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A Review on Stability Analysis of Multi-Source Power Generation Systems with Automatic Generation Control

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Abstract- The hybrid power system is made up of power plants that use both conventional and renewable energy sources. There are power quality issues as a result of this integration, including longer settling periods and more transient contents. The core issue with the hybrid power system is the frequency shifts caused by this link. The dependable and efficient operation of the power system is ensured by the design of the load frequency controller (LFC). 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 paper 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. The basic operation of single-area, multi-area, and multi-stage power system designs was investigated. Numerous controller kinds that were created using different control methodologies that had been investigated were used. Many controllers and methods were compared using graphical analysis. The future scope of work that is provided includes a list of possible study areas. The research concludes by highlighting the need for better LFC design in scenarios with intricate power system topologies.

***Index terms*- Renewable energy systems, load frequency control, Single and multi-area power system, optimization algorithms, artificial neural networks.**

I. INTRODUCTION

Power system stability is the primary concern for modern, integrated power systems. The ability of a power system to self-stabilize after disturbances have been eliminated is known as this. Desynchronization causes an unstable system to lose control, but it can also have catastrophic consequences for the power system's overall performance. As stability considerations have become an integral part of the design of a reliable system, power system engineers have a considerable problem in maintaining synchronism across various components of the power 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.

The analysis of current load frequency control techniques and recommendations for further advancements are the main goals of this work. The purpose of the performance study was to comprehend the outcomes of various simulated parameters. The drawbacks of several approaches were identified, and a roadmap for improving controller design going forward was established. As renewable energy systems are installed, the integration problem becomes more intricate. The implementation of diverse load frequency control strategies is the only way to attain an improved power system architecture with superior power quality.

II. LITERATURE REVIEW

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Modern power networks are rapidly changing as a result of the integration of several renewable energy sources and the introduction of novel systems like autonomous grids, micro-grids, nano-grids, and smart grid technologies. [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. Fig. 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]. As a result, frequency variations cause the power system to operate unreliably. These days, a power system is not vertically integrated, but rather a deregulated entity that needs to be separated into its horizontal and vertical components. It is vital to analyze the situation and create better frequency controller units in such circumstances. A great deal of research has been done to develop and improve 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].

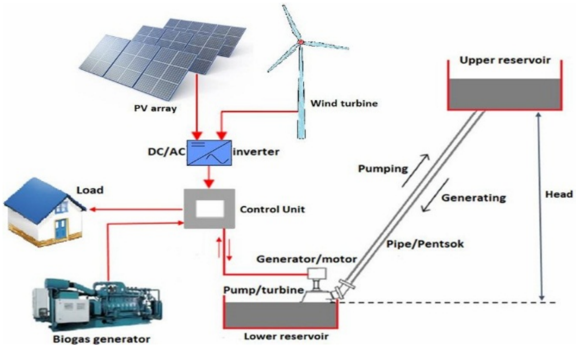

Fig. 1. Hybrid Renewable Energy Systems.

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

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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.

Fig2 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.

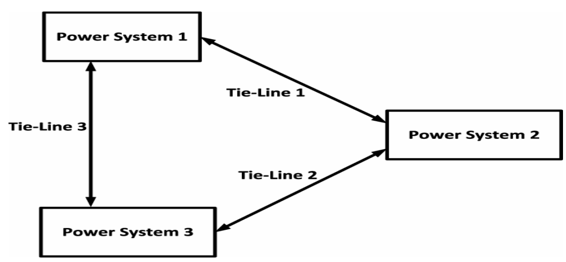

Fig. 2. Power between areas

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. Fig. 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.

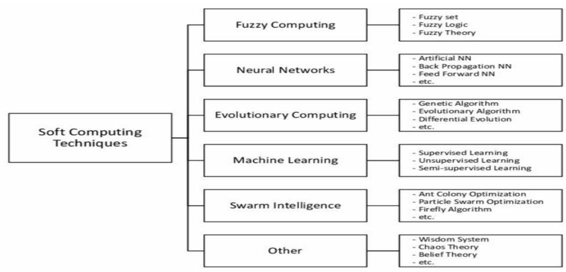

Fig. 3 Soft computing techniques

VII. CONCLUSIONS

LFC provides dependable, efficient, and consistent power to modern power systems. Power systems with one or more areas as well as numerous areas are addressed. The main objective of LFC is to offer frequency regulation in power systems while continually monitoring the load demand under diverse uncertainty, non-linear output, and multi-variable power system situations. Several algorithmically improved LFC power system topologies are examined in this study. 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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