To Optimize the Cost of Electricity Generated by Hydro Power Plant Using Artificial Neural Networks

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Abstract

The paper presents a proposal for the optimization of the cost of generating units of hydro power plant by genetic algorithms. Genetic algorithm (GA) is used for optimization of integral gains and bias factors, which are applied to automatic generation control (AGC). Tie-line bias KI and frequency bias parameter B are optimized by using real coded GA. It is used to search for the optimal set of parameters (KI and B), which in turn optimize the frequency factor. . The objectives are to minimize the transient deviations in frequency so that constant power can be generated. Then the optimized cost of each area is calculated which turns out to be Rs.4.60.Average cost of the whole system is also calculated as Rs.7.90.

1. INTRODUCTION

Economic operation and control of interconnected power systems involves the solution of difficult optimization problems that require good computational tools. Evolutionary Computation is an area of computer Science that uses idea from biological evolution to solve problems. Evolutionary computation is one such tool that has shown its ability in solving complex problems. It can be implemented in various forms such as genetic algorithms. In present work, the genetic algorithm is applied in the solution of Optimization of cost of electricity generated by hydro power plant.

Genetic algorithms (GA) have been developed using ‘‘the survival-of-the fittest’’ concept in searching for better solution. GA , which are known as time intensive, can find global minimum. GA’s have attractive features such as robustness, simplicity, etc. GA’s have also been applied to power system problems such as optimal power flow, analysis of system topologies, the design of power distribution and to solve the economic dispatch.

Hydro Power systems (HPS) are used to convert natural energy into electric power. It transports electricity to factories and houses to satisfy all kinds of power needs. To optimize the cost of generated electricity, it is important to ensure constant generation of electricity during a time period. It is well known that three-phase alternating current (AC) is generally used to transport the electricity. During the transportation, both the active power balance and the reactive power balance must be maintained between generating and utilizing the AC power. Those two balances correspond to two equilibrium points: frequency and voltage. When either of the two balances is broken and reset at a new level, the equilibrium points will float. A good quality of the electric power system requires both the frequency and voltage to remain at standard values during operation. It will be impossible to maintain the balances of both the active and reactive powers without control. As a result of the imbalance, the frequency and voltage levels will be varying with the change of the loads. Thus a control system is essential to cancel the effects of the random load changes and to keep the frequency and voltage at the standard values. As load increases, it will lead to deviation of frequency and hence generated power. The foremost task is to keep the frequency constant against the randomly varying active power loads, which are also referred to as unknown external disturbance. The objectives are to minimize the transient deviations in frequency and to ensure their steady state errors to be zeros, so that constant power can be generated. Once optimized power will be generated it will automatically optimize the cost of generated power because generated power and cost of generated power are directly proportional to each other.

In current work the HPS is assumed to contain two hydro units in Area A1, Area A2, and Area A3.Each area includes two GENCOs (generation units) and two DISCOs (distribution units).GENCO – DISCO contract is imposed with ‘ DISCO participation matrix ‘ .Each entry of this matrix is the fraction of total load demanded by DISCO towards GENCO. This fraction is represented by ‘contract participation factor’ (cp).The number of rows has to be equal to number of GENCOs and number of columns has to be equal to number of Discos. Area control error (ACE) signal must be shared by all GENCOs according to their participation. The sharing is represented by ‘ACE participation factors (aps) ’.In case of three area power system scheduled steady state power flow is given as follows:

$\Delta P_{i\text{-}j\ \text{scheduled}}$ = [demands of DISCOs in area j from GENCOs in area i] - [demands of DISCOs in area j from GENCOs in area j] (1)

$\Delta P_{1\ \text{scheduled}}(k) = \Delta P_{1\text{-}2\ \text{scheduled}}(k) + a_{31}\Delta P_{3\text{-}1\text{scheduled}}(k)$ (2)

$\Delta P_{2\ \text{scheduled}}(k) = \Delta P_{2\text{-}3\ \text{scheduled}}(k) + a_{12}\Delta P_{1\text{-}2\ \text{scheduled}}(k)$ (3)

$\Delta P_{3\ \text{scheduled}}(k) = \Delta P_{3\text{-}1\text{scheduled}}(k) + a_{23}\Delta P_{2\text{-}3\ \text{scheduled}}(k)$ (4)

The errors for the above powers can be calculated as:

$$\Delta P_{i\ \text{error}} = \Delta P_{i\ \text{actual}} - \Delta P_{i\ \text{scheduled}} \quad (5)$$

ACE signals can be generated as:

$$ACE_i = \Delta P_{i\text{actual}} - \Delta P_{j\text{scheduled}} \quad (6)$$

Equations of the considered power system including three areas are given in steady state as follows:

$$X = A^{new} X + B^{new} U$$

Where X is state vector and U is vector of demand of DISCOs, calculated as follows:

$$X = [\Delta\omega_1 \Delta P_{R1} \Delta P_{R2} \Delta P_{GI} \Delta P_{G2} \Delta P_{ref1} \Delta x_{E1} \Delta x_{E2} \Delta\omega_2 \Delta P_{R3} \Delta P_{R4} \Delta P_{G3} \Delta P_{G4} \Delta P_{ref2} \Delta x_{E3} \Delta P_{R1} \Delta x_{E4} \Delta\omega_3 \Delta x_{E5} \Delta x_{E6} \Delta P_{R5} \Delta P_{R6} \Delta P_{G5} \Delta P_{G6} \Delta P_{ref3} \Delta P_{1\text{-}2} \Delta P_{2\text{-}3} \Delta P_{3\text{-}1}]^T$$

$$U = [\Delta P_{L1} \Delta P_{L2} \Delta P_{L3} \Delta P_{L4} \Delta P_{L5} \Delta P_{L6}]$$

In this study following case is considered:

All of the ACE participation factors are the same as 0.5, so contribution of each area to AGC is assumed as equal. In the steady state, any GENCO generation must match the demand of DISCO in contract with it, as expressed as follows:

$$\Delta P_{Mi} = \sum cp_{ij} \Delta P_{Lj}$$

Where ΔP_{Lj} is the total demand of $DISCO_j$ .In this case GENCOs belonging to area 2 and area 3 are not contracted by any DISCO in another area for transaction of power, so changes in generated power by them are zero in steady state.

2. Optimization of ACE parameters

A quadratic performance index that includes the parameters affecting to AGC is proposed as follows:

$$I = \int [-KI_1(\Delta P_1)^2 - KI_1B_1(\Delta f_1)^2 - K_{I2}(\Delta P_2)^2 - K_{12}B_2(\Delta f_2)^2 - K_{I3}(\Delta P_3)^2 - K_{13}B_3(\Delta f_3)^2]\, dt \quad [1]$$

Where value of limit varies from 0 to ∞. K_{Ii} and B_i (i=1,2,3…..) and ΔP_i (i=1,2…)

GAs effectively searches a design space to find global minimum of the performance index. Individuals in the GA population are formed and reproduced as in nature. Different population members are assigned different reproduction rates proportional to their fitness. The fitness corresponds to the objective function of the considered problem. A GA is based on a structure similar to a biological gene and an optimal solution is inspected applying selection, reproduction, crossover and mutation processes. The best individual survives during the optimization.

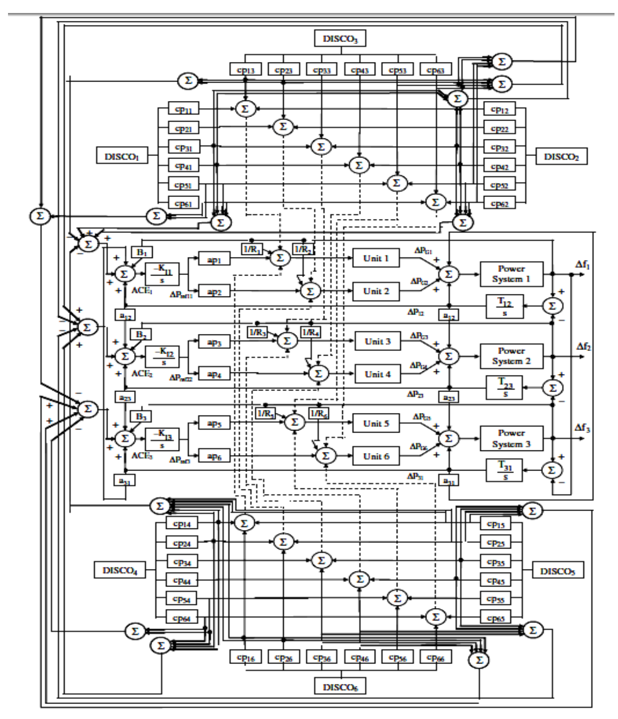

Fig .1.Configuration of three area power system. [1]

Steady state equations of the power system:

$$\Delta\omega_1(s) = \frac{K_{P1}}{1+sT_{P1}}(\Delta P_{G1}(s) - P_{G2}(s) - P_{L1}(s)$$

$-P_{L2}(s) - \Delta P_1(s))$ (1)

$$\Delta P_{R1}(s) = \frac{1}{1+sT_{T1}}\Delta x_{E1}(s) \quad (2)$$

$$\Delta P_{R2}(s) = \frac{1}{1+sT_{T2}}\Delta x_{E2}(s) \quad (3)$$

$$\Delta P_{G1}(s) = \frac{1+sK_{R1}T_{R1}}{1+sT_{R1}}\Delta P_{R1}(s) \quad (4)$$

$$\Delta P_{G2}(s) = \frac{1+sK_{R2}T_{R2}}{1+sT_{R2}}\Delta P_{R2}(s) \quad (5)$$

$$\Delta P_{ref1}(s) = -\frac{K_{I1}}{s}\left(\frac{B1}{2\pi}\Delta\omega_1(s) + \Delta P_1(s)\right) \quad (6)$$

$$\Delta x_{E1}(s) = \frac{1}{1+sT_{G1}}\left(ap_1\Delta P_{ref1}(s) - \frac{1}{2\pi R_1}\Delta\omega_1(s)\right)$$

(7)

$$\Delta x_{E2}(s) = \frac{1}{1+sT_{G2}}\left(ap_2\Delta P_{ref2}(s) - \frac{1}{2\pi R_2}\Delta\omega_1(s)\right)$$

(8)

$$\Delta\omega_2(k) = \frac{K_{P2}}{1+sT_{P2}}(\Delta P_{G3}(s) - \Delta P_{G4}(s) - \Delta P_{L3}(s)$$

$-\Delta P_{L4}(s) - \Delta P_2(s))$
(9)

$$\Delta P_{R3}(s) = \frac{1}{1+sT_{T3}}\Delta x_{E3}(S) \quad (10)$$

$$\Delta P_{R4}(s) = \frac{1}{1+sT_{T4}}\Delta x_{E4}(S) \quad (11)$$

$$\Delta P_{G3}(s) = \frac{1+sK_{R3}T_{R3}}{1+sT_{R3}}\Delta P_{R3}(s) \quad (12)$$

$$\Delta P_{G4}(s) = \frac{1+sK_{R4}T_{R4}}{1+sT_{R4}}\Delta P_{R4}(s) \quad (13)$$

$$\Delta P_{ref2}(s) = -\frac{K_{I2}}{2\pi}\left(\frac{B_2}{2\pi}\Delta\omega_2(s) + \Delta P_2(s)\right) \quad (14)$$

$$\Delta x_{E3}(s) = \frac{1}{1+sT_{G3}}\left(ap_3\Delta P_{ref2}(s) - \frac{1}{2\pi R_3}\Delta\omega_2(s)\right)$$

(15)

$$\Delta x_{E4}(s) = \frac{1}{1+sT_{G4}}\left(ap_4\Delta P_{ref2}(s) - \frac{1}{2\pi R_4}\Delta\omega_2(s)\right)$$

(16)

$$\Delta\omega_3(s) = \frac{K_{P3}}{1+sT_{P3}}(\Delta P_{G5}(s) - \Delta P_{G6}(s) - \Delta P_{L5}(s) -$$

$\Delta P_{L6}(s) - \Delta P_3(s))$ (17)

$$\Delta x_{E5} = \frac{1}{1+sT_1}\left(ap_5\Delta P_{ref2}(s) - \frac{1}{2\pi R_5}\Delta\omega_3(s)\right) \quad (18)$$

$$\Delta x_{E6} = \frac{1}{1+sT_4}\left(ap_6\Delta P_{ref2}(s) - \frac{1}{2\pi R_6}\Delta\omega_3(s)\right) \quad (19)$$

$$\Delta P_{R5}(s) = \frac{1+sT_2}{1+sT_3}\Delta x_{E5}(s) \quad (20)$$

$$\Delta P_{R6}(s) = \frac{1+sT_5}{1+sT_6}\Delta x_{E6}(s) \quad (21)$$

$$\Delta P_{G5}(s) = \frac{1-sT_w}{1+0.5sT_W}\Delta P_{R5}(s) \quad (22)$$

$$\Delta P_{G6}(s) = \frac{1-sT_w}{1+0.5sT_W}\Delta P_{R6}(s) \quad (23)$$

$$\Delta P_{ref3} = -\frac{K_{13}}{s}\left(\frac{B_3}{2\pi}\Delta\omega_3(s) - \Delta P_3(s)\right) \quad (24)$$

$$\Delta P_{12}(s) = \frac{T_{12}}{2\pi s}(\Delta\omega_1(s) - \Delta\omega_2(s)) \tag{25}$$

$$\Delta P_{23}(s) = \frac{T_{23}}{2\pi s}(\Delta\omega_2(s) - \Delta\omega_3(s)) \tag{26}$$

$$\Delta P_{31}(s) = \frac{T_{31}}{2\pi s}(\Delta\omega_3(s) - \Delta\omega_1(s)) \tag{27}$$

A Formal flow of work has been depicted below in Fig. 2

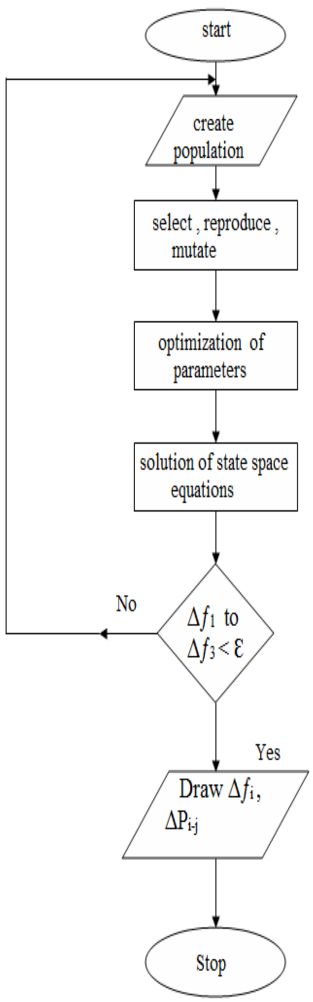

Fig. 2. Flowchart of Simulation

3. RESULTS

Following equations are implemented in MATLAB. Results with optimized values in table and deviation of values are represented in figures from fig [2] to fig [10].Fig [3]-fig [5] represents the deviation of frequency in three areas. Fig [6]-fig [8] represents change in $\Delta P_{i\text{-}j}$ .fig [9]-fig [11] represents change in output of ACE. As the frequency curve reaches to constant position, its means constant power can be generated with standard cost.

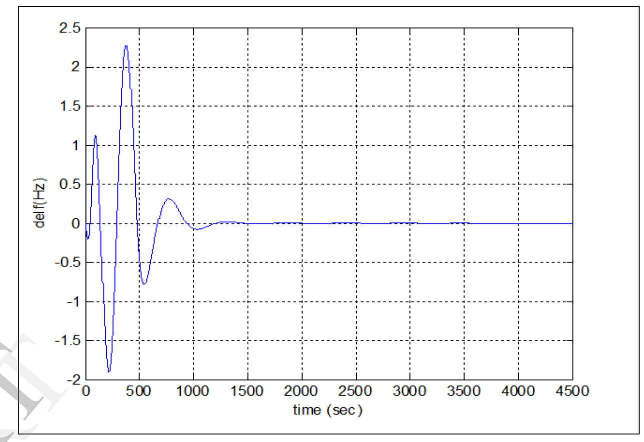

Fig .3.The frequency deviation of area 1 for the first operation case

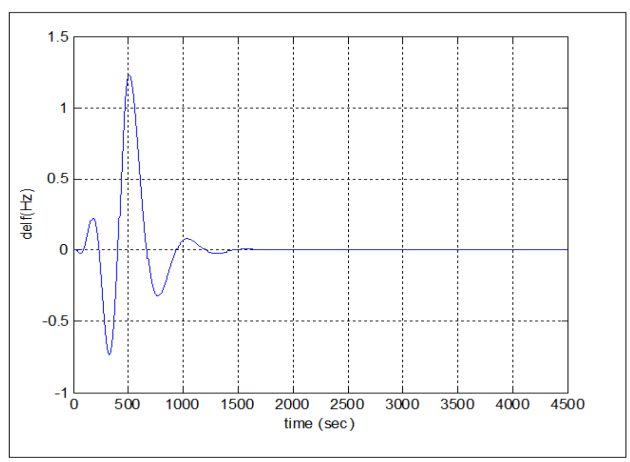

Fig .4.The frequency deviation of area 2 for the first operation case

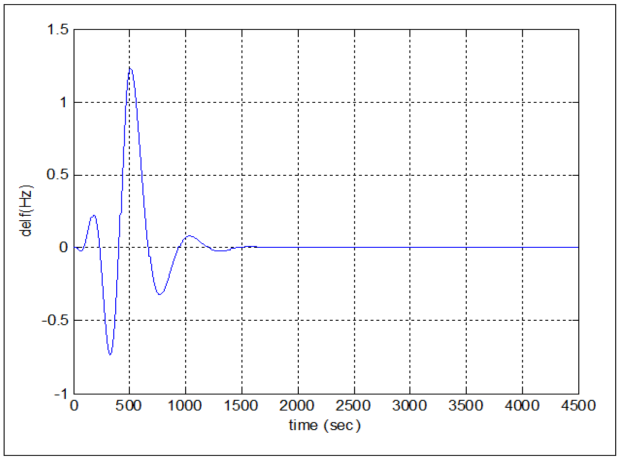

Fig .5.The frequency deviation of area 3 for the first operation case

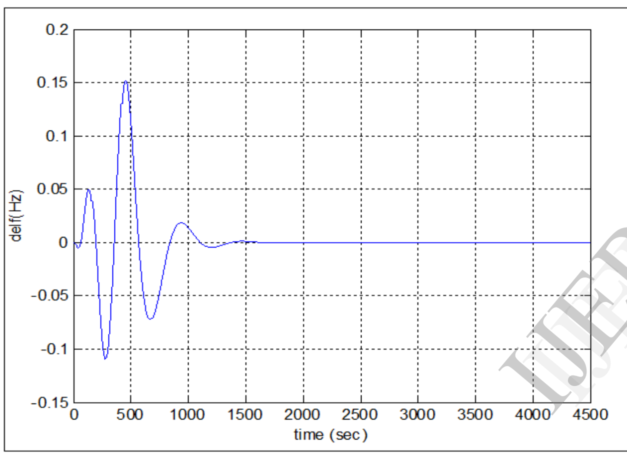

Fig . 6 .The deviation of P_{12}

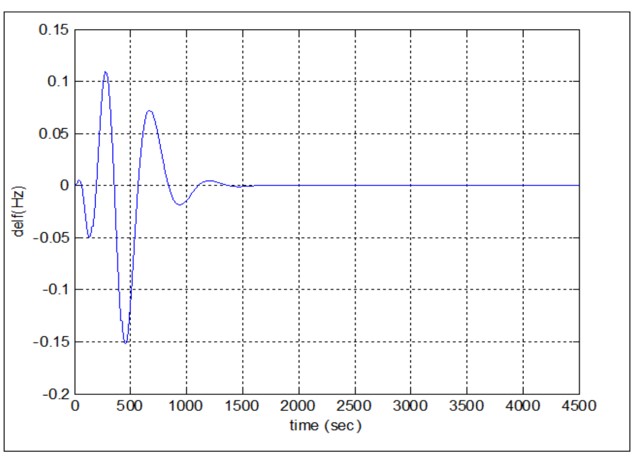

Fig .7.The deviation of P_{23}

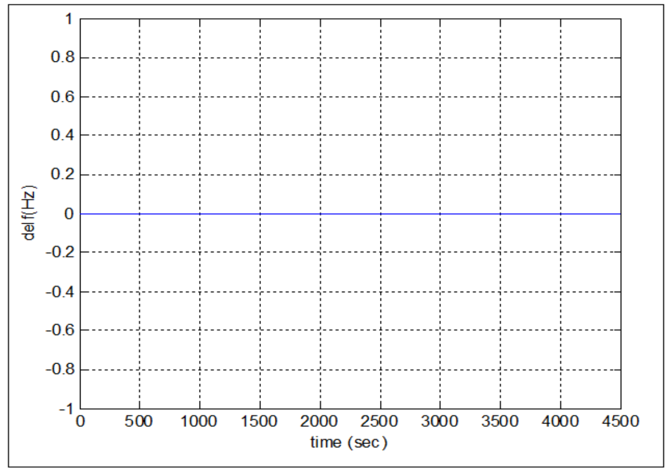

Fig . 8. The deviation of P_{31}

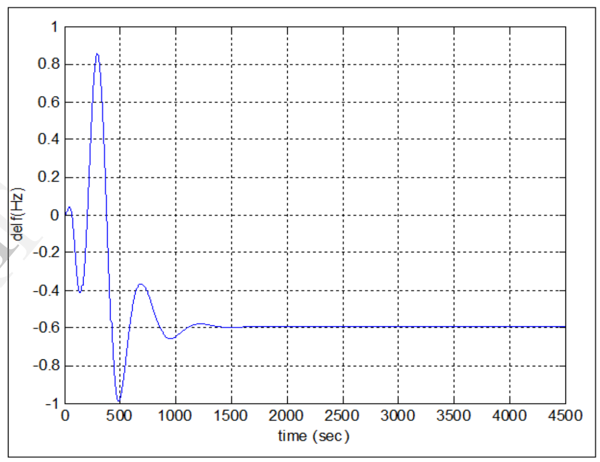

Fig. 9.The deviation of $P_{ref\ 1}$

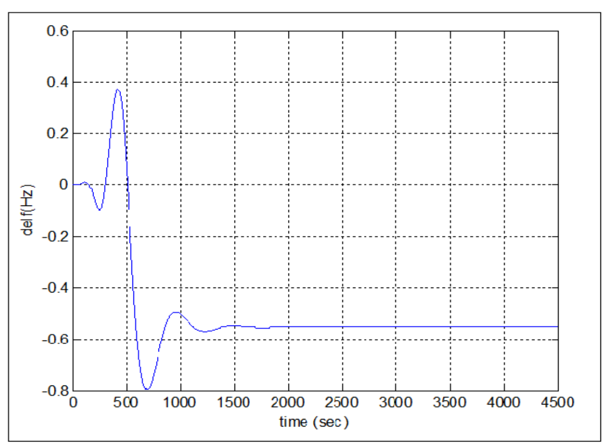

Fig .10.The deviation of $P_{ref\ 2}$

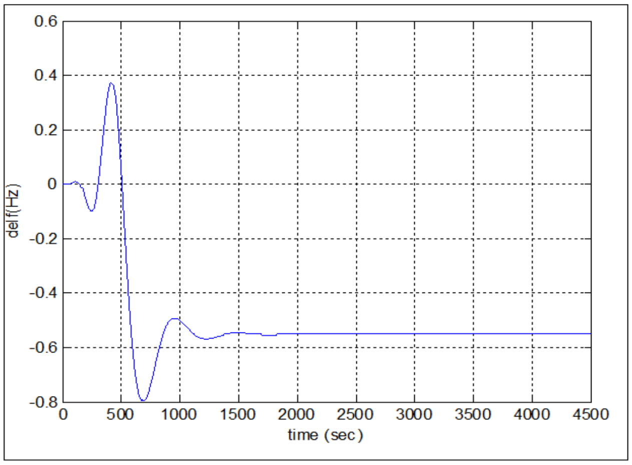

Fig .11.The deviation of $P_{ref\ 3}$

4. CONCLUSION

In this paper, cost of generated power is optimized by optimizing the frequency factor of generated power. ACE parameters are optimized for an appropriate performance index by using continuous parameter GA based on real values. This type of GA is chosen since the computational time is saved using this algorithm and it is more sensitive than simple GA. The cost of each area is calculated which turns out to be Rs.4.60.Average cost of the whole system is also calculated as Rs.7.90.Frequency Deviation in three areas is also depicted in graphs.

LIST OF SYMBOLS

f	Frequency
ω	Angular speed
K_p	Transfer function gain of generator
T_p	Time constant of generator
T_T	Time constant of turbine
X_E	Governor Valve position
T_G	Time constant of governor
P_G	Fluctuation in turbine output power
P_{ref}	The output of ACE
P_L	Electrical load variations
T_1	Time constant of hydro governor
T_2	Time constant of hydro governor
T_3	Time constant of hydro governor
T_W	Water starting time
R	Regulation parameter
K_I	Integral controller gains
B_i	Bias factor
X	State vector
U	Input vector
A,B	State matrices
GENCO	Generation units
DISCO	Distribution units
DPM	Disco participation matrix
Cp_{ij}	Contract participation factor
ap_i	ACE participation factor
$P_{i\text{-}jactual}$	Tie line real power
$P_{i\text{-}jscheduled}$	Tie line scheduled power
$P_{i\text{-}jerror}$	Tie line power error
ACE	Area control error

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