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Stand Alone Power System Load Frequency and Excitation Voltage Control Techniques Review

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ABSTRACT
Failure in regulating active power demand could result to varying machine speed from its set values, thus leading to fluctuations in operating frequency .Generator excitation must be regulated continuously to match both demanded and generated reactive power. If this regulation is not done, it always leads to bus voltages exceeding and swinging beyond their allowable limits, excessive wear and tear of the rotating machines and control equipment, loss of synchronism etc. Thus the need to study how these controls are done has become sacrosanct. In this work, comparative analysis of Load Frequency Control (LFC) techniques is reviewed as the purpose of these controls is to ensure allowable frequency stability at any point in time on the power system network. These include Fuzzy Logic Control (FLC), Proportional Integral Derivative control (PIDC), Uncompensated system using pole placement Control (PPC), Optimal Control System, Automatic Generation Control (AGC) and series compensator techniques.

Key words: Load Frequency Control (LFC), Fuzzy Logic Control (FLC), Proportional Integral Derivative control (PIDC)

1. INTRODUCTION

Stand-alone power system (SAPS or SPS) also known as remote area power supply (SAPS), is an off grid electricity system for locations or areas that are not fitted with electricity distribution system [1]. Millions of people living in coastal community, small remote villages or islands lack access to electricity because they are far from power grid [2]. Utility grid extensions to off grid locations are impractical and uneconomical because of conditions such as dispersed population or rugged terrains. As a result, electricity demand of such places is normally powered by diesel generators. Although electrical power systems are designed to have constant supply of Electrical Energy to Electrical Loads. However, active and reactive power demands are never steady and continually change with rising or falling trend that is observed at the consumer terminal. Power sources such as one from Generating Plant must be continuously regulated to match active power demand. Failing to regulate it will vary machines speed from its predetermined value which in turn leads to changes in operating frequency [3]. The excitation of generator must be continuously regulated to match reactive power demand with reactive generation, otherwise voltages at various system buses may swing beyond prescribed limits. The generating plant is not only regulated to meet active power demand but also required to meet reactive power demand by constantly regulating the excitation of the generator; failure of which will lead to voltages exceeding the prescribed limits at various system buses. Thus the generating plant controllers need to be adjusted manually or automatically to meet these needs [4]. In modern interconnected systems, manual regulation is not feasible and therefore controllers are installed to take care of small changes in load demands without frequency and voltage exceeding the prescribed limits. With the passage of time as the change in load demand increases and becomes large the controllers need to be reset either manually or automatically [5]. It is true that for small changes, active power is dependent on internal machine angle δ and independent of bus voltage. Change in angle δ is caused by momentary change in generation speed. Therefore, load frequency and excitation voltage controls are non-interactive for small changes and can be modeled and analyzed independently. The main difference between control of excitation voltage and that of frequency is that excitation voltage control is fast acting because of the time constant encountered and also that of the magnetic field of the generator, while frequency control is slow acting since the major time constant is contributed by the turbine and generator moment of inertia. Due to speedy response of excitation voltage control, transients encountered disappear much faster and have little or no effect on dynamics of power frequency control [6].

Changes in load demand can be identified as slow varying changes in mean demand or fast random variations around the mean. The regulators must be designed to be insensitive to fast random changes; otherwise the system will spend more time changing its regulation which will result to excessive wear and tear of rotating machines and control equipment. The control of Generators by means of automation adopts a technique of adjusting the output power of several generators at different plants in response to variations in load demand [5]. Proportional Integral Derivative (PID) controller is a generic loop feedback controller widely used in industrial control systems. It attempts to correct error between measured process variable and desired set point by calculating and then instigating corrective action(s) that can adjust the process accordingly and rapidly, to keep the error minimal. PID controller calculation involves three separate parameters; Proportional, Integral and Derivative values. The proportional value determines the reaction to current error. Integral value determines reaction based on the sum of recent errors, and the derivative value determines the reaction based on the rate at which the error has been changing [7-9]. The weighted sum of these three actions is used to adjust the process via a control element such as position of control valve or power supply of a heating element. The system dynamics are described by a set of linear differential equations and the cost is described by a quadratic function called LQ problem. One of the main results in the theory is that the solution is provided by Linear-Quadratic Regulator (LQR). In layman's terms, it means that the settings of a (regulating) controller governing either a machine or process (like an airplane or chemical reactor) are found by using a mathematical algorithm that minimizes a cost function with weighting factors supplied by human (engineer). The "cost"(function) is often defined as sum of deviations of key measurements from their desired values. In effect, this algorithm therefore finds those controller settings that minimize the undesired deviations, like deviations from desired altitude or process temperature. Often the magnitude of the control action itself is included in this sum so as to limit the energy expanded by the control action. LQR algorithm is, at its core, just an automated way of finding an appropriate state feedback controller. As such it is not uncommon to find that control engineers prefer alternative methods like full state feedback (also known as pole placement) to find a controller over the use of LQR algorithm. With these, the engineer has a much clearer linkage between adjusted parameters and the resulting changes in controller behavior. Thus this work aim to carryout comparative analysis of load frequency control techniques. This study evaluates the following frequency control techniques; Fuzzy Logic control, Proportional integral control, uncompensated system and Automatic generation control.

2. LITERATURE REVIEW

The main aim of power systems engineers is to provide the required power supply to customers with a given quality voltage and frequency. Considering the growing energy demand of customers, stability and reliability of power systems are important. Load-Frequency Control (LFC) problem in power system deals with sudden disturbances that disrupt normal conditions of system operation and occur due to outage and connection of loads on different hours in power system. Any change in active power demand is reflected throughout the system as frequency change. The problem of output active power control in response to power system frequency changes and between regional power system lines in a specified range is known as LFC problem. For optimal performance and operation, frequency changes must be maintained within certain limits. Many process control systems, such as computers, are sensitive to changes in frequency and their operation is impaired. For such systems, their frequency must be regulated and controlled [10]. Therefore, adequate supplementary controller to regulate and prevent frequency deviations must be used in the main control center. The purpose of LFC problem is to maintain uniform frequency and adjust/control converted power between areas of power system in a planned manner. In other words, solving LFC problem is aimed at keeping the system's steady-state error on zero. In previous studies on solving LFC problem, various methods have been used. In the proposed methods, PI controller is most widely used in industry. Proportional Integral (PI) controller has a fixed gain that is designed in rated operating conditions and its utilization is simple, but frequency oscillations can also appear in this case. This means that PI controller indicates poor dynamic performance against system parameters variation and non-linear conditions such as generation rate constraint [11-12]. Different types of fixed gain controllers are designed in rated operating conditions while they are unable to achieve performance in practice under many changes in the operating conditions of the system. In order to solve LFC problem and to minimize power system deviations, operating conditions and system parameters variations must be considered; genetic algorithms and other intelligent methods can be used to improve PI controller performance and optimize controller coefficients. As for the non-linearity of power system and inability to extract its precise mathematical model, in recent years the use of fuzzy logic method in design of controllers was proposed [13]. Many research works on frequency and voltage control have been proposed. There has been ongoing interest in designing load frequency controllers with better performance to maintain the frequency and to keep tie-line power flows within pre-specified values, using various decentralized robust and optimal control methods during the last two decades [10]. However, most researchers suggest complex state-feedback or high order dynamic controllers, which are not practical for industrial practices. The existing LFC systems in the practical power systems use PI type controllers that are tuned online based on classical and trial-and-error approaches. Recently, some control methods have been applied to design the decentralized robust PI or low-order controllers to solve the LFC problem. A PI control design method has been proposed, which uses a combination of $H\infty$ control and genetic algorithm (GA) techniques for tuning PI parameters. The sequential decentralized method based on m-synthesis and analysis has been used to obtain a set of low-order robust controllers. The decentralized LFC method has been used with structured singular values. The Kharitonov theorem and its results have been used to solve the same problem.

3. REVIEWING VARIOUS CONTROL METHODS

It should be noted that the primary aim of power frequency control is to ensure a stable state of constant frequency and also to control the power system in an orderly manner within a region. In the quest for finding suitable controller to achieve this objective, several methods of frequency control by various researchers has been reviewed including merits and demerits of each of the frequency control technique.

3.1. PID Controller Techniques

PID controller is the most common form of feedback control system. It attempts to correct the difference between the process variable and predetermined set point by calculating and making corrective actions that can adjust the process to required condition. PID controller is made up of three separate parameters; proportional, integral and derivative actions. The proportional gain offers high stability and frequency response. The integral action makes it possible for the average error to go to zero. One of the advantages of PI controller is that only two gains can be tuned and there is no long-term error in the system. This technique usually delivers highly responsive systems. The main weakness of PI controllers is that it produces excessive overshoot to a step command. It is described by the transfer function as:

$$Gc(s) = K_p + Ki/s \qquad 3.1$$

PI controller is an example of lag compensator. It retains a zero at s = -1/Ti and a pole at s = 0. A typical PI controller has an immeasurable increase at zero frequency and helps to improve steady-state characteristics of the system. The addition of PI control action in the system raises the number of compensated system by 1 and this make the compensated system to be unstable. The values of Kp and Ti need to be selected with caution to ensure that suitable transient response is achieved over a period of time. When designing PI controllers, transient response to a step input can be made to display comparatively small or no overshoot. The response speed becomes much slower. The formulations of PID controllers make them simple and adaptable to different controlled plants. However, if the system is of higher order and nonlinear in nature, then it cannot yield a good control performance. The PID controller is made of PI and PD. The lead compensator of PD controllers enhances transient-response characteristics of the system. This will improve the stability, bandwidth and fast rise time of the system. PI and PD control actions respectively occur in diverse frequency states. PI and PD control action takes place at low and high- frequency regions respectively. For improvement in both transient and steady-state performances, PID controller is more appropriate.

MATLAB function: [numo, deno, denc] = rl design (num, den, s1) is used in simulating PID controllers. However, PID system can display maximum overshoot in the step response, which is undesirable. In this regard, selective tuning is needed until a suitable outcome is achieved. The Ziegler-Nichols tuning law provides a sophisticated prediction for the parameter values and give an initial point for fine tuning, instead of providing the final settings for Kp, Ti and Td in a single shot.

PID controller is a static parametric controller that has dynamic power system and its pattern varies in responds to expansion. Thus, fixed parametric PI or PID controllers are constrained to provide optimal performances. To deal with these difficult dynamic and uncertain situations, fuzzy logic was proposed by many researchers. PID controller combines proportional, integral and derivative components to obtain classical equations. Most PID controllers do not use derivative action which consequently means that the most suitable name is PI controllers. However, the generic name (PID) is still maintained for this class of controllers. Despite the simplicity and the common use of this type of controller in practice, it has its drawbacks [7-9].

3.1.1 Proportional Action, Kp

Proportional action facilitates the changes to the output proportional to recent error value. The response from Proportional term is regulated by increasing the error by a constant Kp, which is called proportional gain. Thus, the larger the error the greater the correcting factor. When the proportional gain is set too high the system will suffer oscillation due to controller's overshooting the set point. One disadvantage of proportional loop is that when the error becomes too smaller, loop output becomes negligible. Thus even when the loop reaches steady-state, there is still error in the system. The larger the proportional gain the more likely the loop is becoming unstable. The output of proportional term is the product of proportional gain, Kp and measured error, e. The proportional term is as shown in equation 3.2

$$P_{out} = K_p e(t) \qquad 3.2$$

where; P_{out} is Output of Proportional term;
K_p: Proportional constant;
e: Error (Predetermined value - Actual value);
t: Time in seconds

3.1.2 Integral Action, Ki

Integral action (is also called reset), it stores all measured error over a given period of time. In other words, it sums all the errors at a particular given time before taking correcting actions. While the proportional takes care of immediate error, the integral takes care of past, error. It does this by accumulating and summing all the errors for correction. One limitation of integral action is the time lag that slows the system due to the accumulation and correction of error. The stored error gotten from accumulation is multiplied by the integral gain before it is added to the controller output. The integral gain, Ki controls the magnitude of the input of the integral term to the whole control action.

The integral term is express as:

$$I_{out} = K_i \int_0^t e(\tau)d\tau \qquad 3.3$$

where I_{out}: Output of Integral term;

Ki: Integral gain,;

e: Error (Predetermine Value- Actual Value)

t: instantaneous time;

τ: Dummy Variable

3.1.3 Derivative Action, Kd

The derivative Action is the least used factor of the three components of the PID. Majority of the PID controllers are actually PI controllers but derivative factor plays certain roles in the control system. The derivative term is influenced by the rate of change of the actuating signal. This rate of change is obtained by determining the slope of the error over a period of time. Again, if the derivative gain Kd is multiplied by the slope, the change in process error is obtained. The derivative gain, K this degree of the contribution of the derivative term to the overall control action. The most important effect of the derivative term is to counter act the overshoot resulting from P and I (Proportional and Integral terms). The derivative term is express as:

$$D_{out} = K_d \frac{d}{dt} e(t) \qquad 3.4$$

D_{out}: Derivative term output;

Kd: Derivative gain;

e: Error (Predetermined Value-Actual Value)

t: time in seconds.

3.2 Optimal Control System

This method is applied as a strategy to reduce the performance index of the system variables. Quadratic performance index for linear systems could also be referred to as linear quadratic regulator. The main objective for designing the optimal regulator is to obtain the law, u*(x, t) which is capable of moving the system from its initial state to the final state by reducing the performance index. The quadratic performance index is extensively used in optimal control design.

Consider a plant:

$$\mathrm{X}(t) = \mathrm{A}x(\mathrm{t}) + \mathrm{Bu}(t) \qquad 3.5$$

The vector K of the control law can be determined.

$$U(t) = -K(t) * x(t) \qquad 3.6$$

Which reduces the value of the quadratic performance index J of the form

$$\mathrm{J} = \int_{t_0}^{t_f} (x'Qx + u'Ru)dt \qquad 3.7$$

Where Q is a positive semi definite matrix and R is real symmetric matrix.

Lagrange multipliers method using an n vector of the unconstrained equation is used to obtain the solution.

$$\boldsymbol{\mathcal{L}}(x, \lambda, u, t) = [x'Qx + u'Ru] + \lambda'[Ax + Bu - \dot{x}] \qquad 3.8$$

Equating the partial derivative to zero, optimal values are found.

Further deduction of equation 3.19 will lead to Riccati equation which is given by:

$$\dot{p}(t) = -p(t)A - A'p(t) - Q + p(t)BR^{-1}B'p(t) \qquad 3.9$$

Where p(t), varies the time of positive matrix which satisfy equation 3.10

$$\lambda = 2\mathrm{p}(\mathrm{t})\mathrm{x}^* \qquad 3.10$$

The MATLAB Control System Toolbox function [k, p] = lqr2(A, B, Q, R) can be applied in the solution of the algebraic Riccati equation.

3.3 Automatic Generation Control (AGC)

When the load on a system suddenly increases, the turbine speed drops before the governor could regulate the steam input to the new load. As the speed of the turbine decreases the error signal becomes smaller and the governor positions as well as the fly balls get closer to the point where the speed is constant. However, addition of an integrator is another way of recovering the speed or frequency to its real value. This integrator has the capacity to monitor the average error over a length of time and also overcome the offset. As the load in the system varies uninterruptedly the generation is regulated automatically to bring the frequency to its nominal value. Thus, a process that adopts this method is called

AGC. An interconnected system comprising of several areas, the duty of AGC is to share the load between the systems, stations and generators to attain maximum and steady frequency.

3.3.1 AGC in a Single Area

Application of Load Frequency Control (LFC) loop causes variation in the load which will result in a stable state of frequency deviation, based on the regulation of the governor. It is possible to reduce the frequency deviation to zero, if reset action is done by means of an integral controller to act on the setting of the load reference to change the speed set point. With the integral controller, the system type would increase by one (1) which will enable the frequency deviation to go to zero. The gain of integral controller is essential to be regulated to obtaining suitable transient response.
The control system of a closed loop transfer functions for AGC in a single area of power network is given by:

$$\frac{\Delta\Omega(s)}{-\Delta P_L} = \frac{s(1+\tau_g s)(1+\tau_T s)}{s(2Hs+D)(1+\tau_g s)(1+\tau_T s)+k_i+s/R} \qquad 3.11$$

3.4 Pole Placement Technique

Alrebdi A *et al* [6] proposed optimal pole placement technique controller for quick damping of power system frequency. In their research, hybrid power system was subjected to the influence of various frequency variations and disturbances. Power system response to these disturbances was observed and comparisons were made between conventional pole placement controller and proposed optimal pole-shifting controller. The result of the digital simulation shows that the proposed optimal pole shifting controller was more responsive than the conventional pole-placement controller regarding fast damping oscillation and small settling time. However, the challenge with this method was how to shift the poles to desired locations while also preserving the imaginary parts. The findings suggested that the shift will be achievable with an optimal feedback control law with respect to quadratic performance index without solving any non-linear algebraic equations.
Pole placement or pole assignment technique is a method where assumption is made on the state variables so that measurement can be done for feedback. A system that is state controllable, have the poles of its closed loop at any desired location with the aid of state feedback through a suitable matrix of state feedback gain. Matlab software can effectively solve the problems of Pole-placement. This software has two commands that are used for the calculation of feedback-gain matrix K:
a). Acker
b). Place
The acker command is founded on Ackermann's formulation and it applies only to single-input systems. Ackermann's formula is given by:

$$K = [00 \ldots 01]S^{-1}a_c(A) \qquad 3.12$$

Where S is given by:

$$S = [B\ AB\ A^2B \cdots A^{n-1}B \qquad 3.13$$

And the notation $\alpha_c(A)$ is given by:

$$a_c(A) = An + a_{n-1}A^{-1} + \ldots\ldots + a_1A + a_0I 3.14$$

The closed-loop poles that are chosen can contain multiple poles (these are poles that are positioned at the same place). In case the system has several inputs, for a set of closed-loop poles, the state-feedback matrix gain K, is not distinctive. This will result to additional freedom to obtain K. It is normally use to maximize the stability margin. Pole placement that adopts this approach is called the robust pole placement and the MATLAB command, "place "is used for the robust pole placement. While the command "place" can be used for single and multiple-input systems, it is required that the multiplicity of poles be less than the rank B in the desired closed-loop.
The application of this theory in the load frequency control of an isolated power system is express as follows:

$$(1+\tau_g s)\Delta P_V(s) = \delta P_{\text{ref}} - (1/R)\Delta\Omega(s) \qquad 3.15$$

$$(1+\tau_T s)\Delta P_m(s) = \Delta P_V$$

$$(2Hs + D)\Delta\Omega(s) = \Delta P_m - \Delta P_L \qquad 3.16$$

Solving for the first derivative term;

$$s\Delta P_V(s) = -(1/r_g)\Delta P_V - (1/Rr_g)\Delta\Omega(s) + (1/r_g)\Delta P_{\text{ref}} \qquad 3.17$$

$$s\Delta P_m(s) = (1/r_g)\Delta P_V - (1/r_g)\Delta P_m \qquad 3.18$$

$$s\Delta\Omega(s) = (1/2H)\Delta P_m - (D/2H)\Delta\Omega(s) - (1/2H)\Delta P_L \qquad 3.19$$

Transforming into time-domain and expressing in matrix form, the state equation become:

$$\begin{bmatrix} \Delta\dot{P_V} \\ \Delta\dot{P_m} \\ \dot{\Delta\omega} \end{bmatrix} = \begin{bmatrix} \frac{-1}{\tau_g} & 0 & \frac{-1}{R\tau_g} \\ \frac{1}{\tau_T} & \frac{-1}{\tau_T} & 0 \\ 0 & \frac{1}{2H} & \frac{-D}{2H} \end{bmatrix} \begin{bmatrix} \Delta P_V \\ \Delta P_m \\ \Delta\omega \end{bmatrix} + \begin{bmatrix} 0 \\ 0 \\ \frac{-1}{2H} \end{bmatrix} \Delta P_L + \begin{bmatrix} \frac{1}{\tau_g} \\ 0 \\ 0 \end{bmatrix} \Delta P_{ref} \qquad 3.20$$

3.5 Series Compensators Technique

This method of frequency control has been used for many years. The merit of this method is that it increases the load-ability and stability of transmission lines by compensating for advanced volt drop of the transmission lines. Actually, it does this by placing advanced or retarded voltage in series with the effective line reactance. In Nayeripour *et al* [14]; proposed two methods of Fuzzy logic controller based on impedance reference tracking (IRT) and power reference tracking (PRT). This method was primarily developed on Thyristor Controlled Series Capacitor (TCSC) controller to improve line load-ability and frequency damping of power system. The uniqueness of this controller was that, special rules based on error and change in error as inputs were used to determine the firing angles of thyristors. The research work conducted in a two area four-machine power system showed simulation results of this controller to be very effective in damping frequency oscillations in the power system. Also, when compared to the classical PI controllers it was observed that, this controller has faster responsiveness to power oscillation damping [14]. Using intelligent techniques in control of power system parameters cannot be over emphasized [15].

3.6 Fuzzy Logic (FL) Technique

FL is a concept first initiated by Professor Lofti A. Zadeh, a computer scientist from University of California, Berkeley in 1965. Basically, FL allows inter-mediate values like true/false, yes/no, high/low [11]. For computer analysis it has made computer system to have human reasoning capacity. Gholampour [16] carried out a research with Type-I FL controller using particle swarm optimization (PSO) algorithm on single area network. This method was used to carry out a research on control of frequency in a single area network. The research shows that this method of load is very effective in damping frequency oscillations. The intriguing thing that captured the interest of other researchers was that this research method was able to put into consideration the non-linear factor of generation rate constraint. A system model for simulating the dynamics of a typical standalone (single area) power system is needed to validate the proposed model. The system comprises of optimization and Fuzzy Logic PID. The optimization part which makes global search for optimal fuzzy scaling factors is based on some predefined frequency fluctuations while the Fuzzy-PID part uses fuzzy control logic to fine tune PID controllers. Both parts are integrated within a standalone power systems model. For the optimization process, classical or evolutionary technique is used to search for the optimal parameters i.e. fuzzy scaling factor. This is usually done with respect to pre-specified performance metric or objective. From the power systems perspective, this will involve minimization of Area Control Error (ACE). From the generator model following equations 3.1, this will involve a minimization of an Integral Time multiplied Absolute Error (ITAE) generated by the system [17-18]. ITAE may be expressed as shown in equation 3.1 [18]:

$$J = ITAE = \int_0^{tsim} \left(|\Delta f| + |\Delta P_{tie}|\right) \cdot t \cdot dt \qquad 3.21$$

Where Δf is system frequency deviation, ΔP_{tie} is incremental change in tie-line power, t_{sim} is simulation time span
A Fuzzy PID view in MATLAB/SIMULINK is as shown in Fig.3.1

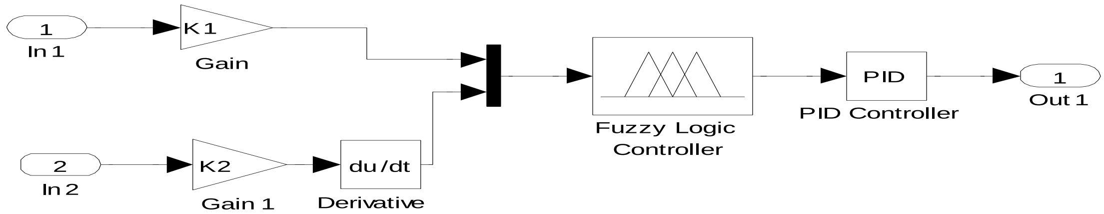

Fig. 3.1 Fuzzy-PID for the controller section; K1/K2 represents the scaling factors.

3.6.1 Fuzzy Logic (FL) Technique

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The Load change is a step input that is $\Delta P_L(s) = (\Delta P_L/s)$, using the final value theorem the steady state value of $\Delta\omega_{ss}$ is:

$$\Delta\omega_{ss} = \lim_{s\to 0} s\Delta\Omega(s) = (-\Delta P_L)\frac{1}{D+1/R} \qquad 3.22$$

3.6.2 Development of FL Controller

A nonlinear mapping rules was established by Fuzzy set theory and FL. Fuzzy sets are used to provide foundation for logical approach of the application of indefinite and undefined models [19]. Control techniques that adopts fuzzy is founded on a logical system called FL which mimics human thinking and natural language. Fuzzy logic is now used in science and industrial applications. FLC fuzzifies controller inputs and takes control decisions based on defined set of rules. The output of FLC is obtained by de-fuzzifying this control decision. FLC is made up of fuzzification interface, knowledge base; fuzzy inference system and de-fuzzification interface [20].

4. CONCLUSION

Although electrical power is designed such that it should always have constant, reliable and quality power supply (i.e. stable frequency and voltage).However, due to sudden and abnormal operational condition(s),as a result of power outage, spikes etc. occur and this result to abnormal/unplanned frequency change and this effect is reflected on every part of the power system network. Thus frequency change should be controlled and maintained within allowable limits. Otherwise, it results to LFC problem. Various ways of controlling load frequency and excitation has been reviewed. It was found out that PIDC is the most widely used in industries because it is simple to use and has a fixed gain designed in rated operating conditions. Its limitations however is that frequency oscillation also occur in its case. Thus PI controllers indicate poor dynamic performance. Though its proportional gain offers high stability and frequency response. The optima; control system has strategy to reduce performance index of system variables. For the case of AGC, as the load in the system varies uninterruptedly, the generation is regulated automatically to bring the frequency to its normal value. Application of pole placement technique ensures that there is quick damping of power network frequency when it is subjected to influence of various frequency and excitation variations and disturbances. The benefits of series compensator technique are that it increases the load-ability and stability of transmission lines by compensating for advanced volt drop of transmission lines. Fuzzy Logic control technique was used to carry out a research on control of frequency in a single area network. The research shows that this method of load is very effective in damping frequency oscillations.

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