DESIGN OF WIDE AREA DAMPING CONTROLLERS IN MODERN POWER SYSTEMS

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DESIGN OF WIDE AREA DAMPING CONTROLLERS IN MODERN POWER SYSTEMS

by

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Dedicated to

My Parents

and

My PhD Supervisor

CERTIFICATE

This is certify that the thesis entitled "**Design of Wide Area Damping Controllers in Modern Power Systems**", being submitted by **Mr. Mahendra Bhadu** for the award of the degree of **Doctor of Philosophy**, is a record of bonafide research work carried out by him in the Department of Electrical Engineering of the Indian Institute of Technology Delhi.

Mr. Mahendra Bhadu has worked under my supervision and guidance and has fulfilled the requirements for the submission of this thesis, which to my knowledge has reached the requisite standard. The matter recorded in this thesis has not been submitted in part or full for the award of any degree or diploma.

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ABSTRACT

In modern geographically distributed power system having meshed network, wide area damping controller(WADC) is an important tool for small signal stability enhancement. Recently proposed various robust control techniques in the domain of wide area control, to damp out inter-area oscillations, make it more interesting and potentially promising. Even though promising results obtained by many researchers in design and implementing the robust WADCs, wide area control system is still in its adolescence due to problems of imperfect communication medium as well as working of controllers in discrete environment. This research is motivated by the objectives of finding solutions to the difficulties in the imperfect communication medium, working of controllers in discrete environments and to reduce the congestion of communication medium in wide area control system. The major contributions of this thesis are as follows:

Firstly, the linear quadratic Gaussian (LQG) control is used to design a WADC in power system. The designed LQG based WADC is robust enough to deal with the problem of imperfect communication medium. The imperfect communication medium includes process noise, measurement noise, packet drop-out and signal latency in the remote control signal. Moreover, the filter based WADCs also have been designed to abate the effect of various noise and time delay. The classical filters- low pass, band pass and band-stop filters along-with the sophisticated filters like Elliptic and Butterworth filters were used in wide area damping control system. **Secondly**, LQG based and POF based discrete mode WADCs have been designed to be used in digital environment. The LQG based WADC is used in fixed sampling rate. However, a WADC must be designed in the discrete domain with specific input data refresh rates as available from the phasor measurement units (PMUs.) The controller output, on the other hand, may be sampled at a different rate so as to obtain maximally enhanced performance. Hence, the concept of periodic output feedback(POF) is used to design and implement a discrete mode WADC with different input and output data sampling rates. Ahead of this, the recommendations of optimal system input sampling time intervals for various PMU data reporting rates, are given. **Thirdly and lastly**, a conceptual design methodology is proposed for event-triggered based communication in wide area control system to mitigate the congestion in communication medium. The remote signal is transmitted to the WADC only when an event-triggering condition based on a predefined system output, is satisfied. The event-triggering mechanism is adopted to

reduce the communication burden between origin of the remote signal and the WADC location, while maintaining the damping objectives.

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LIST OF ABBREVIATIONS

AVR	Automatic Voltage Regulator
FACTS	Flexible AC Transmission Systems
ISS	Input-to-State Stability
LQG	Linear Quadratic Gaussian
PDC	Phasor Data Concentrators
PMU	Phasor Measurement Unit
POF	Periodic Output Feedback
PSS	Power System Stabilizer
PSO	Particle Swarm Optimization
RTDS	Real Time Digital Simulation
WADC	Wide Area Damping Controller
Hz	Hertz
kV	Kilo-Volts