International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878, Volume-8 Issue-3, September 2019

Frequency Regulation of Renewable Energy Integrated Deregulated Power System using Novel Optimization Scheme

Sayantan Sinha, Ranjan Kumar Mallick

Abstract**: *The proposed work deals with the automatic generation control of a two area system under deregulated power environment. The two area system considered for analysis implements the integration of renewables into it. The system model consists of a solar thermal plant and a reheat thermal plant in area 1. The reheat thermal plant is replaced with the nuclear power plant in area 2. So the second area consists of a nuclear plant and a solar thermal plant for study. This work also deals with the application of a new controller namely the Tilted Integral Derivative controller as a secondary controller for minimizing the Area control Error (ACE) and bring it to zero. This work also proposes the implementation of a novel optimization technique-Dragonfly algorithm (DA) technique. The superiority of DA tuned TID controller was established in terms of settling time, maximum overshoot and minimum undershoot. The behaviour of the DA tuned TID controller is also tested in the new model for two different market scenarios namely the base case and the bilateral transaction. The dynamic system performance parameters are evaluated and noted. The robustness of the proposed DA tuned controller is effectively established.***

Keywords **: AGC, TID controller, DA, Nuclear plants**

I. INTRODUCTION

Modern day power system is characterized with an increasing number of interconnections for ensuring better stability, reliability and security. This interconnection eases the power system operation to a great extent but has some major concerns. During the occurrence of a fault, the frequency of the entire system gets hampered and the tie lines acting as interconnections between power system experience an abnormal swing of the power flowing through them. The function of Automatic generation control is to reduce the deviations in frequency and the tie line energy flows and to restore stability in the power system inside shortest interval of time

In earlier days the generation, distribution and the transmission sections of the power system was governed by a single entity called the VIU (Vertical integrated utility). However with time the concept of VIU became extinct and the generation and distribution was decentralized. A new governing body called the Independent service operator (ISO) was setup to exercise control over the GENCOs and the DISCOs. The DISCOs and the GENCOs come in a mutual contract between them for sharing of power. This deregulated market is very sensible to any change in frequency due to sudden load disturbances and hence AGC plays a pivotal role in restructured environment for maintaining the frequency and tie line power under nominal values.

In the recent years many researches have been made based on the performance of automatic generation control in the power system world like analysis of the power flow taking AGC into consideration in multi-area interconnected power grid [1]. In paper [2], a work has been done on an algorithm technique known as symbiotic organisms search for AGC in the interlinked power environment which includes wind farms. A recent paper [3] on AGC describes multiple unit of multiple area of deregulated power network by considering an algorithm method known as novel-quasi oppositional harmony search. A research has been made on the judgement of the influence of unreliability on AGC systems [4]. A method of modelling technique and a survey has been made on system stability of AGC on radio systems in smart grids [5]. Paper [6] describes the safety games for threat minimisation in automatic generation control. In previous years, a work has been done on a model based strike diagnosis and reduction for automatic generation control [7]. The extensive literature survey has broadly established the fact that the efficacy of AGC in maintaining system stability during sudden load changes mainly depends upon the various optimization techniques that are needed for proper tuning of the controller gains. So, the innovations of various optimization techniques are always a welcoming step for the role enhancement of automatic generation control of the entire power system. Many works have been done on various algorithm techniques and methods such as a flower pollination technique based AGC of interlinked power environment and cross characterized 'gbest'-mentored gravitational search and marking search algorithm for AGC of multiple area power system [8-9]. Several strategies have been made for control for automatic generation control in multi terminal DC grids [10] and other strategies such as in [11],

Manuscript published on 30 September 2019
* Correspondence Author
Sayantan Sinha, Dept of EE, SOA deemed to be University, Bhubaneswar, India. Email: sayantansinha51@gmail.com
Ranjan Kumar Mallick*, Dept of EEE, SOA deemed to be University, Bhubaneswar, India. Email: rkm.iter@gmail.com

divided model predictive control strategies with demand to power system automatic generation control and in paper [12], distributed automatic generation control using horizontal-based method for large perforation in generation of wind.

In [13], an approach has been made to AGC with different nonlinearities by using two degrees of PID controller. In paper [14], a recent study has been done in AGC by using the application of the surfaces of Bezier for a controller model known as genetic algorithm fuzzy controller. A recent view has been done on the show indices for gains of the controller of AGC [15]. Extensive literature surveys brought to light much effort on implementing Load frequency control on deregulated systems. [16-18]. Paper [16] brings to light the implementation of an ANFIS based controller for the Load frequency studies in deregulated market. The use of redox batteries and the implementation of FACTS device specially the IPFC in a multi area system and the study of AGC during deregulated market in vividly described in [17]. Paper [18] deals with the AGC in a multi-source power generation system under deregulate environment.

In this work an attempt has been made to develop a novel controller with the gains tuned by a hybrid optimization technique. The research work has the work flow like:

a. The primary step is the design of a binary power system with the inclusion of non-conventional energy sources. This step also includes the replacement of traditional thermal generation system with the nuclear power plant..

b.Design of a novel Tilted integral derivative controller for the AGC of the above designed multi-source power system under deregulated environment with the implementation of renewables.

c.Optimization of the gains of the proposed controller with Dragonfly Algorithm DA technique..

d. Establishing the robustness of the proposed controller by analysing the system dynamic parameters like settling time, maximum overshoot and minimum undershoot. The analysis is to be executed for two market scenario conditions i.e the base case and the bilateral condition

II. SYSTEM PROPOSED

This research work puts a proposal of a power system model consisting of a thermal plant in one area and nuclear power plant in another area. Now since due to environmental reasons and safety concerns, these two plants are normally located far away from the busy habitat; thermal plants being located close to coal fields to reduce the transmission costs and nuclear plants are located close to water bodies for easy disposal of nuclear wastes. Due to the presence of a large amount of barren land in areas adjoining to there power plants, solar power generation can be chosen as a viable option. Hence solar thermal power plant is incorporated as a secondary generation source in each area.

Modeling of nuclear power plant

The nuclear generation plant consists of a turbine having two Low pressure turbines (LP) and single high pressure turbine (HP). THE LP turbines are also coupled with reheat turbines[19].

.

Let ΔPm(s) be the governor input and ΔPv(s) be the generator control signal. Then the nuclear governor can be mathematically modelled as:

$$\frac{\Delta P_m(s)}{\Delta P_v(s)} = \frac{1}{T_{RN}(s)+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(1)$$

Where $T_{RN}(s)$ denoted the nuclear governor time constant.

The transfer function representation of the high pressure turbines are:

$$\frac{\Delta F_n(s)}{\Delta P_v(s)} = \frac{K_{HP}}{T_1 s+1} \quad \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots (2)$$

Where K_{HP} stands for the High pressure turbine constant and T_1 denotes the HP turbine time constant

Retrieval Number: C5119098319/2019©BEIESP
DOI:10.35940/ijrte.C5119.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

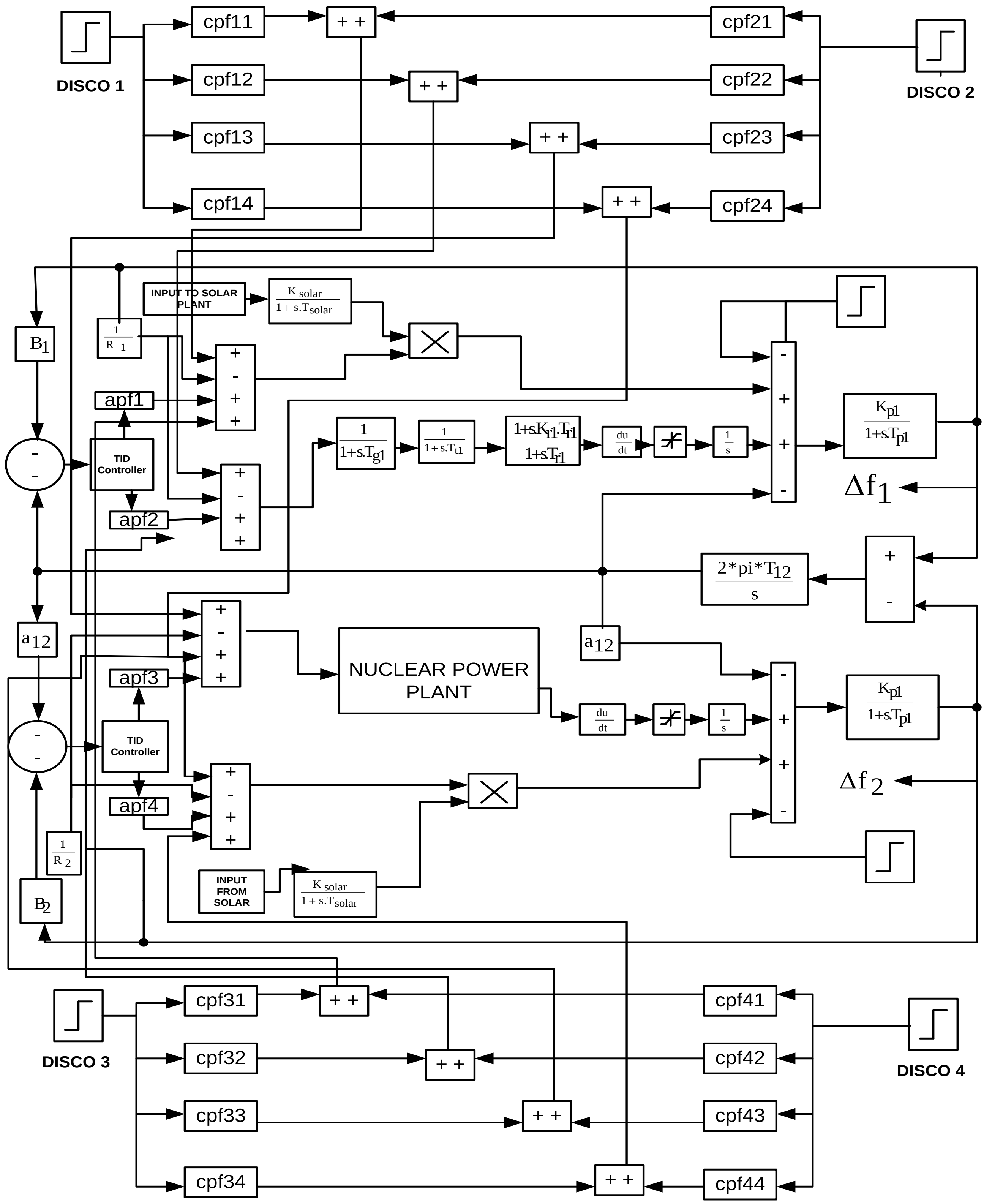

Figure 1: Linearized Transfer function model of the proposed system

The low pressure turbines can be mathematically modelled as:

$$T_{LP}(s) = \frac{k}{T_2 s + 1} \;\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\; (3)$$

Where T_{LP} stands for the transfer function of the LP turbines, k stands for the LP turbine constant and T_2 stands for the LP turbine time constant.

The reheat for the first low pressure turbine can be mathematically modelled as:

Retrieval Number: C5119098319/2019©BEIESP
DOI:10.35940/ijrte.C5119.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

$$R_{LP}(s)=\frac{1}{T_{RH_1}s+1}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(4)$$

Where T_{RH_1} stands out for the reheat time constant for turbine 1.

The reheat for the Low pressure turbine 2 can be modelled as

$$R_{LP}(s)=\frac{1}{T_{RH_2}s+1}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots(5)$$

Where T_{RH_2} stands for the reheat time constant for turbine 2

The low pressure turbine 1 can therefore be mathematically modelled as:

$$T_{LP_1}(s)=\frac{1+sT_{HR_2}}{1+sT_{HR_3}}\ \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(6)$$

The actual power flowing in tie line is represented as

$$\Delta P_{tieactual}=\frac{2\pi T_{12}}{s}\left(\Delta f_1-\Delta f_2\right)\ldots\ldots\ (7)$$

The tie line power flow when explained from the restructured point of view can be represented as:

$$\Delta P_{tiescheduled}=\sum_{i=1}^{2}\sum_{j=3}^{4}cpf_{ij}\Delta P_{Lj}-\sum_{i=3}^{4}\sum_{j=1}^{2}cpf_{ij}\Delta P_{Lj}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(8)$$

$$\Delta P_{tiescheduled}=\left[P_{\exp 1}\right]-\left[P_{imp1}\right]\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(9)$$

Where the net power output from area 1 that matches the demand of area 2 DISOCs are given by $\lfloor P_{exp}\rfloor$. $\lfloor P_{imp}\rfloor$ represents the area 1 power input that respectively balances the demands of the DISCOs stationed in two areas.

. The power deviation in the Tie line can be mathematically denoted as:

$$\Delta P_{tieerror}=\Delta P_{tieactual}-\Delta P_{tiescheduled}\ldots\ldots\ldots\ldots\ldots\ldots\ldots(10)$$

The area control error under the restructured scenario mathematically is expressed as:

$$ACE_1=\beta_1\Delta f_1+\Delta P_{tieerror1}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(11)$$

$$ACE_2=\beta_2\Delta f_2+\alpha_{12}\Delta P_{tieerror2}\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots(12)$$

where α_{12} denotes the error coefficients and β_1 and β_2 denotes the frequency bias factors for area 1 and area 2 respectively.

III. CONTROLLER STRUCTURE

Nonlinear control schemes ask for a greater degree of maintenance, data control and implementation strategies and are very sensible to slight parametric variations. Linear control schemes are therefore implemented as secondary controllers for the automatic generation control studies. The reliability and easy to access attributes of the Proportional Integral Derivative controller makes it the most extensively exploited controller for industries and engineers. The control action of the PID controller is basically brought about by three gains namely the proportional gain which deals with the error that is to be reduced at the current time, the integral gain working on the addition of all the errors that is to be minimized and the derivative gain which compares the magnitude of the present error with the past.

In the present control scheme i.e. the tilted integral derivative controller, the only difference that exists from the traditional PID is the replacement of the proportional gain with a unit having a transfer function of $\left(\frac{1}{s}\right)^{\frac{1}{n}}$ which is multiplied with the gain. The modified gain is therefore coined the name Tilted. As compared to traditional PID controllers the Tilted Integral Derivative controller introduces an exponential term in the compensator transfer function. This ensures the controller to achieve the control action theoretically much closer to that explained by the Bode plot. The controller transfer function can be mathematically expressed as:

$$G(s)=K_T\left(\frac{1}{s}\right)^{\frac{1}{n}}+\frac{K_I}{s}+K_Ds\ \ldots\ldots\ldots\ldots\ldots(13)$$

Where KT denotes the tilted gain, KI stands out for the integral gain and KD signifies the derivative gain. N is a whole number which ranges for 0 to 100 for stable control action. The control block is diagrammatically represented as

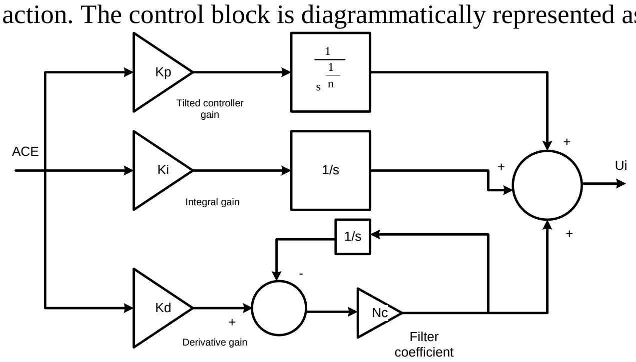

Fig. 2: The Tilted Integral Derivative controller

IV. OPTIMIZATION TECHNIQUE

Dragonfly algorithm:

Put forward by mirjalili [21], this optimization scheme is mainly inspired by the actively streaming and steady behaviour of the Dragonflies. The dragonflies are mainly involved in such streamline and steady activities during their search of food.

In this act they usually cover large distances and usually involves an appreciable number of dragonflies. The algorithm is computed based on the PSO structure where two vectors are dealt with, a position vector and a velocity vector. The dragonfly algorithm draws its main inspiration form the static and dynamic behaviour of the flies. These two behavioural traits replicate the two main phases of optimization: exploration and exploitation. These two phases can be expressed as follows:

1. Separation: the term implies the tendency of individuals to avoid collision from other nearby individuals in their path of motion.
2. Alignment: The term stands for the matching of velocities of one individual with other in the entire population.
3. Cohesion: The term implies the tendency of each individual to travel towards the centre part of the group i.e towards the central solution.

Taking into consideration the above behaviour of the flies, they are mathematically modelled as:

$$S_i = -\sum_{j=1}^{N} X - X_j \quad (16)$$

Where S_i is the separation vector and X refers to the current individual position and X_j gives the j^{th} individual position.

$$A_i = \frac{\sum_{j=1}^{N} V_j}{N} \quad (17)$$

Where A_i is the alignment vector and V_j is the velocity of the current individual that is to be matched with the rest of the swarm.

$$C_i = \frac{\sum_{j=1}^{N} X_j}{N} - X \quad (18)$$

Where Ci is the cohesion vector, N indicates the number of particles, Xj denotes the current particle position and X indicates the central solution as discussed above.

The step vector for the updation of the dragonfly position can be calculated as the summation of all these factors and can be mathematically expressed as:

$$\Delta X_{t+1} = \left(sS_i + aA_i + cC_i + fF_i + eE_i\right) w\Delta X_i \quad (19)$$

After the generation of the step vector, the position of the dragonflies is updated as:

$$X_{t+1} = X_t + \Delta X_{t+1} \quad (20).$$

V. RESULTS AND ANALYSIS

The main aim of AGC is to maintain the frequency deviations under scheduled limits. The deviations in frequency and tie line power during sudden load changes are to be minimized by bringing the Area control Error (ACE) to zero. This is done with the help of secondary controllers. The tilted Integral Derivative controller (TID) is used as a secondary controller in this research work. The discussed two area power system model is put to simulation with the help of MATLAB/ Simulink. The TID controller gains are tuned to optimum value with the help of a novel DA technique. The objective functions employed in the tuning process are as follows:

$$IAE = \int_0^t \left(|\Delta f_1| + |\Delta f_2| + |\Delta p_{tie}|\right) dt \quad (21)$$

$$ITAE = \int_0^t \left(|\Delta f_f| + |\Delta f_2| + |\Delta p_{tie}| tdt\right) \quad (22)$$

$$ISE = \int_0^t \left(\Delta f_1{}^2 + \Delta f_2^2 + \Delta p_{tie}^2\right) dt \quad (23).$$

$$ITSE = \int_0^t \left(\Delta f_1{}^2 + \Delta f_2^2 + \Delta p_{tie}^2\right) tdt \quad (24)$$

The values of each of the above objective functions during the tuning process is noted and scripted in Table 3. The table clearly indicates that the value of the objective function J is the minimum in the case of ISE (Integral square error) and henceforth all the tuning process in the paper has been done considering ISE as the cost function. The optimal controller gains for TID controller is listed down in Table 1.

Table 1: optimized TID gains tuned by DA algorithm

Market scenario	Kt1	Kd1	Ki1	Kt2	Kd2	Ki2
Basecase	0.2401	0.2802	0.1590	0.1539	0.0952	0.1302
Billateral contract	0.2556	0.1503	0.3057	0.1995	0.1976	0.2974

Table 2: Values of objective function for both base case and bilateral scenario

Market scenario	Objective function			
	ITAE	IAE	ITSE	ISE
Base case	1.9265	0.5472	0.0712	0.0354
Billateral transaction	1.6159	0.5789	0.0812	0.0398

Base case:

In this case the GENCOs and DISCOs come into mutual participation for the electricity market over a common area. This implies DISCOs of one area can only come in contract with the GENCOs of the respective areas. This mutual contract scenario can be represented with the help of Distribution Participation Matrix (DPM).

$$DPM = \begin{bmatrix} 0.5 & 0.5 & 0 & 0 \\ 0.5 & 0.5 & 0 & 0 \\ 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 \end{bmatrix} \ldots\ldots..(25)$$

The area participation factor apf is taken equal for all the GENCOs in this particular case. So $apf_1 = apf_2 = apf_3 = apf_4 = 0.5$. The simulation is carried out inclusive of a SLP of 0.01 pu in area 1. The demands of DISCOs are generally fixed at 0.1 MW. *Fig.* 11, *Fig.* 12 and *Fig.* 13 represents the frequency deviation in area 1 (Δf_1), area 2 frequency deviation (Δf_2) and tie line power flow deviation (Δp_{tie}) respectively. Table 3 clearly gives us the values of settling time, maximum overshoot and minimum undershoot for the DA optimized TID controller.

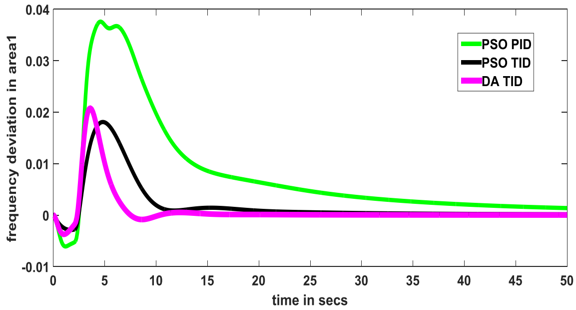

Fig. 3: Frequency Deviation In Area 1

Billateral case:

Case 2: Bilateral transaction

In this case the DISOCs and the GENCOs of both area come to a mutual contract participation and the scenario is denoted as:

$$DPM = \begin{bmatrix} 0.5 & 0.25 & 0 & 0.3 \\ 0.2 & 0.25 & 0 & 0 \\ 0 & 0.25 & 1 & 0.7 \\ 0.3 & 0.25 & 0 & 0 \end{bmatrix} \ldots\ldots\ldots\ldots\ldots\ldots$$

(26)

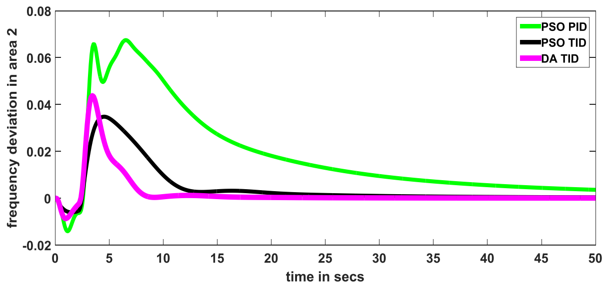

Fig. 4: Frequency Deviation In Area 2

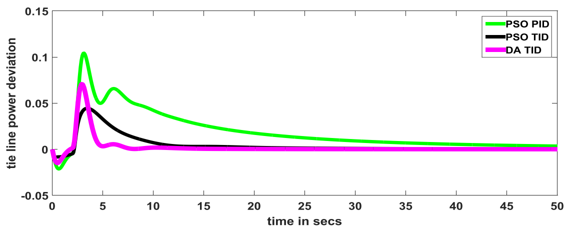

Fig. 5: Tie Line Power Deviation

The area participation factor in this case is taken as $apf_1=0.75$; $apf_2=1-apf_1= 0.25$; $apf_3=apf_4=0.5$. A sudden load change is inflicted on the system under bilateral market condition and the observations are plotted and analyzed. *Fig.* 18 and *Fig.* 19 portrays the frequency deviation pattern in respective areas. The tie line power variation is noted in *Fig.* 20. The dynamic system parameters are tabulated in Table 4

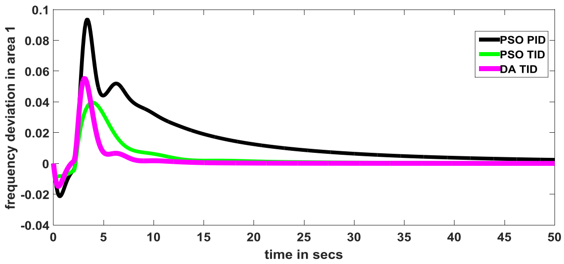

***Fig.* 6: Frequency Deviation In Area 1**

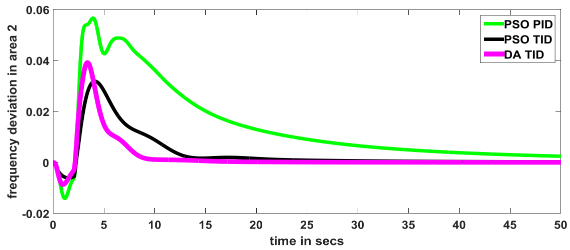

Fig. 7: Frequency Deviation In Area 2

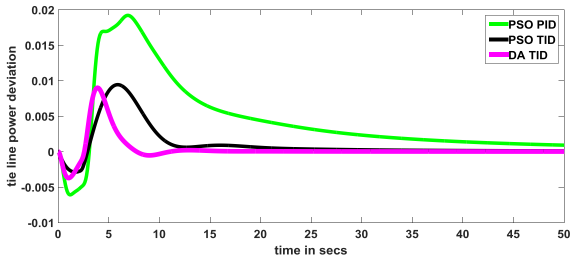

Fig. 8: Tie Line Power Deviation

Table 4: Dynamic system parameters when applied to the new system proposed

Market scenario	System data	Settling time	Maximum overshoot	Minimum undershoot
Billateral	Δf_1	9.0890	0.0461	-0.0142
	Δf_2	9.7764	0.0349	-0.0081
	Δp_{tie}	16.0800	0.0069	-0.0035
Base case	Δf_1	7.4180	0.0649	-0.0142
	Δf_2	12.4016	0.0398	-0.0071
	Δp_{tie}	12.6502	0.0194	-0.0035

VI. CONCLUSION

Due to the deregulated nature of modern day power system, the minimization of frequency deviations and tie line power changes is of utmost concern. Moreover the integration of renewables with the standard power system gives rise to frequency deviations which is to be mitigated in the fastest possible rate. This is attained by the proposed Dragonfly Algorithm (DA) tuned Tilted Integral Derivative controller (TID) in the AGC of the proposed system.

Retrieval Number: C5119098319/2019©BEIESP
DOI:10.35940/ijrte.C5119.098319
Journal Website: www.ijrte.org

Published By:
Blue Eyes Intelligence Engineering
& Sciences Publication

The benchmark function testing method has proved the supremacy of the hybrid control scheme in which the minimum values of the standard deviation for each benchmark functions prove the robustness of the proposed optimization technique.. The optimized parameters of the TID control help in bringing the ACE to zero in the smallest time possible. Detailed analysis of the system performance has been given in tabular form in Table 4. The values of the settling time, maximum overshoot and minimum undershoot clearly indicates the efficacy of the proposed Dragonfly Algorithm (DA) tuned TID controller in minimizing the deviations in frequency and in maintaining the tie line power within prescribed limits.

REFERENCES

1. Dong, Xiaoming, et al. "Power Flow Analysis Considering Automatic Generation Control for Multi-Area Interconnection Power Networks." IEEE Transactions on Industry Applications53.6 (2017): 5200-5208.
2. Hasanien, Hany M., and Attia A. El-Fergany. "Symbiotic organisms search algorithm for automatic generation control of interconnected power systems including wind farms." IET Generation, Transmission & Distribution 11.7 (2016): 1692-1700.
3. Shiva, Chandan Kumar, and Vivekananda Mukherjee. "Automatic generation control of multi-unit multi-area deregulated power system using a novel quasi-oppositional harmony search algorithm." IET Generation, Transmission & Distribution 9.15 (2015): 2398-2408.
4. Apostolopoulou, Dimitra, Alejandro D. Domínguez-García, and Peter W. Sauer. "An assessment of the impact of uncertainty on automatic generation control systems." IEEE Transactions on Power Systems 31.4 (2016): 2657-2665.
5. Liu, Shichao, Peter X. Liu, and Abdulmotaleb El Saddik. "Modeling and stability analysis of automatic generation control over cognitive radio networks in smart grids." IEEE Transactions on Systems, Man, and Cybernetics: Systems45.2 (2015): 223-234.
6. Law, Yee Wei, Tansu Alpcan, and Marimuthu Palaniswami. "Security games for risk minimization in automatic generation control." IEEE Transactions on Power Systems 30.1 (2015): 223-232.
7. Sridhar, Siddharth, and Manimaran Govindarasu. "Model-based attack detection and mitigation for automatic generation control." IEEE Transactions on Smart Grid 5.2 (2014): 580-591.
8. Jagatheesan, K., et al. "Application of flower pollination algorithm in load frequency control of multi-area interconnected power system with nonlinearity." Neural Computing and Applications 28.1 (2017): 475-488.
9. Khadanga, Rajendra Kumar, and Amit Kumar. "Hybrid adaptive 'gbest'-guided gravitational search and pattern search algorithm for automatic generation control of multi-area power system." IET Generation, Transmission & Distribution11.13 (2016): 3257-3267.
10. Mc Namara, Paul, et al. "Control strategies for automatic generation control over MTDC grids." Control Engineering Practice 54 (2016): 129-139.
11. .Venkat, Aswin N., et al. "Distributed MPC strategies with application to power system automatic generation control." IEEE transactions on control systems technology 16.6 (2008): 1192-1206.
12. Variani, Maryam Hassani, and Kevin Tomsovic. "Distributed automatic generation control using flatness-based approach for high penetration of wind generation." IEEE Transactions on Power Systems 28.3 (2013): 3002-3009.
13. Ibrahim, Ahmed Nabil Abd Alzaher, Mohamed Abdul Raouf Shafei, and Doaa Khalil Ibrahim. "Linearized biogeography based optimization tuned PID-P controller for load frequency control of interconnected power system." Power Systems Conference (MEPCON), 2017 Nineteenth International Middle East. IEEE, 2017.
14. Boesack, Craig D., Tshilidzi Marwala, and Fulufhelo V. Nelwamondo. "On the application of Bezier Surfaces for GA-Fuzzy controller design for use in Automatic Generation Control." Energy Procedia 14 (2012): 457-463.
15. Pathak, Nikhil, T. S. Bhatti, and Ashu Verma. "New performance indices for the optimization of controller gains of automatic generation control of an interconnected thermal power system." Sustainable Energy, Grids and Networks 9 (2017): 27-37.
16. Selvaraju, Ramesh Kumar, and Ganapathy Somaskandan. "ACS algorithm tuned ANFIS-based controller for LFC in deregulated environment." Journal of Applied Research and Technology 15.2 (2017): 152-166.
17. Gorripotu, Tulasichandra Sekhar, Rabindra Kumar Sahu, and Sidhartha Panda. "AGC of a multi-area power system under deregulated environment using redox flow batteries and interline power flow controller." Engineering Science and Technology, an International Journal 18.4 (2015): 555-578.
18. Hota, P. K., and Banaja Mohanty. "Automatic generation control of multi source power generation under deregulated environment." International Journal of Electrical Power & Energy Systems 75 (2016): 205-214.
19. Mishra, Mugdha, Nitin K. Saxena, and Pragya Mishra. "ANN Based AGC for Hybrid Nuclear-Wind Power System." Micro-Electronics and Telecommunication Engineering (ICMETE), 2016 International Conference on. IEEE, 2016.
20. Storn, Rainer, and Kenneth Price. "Differential evolution–a simple and efficient heuristic for global optimization over continuous spaces." Journal of global optimization 11.4 (1997): 341-359.
21. Mirjalili, Seyedali. "Dragonfly algorithm: a new meta-heuristic optimization technique for solving single-objective, discrete, and multi-objective problems." Neural Computing and Applications 27.4 (2016): 1053-1073.
22. Ismayil, Chathoth, Ramdas Sreerama Kumar, and Thiruthimana Krishnan Sindhu. "Optimal fractional order PID controller for automatic generation control of two-area power systems." International Transactions on Electrical Energy Systems 25.12 (2015): 3329-3348.
23. Saha, Debdeep, and Lalit Chandra Saikia. "Automatic generation control of an interconnected CCGT-thermal system using stochastic fractal search optimized classical controllers." International Transactions on Electrical Energy Systems 28.5 (2018): e2533.

AUTHORS PROFILE

Sayantan Sinha was born in 1991 in India. He received his BTech degree from WBUT and Mtech degree from ITER, S'O'A deemed t o be universit y. He is current ly pursuing his P hD research fellowship from S'O'A university. His areas of expert ise are FACTS, AGC and opt imizat ion technique.

Ranjan Kumar Mal l ick was born in India in 1972. He received his degree in elect rical engineering from inst itut ion of engineers (India) in 1996 and M.E degree in power system engineering from vssut , burla in 2001. He received his PhD from Bput , Odisha in 2013. He is current ly working as professor in the department of EEE, IT ER, S'O'A universit y, odisha, India. His research int erest s are applicat ion of power elect ronics and opt imizat ion techniques in power system such as facts cont roller, AGC cont roller, st rategic bidding, economic load dispatch, design of hvdc converters and voltage and frequency stability of interconnected power system, microgrid protection. He is having 18 years of experience in teaching and research. He has published around 50 papers in internat ional journal and conference