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ORIGINAL ARTICLE

A comprehensive analysis of load frequency control of multi-area power systems

Robin Jangra, Puneet Pahuja, Ashwani Kumar

Department of Electrical Engineering, Hindu collage of engineering Sonepat, India.

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Abstract

This study models the implications of reconfiguring a three-area power system on frequency control. A tried-and-true traditional load frequency control (LFC) approach is provided to improve power system performance. The tie line power and frequency fluctuation are provided with a dependable three-area power system. A PID controller and one without were made for this Simulink model. The system is transferred without changes in tie line power or frequency variation from its starting condition to its final form. In other words, the precision of the ultimate steady state is zero. These results are compared in terms of how the load is distributed between systems with and without integrated controllers for three area power systems. For this application, MATLAB/SIMULINK software is used. An LFC problem is brought on by frequency changes brought on by the power system's demand varying over time. The variability in frequency is quite detrimental. The frequency can vary by no more than 0.5Hz. To address these problems, a novel fuzzy LFC is proposed to quench the frequency and tie-line power variation caused by various load disturbances. The fuzzy control method used in this work to perform LFC was quicker than the PI controller.

1. Introduction

By modifying the MW outputs of the load frequency control (LFC) generators to account for varying load demands, the power system's load frequency control (LFC) maintains the frequency of each region and tie-line power flow within a prescribed tolerance. Additionally, LFC is an autonomous generation control system (AGC). In the past 60 years, much research on the LFC of networked systems has been published. Many control strategies have been used to improve dynamic performance in the design of load frequency controllers [1-5]. It is typically necessary to transmit power using a three-phase alternating current (A.C.). However, this could be done by balancing the reactive and active power on the generation and use sides. Voltage and frequency are each affected separately by active and reactive power. While the voltage relies on active power, the frequency primarily depends on reactive power [6]. Due to the imbalance between generation and demand for the loads and system losses, the LFC problem is one of the most critical problems in large-scale power systems. A vast, interconnected electricity system requires more monitoring and upkeep than previously. Due to its dispersed nature and the requirement for advanced control capabilities in the smart grid (SG) context, the LFC issue has recently taken on a substantial amount of significance. Traditional centralized LFC systems have several challenges due to information exchange restrictions with large-scale, widely dispersed control regions and their increasing computing and storage complexity.

Corresponding author: Robin Jangra
Email Address: jangraaakash5@gmail.com
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Creating distributed/decentralized LFC structures might be an excellent solution to this issue. Distributed control is more practical, dependable, easy to use, and economical [7]. For a power structure to maintain a regular and dependable activity, it must be in operation. Disasters like the power blackout in July 2012 in India due to dissatisfaction with keeping up as feasible across grids, might result from deviation from the optimum repeatItalia, Southern Brazil, the Northeastern United States, and Canada all experienced blackouts due to the shift in occurrence. Transient reactions are further encouraged by standard regulators, such as PID, in the available System of Load Flow power. With a proportional-integral controller, a better edge of unwavering quality is guaranteed. With zero overshoot, the proportional integral controller produces a dependable state blunder. Recurrence control refers to the problem of regulating the actual output power of forming units due to variations in structural repetition and tie-line power not fixed in explicit stone emphasis. LFC aims to provide zero dependable state error of duplication and tie-line trade variety, high repeat motion damping, and reduced aggravation overshoot, so the framework isn't unreasonable far from security. A power structure is frequently divided into control areas, each of which has at least one association with a utility of power. Adequate supply for individually associated location to meet customer load requirements [8]. According to a literature review, multi-area interconnected hydro-thermal systems have received considerably less attention than linked thermal systems in LFC [9]. The proportional & integral (PI) and balanced, critical & derivatives (PID) controllers have superior dynamic responses and are relatively easy to construct. Still, their performance degrades when the system complexity rises owing to non-linearity, such as load and boiler dynamics [10]. Therefore, a controller that can solve this issue is required. Fuzzy and neural control techniques are examples of artificially intelligent controllers that are better suited in this regard. The LFC issues have been addressed in fuzzy systems, and the results are encouraging [11].

2. Interconnected power system and its advantage

A linked system is more significant than a single isolated system regarding the LFC problem. However, the conceptual problem of a single area is more crucial to comprehending the issue of a linked power system. Today, all electricity infrastructure is linked to its neighbours, creating the LFC dilemma.

2.1 Impact on size

One of the critical advantages of the integrated power framework will be this one. The increased strength is momentarily derived from the machine motor power at the point in time when the load block is introduced. The availability of energy is often essential for larger systems. It has a smaller static recurrence decrease than that. Despite having a one-region power structure, the same amount of load adjustments could result in a superior rate of recurrence decline.

2.2 Necessitate to decrease preserve capability

Since peak loads do not occur at any particular time or place, they might occur at any random moment of the day in many locations. The ratio between peak and load is typically lower for an extensive power system than for smaller systems. Consequently, a decreased necessity for breaking points possessed by the intended associations of exchanging energy can benefit all tie-line or linked power framework places.

2.3 Utilization of more established plant

There aren't enough old and inadequate producing stations available in the power framework organization to run continuously, although they can theoretically support temporary peaks in load. The transmission line connects these plants—which are used to meet peak load demand—and the existing plants if the framework is interconnected. By aiding older and insufficient production sites, we can fulfil peak load demand without adding more load to current facilities.

2.4 Affordable process

Every generating station use the same voltage and repetition stage. For the power plants to easily employ greater effectiveness and control, load sharing is implemented. Older, less skilled production facilities are not continuously employed; instead, they are specifically used for entire shifts. As a result, the system's connectivity enables the power stations to operate efficiently.

2.5 Decrease Plant Preserve Ability

Every energy plant has a reserve unit if a crisis arises. If an integrated framework existed, all plants would be related equally. In this approach, the framework's efficacy is increased, and the associated framework's limit is decreased.

2.6 Increment Diversity factor

It is a ratio between each customer's maximum demand and the power plant's overall maximum demand. All creating stations in a linked framework have a different load curve. In this approach, connectivity improves the diversity factor and increases the amount of maximal individual demands on separate power stations relative to the system's overall requirement. Additionally, the sufficient capacity grows.

3. Droop Characteristics

Drooping refers to the reduction of a value to a reference. When loaded, the primary PRIME MOVER's actual speed is allowed to "droop" or decrease compared to the reference speed. As load increases, lead representative capacity reduces lead representative reference speed. The mechanical management representatives' job is integrated into the management structure and cannot be changed. The temporary droop that hydraulic lead representatives might incorporate is known as compensation. Isochronous speed control is the ability to return to the original speed after changing the load. A load increase would cause the motor to slacken. As the control valve position shifts to increment with the droop.

$$\text{Droop\%} = \frac{\text{No load speed} - \text{full load speed}}{\text{No load speed}}$$

If the machine's blade rotation speed drops from the turbine's rated speed of 3000RPM under no load conditions to 2860RPM, the droop percentage is 4% when it is piled from no or free load to base load. The speed will be 104% for this situation's base or reference, but the actual rate will be 100%. Droop lead representatives often reduce the reference speed from 4 to 6 of the reference speed across the scope of the demonstrative yield.

4. Hydro-Thermal interconnected system

The LFC of the power system is crucial to the generation of electricity. A specific number of load recurrence control regions that are connected by tie lines may be segregated from the power framework. Currently, the main goal is to manage or limit the recurrence of every area and to continue managing the tie line power according to region. If there is a change in the system load in the primary LFC loop, it will result in a consistent state variation in frequency and depend on the lead representative's speed guideline.

The modelling of thermal speed governor is

$$\Delta Y_E(s) = \left(\frac{K_{gs}}{1+ST_{gs}}\right) \times \left[\Delta P_C(s) - \frac{1}{R}\Delta F(s)\right] \quad (1)$$

Thermal generator modelling may be expressed as

$$\Delta F(s) = \left(\frac{K_{PS}}{1+sT_{ps}}\right) \times \left[\Delta P_G(s) - \Delta P_D(s)\right] \quad (2)$$

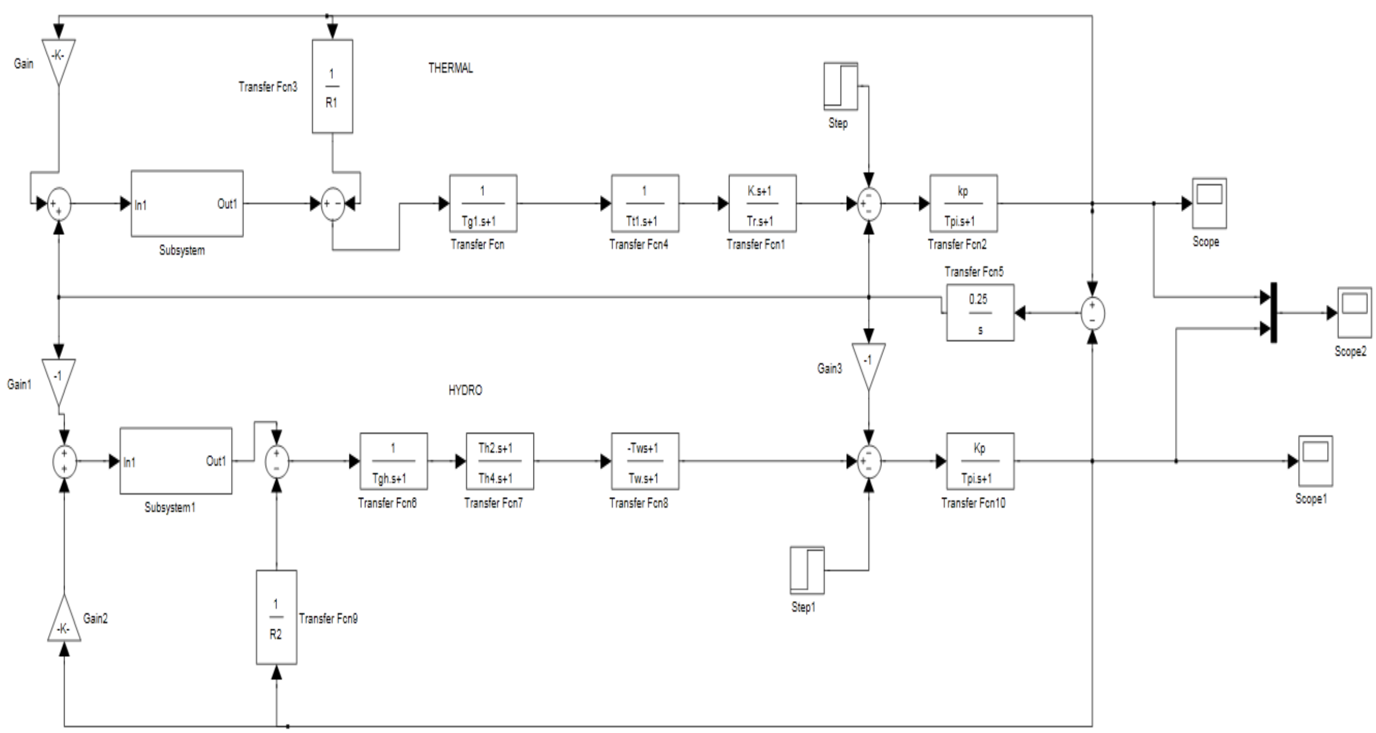

Figure 1: Two area thermal hydro system diagram

Where

K_{gh} Gain of Governor speed
T_w Starting time of water
T_{gh} Time constant of Hydraulic speed governor
B_i Frequency Biasing Parameter
K_p Load
T_r Constant of reheat time
T_{t1} Time constant of steam turbine
T_{g1} Time constant (speed governor) of thermal plant

The transfer function of thermal load may be written as

$$\Delta F(s) = \Delta P_m(s) - \Delta P_D(s)\left(\frac{1}{2Hs+D}\right)$$

A speed governor, turbine, and generator model were necessary for the hydroelectric power framework used to demonstrate LFC. The pressure-driven opposition is assumed to be inconsequential, the penstock pipeline is considered to be inelastic, and water is assumed incompressible to provide a stable depiction of the hydraulic turbine and water column.

T.F of hydro turbine is shown as $\frac{\Delta P_{Th}}{\Delta Y_{eh}} = \frac{1-sT_w}{1+0.5sT_w}$
Transfer function of hydroelectric governor is

$T_{Gh} = (\frac{K_{gh}}{1+sT_{gh2}})(\frac{1+sT_{h2}}{1+sT_{h4}})$

Load model for hydro system

$\Delta P_{e\,=} = \Delta P_L + D\Delta w$

The results were obtained by using techniques i.e, like PI, AI, Fuzzy Logic Controller etc.

5. Three area Thermal-Nuclear-hydro system

The research's three-region power framework is made up of thermal energy generating units with warmers in one area, a hydroelectric generating unit in the second, and nuclear power generating units in the third. Through tie lines, these three locations are connected. As far as settling time is concerned, the three regions are fundamentally different. Fig. 2 shows working model representations for the framework of three areas under investigation. There is no doubt that the statement "LFC has two control loops" refers to the complete control over any slight deviation that took place inside the area.

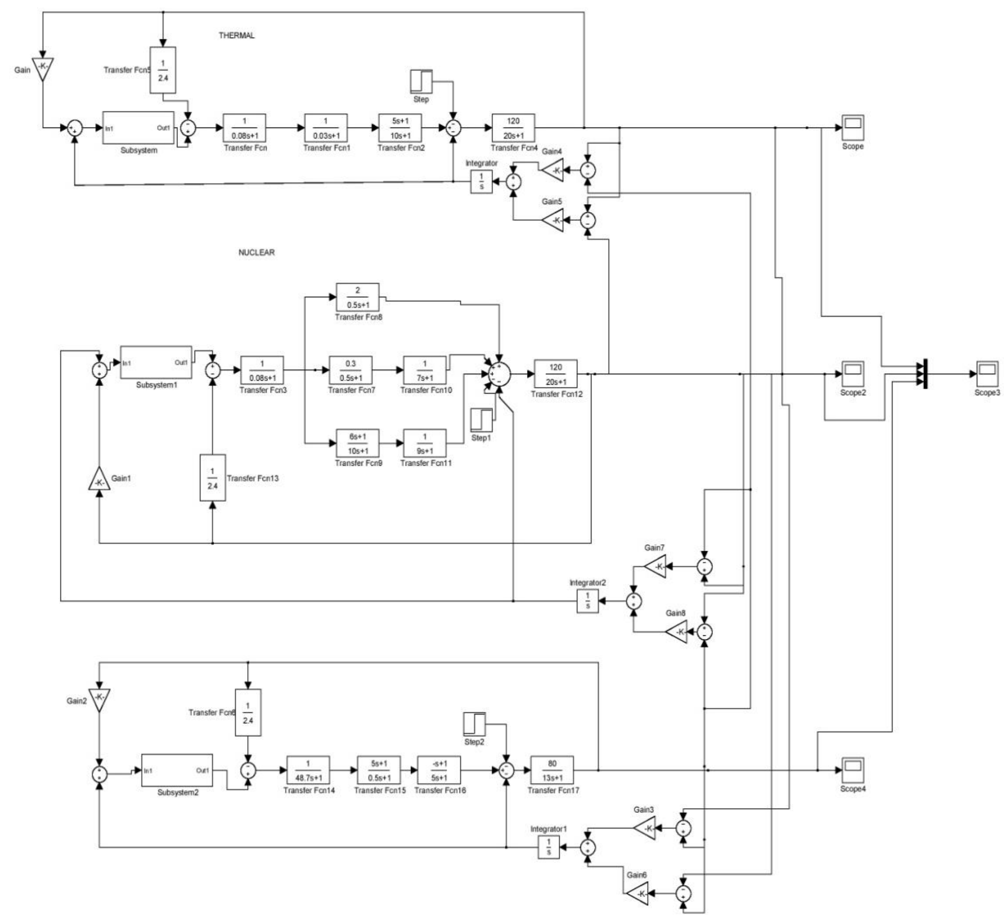

Figure 2: Simulink model three area system

On the other hand, auxiliary control is only applied after the primary regulator has taken action. The predicted regulators are examined for intra-regional variance in recurrence and tie-line power in an alternative control circle. The interdependence of at least two force frameworks is done using the timeline. The tie line causes the electric force to advance between two places. When the load in that area changes, a region will get energy by utilizing timelines from another location. Consequently, based on this number, each area gives a percentage of its capability to every other component. Thermoelectric reheat, pressure-driven, and LP and HP turbines are the three categories considered here. The superiority and development of recurrence-sensitive firms were significantly influenced by the variation in recurrence across all locations. As a result, the life of machine components is reduced on the load side. The progressions regarding replication and timeline control stream affect every place in the load. Every area's chronological power stream and repetition rate must be restricted. Similar to discussing the demonstration of a two-region power framework is the presentation of a four-region power framework using a controller. This system solves the frequency issue in two area power systems using a conventional controller and artificial intelligence approaches.

6. Controlling methods

6.1 Fuzzy logic controller

The fuzzy theory has a variety of applications. In addition, fuzzy thinking is referred to as FLC. A fuzzy control system is a control system that relies on fuzzy logic mathematics and analyses fundamental information values up to sensible factors that have constant values between 0 and 1, as opposed to digital logic, which operates on discrete upsides of one or more 1s or 0s. Fuzzy logic controllers tackle various control difficulties for system dependability since traditional controllers are less effective in non-direct framework applications and operate more slowly

6.1.1 Defuzzifier

It transforms ambiguous values into precise ones.

6.1.2 Fuzzification

A cycle of adding a crisp quantity into the fuzzy is called "fuzzification." They exhibit remarkable susceptibility. At that time, the variable can be ambiguous and be addressed by a membership function if the kind of vulnerability occurs to increase due to imprecision, uncertainty, or ambiguity.

6.1.3 Defuzzification

Fuzzification is the conversion of a particular amount to a fuzzy amount, while defuzzification is the transformation of a fuzzy number into a crisp amount.

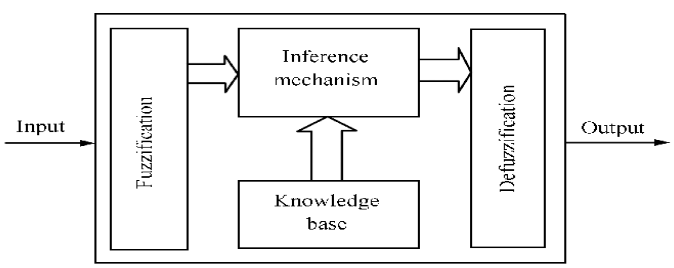

Figure 3: Fuzzy Inference system

6.2 Rule base for Fuzzy logic system

Information signals are originally converted to fuzzy no using membership functions in the fuzzifier. The use of fuzzy logic to manage the operation of physical systems is known as a fuzzy logic controller. It also employs membership functions to specify input variables as fuzzy variables in fuzzy logic controllers. The result of the fuzzification process is then forwarded to the inference module. It consists of a fuzzy rule base that accepts fuzzy inputs, produces potential fuzzy outputs, and serves as an input for defuzzification. Which transforms the fuzzy output into a crisp value; the defuzzifier procedure then achieves the result, and the rest of the process continues as shown in fig. 4-10..

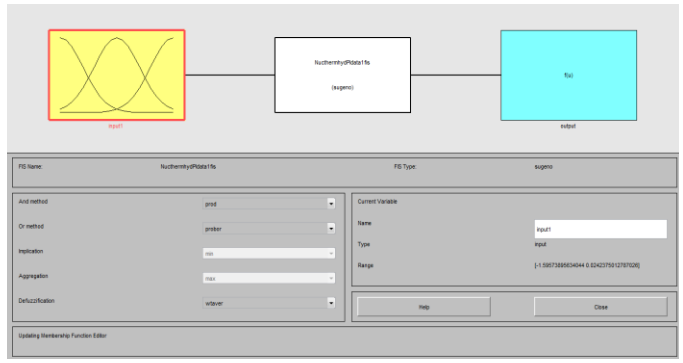

Figure 4: Scheduling of Fuzzy gain

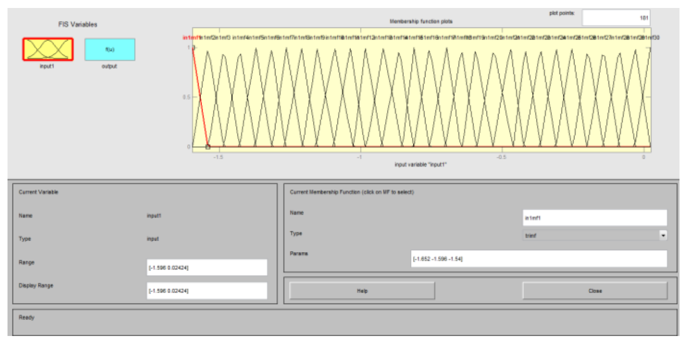

Figure 5: Thermal plant's I/P M.F

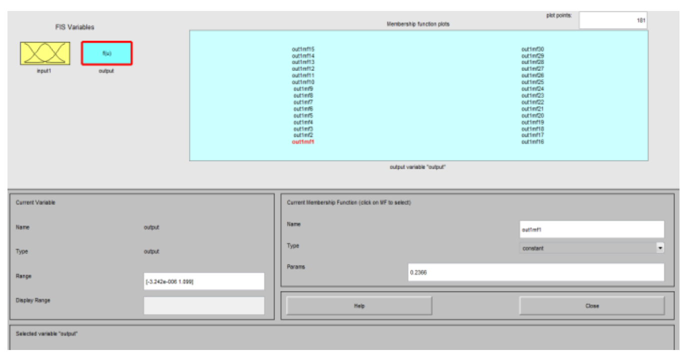

Figure 6: Thermal plant' O/P M.F

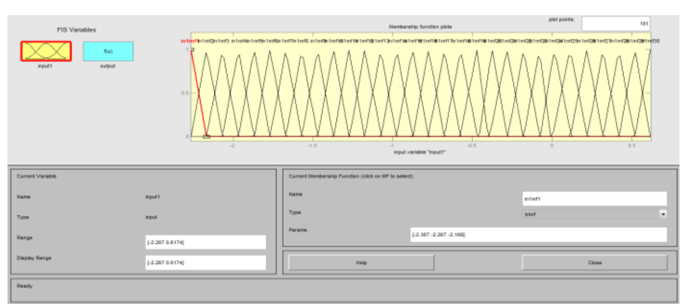

Figure 7: Hydro plant' I/P M.F

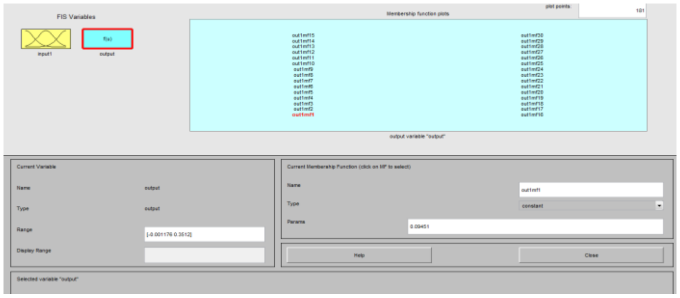

Figure 8: Hydro plant's O/P M.F

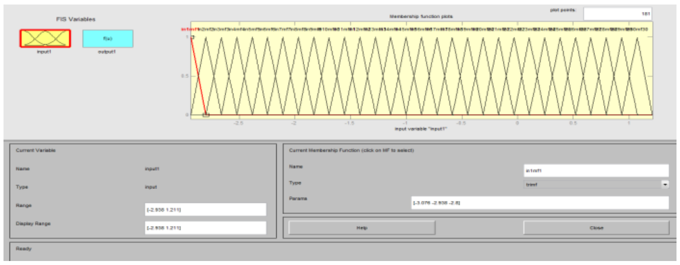

Figure 9: Nuclear plant's I/P M.F

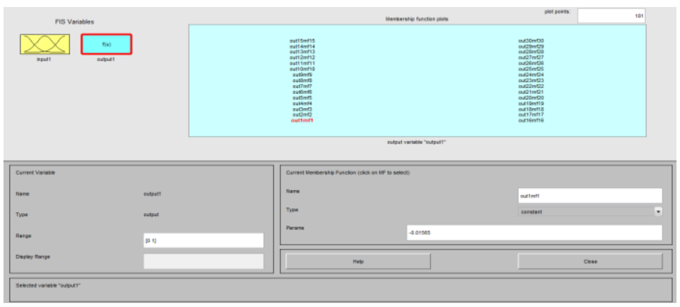

Figure 10: Nuclear plant's O/P M.F

7. Conclusions

When two or more plants are linked together, the different advantages also apply, i.e., In a power framework organization, there are only a few inadequate and old production facilities that can manage a brief peak load. Nevertheless, these industrial facilities are too run-down to be used constantly. The transmission line connects these plants, which are utilized to satisfy peak load requirements and to complement the existing plants if the framework is linked. Utilizing inadequate and antiquated production facilities may meet top load standards without putting additional strain on more modern units.

The voltage and repetition rate used by the generating station is the same. The connectivity at the power plant is dependable and efficient. The connection of the power framework includes several suppliers for each load. If one inventory fails in this scenario, the load is given from a different source. For this reason, in the event of a significant power station breakdown, the load is linked to different healthy power stations. As a result, system dependability is increased since the load is constantly connected to a consistent power supply. The Fuzzy Controller reacts swiftly to a 1% disturbance, and its settling period is also short, proving that FLC responds more forcefully than a PI regulator. A fuzzy regulator significantly diminished the transient's response.

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