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A comprehensive state of the art literature survey on LFC mechanism for power system

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ABSTRACT

Over the past few decades, many publications have been made in the area of Load frequency control (LFC) of interconnected power systems. Load frequency control is necessary to develop better control in order to achieve less effect on the frequency and tie line power deviations after a load perturbation. However, number of control strategies has been employed in the design of load frequency controllers in order to achieve a better dynamic response and the exact choice of the LFC controller in a particular case requires sufficient expertise because each controller has its own merits and demerits. Due to this, an appropriate review of load frequency control (LFC) mechanism is essential and a few attempts have been made in this concern. This paper presents a detailed survey on load frequency control (LFC) mechanism. The overall study explores the depth study issues related to LFC mechanism based on different sources of power system models. This paper focused on different control techniques of LFC, which also includes all the recent application of FACTS devices. This review reveals the investigation of soft computing based optimization technique and application of Energy Storage System (ESS) and HVDC-link in LFC. These studies also illustrates conventional power system, deregulated of power environment as well as distributed generation and micro grids. This paper is designed in order to highlight the major traits of Load forecasting and some critical case studies on LFC.

1. Introduction

As the title of this paper suggest that, this paper revolve around LFC and its mechanism for power system. It explores the types of power system models; with linearity or non-linearity, different types of control techniques like classical control approach and modern, advance and intelligent control. It highlights how LFC incorporating with FACTS (Flexible AC Transmission System) devices, Energy Storage System (ESS) and HVDC links. This paper also deals with classification of LFC based on soft computing technique and different algorithms and LFC in restructured power environment and also reflects how LFC works with load forecasting techniques.

Before knowing all these above-mentioned issues regarding LFC there is need to know, what is LFC* As we know, that LFC plays very significant role in designing and operation of a healthy power system. In a power system, the loads are unpredictable and uncertain in nature, which indirectly affects the system frequency that is not desirable. Thus, through LFC mechanism either by increasing generation capacity or minimizing the frequency deviation this issue can be kept within desired limits. This technique is termed as Load Frequency Control (LFC) [1–6]. LFC plays very significant role in design and operation of a better system. A healthy designed structure and properly operated power system have to withstand the load disturbance and should provide acceptable and economic power quality by keeping both generation capacity and frequency deviation within sufferance limits.

In the beginning, Automatic Generation Control (AGC) regulators, governor design, excitation controller design, different load profile and control performances with respect to parameter modification and contingency were implemented [7–21]. With the development of technologies, the power system becomes more wide and interconnected for many benefits. These research works express the basic information about an interconnected power system for different frequency regulations of the power system [22–24]. Due to the complexity of the modern power system, the system oscillation exposed to any electrical disturbance may spread to wide interconnected system of different control area. It creates undesirable disturbance, which cause the instability that will lead to complete system black out. For mitigation or to control over the above-discussed problem different controlling aspects of LFC are developed and successfully employed in the power system i.e., conventional controller, adaptive controller, optimal con-

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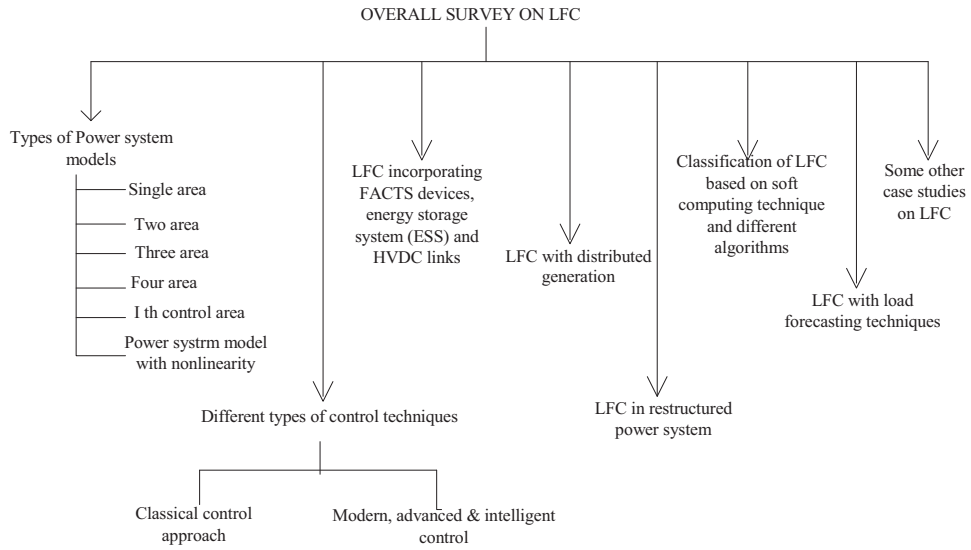

Fig. 1. : Flow Chart of Survey on LFC Review.

troller, advanced fuzzy and ANN controller etc. Linearized model of LFC is studied, but in real scenario, non-linearity is always present in the system, which can be further analysed. In this paper the inclusion of dead band and Generation Rate Constraint (GRC) , delay-dependent stability [25]with time varying delay and probabilistic internal delays [26] are well researched . Sensitivity analysis [27] of any controller is a very important aspect, which works out for load damping characteristic considering frequency regulation of the power system. The conventional controller like integral (I), Proportional-Integral (PI), Proportional-Integral-Derivative (PID), Double Integral-Derivative (IID) & other control technique [28–31] are studied which gives the basic analysis of the LFC of the power system. This paper also discussed various robust controller and different control strategies for LFC and gives the feedback gains of VSC by using genetic algorithm, sliding mode controller [32], linear matrix inequality [33], predictive and adaptive control [34], optimal control [35] and decentralized control [36,37] which explores the basic conventional concepts of LFC. With the evaluation of static electronic device, the concept of conventional control strategies have been modified and many controllers are designed by FACTS devices, energy storage system (ESS) like redox flow battery, interline DC power flow controller, Intelligent controller and HVDC link [38–45]. Nowadays conventional power system is redesigned in deregulated power environment and incorporated with the classical concepts of LFC. Restructured power system extend its definition and gives the evaluations of DISCO (Distribution Company), GENCO (Generation Company), TRANSCO (Transmission Company) components and successfully incorporate the LFC algorithm so as to decrease the dependability on conventional sources of power system and incorporation of renewable resources which leads to the development of hybrid power system [46–52].

In this regard, many development and research work are presented like distributed generation and micro-grid [53] which play a vital role in LFC mechanism. Some important coordinated control of distributed energy resources for LFC are described as well as primary frequency control is also developed from smart load via reactive compensation which technically support the LFC mechanism [54–69]. The development of soft computing techniques in a modern power system are handling the difficulties or the complexity of the non-linearities of the system very smartly. Soft computing algorithm like biogeography based optimization [70,71], single objective and many objective based optimization [72], novel quasi-opposition harmony search algorithm [73], multi-objective genetic algorithm [74], grey wolf optimization [75] etc., are successfully used to handle the tuning complexity of different parameters of the load frequency controller. Soft computing application indirectly supports the stability of Load Frequency Controller by considering the different system constraints that reduces the human effect error considerably. Load forecasting technique is a very challenging job in the power sector but its application can improve the performance of Load Frequency Controller at a great extent. Thus application of load forecasting technique is able to predict the load demand and hence corrective measures can be taken before the load perturbation, which can enhance the performance aspect of the controller. Apart from these research works many other authors represented LFC mechanism via wavelet neural network with data filtering [76], ANN technology [77] and Fuzzy approach [78] which intensifies the performance of LFC methodology. Some other critical control approaches are also presented in recent research trend [79–97] which signifies the different control aspects of the load frequency control. Some attempts were made for literature review survey on load frequency control and its different strategies [98–100] but are not sufficient in context with recent control mechanism for LFC. In this regard, there is need of more study and reviews, which focuses on different control methodologies in a very precise manner and covering all conventional, recent and future trends for the LFC of the power system. Thus, the objective of this paper is to present an overall state of the art comprehensive survey, recent up to date technical core issues on load frequency controller and its different control aspects methodologies for the interconnected power system. The flow chart of the survey carried out for LFC depending on area and controller is shown in Fig. 1.

According to this above mentioned chart we find that the first section provides the elementary sketch of different types of power system models according to the suitability of the control area as well as nonlinearities for single area, two-area, three-area etc., of the interconnected power system. In the next section, the classification of LFC based on various control techniques are discussed which cover conventional and modern control mechanism for the power system. Ahead of this section, it deals with the classification of LFC methodology according to the application of different FACTS devices, Energy Storage Systems (ESS) and HVDC links. The Section 4 illustrates about the LFC incorporated with distributed generation, hybrid power scheme, micro grids and smart grid for modern power scenario. Furthermore Section 5 describes the LFC in the deregulated power environment. Beside from these discussions, the next Section of this survey provides and investigates the classification of LFC based on the application of soft computing and different control algorithm in brief.

Section 7 of this survey work gives the platform, which includes the