

A Review of Load Frequency Regulation for the Purpose of Ensuring the Stability of the Power System

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Abstract

Power system stability is the capability of power systems to maintain load magnitude within specified limits under steady state conditions in electrical power transmission. In modern days, the electrical power systems have grown in terms of complexity due to increasing interconnected power line exchange. For that, an inherent of controllers were essential to correct the deviation in the presence of external disturbances. This paper hence aims to review the basic concepts of power system stability in load frequency control. Various control techniques were analyzed and presented. Power system stability can be classified in terms of method to improve power system stability, which are rotor angle stability, frequency stability and voltage stability. It is found that each method has different purpose and focus on solving different types of problem occurred. It is hoped that this study can contribute to clarify the different types of power system stability in terms of where it occurs, and which is the best method based on different situation.

Keywords: *Rotor angle stability, Voltage stability, Power line exchange, Power system stability, Load frequency control*

INTRODUCTION

The capacity of an interconnected power system to recover to steady functioning after being disrupted is known as its

stability. Instability in a power system, on the other hand, denotes a loss of synchronism or out of step. In power systems that are constantly increasing and

spreading across wide geographical regions, stability is acknowledged as a critical component. As a result, engineers' primary objectives have been sustaining the stability area in power system operation and ensuring synchronism between various sections of the power system.

The matching of total generation with total load demand, as well as system losses, is required for successful functioning of interconnected power networks. Changes in the operating point of a power system can cause a deviation from the nominal frequency. The capacity to match total generation with total load demand, as well as the ability to tolerate related system losses, is required for successful operation of an interconnected power system. As a result, a linked power system with a weak stability condition may experience nominal system frequency variations, which can lead to catastrophic consequences.

Load frequency control (LFC) is an important component of power system stability. After a disruption, it's critical to keep the frequency at a comfortable level. Several kinds of control have been established in recent years [3-10]. Previous control approaches, on the other

hand, have continuously demonstrated a lack of resilience when it comes to the uncertainty's parameter, according to study. As a result, the goal of this work is to examine a few traditional approaches while also highlighting research gaps and new research prospects in LFC.

POWER SYSTEM STABILITY CONCEPTS

Stability in a power system refers to the system's capacity to return to a state of operating equilibrium after being disrupted. All variables in a power system are bounded. As a result, the entire system is intact and linked. Faults, load shifts, generator outage, and line outage or voltage collapse are examples of disruptions. Furthermore, the source of disruptions might be a mix of all of them. Figure 1 shows how power system stability is divided into three categories: rotor angle, voltage stability, and frequency stability. Each of these three types of stability may be further divided into major and minor disturbances, as well as short- and long-term stability concerns.



Figure 1 Classification of power system stability

Rotor angle stability

When a system is subjected to a disturbance, rotor angle stability is the capacity of the system to maintain a synchronised state. The rotor angle of a generator is determined by the balance of mechanical and electromagnetic torques. The mechanical torque is generated by the input of mechanical power exerted by the primary mover. The electromagnetic torque, on the other hand, generates electrical power for the generator. The electromagnetic torque of all generators in the synchronising condition is precisely equivalent to the mechanical torque in the opposite direction. The rotor angle will fluctuate if the balance between mechanical and electromagnetic torque is disrupted by any disruption. Small disturbance angle stability and high

disturbance angle stability are two types of rotor angle stability.

Voltage stability

When a system is subjected to a disturbance, voltage stability refers to the system's capacity to maintain steady state voltages across all system buses. Larger disturbances result in a high level of disturbance voltage stability. While a minor disturbance provides a small disturbance voltage stability, a larger disturbance produces a large disturbance voltage stability. In comparison to rotor angle stability, voltage stability may be divided into two categories: long-term and short-term. The time frame for understanding the stability of a voltage fluctuation caused by a fast switching device such as an induction motor, power electronic drive, or HVDC is in the range

of 10-20 seconds. As a result, the problem can be classified as a short-term phenomena. The time frame for voltage stability can be longer if the voltage variations are caused by slow changes in load, line overloading, generators reaching reactive power limits, or tap changing transformers. The documented time frames have ranged from 1 minute to several minutes in the past (more than 1 minute).

Frequency stability

Frequency stability refers to the power system's capacity to maintain a constant frequency in the face of significant disturbances between generation and load. The system's capacity to reestablish equilibrium between system generation and load with little load loss can be used to assess performance. Frequency instability can create frequency fluctuations, which can cause generating units or load to trip.

TECHNICAL WORKS ON LOAD FREQUENCY CONTROL

The term "LFC" stands for "power system frequency control." LFC has long been one of the functions of automated generation control (AGC), and it is currently one of the most significant control issues under investigation. The

frequency variation from its nominal value is a major factor in the power system's dependability and stability. LFC aims to maintain constant frequency across the system, maintain tie line power at a planned level regardless of load fluctuations in any region, reduce area control error (ACE), and enhance transient performance. Over the last six decades, AGC systems have developed. This is based on the notion of tie line load bias management. Frequency and tie line power exchanges are the two factors of relevance. A linear combination to a single variable termed ACE weights their variances collectively. Power engineers have been able to cope with the AGC problem more efficiently and effectively because to continual advancements in the design and execution of AGC solutions. Several studies relating to load frequency management in linked multiarea power systems have been published in the past. Some control systems based on classical linear control have been developed in the literature. The functioning purpose of the power system varies constantly during a daily cycle, according to the existing attributes of shifting loads. As a result, a fixed controller may no longer be appropriate in every linked variable structure control to assure system parameter insensitivity.

Concordia published the first article in the topic of autonomous generation control in 1954. In the areas of autonomous generation control and load frequency control, there is now a lot of research going on. The smart load frequency control was investigated in the problem of two equal-area hydro, thermal, and hydro-thermal systems in the study. In order to achieve minimal interaction between control areas, the frequency bias must be set equal to the frequency response characteristic, according to the research. The megawatt-frequency (P-f) control problem was proposed by Elgerd and Fosha, and it has been chosen for critical examination. This issue is as old as the technology of power systems. The revolutionary optimal control is a concept for interconnected power systems' automatic generation control regulator designs. Because of recent system failures, attention has been drawn to the overall stability of the system. Cohn presented a system-wide coordinated correction strategy based on unintentional exchange and temporal inaccuracy. It looked at the static aspects of the net interchange tie line bias control strategy, specifically the factors to consider when setting the frequency bias. Based on static analysis, the frequency setting of the control area should be matched to combine the area's

generation and load frequency response for minimal interaction between controls areas. However, it was silent on the magnitude of the controller's gain setting and the dynamic aspects.

The first attempt in the area of AGC was to control the frequency of a power system via the synchronous machine's flywheel governor. After it was discovered that this approach was insufficient, a supplemental control was added to the governor using a signal directly proportional to the frequency integral plus its deviation. This technique represents the traditional approach to power system AGC. Cohn et al. carried performed some of the first research in this vital area of AGC. The tie-line bias control approach was used in these studies. On the other hand, Quazza has addressed non-interactive control in terms of frequency and tie line powers control, where each control region deals with its own load changes. Aggarwal and Bergseth commented on their work with large signal dynamics in LFC systems. Supplementary controllers were created to successfully regulate the ACEs to zero. Energy source dynamics were later integrated into the design of AGC regulators the standard definitions of words linked with power system AGC were finalised. Then, proposals for

dynamic modelling for LFC are fully examined. Modifications to the concept of ACE are recommended from time to time to cope with the changing power system environment, based on experiences with actual implementation of AGC systems. The consequences of deregulation of the electricity industry on LFC have been fully explored, because many currently regulated markets are anticipated to evolve into a hybrid scheme, and some deregulated markets are already of this sort (e.g., Norway).

PERFORMANCE ANALYSIS ON PREVIOUS CONTROL STRATEGIES

The researchers proposed a number of control strategies based on conventional proportional-integral-derivative (PID) control techniques, a linear quadratic regulator (LQR) based regulating techniques, and linear matrix inequalities in their pioneer work to create LFC controller. Aside from that, the LFC was designed using soft computing or artificial intelligence (AI) approaches such genetic algorithms, neural networks, fuzzy logic, bacterial foraging optimization and sliding mode control, H, and particle swarm based techniques. Vijay evaluated the performance of bacterial foraging optimization (BFO) with genetic algorithm (GA) and particle swarm

optimization in his paper. (PSO). The new aspect of BFO is that it addresses the issue of economic load dispatch (ELD), which includes valve point impacts. A testbed with three to thirteen generating units was used to test the suggested method. The findings demonstrated that the suggested algorithm provided high-quality solutions for ELD issues while simultaneously lowering fuel expenses. Meanwhile, Sabahil studied power system load frequency regulation in a two-area power system using a modified dynamic neural network (MDNN) controller for high-quality electricity generation. In the buried layer of the controller, there are dynamic neurons, and in the other levels, there are conventional neurons. To account for sensitivity in the system model, the neural network emulator (NN-emulator) was utilised to identify the model simultaneously with the control process. The weighted total of these inputs formed the argument of a fixed nonlinear activation function, which the neuron receives either from other neurons or via neural sensors. The suggested controller was utilised since the whole structure of a power system has nonlinear dynamics and their operating points may vary, necessitating the usage of an adaptive controller, which has proved that the

system performed well when compared to a traditional neural network (CNN).

Kumar also noticed that the PID controller parameter and bias coefficient for load frequency control (LFC) are built using a novel technique. The power system instabilities and nonlinear obstacles of governors and turbines, such as valve speed limit (VSL) and generation rate constraint (GRC), are taken into account in the suggested approach. With a 5% step, variations in uncertainties and nonlinear constraints are estimated to range between -40% and +40% of nominal quality. The influence of frequency and tie line power fluctuations was nullified using a PID controller calibrated using GA. Sreedhar Allu, on the other hand, stressed the advantages of fractional order PID (FOPID) controllers in single area power systems over traditional PID with root locus tuning. The concept was expanded to a multi-area thermal power system with GRC non-linearity. The FOPID controller was modified using the bacterial foraging optimization algorithm (BFOA), which uses an integral time multiplied absolute error (ITAE) as an objective function to achieve the study goals. Using a transport delay, the resilience of the suggested controller was demonstrated (TD). Padhan investigated the tuning approach used to

simulate a PID load frequency controller for power systems, as well as a transfer-based acknowledgement mechanism for power system flow estimates. In connection with vulnerabilities in plant parameters, strength evaluations on dependability and execution were performed, and it was discovered that the system stays asymptotically relentless for every enclosed uncertainty not withstanding movements in the system.

Saikia observed that increasing the degree of freedom reduces the effect of undesired postings of unsettling influence, thereby improving the aggravation-reducing execution of a closed-circle system. In this research, the Firefly algorithm (FA) was used as part of frequency control in a combined cycle gas turbine (CCGT) plant to improve controller performance. Similarly, the performance of traditional controller parameters in integral (I), proportional-integral (PI), PID, and extra integral derivative (ID) was carefully investigated. Meanwhile, in [40], Wen Tan proposed a PID tuning scheme for LFC in power systems that is sensitive to two-level flexibilities. Similarly, the time domain as well as the resilience of an essential PID controller were linked to two regulatory restrictions, and their strength was investigated. The findings point to

changes in the power system's dampening. El-Sherbiny examined the use of fuzzy logic in the construction of a load frequency control system to dampen frequency and tie line power oscillations caused by various load disturbances. The suggested fuzzy logic frequency controller has two levels and is referred to as a two layered fuzzy controller. The feedback fuzzy logic controller is the second counterpart. PID controllers have recently become popular in a variety of applications. To compare with the traditional controller, Lokanatha presented a particle swarm optimization PID (PSO-PID) controller. The PSO adjusted PID controller's performance in a two-area power system has been demonstrated. The error has been decreased, and the system's dynamic reaction has greatly improved. The performance and durability of the proposed PSO-PID controller are satisfactory when compared to traditional PI and PID controllers under various load circumstances.

Ali reported that an unique artificial intelligence search approach was used to improve three-term PID parameters for a nonlinear load frequency controller. A two-area non-reheat thermal system was explored in this article. While looking for

ideal controller parameters, a technique called a bacterial foraging optimization algorithm (BFOA) is used to minimise the time domain objective function., Ahsan compares a two-term PI controller with fuzzy logic for an interconnected power system with a load frequency controller. When compared to a traditional PI controller, the results demonstrated that fuzzy logic improves transient performance.

Using evolutionary algorithms and linear matrix inequalities, Rerkpreedapong suggested two decentralised resilient load frequency control schemes in. The first one used H Infinity (H) control design, while the second used genetic algorithm (GA) optimization. Both were utilised to fine-tune the PI controller's control parameters, which were referred to as genetic algorithm linear matrix inequalities (GALMI). Both controllers presented are

To illustrate the resilience of their performances, they were tested on a three-area power system with three scenarios of load disturbances. The responses of GALMI adjusted PI load frequency controllers were virtually identical to those of robust H controllers, which have effective control performance and

resilience against probable disturbances, according to the simulation findings. Pandey developed a unique LQR control strategy in conjunction with a wind energy doubly fed induction generator (DFIG) in.

To operate the linked power system, the design controller was employed to extract the kinetic energy of DFIG. As a consequence, the suggested controller reduced the control error area and improved the tie line and frequency deviation time responsiveness. The LQR was added in the feedback element to provide a stable system with enhanced time responsiveness.

Kumari and Jha give a scientific demonstration of a two-area system in state space with an integrated warm power system. LQR is the name of the control system process, which is used in conjunction with the PI controller, which is a must. The goal of this work was to improve the frequency response of the system. The optimal state-input takes up alongside other state variables of the system for AGC was the PI controller increment.

For the system, a warm turbine for a warm region has been suggested. For a system with well designed automated area

control, the variation in frequency should be the least when the load on the system varies. PSO tweaked LQR to improve the frequency responsiveness to heap changes. Mi presented a sliding mode control LFC technique . (SMC).

The study focuses on uncertain hybrid power systems in order to minimise frequency deviations caused by mismatched parameter uncertainties, such as renewable energy sources and varied load disturbances. Based on the developed disturbance observer, the suggested controller was recreated (DOB). The result indicates an improvement in dynamic performance as well as the suppression of chattering, resulting in a more steady and faster reaction. The disturbance observer was also built to increase the sliding mode load frequency controller's accuracy.

Meanwhile, Rani suggested a multi-area AGC method using a genetic algorithm-based PID (GAPID) controller. To find the best PID controller parameter, the GAPID was modified by minimising the fitness function. The fitness function for GA was chosen using the integral of the square of the area control error (ISACE). The population size of 50 is thought to be sufficient for GA to acquire the best PID controller settings. The specified optimum

AGC techniques were applied in one of the power system sectors to accommodate a 1% load disturbance. The AGC with the GAPID controller has a settling time of 11 seconds. Finally, Karun suggested a Fuzzy Logic-based control for designing an electric car bidirectional power charging controller (EV). With photovoltaic (PV) systems, the suggested design tries to stabilise frequency fluctuation in the system. By sending a signal to all EVs, the grip operator adjusts the charging power to the desired level. The results demonstrate that the system is resilient to load variations and that the EV is stable against PV power generation.

CONCLUSION

Power stability is divided into three categories. Rotor angle, voltage stability, and frequency stability are the three basic components. A bus's voltage breakdown causes a substantial shift in frequency and rotor angle. Substantial frequency variations, on the other hand, result in large changes in voltage magnitude. To maintain stability, the power system must operate normally and consistently at rated operating conditions. Lists of contributions for managing and stabilising system frequency in a single or multi-area linked power system were mentioned in the article. The behaviour of the system

and its performance under various situations were studied using various control methodologies. It is believed that this assessment would pave the way for additional research into power system stability.

REFERENCES

1. Wang C, Nehrir MH. Power Management of a Stand- Alone Wind/Photovoltaic/Fuel Cell Energy System. IEEE Transactions on Energy Conversion 2008; 23(3).
2. Jacob T, Arun S. Modeling of hybrid wind and photovoltaic energy system using a new converter topology. Electrical and Electronics Engineering: An International Journal (EEEIJ) 2012; 1(2).
3. Almi MF, Arroufb M, Belmilia H et al. Energy management of wind/ PV and battery hybrid system. The Society of Digital Information and Wireless Communications, International Journal of New Computer Architectures and their Applications (IJNCAA) 2014; 4(1): 30-38. ISSN: 2220-9085.

4. P. Kundur, et al., "Definition and classification of power system stability IEEE/CIGRE joint task force on stability terms and definitions," in IEEE Transactions on Power Systems, vol. 19, no. 3, pp. 1387-1401, Aug. 2004.
5. IEEE TF report, "Proposed Terms & Definitions for Power System Stability," in IEEE Transactions on Power Apparatus and Systems, vol. PAS-101, no. 7, pp. 1894-1898, July 1982.
6. O. I. Elgerd and C. E. Fosha, "Optimum Megawatt-Frequency Control of Multiarea Electric Energy Systems," in IEEE Transactions on Power Apparatus and Systems, vol. PAS-89, no. 4, pp. 556-563, April 1970.
7. H. G. Kwatny, K. C. Kalnitsky and A. Bhatt, "An optimal tracking approach to load-frequency control," in IEEE Transactions on Power Apparatus and Systems, vol. 94, no. 5, pp. 1635-1643, Sept. 1975.
8. "IEEE Standard Definitions of Terms for Automatic Generation Control on Electric Power Systems," in IEEE Transactions on Power Apparatus and Systems, vol. PAS-89, no. 6, pp. 1356-1364, July 1970.
9. I. C. Report, "Dynamic Models for Steam and Hydro Turbines in Power System Studies," in IEEE Transactions on Power Apparatus and Systems, vol. PAS-92, no. 6, pp. 1904-1915, Nov. 1973.
10. Working Group Prime Mover and Energy Supply, "Hydraulic turbine and turbine control models for system dynamic studies," in IEEE Transactions on Power Systems, vol. 7, no. 1, pp. 167-179, Feb. 1992.
11. P. Kundur, "Power System Stability and Control," New York: McGraw- Hill, 1994.
12. "Current Operating Problems Associated with Automatic Generation Control," in IEEE Transactions on Power Apparatus and Systems, vol. PAS-98, no. 1, pp. 88-96, Jan. 1979.

13. N. Jaleeli, L. S. VanSlyck, D. N. Ewart, L. H. Fink and A. G. Hoffmann, "Understanding automatic generation control," in IEEE Transactions on Power Systems, vol. 7, no. 3, pp. 1106-1122, Aug. 1992.

14. Naimul Hasan, "An Overview of AGC Strategies in Power System," National conference on Recent Advances in Electrical & Electronics Engineering, RAEEE-09, NIT- Hamirpur, India, 2009.

15. C. Concordia and L. K. Kirchmayer, "Tie-Line Power and Frequency Control of Electric Power Systems - Part II [includes discussion]," in Transactions of the American Institute of Electrical Engineers. Part III: Power Apparatus and Systems, vol. 73, no. 2, pp. 133-146, April 1954.