International Journal of Research Publication and Reviews

Journal homepage: www.ijrpr.com ISSN 2582-7421

Load Power Control of two Area System using PSO

Chandan Kumar Saurav and Prof. Manish Kethoriya

Department of Electrical Engineering
School of Research and Technology, People' University, Bhopal [MP], India

A B S T R A C T

This work is a novel approach for power control of two-area systems using Particle Swarm Optimization (PSO). The proposed approach seeks to provide a cost-effective and efficient solution to the problem of controlling the power of two-area systems. The main components of the proposed approach are the power control of the two-area system, PSO algorithm, and simulation of the results. The power control of the two-area system is achieved through the use of a controller, which is designed using a PID controller. The PSO algorithm is used to optimize the parameters of the controller in order to achieve the desired power control of the two-area system. The performance of the proposed approach is evaluated using MATLAB/SIMULINK simulation. The response from the AGC controller for area 1 also getting the settling time 5.01 second, overshoot time 0.003 per unit and undershoot 0 per unit whereas the response for area 2 settling time 5 second, overshoot time 0 per unit and undershoot 0 per unit after using PSO optimization. Also get the ITAE response 0.01192 after 100 iteration. The results improved when a PID controller was utilised as a controller in a two-area system. The Particle Swarm Optimisation method was used to optimize the parameters of the PID controller. When the parameters were optimized, the system performed best. PSO optimization was more effective than the PID controller for the both system single is as well as two area system.

Keywords:Load Power control, PID, PSO

1. Introduction

Particle Swarm Optimisation (PSO) for power management of two area systems is a prominent method in the power system sector for optimising the frequency and power control of two areas. It's a nonlinear optimization method that combines the benefits of PSO with power system models. The PSO algorithm has been employed in a variety of power system applications, including optimal power flow, transient stability, economic dispatch, and so on. The PSO technique was utilised to tackle the frequency and power control problem in a two-area system.The two area systems are electrical networks that are linked by generators, transmission lines, and load buses. The purpose of power control is to keep the two area systems in frequency and power balance. The PSO algorithm can be used to optimize the control parameters of the two area systems in order to maintain optimal frequency and power balance.
This effort was done to regulate the power of two area systems using PSO. It goes over the principles of the PSO algorithm, the structure of the two-area system, and the problem formulation. The study then presents the optimization process's outcomes and discusses the performance of two area systems' power regulation using PSO.

1.1 *Structureof Two Area System*

A two-area system is a network of interconnected generators, transmission lines, and load buses. The two-area system is a distributed system made up of two areas that are linked together. Each region has its own generators, transmission lines, and loads. The transmission lines connect the generators, while the transmission lines connect the loads. The transmission lines are linked, allowing power to be transported between the two zones.The two-area approach is designed to maintain the best power balance possible. This is accomplished by modulating the power output of the generators in each location. The governor, excitation system, and automatic voltage regulator are among the components of the two-area system. These components work together to keep the power balance optimal.

1.2 *Objective of the Research Work*

1. To comprehend the operation of a two-area power system and its components.

* *Corresponding author.* Tel.: +91 86388 25390.
E-mail address: Cksaurav69@gmail.com

2. Create a system that uses the Particle Swarm Optimisation (PSO) method to control the power of a two-area power system.
3. Run the system through its paces and analyse the outcomes in the simulation environment.
4. To compare the system's performance with traditional approaches and discover the advantages.
5. To compare the system in a real-time setting and assess its performance.

1.3 *TwoAreaInterconnectedPowerSystem*

Tie-lines allow power systems to communicate with one another. Tie-lines allow electric electricity to travel across regions. When the load in that location changes, the area will acquire energy from other areas via tie-lines. As a result, LFC must additionally control the tie-line power exchange fault. The integral of the frequency difference between two locations is used to calculate tie-line power error.
Tie-linepower canbewrittenmathematicallyas

$$P_{12}^0 = \frac{|V_1^0||V_2^0|}{X}\sin\left(\delta_1^0 - \delta_2^0\right)$$

Eqn. **Error! No text of specified style in document.**.1

Where
$\delta^0\delta^0$=poweranglesofequivalentmachines
Forsmalldeviationsintheanglesthetie-linepowerchangesto

$$\Delta P_{12} = T_{12}(\Delta\delta_1 - \Delta\delta_2)$$

Eqn. **Error! No text of specified style in document.**.2

Where

$$T_{12} = \frac{|V_1^0||V_2^0|}{X}\cos\left(\delta_1^0 - \delta_2^0\right)$$

Eqn. **Error! No text of specified style in document.**.3

isthesynchronizingcoefficient
Frequencydeviation Δfisrelated to referenceangle by

$$\Delta f = \frac{1}{2\pi}\frac{d}{dt}\left(\delta^0 + \Delta\delta\right)$$

Eqn. **Error! No text of specified style in document.**.4

$$= \frac{1}{2\pi}\frac{d}{dt}(\Delta\delta)$$

$$\Delta\delta = 2\pi\int \Delta f dt$$

$$\Delta P_{12} = 2\pi T_{12}\left(\int \Delta f_1 dt - \int \Delta f_2 dt\right)$$

Eqn. **Error! No text of specified style in document.**.5

TakingLaplacetransformationofaboveformula gives

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

Eqn. **Error! No text of specified style in document.**.6

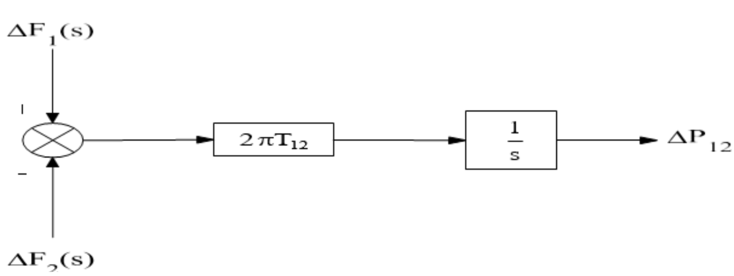

Figure **Error! No text of specified style in document.**.1 Linear representation of tie-line

Similarly,T_{21}can bewritten in terms ofT_{12}as

$$T_{21} = a_{12}T_{12}$$

Eqn. **Error! No text of specified style in document.**.7

So,forcontrol area2

$$\Delta P_{21}(s) = \frac{-2\pi a_{12} T_{12}}{s}\left(\Delta f_1(s) - \Delta f_2(s)\right)$$

Eqn. **Error! No text of specified style in document.**.8

1.4 *Area ControlError*

Each area's control error is a linear mix of tie line flows and frequency. A mismatch between area generation and load (AGC) is represented by ACE. The goal of LFC is to keep the tie-line error to a specified value while minimizing the error in frequency of each area, which is difficult in the presence of changing load. If we control the frequency error back to zero, all steady-state frequency defects in the system would result in tie-line power problems, because the error in tie-line power equals the integral of the frequency shift between each pair of regions.
As a result, the information of the tie-line power deviation must be considered in the control input. As a result, an error called ACE is defined as

$$ACE_i = \sum_{j=1}^{n} \Delta P_{tie,ij} + B_i \Delta f_i$$

Eqn. **Error! No text of specified style in document.**.9

Where,
ACE_i istheith area control error
Δf_i=itharea frequency error
$\Delta P_{tie,ij}$=power flow error in tieline betweenithandjth area
B_i=itharea frequency bias coefficient
The controller's input is area control error, with the goal of controlling the ACE and frequency deviation.
Which controller is to be considered now is determined by the controller's performance and the process's requirements.

1.5 *Controllers*

Thefundamentalcontrolloopcanbesimplifiedfora SISO(single-input-single-output)systemas inFigure 1.2Herewe areignoringthedisturbances in thesystem.

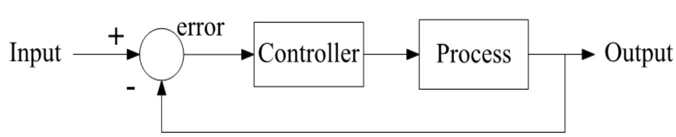

Figure Error! No text of specified style in document.**.21 Basic controlloop**

The controller might have several structures. However, the Proportional-Integral-Derivative (PID) type controller is the most widely used. In fact, PID controllers account for more than 95% of all industrial controllers.
Thetransferfunctionofthecontrollerisgivenby:

$$C(s) = K_p\left(1 + \tau_d s + \frac{1}{\tau_i s}\right)$$

Eqn. **Error! No text of specified style in document.**.10

WhereK_p=Proportional gain
τ_d=Derivative time,and

τ_i=Integral time
The temporal response of a proportional controller improves (i.e. the time constant reduces) and there is an offset between the output response and the desired response. This offset can be decreased by raising the proportional gain; however, higher order systems may experience increased oscillations as a result.
When only the integral action of the controller is examined, the order of the closed loop system grows by one. If the process has higher order dynamics, this increase in order may lead the closed loop system to become unstable. The main benefit of this integral control action is that it decreases steady-state error due to step input to zero. However, the system reaction is generally oscillatory, slow, and occasionally unstable.
PI has the dual benefit of quick response owing to P-action and zero steady-state error due to I-action. The steady-state error can be reduced to zero by utilizing a P-I controller, while the transient responsiveness can be improved.
The P-D controller appears to be ineffective since it cannot lower the steady-state error to zero. However, for higher order processes, the P-D controller can be used to improve the stability of the closed loop system.
A well-chosen combination of proportional, integral, and derivative actions can offer all of the required results: quick reaction, zero steady-state error, and low offset. This order is low, however it is globally applicable because it may be applied in any system. PID controllers have also been proved to be robust, which is why they are widely used in industrial processes.
The parameters are adjusted using optimization and an objective function that is a function of error and time, and the function is the integral of time-multiplied absolute error criterion (ITAE).
Another objective function that is a function of error and time is known as the integral of the square of the error criteria (ISE), however this performance indicator is not used because it is computationally difficult and less sensitive than ITAE. Whereas ITAE has the advantages of causing fewer oscillations and lesser overshoots, maintaining robustness, and being the most sensitive (i.e. best selectivity), this makes the ITAE index the preferred criterion for control system design. The emphasis is on lowering the ITAE criterion.

ITAE is made up of both locations' tie line power and frequency variation. The primary function is

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

Eqn. **Error! No text of specified style in document.**.11

Where, $\Delta f_1$and Δf_2arefrequencydeviations;
$\Delta P_{tie}$is the change in tie line power
Because integrating to infinity is impractical, a large enough value of T should be chosen to ensure that error is insignificant. T=50 seconds is used here.

1.6 *Particle Swarm Optimization*

PSO optimization is one of the most effective LFC optimization techniques. It was created in 1995 and is based on bird flocking and fish schooling mapping. It is dependent on the swarms' population. For optimization problems, it requires extremely little processing time and memory. Bird flocking is a technique that is based on how birds go in search of food. They take the shortest route to their goal. The population of swarms is randomly produced in this technique, and the optimal solution in their position is determined using the fitness value. The global value is another excellent option. The particle's position is changed to its best value at the end of each cycle. Every iteration, the particles' velocity is updated. Particle Swarm Optimisation (PSO) is an optimization technique based on the flocking behaviour of birds. It is a population-based optimization method inspired by flock behaviour of birds. The PSO method is based on the idea of particles in a search space representing potential solutions. The particles move around the search space, altering their positions based on their current fitness and the best position discovered by their neighbours. The particles can communicate with one another, conveying information about their current location and the optimal place discovered.There are various advantages to using the PSO algorithm over other optimization strategies. It is simple to use and can tackle both continuous and discrete optimization problems. It's also computationally efficient and can handle large-scale challenges. The PSO algorithm has been employed in a variety of applications, including optimal power flow, transient stability, and economic dispatch.

2. Research Methodology

Particle Swarm Optimisation (PSO) is a strong optimization technique that can control the power of two-area systems.

1. **Define the Objective Function:** Defining the objective function is the initial step in adopting PSO for power control of two-area systems. The objective function should explain the desired power behaviour of the two-area system.
2. **Initialize the Swarm:** Once the objective function has been defined, the swarm must be initialized. This includes defining the number of particles, the beginning position and velocity of each particle, as well as the PSO algorithm parameters.
3. **Execute the PSO Algorithm:** The PSO algorithm is then executed for a predetermined number of iterations. The velocity of each particle is changed throughout each iteration depending on the current best position, the global best position, and the particle's own previous best position. The particles are then repositioned based on their modified velocities**.**
4. **Evaluate Performance:** After running the PSO algorithm for a predetermined number of iterations, the performance of the two-area system can be evaluated. This entails measuring each area's power and comparing it to the desired behaviour indicated in the goal function.
5. **Change the parameters:** If the two-area system's performance does not match the expected behaviour indicated in the objective function, the PSO parameters can be changed and the algorithm re-run. This could include raising or decreasing the number of particles, modifying the beginning velocity, or changing the PSO algorithm settings.
6. **Repetition:** The procedure of establishing the objective function, initialising the swarm, executing the PSO algorithm, and evaluating performance should be repeated until the two-area system's desired behaviour is attained.

2.1 Methodology

1. Fist design and simulate single area power system using MATLAB/SIMULINK.
2. Then design and simulate two area power system using PID controller.
3. Now design and simulate two area power system using POS.
4. Now compared the result as per unit step and calculate the error in terms of over shoot and under shoot for two area power control.

2.2 Single Area System

It is an electrical region that is separate from the rest of the power system network and has one or more generating units that distribute electricity in the same area. In this specific area, it is the responsibility of the single generating unit to maintain the usual frequency in the event of a system disturbance. These single-area power systems serve as the foundation for bigger multi-area power systems. The properties of a single area network are quite simple and straightforward. In the next sections, we will describe two-area networks.

2.3 Two-Area Systems

In reality, the power system is composed of many single areas that are linked together to form a bigger two-area system. They are linked to one another by tie-lines. Thus, in a two-area system, every fluctuation or disturbance in the load induces a change in frequency and a change in power exchange in the tie-lines. The governor action of the generators must correct this mismatch in power and frequency. This section will go over two area systems with disturbance. Figure 2.1depicts a general representation of a two-area system.

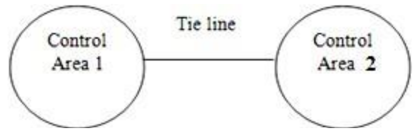

Figure 2.2 Two area system

Any fluctuations in a two-area system should be handled by the generators in both regions. Furthermore, the tie-line power change should be set to zero. This is accomplished by employing an integrator, which integrates power from the tie-line and feeds it back to the governors. We use the word ACE to describe this. ACE is an abbreviation for Area Control Error. It is the result of a combination of incremental frequency and tie-line power change. ACEisdefinedas

$$ACE_i = P_i + b_i \Delta f_i \quad \text{Eqn. 2.1}$$

Where,

b_i=biasingfactor

Δf_i=changeinfrequencyofarea1

Two areas are dependent on each other in a two-area system. As a result, the ACE for a two-area system can be defined as follows.
ACEforarea1isgiven by,

$$ACE_1(s) = P_1(s) + b_1 \Delta f_1(s) \quad \text{Eqn. 2.2}$$

ACEforarea2isgivenby,

$$ACE_2(s) = P_2(s) + b_2 \Delta f_2(s) \quad \text{Eqn. 2.3}$$

3. Resultand Discussion

In this section, investigate the load power regulation on single and two-area power systems using the MATLAB/SIMULINK model. Block diagrams are used to create a model of the power system. A unit step input is used to cause a disturbance in the system. The system responds to the unit step disruption, resulting in a change in power at the output. There is no controller in this area to compensate for the change in load. First, we will do a load control analysis on a single area, and then we will move to two-area systems.

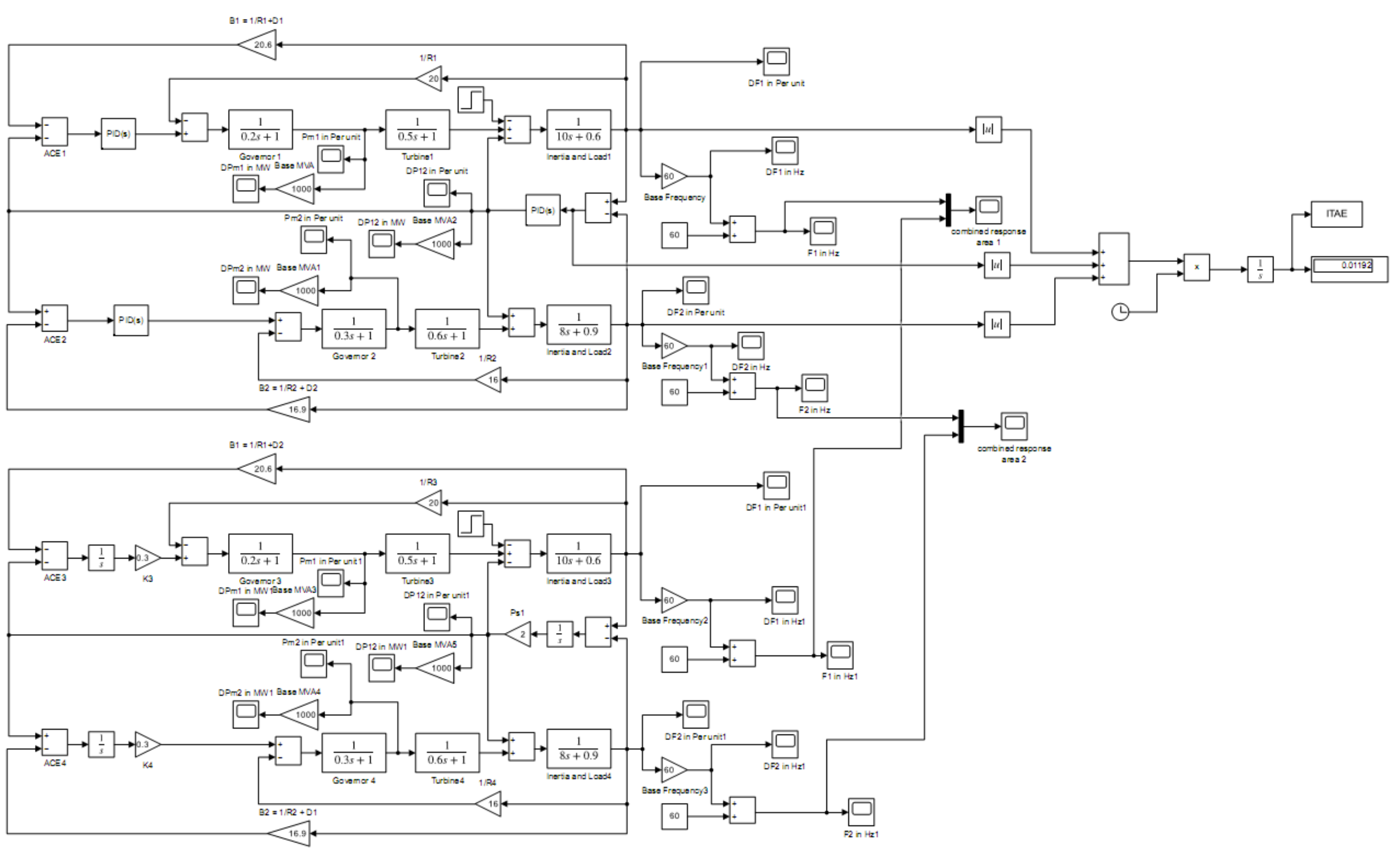

Figure 3.1 PSO Based Automatic Generation Control of two Area Power System

3.1 Power Control of Single and Two Area System Using PSO

Now two-area power control system is used. In this section an Automatic Generation Control (AGC) used using PSO optimization and get the ITAE 0.01192 after 100 iteration. The schematic diagram of the single area power control using PID controller shown in Figure 3.2.

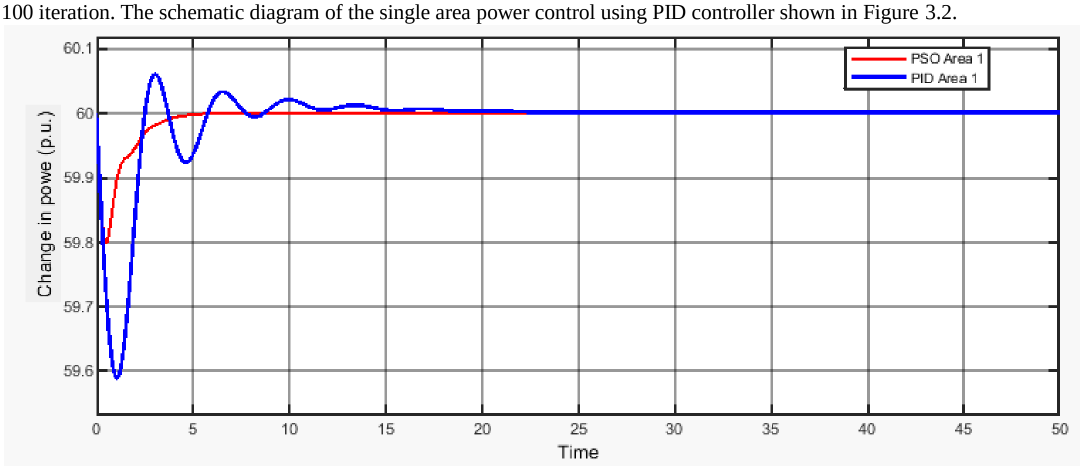

Figure 3.2 Response of single area power control using PSO

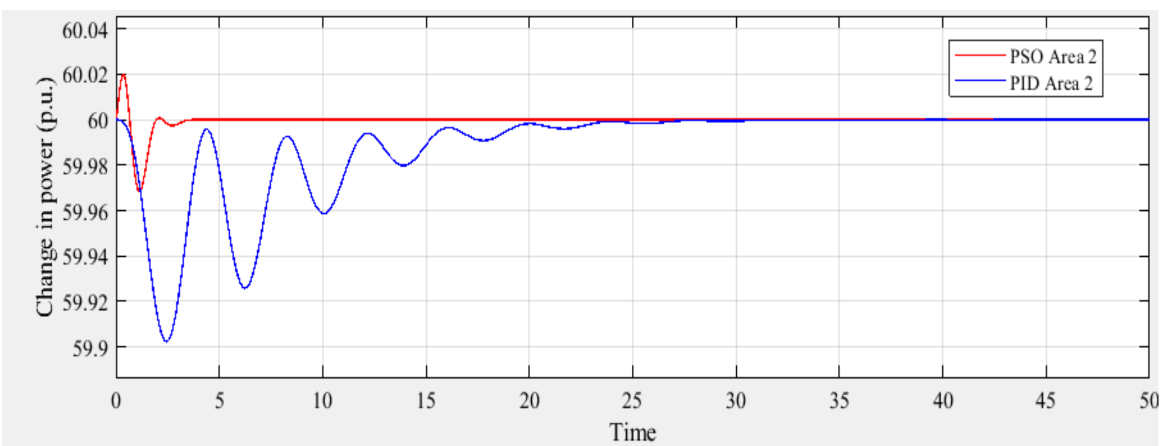

Figure 3.3 Response of two area power control using PSO

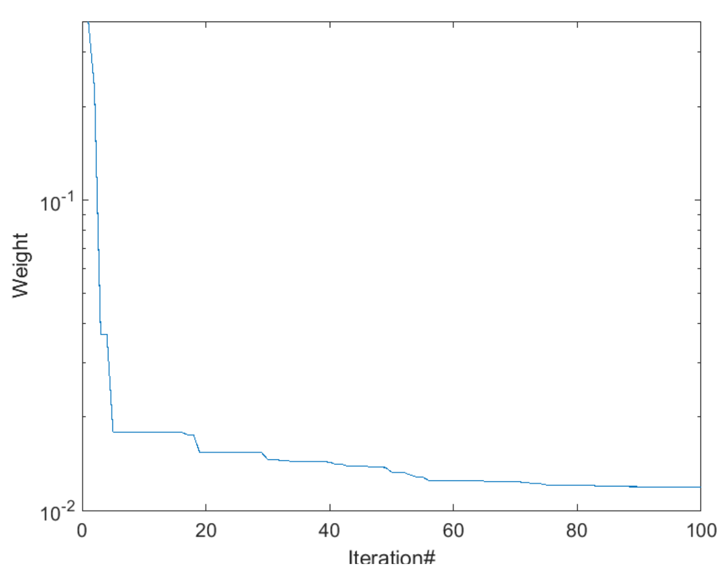

Figure 3.4 Weight Vs Iteration response of AGC based on PSO

The response of AGC using PID and PSO as shown in Figure 3.2 for single area controller and Figure 3.3 shows the response of two area controller using PSO. Figure 3.4 shows the weight response of the PSO optimization with respect to number of iterations.

Table 3.1 Response of two area AGC system with PSO

Settling time (in seconds)		**Overshoot (in p.u.)**		**Undershoot (in p.u.)**	
Area1	**Area 2**	**Area 1**	**Area 2**	**Area1**	**Area 2**
5.01	5	0.003	0	0	0

After using the PSO optimization the response from the Table 3.1 the overshoot per unit is 0.003 which is the least value on the settling time 5.01 second as compared to PID for the single area system response. Whereas the overshoot per unit is 0 which is the least value on the settling time 5 second to achieve the peak value as compared to PID for the two-area system response. Also get the ITAE 0.01192 after 100 iteration using PSO optimization which is very less error response for this system.

4. Conclusions and Future Scope

4.1 Conclusions

This research contributes to the Load power regulation in a Two-Area Power Control System and the regulation of load power using conventional PID controllers. These controllers were used to manage the load power with disturbance in area 1 and area 2. The response from the AGC controller for area 1 also getting the settling time 5.01 second, overshoot time 0.003 per unit and undershoot 0 per unit whereas the response for area 2 settling time 5 second, overshoot time 0 per unit and undershoot 0 per unit after using PSO optimization. Also get the ITAE response 0.01192 after 100 iteration. The results improved when a PID controller was utilised as a controller in a two-area system. The Particle Swarm Optimisation method was used to optimize the parameters of the PID controller. When the parameters were optimized, the system performed best. PSO optimization was more effective than the PID controller for the both system single is as well as two area system.

4.2 Future Scope

Work done in this dissertation can be extended to following directions:

1. The created Fuzzy logic controller can be employed in increasingly complicated systems to achieve the best performance.
2. PSO can be combined with a fuzzy controller to improve outcomes.
3. To achieve best results, LFC of renewable energy sources can be performed using the PSO algorithm.
4. PSO can be used to investigate the case of fluctuating load in power systems.

REFERENCES

[1] DolaGobindaPadhan, and Somanath Majhi, "A new control scheme for PID load frequency controller of single-area and multi-area power systems," ISA Transactions, Vol. 52, no. 2, pp. 242–251, March 2013.

[2] H. K. Shaker, H. E. Zoghbv, M. E. Bahgat and A. M. Abdel-Ghany, "Load Frequency Control for An Interconnected Multi Areas Power System Based on optimal Control Techniques," 2020 12th International Conference on Electrical Engineering (ICEENG), Cairo, Egypt, pp. 62-67, 2020. doi: 10.1109/ICEENG45378.2020.9171769.

[3] Haroon, M., & Khan, A. U., "Frequency and Power Control of Two Area System Using Particle Swarm Optimization," In 2015 International Conference on Innovations in Computing and Communication, IEEE, pp. 886-889, 2015.

[4] J. Seekuka, "AGC Using Particle Swarm Optimization based PID Controller Design for Two Area Power System," IEEE, vol. 1, no. 1, pp. 7-10, 2016.

[5] K. B. Dinesh, M. Sathiavel, and M. Saravanan, "Optimal frequency and power control of two area system using multi-objective particle swarm optimization," in 2017 International Conference on Inventive Computing and Informatics (ICICI), pp. 971-975, 2017.

[6] Khan, A. U., & Haroon, M., "Particle swarm optimization-based frequency and power control of two area system," In 2016 International Conference on Computing, Communication and Automation (ICCCA), IEEE, pp. 633-638, 2016.

[7] Kumar, S., "Optimal frequency and power control of two area system using particle swarm optimization," International Journal of Engineering, 11(3), 441-449, 2018.

[8] M. S. Redoy and Ruma, "Load Frequency Control of an Inter Connected Power System Using PSO Based PID Controller," 2022 International Conference on Advancement in Electrical and Electronic Engineering (ICAEEE), Gazipur, Bangladesh, pp. 1-5, 2022. doi: 10.1109/ICAEEE54957.2022.9836435.

[9] N. Nagarjuna and G. Shankar, "Load frequency control of two area power system with AC-DC tie line using PSO optimized controller," Proc. 2015 IEEE Int. Conf. Power Adv. Control Eng. ICPACE 2015, vol. 2, no. 2, pp. 227-231, 2015, doi: 10.1109/ICPACE.2015.7274948.

[10] N. V. Gorantla and V. S. Prasad, "Optimal frequency and power control of two area system using particle swarm optimization," in 2016 International Conference on Computing and Communication Technologies (ICCCT), pp. 1-7, 2016.

[11] P. C. Nayak, A. Sahoo, R. Balabantaraya and R. C. Prusty, "Comparative study of SOS & PSO for fuzzy based PID controller in AGC in an integrated power system," 2018 Technologies for Smart-City Energy Security and Power (ICSESP), Bhubaneswar, India, pp. 1-6, 2018. doi: 10.1109/ICSESP.2018.8376700.

[12] P. S. Hosseinian, S. Ebrahimi and J. Jatskevich, "An Optimization-based Load Frequency Control in an Interconnected Multi-Area Power System Using Linear Quadratic Gaussian Tuned via PSO," 2021 IEEE Electrical Power and Energy Conference (EPEC), Toronto, ON, Canada, pp. 119-124, 2021. doi: 10.1109/EPEC52095.2021.9621658.

[13] Ravi, K. V., & Parekh, B., "Optimal frequency and power control of two area system using particle swarm optimization," In 2017 International Conference on Inventive Computation Technologies (ICICT), IEEE, pp. 267-272, 2017.

[14] S. J. Gambhire, D. R. Kishore, P. S. Londhe, and S. N. Pawar, "Review of sliding mode based, control techniques for control system applications," Int. J. Dyn. Control, vol. 9, no. 1, pp. 363-378, Mar. 2021, doi: 10.1007/s40435-020-00638-7.

[15] S. K. Saini, V. Agarwal, S. Kant, and S. K. Singh, "A new approach for optimal frequency and power control of two area system using PSO and GA," in 2016 International Conference on Inventive Computing and Informatics (ICICI), pp. 864-869,2016.

[16] S. Selvakumaran, S. Parthasarathy, R. Karthigaivel, and V. Rajasekaran, "Energy Procedia Optimal Decentralized Load Frequency Control in a Parallel AC-DC Interconnected Power System Through HVDC Link Using PSO Algorithm," 2ndInternational Conf. Adv. Energy Eng. (ICAEE 2011) Optim., vol. 00, no. 2011, pp. 1849-1854, 2012, doi: 10.1016/j.egypro.2011.12.887.

[17] Saadat H. Power system analysis. USA: McGraw-Hill; 1999.

[18] Sharma, V., &Pareek, S., "Optimal frequency and power control of two area system using particle swarm optimization," International Journal of Computer Applications, 157(2), pp.23-30, 2017.

[19] Sharma, V., &Pareek, S., "Optimal frequency and power control of two area system using particle swarm optimization algorithm," International Journal of Innovative Technology and Exploring Engineering, 8(2), 14-18., 2019.

[20] V. P. Singh, N. Kishor, and P. Samuel, "Communication time delay estimation for load frequency control in two-area power system," Ad Hoc Networks, vol. 000, no. 1, pp. 1–17, 2015, doi: 10.1016/j.adhoc.2015.10.010.

[21] V. Van Huynh, B. L. N. Minh, E. N. Amaefule, A.-T. Tran, and P. T. Tran, "Highly Robust Observer Sliding Mode Based Frequency Control for Multi Area Power Systems with Renewable Power Plants," Electronics, vol. 10, no. 3, p. 274, Jan. 2021, doi: 10.3390/electronics10030274.

[22] V. Veerasamy et al., "A Hankel Matrix Based Reduced Order Model for Stability Analysis of Hybrid Power System Using PSO-GSA Optimized Cascade PI-PD Controller for Automatic Load Frequency Control," IEEE Access, vol. 8, no. 1, pp. 71422–71446, 2020. doi: 10.1109/ACCESS.2020.2987387.

[23] Vandana Dhawane and Rajankumarbichkar, "Load Frequency Control Optimization using PSO Based Integral Controller" International Journal of Recent Technology and Engineering (IJRTE) ISSN: 2277-3878 (Online), Volume-8 Issue-6, pp. 97-103, March 2020.

[24] W. Yinsha, L. Wenyi and L. Zhiwen, "Research on PSO-Fuzzy Algorithm Optimized Control for Multi-area AGC System with DFIG Wind Turbine," 2019 14th IEEE Conference on Industrial Electronics and Applications (ICIEA), Xi'an, China, pp. 877-881, 2019. doi: 10.1109/ICIEA.2019.8834232.

[25] Wood A, Wollenberg B. Power generation, control and operation. 2nd ed. John Wiley & Sons; 1996.

[26] X. Guo and X. Liu, "Particle swarm optimization sliding mode control on interconnected power system," Proceedings of the 33rd Chinese Control Conference, Nanjing, China, pp. 93-97, 2014. doi: 10.1109/ChiCC.2014.6896602.