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A Survey on Load Frequency Control (LFC) Problem in Hybrid Power System

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ABSTRACT

In this paper, an ample literature survey on load–frequency control (LFC) problem in power system has been foreground. The different configurations of power system models and control techniques strategies that related to LFC problem have been considered in conventional as well as distribution generation-based power systems. Hybrid power system (HPS) consisting of multiple power generating units and energy storage units. Further, study on LFC challenges incorporating storage devices BESS/SMES, FACTS devices, wind–diesel and PV system etc have been discussed too.

Keywords: Distribution generation Deregulated power systems Load–frequency control Optimal control Artificial intelligent techniques.

I. INTRODUCTION

Load–frequency control (LFC) is of importance in an interconnected electric power system design and operation. The main objectives of the LFC in an interconnected power system is to maintain the frequency of each area with in limits and to keep tie-line power flows with in some pre-specified tolerances limits by adjusting the MW outputs of the generator so as to adjust fluctuating load demands. The well designed and operated power system must accumulated with changes in the load and with system disturbances, and it must provide acceptable high level of power quality while maintaining both voltage and frequency with into specified limits. Subjected to any kind of disturbance, the nominal operating value of a power system changes from its pre-specified value. As a result the deviation occurs about the operating point such as nominal system frequency, scheduled power exchange to the other are as which is undesirable. The LFC problems have been investigated with by the various researchers in different time through AGC regulator, excitation controller design and control performance with respect to parameter variation and uncertainties and different load characteristics. As the layout of the today modern power system is very-very complex, the oscillation incurred subjected to any disturbance may spread to wide areas leading to whole system blackout. In this surrounding, advance control methodology such as optimal control, variable structure control, and adaptive control, self-tuning control, robust and intelligent control was applied in LFC problem. In further research in the area has been carried out by use of various soft computing techniques such as artificial neural network (ANN), fuzzy logic and fusion of the se such as neuro-fuzzy, neuro-genetic etc. to tackle the difficulties in the design due to non-linearity in various segregated components of the controller. The controller parameters plays important role for its performance, thus it should be tuned properly with suitable optimization techniques. In this context, the application of genetic algorithm (GA), particle swarm

optimization (PSO), simulated annealing (SA) etc. is exploited to address the optimization objective. Due to non- linearity in the power system components and also the uncertainty in the system parameters, the performance differ from actual models, so robust control design is in dispersible to achieve acceptable deviation in frequency about the nominal operating point. Various robust control techniques such as Riccati equation, H∞, m-synthesis, robust pole assignment, loop shaping, linear matrix inequality (LMI) has been adopted to tackle the LFC problems. Now, there is rapid momentum in the progress of the research to tackle the LFC in the deregulated environment, LFC with communication delay, and LFC with new energy systems, FACTS devices, and HVDC links as well. This survey paper comprehensively highlights the LFC problems in conventional and distribution generation based power system.

LFC in distributed generation power systems

Due to speedy decline of the fossil fuel and advancement in the green power, the DG such as wind, solar comes into play to meet the shortage of demand of load. PV, wind farms, diesel engine and energies to rage system based hybrid DG. The PV power generating systems are supposed to play a very important role in meeting future demand for electricity. The relatively very high cost of PV generated electricity makes it attractive only for remote stand-alone loads or small applications. In isolated operation of wind–diesel–photovoltaic hybrid power system, the intermittency in wind speed, and solar radiation causes a large fluctuation in power system, voltage and frequency. The effect of PV power generation on LFC is discussed in this paper [1]. Apart from this BESS, SMES units, a favorable effect of integrating a FC into the power system has also been discussed [2]. The authors [3] presented a coordinated control approach for output power fluctuation leveling of PV systems using fuzzy logic controller concept with consideration of power system condition and insulation condition. A coordinated control approach based on the minimal-order observer for the LFC problem is discussed in [4]. The LFC problem of isolated utility-connected large PV-diesel hybrid power system based on simple fuzzy logic approach is also proposed in [5]. The LFC problem becomes complex by integration of wind farm grid because of the fluctuating output power due to intermittent nature of wind speed. Thus in such cases, the LFC needs to be addressed differently. The studies related to LFC in corporation the dynamics of wind farms are presented in [6–9]. In [6], the authors have discussed revision in unit commitment, economic dispatch, regulation and frequency controls, when the level of wind generation capacity is significant. Curticeetal. [7] modification a study on how to analyze the effects of small wind turbines output on the LFC. The effect of large number small wind turbines on LFC are modification in [10]. The LFC of WT based power system is discussed in [11]. In [12], a wind-turbine driven self-excited induction generator is considered as constant frequency constant voltage, variable speed, and supply with isolated resistive load connected. The simplified model is used for construct a control strategy that objective to maintain the generator frequency and terminal voltage constant in case of variations in the load and/or wind speed. The wind farms with HVDC with contribution in LFC or active power sharing during generation change or system load is presented in [13]. In [14], frequency control method is discussed by the WF and the BESS using load estimation, in which the frequency deviation in low and high frequency domain are reduced by the WF using pitch angle control and charge/discharge, respectively. The frequency control with controlling of speed in wind turbine is discussed in [15–31]. The frequency maintain from double fed induction generator wind turbines are discussed in [32–41,42]. The wind diesel hybrid system is an economical process for large as well as small group. Bhattietal. [43] outline a load frequency controller for isolated wind–diesel hybrid power systems, and explain its effect on the transient performance of the system. Milanovic and Soultanis

[44] evaluated the operation of autonomous wind–diesel system with the load control. The basic concept is obtained using the PSCAD/EMTDC computer simulation package. Next, the authors in [45] analyzed the effect of stand-alone hybrid power system consisting WTGs, DEG, FC, and A Eon frequency variation. Goyaetal. [46] discussed H∞ control theory based on droop characteristics for the frequency control by using parallel operated battery in isolated island. The PSO based design of the robust fuzzy logic-based-PID controller for LFC in isolated wind–diesel hybrid power system is proposed in [47]. The design of robust frequency controller of SMES in a hybrid wind–diesel power system by using loop shaping control technique and tuning of controller parameters using GA is discussed in [48]. The time-domain simulation for small-signal analysis of a hybrid power generation and energy storage system is evaluated in [49]. The authors presented that the power generation from the WTG, PV, DEG, and FC with energy stored or released from the BESS and FESS can effectively meet the variations in load power demand. Also, the system frequency deviation should be controlled within a very small range efficiently. The effect of wind power generation on power system frequency control is presented in [50]. The LFC by coordination control of WTG and the double layer capacitor in an independent hybrid power generation renewable energy is presented in [51]. In the suggested method, the load variation is decreased to low and high frequency domain by FC and capacitor, respectively. The GA based PID controller for LFC of independent hybrid generation systems consisting different renewable energy generation and storage systems such as three a DEG, FCs, WTGs, and a PV, a BESS, and an FESS is presented in [52]. The frequency control of wind energy storage system (BESS taken as energy storage system) based on model predictive control approach; having tested on real measurement from a power grid is discussed in [53]. The authors [54] presented a stable active power control of DFIG with wind power variations. Depending upon the rotor speed condition, the DFIG can be controlled to trace operator's active power command. The moving average with K deviation method is also introduced to preserve a certain amount of wind power reserve for wind power frequency regulation in the study. The LFC of two and three-area interconnected power system in the DFIG based wind turbine using the model predictive control (MPC) technique is presented in [55]. The robust performance is demonstrated against uncertainties due to governors and turbine sparameters variation and load disturbances. The LFC of variable speed, variable pitch wind generators are presented in [56], in which two control strategies are used. The first one is based on over speeding, de-loading for wind speed control to avoid overloading of the converter of DFIG, and second one uses pitch-controlled de-loading fast LFC action.

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