RECENT PHILOSOPHIES OF AGC OF A HYDRO-THERMAL SYSTEM IN DEREGULATED ENVIRONMENT

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ABSTRACT

In restructured power system, engineering aspects of planning and operation have to be reformulated although essentials ideas remain same. With emergency of distinct identities of GENCO's, TRANSCO's, DISCO's, and the ISO's many of the ancillary services of the vertically integrated utility will have a different role to play and hence have to be modified differently. Among these, ancillary services are, "the automatic generation control (AGC)".An attempt is made in this paper to present critical literature review and an up-to-date and exhaustive bibliography on the AGC of a hydro thermal system in deregulated environment. Various control aspects concerning the AGC problem have been highlighted.

KEYWORDS: *Automatic generation control, Hydro-Thermal system, Deregulation.*

I. INTRODUCTION

In modern power system network there are number of generating utilities interconnected together through tie-lines. In order to achieve integrated operation of a power system, an electric energy system must be maintained at a desired operating level characterized by nominal frequency, voltage profile and load flow configuration.

Modern power system normally consists of a number of subsystems interconnected through tie lines. For each subsystem the requirements usually include matching system generation to system load and regulating system frequency [5]. This is basically known as load-frequency control problem or automatic generation control (AGC) problem. It is desirable to achieve a better frequency constancy than is obtained by speed governing system alone. In an interconnected power system, it is also desirable to maintain the tie line flow at a given level irrespective of the load change in any area. To accomplish this, it becomes necessary to manipulate the operation of main steam valves or hydro gates in accordance with a suitable control strategy, which in turn controls the real power output of the generators. The control of the real power output of electric generators in this way is termed as "Automatic Generation Control (AGC)".This paper discuss the critical literature review of AGC schemes of hydro thermal system in deregulated environment.

II. AUTOMATIC GENERATION CONTROL

Power system loads are sensitive to frequency and following system frequency changes the aggregate load change follows deviation. When a generating unit is tripped or additional load is added to the system, the power mismatch is initially compressed by an extraction of the kinetic energy from the system inertial storage that causes a system frequency drop. [19]

As the frequency decreases, the power consumed by loads also decreases. Equilibrium for large system can be obtained when the frequency sensitive reduction of loads balances the power output of tripped unit or that delivered to the additional load resulting in new frequency. This effect could stop the frequency decline in less than a couple of seconds. However, if the mismatch causes the frequency to deviate beyond the governor dead band of the generating units their outputs will be increased by the governor action. For such mismatches equilibrium is obtained when reduction in power consumed by the loads plus the increased generation due to governer action compensate the mismatch. Such equilibrium is normally obtained with a dozen seconds of the frequency incident. Governor droop is the percentage change in frequency that would cause unit generation to change buy 100% of its capability. Typically speed droops for active generators are in the range of about 4%. With this level of frequency sensitivity and at the expense of some frequency deviation, generation adjust by governors provide ample opportunity for follow up manual control of units.

This automatic adjustment of generation by free governor action is known as primary frequency regulation. The objectives of the follow up control especially under normal changes of load are to return frequency to, schedule, to minimize production cost, and to operate the system at an adequate level of security.

Automatic generation control is a closed loop control system that particularly replaces this manual control. This form of generation control has become essential to the real time operation and control of interconnected power systems and operates in widely varying power system control environments ranging from autonomous to strongly interconnected systems with hierarchy multi- level control.

The purpose of AGC is to replace portions of the manual control.

As it automatically responds to normal load changes, AGC reduces the response time to a minute or more or less. Mainly due to delays associated with physically limited response rates of energy conversion, further reduction in the response of AGC is neither possible nor desired.

Neither follow up manual control nor AGC is able or expected to play any role in limiting the magnitude of their just frequency swing, which occurs within seconds after the loss of a block generation or load in the systems. For conditions where change of generation due to governor action and change of load due to its sensitivity to frequency are not enough to intercept the runaway frequency. Over and under frequency relay are among the last resorts for shedding loads to prevent system collapse or tripping generating units to prevent their damage.

The main aims behind the design of AGC are:

a) The steady state frequency error following a step load perturbation should be zero.
b) The steady state change in the tie flow following a step load change in an area must be zero.
c) An automatic generation controller providing a slow monotonic type of generation responses should be preferred in order to reduce wear and tear of the equipment.

The objectives of AGC may, therefore be summarized as follows:

1. Each area regulates its own load fluctuations.
2. Each area assists the other areas, which cannot control their own load fluctuations.
3. Each area contributes to the control of the system frequency, so that the Operating costs are minimized.
4. The deviations in frequency and tie line power flow error to zero in the steady state.
5. When load changes are small, the system must be permitted to come back to the steady state (by natural damping) so that the mechanical power does not change small disturbances for economic reasons.

The problem of AGC can be subdivided into fast primary control and slow secondary control modes. The fast primary control (governing mechanism) mode tries to minimize the frequency deviations and has a time constant of the order of seconds. But, primary control does not guarantee the zero steady state error. The slow secondary control channel (supplementary control), with time constants of the order of minutes, regulates the generation to satisfy certain loading requirements and contractual tie-line loading agreements. The overall performance of the AGC in any power system depends on the proper design of both primary and secondary control loops.

The traditional power system industry has a “vertically integrated utility” (VIU) [9],[10],[14],[15],[32] structure and treated as a single utility company which monopolies generation, transmission and distribution in a certain geographic region. Interconnection between networks and interaction between companies is usually voluntary to improve system reliability and performance. In the restructured or deregulated environment, vertically integrated utilities no longer exist. The first step in deregulation has been to separate the generation of power from the transmission and distribution, thus putting all the generation on the same footing as independent power producers (IPPs). So in the new scenario the utilities no longer own generation, transmission, and distribution; instead, there are three different entities, *viz.*, GENCOs (generation companies), TRANSCOs (transmission companies) and DISCOs (distribution companies)

III. DEREGULATION

Analysis of the electrical industry beings with the reorganization of three components; Generation, Transmission and Distribution.

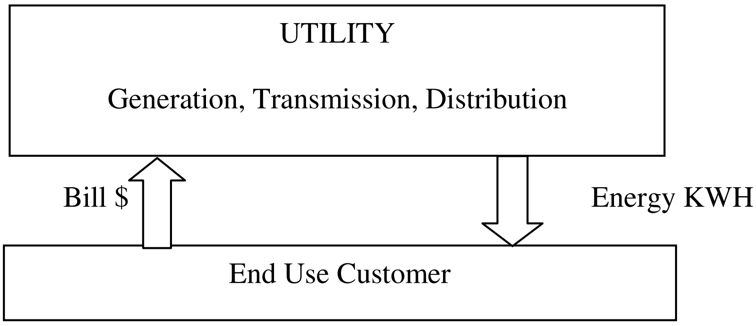

Fig.1 Schematic Diagram of Power System

Once electricity is generated,[3],[7] whether by burning fossil fuels, harnessing wind, solar or hydro energy, or through nuclear fission it is sent through high voltage, high capacity transmission lines to the local regions in which the electricity will be consumed. When electricity arrives in the region in which it is to be consumed, it is transformed to a lower voltage and sent through local distribution wires to end-use consumers. In general, all three of these vertically related sectors have typically been tied together within a utility, which has been either investor-owned or state de-regulated or owned by the municipality. For many years each sector was thought of is a natural monopoly.

Electric deregulation also known as electric restructuring, is the process by which the traditional monopoly structure for generating and delivering power to retail consumer is opened to competition by legislative or regulatory initiative. Addressed at the state level, electricity deregulation in its early stages and already beginning to benefits for consumers, the economy and future reliability of energy sources.

In the transmission and distribution sectors, effective competition would require that rival firms duplicate one another's wire network, which would be inefficient. If wires owned by different companies were allowed to interconnect to form a single network, the flow on one line affects the capacity of other lines in the system to carry power. The commodity that is opened to competition is called electricity generation or supply. Competitive suppliers offer it for sale. Customer can choose their competitive supplier. A customer's electricity bill will show a generation charge that represents the fee for the use of certain amount of electricity. Other elements the bills include amounts owned to the utility (now known as Distribution Company) for delivering the power to consumers through poles and wires. This delivery function is not being to competition.

Deregulation presents a chance to do better job at keeping cost down and making sure consumers have the kind of choice that best suits their needs. Historical deregulation or restructuring has the potential to produce gains in three broad sectors of the electricity utility industry operations, investment and consumption.

Concordia and Kirchmayer [1]-[3] have analyzed the AGC problem of two equal area thermal, hydro and hydro-thermal systems. They have studied the AGC of a hydro-thermal system considering non-reheat turbine and mechanical governor in hydro system, neglecting generation rate constraints. Their conclusion from simulation studies show that for minimum interaction between control areas frequency bias (B) must be set equal to area frequency response characteristics β. Although they have extensively studied the effect of variation of several parameters on dynamic performance of the system, no explicit method has been suggested by them for the optimization of controllers. Concordia [3] has given the basic concepts of load-frequency control of an interconnected power system. He has discussed the effect of frequency bias and governor turbine model of a thermal system.

Cohn [7]-[8] has discussed mainly regarding the selection of frequency bias setting for large multi-area power system. His investigations reveal that for minimum interaction between control areas ideally the frequency bias setting (B) of a control area should match the combined generation and load frequency response i.e. area frequency response characteristics (β) of the area. However, Cohn has not addressed to the problem of optimum gain setting and structures of the supplementary controllers form the point of view of dynamic behavior of the system.

Nanda and Kaul [9],[10]have extensively studied the AGC problem of a two area reheat thermal system, using both parameter plane and ISE techniques for optimization of integral gain setting and for investigating the degree of stability of the system. They have studied the effect of GRC, area capacity effect, speed regulation parameter on optimum controller setting and system dynamic responses. The effect of variation of significant parameters on optimum controller setting and cost function has been brought out through sensitivity analysis neglecting GRC. However, they have not addressed to the problem pertaining to correction of time error and inadvertent interchange accumulations.

IEEE committee report on "Power Plant Responses" [13] shows that in practice GRC for reheat thermal system varies between 2.5% to 12% per minute and the permissible rate of generation for hydro plant is relatively much higher (a typical value of generation rate constraints (GRC) being 270% per minute for raising generation and 360% per minute for lowering generation), as compared to that for reheat type thermal units having GRC of the order of 3% per minute. Ref. [13] provides the transfer function model for steam and hydro turbines for AGC.

Nanda [14], [15] ,[32] have investigated the AGC problem of an interconnected hydro-thermal system in both continuous and discrete mode, with and without GRC. They are possibly the first to consider GRC to investigate the AGC problem of a hydro-thermal system with conventional integral controllers. They have found out the optimum integral controller settings and their sensitivity to GRC, speed regulation parameter 'R', base load condition etc. They have also studied the AGC problem of hydro thermal system, considering GRC where their main contribution is to explore the best value of speed regulation parameter. They have considered mechanical governor for hydro turbine.

V. Donde and M A..Pai, I.A. Hiskens [5] present AGC of a two area non reheat thermal system in deregulated power system. The concept of DISCO participation matrix (DPM) and area participation factor (APF) to represent bilateral contracts are introduced. However, they have not dealt with reheat turbine, GRC and hydro-thermal system in their work.

Bekhouche [25] has compared load frequency control before and after deregulation. Before deregulation ancillary services, including AGC are provided by a single utility company called a control area that owns both transmission and generation systems. After deregulation, the power system structure has changed allowing specialized companies for generation, transmission, distribution and independent system operator.

Richard D. Christie and Anjan Bose [20] have dealt with LFC (Load Frequency Control) issues in deregulated power system. It identifies the technical issues associated with load frequency control and also identifies technical solutions such as standards and algorithms, needed for the operation in this new restructured power system.

Meliopoulos, Cokkinides and Bakirtzis[23] have given the concept that in a deregulated environment, independent generators and utility generators may or may not participate in the load frequency control of the system. For the purpose of evaluating the performance of such a system, a flexible method has been developed and implemented They proposed a method in which they assumed that load frequency control is performed by ISO (Independent System Operator) based on parameters defined by participating generating units. The participating units comprise utility generators and independent power producers. The utilities define the units which will be under load-frequency control, while the independent power producers may or may not participate in the load frequency control. For all the units which participate in the load-frequency control, the generator owner defines (a) generation limits, (b) rate of change and (c) economic participation factor. This information is transmitted to the ISO. This scheme allows the utilities to economically dispatch their own system, while at the same time permit the ISO to control the interconnected system operation. In the paper it has been shown that if the percentage of units participating in this control action is very small, system performance deteriorates to a point that is unacceptable. It is therefore recommended that minimum requirements be established, based on system.

J. Kumar, Kah-Hoe Ng and G. Sheble[21][22] have presented AGC simulator model for price based operation in a deregulated power system. They have suggested the modifications required in the conventional AGC to study the load following in price based market operations. A framework for price-based operation is developed to assist in understanding AGC operation in the new business environment. The modified AGC scheme includes the contract data and measurements, which are continuous, regular and quiescent and hence, greatly improves control signals to unit dispatch and controllers. The proposed simulator **is** generic enough to simulate all possible types of load following contracts (bilateral and poolco). The proposed scheme includes ACE as a part of control error signal and thus, also satisfies the NERC performance criteria. The new framework requires establishment of standards for the electronic communication of contract data as well as measurements. They have highlighted salient differences between the automatic generation control in a vertical integrated electric industry (conventional scenario) and a horizontal integrated electric industry (restructured scenario).However; they have not addressed the aspects pertaining to reheat turbine, GRC and hydro-thermal system.

Donde, Pai and Hiskens [24] present AGC of a two area non-reheat thermal system in deregulated power system. In a restructured power system, the engineering aspects of planning and operation have to be reformulated although essential ideas remain the same. With the emergence of the distinct identities of GENCOs, TRANSCOs, DISCOs, many of the ancillary services of a vertically integrated utility will have a different role to play and hence have to be modeled differently. Among these ancillary services is the automatic generation control (AGC). In the new scenario, a DISCO can contract individually with a GENCO for power and these transactions are done under the supervision of the ISO or the RTO. In this paper, the two area dynamic model is formulated. Specifically it had focused on the dynamics, trajectory sensitivities and parameter optimization. The concept of a DISCO participation matrix (DPM) is proposed which helps the visualization and implementation of the contracts. The information flow of the contracts is superimposed on the traditional AGC system and the simulations revealed some interesting patterns. The trajectory sensitivities are helpful in studying the effects of parameters as well as in optimization of the ACE parameters *viz.* tie line bias and frequency bias parameter. The concept of DISCO participation matrix (DPM) and area participation factor (APF) to represent bilateral contracts are introduced.

IV. CONCLUSION

Literature survey shows that most of the earlier work in the area of automatic generation control in deregulated power system pertains to interconnected thermal system and no attention has been devoted to hydro-thermal systems involving thermal and hydro subsystems of widely different characteristics. The paper presents a critical review of AGC of hydro thermal system in deregulated environment. It has paid particular attention to categorize various AGC strategies in the literature that highlights its salient features. The authors have made a sincere attempt to present the most comprehensive set of references for AGC. It is anticipated that this document will serve as a valuable resource for any worker of the future in this important area of research.

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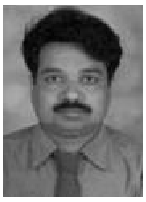

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