FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) CONTROLLERS FOR DAMPING POWER SYSTEM OSCILLATIONS

By

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Dedicated

to

My parents Mr. and Mrs. Tambey

and

My parent-in-laws Mr. and Mrs. Jambhrunkar

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ABSTRACT

The thesis deals with the design of FACTS controllers for damping power system oscillations. Investigations have been carried out considering Thyristor Controlled Series Capacitor (TCSC), Static Synchronous Series Compensator (SSSC) and Unified Power Flow Controller (UPFC). The linear dynamic models of the system (known as modified Heffron-Phillips models) with TCSC, SSSC and UPFC have been used. A comprehensive approach for optimizing the FACTS controllers is presented considering conventional techniques (i.e. Gradient type Newton algorithm and Multi-modal decomposition technique) and Genetic and Evolutionary Algorithm (GEA). The dynamic interaction between the power system stabilizers (PSS) and FACTS based damping controller has been investigated.

The effect of variation of apportioning a total specified degree of series compensation to a conventional fixed compensation and TCSC on the optimum parameters of the TCSC based damping controller and system dynamic performance has been investigated in the presence of a PSS. Studies show that whereas optimum gain setting of the damping controller decreases significantly, the time constants remain more or less unaffected with the increase in contribution of TCSC to the total series compensation. However, variations in apportioning of the total series compensation to fixed and TCSC hardly affect the damping of the system oscillations provided the corresponding optimum damping controllers are considered.

A systematic approach for the design of SSSC controllers (i.e. power flow

controller, DC voltage regulator and damping controller) for a single machine infinite bus (SMIB) system has been presented using conventional techniques and GEA. The effect of variation in loading condition on the constants of the system model and hence on the optimum parameters of the SSSC based damping controller and dynamic performance of the system has been investigated. The detailed studies reveal that although the model constants and the optimum parameters of the damping controller vary widely with the variations in loading condition, the dynamic performance of the system with nominal optimum SSSC based damping controller is quite robust to wide variations in loading condition. Investigations reveal that the variation in apportioning of the total series compensation to conventional fixed compensation and SSSC, results into wide variation in model parameters and optimum settings of damping controller. However, the dynamic performance of the system remains more or less unaffected following variations in apportioning of the total compensation to SSSC and conventional fixed capacitor, provided the corresponding optimum damping controllers are considered. Studies show that the dynamic responses of the system obtained with SSSC controllers optimized simultaneously applying GEA are slightly better than those obtained with sequentially optimized SSSC controllers by GEA and conventional techniques.

A comprehensive approach, for optimizing the UPFC controllers (i.e. power flow controller, DC voltage regulator and damping controller) for a SMIB system using conventional optimization techniques has been presented. The power flow and DC voltage regulators are designed by applying Gradient type Newton Algorithm and the damping controllers by applying multi-modal decomposition and phase compensation techniques. Studies reveal that the damping gets adversely affected with the incorporation of DC voltage regulator. Investigations have been carried out to understand the relative effectiveness of modulation of the UPFC control signals (m_B, δ_B, m_E and δ_E) on damping of the system oscillations using a controllability index. Investigations show that the effect of modulation of the control parameter $\Delta\delta_B$ is quite insignificant in damping the oscillations. A novel dual damping controller based on simultaneous modulation of UPFC control signals m_B and δ_E has been proposed.

Investigations reveal that the optimum TCSC, SSSC and UPFC based damping controllers designed using linear models also assist in improving transient stability of the system.

UPFC controllers for a multimachine system have been designed in the presence of PSS. An approach for optimum location of PSS using residue technique has been presented. The optimization of PSS has been carried out using multi-modal decomposition and phase compensation techniques. Studies reveal that the UPFC based damping controllers modulating control parameter m_B is most effective in damping the oscillations. UPFC controllers for a multimachine system have been optimized using conventional optimization techniques and GEA.

The dynamic performance of the system with UPFC controllers optimized sequentially using conventional techniques, has been compared with those obtained applying GEA. The studies reveal that the overall dynamic performance of the system with UPFC controllers optimized simultaneously using GEA is better as compared to that obtained with UPFC controllers optimized sequentially using GEA and by conventional optimization techniques.

Studies are carried out to understand the effect of number of subpopulations and number of individuals on the convergence of GEA. The studies reveal that although the initial convergence rate is somewhat affected by the number of individuals and number of subpopulations, the GEA converges in more or less same number of generations.

Investigations reveal that the PSS and UPFC based damping controller cooperate with each other in enhancing the system damping.

CERTIFICATE

This is to certify that the dissertation entitled, "**FLEXIBLE AC TRANSMISSION SYSTEMS (FACTS) CONTROLLERS FOR DAMPING POWER SYSTEM OSCILLATIONS**" being submitted by **Neelima Tambey** to the Indian Institute of Technology, Delhi for the award of the degree of **Doctor of Philosophy in Electrical Engineering**, is a record of bonafide research work carried out by her. She has worked under my supervision and guidance and has fulfilled the requirement for submission of the thesis. The matter embodied in this thesis has not been submitted elsewhere in part or full for award of any other degree or diploma.

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