INFLUENCE OF GENERATING UNITS CONTROL ON POWER SYSTEM STABILITY

THESIS

SUBMITTED TO THE

FACULTY OF ENGINEERING

AIN SHAMS UNIVERSITY

By

Eng. Fahim Ahmed Khalifa

FOR

THE (Ph. D.) DEGREE

in Electrical Engineering

(Power & Machines)

SUPERVISED BY :

Prof. Dr. A. K. EL KHARASHI

Prof. Dr. M. A. L. BADR

1986

EXAMINERS

1. Prof. Dr. G.S. Hope
   Prof. and Head of the Dept.
   of Electrical Engineering
   University of Calgary
   Calgary - Alberta
   Canada.

2. Prof.Dr. Ahmed M. El Arabaty
   Prof. and Head of Electrical
   Power & Machines Dept.
   Faculty of Engineering
   Ain Shams University
   Cairo - Egypt.

3. Prof.Dr. Ali K. El-Kharashi (Supervisor)
   Electrical Power & Machines Dept.
   Faculty of Engineering
   Ain Shams University
   Cairo - Egypt.

4. Prof.Dr. M.A.L. Badr (Supervisor)
   Electrical Power & Machines Dept.
   Faculty of Engineering
   Ain Shams University
   Cairo - Egypt.

بسم الله الرحمن الرحيم

ACKNOWLEDGEMENT

The author wishes to express his deep gratitude to Prof. DR. Mohamed Abdellatif Badr for suggesting the topic of this research and for continuous guidance and encouragement throughout the work. His ideas of combining a PID controller with adaptive techniques and his suggestions during the development of control algorithm have enhanced the work to attain this standard.

The author also wishes to express his thanks to Prof. Dr. Ali Kamel El-Kharashi for his supervision and steadily follow up.

The author thanks his wife and sons for the good family atmosphere which helped in completing this research.

ABSTRACT

The thesis presents a study of the control and stability of a synchronous generator connected to an infinite bus through two parallel lines and a local load representing the interconnection of a large power system. The study includes the application of different techniques of automatic voltage regulators and speed governing systems for synchronous machines. The development of digital equipment has made it possible to apply efficient techniques of digital controllers as automatic voltage regulators or as speed governors for the synchronous machines.

The proportional-plus-integral-plus derivative (PID) digital automatic voltage regulator(DAVR) presents an effective means for improving the transient and dynamic performances of the synchronous machine when equipped with this kind of DAVR. The main feedback signal for such a DAVR which controls the excitation voltage is the terminal voltage of the synchronous generator. This terminal voltage is sampled and introduced to the DAVR at constant intervals. The DAVR receives this signal , converts it into digital,computes a control signal by means of a programmed algorithm,converts the control signal into a voltage and delivers it to the excitation system.

In addition, other stabilizing signals proportional to the derivative of power angle, output power,power angle and armature current were used. A weighting factor is assigned for each one of these

signals and the input signal to the controller is the weighted sum of different combinations of these signals.

Different control strategies are considered in this study . These are (1) keeping weighting coefficients constant or (2) dynamically changing them according to the variances of their respective signals.

One of the problems in the application of PID-DAVR is the tuning of this kind of regulators i.e the best selection of their parameters (controller gain, integral time, derivative time). The modern trends in computer technology is to use adaptive control system as AVRs or governors. One of these controllers is the self-tuning regulator. In this case the parameters of the regulator are not held constant but are computed and updated every sampling instant.

In the current study these types of AVR's and speed governors are examined. The study is performed using the facilities of a high-speed digital computer. A power system has been chosen and the mathematical model which represents it was derived .The model consists of a set of first order differential equations written in the state-space form. The equations of the digital controllers are derived in the form of difference equations. The combined mathematical model has been solved on the computer.

An interactive computer program for the simulation of this system was designed and written for the computer. It performs the modeling of the system and it is capable of handing nine different transient and dynamic types of variations on the power system.

The transient and dynamic operation of the power system when the machine was equipped with (a) constant parameters, constant weighting coefficients DAVR (b) constant parameters, dynamically changing weighting coefficients DAVR and (c) self tuning regulators are examined.

Also the dynamic performance of the machine has been checked when the turbine was governed by a PID digital controller. The transient and dynamic response of the machine under different initial loading and types of variations are computed.

Results are compared to both theoritical and experimental results already published in literature sources.

CONTENTS

LIST OF SYMBOLS

H	Inertia constant
I, i	Current
I_{RF}	Reference current
$\dot{i}$	First derivative of current
i_{KD}, i_{KQ}	Damper winding d and q-axis currents respectively
i_F	Field current
i_{de1}, i_{de2}	Current d-axis component in transmission line No.1,2 respectively
i_{dL}, i_{qL}	d and q-axis currents in local load respectively
i_{qe1}, i_{qe2}	Current q-axis component in transmission line No.1,2 respectively.
K	Gain of real PID regulator algorithm for speed governor
K_A	Amplifier gain of the exciter
K_C	Gain of the speed control system of speed governor
K_F	Gain of exciter stabilizing circuit
K_P	Gain of the ideal PID regulator algorithm
K_S	Magnetic saturation coefficient
K_1	Gain of real PID regulator algorithm for AVR
L	Inductance
l	Leakage inductance
L_{KD}, L_{KQ}	Damper winding d and q-axis inductances respectively
L_F	Field winding inductance
L_d, L_q	Synchronous machine d and q-axis inductances respectively.
l_p	Potier inductance
P	Output power
P_{RF}	Reference output power
r	Resistance
r_{KD}, r_{KQ}	Damper winding d and q-axis resistances respectively.
r_F	Field winding resistance

S	Laplace transform operator
s	Second
T	Transient period
t	Time
T_A	Amplifier time constant of the exciter
T_C	Time constant of the speed control system of speed governor
T_D	Derivative time of the ideal PID regulator algorithm
T_F	Time constant of exciter stabilizing circuit
T_G	Integral time of the real PID regulator algorithm for speed governor
T_I	Integral time of the ideal PID regulator algorithm
T_S	Time constant of steam system of the speed governor
T_{SM}	Sampling period
T_{D1}	Derivative time of the real PID regulator algorithm for speed governor.
T_m	Mechanical torque
T_1	Integral time of the PID regulator algorithm for AVR
T_2	Derivative time of the PID regulator algorithm for AVR.
V, v	Voltage
V_{RF}	Reference voltage
δ	Power angle
δ_{RF}	Reference power angle
ψ	Flux linkage
γ	Rate amplitude constant
w	Rotor speed
w_{RF}	Reference rotor speed

CHAPTER 1

INTRODUCTION

1.1 GENERAL

The continuous growth of large interconnected power networks and the requirements of system reliability have made the problem of stability investigation of ever increasing importance. Electrical engineers, being interested in finding ways for improving system stability are obliged to develop and employ better techniques for power system control.

The power system stability may be defined as that property of the network which enables the synchronous machines of the system to respond to a disturbance from a normal operating condition so as to return to a condition at which their operation is again normal. Stability studies are primarily concerned with variations in speeds and rotor positions. They focus attention on the transmission network, since it is concerned more than the power plant or system controls, with the power transfer between generators required to maintain synchronism. Stability studies are well reported in many technical sources [1-7] . These stability studies are traditionally classified into three types depending upon the nature and order of mag-