ON SOME ASPECTS OF AUTOMATIC GENERATION CONTROL OF INTERCONNECTED POWER SYSTEMS

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CERTIFICATE

Certified that the dissertation entitled "ON SOME ASPECTS OF AUTOMATIC GENERATION CONTROL OF INTERCONNECTED POWER SYSTEMS" which is being submitted by Shri G.G. BHISE for the award of **Doctor of Philosophy in Electrical Engineering** of the Indian Institute of Technology, Delhi is a record of the students' own work carried out by him under our joint supervision and guidance at the Indian Institute of Technology, Delhi. The matter embodied in this dissertation has not been submitted elsewhere for the award of any other degree.

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ABSTRACT

This thesis deals with some aspects of Automatic Generation control (AGC) of interconnected thermal and hydrothermal systems considering alternative AGC strategies based on conventional Area Control Error (ACE), New Area Control Error (ACEN) and Modified Area Control Error (ACEM).

Continuous and discrete-continuous time dynamic models of the system considering generation rate constraints (GRCs) have been developed.

A comprehensive approach for optimizing the parameters of the supplementary controllers for a two area reheat thermal system with AGC strategy based on conventional ACE using ISE technique considering two alternative performance indices i.e. conventional performance index based on area control errors and new performance index based on area control errors, the time error and inadvertent interchange has been presented. Investigations reveal that the optimum integral gain settings based on the new performance index provide better dynamic performance and reduced steadystate time error and inadvertent interchange accumulations, thus requiring less frequent offsetting of scheduled frequency and net interchange for correcting these errors.

Studies pertaining to variation of GRC show that the optimum integral gain setting increases and system dynamic performance improves as the permissible generation rate increases. For a generation rate of 12% per min. the optimum integral gain setting is close to that obtained neglecting GRC. Moreover, optimum integral gain setting obtained for GRC=3% per min. is more or less acceptable for

GRC > 3% per min. However, for GRC < 3% per min, optimum gain setting needs to be evaluated considering the actual value of GRC.

Investigations dealing with variation of frequency bias B show that optimum integral gain K_I decreases with increase in B and the dynamic performance of the system both under normal and abnormal operating conditions is not much affected with increase in B provided optimum K_I computed for the given value of B is chosen. However, both under normal and abnormal conditions the steady state value of time error (ϵ) decreases while inadvertent interchange (I) increases with increase in B. Investigations further reveal that K_I obtained for $B = \beta_{max}$ provides acceptable dynamic performance following wide variation in system β i.e. $\beta_{min} = \beta$ to $\beta_{max} = 4\beta$.

Optimum integral gain (K_I^*) and inadvertent interchange bias α^* for a two area reheat thermal system with AGC based on new area control error (ACEN) using ISE technique have been obtained. The effect of variation of B on K_I^*, α^* and dynamic performance, both under normal and abnormal operating conditions has been studied. Investigations reveal that the dynamic performance under normal operating condition is not much affected with increase in B provided K_I^* and α^* computed for the given B are considered. For all practical purposes α^* obtained for $B = \beta$ may be used even if B varies over a wide range.

Further studies pertaining to a two area reheat thermal system are carried out in discrete-continuous mode considering GRC with AGC based on ACE and ACEN. The optimum parameters of the supplementary controllers of the system are obtained using ISE technique based on new performance index. The effect of variation of sampling period T on optimum controller parameters and system dynamic performance has been examined. Investigations reveal that sampler and Zero Order Hold (ZOH) may conveniently be divorced from the dynamic model since there is hardly any change in dynamic performance both for AGC based on ACE and ACEN over a wide range of sampling period T. Moreover, for a two area thermal system T=8 seconds may be chosen as it provides the best overall dynamic performance.

A detailed sensitivity analysis reveals that the optimum nominal integral gain setting K_I^* is quite robust and need not be reset following a change of ± 25% in $R, T_t, T_r, K_r, P_D^\circ$ and 25% decrease in H. However, K_I^* is some-what sensitive to 25% increase in H, and it is desirable to reset K_I^* following 25% increase in H.

A new AGC strategy based on Modified Area Control Error (ACEM) for a two area reheat thermal system has been proposed. ACEM is the weighted sum of frequency deviation, tie power deviation and inadvertent interchange. Investigations reveal that the dynamic performance of the system with AGC based on ACEM is comparable to that based on ACEN and hence AGC based on ACEM may be used by utilities for simultaneously regulating ACEs and inadvertent interchange accumulations, since the realization of AGC based on ACEM is relatively simpler to that based on ACEN. Moreover, T=8 seconds provides the best overall dynamic performance with AGC based on ACEM like that for AGC based on conventional ACE and ACEN. Studies also show that the K_I^* and α^* obtained using continuous time dynamic model work well for the actual discrete-continuous time model.

Investigations dealing with the variation of B with AGC based on ACEM reveal that under normal operating condition the dynamic responses for ΔF_1 and ϵ_1

are hardly affected with increase in B, while the dynamic responses for ΔP_{tie1} and I_1 require increased settling time as B is increased. Moreover, under abnormal operating conditions, the assistance to the deficient area increases with increase in B like that with AGC based on ACE and ACEN.

A comprehensive approach for optimum selection of hydrogovernor parameters (permanent droop σ and temporary droop δ) for AGC of a hydro thermal system has been presented. Studies show that optimum hydrogovernor parameters obtained based on maximum degree of stability considering uncontrolled and unconstrained mode of operation are not acceptable in the actual constrained mode of operation. However, the optimum value of hydrogovernor parameters obtained considering uncontrolled and constrained mode of operation are found to remain optimum even in the controlled and constrained mode of operation. Moreover, the optimum value of temporary droop δ = 1.0 and integral gains obtained for a typical low value of R = 2.4 Hz/pu MW also provide a dynamic performance comparable to that obtained with overall optimum hydrogovernor parameters and integral gains.

Investigations reveal that the optimum integral gains for continuous time dynamic model work satisfactorily in actual discrete-continuous mode operation of the system without hardly affecting dynamic performance over a wide range of sampling period. The degradation in dynamic performance of the system with wide variation in T (T = 2 to 10 secs) is insignificant, and hence a large value of T may be chosen by utilities as this would result in reduced loading of communication channels.

A detailed sensitivity analysis reveal that optimum integral controller settings obtained for nominal condition are quite robust to ±25% change in R_1, H_1, T_t, K_r, $P_{Di}°$ of the thermal area and R_2, T_w, T_R, $P_{D2}°$ of the hydro area and also to ±25 change in δ_{12}. The optimum integral gain settings are quite robust to 25% increase in H_2 while a decrease in H_2 by 25% makes the system unstable.

For a hydrothermal system with AGC based on ACEN an iterative approach for obtaining optimum K_{Is} and α_s is proposed. Further studies reveal that for a hydrothermal system, in the presence of GRCs, the optimum K_{Is} and α_s obtained in continuous mode AGC are not acceptable in the realistic discrete-continuous mode AGC for credible values of T, unlike that with the AGC based on conventional ACE. Hence optimum K_{Is} and α_s have to be obtained for the given value of T using discrete-continuous time model. Moreover, investigations reveal that the degradation in dynamic performance of the system with increase in T is not very significant over a wide range of T provided K_{Is}^* and α^* are obtained for a given T are chosen. Thus, even with AGC based on ACEN of a hydrothermal system a large value of T may be chosen without sacrificing the quality of the dynamic performance. Studies also show that with increase in B, the dynamic responses for frequency deviations and time error are hardly affected while the responses for tie power deviation and inadvertent interchange deteriorate similar to that observed for a two area thermal system.

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