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A Review On Load Frequency Control Of Multisource In Interconnected Power System

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Abstract- Power plants using both renewable and conventional energy make up the hybrid power system. Due to this integration, there are problems with the power quality, such as slow settling times and more transient contents. The frequency changes brought on by such connectivity are the fundamental problem for the hybrid power system. The Load Frequency Controller (LFC) design guarantees the power system's dependable and effective operation. LFC's primary job is to keep the system frequency within safe bounds, which also keeps power within a certain range. For an LFC to supply the system with enough power, it should be backed with contemporary and sophisticated control mechanisms. This study provides a thorough analysis of various LFC structures in a variety of power system configurations. First, a description of a power system based on renewable energy and the need for LFC development are given. Single-area, multi-area, and multi-stage power system designs were examined for the fundamental operation. Utilized were many controller types that were designed using various control strategies that had been explored. Graphical analysis was used to compare different controllers and techniques. There is a list of potential study areas in the supplied future scope of work. Finally, the paper emphasises the necessity of improved LFC design in situations with complicated power system architectures.

Index terms- **Load frequency control, renewable energy systems, multi-area power system, optimization algorithms, artificial neural networks.**

I. Introduction

Modern, linked power systems' main area of concern is power system stability. It is referred to as a power system's capacity to stabilise itself following the elimination of disruptions. While an unstable system loses control through desynchronizing, this event could have a disastrous effect on how well the power system functions. Maintaining synchronism between various components of the power system is a significant task for power system engineers as stability considerations have become an inherent aspect of the design of a dependable system [1]. Electricity must be produced in accordance with load side demand while also taking losses into account. A stable power system runs within a defined region, and various external factors may cause the power system's nominal frequency to diverge to an unstable region [2].

Two control loops—one primary and the other secondary—are used in contemporary power systems to regulate frequency [3]. The first one is in charge of stopping the frequency transients caused by governor droop that can cause steady state error [4]. The second approach, sometimes referred to as automatic gain control or load frequency control, has the potential to maintain a consistent level of system frequency regulation. In the beginning, load frequency management was achieved using traditional PID controllers; however, as research progressed, intelligent controllers, fuzzy controllers, sliding mode controllers, and tilt integral derivative controllers were created. A more effective real-time control of the power system is provided by a modern controller architecture based on sliding mode control and adaptive control pattern. To enhance performance, more study is being done on support vector machine-based controllers and brain emotional learning-based intelligent controllers.

This work focuses on the study of existing load frequency control strategies and suggestions for further improvements. The performance analysis was conducted for understanding the results of different simulated parameters. The shortcomings in different techniques were noted and the future road map was defined for better controller design. With the installation of renewable energy systems, the integration problem is getting complex. The improved power system design is only achieved with better power quality by implementing various load frequency control techniques.

II. Literature Review

Due to the incorporation of numerous renewable energy sources and the introduction of novel systems like autonomous grids, micro-grids, nano-grids, and smart grid technologies, modern power networks are undergoing a rapid transformation [5]. The production of active electricity is uncertain due to the interconnection of renewable energy sources, such as wind turbines, tidal turbines, geothermal plants, biomass plants, hydro power plants, and solar cells, etc. Figure 1 [6] illustrates this. The use of solar energy resources has been the subject of extensive investigation. Solar energy is viewed as an easier alternative to hydro energy systems because of its cheaper construction costs and portability. Hydro energy systems are traditionally thought of as the best environmentally friendly source of energy, but their initial cost and time of development are high [7]. Thus, frequency fluctuations lead to the unreliable operation of the power system. Nowadays, a power system must be unbundled into its horizontal and vertical components because it is not vertically integrated but rather a deregulated entity. In such cases, it is crucial to analyse the situation and build improved frequency controller units. Numerous studies have been conducted to create and enhance the design of load frequency controllers [8]. A PID controller was used by Krishan et al. in [9] to work on the autonomous generation regulation of multi-area power plants. In [10], effective generation rate-constrained robust multivariable predictive-based load frequency control was accomplished. The developed controllers, however, do not offer particularly impressive settling time, peak overshoot, or peak undershoot values. A load frequency controller's primary responsibility is to immediately stabilise by adjusting its parameters in response to its surroundings [11,12]. There has been extensive study done to develop the perfect load frequency controller, but the majority of these controllers have poor settling time concerns. More recently, the intelligent design technique has become popular in LFC design. An LFC design based on an artificial neural network was aimed at the deregulated power market in [13,14]. It is an illustration of an intelligent controller with a system for learning from external events and situations. Smaller settling periods and lower transient values are required to quickly approach the steady state response [15,16].

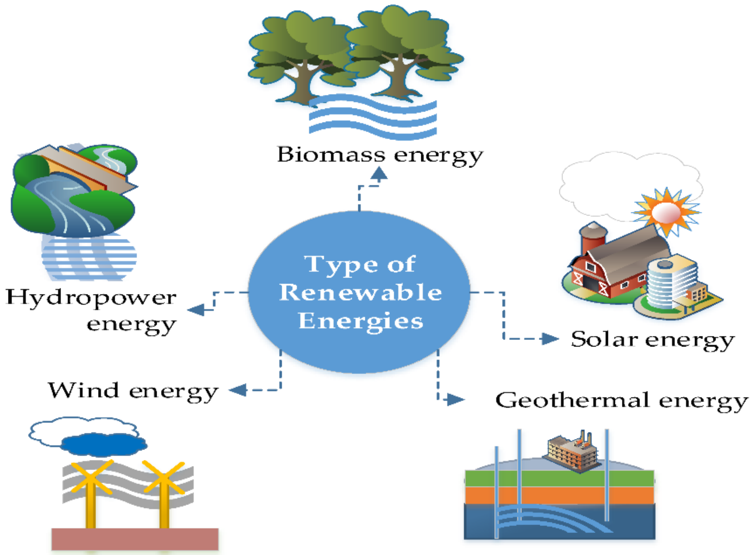

Figure 1. Renewable Energy Systems.

When applied for attack detection on LFC in [17], the stochastic process with unknown input estimators serves as an illustration of the cyber security technique used in LFC applications. The best firefly algorithm was employed in [18] to control load frequency in unregulated situations.

III. Research Motivation

The focus of this research is on understanding various LFC control techniques in hybrid power systems based on renewable energy sources. Numerous LFC control techniques for connected hybrid power systems are presented in the literature review. These methods concentrate on giving hybrid power systems the best possible control for increased power system responsiveness. Most researches focused on the conventional, integrated power networks that are ageing [19]. The development of renewable energy sources is currently a global priority due to their environmental friendliness and low operating costs. Power quality problems result from the integration of renewable energy sources with a conventional power grid. Maintaining load frequency control while supplying the necessary quantity of power is not always simple. Issues with frequency deterioration are brought on by the inertia of the power system and intermittent generation [20]. A greater number of interconnected systems could result in problems such voltage instability, frequency skew, and poor power quality. To overcome these difficulties and improve the level of integration of renewable energy sources in current power system networks, some inventive work and fresh ideas are required. Reviewing prior study, it was found that scientists tended to concentrate on conventional LFC development, but that load frequency control research has been stimulated by the ongoing integration of renewable energy sources into existing power grids [21]. The present review, which describes the integration of renewable energy sources with existing power system networks, was motivated by this.

IV. Review on Load Frequency Control with Renewable Energy Sources

systems. In contrast to the latter, which is often a tied power system, the former is an isolated power system. The integration of renewable energy sources creates transients and frequency deviations, and environmental non-linearity affects the power system's regular operation [22]. The introduction of contemporary methods for power generation, transmission, and distribution has complicated how the power system functions. In the area of load frequency controllers, research and development is being done to address power quality issues in complicated power systems. For the improvement of power quality and the system's responsiveness to irregularities, a variety of control schemes and optimization algorithms have been proposed [23]. Figure 2 displays the application of LFC in several fields along with optimization methods. For LFC optimization, many algorithms are applied to enhance the transient response and settling time.

Classical control, optimum control, adaptive control, variable structure control, and robust control are some of the several control techniques used in LFC development. The deregulation of the power system was brought about by the government's reform of laws and regulations. Nowadays, transmission congestion is a problem since power is traded like any other commodity. The difficulties of transmission congestion brought on by multi-area deregulated networks centre on the requirement for complex LFC structures. Distributed generation is gaining popularity as more people install renewable energy systems in their homes. A better-designed LFC can handle the power quality problems brought on by the power generated at several isolated places. The power system can be divided into single-area and multi-area power systems depending on how it is configured.

In contemporary power systems, LFC controllers are intelligently tuned using a variety of soft computing techniques [24]. A FOFPID controller has been created for islanded microgrids utilising the multi-objective extremal optimization method [25]. The PI-PD cascade controller's AGC regulation in multi-area power systems was optimised using the Flower Pollination algorithm [26]. To iteratively stabilise the power system transients in a hybrid context, the iterative proportional-integral-derivative H controller was created [27]. The load frequency control of a hydrothermal system in a deregulated environment has been established using the biogeography-based optimised three-degrees-of-freedom integral-derivative controller [28]. A framework for cost-effective load frequency regulation in hybrid power systems was developed using the modified multi-objective genetic algorithm [41]. In this instance, the power system quality is kept up to par economically and to satisfy consumer demands.

V. Multi-Area Power System

Renewable energy sources like wind and solar can be used with traditional power plants in today's flexible power networks. The connectivity of several generation sources increases instability, making load frequency regulation a challenging issue in multi-area power systems. The amount of frequency deviation in each area of control is used to determine the LFC design for a multi-area power system. The tie line power deviation is a severe problem in systems that are coupled because it can cause transients and power system instability. A sudden change in the demand and power produced by renewable energy sources might result in extremely unstable output power.

Figure 2 depicts the tie line power exchange between various locations. Each area is made up of conventional units with distributed generation and is connected by different sub-systems. Transients and harmonics are two examples of issues brought on by the interaction of various locations. Power flow on the connected lines becomes a problem due to power imbalances, hence frequency control entails measuring power flow on the connected lines. The entire power system is characterised by frequency management, and reliable functioning depends on this control. The entire quantity of active power generation must match the active power consumption at any given moment in order to keep the power system frequency constant.

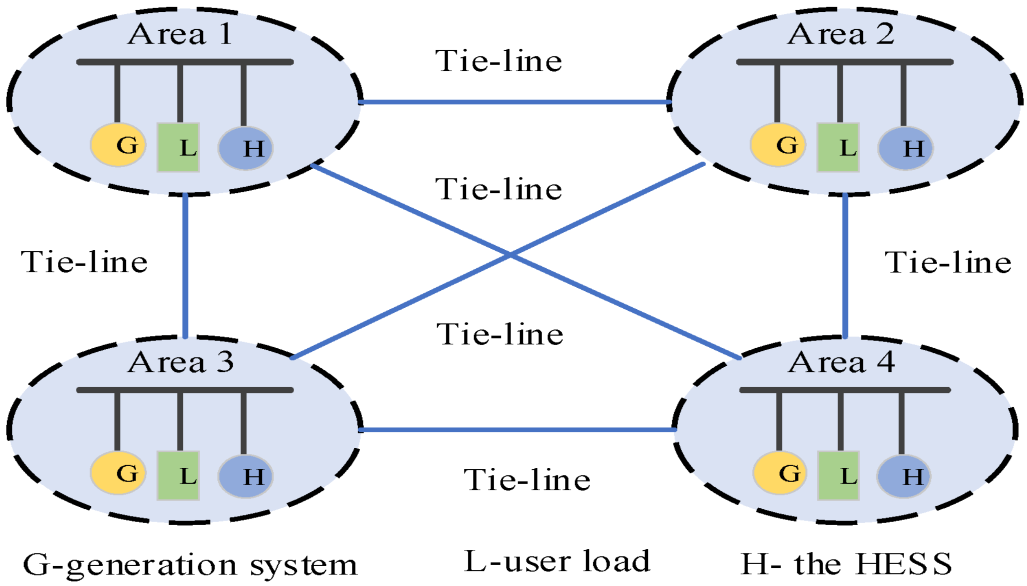

Figure 2. Power between areas

VI. Controllers based on Different Control Techniques

As research has been done to address one of the shortcomings in the current controllers, various controllers have been produced over time. Artificial Neural Network (ANN) controllers were created as a result of the advancement of intelligent computing techniques, simplifying the decision-making process in control structures. Multi-level control schemes between two extreme values were produced as a result of the development of fuzzy logic; these controllers increased the amount of control and accuracy of output signals.

Every control system experiences non-linearity, hence non-linear control systems have been created to address irregularities. The statistical analysis and approaches for creating better control systems were proved by the work in probability. While the swarm intelligence incorporated the principles of colonial intelligence for the development of ant colony optimization and particle swarm optimization, numerous algorithms, such as Genetic and Differential Evolution, were developed to address various inadequacies in power systems. Figure 3 illustrates many soft computing techniques. As various fields grow over time, better control algorithms are produced. Swarm intelligence and evolutionary tactics are developed as a result of metaheuristic methods. Ant colony optimization and particle swarm optimization are subfields of swarm intelligence, while the genetic algorithm and differential evolution are some of the fundamental evolutionary techniques.

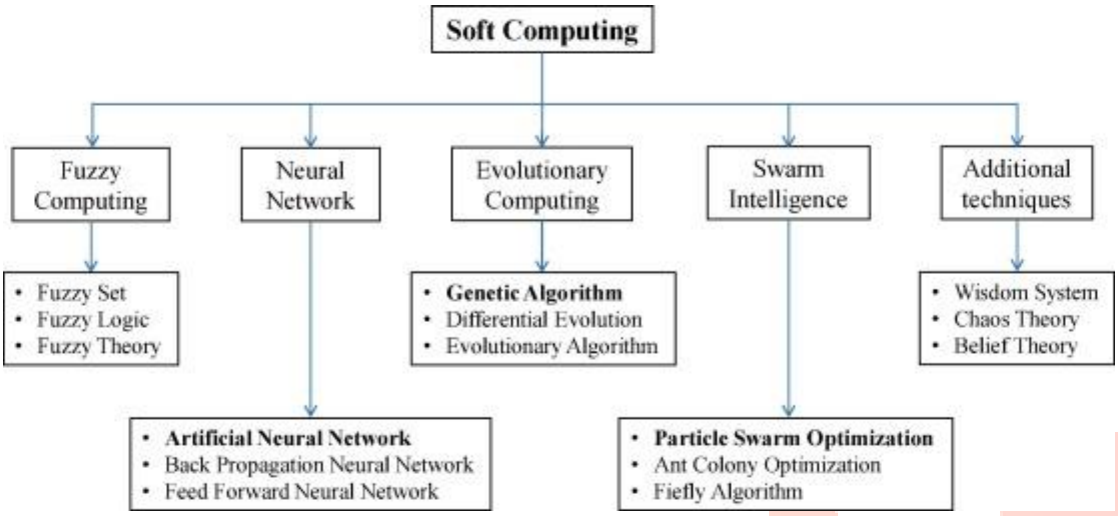

Figure 3 Soft computing techniques

VII. Conclusions

Modern power systems depend on LFC to supply power consistently, effectively, and reliably. Both single-area and multiple-area power system types are covered. Under conditions of various uncertainties, non-linear output, and multi-variable power system conditions, the primary goal of LFC is to provide frequency regulation in power systems while continuously monitoring the load demand. This article examines numerous LFC power system topologies that have been algorithmically improved. The most recent developments in LFC structure used in different types of renewable energy systems are succinctly addressed. The conclusion of this work emphasises the necessity for further research and development in the field of load frequency controllers. This work is anticipated to be a valuable resource for knowledge in the area of load frequency control for renewable energy systems.

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