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Title of thesis: **AUTOMATIC GENERATION CONTROL OF MULTI AREA POWER SYSTEMS WITH HYBRID POWER GENERATION SOURCES**

ABSTRACT

The automatic generation control problem (AGC) problem of large interconnected power systems have been studied by considering the whole power system as a group of control areas. A control area may be described as a power system, a part of a system or a combination of systems to which a common generation control scheme may be assigned the duty of the system control. All the generators in a control area operate coherently or swing in unison and are characterized by a single frequency. In normal steady-state operation each control area of a power system should strive to meet its own load demand. Simultaneously each control area of a power system should participate in regulating the frequency of the system as a whole.

The electrical equipments from household devices to prime movers, is interconnected to a synchronous grid and is designed to operate at nominal frequency. Small deviations from nominal frequency i.e. in the range of mHz are normal due to continuous variations in loads but not affect the dynamic behaviour of power system as a whole. In the power system, frequency deviations are mainly due to real power mismatch between generation and load, this mismatch can be mitigated by controlling the generation through the scheme called automatic generation control. In interconnected power systems, the main objectives of AGC are to maintain the desired power output, nominal frequency and the net interchange of power between control areas at predetermined values.

In recent years, intelligent techniques based on artificial neural networks, fuzzy logic, multi-agent systems, genetic algorithm (GA), simulated annealing, particle swarm optimization, ant colony optimization; honey bee colony optimization and hybrid intelligent techniques have been applied to power system control problems replacing effectively the control scheme based on conventional and modern control theory. GA is one of the most popular and widely used algorithms among artificial intelligent algorithms. GA has been widely applied to solve complex non-linear optimization problems. However, the applications of GA in systems with highly epistatic objective functions (i.e. where parameters being optimized are highly correlated) have resulted in premature convergence which degrades GA performance and reduces its search capability.

The problems associated has been eliminated to a great extent by a new evolutionary computation technique, called bacterial foraging algorithm (BFA). It has been developed in recent years by modelling- behaviour of E. Coli bacteria which is present in human intestines. It has unique feature of eliminate the premature convergence problem and enhance the search capability and therefore, it is found suitable optimization tool for designing the AGC regulators for power systems. Therefore, in this research work BFA tuning technique is applied for tuning of gains of AGC regulators.

In the majority of the previous research work, a heap of articles have been appeared regarding the investigations of AGC of interconnected power systems. In these literatures AGC studies have been carried out in interconnected power system by considering single source of power generation in a control area. But in a practical situation a control area comprises a mix of thermal, hydro, gas and non-conventional sources of power generation. A control area having conventional sources i.e. hydro,

thermal, gas etc. based generating station called diverse sources power plants. However a control area having conventional and un-conventional sources based generating station called hybrid sources power plants. In the literature rarely studies are carried out by considering diverse/hybrid sources of power generation in the control area.

Keeping in foregoing discussion, a study has been carried out for AGC of two-area interconnected power system with diverse/hybrid sources of power generation in each area. The present research work provides an essence of AGC strategies in interconnected power systems, literature review, mathematical modelling of diverse/hybrid source power system, design and implementation of optimal AGC regulators using various intelligent techniques. The investigations to design and implementation of two area power system interconnected by AC/DC links with diverse sources in each area are also carried out.

To carry out the investigations, optimal AGC regulators are designed using optimal control theory for two area interconnected power systems in this research work. It has been observed that for most of the system states the real parts of closed-loop eigenvalues are more negative as compared to that of open-loop eigenvalues. Therefore, the closed-loop system is highly stable and the exponential decay of system response is fast. Similarly the imaginary part of the eigenvalues gets reduced resulting in less oscillation along with the fast exponential decay. It is seen from the transient responses with optimal AGC regulator, the transient responses of ΔF_1, ΔF_2 and $\Delta Ptie_{12}$ have improved significantly as compared to those obtained with conventional regulators.

The study carried out in this work, incorporates the design of PID structure AGC regulators using optimization algorithm based on modelling-behaviour of E. Coli bacteria present in human intestines. From the results obtained, it has been observed that the performance index value for BFA tuned AGC regulators is less than GA tuned AGC regulators. Also the superiority of BFA tuned AGC regulators over GA based AGC regulators is demonstrated in the study. In majority of the previous research studies reported the gains of AGC regulators have been designed by creating load disturbance in one of the control areas. However, these AGC regulators are feasible only for particular set of contribution of generation from various power plants participating in the control area. Therefore, this thesis investigates feasibility of designs and other performance under variation in generation based AGC regulators rather than load disturbance.

This thesis has also demonstrate how transient performance of power system is influenced by hydro, thermal, and gas power plants participating for AGC based on type of power generation sources. The significantly improvement in transient performance of power system has been observed when thermal and gas power plants participating in the AGC while transient performance of system has degraded while hydro power plants are participating only in the AGC. The observation from dynamic performance of generation based AGC regulators have revealed that an increase in thermal and gas generation has resulted in improved dynamic performance but the dynamic performance is degraded with similar variation in hydro generation.

The dynamic performance of PID structured AGC regulator is better than PI controller however, PID controller as an AGC regulator is not popular to use this structure amplifies the measurement noise, causing a noisier control signal due to presence of D-term in PID controller. To overcome this drawback fractional-order PID structured AGC regulators are designed and implemented for power system model under investigation. The results are obtained using BFA optimization technique considering load and wind disturbance in one of the control area. The investigation of responses has revealed that fractional-order AGC regulators are capable to offer significantly improved dynamic performance of system as compared to PI structured based AGC regulators.

This work also presents a comprehensive study on dynamic performance of a more realistic power system with diverse sources in each area and interconnected via parallel AC/DC links. Optimal AGC regulators are designed for minimum performance index criterion with state vector feedback control strategy. From the results obtained in the study, it is observed that the use of parallel AC/DC links as area interconnection in the system dynamic model has improves the stability margins and system dynamic performance.