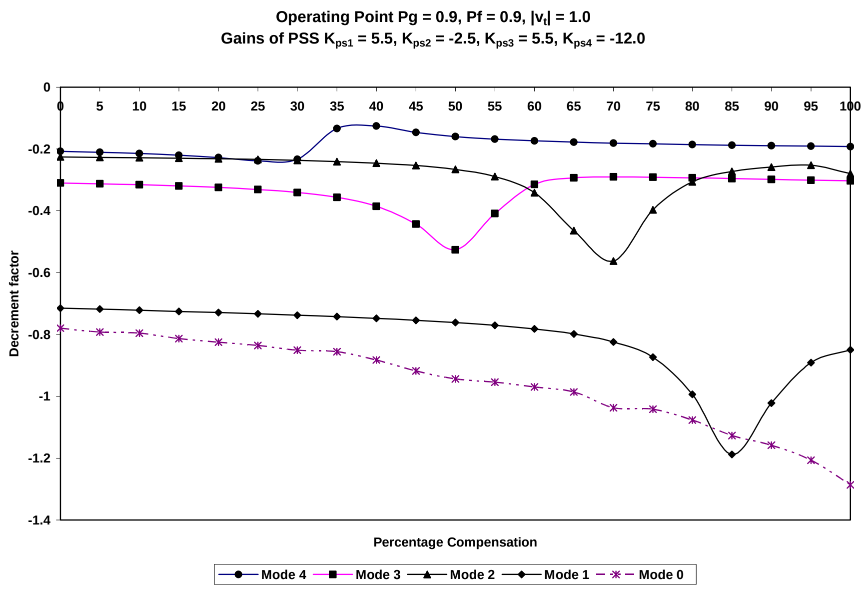

Fig.6. Type of Control: One PSS with modal speed deviation input.

4.3 Two PSS with Modal Speed Deviation as Input

In this case two modal speed signals w_{m1}, w_{m2} with gain controls Kps_1, Kps_2 which are used to damp the torsional modes 1 and 2 are given to one PSS. The other 2 modal signals w_{m3}, w_{m4} with gain controls Kps_3 and Kps_4 which are used to damp the torsional modes 3 and 4 are given to second PSS. The plot of decrement factor vs. percentage compensation is shown in Fig.7. From this study it is observed that two PSS with modal speed deviation feed back provides good damping to all torsional modes.

The study of maximum positive damping which is indicated by its negative decrement factor for all the torsional modes in different cases, it is observed that two PSS with modal speed deviation signal input provides better damping to all torsional modes.

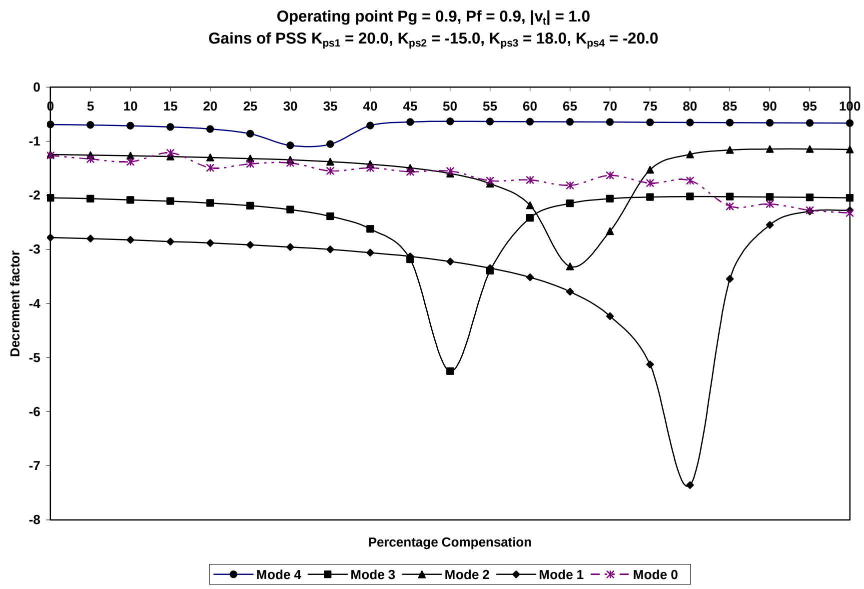

Fig.7. Type of control: Two PSS with modal speed deviation input.

4.4 Static var compensator (SVC) with voltage control

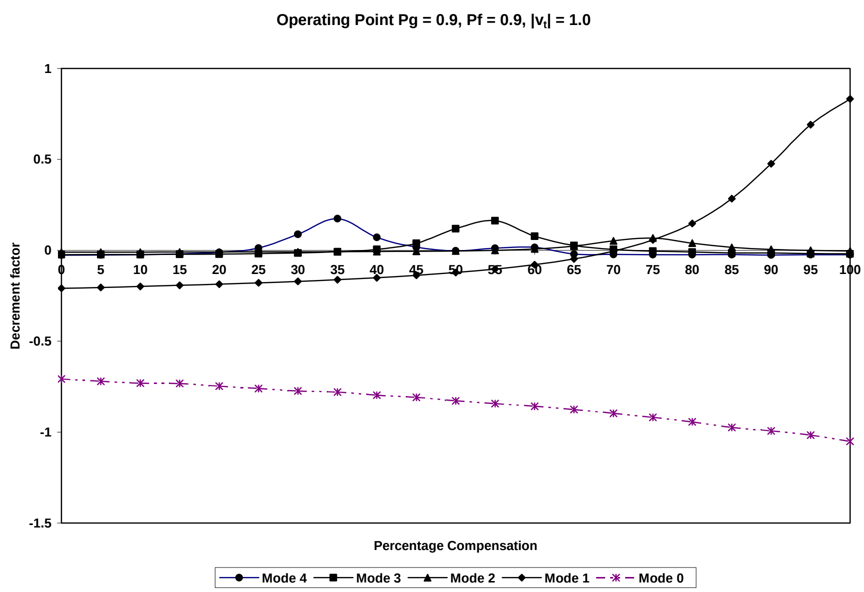

Fig.8. Type of control: SVC with voltage control.

The plot of decrement factor vs. percentage compensation is shown in Fig.8. This study shows that SVC with only voltage control is not sufficient to damp all torsional modes.

4.5 Static var compensator (SVC) with auxiliary controls

The plot of decrement factor vs. percentage compensation is shown in Figs. 9, 10 and 11 respectively for the auxiliary controls: Proportional control with filter, Proportional Derivative control with filter and Proportional Integral Derivative control with filter. From this study it is observed that SVC with auxiliary controls provide effective damping to all torsional modes and PID auxiliary control provide better damping compared to P and PD auxiliary controls.

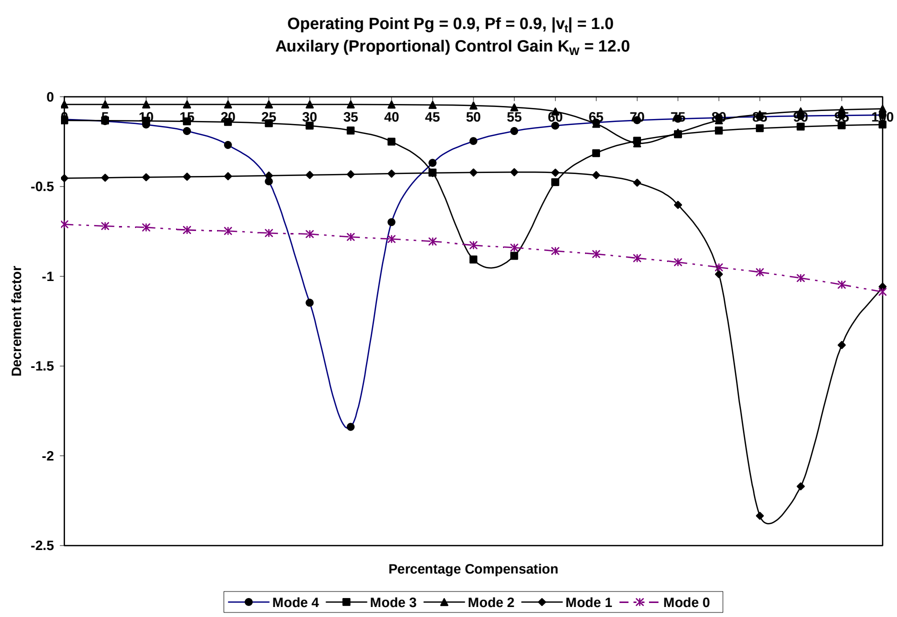

Fig.9. Type of Control : SVC with Auxilary Control (with filter).

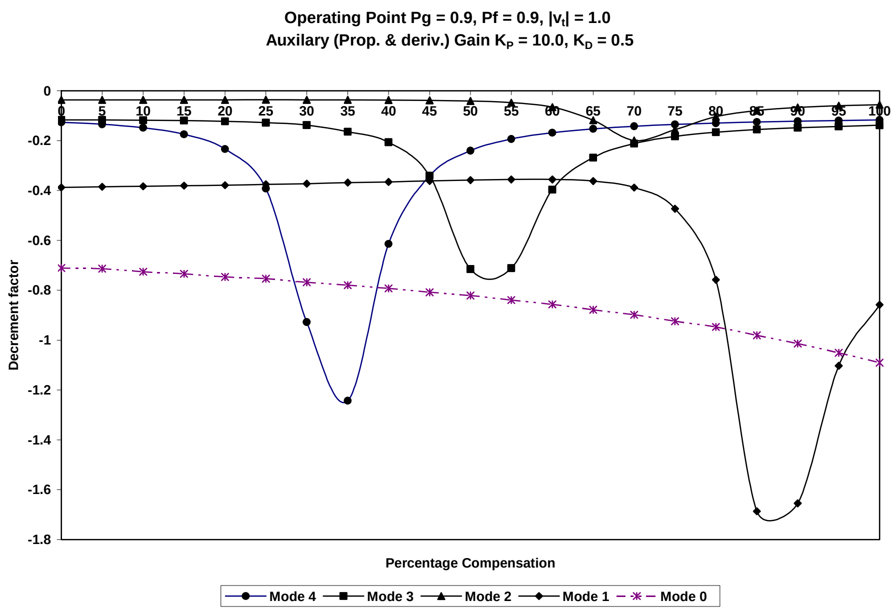

Fig.10. Type of control : SVC with auxiliary control (with filter).

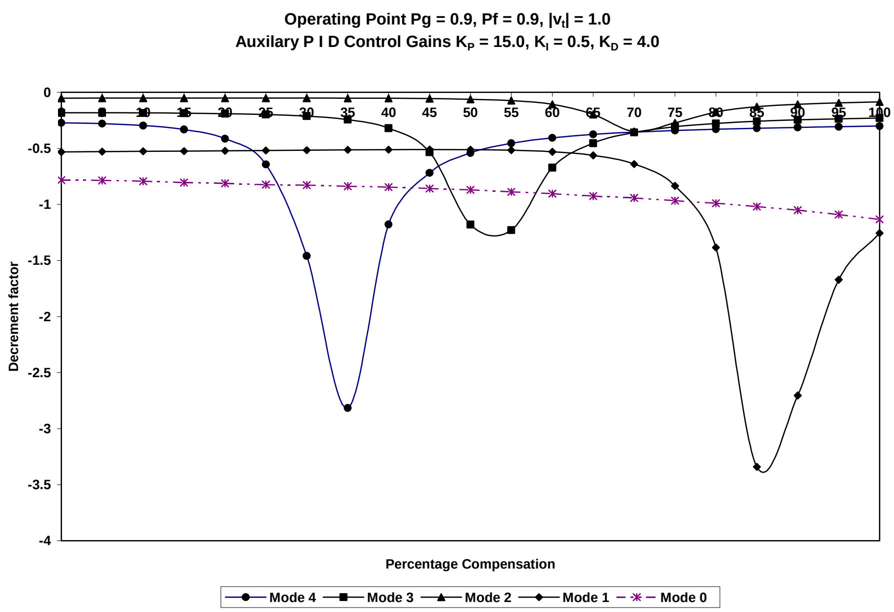

Fig.11. Type of Control : SVC with auxiliary control (with filter).

4.6 Static var compensator (SVC) with voltage and auxiliary controls

The plot of decrement factor vs. percentage compensation is shown in Figs.12, 13 and 14 respectively for the auxiliary controls: Proportional control with filter, Proportional Derivative control with filter and Proportional Integral Derivative control with filter. From this study it is observed that SVC with voltage control and auxiliary control of PID type provides very good damping to all torsional modes.

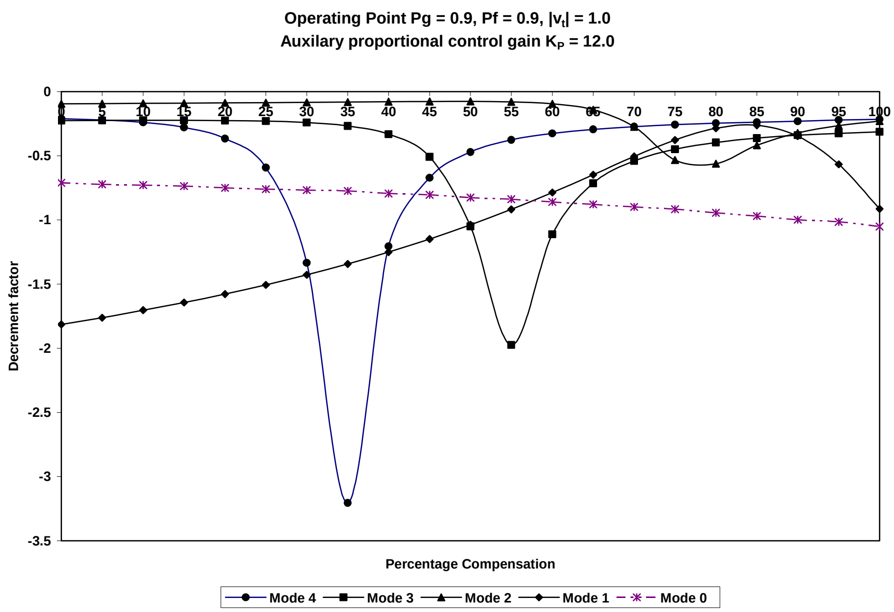

Fig.12. Type of control: SVC with voltage and auxiliary controls (with filter).

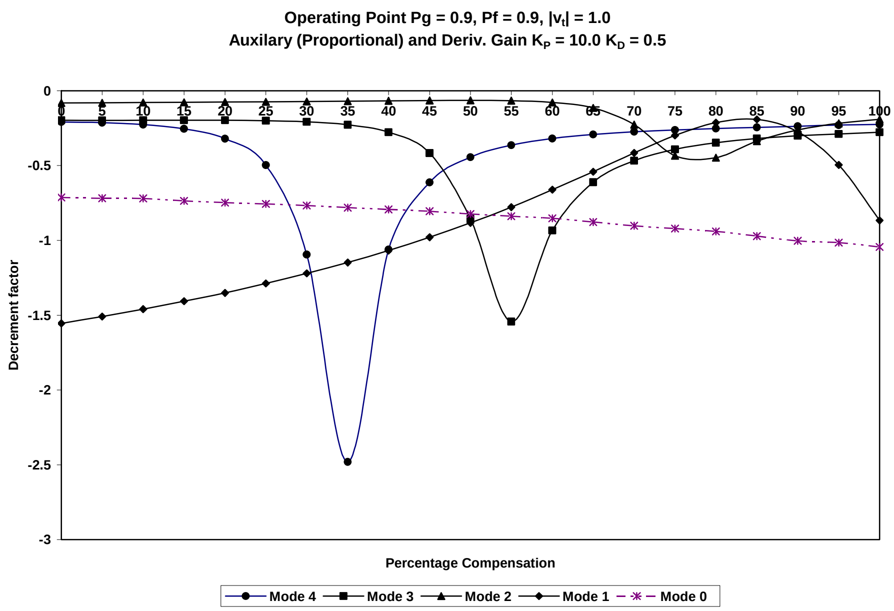

Fig.13. Type of control : SVC with voltage and auxiliary controls (with filter).

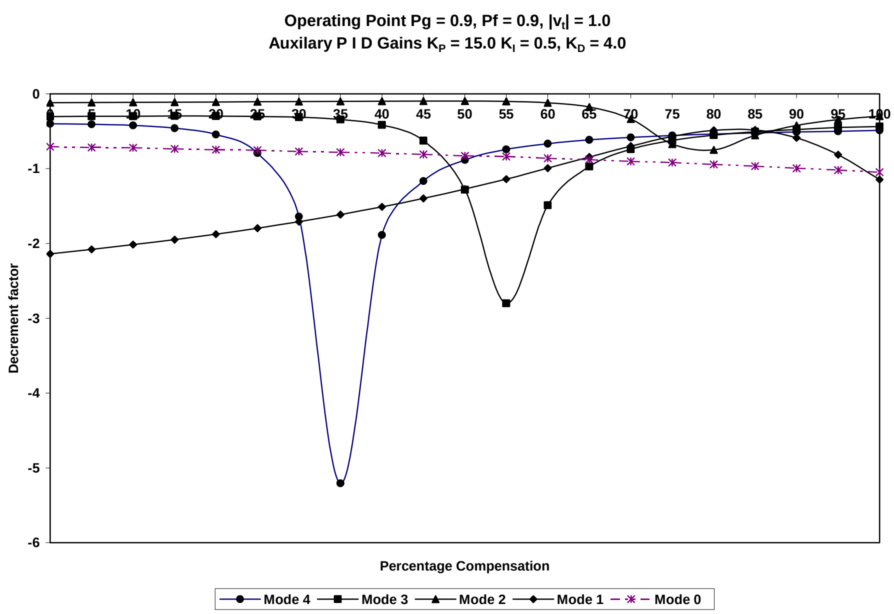

Fig.14. Type of control: SVC voltage and auxiliary Controls (with filter).

5. Conclusions

Damping of subsynchronous modes of oscillations using PSS and SVC control strategies is investigated and the following observations are made. The PSS with generator speed deviation feed back is found to be ineffective in stabilizing all the unstable modes of oscillation. PSS with modal speed deviation feed back is capable of effectively damping all the unstable torsional modes. Two PSS with modal speed deviation feed back provides better damping to all torsional modes when compared to other cases of PSS.

This study shows that SVC with only voltage control is not sufficient to damp all torsional modes. It is observed that SVC with auxiliary controls provide effective damping to all torsional modes and PID auxiliary control provide better damping compared to P and PD auxiliary controls. SVC with voltage control and auxiliary control of PID type provides very good damping to all torsional modes when compared to other cases of SVC.

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