AGC CONTROLLERS IMPLEMENTATION IN DEREGULATED WIND INTEGRATED POWER SYSTEM

ADITI GUPTA, RINTU KHANNA, DEEPAK KUMAR

Abstract: This paper presents the load frequency control of deregulated hybrid multi area power system including one of the most prominent renewable power plant viz. wind power plant. The interconnected two area power system is thermal-hydro system with two GENCOs in thermal area and one GENCO in hydro area. Integral square error technique is used to optimize the gains of various integral controllers used. DISCO participation matrix is chosen on open market strategy which is continuously changing. So, effect of changing DPM on dynamic responses is studied. Also, the comparison of mechanical and electric governor for hydro power plant is made, in terms of transient responses of power plant following a step load perturbation.

Keywords: Automatic generation control (AGC), deregulated power system, DISCO participation matrix (DPM), wind turbines, electrical governors.

Introduction: Automatic generation control (AGC) or megawatt frequency control involves the problems of transient load perturbations that make the frequency and tie line power to deviate from their nominal values. These perturbations also lead to the mismatch in generation of power system and overall load demand. But these are the most important parameters of power system that are needed to be controlled to their nominal values even after the disturbances [1]. So, synthesis of AGC controllers is required like integral controllers, proportional integral controllers, proportional integral derivative (PID) controllers and fuzzy logic controllers etc. that provide the secondary control in the overall AGC. Primary control is provided by governor-turbine speed regulation model only. Now a days, focus is shifted towards the restructuring of power system. Initially, a single entity namely vertically integrated unit (VIU) owned the overall power system structure but now independent power producers (IPPs) have evolved and independent organizations like generation companies (GENCOs), transmission companies (TRANCOs) and distribution companies (DISCOs) have come up

which generate and sell power at their own regulated rate. There are no geographical domain restrictions for these companies to operate [3, 5]. Conventional power plants like thermal, hydro, nuclear etc pose a threat to the environment and lead to the global warming due to harmful gas emissions. So, it is of great importance to include cleaner sources of power into the power system like solar power, wind power etc. Solar power plants have low energy conversion efficiency and are more expensive than wind power plants, so focus is mainly shifted towards wind power plant [2].

The objective of the paper is to present a two area deregulated hydro-thermal power system including wind power plant. However, with large penetration of wind power into the power system, the grid frequency will be more vulnerable to disturbances because wind power converters mostly do not participate in the frequency regulation or AGC services. But again in the view of continuous depleting conventional energy resources, it becomes important to shift our focus to such non-conventional resources. There are some advanced techniques like doubly fed induction generators (DFIG) based wind turbines that support the system.

inertia and participate in the overall AGC. But these advanced techniques are ignored here for time being.

The main objectives of the paper are:

a)

o study the effect of changing DISCO participation matrix (DPM) on the dynamic responses of the system.

b)

o study and compare the performance of electric and mechanical governor for hydro power plant.

The rest of the article is organized as follows:

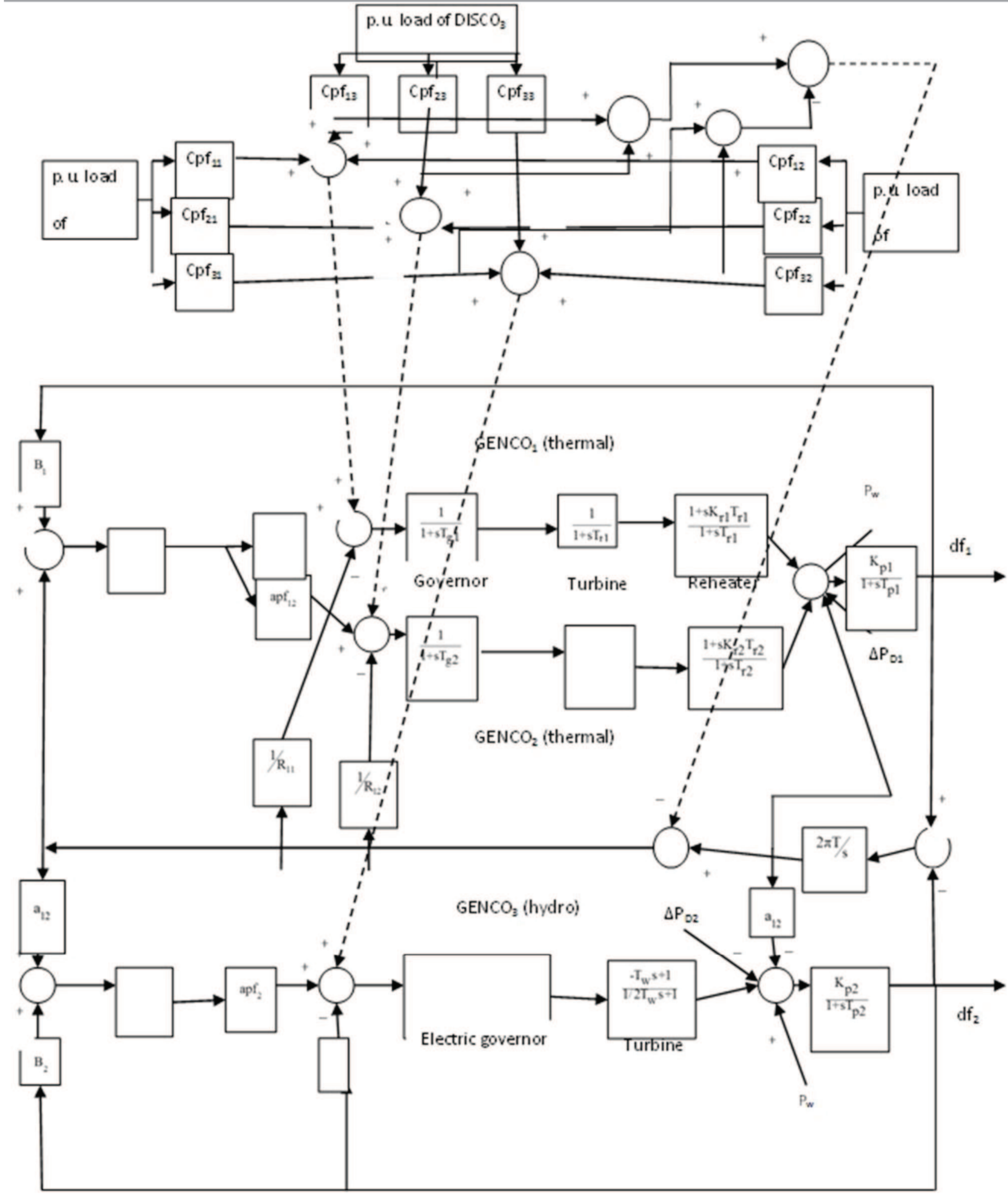

Fig. 1 Two area hydrothermal deregulated system including wind turbine.

System under investigation: A two area hybrid deregulated power system as shown in Fig. 1 is considered as a test system to study the AGC problem. An interconnected hybrid system comprising of thermal-hydro-wind has been used for simulation studies. Area1 is thermal system and has two GENCOs each equipped with reheat turbine and area2 is a hydro system having one GENCO equipped with mechanical or electric governor. In addition to thermal and hydro plants, fixed speed wind power plant is also integrated into the each area of the system. Wind speed varies with time and is related to the wind speeds of the previous time [7]. In this paper, it is considered that the output power of wind

generators depends on the wind speed at that time. The output power of wind turbine Pw is calculated as:
$P_w = 0$, $V_s < V_i$ and $V_s > V_o$
$P_w = P_{wr}*[(V_s-V_i) / (V_r-V_i)]$, $V_s \geq V_i$ and $V_s \leq V_r$
$P_w = P_{wr}$, $V_s \geq V_r$ and $V_s \leq V_o$
where V_i, V_r and V_o are the cut-in wind speed, rated wind speed and cut-out wind speed respectively. Their values are taken as 5, 15, 45 m/s respectively. V_s is wind speed at any instant. P_{wr} is the rated power output of wind turbine.

Simulation model has been developed in MATLAB 7.0 to obtain dynamic responses for various parameters for different step load perturbations (1% or 2%) in each area or in
both the areas. The power system parameters used in the model are given in appendix. The optimum values of integral controller gains have been found using ISE technique, considering step perturbation in any one area, keeping all other areas uncontrolled. The objective function (cost function) J for ISE technique [6] is
$J = \int [df_1^2 + df_2^2 + dP_{tie}^2]\, dT$
where,
dT = small time interval during sample
df_1 & df_2 = incremental change in frequency of area1 & area2.
dP_{tie} = incremental change in tie line power of area.

In the control application, we use integral method to decrease the rise time and reduce the steady state error. The speed changer setting can be adjusted automatically by monitoring the frequency changes. The signal fed to the integral controller is called ACE (area control error). The integrator output, thus the speed-changer position, attains a constant value only when the frequency error has been reduced to zero.

Effect of DPM: In deregulated environment, DPM is chosen on the basis of open market strategy [4, 8]. As the market strategy changes every day, so is the DPM. So it becomes important to see the effect of changing DPM on the dynamic responses of the system involving wind power plant. Also, controllers are to be optimized for different DPMs, again using ISE technique. Table I shows the optimized values of integral controller gains and electric governor parameters for the following two DPMs:

$$DPM_A = \begin{pmatrix} 0.6 & 0 & 0.3 \\ 0 & 0.7 & 0.3 \\ 0.4 & 0.3 & 0.4 \end{pmatrix}$$

$$DPM_B = \begin{pmatrix} 0.5 & 0.8 & 0.5 \\ 0.5 & 0.1 & 0.3 \\ 0 & 0.1 & 0.2 \end{pmatrix}$$

Table I. Optimized Values Of Various Gains

DPM	**Electric Governor Parameters**			**Integral Controller Gains**	
	K_d	**K_p**	**K_i**	**K_{i1}**	**K_{i2}**
A	3.6	3.3	4.6	0.472	0.041
B	1.2	3.4	3.1	0.3435	0.044

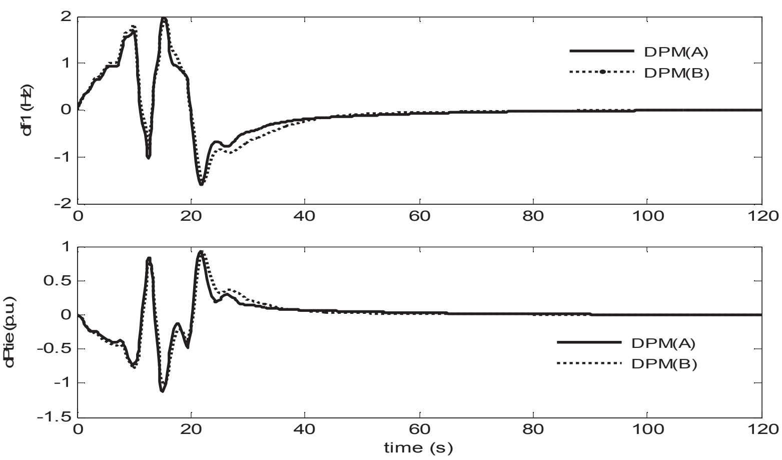

Fig. 2 Dynamic responses comparison for sets of DPMs.

In present system, area contro error (ACE) participation factors i.e (apfs) are chosen as follows:

- For thermal area, the apf of GENCOs are proportional to their respective generations. So,

$apf_{11} = P_{g1}/ (P_{g1}+P_{g2})$

and $apf_{12} = P_{g2}/ (P_{g1}+P_{g2})$

-

or hydro area, apfs of various GENCOs are considered to be equal. So,

$apf_2 = 1$

Analysis: The two sub-figures of Fig. 2 show the dynamic response comparison of df_1 and dP_{tie} for two DPMs corresponding to their respective optimum gains from Table 1. From the figures, it is clear that there is hardly any difference in the responses when different DPMs are considered with their respective optimum controller gains. However, the optimum gains corresponding to different DPMs are quite different.

Comparison of electric & mechanical governors: Fig. 3 shows the model for mechanical governor that replaces the electric governor of hydro area in Fig. 1. The temporary droop (δ) in mechanical governor plays a very important role in the stability of the system. An improper selection of δ will make the system unstable. The approach for finding out the suitable value of δ from stability considerations is as follows [1]:

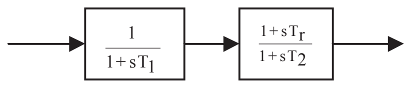

Fig. 3 Mechanical governor mode

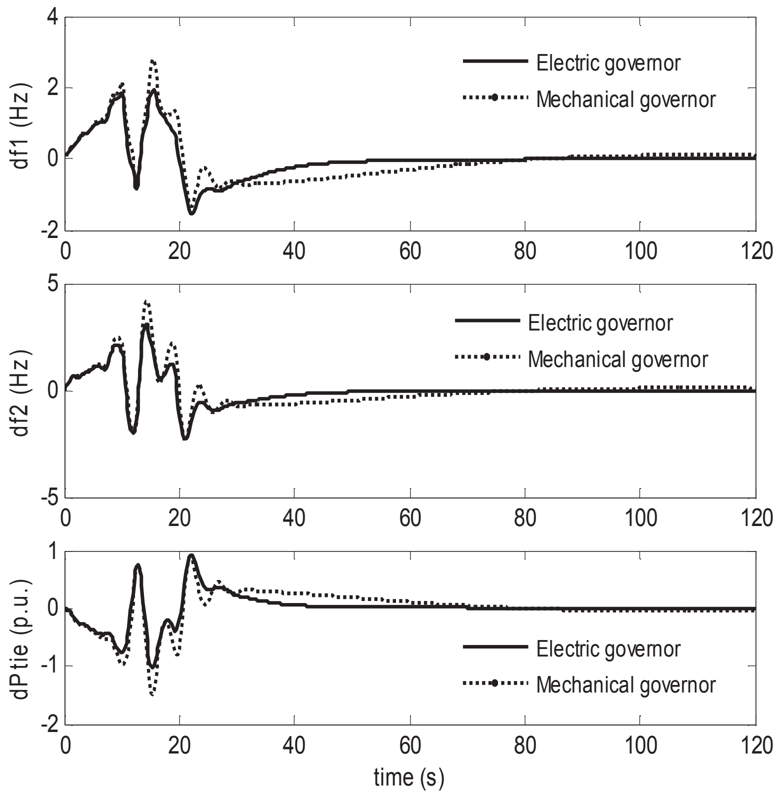

Fig. 4 Dynamic responses comparison for two governors.

a) consider both the areas uncontrolled, it is seen that any value of δ less than 0.7 and greater than 1.1 makes the system unstable. When δ is increased beyond 0.7, the system become stable and more or less the best response is obtained at δ = 0.95.
b) In the presence of optimum integral controller in both areas, δ is varied around 0.95. Responses reveal that δ = 0.95 again provides more or less the best response.

Analysis: Various sub-figures of Fig. 4 show the comparison of mechanical governor with δ = 0.95 and electric governor in terms of dynamic responses. It is clearly seen that electric governor provides much better response compared to mechanical governor in terms of peak deviations and settling time.

Conclusions: Frequency is one of the most important parameter to determine the stability of a system. To improve the overall dynamic performance in the presence of the plant parameters changes and system non linearities, the conventional integral controller based AGC problem has been formulated as an optimization problem based on system performance index ISE for multiple operating conditions. Wind power plant is included in the system for taking care of continously increasing load demands and in the view of depleting conventional energy resources. The overall power plant is analysed in deregulated or restructured scenario. Transient responses hardly vary for varying DPM in terms of peak deviations (overshoots and undershoots) and settling time. The AGC system balances it well in terms of frequency deviations and tie line power deviations. So, any DPM can be chosen based on the market economy. It is also analysed that electric governor gives better dynamic reponses as compared to mechanical governor in terms of peak deviations and settling time.

Appendix: The various system parameters and their description in given in Table II.

TABLE II. SYSTEM PARAMETERS

Name	**Description**	**Value**
P_{r1}, P_{r2}	Rated power	2000MW
T_{g1}, T_{g2}	Speed governor time constant	0.08 sec
T_{t1}, T_{t2}	Steam turbine time constant	0.3 sec
K_{r1}, K_{r2}	Reheater gain	0.5
T_{r1}, T_{r2}	Reheater time constant	10 sec
K_{p1}, K_{p2}	Power system gain	60 Hz/puMW
T_{p1}, T_{p2}	Power system time constant	20 sec
B_1, B_2	Frequency bias constant	0.4249
R_{11}, R_{12}, R_2	Speed regulation parameter	2.4 Hz/puMW
a_{12}	$-P_{r1}/P_{r2}$	-1
T_w	Water time constant	1 sec
T	Synchronizing time constant	0.0866puMW/rad
ΔP_{D1}, ΔP_{D2}	Step load perturbation	Can be varied
P_{wr}	Rated wind power output	1 pu
f	Nominal frequency	60 Hz

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