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Review Paper on Different LFC Control Techniques for Conventional and Distributed Generation Power System

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Abstract: The paper examines the problem of load-frequency regulation in power systems. It discusses several power system models and control strategies for traditional and distributed generation-based systems. The process of balancing power generation with power consumption in order to keep system frequency and voltage within acceptable limits is known as load frequency control. It plays a critical role in guaranteeing the stability and dependability of power systems. Load frequency regulation is a critical component of electric power system design and operation. Effective LFC assures steady and consistent power supply, prevents generator overloading, and involves a collaborative effort from system operators, generators, and other stakeholders
Key words: Load frequency regulation, Power system, Distributed generation

1 Introduction

Load frequency regulation is an important part of electric power system design and operation that contributes to system stability and dependability. Load frequency con- trol is concerned with balancing power generation and consumption in order to keep system frequency and voltage within acceptable norms [1]. LFC's objective is to keep frequency and power flow within limits by adjusting generator outputs, to accommodate unstable load demands, and to deal with changes and disturbances in the power system. Various researchers have addressed load frequency control difficulties utilizing advanced control methods such as optimum control, adaptive control, self-tuning control, and intelligent control. Soft computing techniques such as fuzzy logic, artificial neural networks (ANN), and neuro-fuzzy have also been used [2]. The efficiency of LFC controllers is dependent on parameter tweaking, which can be accomplished through the use of optimization techniques like as genetic algorithms, Jaya algorithm, particle swarm optimization, and simulated annealing [3]–[6]. To address LFC difficulties in the presence of uncertainty, robust control approaches such as H, LMI, and m- synthesis are applied. Recent research on LFC in deregulated environments, with communication delays, renewable energy systems, FACTS devices, and HVDC links is also highlighted in the study [7]–[10]. The survey gives an in-depth look at LFC concerns in conventional and distribution generation-based power systems, as well as their integration with renewable energy sources [11]–[13].

2 Power system models and its type

Load frequency control (LFC) is the process of adjusting the frequency of the power system in order to keep the power supply and demand balanced. To ensure the stability and reliability of the power system, the frequency of the power system should be kept constant at 50 Hz or 60 Hz.

In the conventional power system, LFC is done by controlling the power generation of large scale power plants. However, in the DG based power system, it is more challenging to control the frequency as the generation is decentralized and scattered. The fluctuations in the power demand, weather conditions and the technical limitations of DG sources pose a challenge to maintain the stability of the system.

Therefore, the LFC in DG based power system has become an important research area in recent years. The control strategies like load shedding, demand side management, micro-grid control and storage management have been proposed to tackle the LFC issue in DG based power system.

It is significant to solve the LFC problem in both traditional and DG-based power systems because it affects power system dependability and stability, which ultimately adversely impacts customers. The deployment of appropriate LFC techniques will ensure the smooth operation of the power system and offer consumers with a stable power supply.

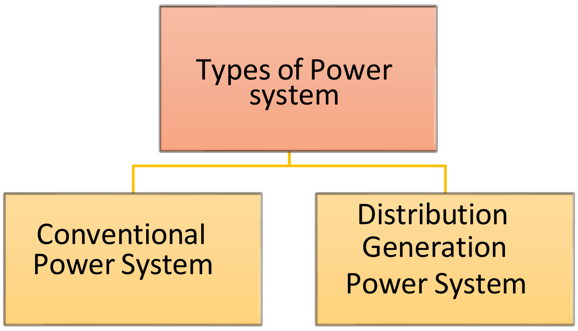

Figure 1 Electrical power system

3 Conventional power system

A conventional power system is a traditional power generating, transmission, and distribution system that generates electricity primarily through centralized power plants (such as hydro, thermal, or nuclear). These power plants are linked to the grid and pro- vide electricity to consumers via a network of transmission and distribution lines. Prior to the introduction of renewable energy sources and the development of decentralized power systems, the conventional power system was the main method of power generation and delivery.

This survey paper is divided into sections. Sections 2.1.1 through 2.1.4 examine several structures of the conventional power system.

3.1 Single area thermal power system

Single area thermal power system refers to a power generation system in which electricity is largely generated by thermal power plants in a single geographic region. The thermal power plants in this system are linked to a shared electrical grid, and the generated power is distributed to consumers in the same region. The primary goal of the single area thermal power system is to balance electricity generation and demand while maintaining a steady grid frequency. In this system, (LFC) is utilized to adjust the frequency and provide a balanced supply of power. In a single area thermal power system, the LFC system is often simpler than in multi-area systems since it just needs to consider the dynamics and control of the power plants inside the system.

3.2 Single area hydropower system

Single area hydropower system refers to a power generation system in which electricity is largely generated by hydropower plants in a single geographic region. The hydro- power plants in this system are linked toa shared electrical grid, and the generated power is distributed to users in the same region. The primary goal of the single area hydro- power system is to match electricity generation and demand while maintaining a steady grid frequency. In this system, Load-Frequency Control (LFC) is utilized to manage the frequency and provide a balanced supply of electricity. When compared to multi-area systems, the LFC system in a single area hydropower system is often simpler because it just needs to consider the dynamics and control of the power plants inside the single area.

3.3 Power system with HVDC link

A power system with a High-Voltage Direct Current (HVDC) link is a system for generating, transmitting, and distributing electrical power that incorporates a direct current (DC) transmission link in addition to the traditional alternating current (AC) transmission network. When compared to AC transmission, the HVDC link enables for the trans- mission of electricity across extended distances with reduced losses. HVDC lines are increasingly being used in power networks to connect diverse regions, integrate renew- able energy sources, and balance electricity supply and demand.

The Load-Frequency Control (LFC) system becomes more difficult in a power system with an HVDC link because it must include the dynamics of both the AC and DC systems. As the DC link can affect the stability of the AC system, the HVDC link offers new control and stability issues.

As a result, specialized control techniques are employed to regulate the frequency and assure the power system's stability.

3.4 Deregulated power system

A deregulated power system is a system that generates, transmits, and distributes electricity in a market-driven environment. The generation, transmission, and distribution of electricity are separated and operated as separate organizations under a deregulated system. To deliver power to consumers, these organizations compete in an open market. This competition in the power sector promotes innovation, lower prices, and more efficiency.

The Load-Frequency Control (LFC) system faces new issues in a deregulated power system, where control of power output and demand is decentralized and market- based. The LFC system must maintain power system stability in a highly dynamic environment where generation and demand might vary fast. In addition, the LFC system must con- sider the market incentives of the various power system actors, such as independent power producers and transmission firms. A deregulated power system's control and stability are more difficult than a standard regulated power system, necessitating advanced control techniques and a well-designed market structure.

4 Distributed generation power system

A distributed generation (DG) power system is an electrical power generating, trans- mission, and distribution system that combines small-scale, decentralized power generation units inside the distribution network. These units are often positioned near end- users and can incorporate renewable energy sources such as solar panel wind turbines, as well as traditional sources like as natural gas-powered generators.

The Load-Frequency Control (LFC) system has unique challenges in a DG power system since power generation control is decentralized and distributed among numerous tiny units. The LFC system must provide power system stability while accounting for the extremely dynamic nature of the DG units. Additionally, the LFC system must ensure that the DG units do not interfere with the distribution network's stability.

Advanced control techniques, such as decentralized control and distributed energy management systems, are often used in DG power systems to ensure the stability and reliability of the power system. The integration of DG units into the power system also requires new grid management strategies, such as the use of smart grids and energy storage systems, to balance the generation and demand of electricity.

5 Control techniques for conventional power system

Load-Frequency Control (LFC) is used in conventional power systems to manage the frequency and provide a balanced supply of electricity. A traditional power system's primary control loop consists of load speed regulation, followed by a secondary control mechanism. The following are some of the control techniques used in conventional power systems for LFC:

5.1 Droop control

This is the most frequently used secondary control technique in conventional power systems. In droop control, each generator has a specific droop setting, which is used to regulate the output power in response to frequency deviations. The generator's output power changes proportional to the frequency deviation, ensuring a balanced supply of electricity.

5.2 Integral square error (ISE) control

This is a supplementary control technique used in addition to droop control. The ISE control adjusts the generator's output power based on the integral of the frequency deviation over time, ensuring that the frequency deviations are quickly corrected.

5.3 Power system stabilizer (PSS)

This is an auxiliary control technique used to improve power system stability. The PSS changes the generator's output power based on the power system's dynamic characteristics, distributing greater stability during disturbances.

5.4 Automatic generation control (AGC)

In conventional power systems, this is a higher-level control approach used to regulate the power output of several generators. The AGC adjusts the generators' power output based on the net system load that guarantees a balanced supply of electricity.

These control approaches are employed in various combinations to assure the traditional power system's stability and reliability. The control technique used is determined by the power system's specific requirements and operating conditions.

6 Control techniques for distributed generation power system

In a distributed generation (DG) power system, the Load-Frequency Control (LFC) faces new challenges due to the decentralized nature of the power generation. The following are some of the control techniques used in DG power systems for LFC:

6.1 Decentralized control

In this approach, each DG unit has its own controller to regulate its output power in response to frequency deviations. The decentralized controllers communicate with each other to coordinate the overall power generation and ensure a balanced supply of electricity.

6.2 Distributed Energy Management System (DEMS)

A DEMS is a centralized control system that coordinates the power generation of multiple DG units. The DEMS receives information from each DG unit and adjusts the power output of the units to maintain a stable frequency and balanced supply of electricity.

Smart grid technology: Smart grids use advanced communication and control technologies to manage the distribution and consumption of electricity. In a DG power system, smart grid technologies can be used to monitor the power generation of each DG unit and adjust the power output to maintain a balanced supply of electricity.

Energy storage systems: To store extra power generated by the DG units, energy storage equipment such as batteries or flywheels can be employed in a DG power sys- tem. The stored energy can be utilized to balance electricity generation and consumption, adding stability to the power system.

These control mechanisms are utilized in accordance to assure the DG power system's stability and reliability. The control strategy used is determined by the power system's specific requirements, operational conditions, and available technologies.

7 Soft computing techniques in load frequency control

Soft computing techniques are employed in Load-Frequency Control (LFC) to increase power system stability and dependability. Soft computing approaches are computer methods based on human-like problem- solving processes like learning, adaptation, and approximation.
The following are some of the most often utilized soft computing approaches in LFC:

7.1 Artificial neural networks (ANNs)

ANNs are used to simulate the dynamic behavior of the power system and to create LFC controllers. ANNs can be trained to simulate the power system's response to various disturbances, resulting in a robust and dependable control method.

7.2 Fuzzy logic

Fuzzy logic is a mathematical framework capable of dealing with imprecision, inconsistency, and partial truth. Fuzzy logic can be utilized to create LFC controllers that deal with uncertainty and unpredictability in the power system.

7.3 Particle swarm optimization (PSO)

PSO is a computational optimization method inspired by bird or insect swarm activity. PSO can be used to discover the ideal parameters for the controllers in LFC, enhancing the power system's performance and stability.

7.4 Genetic Algorithms (GAs)

GAs are a type of optimization algorithm inspired by natural selection and evolution ideas. GAs can be used to optimize LFC controllers, enhancing power system stability and dependability.

These soft computing algorithms enable flexible and adaptable control solutions for LFC, enhancing power system performance and stability under varying operating situations. The soft computing technology used is determined by the power system's specific requirements and operating conditions. Account the greatest and worst members of the population, the entire population can be improved in each iteration. The algorithm is simple to use and put into practice because no parameters need to be set.

8 Different controllers employed for LFC

Load-Frequency Control (LFC) is the fundamental control problem in power systems, where the objective is to match the real power generation with the load and losses. The following are the most commonly used controllers in LFC.

8.1 Robust control

A robust controller is a sort of control system that performs consistently and reliably in the presence of uncertainties, changes, and disturbances. Robust controllers are in- tended to maintain the stability and performance of the controlled system even when system characteristics or external disturbances change.

Robust control techniques in Load-Frequency Control (LFC) can be utilized in power systems to increase the stability and reliability of the power system under various operating situations. Robust controllers can handle the power system's uncertainty and variability by providing a flexible and adaptive control technique.

8.2 Variable structure controller

A variable structure controller (VSC) is a type of control system that provides a flexible and adaptive control strategy in the presence of uncertainties and variations. VSCs are designed to handle the changes in the system parameters or external disturbances by adjusting the control strategy in real-time.

In power systems, VSCs can be used in Load-Frequency Control (LFC) to provide a flexible and adaptive control strategy, when there are uncertainties and disturbances.

9 Application of smes, bess and facts devices in conventional power system

Superconducting Magnetic Energy Storage (SMES) and Battery Energy Storage Sys- tem (BESS) are two commonly used energy storage systems in various applications.

9.1 SMES

SMES is a high-density energy storage system that stores and releases energy using superconducting materials. SMES's primary applications include:

Power Quality Improvement: SMES is used to respond quickly to power quality is- sues such as voltage sag, harmonics, and frequency variations and solar can be stored and released when needed. Load-Frequency Control: SMES can be used to adjust power system frequency and respond quickly to variations in load demand.

9.2 BESS

BESS is an energy storage system that stores and releases energy via batteries. The following are the primary applications of BESS:

Grid Support: BESS can be utilized to provide ancillary services such as frequency regulation, spinning reserve, and voltage management to the power grid.

Integration of Renewable Energy: BESS may store excess energy generated by renewable sources such as wind and solar and release it when needed.

Isolated micro-grids: BESS can be utilized to store energy in off-grid or isolated micro-grids.

Electric Vehicle Charging: BESS can be used to store renewable energy and then re- lease it to charge electric vehicles.

SMES and BESS are vital components of modern power systems, providing flexible and efficient energy storage options to aid in the integration of renewable energy sources while also improving power grid reliability and stability.

9.3 Flexible ac transmission system (facts) devices

FACTS devices are power electronics-based systems that are used to increase the stability, reliability, and efficiency of the alternating current transmission grid. FACTS devices that are commonly used include:

Static VAR Compensator (SVC): An SVC regulates voltage at a specific location in the power system, providing fast and accurate reactive power control.

Static Synchronous Compensator (STATCOM): A STATCOM is a shunt-connected device that provides fast and accurate reactive power control, enhancing the power grid's stability and efficiency.

UPFC: is a combination of a series-connected voltage- sourced converter and a shunt-connected current-sourced converter that provides both series and shunt correction. Itis used to control the actual and reactive power flow in the transmission grid, hence enhancing the power system's stability and reliability.

Thyristor-controlled series capacitor (TCSC): A series-connected device that uses thyristors to manage the flow of reactive electricity, boosting the power grid's stability and efficiency.

Thyristor-Controlled Reactor (TCR): A shunt-connected device that uses thyristors to manage the flow of reactive electricity, boosting the power grid's stability and efficiency.

These FACTS devices enable fast, accurate, and flexible transmission grid control, enhancing the power system's stability, reliability, and efficiency. They also contribute to lower transmission losses and higher transmission capacity.

10 Conclusion

In conclusion, Load-Frequency Control (LFC) is an important issue in power systems since it includes balancing real power generation and load while accounting for losses. Power system structure and operation have evolved dramatically over time, from traditional power systems to deregulated power systems and distributed generation power systems. LFC techniques have also changed throughout time, transitioning from traditional controllers like proportional-integral- derivative (PID) controllers to more advanced techniques like robust controllers and variable structure controllers. Soft Computing methods like Artificial Neural Networks (ANNs) and Fuzzy Logic Systems (FLSs) have also gained popularity in LFC. In addition to the controllers, FACTS de- vices such as SVC, STATCOM, UPFC, TCSC, and TCR have been introduced to improve the AC transmission grid's stability, dependability, and efficiency. With rising energy demand and increasing power system complexity, the development and deployment of new LFC techniques and FACTS devices will be critical in guaranteeing the stability, dependability, and efficiency of power systems in the future.

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