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Impact and Analysis of Controller Tuning Methods in LFC Systems

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Abstract

In this paper, different point of load frequency control (LFC) has presented. A two area interconnected systems have developed with different type of area control characteristics namely as supplementary control loop and primary control loop. Developed LFC model is scrutinize for overall stability with the effects of primary and supplementary control loop.Tuning methods of PID controllers for the load frequency control of interconnected power system is presented. This model examined for overall stability and the effect of the different parameter tuning method in PID controller. The performance of various tuning methods of PID controller is validated on MATLAB software.

Keywords*—Load frequency control, Automatic generation control, PID controllers, GEP Tuning Method, P-Vr Tuning Method, Residues method.*

I. INTRODUCTION

LOAD frequency control (LFC) is considered as one of the important issues in the power system for provided reliable power with best quality[1]. Power system is used for transformation of natural energy into electrical energy.Power system is used for transformation of natural energy into electrical energy. It is necessary to ensure electrical power quality for optimization of electrical equipment. For transportation of electricity three phases AC is used [2].A control system technique is used to maintain of load variation, frequency and voltage at scheduled value. The frequency and voltage control problem can be evaluated even though active power and reactive power have a combined effect on frequency and voltage. Frequency mainly depends on active power and voltage mainly depends on reactive power [5].

Main Objectives of LFC are, (a) to minimize transient fluctuation, (b) Minimizing undesired tie line power flow between neighboring control areas, (c) to guarantee for steady state values to be zero, and (d) to maintain desirable tie line power deviation, overshoot and settling time on frequency.

Major drawbacks of conventional integral controller are (a) these are very slow in operation; (b) these controllers do not care for intrinsic nonlinearity of different system components, (c) inherent characteristics of system. The gain of integrator should be change according to change in operating point for best results. In case of dynamic response, it should be ensuring that the value of gain is the best between fast transient recovery and low overshoot. But practically this is very tough to achieve. In one condition, it’s optimal but unsuitable at another operating point. So applied controlling rules are suitable with dynamics of power system. Therefore the advance controllers would be suitable for controlling power system. [4],[5].

There are several different techniques for tuning the parameters of PID controllers. The main aim of parameter tuning of PID controllers are to achieve fast response and best stability. But in practical system, both wishes can’t be gained at same time. When control systems are obtaining faster response then stability will decrease. In other way, when

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control systems obtain better stability then response will be slow. Therefore in control systems, there is medium faster responses and acceptable stability [6]-[10].Methods for parameter tuning of PID controllers are, (a) Hit and trial method, (b) P-Vr method, (c) Residue method, and (d) GEP method [11]-[18].

Developing a design for two area load frequency control system is integrated with AGC(automatic generation control) system which results in significant cost reductions and improved system efficiency [19].

In literature, researcher have investigated about load frequency control and automatic generation control using PID control, integral double derivative filter controllers, self-tuning control but there is need of using various tuning methods of PID controller used in LFC system. A comparison should be made in the primary and supplementary LFC system along with tuning methods [1], [3], [4], [20]-[23].The main contribution in this paper, is to consider two area power system and find the steady state frequency deviation step response and also power deviation step response using various tuning methods of PID controller in MATLAB/Simulink. The main objectives of this paper are,

(i). To study and analyze the need of the constant frequency and the scheduled power interchange (MW).
(ii). To control the change in tie lines.
(iii). To analyzed the nature of overall system stability with different tuning methods of PID controller.

II. MODELLING OF LFC

In an interpreted power system, there are two major control installed in each generator, the Load Frequency Control (LFC) and Automatic Voltages Regulator (AVR) [8].

A. Generator model

The equation (1), and (2) of Generator can be written,

$$\frac{2\mathrm{H}}{\mathrm{w_s}}\frac{\mathrm{d}^2}{\mathrm{dt}^2}(\Delta\delta) = \Delta P_m - \Delta P_e$$

(1)

$$\Delta\Omega(s) = \frac{1}{2H_s}[\Delta P_m(s) - \Delta P_e(s)]$$

(2)

Where, $P_m, and\ P_e$ = Mechanical power, and Electricalpower in per unit, H = Inertia constant (MW-sec/MVA), $\Delta\delta$ = Rotor angle deviation in per unit, and $\Delta\Omega$ = System Frequency deviation.

B. Load model

The characteristics of a load that is composite can be expressed as electrical power change,

$$\Delta P_e = \Delta P_L + D\Delta\omega_r (3)$$

Where:ΔP_L = Non-frequency sensitive load, $\Delta\omega_r$= Frequency sensitive load change, D = Load damping constant, it is the percent of load change with respect to 1 percent ofchange in frequency.

C. Prime Mover model

The characteristic of the turbine is depending on the type of turbine used, can be estimated by time constant T_t(s),

$$G_T(s) = \frac{\Delta Pm(s)}{\Delta Pv(s)} = \frac{1}{1+T_t(s)}$$

(4)

Where,$\Delta Pv(s)$change in the valve position.

D. Governor model

The speed of the governor $\Delta Pg(s)$ is transformed into valve position ΔPv by the following equation,

$$\Delta Pv = \frac{1}{1+Tg}\Delta Pg(s)(5)$$

In Fig. 1. (a),load frequency control presented. Eq. (6) is open loop transfer function,

$$\mathrm{KG}(s)\mathrm{H(s)} = \frac{1}{R}\cdot\frac{1}{(2Hs+D)(1+T_g s)(1+T_t s)}(6)$$

With respect to "$-\Delta P_L$", the closed loop transfer function is,

$$\frac{\Delta\Omega(s)}{-\Delta P_L(s)} = \frac{(1+T_g s)(1+T_t s)}{(2Hs+D)(1+T_g s)(1+T_t s)+\left(\frac{1}{R}\right)}$$

(7)

steady state speed deviation is,

$$\Delta\omega_{ss} = (-\Delta P_L)\frac{1}{D+\frac{1}{R1}+\frac{1}{R2}+\cdots+\frac{1}{Rn}}$$

(8)

Fig. 1 show the simple load frequency control system.The block diagram of addition of integral controller on generating units selected for AGC is illustrated in Fig. 2.

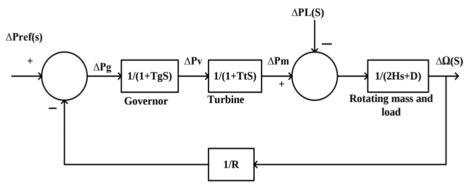

Fig. 1 Load frequency control model

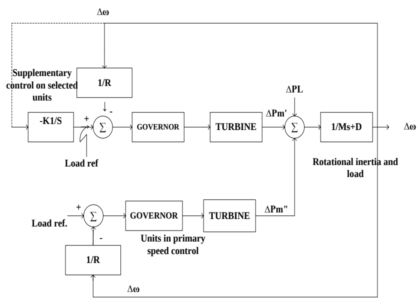

Fig. 2 PID control on generators for AGC.

E. Area control Error (ACE)

Area control error is an indicator used by load frequency control for sending control signals to the appropriate areas under its control. When power changes occur in area 1 then that should be meet by changing the generation of both the areas. ACE is the function of both tie line power deviation and frequency. For calculation of area control error both tie line power deviation and frequency are required. Area control error is given by the following equation,

$$ACE_i = \sum_{j=1}^{n} \Delta P_{ij} + K_i\, \Delta\omega \quad (9)$$

Where: K_i Area Bias, $\Delta\omega$=Rotor speed.

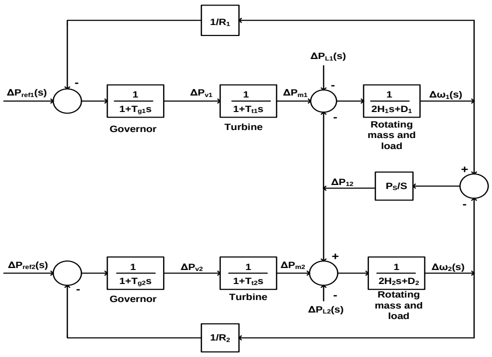

Fig. 3 Simple 2-area systems

By transferring load between different areas, the frequency of generating stations is restored back to the required value. When frequency is controlled by governors followed with turbine and generator then that control is called primary control. When the frequency control only by governors is not satisfactory then secondary control is required. Second level of generation control is called supplementary load frequency control. Fig. 4, show the block diagram of two area system with supplementary control.

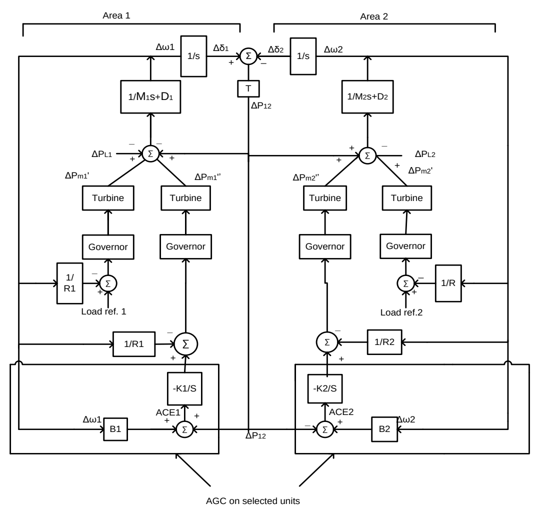

Fig. 4 2-area system modal with supplementary control

F. Multi-Area Power System

The main objective of multi area power system is to make the transactions profitable by buying or selling power with neighboring areas. When no power transmitted through tie lines due to loss of any generator occurs in a system then frequency change is experienced by the units of all the interconnection. Tie lines distribute power networks in consistent units. For maintaining synchronism between tie lines and connected areas, generators are required.

III. CONTROL STRATEGIES PID CONTROLLER

a. PID Controller

The transfer function of the ith order PSS is,

$$u_{cpss} = K_p \frac{sT_w}{1+sT_w}\left(\frac{(1+sT_1)(1+sT_3)}{(1+sT_2)(1+sT_4)}\right)\Delta\omega(s) \quad (10)$$

Where, K_p = PSS gain, T_w= Washout Time Constant, T_1, T_2, T_3, T_4 = Time Constants.

a) P-Vr Tuning Method

For linearized single machine infinite bus system there is a model of basic Philips- Heffron which utilizes to analysed the concept employed in tuning of conventional PSS is called as P-Vr method of parameter tuning. The transfer function is given by equation (11),

$$H_{PSS}(s) = kG(s) = k.\frac{sT_W}{1+sT_W}.\frac{1}{k_c}.\frac{1+c_1 s+c_2 s^2}{(1+sT_1)(1+sT_2)} \quad (11)$$

Definitions of right hand side part of transfer function are given below. There are five steps considered for tuning of the transfer function of PSS.

Step 1: To determination of GC(s) (compensation transfer function) on selected ranges of modal frequency, electromagnetic torque directly proportional to speed is induce by PSS over generator shaft

Step 2: To determination of k (damping gain)oftransfer function of PID controller:

It is the 2nd step to determine damping gain k in parameter tuning procedures.

The k (damping gain) obtained must be large enough:

- To swampin-built negative damping torque on ranges of rotor mode forranges of operating condition.
- To Ensure that rotor mode with most lightly damped satisfy criteria for damping of system.Moderate gain considered is damping gain of 20 to 30 pu on machine rating.

Step 3: Determination of parameters of the washout filter of the PSS

b) Residues tuning method

In residues tuning method, the transfer function is given by equation (12),

$$G(s) = \frac{P(s)}{Q(s)} = \frac{K1}{S-P1} + \frac{K2}{S-P2} + \cdots \frac{Ki}{s-pi} + \cdots \frac{Kn}{s-pn} \quad (12)$$

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For calculating K_1, equation (13) is used (m<n)

$$K_1 = \left[(s-p_1)\left(\frac{P(s)}{Q(s)}\right)\right] = \frac{A(p_1-z_1)(p_2-z_2)....(p_m-z_m)}{(p_1-p_2)(p_1-p_3).....(p_1-p_n)} \quad (13)$$

The constant r is known as residue, which is shown in equation (14).

$$G(s) = \frac{r_1}{s-p_1} + \frac{r_2}{s-p_2} + \cdots + \frac{r_i}{s-p_i} + \cdots + \frac{r_n}{s-p_n} \quad (14)$$

Transfer function of PSS is shown in equation (15),

$$F(s) = k_R H(s) = k_R G_c(s).G_w(s).G_{LP}(s) \quad (15)$$

$G_C(s)$ = transfer function of the PSS which is created to give proper phase compensation and it consists of m lead and m lag blocks, as given in equation (16),

$$G_c(s) = \left[\frac{1+T_n s}{1+T_d s}\right]^m \quad (16)$$

Tuning process in residues method is start with determining of PSS parameters that is based on both the value of complex rotor modes with open loop and with changing of mode on closed loop as the gain Kr is increased. In this method analysis is based on complex modal frequencies but in P-Vr method and GEP method analysis is based on frequency response.

c) GEP Tuning Method

Transfer function which is between voltage reference inputsignal to AGC and electric torque develop on shaft is known as generator, excitation and power (GEP). GEP may show as proportional to transfer function from reference voltage ($V_r(s)$) to terminal voltages ($V_t(s)$). The transfer function for GEP tuning method is given in equation (17) and (18),

$$\frac{\Delta P_2(s)}{\Delta V_r(s)} = \frac{K_2 K_3 K_{ex}}{s^2 K_3 T_{ex} T_{d0} + s(T_{ex} + K_3 T_{d0}) + (1 + K_3 K_6 K_{ex})} \quad (17)$$

$$\frac{\Delta V_t(s)}{\Delta V_r(s)} = \frac{K_6 K_3 K_{ex}}{s^2 K_3 T_{ex} T_{d0} + s(T_{ex} + K_3 T_{d0}) + (1 + K_3 K_6 K_{ex})} \quad (18)$$

These both are not depend on dynamics of shaft. A review of these transfer functions discloses that:

These are just normally related with scalar ratios The phase response of both P-Vr characteristics and terminal voltage are similar. When PSS tuned with GEP method then to provide compensation for lagging phase characteristics, phase lead must be introduced.

IV. RESULTS AND ANALYSIS

2-area LFCsystems with different parameter tuning techhniques of PID controller are discussed.

Performance analysis with primary LFC

Figure 5 and figure 6 is presented the frequency and power deviation respectively in area 1 with respect to the area 2.

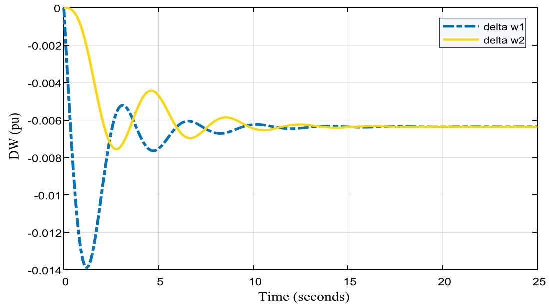

Fig. 5 Frequency deviation with primary LFC

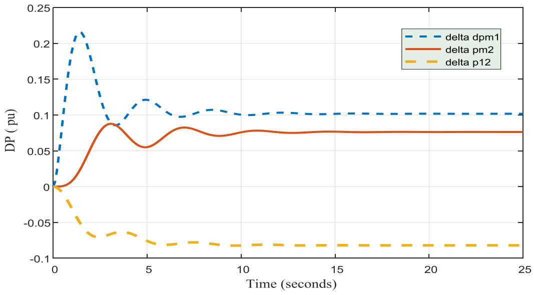

Fig. 6 Power deviation with primary LFC

Performance analysis with supplementary LFC

Figure 7 and figure 8 is presented the frequency and power deviation respectively in area 1 with respect to the area 2 using supplementary LFC.The Fig. 9 shows the comparison of both the LFC; here ACE is used in supplementary LFC to reach at steady state.

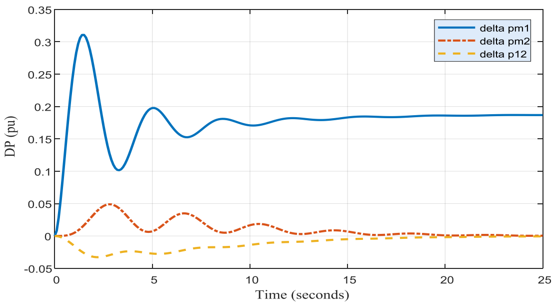

Fig. 7 Power deviation (step response) with supplementary loop

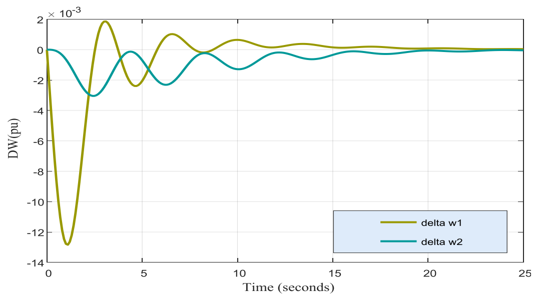

Fig. 8 Frequency deviation (step response)with supplementary control loop

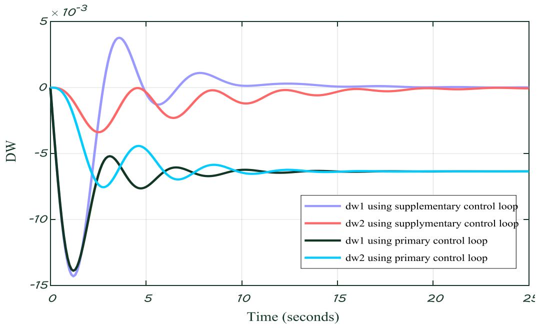

Fig. 9 Comparison between frequency deviation step responses with primary and supplementary control loop.

Performance analysis with primary and supplementary LFC with different parameter tuning techniques

From Fig. 10 to Fig. 17, comparison response of frequency deviation and power deviation with primary control and supplementary control with different parameter tuning techniques of PID controller in area 1 are presented respectively.

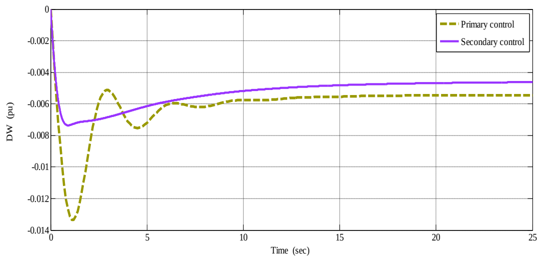

Fig. 10 step response with primary control and supplementary control with PID controller tuning in area 1

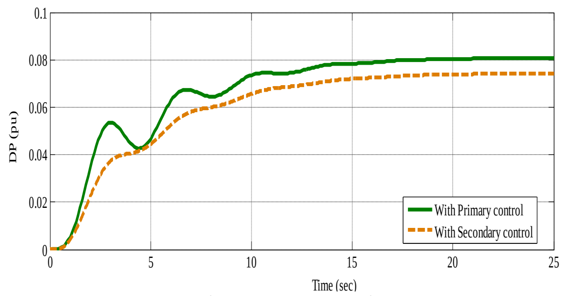

Fig. 11 Comparison of step response of power deviation with primary control and supplementary control with PID controller

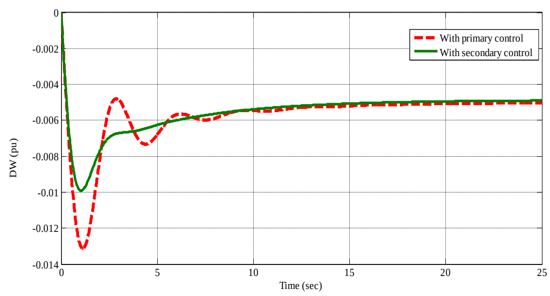

Fig. 12 response with primary and supplementary control with P-Vr method of PID controller tuning in area1

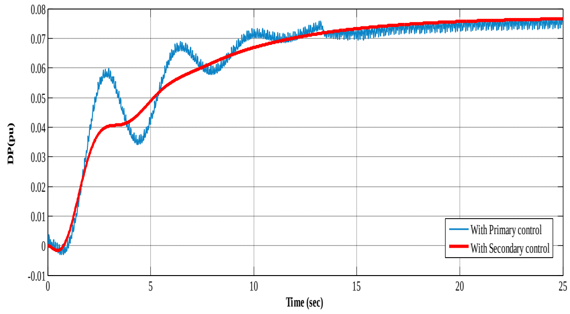

Fig 13 response of power deviation with primary and secondary control with P-Vr method of PID controller tuning in area 1

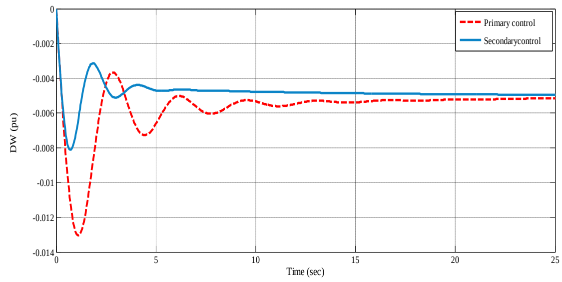

Fig. 14 Comparison of response with primary and supplementary control of residue method of PID controller

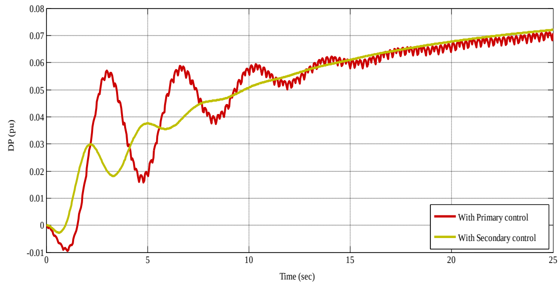

Fig. 15 Comparison of response with primary control and supplementary control with residue method of PID controller tuning method

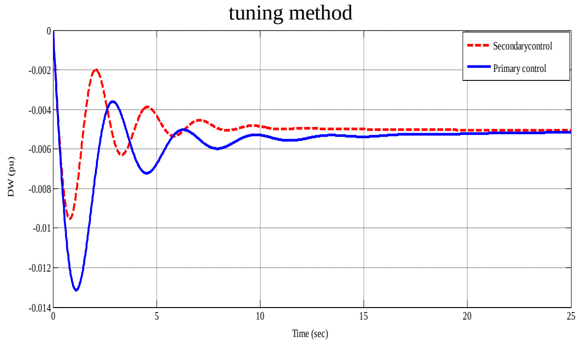

Fig. 16 Comparison of responce with primary control and supplementary control with GEP method of PID controller tuning in area 1

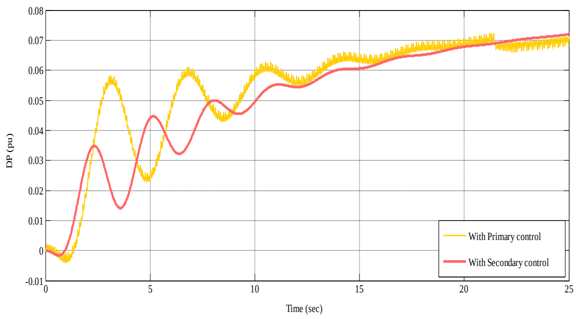

Fig. 17 Comparison of step response of power deviation with

primary control and supplementary control with GEP method of PID controller tuning in area 1

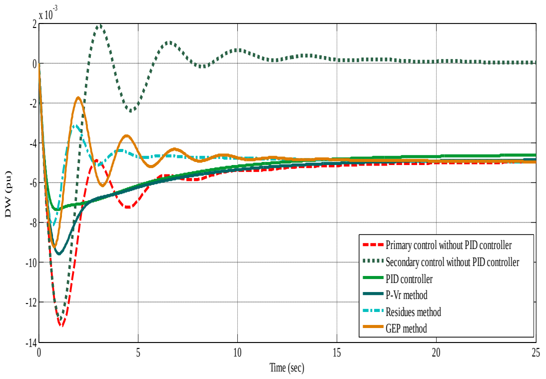

Fig. 18 Comparison of step response of power deviation with all controllers

Comparison of all tuning methods of PID controller

In fig. 18, Comparison results of conventional PID controller and different techniques of parameter tuning of PID controller presented and when we compare all the parameter tuning methods of PID controller then we find out that P-Vr method is the best for two areas LFC system. The results are compared using MATLAB software package.

V. CONCLUSION

In this paper successfully examined the overall stability and effects of primary control loop as well as supplementary control loop in LFC. The effect of the different parameter tuning methods in PID controller for two area system on overall stability is analyzed in this paper. Further, work is being done to optimize the controllers and minimize the transient changes and steady state error to zero in advance. Comparison results of conventional PID controller and different methods of parameter tuning of PID controller system are presented and when all the parameter tuning methods of PID controller are compared then it has been found that P-Vr method is the best for two area LFC systems.

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