Automatic Generation Control of Two-Area ST-Thermal Power System using Jaya Algorithm

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Received: 14.03.2018 Accepted:30.03.2018

Abstract- This article present automatic generation control (AGC) of a two area thermal system incorporating solar thermal power plant (STPP) in one of the areas. The performance of the conventional two area system is compared with the proposed system. Similarly, the performances of integral (I), proportional plus integral (PI), and proportional plus integral plus derivative (PID) controller are evaluated in the system with STPP. For optimization of the proposed system, a new optimization technique, *i.e*. Jaya Algorithm is used for the optimization of secondary controller gains. Examinations uncover that Jaya optimized PID controller's performance is better as compared to integral and proportional integral control. Better dynamic performances like settling time, overshoot, undershoot is achieved by Jaya algorithm for the proposed system. Further, robustness of the systems are studied by changing all the system parameter from -25% to 25%. Analysis reveals that Jaya algorithm based PID controller gains are quite robust and need not be reset for large variations in system parameters.

Keywords Automatic Generation Control, Solar Thermal Power plant, Area control error, Integral Square Error, Settling time, Over shoot, Under shoot, Jaya algorithm.

1. Introduction

The objective of the AGC is to make system frequency stable and tie line power deviation zero for reliable and efficient operation of the power plant. Automatic generation control plays a vital role in power systems in maintaining scheduled tie line power flow and specified frequency during the normal operating condition as well as under small perturbation [1-4].The main function of AGC is proper selection of secondary controller gain. Frequency control is the biggest issue because if frequency fluctuates in power plant, speed keeps on changing and performance of power plant will be disturbed. A Lot of work has been done earlier on AGC but their focus was on conventional generation (Thermal generation) [5-8] .These literature surveys are not based on renewable energy source and no attention has been paid to non conventional energy sources. Due to rapidly decreasing conventional energy resources and carbon emission issues, there is a need to find some other sources so that future energy demand can be met. Solar and wind energy sources are such options and solar energy has large potential. From recent studies, it is said that it has potential to be a source of the future. There are many problems with availability of non renewable energy resources, which made renewable energy sources the present research issue. Das et al. [9] Describes the concept of integration of the solar thermal power plant for AGC, but their work is limited to an isolated system only. Solar energy is the huge source of the clean energy and transformation of solar energy into electric energy does not give off greenhouse gases, also these renewable energies cut down the consumption of conventional sources of energy. Hence, automatic generation control of a multi-area system with STPP is important for further studies.

There are two control modes in AGC, primary and secondary control. Primary control is very fast and the secondary control is slow as compared to primary control. Nowadays, almost all studies on AGC are based on the design of the secondary controller. Many optimization methods have been studied for controller gain such as a Bacterial foraging optimization algorithm (BFOA) [10], Particle Swarm Optimization (PSO) [11], Genetic Algorithm (GA) [12], Firefly Algorithm (FA) [13], Artificial Neural Network (ANN) [14], Differential evolution (DE) [15], fuzzy logic [16], grey wolf optimization (GWO), flower pollination algorithm (FPA) and many more. All the evolutionary and swarm intelligence optimization techniques need appropriate tuning of algorithm, specific parameters in addition to tuning of common controlling parameters. The proper tuning of these parameters is very much necessary.

Improper tuning of these parameters may increase the computational cost or tendency towards the local optimal solution. Hence, to avoid tuning problems of different algorithm specific parameters, teaching learning based optimization algorithm [17] was proposed. Keeping in view good performance of the TLBO another very simple and new algorithm which is specific parameter less and flexible optimization method, *i.e*. JAYA ALGORITHM was proposed by R.V. Rao [18] which is quite more simpler so it is named as 'JAYA'(means triumph originated from Sanskrit),as it doesn't consider any specific algorithm parameter. Jaya algorithm considers the best and worst solution among the whole population for update [19]. So it becomes very easy and it has better convergence towards global optimum point.

Following is the main objective of this work:

(a) Modeling and integration of solar thermal power plant with two area thermal systems for AGC.

(b) Application of the Jaya algorithm for the optimization of controller gains in two area system.

(c) Comparison of dynamic responses of frequency and tie line power deviation with and without STPP to find the best solution.

(d) Comparison of integral and PI controller with PID controller.

(e) Sensitivity analysis of the system in the presence of solar thermal power plant.

2. System Modelling

Two area thermal power systems are considered for AGC. Value of specified parameter has been taken from [20]. In Fig. 2 Solar Thermal Power Plant is used.

2.1. Thermal Power System

Thermal Power System consists of two areas Area1 and Area2. Different values of parameters have been taken such as time constants and other to make the analysis realistic. Table 1 shows the transfer function of different components present in the system.

Area Control Error (ACE) is the linear combination of frequency deviation and change in tie line power. ACE is taken as input to the PID controllers.

$$ACE_1 = \Delta P_{tie} + B_1 \Delta w_1 \tag{1}$$

$$ACE_2 = \Delta P_{tie} + B_2 \Delta w_2 \tag{2}$$

Where, $B_1 = \frac{1}{R_1} + D_1$ and $B_2 = \frac{1}{R_2} + D_2$

The output of the PID controllers are obtained as given below

$$u_1 = K_{P1} ACE_1 + K_{I1} \int ACE_1 + K_{D1} \frac{d}{dt} ACE_1 \tag{3}$$

$$u_2 = K_{P2} ACE_2 + K_{I2} \int ACE_2 + K_{D2} \frac{d}{dt} ACE_2 \tag{4}$$

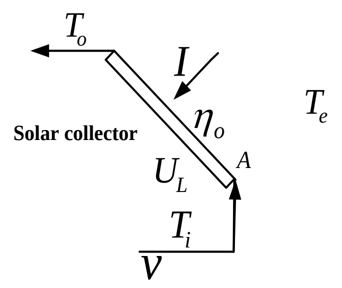

Fig. 1. Scheme of solar collector.

2.2. Collector Model

The derivative of output temperature is as follows

$$\frac{dT_o(t)}{dt} = \frac{A\eta_o}{C} I(t) - \frac{U_L A}{C}\left(T_a(t) - T_e(t)\right) + \frac{v(t)}{V}\left(T_i(t) - T_o(t)\right) \tag{5}$$

Time dependency of the variable are denoted as

$$T_a = \left(T_i(t) + T_o(t)\right)/2 \tag{6}$$

Let *v(t)* be the constant represented as '*v*'. Putting Eq. (6) into the Eq. (5) and then rearranging the parameters such that output parameter is on one side and input parameter on the other side of the equation.

$$\frac{dT_o(t)}{d(t)}+\left(\frac{U_L A}{2C}+\frac{v}{V}\right)T_o(t)=\frac{A\eta_o}{C}I(t)+\left(\frac{v}{V}-\frac{U_L A}{2C}\right)T_i(t) + \frac{U_L A}{C}T_e(t) \quad (7)$$

Taking Laplace of the above equation and the outcome of the Laplace transform is as given below.

$$sT_o(s)-T_o(0)+\left(\frac{U_L A}{2C}+\frac{v}{V}\right)T_o(s)=\frac{A\eta_o}{C}I(s) + \left(\frac{v}{V}-\frac{U_L A}{2C}\right)T_i(s)+\frac{U_L A}{C}T_e(s) \quad (8)$$

Rearranging above equation …

$$T_o(s)=\frac{T_s}{1+T_s}T_o(0)+\frac{T_s}{1+sT_s}\frac{A\eta_o}{C}I(s)+ \frac{T_s}{1+sT_s}\left(\frac{v}{V}-\frac{U_L A}{2C}\right)T_i(s)+\frac{T_s}{1+sT_s}\frac{U_L A}{C}T_e(s) \quad (9)$$

where, Ts is the time constant of the collector and given by

$$T_s=\frac{1}{\frac{U_L A}{2C}+\frac{v}{V}}$$

To calculate the transfer function for a given input, other inputs are considered and initial conditions are assumed to be zero. The transfer function for each input is

$$W_1(s)=\frac{T_o(s)}{I(s)}=\frac{T_s}{1+sT_s}\frac{A\eta_o}{C} \quad (10)$$

$$W_2(s)=\frac{T_o(s)}{T_i(s)}=\frac{T_s}{1+sT_s}\left(\frac{v}{V}-\frac{U_L A}{2C}\right) \quad (11)$$

$$W_3(s)=\frac{T_o(s)}{T_e(s)}=\frac{T_s}{(1+sT_s)}\frac{U_L A}{C} \quad (12)$$

Similarly, initial condition response can be obtained by

$$W_o(s)=\frac{T_o(s)}{T_o(0)}=\frac{T_s}{1+sT_s} \quad (13)$$

Hence the following equation gives the outlet temperature of the collector considering the effects of the inputs and the initial temperature.

$$T_o(s)=W_o(s)T_o(s)+W_1(s)I(s) + W_2(s)T_i(s)+W_3(s)T_e(s) \quad (14)$$

This is the collector model when the heat transfer rate is taken constant.

Various atmospheric parameters add their effects on solar collector models such as solar irradiance, inlet temperature and environment temperature, etc. But the major effect is of solar irradiance. So for simplified model only solar irradiance is considered. Hence transfer function of solar field with respect to solar irradiance is given by Eq. (15).

$$G(s)=\frac{K_s}{1+T_s s} \quad (15)$$

Where, K_s is the gain value and T_s is the time constant of the solar field. Hence, steam is produced in heat exchanger which drives the turbine. Solar irradiation is taken as 0.4 and transportation delay is taken for the various processes of STPP.

Table1 Component transfer function of two area system

Components	Transfer Function
Governor	$TF_g = 1/1+sT_g$
Turbine	$TF_t = 1/1+sT_t$
Load and machine	$1/Hs+D$

2.3. Solar Thermal Power Plant

Renewable energy sources are current issue of research [21, 22]. In view of system efficiency and keeping in mind the protection of the surrounding environment, renewable energy has gained the importance day by day. It is very important to reap solar energy effectively by developing solar collectors. In this article STPP has been implemented in area 1. In addition to solar energy, transfer function of solar field has been studied [23, 24]. Solar energy has enormous potential. PV system and concentrated solar power are the systems which can produce electrical power from solar energy. The demand of CSP is growing rapidly all over the world. The main function of solar collectors is to focus the solar irradiance to the pipes that carry working fluids. Fig. 1 represent the scheme of solar collector. This hot working fluid is used to produce steam in the heat. This steam is used to drive a turbine and produce electricity.

2.4. Fitness Function

The Aim of Automatic Generation Control (AGC) is to make ACE zero as soon as possible. To make it possible, objective function is required for estimation of PID gain values of the proposed system.

The objective function used in this paper is ISE (integral square error) given by Eq. (16)

$$J = \int_0^t \{(\Delta f_i)^2 + (\Delta P_{tiei-j})^2\} dt \tag{16}$$

i, j=area number for i =1,2,3 and j=2,3 ($j \neq i$)

The parameters are system specific and hence design problem can be obtained as

Minimize 'J' *i.e*. objective function

Subjected to

$$K_p^{\min} \le K_P \le K_p^{\max}$$

$$K_i^{\min} \le K_i \le K_i^{\max}$$

$$K_d^{\min} \le K_d \le K_d^{\max}$$

3. Jaya Algorithm

It is a new optimization technique which can be used for future purpose. There are some reasons which made Jaya algorithm [9] useful for AGC like its flexibility, simplicity, deviation free mechanism. The main concept of this algorithm is that the solution obtained for a given problem should move towards the best solution and avoid the worst solution. The various steps involved in Jaya algorithm

Step (1): Initialization of all candidates by randomizing the variables under their boundary limits.

Step (2): Calculate the value of fitness function f(x) for all candidates and identify the best and worst solution.

Step (3): Modify every candidate by altering designed variables according best and worst solution.

Step (4): Calculate f(x) for each candidate after modification and then compare them with previous value; update the candidate having a better solution among them.

Step (5): Identify the new best and worst solution from updated candidates and replace with the previous one.

Step (6): Go to step second and repeat the step from 2 to 5 until the stopping condition is satisfied.

Implementation of Jaya algorithm for AGC

Initialization: Decide the no. of candidates as 'r', stopping criteria *i.e.* no. of iteration as's', and the no. of designing variable as'm' i.e. gain value of the controller.

For each candidate randomize gain values.

$$K_i = K_{i\min} + u(K_{i\max} - K_{i\min}) \tag{17}$$

'u' is the random number [0,1]. Calculate the fitness value for each candidate and identify best and worst candidate.

Modification:

When initialization is over, start the iteration by setting s=1; and modify the gain value of the controller according to the given formula

$$K'_{s,j,i} = K_{s,j,i} + u\left[\left(K_{s,best,i} - \left|K_{s,j,i}\right|\right)\right] - v\left[\left(K_{s,worst,i} - \left|K_{s,j,i}\right|\right)\right] \tag{18}$$

Here u and v are the random variables lies between [0, 1].

Update:

Calculate the fitness value of modified candidate, compare new modified fitness value with previous values for each candidate.

If new modified fitness value is lower, then update the candidate, otherwise retain the previous values.

Again, identify new best and worst solution according to new updated fitness value.

Again perform the modification with new updated value.

Stopping criteria:

Stop algorithm when the number of iterations reaches the maximum value.

Working example of Jaya algorithm:

In order to study the working of Jaya algorithm, an objective function should be considered. Let the fitness function be the estimation of 'a_i' that minimize its function value.

$$Min\ f(a_i) = \sum_{i=1}^{n} a_i^2 \tag{19}$$

Subjected to "$-100 \le a_i \le 100$"

Let the population size be of 5 (i.e. applicant solutions), two design variables be a_1 and a_2 and the number of end criteria be two. The initial population is arbitrarily created inside the limits of the variables and the related estimation of the fitness function is given in Table 2. Since it is a minimization function, the smallest value of *f (a)* is taken as the best result and the largest value of *f (a)* is taken as the most awful solution.

Table 2 Initial population

participant	a_1	a_2	*f(a)*	condition
1	-4	17	305	–
2	13	62	4013	–
3	69	-5	4786	worst
4	-7	6	85	best
5	-11	-17	410	–

From Table 2 it can be observed that the best solution is corresponding to the fourth applicants and the awful result is corresponding to the third applicant. Now expecting arbitrary numbers u_1 = 0.57 and u_2 = 0.80 for a_1 and u_1 = 0.91 and u_2 = 0.48 for a_2, the new estimation of the variables for a_1 and a_2 are estimated using Eq. (19) and putting in Table 2. For instance for the first applicants, the new estimated value of a_1 and a_2 during the first iteration are calculated as shown below.

$$a'_{n,r,i} = a_{n,r,i} + u_1\left(a_{n,best,i} - \left|a_{n,r,i}\right|\right) - u_2\left(a_{n,worst,i} - \left|a_{n,r,i}\right|\right) \tag{20}$$

$$a'_{1,1,1} = a_{1,1,1} + u_1\left(a_{1,4,1} - \left|a_{1,1,1}\right|\right) - u_2\left(a_{1,3,1} - \left|a_{1,1,1}\right|\right)$$

$= -4 + 0.57(-7-|-4|) – 0.80(69 - |-4|) = -62.27$

$$a'_{2,1,1} = a_{2,1,1} + u_1\left(a_{2,4,1} - \left|a_{2,1,1}\right|\right) - u_2\left(a_{2,3,1} - \left|a_{2,1,1}\right|\right)$$

$=17+ 0.91(6 -|17|) -0.48 (-5-| 17|) = 17.55$

Also, the new estimation of a_1 and a_2 for the other participants is computed. Table 3 demonstrates the new estimation of a_1 and a_2 and the corresponding values of the fitness function.

Table 3 New values of the factors and fitness function after first iteration

participant	a_1	a_2	*f(a)*
1	-62.27	17.55	4185.5554
2	-43.2	43.2	3732.48
3	25.68	0.71	659.9665
4	-64.58	11.28	4297.8148
5	-67.66	-16.45	4848.4781

Presently, the estimations of *f (a)* of Tables 2 and 3 are found out and the best estimations of *f (a)* are taken and put in Table 4. This finishes the primary emphasis of the Jaya algorithm.

Table 4 Updated values of the factors and the fitness function in view of fitness comparison at the end of first iteration.

participant	a_1	a_2	*f(a)*	condition
1	-4	17	305	-
2	-43.2	43.2	3732.48	worst
3	25.68	0.71	659.9665	-
4	-7	6	85	best
5	-11	-17	410	-

From Table 4 it can be observed that the best result is corresponding the fourth applicant and the awful result is corresponding to the second applicant. Now, amid the second iteration, let arbitrary numbers 'u_1= 0.26 and u_2 = 0.22' for a_1 and 'u_1= 0.37 and u_2 = 0.50' for a_2, the new estimation of the variables for a_1 and a_2 are estimated using Eq. (19). Table 5 demonstrates the new estimation of a_1 and a_2, the corresponding values of the fitness function amid the second iteration.

Table 5 Modified values of candidates after second iteration

participant	a_1	a_2	*f(a)*
1	3.524	-0.17	12.4474
2	-37.244	29.436	2253.6
3	32.3368	-18.5777	1390.8
4	0.404	-12.6	158.93
5	-3.756	-34.17	1181.6964

The obtained solution of *f (a)* of Tables 4 and 5 are taken and the best estimation of *f (a)* are considered and set in Table 6. This finishes the second iteration of the Jaya algorithm.

From Table 6 it can be observed that the favorable result is corresponding to the first participant and the worst result is corresponding to the second applicant. It can also be seen that the estimated result of the fitness function is decreased from 85 to 12.4474 in only two cycles. Again, if we add up the number of iterations, then the known values of the fitness function (i.e. 0) can be acquired within a few numbers of iterations. Likewise, in the case of maximization problems, the best value infers the maximum measure of the fitness function and the computations are to be continued with as need be. In this way, the proposed strategy can manage both minimization and maximization issues.

Table 6 Final updated values of the factors of the candidates after second iteration

participant	a_1	a_2	*f(a)*	condition
1	3.524	-0.17	12.4474	best
2	-37.24	29.436	2253.6	worst
3	25.68	0.71	659.9665	-
4	-7	6	85	-
5	-11	-17	410	-

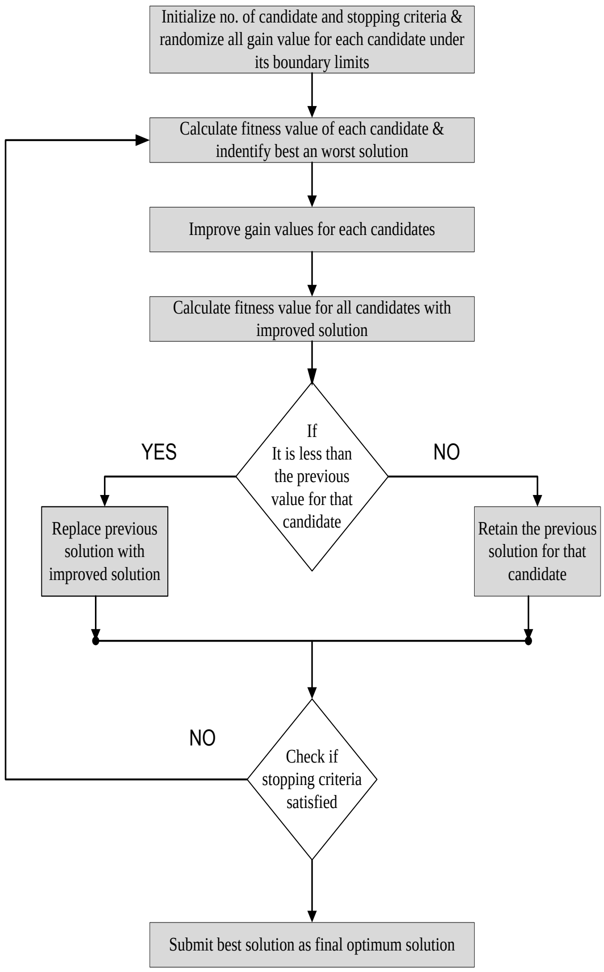

Fig4 Flow chart of best candidate updating

4. Simulation Results and Discussion

The dynamic performance of the proposed system is compared with two area thermal systems at step load perturbation of 0.2pu in both the area using Jaya algorithm. Fig. 5 shows the convergence curve for the proposed system. Frequency deviation in area1, area2 and tie line power deviation are shown in the Fig.6, 7 and 8 respectively. Table7 shows the PID gains for both the system. Result shows that power plant with solar power gives quick settlement of frequency and power deviation to zero. From the Fig. 6-8 it is clear that Jaya algorithm based PID controlled for the two area power system with STPP gives better dynamic response when subjected to sudden increase in the power demand. Settling time (T_s), peak undershoots (U_{sh}) and peak overshoots (O_{sh}) of $\Delta\omega_1, \Delta\omega_2$ and ΔP_{tie} are shown in Table 8. From Table 8 it is easily observed that settling times, undershoots and overshoots of frequency and tie-line power deviation are less with the proposed framework as compared to two area thermal systems using Jaya algorithm. A clear pictorial view of settling time, undershoots and overshoots are shown in Figs. 9-11, respectively.

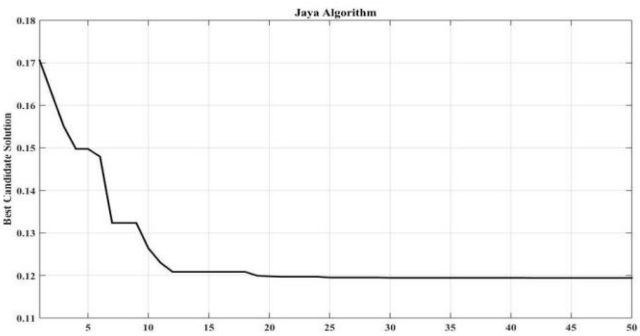

Fig.5 Best candidate solution with STPP

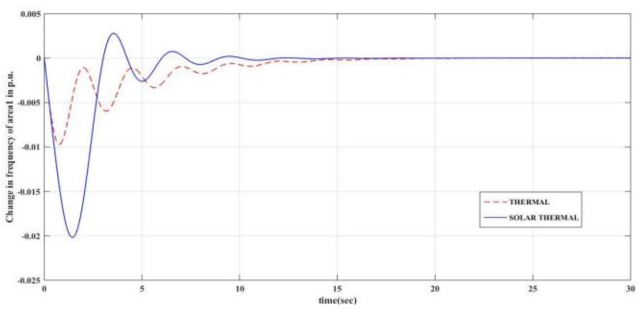

Fig. 6. Frequency deviation of area1 with & without STPP

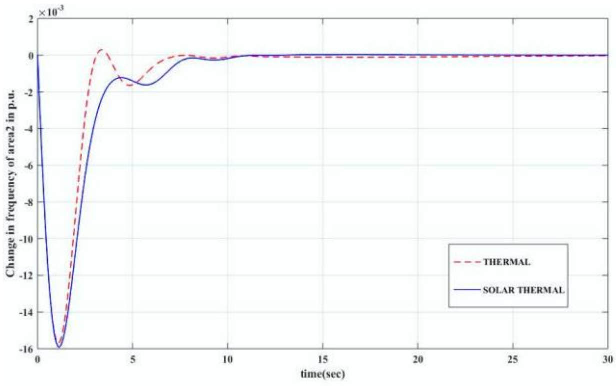

Fig. 7. Frequency deviation of area2 with & without STPP

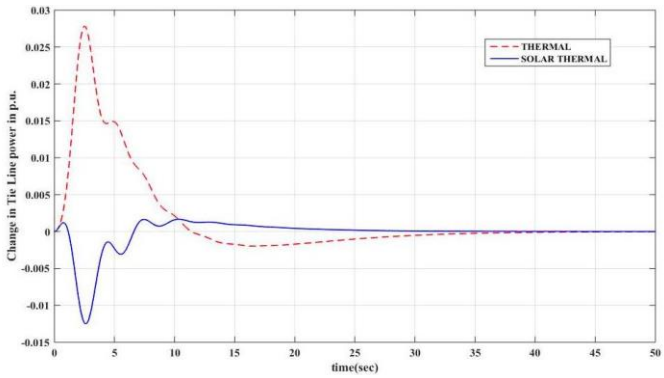

Fig.8. Tie line power with and without STPP.

Table 7 Controller gains with and without STPP

Controller gain	Without STPP	With STPP
K_{p1}	0.9067	1
K_{p2}	1	0
K_{i1}	0.7798	0.3539
K_{i2}	1	0.3197
K_{d1}	1	1
K_{d2}	0.9015	0.2560

Table 10 Controller gain values with variation in SLP

Controller gain	0.2pu SLP	0.3pu SLP
K_{p1}	1	1
K_{p2}	0	0
K_{i1}	0.3539	0.3373
K_{i2}	0.3197	0.3039
K_{d1}	1	1
K_{d2}	0.2560	0.1852

Table 8 Dynamic performance with and without STPP

Parameters	Dynamic performance	Without STPP	With STPP
Δw_1	Settling time	15.256776	8.5291308
	Over shoot	0.002817183	0.002786487
	Under shoot	0.0096840185	0.020188473
Δw_2	Settling time	8.2250906	7.5307438
	Over shoot	0.00019557712	0.00003422029
	Under shoot	0.0090073828	0.015908331
ΔP_{tie}	Settling time	37.552106	22.898826
	Over shoot	0.0053578033	0.00167344
	Under shoot	0.0024127723	0.012513358

Table 9 Comparison of Integra, PI controller with PID using Jaya algorithm for STPP

Parameters	Dynamic performance	Integral control	PI control	PID control
Δw_1	Settling time	11.92054	14.418729	8.5291308
	Over shoot	0.012924503	0.0023281984	0.002786487
	Under shoot	0.025128898	0.020845056	0.020188473
Δw_2	Settling time	14.658047	13.978827	7.5307438
	Over shoot	0.0021795308	0.0016410739	0.00003422029
	Under shoot	0.018085167	0.019666237	0.015908331
ΔP_{tie}	Settling time	24.370994	31.009171	22.898826
	Over shoot	0.014122517	0.0040503251	0.00167344
	Under shoot	0.045736824	0.0087653243	0.012513358

4. *Sensitivity analysis*

For sensitivity analysis the parameters and loading condition of the system are changed and controller gains are optimized using Jaya algorithm. The dynamic responses corresponding to these changes are obtained and compared with the result with the dynamic responses at nominal condition. It is essential for a robust controller that response should be more or less same and there must be no need to reset the controller. In the present work, sensitivity analysis is performed to confirm the robustness of the system with STPP at nominal condition and parameters. To accomplish the analysis, system parameter is changed from '-25% to +25%' and SLP is changed to 0.2pu and 0.3pu.For every changed condition the Jaya algorithm is used. Table10 and Table11 give the complete dynamic response of the proposed system for SLP and parameter variation when sensitivity analysis is performed. By observing the responses, it is very clear that obtained responses more or less are same. Thus, it is not necessary to change the gains of the PID at nominal to large change in system parameter and system loading condition. That means Jaya optimized PID controlled AGC with STPP is quite robust towards variation in the system over a wide range.

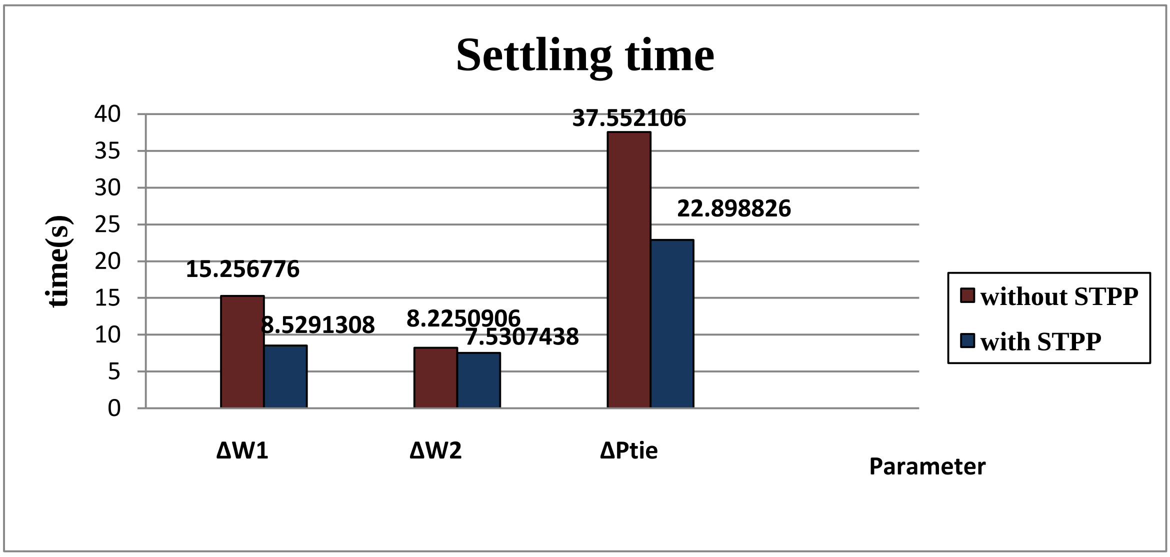

Fig.9 Settling time variation with and without STPP

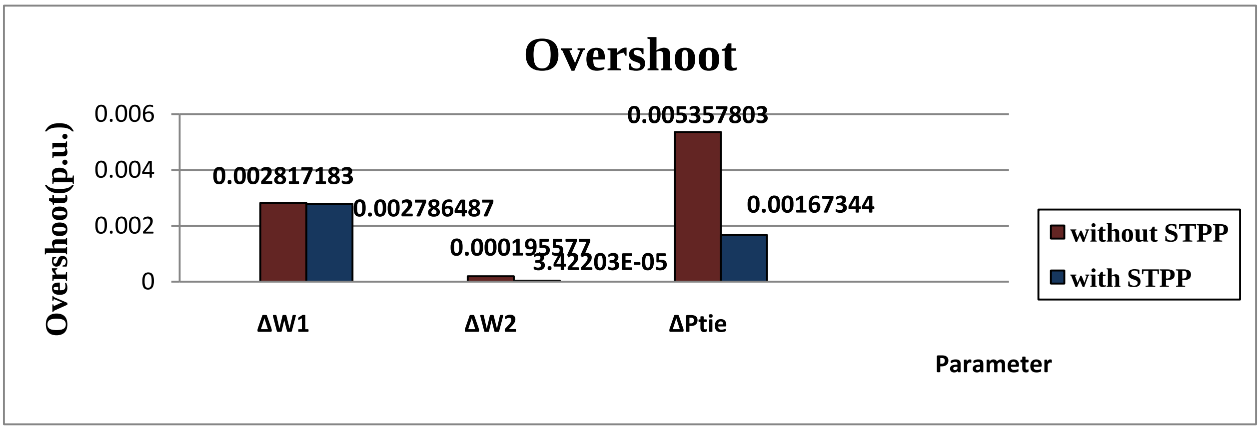

Fig. 10 Overshoot bar graph comparisons with and without STPP.

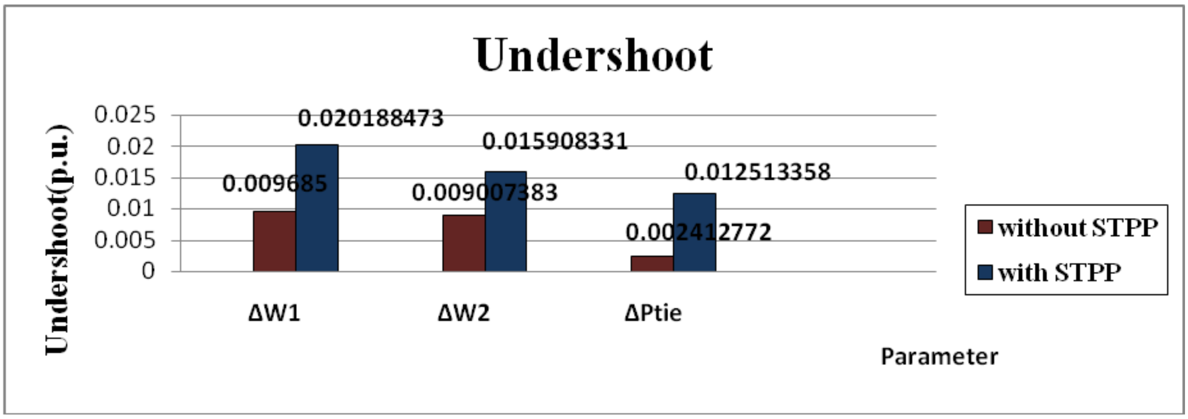

Fig.11 Undershoot bar graph comparisons with and without STPP.

Table 11 Variation of dynamic response due to parameter variation

parameter	% change	$\Delta w1$			$\Delta w2$			ΔP_{tie}		
		Tsh	**Osh**	**Ush**	**Tsh**	**Osh**	**Ush**	**Tsh**	**Osh**	**Ush**
H1	**-25%**	9.967	0.00378	0.023727	9.99	0.000026	0.017494	20.940134	0.00240236	0.01464
	+25%	7.843218	0.0023124974	0.01774943	7.6773387	0.000057	0.014045275	24.536005	0.0031159903	0.012141874
H2	**-25%**	8.447504	0.00329	0.02031574	7.1903782	0.000055	0.014995355	22.042253	0.0033296802	0.016895385
	+25%	8.4718598	0.0026352639	0.019951027	7.7642598	0.000478	0.015618253	25.364941	0.0020970231	0.010781626
B1	**-25%**	9.1284712	0.003147332	0.021114225	9.8274345	0.000045	0.015275278	22.536033	0.0028675887	0.019748915
	+25%	8.1568069	0.0027468093	0.019345793	7.2142669	0.000023	0.015085191	19.846182	0.0014140686	0.011864722
B2	**-25%**	8.6601691	0.0026837065	0.020178607	9.4541039	0.00004	0.015311252	18.909338	0.0020493035	0.015182851
	+25%	8.6860817	0.0025852562	0.020200881	9.6689652	0.000012	0.015541179	21.386598	0.0018671772	0.014848399
R1	**-25%**	10.438101	0.008650002	0.02003173	11.850764	0.000661	0.010027439	21.669692	0.0054400836	0.015981231
	+25%	8.9902774	0.0028079957	0.02082685	9.7952811	0.000051	0.015283233	23.261783	0.002474558	0.018501153
R2	**-25%**	11.437101	0.0099500018	0.019403173	13.748764	0.000502	0.011047439	22.639682	0.0063248836	0.025981111
	+25%	9.7295637	0.0030324743	0.020172373	7.1730084	0.000585	0.016606628	27.42467	0.001952615	0.0083626957
Tt1	**-25%**	6.8343678	0.0022591771	0.0189408	6.7699531	0.000099	0.014782653	27.920121	0.0019045057	0.010543049
	+25%	12.149776	0.0039474897	0.021261441	10.583439	0.000005	0.016943349	18.472651	0.0027113535	0.014908602
Tt2	**-25%**	8.6735947	0.0026346944	0.020188579	9.5685389	0.000023	0.015414931	20.587431	0.0019878199	0.014996786
	+25%	8.4416353	0.0028348692	0.020177253	7.487368	0.000045	0.016165546	25.444204	0.0016714428	0.010398255
Tg1	**-25%**	7.9997093	0.0017949551	0.019562933	7.535956	0.000032	0.015742732	23.415229	0.0013005842	0.010898016
	+25%	11.528843	0.0035601232	0.020816417	10.058958	0.000023	0.016412503	20.461281	0.0024131651	0.013639974
Tg2	**-25%**	8.5556907	0.0028410849	0.020164081	7.6799391	0.000039	0.015471428	23.076302	0.0019452797	0.013691793
	+25%	8.4606812	0.0029495722	0.020183418	7.3824903	0.000045	0.016144485	25.215021	0.0019252055	0.011469311

5. Conclusion

In this paper renewable energy source that is solar thermal power plant (STPP) is incorporated with two area automatic generation control system and also a new optimization technique i.e. Jaya algorithm is used. It was also concluded that after using solar power in area one, the dynamic performance of the framework is improved compared to without STPP. Jaya algorithm is used for the first time in Automatic Generation Control for optimization of several parameters such as gain value of the PID controller. Comparison of performance of classical controller such as integral (I), proportional integral (PI), proportional integral derivative (PID) reveals that the PID controller gives better result with STPP. It is also found that the dynamic response of the system with STPP is improved from the view point of settling time, peak overshoot, undershoot and magnitude of the oscillations. From sensitivity analysis point of the system, it is found that Jaya algorithm based PID controller gains obtained at specified condition and specified system parameters is quite robust and it is not necessary to reset parameter for large variations in the system and other system parameters.

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