Load Frequency Control In Conventional And Distributed generation Power System: A Literature Survey

Reena Goyal[1], Gagandeep Yadav[2]

[1]M.tech Scholar YIET/EED, YAMUNANAGAR, INDIA

[2]YIET/EED, YAMUNANAGAR, INDIA

Email: reena.go26@gmail.com, yadavgd@gmail.com

Abstract -In this paper an extensive literature review on load frequency control (LFC) problem in power system has been highlighted. The various configuration of power system models and control techniques/strategies that concerns to LFC issues have been addressed in conventional as well as distribution generation based power systems. Further, investigations on LFC challenges incorporating storage devices BESS/SMES, FACTS devices, wind–diesel and PV systems etc. have been discussed too.

Key Words: Distribution generation, Deregulated power systems, Load frequency control, Optimal control, Artificial intelligenttechniques

1.INTRODUCTION

The successful operation of interconnected power systems requires matching the total generation with the total load demand and with the associated system losses. With time, the operating point of a power system changes, and hence, systems may experience deviations in nominal system frequency and scheduled power exchanges to other areas, which may yield undesirable effects [1]. LFC or AGC is one of the most important issues in electric power system design and operation for supplying sufficient and reliable electric power with good quality. The main objectives of LFC for a power system are

- Ensuring zero steady-state error for frequency deviations. Minimizing unscheduled tie line power flows between neighboring control areas.
- Getting good tracking for load demands and disturbances.
- Maintaining acceptable overshoot and settling time on the frequency and tie line power deviations.

Based on the above objectives, the two variable frequencies and the tie line power exchanges are weighted together by a linear combination to form a single variable called ACE, which is used as the control signal in the LFC problem.

Nowadays, the electric power industry is in a transition from a vertically integrated utility scenario, where a single utility owned and operated the generation, transmission and distribution systems and provided power at regulated rates, to the deregulated scenario, where competitive companies sell unbundled power at lower rates. Furthermore, various kinds of apparatuses with large capacity and fast power consumption, such as testing plants for nuclear fusion and steel factories, increase significantly. When these loads are concentrated in power systems, they may cause a serious problem of frequency oscillations. Thus, it is very important to consider how the control services of system frequency should be implemented. In a deregulated environment, any power system control, such as LFC as an ancillary service, acquires a principal role to maintain the electric system reliability at an adequate level, and is becoming much more significant today in accordance with the complexity of interconnected power systems [2,3].

Thus, stabilization of frequency oscillations in an interconnected power system becomes challenging when implemented in the future competitive environment. A new frequency stabilization service that emphasizes not only efficiency, reliability and economics but also advanced and improved controls for satisfying the requirements of power system operation is much in demand.

The LFC problem has been augmented with valuable research contributions from time to time, such as LFC regulator designs to cope with parameter variations uncertainties, load characteristics, excitation control and parallel ac/dc transmission links. The microprocessor based LFC Controller, robust controller, self-tuning and adaptive controllers designs have also been presented. The most recent advance in this area is the application of concepts such as neural networks, fuzzy logic and genetic algorithms to tackle the difficulties associated with the design of LFC controllers for power systems with nonlinear models and/or insufficient knowledge about the system required for its accurate modeling. Apart from advances in control concepts, there have been many changes during the last decade or more, such as deregulation of the power industry and use of superconducting magnetic energy storage, wind turbines and photovoltaic cells as other sources of electrical energy to the system. Because of these, the control philosophies associated with the LFC problem have changed to accommodate their dynamics and their effects on the overall system dynamic performance. Generally, the methodologies of LFC controller designs can be categorized as

(i) Classical methods

(ii) Adaptive and variable structure methods

(iii) Robust control approaches and

(iv) AI-based methods.

In this study, the types of power system models for LFC, digital LFC schemes and the history of various control strategies with their salient features are outlined.

1.2 LFC MODELS IN POWER SYSTEM

The LFC problem has been dealt with extensively for more than three decades. The power systems are usually large-scale systems with complex nonlinear dynamics. However, the major part of the work reported so far has been performed by considering linearized models of two/multi-area power systems [1,4]. The effect of GRCs was included in these types of studies, considering both continuous and discrete power system models [5,6]. The first attempt in the area of LFC problems has been to control the frequency of a power system via a flywheel governor of the synchronous machine. This technique was subsequently found to be insufficient, and a supplementary control was included to the governor with the help of a signal directly proportional to the frequency deviation plus its integral. This scheme constitutes the classical approach to the solution of the LFC problem. Aggarwal et al. [7] and Cohn [8] have illustrated that supplementary controller designs based on tie-line bias control strategy are the reason that the ACEs are regulated to zero effectively. The standard definitions of the terms associated with LFC of power systems were finalized in Ref. [9]. Following that, suggestions for dynamic modeling for LFC are discussed thoroughly in Refs. [10,11]. Based on the experiences with actual implementation of AGC schemes, modifications to the definition of ACE are suggested from time to time to cope with the changing power system environment [12-14]. Since many presently regulated markets are likely to evolve into a hybrid scheme and some deregulated markets are already of this type (e.g. Norway), the effects of deregulation of the power industry on LFC have been addressed in Ref. [15]. In deregulated power systems, the vertically integrated utility no longer exists. However, the common LFC objectives, i.e. restoring the frequency and the net interchanges to their desired values for each control area, still remain. The deregulated power system consists of GENCOs, TRANSCOs and DISCOs with an open access policy. In the new structure, GENCOs may or may not participate in their own or other areas. Thus, various combinations of possible contracted scenarios between DISCOS and GENCOS are possible.

2. CONTROL STRATEGIES

In many reported works on the LFC area, control schemes based on a centralized control strategy are used for solution of the LFC problem [19]. The main limitation of the works presented on LFC considering a centralized control strategy is the need to exchange information from control areas spread over distantly connected geographical territories along with their increased computational and storage complexities. The decentralized LFC concept appeared in the power system control scenario to deal with such problems very effectively, and consequently, many research papers using this concept with continuous and discrete time system models have been presented in the literatures [20]. In Ref. [21], the authors have examined the structural properties of observability and controllability for a class of interconnected power system models. The proposed scheme provides for complete decentralization of a global state feedback control policy in the sense that the area control feedback loops are completely decoupled. Again, a class of systematically distributed control design methods based on (i) distributed implementations of centralized control systems, (ii) model reduction of dynamical systems and (iii) modeling of the interactions between the subsystems comprising the global control system is presented in Ref. [44]. The salient feature of the design is to achieve almost identical results as those obtained with the centralized design. It should be noted that in the dynamical operation of power systems, it is usually important to aim for decentralization of the control actions to individual areas. This aim should coincide with the requirements for stability and load frequency scheduling within the overall system. In a completely decentralized control scheme, the feedback controls in each area are computed on the basis of measurements in that area only. This implies that no interchange of information among areas is necessary for the LFC task. The advantage of this operating philosophy is apparent in providing cost saving in data communications and in reducing the scope of network monitoring. Because of these, the design of decentralized load frequency controllers is based on structured singular value and H1 norm [22] and [23]. Yang et al. [24] and Shayeghi and Shayanfar have demonstrated that when the frequency response-based diagonal dominance cannot be achieved, the structured singular values and H1 norm can be applied to design the decentralized LFC to achieve the desired system dynamic performance, respectively, in such a way that the stability of the overall system with the decentralized controllers is guaranteed. using the Lyapunov function it was illustrated that the overall system was asymptotically stable for all admissible plant parametric uncertainties when all local controllers were working together. Kazemi et al. introduced a suitable transformation matrix that transformed the initial reference model to an equivalent reference model, such that the convergence of the output errors was guaranteed. An appropriate adaptive law was derived for adjusting this transformation matrix. Various LFC schemes, based on two-level and multi-level control concepts have been reported in the literatures. A two-level suboptimal controller has been suggested by Wang et al. However, this approach does not ensure zero steady state error, and hence, a multi-level finite time optimal controller design, ensuring zero steady-state error, has been reported . The advantage of the hierarchical structure is reflected in the fact that even if one of the control levels fails, the system remains in operation. A global controller, which also exploits the possible beneficial aspects of the interconnections, has been applied for the LFC problem and favorable results have been achieved. The reduction of control efforts required in LFC of the interconnected power systems is sought with the help of a singular perturbation approach. This can be achieved by decomposing the system into slow and fast subsystems, designing controllers separately for each of the subsystems and then combining the controllers to yield a composite controller. Investigations on LFC of large power systems using this approach are available in the literature. The separate controllers were designed for slow and fast subsystem and were combined in such a way that the slow subsystem always interacts with only one of the fast subsystems at a time. The study also involves the effect of parameter variations and GRCs.

3 CONTROL TECHNIQUES

Generally, LFC control design methodologies can be categorized as (i) classical methods, (ii) adaptive and variable structure methods, (iii) robust control approaches, (iv)intelligent techniques and (v) digital control schemes.

3.1 ADAPTIVE AND VARIABLE STRUCTURE METHODS

The Adaptive control has been a topic of research for more than a quarter of a century. Basically, adaptive control systems can be classified into two categories: namely self-tuning regulators and model reference control systems. The task of the adaptive control technique is to make the process under control less sensitive to changes in plant parameters and to un-modeled plant dynamics. Various adaptive control techniques were proposed for LFC schemes for dealing with plant parameter changes. Ross described the control criteria in the LFC problem and the related practical difficulties encountered in trying to achieve these criteria. The implementation and analysis of an adaptive LFC strategy on the Hungarian power system have been done by Vajk et al. Pan and Liwa proposed an adaptive controller using a proportional integral adaptation to meet the hyperstability condition requirements considering plant parameter changes. A multi-area adaptive control strategy for a LFC scheme and a reduced order adaptive load frequency controller for interconnected hydrothermal power system have been presented in the literatures. A self-tuning algorithm for solution of the LFC problem of interconnected power systems was reported by Lee et al. to provide the best control performance for a wide range of operating conditions.

CONCLUSIONS

Load frequency control is one of the important issues in powersystems operation and control for supplying sufficient and reliable electric power with good quality. Especially in the deregulated electricity market, it will serve as an ancillary service and acquires a principal role to enable power exchanges and to provide better conditions for electricity trading. LFC goals, i.e. frequency regulation and tracking load demands, maintaining tie line power interchanges to specified values in the presence of modeling uncertainties, system nonlinearities, complexity and multi-variable condition of power system, determine LFC synthesis as a multi-objective optimization control problem. This paper is focused on the recent research in the area of LFC and intends to be a useful reference and search tool as well as a critical account of the up-to date use of AI technologies in the LFC problem. Emphasis has been given to categorizing various LFC strategies reported in the literature and their salient features and disadvantages. Among the discussed categories of LFC strategies, robust control and AI-based methods have shown an ability to give better performance in dealing with the system nonlinearities, modeling uncertainties and area load disturbances under different operating conditions. The main capability of robust control approaches is alleviation of the impossibility of controller design based on a more complete model of the system that considers uncertainties and physical constraints, too. The salient feature of the AI technique is that it provides a model-free description of the control system and does not require an accurate model of the plant. In conclusion,

we can say that the robust and AI techniques, like all other control techniques, have relative advantages and disadvantages. There are no rules as to when a particular technique is more suitable for the LFC problem. It is envisaged that this paper will serve as a valuable resource to any further worker in this important area of research.

REFERENCES

[1] Kothari DP, Nagrath IJ. Modern power system analysis. 3rd ed. Singapore: McGraw-Hill; 2003.

[2] Raineri R, Rios S, Schiele D. Technical and economic aspects of ancillary services markets in the electric power industry: an international comparison. Energy Policy 2006;34(13):1540–55.

[3] Kumar J, Hoe NG, Sheble G. AGC simulator for price-based operation. Part I: Modeling. IEEE Trans Power Syst 1997;12(2):527–32.

[4] Saadat H. Power system analysis. USA: McGraw-Hill; 1999.

[5] Cohn N. Considerations in the regulation of interconnected area. IEEE Trans Power Syst 1967;86:1527–38.

[6] Van Ness JE. Root loci of load frequency control systems. IEEE Trans Power Appl Syst 1963;82(5):712–26.

[7] Wood A, Wollenberg B. Power generation, control and operation. 2nd ed. John Wiley & Sons; 1996.

[8] Elgerd OI, Fosha C. Optimum megawatt frequency control of multi-area electric energy systems. IEEE Trans Power Appl Syst 1970;89(4):556–63.

[9] Kwatny HG, Kalnitsky KC, Bhatt A. An optimal tracking approach to load frequency control. IEEE Trans Power Appl Syst 1975;94(5):1635–43.

[10] Elgerd OI. Electric energy system theory: an introduction. 2nd ed. New York: McGraw-Hill; 1982.

[11] Aggarwal RP, Bergseth FR. Large signal dynamics of load-frequency control systems and their optimization using nonlinear programming: I & II. IEEE Trans Power Appl Syst 1968;87(2):527–38.

[12] Cohn N. Techniques for improving the control of bulk power transfers on interconnected systems. IEEE Trans Power Appl Syst 1971;90(6):2409–19.

[13] IEEE Committee Report. Standard definitions of terms for automatic generation control on electric power systems. IEEE Trans Power Appl Syst 1970;89.

[14] IEEE PES Committee Report. Dynamic models for steam and hydro-turbines in power system studies. IEEE Trans Power Appl Syst 1973;92.

[15] IEEE PES Working Group. Hydraulic turbine and turbine control models for system dynamic. IEEE Trans Power Syst 1992;7(1):167–74.

[16] Kundur P. Power system stability and control. New York: McGraw-Hill; 1994.

[17] IEEE PES Committee Report. Current operating problems associated with automatic generation control. IEEE Trans Power Appl Syst 1979;98:98.

[18] Jaleeli N, Vanslyck LS, Ewart DN, Fink LH, Hoffmann AG. Understanding automatic generation control. IEEE Trans Power Appl Syst 1992;7(3):1106–22.

[19] Green RK. Transformed automatic generation control. IEEE Trans Power Syst 1996;11(4):1799–804.

[20] Christie RD, Bose A. Load frequency control issues in power system operations after deregulation. IEEE Trans Power Syst 1996;11(3):1191–200.

[21] Donde V, Pai A, Hiskens IA. Simulation and optimization in a LFC system after deregulation. IEEE Trans Power Syst 2001;16(3):481–9.

[22] Shayeghi H, Shayanfar HA, Malik OP. Robust decentralized neural networks based LFC in a deregulated power system. Electr Power Syst Res 2007;47:241–51.

[23] Concordia C, Kirchmayer LK, Szymanski EA. Effect of speed governor deadband on tie-line power and frequency control performance. Am Inst Elect Eng Trans 1957;76:429–35.

[24] Wu FF, Dea VS. Describing-function analysis of automatic generation control system with governor dead band. Electr Power Syst Res 1978;1(2):113–6.