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An Overview Of Load Frequency Control Strategies: A Literature Survey

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***Abstract*- The job of automatic frequency regulation is achieved by governing systems of individual turbine-generators and Automatic Generation Control (AGC) or Load frequency control(LFC) system of the power systemThis paper addresses a comprehensive literature survey on load frequency control in power systems. The article is aimed to present the various control and structural schemes of LFC present in the power systems. The LFC schemes on different aspects like classical control based LFC schemes ,LFC schemes based on modern control concepts are discussed .Due to the rising penetration of the renewable energy sources LFC on RESs also discussed to an extent.**

***Keywords*-classical control based LFC schemes, high penetration of RESs,Load Frequency Control (LFC), modern control concepts, Intelligent control techniques,**

I INTRODUCTION

To maintain power system frequency to a specified value at power generating equipment and the utilization equipment at the customer end, efficient LFC schemes are required. The job of automatic frequency regulation is achieved by governing systems of individual turbine-generators and Automatic Generation Control (AGC) or Load frequency control(LFC) system of the power system. Along with this the main objective of power system operation and control is to maintain power balance .In AC form transmission there is real power and reactive power components, so have to balance these two components also. There are two schemes for controlling all the problems above, called the automatic voltage regulator (AVR) and Automatic Load Frequency Control (ALFC) or Automatic Generation Control (AGC).

The Automatic Generation Control (AGC)Automatic load frequency Control usually consist of Load frequency control, Economic Dispatch and interchange schneduling .Here discussion is about Load Frequency Control (LFC). The concept of speed/ frequency variation can be extended from a single turbine- generator system to a large powersystem by considering several turbine- generators. The imbalance between the total power generated and the total electrical load causes the frequency change as per the combined system inertia. The speed governors of all the machines sense the mechanical outputs and the frequency will be changed automatically to match with combined generation of new combined load. This action is called primary frequency regulation. But frequency set points must be adjusted, as in single machine's frequency restoration. This process is done by the Automatic Load Frequency controller (ALFC).This method of set point adjustment is called secondary frequency regulation.

There is no automatic load frequency control in many regions because supply providers would not like to adjust their generation levels by ALFC in order to raise their generation level to maximum extent. . In many cases, generators are not allowed to participate in primary frequency regulation also disables natural ability of generators to raise/lower the level of generation during variation in frequency. So the frequency is always will be less than the rated value. When sudden disturbances occur, system collapses causing blackouts.

The power system in India is divided into different regions. By the interaction with State Dispatching Centre and the generating station under the each the state, the Load Dispatch Centre will monitor and governor the frequency variation. The Regional Load Dispatch Centers (RLDC) function under Power Grid Corporation of India. Then, for the purpose of frequency regulation each region can be considered as a coherent unit. For instance Southern RLDC comprises AP, TN, Karnataka, Kerala and Goa, SRLDC is located in Bangalore. For the load frequency control, at Hydro power plant generating units are normally adjusted as the response is faster to raise/lower the power. Thermal power plants have rate restrictions due to thermal stresses even though all units are expected to participate in primary frequency regulation.

When frequency changes, primary frequency regulation governors respond immediately. But as mentioned above, frequency does not get restored but will settle down at a different value. At this point of time LFC comes in to the picture.LFC maintains the system frequency by performing the concept of Secondary Regulation. It provides generation set points to the generators participating in the frequency regulation. This paper discuss with an overview of LFC schemes ,classical model based LFC schemes ,modern control based LFC schemes.

II AN OVERVIEW OF ISSUES IN LFC

Christie et.al(1995) discussed about load frequency control issues after deregulation where the simple frequency control become a challenging issue due to this competitive environment. The paper identified deregulation scenarios, technical Issues associated with load frequency control, and identify technical solutions, such as standards and algorithms.

A . M Stankovic et.al (1998) addresses the analysis and design issues in Load Frequency Control (LFC) for a power system participates in interconnection. This gives a effective closed-loop control on the bases of Quantitative feedback theory .That provides convenient graphical tools for design and analysis methods for two system interconnected model. George Gross et.al (2001) presents development and application of an analytic framework based on NERC criteria CPS1 and CPS2.The frame work provided a solid analytic basis for formulation ,analysis and evaluation of LFC criteria.

In the case of RESs, H. Bevrani et.al(2010) gave overview of the key issues and new challenges on frequency regulation concerning the integration of renewable energy units into the power systems. Power system frequency response in the presence of RESs and associated issues is analyzed, and the need for the revising of frequency performance standards is emphasized. A non-linear time-domain simulation study considering a standard 39-bus and 24-bus test systems. Johan Morren et.al (2006) discussed about Wind Turbines Emulating Inertia and Supporting Primary Frequency Control. The increasing penetration of wind turbines require changes in the way in which the grid frequency is controlled. In paper a method was suggested such that variable-speed wind turbines are able to support primary frequency control and to emulate inertia by applying additional control loops.Ronan Doherty et.al (2010) discussed about the inertial characteristics associated with turbine technology during high penetration. Doubly fed induction generators and high-voltage dc interconnection alter the frequency behavior significantly. The analysis in this paper applied extensive time series dispatch sampling, recorded historical wind turbine operating characteristics, and simplified dynamic simulation models to investigate the effects of changing plant portfolios on system frequency control Time-series sampling studies such as applied.

III CONTROL SYSTEM DESIGN CONCEPTS

The developments in the area of LFC in the interconnected power systems have been discussed through the control system designs. Most of the LFC designs are based on the application of techniques developed in the area of control system designs. The first era of classical control theory, which deals with the techniques developed before 1950. Classical control methods as Root Locus, Bode, Nyquist and Routh - Harwitz. These methods commonly use the transfer functions in the complex frequency domain, the use of feedback, and the use of simplifying assumptions to approximate the time response. A major drawbacks of classical control methods was the use of single-input, single-output (SISO) methods. Also the use of transfer functions and frequency domain limited to linear time invariant systems.

The second era of control systems is known as an era of modern control mainly using state-space model based methods developed in the late 1950s and early 1960s. In modern control. analysis and design are carried out in the time domain. State space model based methods removed the limitations of classical control and provided insight into system structure and properties, but it masked other important feedback properties that could be studied and manipulated using classical control. During the third era of the 1970s and 1980s, provide solutions to uncertainty problem of the systems. It Includes robust control ,the combination of modern state space and classical frequency domain techniques, optimal and adaptive control, are also formulated in state space. More recent trends have been towards the intelligent control systems that tend to use both the ideas of conventional control as well as methods such as fuzzy logic, genetic algorithms and neural networks.

IV LFC SCHEME BASED ON CLASSICAL CONCEPTS

W. R. Barcelo et.al (1973) discussed about the effect of the power plant time response on the closed loop roots which minimizes the different control signals obtained using root square locus techniques. A maximum value of 30 seconds for the first order plant time constant was estimated by considering rate limiting and bandwidth reduction effects. Later the paper by J.L Willems et.al (1974) deals with the determination of optimum parameter values of conventional load-frequency regulation of interconnected power system by changing the parameters in the vicinity of their optimum values or the optimum value of the bias parameter. H. G. Kwatny et.al (1979) dealt with the coordination of the economic dispatch and regulation functions of Load Frequency Control in electric power systems. The coordinating controller is obtained through the formulation of a suitably extended load-frequency control problem in the context of linear multivariable control theory.In a paper by T. Hiyama (1982) a method of designing discrete-type load-frequency regulators of a two-area reheat-type thermal systems was discussed. The construction of the regulators is based on the conventional tie-line bias control. The optimization of the parameters is achieved by using a Newton-Raphson iterative algorithm.

Kiffmeier et.al(1994) investigated modern H_∞ control concepts for frequency and voltage control of power plants.

Based on a linearized model for a national grid H_∞-optimal servo compensators .Controller shows superior performance with respect to settling time and damping of oscillations compared to classical controllers of P/PID type.

M. Albadi et.al (2002) addressed a comparative study of three different load frequency (LF) controller designs , conventional integral controller, a controller based on the pole-placement technique, and a controller based on optimal control law combined optimal controller with conventional integral controller can provide good damping to the system and reduce the overshoot. Then the paper R. Dhanalakshmi et.al (2011) describes the modeling of Load Frequency Control (LFC) of an isolated wind-diesel micro hydro hybrid power system using conventional Proportional –Integral (PI) controller with different load disturbances. Controller can generate the best dynamic response for a step load change. For this application, MATLAB-Simulink software is used. V. Ganesh et.al (2012) described LQR controllers to improve dynamic stability and response of LFC of system. This paper investigates LFC and AGC for interconnected power systems and shows that LQR controllers perform better than classical integer order controllers in these systems.

V. LFC SCHEMES BASED ON MODERN CONTROL CONCEPT

The modern power systems are multi-input and multi-output type systems. The classical control theory, which is capable to handle single-input and single-output systems, becomes entirely powerless for such systems. One of the developments in the field of modern control theory is in the direction of its application in optimal control. The LFC regulator design techniques using modern control theory enable the power engineers to design optimal LFC with respect to a given performance criteria.

A. Optimal LFC Schemes

C. E. Fosha et.al (1970) discussed the development of a state variable model of the megawatt-frequency control problem of multi-area electric energy systems. The .model is in a mathematical form necessary for application of theorems of modem optimal control theory. R. K. Cavin et.al (1971) discussed the Optimal Linear Systems Approach to Load-Frequency Control. A control algorithm is developed which provides improved power system performance in both large and small signal modes of operation.

S. M. Miniesy et.al (1972) put forwarded Optimum Load-Frequency Continuous Control with Unknown Deterministic Power Demand . M. S. Calovic(1972) presented a dynamic optimization procedure in the design of load and frequency control (LFC) based on the optimal linear regulator theory. A proportional-plus-integral control law is considered. The paper also analyzes the influence of system and design parameters on power system performance considering two-and three-area interconnections. R.Doraiswami(1978) addressed a load frequency control for a two-area interconnected system is designed by considering the nonlinearity and stochasticity of the load and using an optimal linear strategy aided by stability analysis. An observer is proposed for its implementation. A coordinating control for the two area system based on acceleration feedback is suggested K. Y. Yamashita et.al (1986) discussed Optimal observer design for load-frequency control.The proposed observer is applied to the reconstruction of the entire state vector for the LFC problem.Performance was cascaded to the optimal controller is compared with that of the uncontrolled system . A. Feliachi (1987) presented Optimal decentralized load frequency control. Design is based on a modified application of the singular perturbation theory .The approach tested numerically through a two-area Load Frequency system model. Adirak Kanchanaharuthai(2004) discussed Optimal sampled-data controller design with time-multiplied performance index for load-frequency control. This sampled-data controller improving faster transient response also in extending the structure of the sampled-data controller from the standard optimal performance index to the case of time-multiplied one. Mariano et.al(2008) addresses the stabilization and performance of the load frequency regulator. It is solved by using the theory of the optimal control. An algorithm, based on the new technique.

B. Intelligent LFC Schemes

A.P Birch (1994) investigate the use of Neural Networks (NN) to act as the control intelligence in conjunction with a standard adaptive load frequency control scheme. In this approach a NN is operated in parallel with a full load frequency adaptive control scheme. This neural control approach is shown to have several advantages over the basic fixed parameter schemes . Abdel-Magid et.al (1995) deals with the application of genetic algorithms for optimizing the parameters of conventional automatic generation control (AGC) systems. A two-area non reheat thermal system is considered to exemplify the optimum parameter search. A digital simulation is used in conjunction with the genetic algorithm optimization Q. P.Ha (1998) put forward a fuzzy sliding mode controller for power system load-frequency control consists of an equivalent control, switching control and fuzzy control. Simulation results demonstrate that the system responses are strongly robust to load disturbances and parameter variations even in the presence of governor's backlash dead-band and imposed generation physical constraints.In Jawad Talaqet.al(1999) An adaptive fuzzy gain scheduling scheme for conventional PI and optimal load frequency controllers hasbeen proposed. A Sugeno type fuzzy inference system is used in the proposed controller. Results of simulation show that the proposed adaptive fuzzy controller offers better performance than fixed gain controllers at different operating conditions D.K Chaturvedi et.al (1999) work dealt with the development of a non-linear neural network controller using a generalized neural network. The drawbacks of existing neural networks have been overcome in the generalized neuron structure which has been developed to control the deviations in load frequency of a power system. Q.P Ha (2000) presented a variable structure-based approach to the load frequency control problem inelectric power generation systems. This approach combines the salient features of both variable structure andfuzzy systems to achieve high-performance and robustness. The control strategy requires low computational costand is amenable for practical implementation

H.L Zeynelgil (2001) discussed about an an application of layered artificial neural network controller to study the load-frequency control problem in a power system. The control scheme guarantees that steady state error of frequencies and inadvertent interchange of tie-lines are maintained in a given tolerance limitation. The performance of an ANN controller is better than conventional controllers. M.K. El-Sherbiny et.al (2002) investigated an application of the fuzzy logic technique for designing the load–frequency control system to damp the frequency and tie line power oscillations due to different load disturbances. The proposed fuzzy load–frequency controller, called a two layered fuzzy controller, having two layers while the second one, called feedback fuzzy logic controller.Then S. K.Aditya et.al (2003) dealt with the application of genetic algorithms for optimizing the parameters of conventional LFC systems. A two-area non reheat thermal system is considered to exemplify the optimum parameter search. A digital simulation is used in conjunction with the genetic algorithm optimization process. The results reported demonstrate the effectiveness of the genetic algorithms in the tuning of the LFC parameters. D. Rerkpreedapong (2003) presented two decentralized robust load frequency control using genetic algorithms and linear matrix inequalities. The first one is based on H_∞ control design second one is genetic algorithms (GAs) optimization is used to tune the control parameters of the proportional-integral (PI) controller called GALMI. Both proposed controllers are tested on a three-area power system with three scenarios of load disturbances to demonstrate their robust performances.

E. Yeşil (2004) presented Self tuning fuzzy PID type load and frequency controller. The self tuning mechanism depends on the peak observer idea, and this idea is modified and adapted to the LFC problem. The self tuning fuzzy PID type controller has been compared with the fuzzy PID type controller without a self tuning mechanism and the conventional integral controller through some performance indices.K.Sabahi1 et.al (2007) presented power system load frequency control by modified dynamic neural networks controller. The controller has dynamic neurons in hidden layer and conventional neurons in other layers. For considering the sensitivity of power system model, the neural network emulator used to identify the model simultaneously with control process.

In A .Sreenath (2008) a fuzzy gain scheduled proportional and integral (FGPI) controller was developed to regulate and to improve the frequency deviation in a two-area electrical interconnected power system. Also, a conventional proportional and integral (PI), and a fuzzy logic (FL), controllers were used to control the same power system for the performance comparison. First, settling times and overshoots of the frequency deviation were compared. Later, the absolute error integral analysis method was calculated to compare all the controllers. M .Mohamed et.al (2012) put forward a paper on Load Frequency Control (LFC) to regulate the power output of the electric generator with in an area in response to changes in system frequency and tie-line loading. It dealt with Control Adaptation Using Artificial Intelligent Techniques for One and Two Different Areas Power System. Hassan Bevrani et.al (2012) Load-frequency control (LFC) in interconnected power systems is undergoing fundamental changes due to rapidly growing amount of wind turbines, and emerging of new types of power generation/consumption technologies. The infrastructure of modern LFC systems should be able to handle complex multi-objective regulation optimization problems characterized by a high degree of diversification in policies.PSO algorithm was used to optimize the membership functions. A time domain simulation is performed on the standard 39-bus test system. The results are compared with conventional LFC design for serious load disturbance and various rates of wind power penetrations.

VI. Conclusion

This paper discusses about the Load Frequency Control (LFC) which gives an overview of issues in LFC and control system design concepts were Followed by discussion about different methods for load frequency control like classical models and modern control concepts.In modern concepts different optimal LFC schemes and intelligent LFC schemes are discussed. Intelligent control techniques with different optimization algorithms may give better results for Load frequency Control.

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