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Automatic Generation Control of a Multi-Source Power System using FOPID Controller by FA

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ABSTRACT: This paper focused on the automatic generation control of multi-source power system comprising of hydro, thermal, gas units by using fopid controller. The fopid controller has good dynamics as compare to the io, pi, pid controller. Selection of parameters is done with firefly algorithm. The firefly algorithm is used for all of the three systems. Fopid controller controls the overshoot and oscillations of the respective system. The firefly algorithm is robust technique used for the optimization of the parameters

KEYWORDS: Automatic Generation Control, Fraction order controller, firefly algorithm, FOPID controller.

I. INTRODUCTION

In the power operation and protection, limiting the frequency and voltage in a nominal or predetermined value is one of the major issues that are being faced in this field. Generation power quality and reliability was expected to depend upon the determined balance between the power generated and demanded, combined with the power losses in the whole power system.

There is some deviation caused in power and frequency because of disruption in balance. Some random change in the loads can also be seen due to this disruption. This is the reason, it is recommended to use the proper control method so that overall constancy of power unit can be obtained. Till the time numerous control method exist and used to control the frequency parameter in different power system.

Automatic generation Control may be described as one of necessary controlling technique in interlinked power units to make sure that the operation is efficient and secure. If any variation among power production unit and power consumption unit has been identified then it will result in unwanted divergence in frequency

Automatic Generation Control is the best strategy to control the system to confirm the operation. If there is any mismatch occurs between generation and demand the frequency changes from its desired value. The primary goal of this strategy is to control the frequency and tieline power flow in interconnected area to its desired value. Therefore in order to achieve it many controllers are introduced in the system. These are integrator controllers, PI, PID, FOPID controllers. All have there own performance values but FOPID controller is the best among all because FOPID gives good dynamics response as compared PI, PID controllers.

There are several control methods like optimal control technique, variable structure control, selftuning etc. some of the industries uses IO, PI based controller. These methods are based on error and trial methods but these controllers have no surety to provide good and improved performance in the realistic conditions like GRC and GDB. So to eliminate these problems new controller was introduced which is based on fractional order that is FOPID controller. This controller is superior than others because it has two extra tuning knobs name as fractional order of integrator and

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 7, July 2017

fractional order of differentiator. These knobs provide more flexibility for dynamics performance of the system. The multisource consists of the hydro, thermal, gas units.

There are many methods to solve the automatic generation problems. These methods include particle swarm optimization (pso), firefly algorithm (fa), genetic algorithm (ga), artificial bee colony (abc). Firefly algorithm is the new technique which is used in automatic generation control problems. The main advantage of FA is its robustness. It is the most efficient method than others to achieve the optimization values.

The three units are taken hydro, thermal and gas units. The advantage of gas units is its ability to turn on and off within minutes, supplying power during peak demand. FA is used for the selection of parameters that are present in supplementary controller.

II. FRACTIONAL CALCULAS

The fractional calculus definition's and the Caputo's definition can be differentiated and chosen is formulated as follow:

$${}_a D_t^\mu f(t) = \frac{1}{\Gamma(\mu-n)} \int_a^t \frac{f^{(n)}(\tau)}{(t-\tau)^{\beta-n+1}} d\tau \dots \dots \dots (1)$$

The equation given above is the operator of the fractional differential where m in the equation shows the integer. In order to use the fractional operator in the study of application, it becomes necessary to give an approximation in the transfer of the integer order function.

$$s^\mu = K \prod_{i=-P}^P \frac{s+\omega'_i}{s+\omega_i} \dots \dots \dots (2)$$

$$\omega'_i = \omega_i \left(\frac{\omega_h}{\omega_i} \right)^{\frac{1+P+0.5(1-\mu)}{2P+1}} \dots \dots \dots (3)$$

$$\omega_i = \omega_i \left(\frac{\omega_h}{\omega_i} \right)^{\frac{1+P+0.5(1+\mu)}{2P+1}} \dots \dots \dots (4)$$

$$K = \left(\frac{\omega_h}{\omega_i} \right)^{-\frac{\mu}{2}} \prod_{i=-P}^P \frac{\omega_i}{\omega'_i} \dots \dots \dots (5)$$

Where μ in the equation shows the FO of derivative, P show count for zeros as well as poles, ω'_i depicts the i^{th} zero the range of $[\omega_i, \omega_k]$ whereas ω_i depicts pole in the range of $[\omega_i, \omega_k]$ respectively.

III. FOPID CONTROLLER

The fractional order Controller can be better described with the use of an equation such as Fractional order differential equations. The Riemann-Liouville is the most commonly used definition of the fractional calculus i.e.

$${}_a D_t^\mu f(t) = \frac{1}{\Gamma(m-\alpha)} \left(\frac{d}{dt} \right)^m \left(\int_a^t \frac{f(\tau)}{(t-\tau)^{1-(m-\alpha)}} d\tau \right) \dots \dots \dots (6)$$

In the above equation $\Gamma(m-\alpha)$ is the Euler's gamma function. Alternatively, another definition for the fractional differentiation is by the Grunwald Letnikov which is described as:

$${}_a D_t^\alpha f(t) = \lim_{k \rightarrow 0} \frac{1}{\Gamma(\alpha) h^\alpha} \sum_{k=0}^{(t-a)/h} \frac{(-1)^k \Gamma(\alpha+1)}{\Gamma(k+1)} f(t-kh) \dots \dots \dots (7)$$

After introducing the fractional order operator, the differentiator and the integrator i.e. ${}_a D_t^\alpha f(t)$ can be combined together. Another important tool used is the Laplace transform which is the nth derivative of a signal represents such as:

$$L\{D^m x(t)\} = \int_0^\infty e^{-xi} {}_0 D_t^n x(t) = S^m X(s) - \sum_{k=0}^{n-1} S^k {}_0 D_t^{n-k-1} x(t)|_{t=0} \dots \dots \dots (8)$$

International Journal of Innovative Research in Science, Engineering and Technology

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Vol. 6, Issue 7, July 2017

Where $x(t)$ is the signal relaxed at $t=0$. The equation 9 shows the normal Laplace transformation. Hence it has shown that fractional differential equation provides $u(t)$ and $y(t)$ signals relaxed at $t=0$. This term can be expressed as a transfer function form as:

$$G(s) = \frac{a_1 s^{\alpha_1} + a_2 s^{\alpha_2} + \dots + a_{m_A} s^{\alpha_{m_A}}}{b_1 s^{\beta_1} + b_2 s^{\beta_2} + \dots + b_{m_B} s^{\beta_{m_B}}} \dots \dots \dots (9)$$

Where $(a_m, b_m) \in R^2, (\alpha_m, \beta_m) \in R_+^2, \forall (m \in N)$
Among different PID controller, the $PI^\lambda D^\mu$ is the most commonly used controller where an integrator order λ and differentiator order μ can be any real numbers. For the given PID controller, the transfer function used is given as:
 $G_c(s) = K_p + \frac{K_i}{s^\lambda} + K_d s^\mu, \lambda, \mu > 0 \dots \dots \dots (10)$

The PID controller with integrator and differentiator is also considered as the Fractional Order PID controller. In this type of controller the integral (δ) and derivative (λ) can be adjusted through the user in addition to the PID constants. The values of λ and δ vary between 0 to 1. By providing these extra knobs i.e. order of differentiation and Order of integration, the level of freedom for the operator is high.

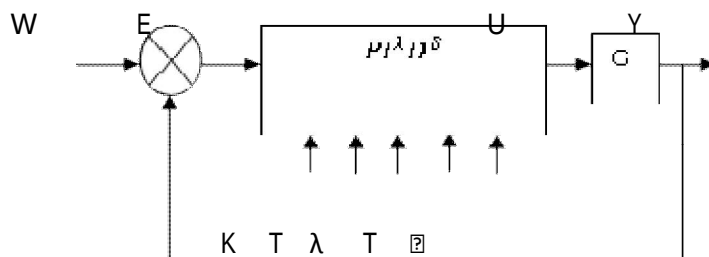


Fig 1. Fractional PID Control System

Moreover, this factor also enhances the flexibility and opportunity to the operator in order to control the system by adjusting the dynamical properties. The fractional order controller is robust but produces significant output in the presence of non-linear actuator.

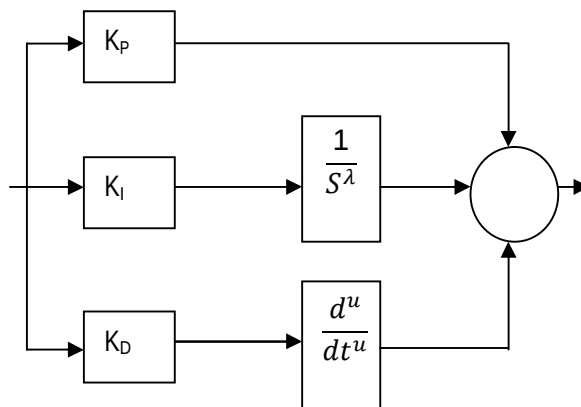


Fig 2.FOPID controller structure

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Figure 3 explains the basic structure of the FOPID controller where three inputs have been forwarded to the system i.e. proportional, Integral and Derivative.

IV. TWO AREA POWER SYSTEM

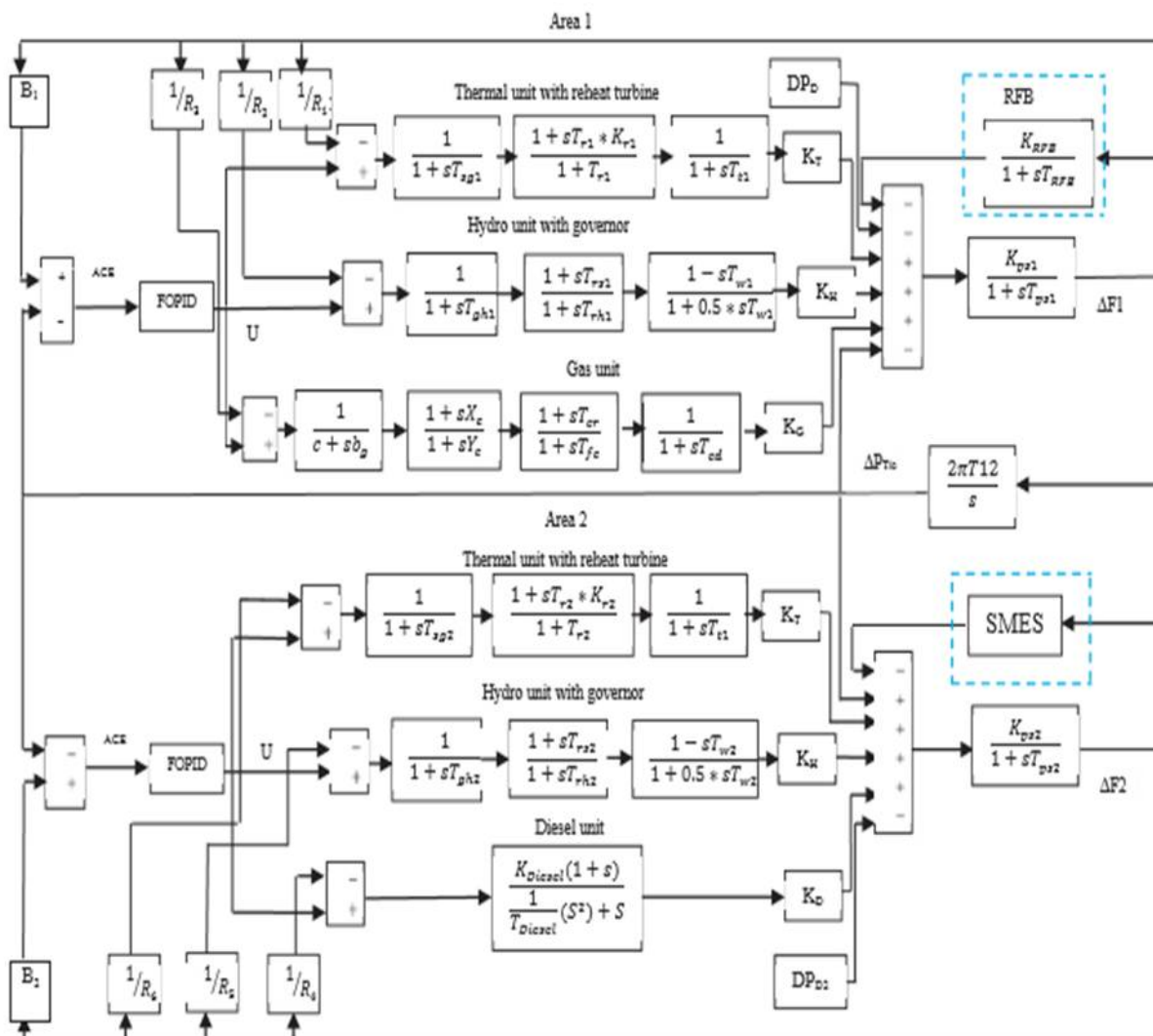


Fig. 3. Multi-source two area interconnected power system

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

PARAMETERS VALUES:

Table 1. Value of SSO algorithm parameters for LFC problem

Parameters	Value
Population size	50
Iteration	50
Female Percent	44
Male percent	6
Upper limit of K_r , K_t and K_o	+10
Lower limit of K_r , K_t and K_o	-10
Upper limit of K_{smes}	2
Lower limit of K_{smes}	0
Upper Limit of λ and μ	1
Lower Limit of λ and μ	0
Upper limit of T_1 , T_2 , T_3 , T_4 and T_{smss}	1
Lower limit of T_1 , T_2 , T_3 , T_4 and T_{smss}	0

Table 2. Value of optimized FOPID controller parameters using SSO algorithm

		Control Parameters	Thermal	Hydro	Gas	Disel
Model without RFB and SMES	Area 1	K_r	-8.5607	8.8461	-1.7102	
		K_t	-7.1027	-0.6398	-1.4562	
		K_o	2.3935	1.1184	-0.1753	
		λ	0.8147	0.2370	0.5135	
		μ	0.3827	0.5080	0.6390	
	Area 2	K_r	-8.5607	8.8461		3.9502
		K_t	-7.1027	-0.6398		-0.9584
		K_o	2.3935	1.1184		-8.4396
		λ	0.8147	0.2370		0.4880
		μ	0.3827	0.5080		0.0797
Model with RFB and SMES	Area 1	K_r	-4.9105	7.4214	-5.2184	
		K_t	-9.6040	-3.3650	-1.8269	
		K_o	0.9718	-0.4741	5.3892	
		λ	0.7585	0.2741	0.2723	
		μ	0.6614	0.5515	0.3467	
	Area 2	K_r	-4.9105	7.4214		1.1368
		K_t	-9.6040	-3.3650		-0.1353
		K_o	0.9718	-0.4741		-6.1911
		λ	0.7585	0.2741		0.6587
		μ	0.6614	0.5515		0.0817

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

Table 3. Value of SMES parameters optimized by SSO algorithm

Parameters	Values
K_s	1.9059
T_1	0.6596
T_2	0.5762
T_3	0.1250
T_4	0.2931
T_5	0.5194

Table 4. Value of ITAE and settling time and peak overshoot without RFB and SMES

Criterion	Case 1	Case 2
ITAE	0.0218	0.0194
Settling Time (0.2%)		
Δf_1	3.5262	2.2943
Δf_2	3.9261	2.7276
$\Delta P_{no-line}$	3.3334	2.3298
Peak Overshoot		
Δf_1	0.0193	0.0144
Δf_2	0.0157	0.0045
$\Delta P_{no-line}$	0.0028	0.0027

V. RELATED WORK

The proposed system develops and FOPID system which is based on firefly algorithm. Two benefits are associated with the FA technique as compare with different algorithm: capability to work with multimodality and ability to automatically divide itself into sub group. In the beginning, FA technique is totally dependent on lure and pleasant appearance reduces with length. From this it can be understood that the complete population will automatically divide itself into different small groups and all the groups can group about the local optimum. The optimum solution can be determined from different modes. After all this, sub groups permits the fireflies to determine all local optima at the same point of time when the size of population is adequately elevated as compare to count for different modes. The average distance among fireflies can be monitored by $\frac{1}{\sqrt{\gamma}}$. Hence, the complete population can be divided into small groups. Consider a situation where $\gamma = 0$, then the complete population will not able to divide itself into subgroups. The capability to automatically divide itself into subgroups makes it appropriate for extremely non linear systems, to resolve the multimodal optimization relates issues.

i. FIREFLY PARADIGM

It is kind of optimization paradigm. This algorithm was introduced by the researcher named as Yang. It is swarm intelligence based on the metaheuristic approach and the idea of this method is obtained by flashing actions of fireflies. These are insects living in groups whose flashes treat as a signal system to other flies. Thus flies based on these patterns

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Vol. 6, Issue 7, July 2017

interact or communicate with each other. Consequently, firefly algorithm is based on two concepts, first is changes in the intensity of light and formulation of pleasant appearance whereas attractiveness of firefly can be firm with brightness exhibit by firefly. And it has treated as an intent function for problems related to optimization. As the attracting feature of firefly is directly propositional to the intensity of light.

The attractiveness of a firefly

can be describe in mathematical form as follow:

$$\beta(r) = \beta_0 e^{-\gamma r^2} \dots \dots \dots (11)$$

Here β_0 defines the pleasant appearance at $r=0$ and β depict the coefficient for absorption of light at the source.

Distance between two fireflies

$$r_{i,j} = |x_i - x_j| = \sqrt{\sum_{k=1}^d (x_{i,k} - x_{j,k})^2} \dots \dots \dots (12)$$

$r_{i,j}$ Has evaluated in eq. 3 which is a Cartesian length among any two differet fireflies i at x_i and j at x_j . Here x_i and x_j depicts the spatial coordinates of the fireflies i and j respectively. This movement of a firefly me, attracted to firefly j can be evaluated.

Movement of a Firefly

$$X_i = x_i + \beta_0 e^{-\gamma r_{ij}^2} (x_j - x_i) + \alpha (\text{rand} - \frac{1}{2}) \dots \dots \dots (13)$$

Here 2nd term in the equation depicts attraction and third term named as Rand is the randomization in which numbers are uniformly distributed in the interval 0 and 1 as [0, 1]. In mostly cases of implementation, $\beta_0 = 1$ and $\alpha \in [0,1]$.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

ii. FLOW CHART OF FIREFLY ALGORITHM

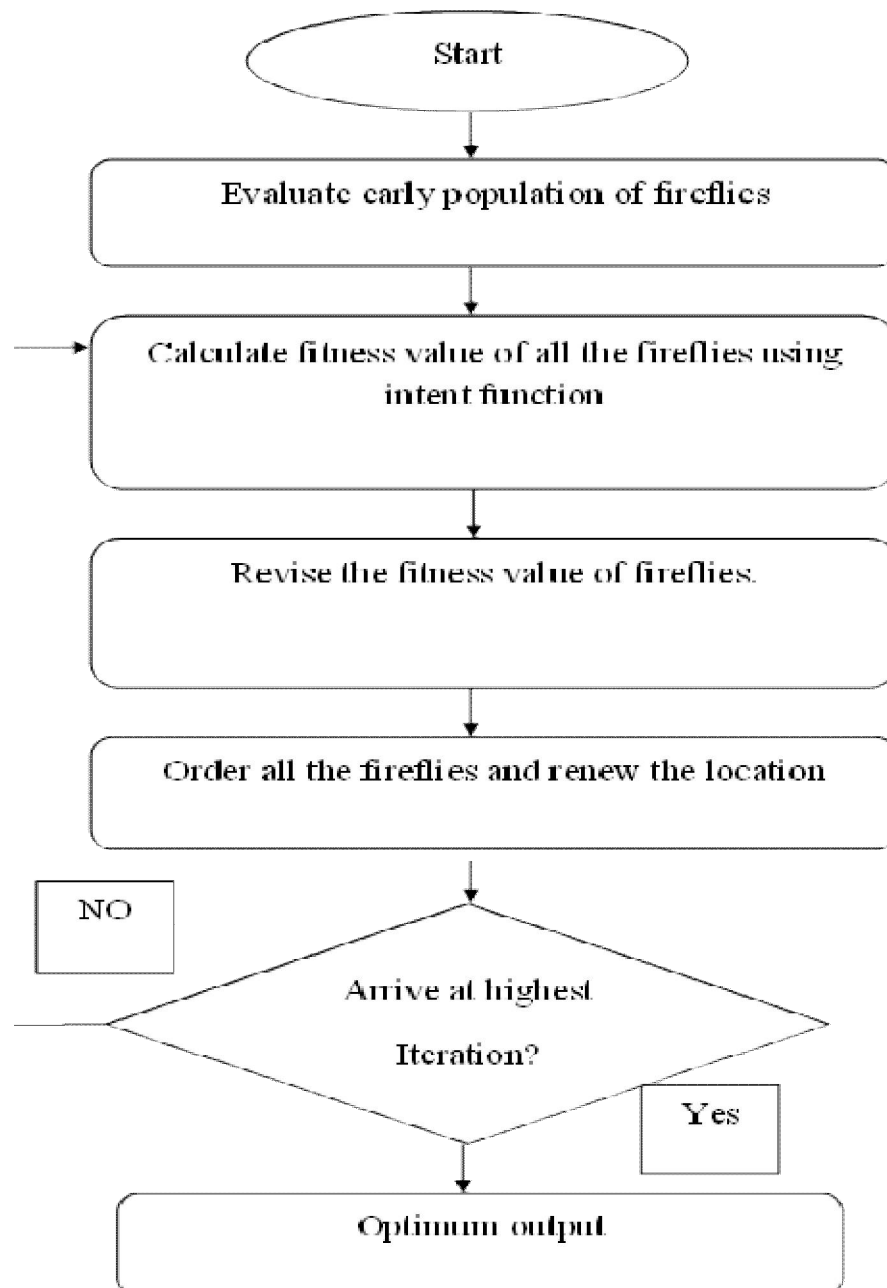


Fig. 4 Flow chart of firefly algorithm

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

VI. EXPERIMENTAL RESULTS

The three units hydro, gas, thermal are controlled differently. The firefly algorithm is applied differently on every unit.

i. ELECTRIC GOVERNOR PID CONTROLLER:

Initially the experiments have performed on the electric governor PID controller using the Firefly optimization algorithm. The acquired results have shown below:

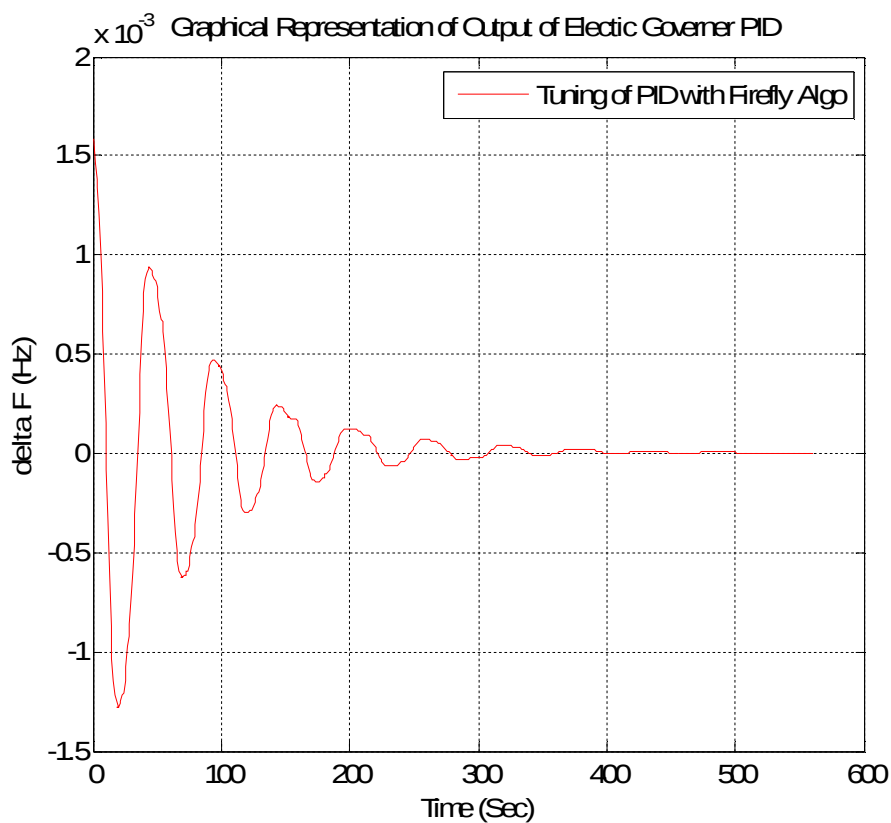


Fig. 5. Output of the electric governor PID controller by using firefly Algorithm

The graph shows the output of the electric governor PID controller by using the firefly algorithm. The graph makes it clear that the output curve has fewer fluctuations and initially it is in negative frequency but then started growing towards the positive frequency.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

ii. HYDROTHERMAL PID CONTROLLER

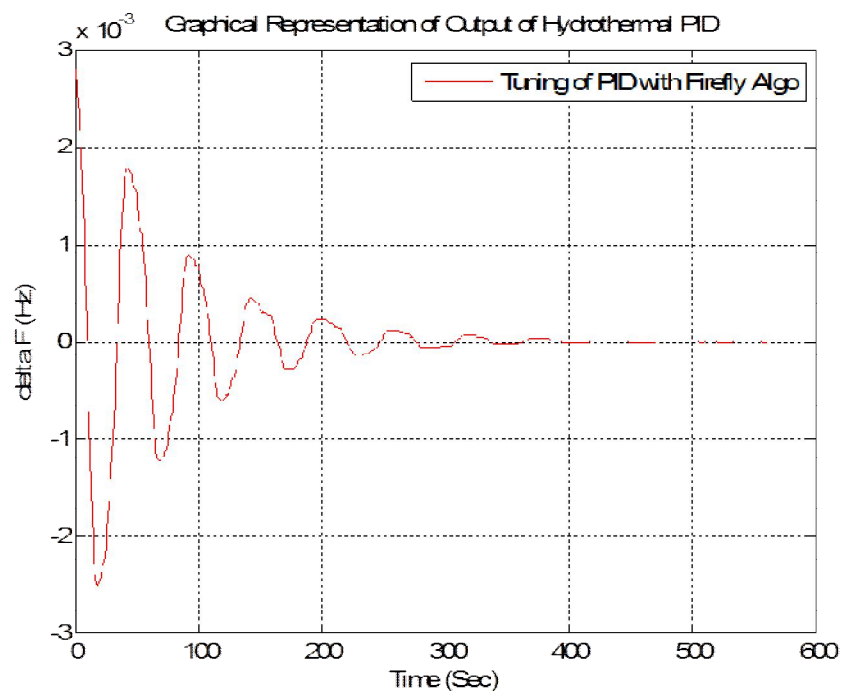


Fig 6. Output of the Hydrothermal PID controller by using firefly Algorithm

The graph shows the output of the hydrothermal PID controller using firefly algorithm. The variation in the output curve can be seen from the graph. Initially the frequency of the output curve is recorded between 3 and 2 but then a fall in the curve can be seen from the graph which shows that the frequency goes down towards -2 and vice versa constantly. When the time interval is recorded nearby 200 and 300 then at the same time the output curve poses the positive frequency which ranges from 0 to 1.

International Journal of Innovative Research in Science, Engineering and Technology

(An ISO 3297: 2007 Certified Organization)

Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

GASTHERMAL PID CONTROLLER

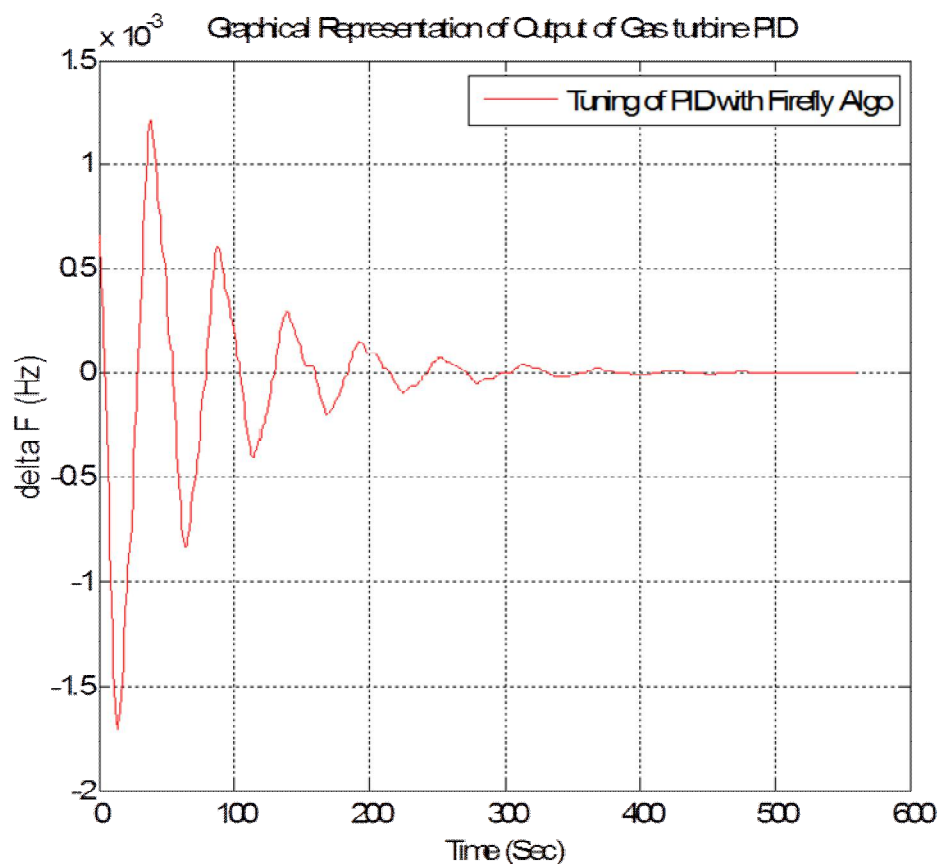


Fig 7 Output of the Gas Turbine PID controller by using firefly Algorithm

The graph depicts the performance of the firefly algorithm which is showed in the form of output curve of the gas turbine PID controller tuned with firefly algorithm. The graph shows that there are less variations in the system using firefly algorithm.

VI. CONCLUSION

This study develops a Firefly Optimization based PID controller for the output of three power grid systems. The simulation is done by considering the output of three power systems such as hydrothermal power system, gas turbine and electric governor power system. The proposed system presents a tuning of PID controller with firefly algorithm. The result section shows that the tuning of PID controller with firefly is better than the others methods.

International Journal of Innovative Research in Science, Engineering and Technology

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Website: www.ijirset.com

Vol. 6, Issue 7, July 2017

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