INTERACTIVE EXCITATION AND SPEED GOVERNOR CONTROL OF POWER SYSTEMS

by

TERLOCHAN SINGH BHATTI

A thesis submitted to the
Indian Institute of Technology, Delhi
for the award of the degree of
DOCTOR OF PHILOSOPHY

DEPARTMENT OF ELECTRICAL ENGINEERING

INDIAN INSTITUTE OF TECHNOLOGY, DELHI

NEW DELHI-110 016

INDIA

MAY, 1984

CERTIFICATE

Certified that the thesis entitled "Interactive Excitation and Speed Governor Control of Power Systems", which is being submitted by Mr. T.S.Bhatti, in fulfilment for the award of the Degree of Doctor of Philosophy in Electrical Engineering of the Indian Institute of Technology, Delhi, is a record of student's own work carried out by him under our joint supervision and guidance. The matter embodied in this thesis has not been submitted to any other university or Institute for the award of any other degree or diploma.

Dr. C.S. Indulkar+ Prof.C.S. Jha* Dr.S.C. Tripathy+*

\+ Professor, Department of Electrical Engineering, Indian Institute of Technology,Delhi,New Delhi-110016,INDIA

* Educational Advisor(Tech.), Ministry of Education, Govt. of India, New Delhi-110001, INDIA

+* Professor, Centre of Energy Studies, Indian Institute of Technology, Delhi, New Delhi-110016, INDIA.

ACKNOWLEDGEMENT

I have great pleasure in expressing my deep sense of gratitude to Prof. C.S. Indulkar, Prof. C.S. Jha and Prof. S.C. Tripathy, the thesis supervisors, without whose constant guidance, supervision and encouragement the work would not have been possible. I am whole-heartedly grateful to Prof. C.S. Indulkar who has given freely of his time and talents from the conception of this research work through its completion.

I am very much indebted to Prof. J.Nanda, Dr.S.I.Ahson, Dr. J.K. Chatterjee, Prof. D.P. Kothari, Dr. B.P. Singh and Dr. Y.P. Singh for the useful discussions I have had with them. I am extremely grateful to Prof. K.L. Chopra for providing encouragement and taking keen interest during the last phase of the work.

I am grateful to the Head, Department of Electrical Engineering and to the Head, Centre of Energy Studies, I.I.T., Delhi for providing facilities for carrying out the research work.

I am grateful to the Institute authorities for giving me an opportunity and providing necessary computing facilities to carry out the work. I am thankful to the computer staff for their help in running the computer programs for this work.

Shri B.L. Tuli's care and interest in typing this thesis and Shri Chandra's skill in drawing the figures are greatly appreciated. Finally, I am grateful to my wife, Rajinder Kaur, for her patient support and encouragement throughout the period of this work.

Tarlochan Singh Bhatti

(T. S. Bhatti)

ABSTRACT

In this thesis, results of simulation studies on power systems with interactive automatic generation control and excitation control loops are reported. The parameter of large generators affect the stability margins and in order to enhance these stability margins most large generating units are equipped with power system stabilizers[36,50]. The interaction between the two main control loops prevails due to the incorporation of a frequency deviation stabilizing signal in the excitation control loop through a power system stabilizer. Two types of power system stabilizers have been considered, namely, one with transient gain reduction and the other without transient gain reduction. The effects of load voltage characteristic, power system stabilizer gain, transient gain reduction and generator parameters on the stability of the interactive automatic generation and excitation control system have been investigated.

As random power impacts occur during the normal operation of a power system, the selection of system parameters on the basis of deterministic load changes may result in non-optimum parameter values. Therefore, a stochastic Liapunov technique has been developed to optimize system parameters when the system is subjected to random load

changes. Liapunov equations have been derived for evaluating system performance indices both for continuous and discrete time case.

The area control error (ACE) signal is usually composed of frequency and tie-line power changes only. While considering the interactive automatic generation control and excitation control systems, the ACE is considered to be composed of frequency, tie-line power as well as terminal voltage deviations from their nominal values. The addition of voltage change signal to ACE has been considered for the first time for power systems having frequency deviation as a supplementary stabilizing signal.

The parameters that have been optimized for a two area interconnected power system are the stabilizer gain, transient gain reduction, frequency bias parameter, voltage bias parameter and proportional and integral controller gains. The optimum values of the above parameters have been sought using the Liapunov technique, both for continuous and discrete time cases, as well as for deterministic and stochastic load changes. Responses for frequency, tie-line power, terminal voltage, exciter voltage and speed changer position deviations for the optimum set of parameter values have been shown.

The effect of the governor dead-band on the stability of the interactive automatic generation and excitation control systems has been studied. The investigations have been performed on an interconnected power system of two areas, having hydro and/or thermal generations.

To test the validity of computer simulation results and to develop new power system control strategies, development of p.s. control models with accessories becomes necessary. With this end in view, hardware for monitoring power system variables under steady state and transient conditions using a micro-alternator and micro-computer has been developed.

CONTENTS

Chapter - VIII

CONSIDERATION OF GOVERNOR DEAD-BAND NON-LINEARITY IN THE INTERACTIVE AUTOMATIC GENERATION AND EXCITATION CONTROL LOOPS

Chapter - IX

MICROPROCESSOR MONITORING OF POWER SYSTEM VARIABLES