Emphasize the Performance of Multi Area AGC in Deregulated Environment Tuned with PI using BFO

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***Abstract*—In this paper the bacterial foraging optimization (BFO) control technique is developed for the design the gain of integral controller, which is applied to AGC in interconnected four area system under the deregulated environment to control the tie line power and frequency of the interconnected hydro-thermal power system in which thermal reheated turbine is used . All four areas have different number of GENCOS, DISCOS and TRANSCOS. A DISCO can individually and multilaterally contracts with a GENCO for power requirements and these transactions are done under the ISO supervision. After deregulation, the bilateral contract on the dynamics of automatic generation control (AGC), DPM has been used. The control strategies guarantees that the steady state error of frequencies and inadvertent interchange of tie-lines power are maintained in a given tolerance limit. The study is carried out on IEEE 75-bus system. The performances of the controllers are simulated using MATLAB/SIMULINK package.**

Keywords— GENCO, DISCO, TRANSCO, DPM, CPF , Automatic Generation Control(AGC).

I. INTRODUCTION

Automatic Generation control is a significant control process that operates constantly to balance the generation and load in power system. The AGC system is responsible for frequency control and power interchange. It improves the reliability of system and makes the system more accurate. AGC also maintains the system frequency constant and makes the system more stable. As the load demand increases or decreases, the speed of generator prime mover set also changes which cause deviation in frequency of the system and hence affect the steady state stability of the system. Automatic generation control regulates the power output of generator in accordance with the change in system frequency, tie line power, so as to maintain the system frequency within the permissible limit. To attain zero steady state error and to maintain the system frequency constant, a control scheme is needed. Here study of the four area restructured power system is done in which each area has its own automatic generation controller (AGC)[8] which maintains the tie line power and system frequency constant by varying the generation according to the area control error (ACE). The AGC varies the set position of generators of that area, which minimize the average time of ACE (Area Control Error). In a deregulated system GENCOs sell power to DISCOs at competitive price and hence, DISCOs have various options for the transaction of power from any of the GENCOs of its own area or different area. In each area, an automatic generation controller (AGC) supervises the tie line power and system frequency, also computes the net change in the generation required which is related to the area control error (ACE) and changes the set position of the generators with in that area due to which net average time of ACE is at minimum. Optimization of auxiliary controller gains has been the main area of attraction. Intelligent control techniques provide a high adaption to changing conditions. In this paper the gain of proportional controller is controlled by the use of Bacterial Foraging Technique. The frequency and tie line power is compared for the LFC in deregulated environment by the use of BFO technique (Kevin M. Passino)[12]. The most frequently used controller in LFC is Proportional Integral Controller (PI). It is simple and better dynamic response in comparison to other controllers but it fails to operate when the complexity of system increases with sudden load change occurs or dynamics of boiler changes. Bacterial Foraging Technique improves the performance of PI Controller by varying its gain as per the requirement of load. The main contribution of this paper is comparison of frequency and tie line power for the LFC in deregulated environment. Bacterial Foraging (BF) technique is used to control the gain of proportional controller.

II. RESTRUCTURED POWER SYSTEM

The problems caused by load and frequency control become more difficult in large interconnected systems having many stations scattered over a wide area. Thus

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Restructured power system is needed which is basically divided into three parts GENCOs (generating companies), TRANSCOs (transmission companies), and DISCOs (distribution companies). The GENCOs generates power and DISCOs have freedom to have contract with any generating company for the sake of power trading. To visualize the contracts between GENCOs and TRANSCOs, the concept of DISCO participation matrix (DPM) is used. DISCO participation matrix is in the form of rows and columns where row represents number of GENCOs and columns represents number of DISCOs[8]. The total load on the GENCOs of an area is the sum of cpf s (elements of DPM) and the pu MW load of all the DISCOs of that area. Entry in DPM is a fraction of total load power contracted by bilateral contract. Due to this, DPM column entries belong to that disco is unity. The ISO may be authorized to set rules for transactions between suppliers and consumers, scheduling and dispatch of generators, loads and network services, maintenance of system surity and reliability, congestion management, service quality assurance and promotion of economic efficiency.

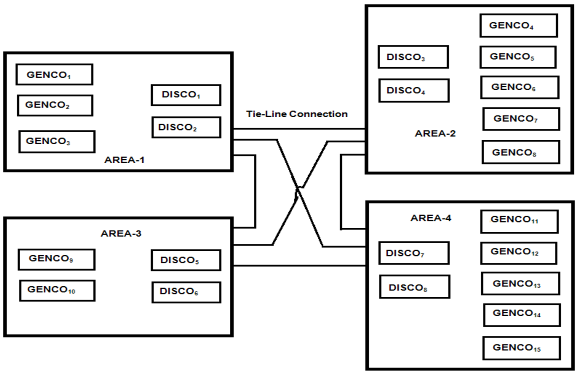

Fig. 1: Configuration of power system under deregulated environment.

$$DPM = \begin{bmatrix} cpf_{1,1} & cpf_{1,2} & .. & .. & cpf_{1,8} \\ cpf_{2,1} & cpf_{2,2} & .. & .. & cpf_{2,8} \\ . & . & .. & .. & . \\ . & . & .. & .. & . \\ cpf_{15,1} & cpf_{15,2} & .. & .. & cpf_{15,8} \end{bmatrix}$$

$$DPM = \begin{bmatrix} 0.2 & 0 & 0 & 0.1 & 0 & 0 & 0 & 0 \\ 0 & 0.2 & 0 & 0 & 0 & 0 & 0 & 0.4 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0.1 & 0 & 0 & 0.2 & 0 & 0 \\ 0 & 0.1 & 0 & 0.2 & 0 & 0 & 0.3 & 0 \\ 0.2 & 0 & 0.4 & 0.3 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0.1 & 0 & 0 & 0.3 & 0.4 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0.2 & 0 & 0 \\ 0.2 & 0.3 & 0.2 & 0 & 0.5 & 0 & 0.5 & 0 \\ 0.2 & 0 & 0.1 & 0.2 & 0 & 0{,}2 & 0 & 0.5 \\ 0.2 & 0.3 & 0.2 & 0.2 & 0.2 & 0 & 0.2 & 0.1 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 0 & 0 \end{bmatrix}$$

The cpf is the contract participation factor. In DPM diagonal element shows the local demand. The demand of one region discos value to another regions GENCO value is shown by the off diagonal element. The steady system consists of four-area. Area-1 consists of three GENCOs and two DISCOs. Their contract at some instant of time is taken as per DPM matrix shown above. The sum of all the entries in a column in this matrix is unity. Coefficients that distributes area control error (ACE) to several GENCOs are termed as ACE participation factor (apfs). Note that

$$\sum_{j=1}^{m} apf_j = 1$$

where m is the GENCO in each area.

III. MATHEMATICAL CALCULATION OF ACTUAL AND STEADY STATE POWER FLOW

The actual and scheduled steady state power flows on the given tie line is:-

$\Delta P_{tie\,i-j,}$ schedule= [Demand from genco of area i by disco of area j –Demand from genco of area j by disco of area i]

The tie line error is given by:-

$$\Delta P_{tie\,i-j,}\ error = \Delta P_{tie\,i-j}\ actual - \Delta P_{tie\,i-j}\ schedule$$

The tie line error disappear the steady state error. The ACE signal given to the ISO is:-

$$ACE_i = B_i * \Delta f_i + \Delta P_{t\,ei-j}\ error$$

Δf_i is change in frequency of area ‘i’ and
Bi is frequency Bias e factor of area ‘i’
Genco1(scheduled) = (0.2+0.1)*0.01 = 0.03 pu
Genco2(scheduled) = (0.2+0.4)*0.01 = 0.06 pu
Genco3(scheduled) = 0 pu
Genco4(scheduled) = (0.1+0.2)*0.01 = 0.03 pu
Genco5(scheduled) = (0.1+ 0.2 + 0.3)*0.01 =0.06 pu
Genco6(scheduled) = (0.2 +0.4 +0.3)*0.01 = 0.09 pu
Genco7(scheduled) = 0 pu
Genco8(scheduled) = 0 pu
Genco9(scheduled) = (0.1 +0.3 +0.4)*0.01 = 0.08 pu
Genco10(scheduled) = (0.2)*0.01=0.02pu
Genco11(scheduled) = (0.2+0.3+0.2+0.5+0.5)*0.01 = 0.17 pu
Genco12(scheduled) = (0.2 +0.1+ 0.2+0.2+0.5)*0.01 = 0.12 pu
Genco13(scheduled) = (0.2+0.3+0.2+0.2+0.2+0.2+0.1)*0.01 =0.14pu
Genco14(scheduled) = 0 pu
Genco15(scheduled) = 0 pu
The schedule tie line powers are:-

ΔP_{tie1-2} = -(0.2*0.1+0.1*0.1)+(0.1*0.1)= 0.02pu

ΔP_{tie1-3} = -(0.1*0.1) = -0.01pu

ΔP_{tie1-4} = [(0.2*0.1+0.2*0.1+0.2*0.1)+
(0.3*0.1+0.3*0.1)]+(0.4*0.1) = -0.08pu

$\Delta P_{tie\ 2-3}$ = 0.2*0.1 = 0.02pu

$\Delta P_{tie\ 2-4}$ = 0.3*0.1+[(0.2*0.1+0.1*0.1+0.2*0.1)-
(0.2*0.1+0.2*0.1)] = 0.06pu

$\Delta P_{tie\ 3-4}$ = -(0.5*0.1+0.2*0.1+0.2*0.1) = 0.09pu

For optimal design, we must formulate the state model. This is achieved by writing the differential equations describing each individual block of figure in terms of state variable. In this paper the dynamic performance is obtained using MATLAB software for Δf, ΔPg *and* $\Delta Ptie\ i{-}j$ for different load disruption.

IV. BACTERIAL FORAGING OPTIMIZATION TECHNIQUE

It is recently epoch computation technique, named as Bacterial foraging (BF) which has been projected by Passino. The bacterial foraging optimized the integral controller gains (ki) and other parameters. The BF technique dependent on the deportment of E.coli bacteria which is found in the human intestine.[8] This The bacteria generally found in groups and they will try to find food in minimum time with maximum energy and avoid the bruising phenomena. The detail algorithm is presented in Ref. [15]. In this simulation work the parameter for coding is to be S=10, Nc=10, Ns=3, Nre = 15, Ned=2, Ped=0.25. D(attr.)=0.061, W(attr.) = 0.04, H(repellent)= 0.061,W(repellent)= 10 and P=18 considered. The optimum value is derived using BFO to reduce cost function J which is the integral square error and is denoted as

$$J = \int_0^T \left\{ (\Delta f_i)^2 + (\Delta P_{tie\, i-j})^2 \right\} dt$$

Where dt is small interval, ΔP_{tiei-j} is the incremental change in the tie line power, Δf_i is the incremental change in frequency of area-i. To optimize this systems various steps utilized in algorithm are chemotaxis, foraging, reproduction, elimination and dispersal [12].

The chemotaxis step is comprised of swimming and tumbling of bacterium via flagella chemotaxix decides whether to move further or to change the direction. To represent a tumble, a unit length random direction,($\emptyset$) say, is generated; this will be used to define the direction of movement after a tumble. In particular, Swarming makes the bacteria congregate into groups and hence move as concentric patterns of groups with high bacterial density. Mathematically, swarming can be represented by

$$\theta^i(j+1,k,l) = \theta^i(j,k,l) + c(i) + \emptyset(j)$$

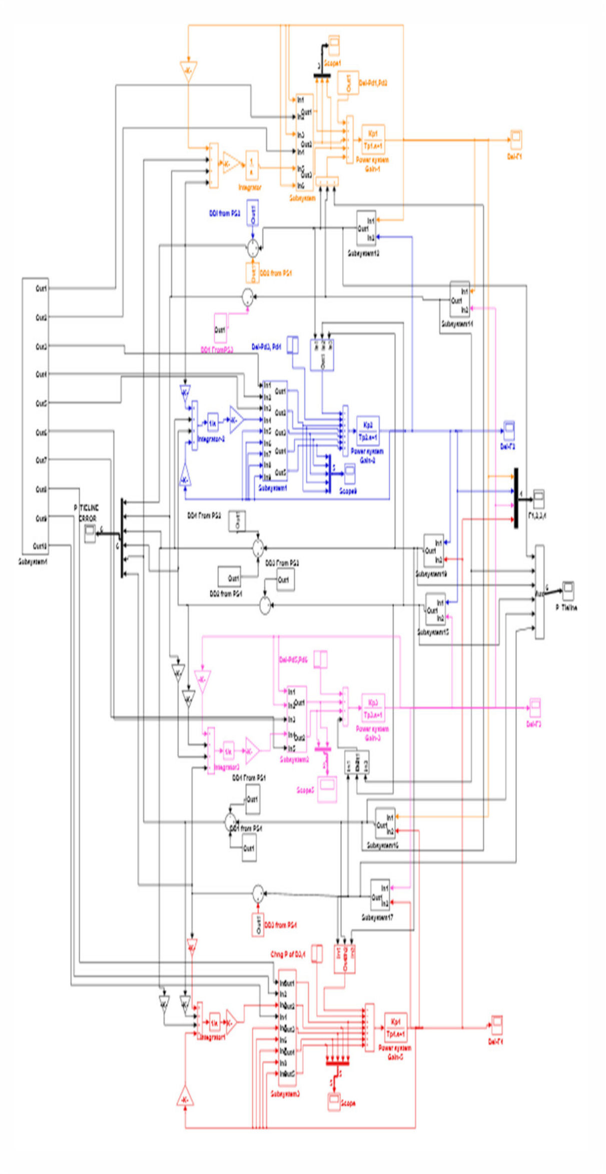

Fig. 2: Block diagram of four area interconnected power system under the deregulated environment.

V. RESULT ANALYSIS

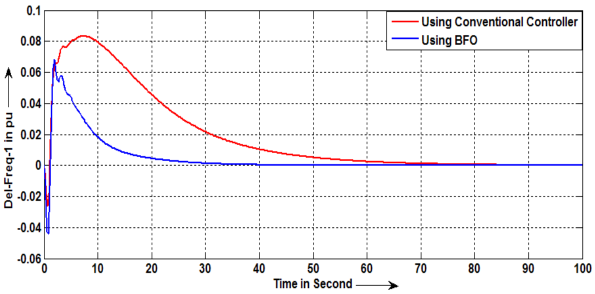

Fig. 3: Del-Freq of Area-1 with and without BFO using optimum value

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of K_i under deregulated environment

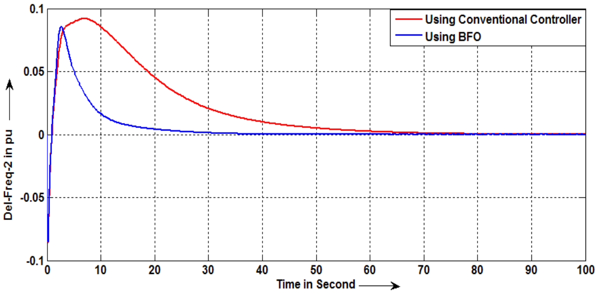


Fig. 4: Del-Freq of Area-2 with and without BFO using optimum value of K_i under deregulated environment

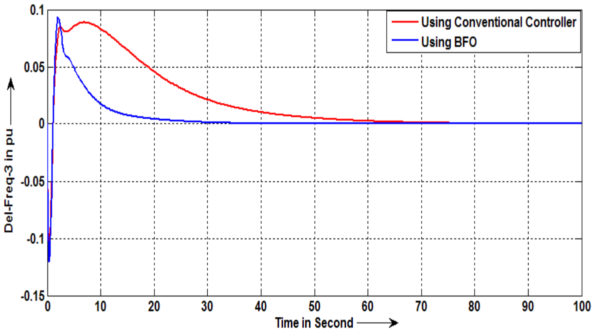


Fig. 5: Del-Freq of Area-3 with and without BFO using optimum value of K_i under deregulated environment

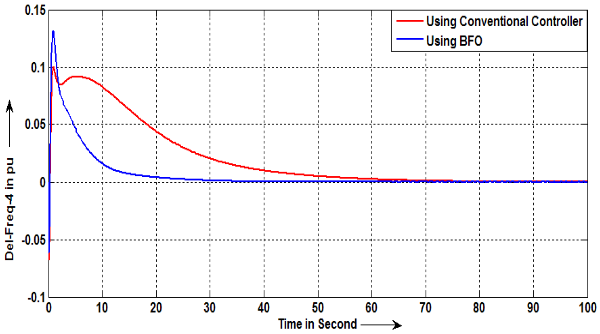


Fig. 6: Del-Freq of Area-4 with and without BFO using optimum value of K_i under deregulated environment

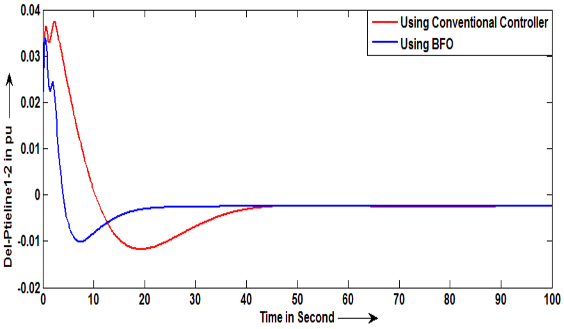


Fig. 7: Comparison of Ptieline1-2 with and without BFO using optimum value of K_i under deregulated environment

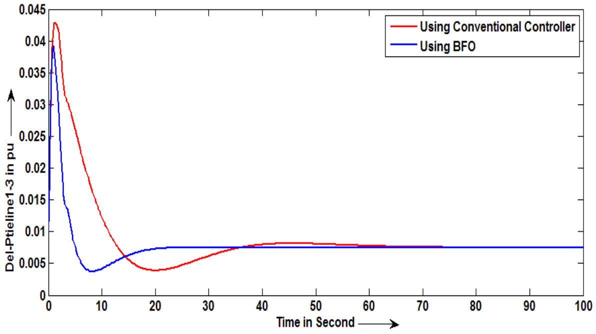


Fig. 8: Comparison of Ptieline1-3 with and without BFO using optimum value of K_i under deregulated environment

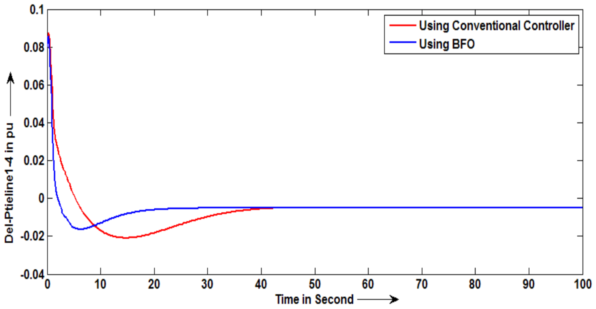


Fig. 9: Comparison of Ptieline1-4 with and without BFO using optimum value of K_i under deregulated environment

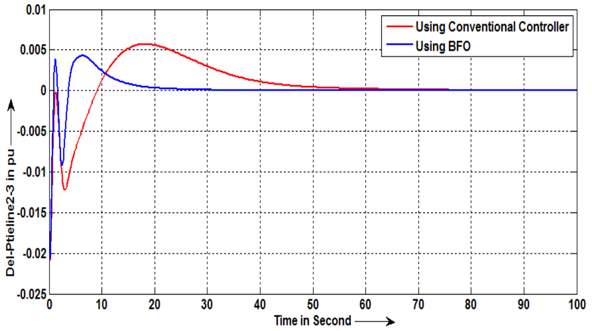


Fig. 10: Comparison of Ptieline2-3 with and without BFO using optimum value of K_i under deregulated environment

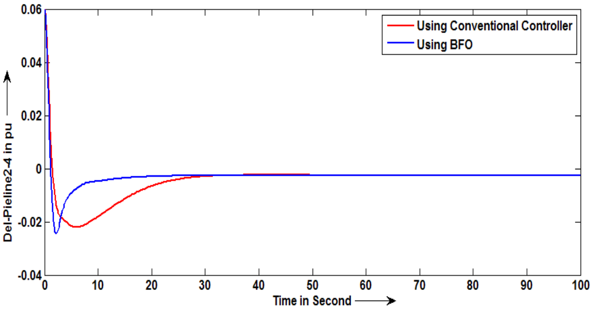


Fig. 11: Comparison of Ptieline2-4 with and without BFO using optimum value of K_i under deregulated environment

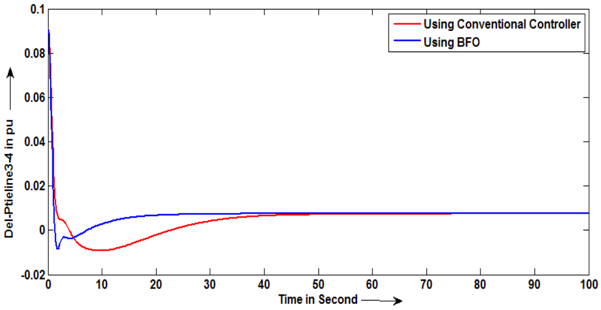
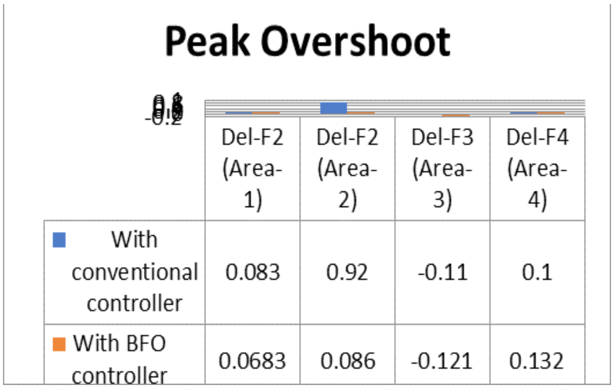
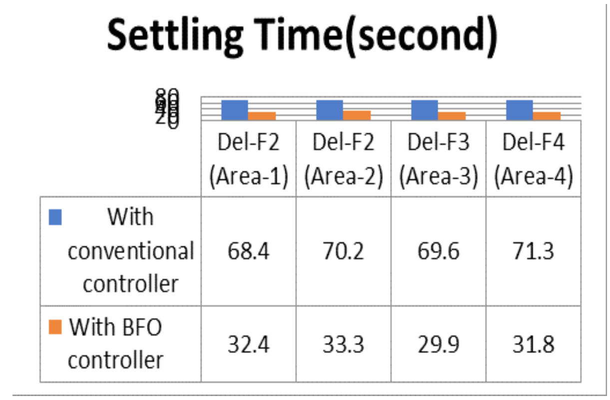


Fig. 12: Comparison of Ptieline3-4 with and without BFO using optimum value of K_i under deregulated environment



	Del-F2 (Area-1)	Del-F2 (Area-2)	Del-F3 (Area-3)	Del-F4 (Area-4)
🟦 With conventional controller	0.083	0.92	-0.11	0.1
🟧 With BFO controller	0.0683	0.086	-0.121	0.132

Fig. 13: First peak overshoot of del-F of 4-Area for different controllers



	Del-F2 (Area-1)	Del-F2 (Area-2)	Del-F3 (Area-3)	Del-F4 (Area-4)
🟦 With conventional controller	68.4	70.2	69.6	71.3
🟧 With BFO controller	32.4	33.3	29.9	31.8

Fig. 14: First peak overshoot of del-F of 4-Area for different controllers

VI. CONCLUSION

The four area AGC interconnected system have better performance when it is tuned with PI and optimized with BFO. The result for four area are compared four different frequency as well as error in tie line power compared in term of settling, rise time and peak over shoot in graphical as well as tabular form.

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Appendix

$$a_{12} = a_{13} = a_{14} = a_{23} = a_{24} = a_{34} = 1$$

$$2\Pi T_{12} = 2\Pi T_{13} = 2\Pi T_{14} = 2\Pi T_{23} = 2\Pi T_{24} = 2\Pi T_{34} = 2$$

Thermal Data

$$T_p = 20s \qquad T_{ij} = 0.086s \qquad a_{ij} = -1 \qquad T_t = 0.3s$$

$$R = 2.4\frac{Hz}{pu}.Mw \ \ K_{pi} = 120\,\frac{Hz}{pu}.Mw \ \ T_g = 0.08s$$

Hydro Data

$$T_p = 20s \ \ T_w = 1s \ f = 60Hz \ T_{ms} = 48.7s$$

$$K_d = 5\,\frac{Hz}{pu}.Mw \ T_d = 0.1s_{\text{ec}}$$

[20]