INDIAN JOURNAL OF SCIENCE AND TECHNOLOGY

RESEARCH ARTICLE

Load Frequency Control in Power Systems Using the Most Valuable Player Algorithm

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OPEN ACCESS

Received: 02-08-2023
Accepted: 11-10-2023
Published: 14-11-2023

Citation: Verma A, Asim M, Mahboob R (2023) Load Frequency Control in Power Systems Using the Most Valuable Player Algorithm. Indian Journal of Science and Technology 16(43): 3854-3861. https://doi.org/10.17485/IJST/v16i43.1690

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Funding: None

Competing Interests: None

Published By Indian Society for Education and Environment (iSee)

ISSN
Print: 0974-6846
Electronic: 0974-5645

Abstract

Objective: The load frequency control is an integral part of the study of power system operation and control and to address the problem, numerous techniques have been proposed. The Most Valuable Player Algorithm (MVPA) is one such algorithm designed to solve any optimization problem in general which in this work is applied to load frequency control for easy implementation and effective results. **Method:** To tackle the load frequency problem, MVPA algorithm is implemented in MATLAB/Simulink. The results which are obtained from different cases of power system, are compared with those obtained using other established algorithms. The pertinent parameters like peak overshoot and settling times have been compared along with ease of implementation. **Findings:** The study demonstrates that the implementation of the MVPA algorithm leads to improved frequency regulation, as evidenced by reduced settling time by 10% and peak overshoot by up to 50%. This performance enhancement establishes the superiority of the MVPA algorithm compared to existing techniques. **Novelty:** This study presents a new approach by applying the Most Valuable Player technique to address the load frequency problem. The results showed that the algorithm exhibits superior performance as compared to other existing techniques used in load frequency control.

Keywords: Load Frequency Control (LFC); Power System Operation; MVPA Algorithm; Frequency Regulation; TieLine Power

1 Introduction

The power system is a dynamic system. The load on the power system is constantly varying. The generator operation output in terms of voltage and frequency is not independent but a function of load. If the power system is in equilibrium and then it is perturbed by increasing the load, the additional load is supplied by fall in the generator speed. The drop in speed directly results in the droop in frequency. As the load increases the frequency drops which causes several problems in load operation. The frequency is to be maintained within the limits of $\pm 5\%$.

To maintain the frequency the steam input is increased by changing the governor setting. For any increase in load, the steam input needs to be increased and vice versa by controlling the governor setting. But the complexity in the control arises due to stochastic fluctuations of the load. Therefore, the automatic load frequency control is inevitable.

Several techniques and algorithms are employed in the automatic controllers with the objective to minimize the disturbance as soon as possible with minimum overshoot and transient time.

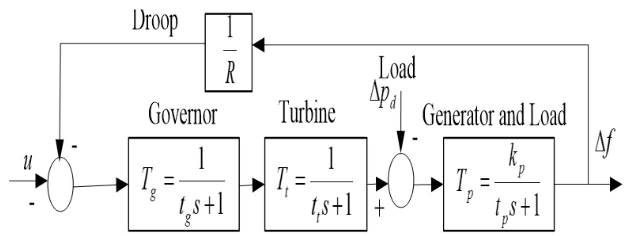

Fig 1. Single Area Power System

The present work proposes the application Most Valuable Player Algorithm (MVPA) with the objective of controlling the load frequency. Optimization algorithms can be categorized into two main types based on their approach to finding solutions: single solution-based algorithms, which aim to find a single optimal solution, and population-based algorithms, which work with a population of candidate solutions and use various techniques to guide the population towards better solutions. Population-based algorithms can be further classified into different categories, including swarm-based, physics-based, maths-based, evolutionary-based, and human-based algorithms. The human based techniques are inspired by the different man-made events and processes[1].

In the field of automatic controllers, various techniques and algorithms are utilized with the objective of minimizing disturbances as quickly as possible, while minimizing overshoot and transient time. In this study, the Most Valuable Player Algorithm (MVPA) is proposed as a method to control the load frequency. The MVPA falls under the category of human-based optimization algorithms, which are inspired by man-made events and processes. Specifically, the MVPA takes inspiration from games. The subsequent sections of the study involve the mathematical modeling of single-area and multi-area power systems, as well as a detailed explanation of the MVPA algorithm and its application in load frequency control. Simulation results are presented, and a comparison with other relevant techniques is conducted to evaluate the performance of the MVPA algorithm.

By implementing the MVPA algorithm and analyzing the simulation results, the study aims to demonstrate the effectiveness of the algorithm in maintaining load frequency control within the desired range. The comparison with other techniques provides insights into the superiority of the MVPA algorithm in addressing the challenges posed by load fluctuations and optimizing power system performance.

2 Methodology

2.1 Modelling of Power System

A single area in power plant consists of speed governor system, reheater, steam turbine and finally generator-load combination. The transfer functions for the same are as follows:

Speed Governor:

$$G_{gr}(s) = \frac{\Delta P_v(s)}{\Delta P_{et}(s)} = \frac{K_G}{1 + s\tau_{gr}} \tag{1}$$

Reheater:

$$G_{tr}(s) = \frac{1 + s\tau_{re}K_{re}}{1 + s\tau_{re}} \tag{2}$$

Turbine:

$$G_{tt}(s) = \frac{K_T}{1 + s\tau_T} \tag{3}$$

Load:

$$G_p(s) = \frac{K_P}{1+sT_p} \tag{4}$$

The single area power system (SAPS) has been shown in Figure 1. The reheater has been omitted for better analysis of the employed control technique. The deviation in frequency in this case is the indication of mismatch in power in the control area itself.

The multi area power system (MAPS) is formed by interconnecting several areas using tie-lines or transmission lines. The frequency deviation in MAPS is the measure of power mismatch in the control area as well as the interconnection. The block diagram for MAPS is shown in Figure 2.

Load frequency control reduces the steady state error which is the combination of tie line power and frequencies . This is expressed mathematically as:

$$ACE_i = B_i \triangle f_i + \triangle P_{tiei} \tag{5}$$

where B_i represents the tie-line bias factor, Δf_i represents the deviation of the system frequency from the nominal value, and the difference between actual tie line power and its scheduled value is represented by the ΔP_{tie}.[2,3]

The controller employed is the PID controller which can be modelled conventionally as in Figure 3. The transfer function is given by

$$TF_{PID} = K_p + K_i\left(\frac{1}{s}\right) + K_d\left(\frac{N}{1+\frac{N}{s}}\right) \tag{6}$$

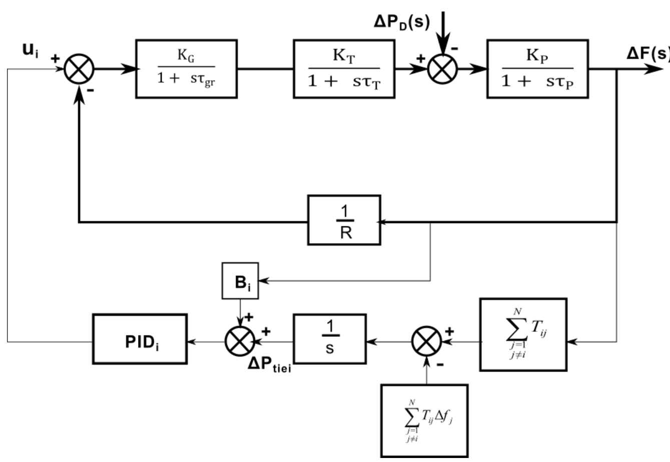

Fig 2. Multi Area Power System

where K_p, K_i and K_d represent the proportional gain, integral gain and differential gain of the controller respectively[4,5].

2.2 Most Valuable Player Algorithm (MVPA)

It is an optimization method that draws inspiration from sports. It has been developed recently by H. Bouchekara to solve optimization problems. Like in sports a player or a member undergoes two phases of competitions to come out as the best player. The Most Valuable Player Algorithm (MVPA) operates in two phases: in the first phase, players compete with each other to be the best player on their team, and in the second phase, they compete with players from other teams to become the Most Valuable Player (MVP) of the franchise.

Initially, a population of size "PlayerSize" is randomly generated, and the players are randomly assigned to teams of size "TeamSize." Next, a team ($TEAM_i$) is chosen randomly, and the competition begins. During phase 1, each player's skill is updated using the following equation:

$$Team_i = Team_i + rand \times (Franchise_i - Team_i) + 2 \times rand \times (MVP - Team_i) \tag{7}$$

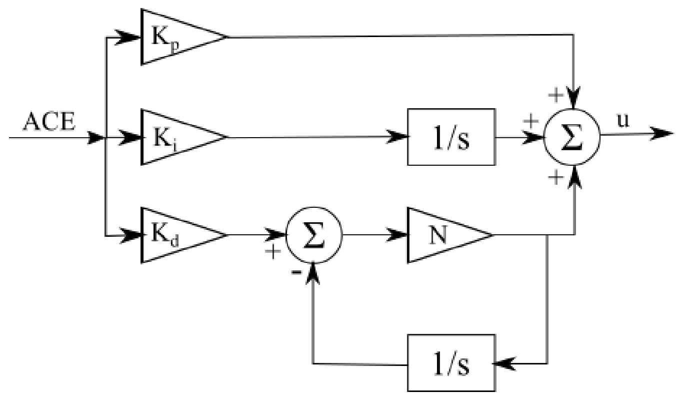

Fig 3. Controller Block Diagram

where rand is a randomly distributed number in the range [0,1] and 2 is a constant empirically found to be most effective though any other number could be used. In the phase 2, $TEAM_i$ plays against $TEAM_j$. If $TEAM_i$ wins the players' skill is updated as follows:

$$Team_i = Team_i + rand \times \left(Team_i - Franchise_j\right) \tag{8}$$

If $TEAM_i$ loses then,

$$Team_i = Team_i + rand \times (Franchise_j - Team_i) \tag{9}$$

The above steps are repeated up to specified number of iterations which forms the end criterion [6,7].

This algorithm has been used in the present study in the load frequency control problem. The complete algorithm has been illustrated by flow chart shown in Figure 4 for the application into load frequency problem. The results have been discussed in the following section.

When compared to other techniques, the MVPA algorithm being a competitive algorithm converges more quickly with higher success rate. It requires much less computational effort.

3 Results and Discussion

The simulations were performed considering five cases. Cases 1-4 pertain to single area power system and case 5 (a) and (b) to two-area power system. The various cases correspond to various expected and random disturbances occurring in a real world power system. The results of two-area power system may be extrapolated for any number of areas. The results have been compared with that of pre-existing techniques.

Case 1:

A single area power system (SAPS) is considered in this case. The thermal power plant is a non-reheated type. The load change is applied at 1 sec and the response is observed. For simulating the perturbation the controller gains are varied by 50%. The most important performance parameters are settling time & peak undershoot. The response as seen in Figure 5 is much superior to that achieved by algorithms PSO, Anwar & Pan, and Padhan & Majhi [8–11] in terms of lower settling time (t_s) and small undershoot (US) both in nominal and perturbed system. The settling time for MVPA based LFC is found to be 3.25 secs which is less than other methods.

Case 2:

In this case a reheated turbine is considered. The conditions used for analysis are similar to that in case 1 where both nominal and perturbed systems are considered and the load is changed at 1 sec. The response has been displayed in Figure 6 along with that of Padhan and Manjhi. Better performance can be observed in terms of peak undershoot and settling time of transients. The settling time for MVPA based LFC is found to be 6.3 secs which is less than other methods.

Case 3:

Here a single area power system with system parameters different to that in cases 1 and 2 is considered. Such a variation is taken into account to analyse the dynamic system and its operation. Rest of the parameters are taken and varied similar to that in

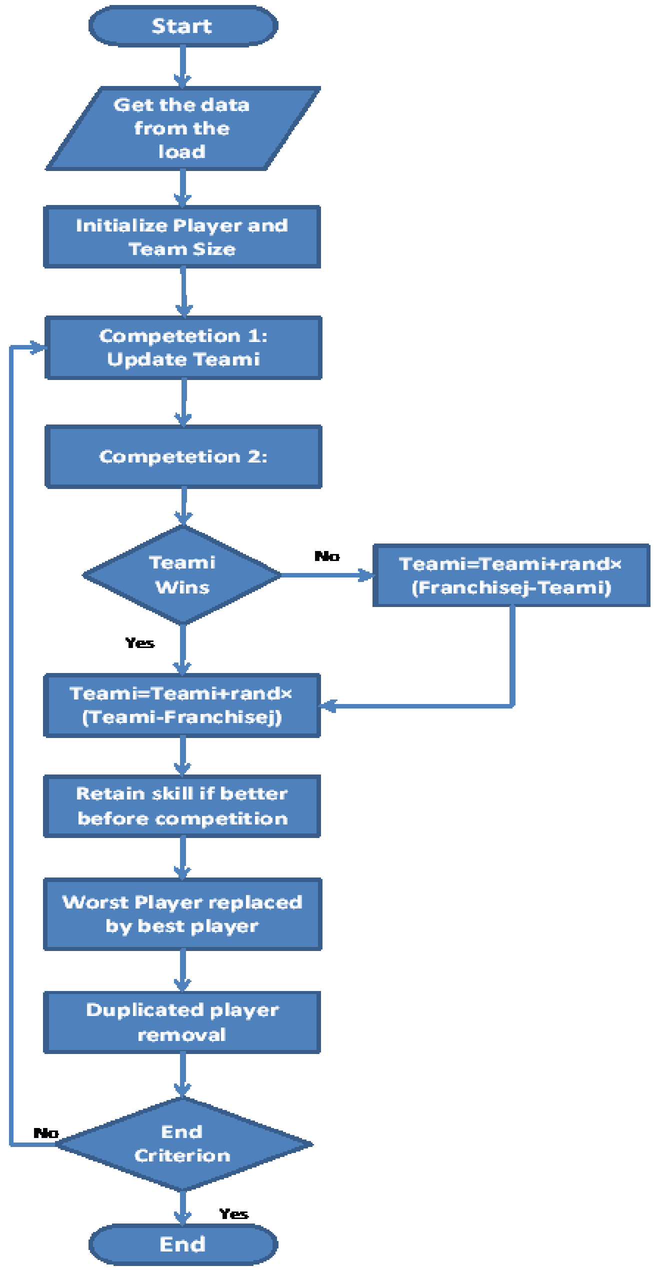

Fig 4. Flow Chart of MVPA

the previous cases. The result is shown in Figure 7 along with comparison with Gundes and Chow [11]. Significant improvement can be observed. The settling time for MVPA based LFC is found to be 5.5 secs which is less than other methods.

Case 4:

Now a non-linearity called generator rate constraint (GRC) is introduced. This poses an additional constraint to the control of the system. It often leads to instable operation and transients. In mathematical modelling the GRC block in cascaded to the turbine block and the parameter is taken to be 0.1 pu/min. The response is shown in Figure 8. The settling time for MVPA based LFC is found to be 5.5 secs which is less than other methods.

Case 5:

This case pertains to a two-area power system with a non-reheated turbine, where the variations in frequency and power exchange through the tie-line between the two areas are monitored. In this scenario, a 10% load step is applied to area 1, and no

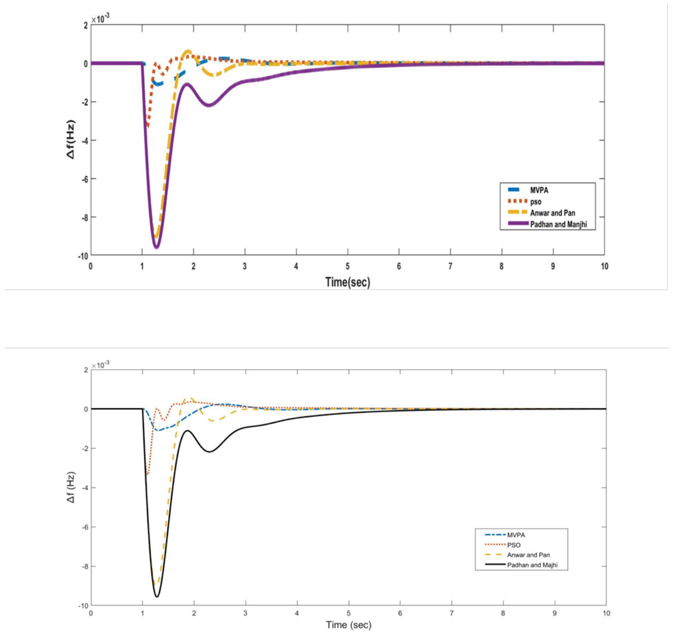

Fig 5. Frequency Response of perturbed and nominal system of case 1

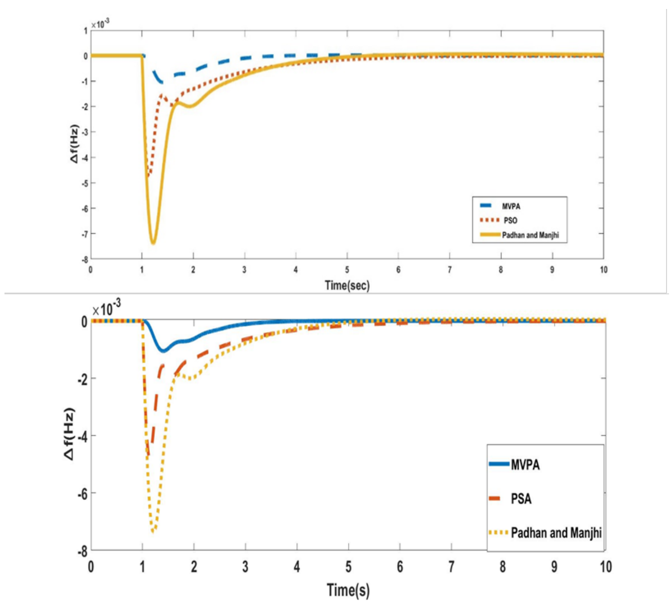

Fig 6. Frequency Response of perturbed and nominal system of case 2

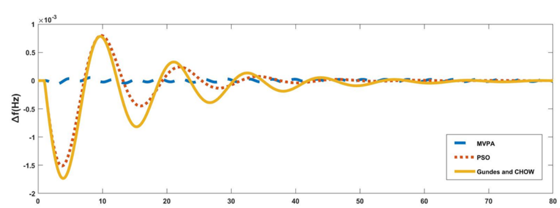

Fig 7. Frequency Response of perturbed system of case 3

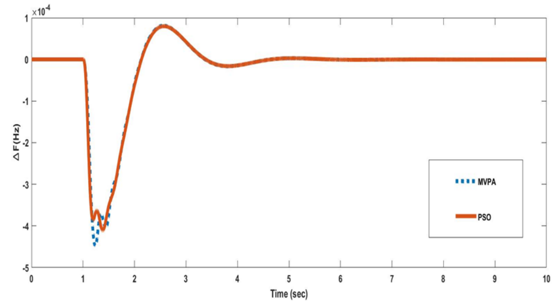

Fig 8. Frequency Response of perturbed system of case 4

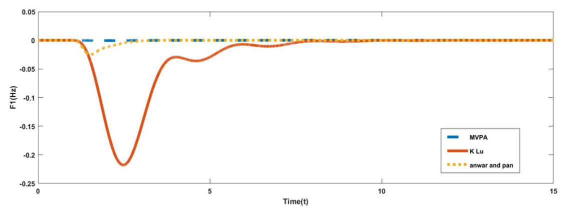

Fig 9. Frequency Response of perturbed system of case 4

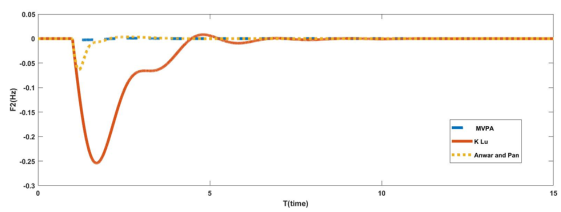

Fig 10. Frequency Responses of areas 1 & 2 of perturbed system of case 5(b)

load step is applied to area 2. The response to this is compared with other algorithms, and as demonstrated in Figures 9 and 10, it exhibits superior performance in terms of settling time and peak undershoot. The settling time for MVPA based LFC is found to be 2 secs for both cases which is less than other methods.

Table 1. Comparison of settling time (seconds) of different algorithms

Case	Proposed	(8)	(9)	(10)	(11)
1	3.25 secs	3.3 secs	3.4 secs	6.8 secs	-
2	6.3 secs	6.1 secs	-	6.3 secs	-
3	5.5 secs	5.8 secs	-	-	6.9 secs
4	5.5 secs	5.5 secs	-	-	5.5 secs
5(a)	2 secs	7 secs	-	4 secs	-
5(b)	2 secs	-	4 secs	-	-

4 Conclusion

This study applies the Most Valuable Player Algorithm (MVPA), initially devised for optimization tasks, to tackle the load frequency problem. The results demonstrate its effectiveness across various other techniques implemented in the literature like PSO, Anwar & PAN etc. The settling time for MVPA based LFC for five different cases have been evaluated and found to be considerably less than other implemented methods in the literature. Therefore, this technique holds significant promise for the effective resolution of the load frequency control problem.

References

1) Gabis AB, Meraihi Y, Mirjalili S, Ramdane-Cherif A. A comprehensive survey of sine cosine algorithm: variants and applications. *Artificial Intelligence Review*. 2021;54(7):5469–5540. Available from: https://doi.org/10.1007/s10462-021-10026-y.
2) Çakıcı FN, Eke İ, Saka M, Taplamacıoğlu MC. Performance Analysis for Load Frequency Control of Interconnected Power Systems with Different Techniques. *International Journal of Engineering Research and Development*. 2020;12(3):89–106. Available from: https://dx.doi.org/10.29137/umagd.817981.
3) Asim M, Verma A, Mahboob MR. Load Frequency Control of Multi-Area Power System using Sine-Cosine Algorithm (SCA). In: 2022 2nd International Conference on Emerging Frontiers in Electrical and Electronic Technologies (ICEFEET). IEEE. 2022;p. 1–6. Available from: https://doi.org/10.1109/ICEFEET51821.2022.9848375.
4) Abualigah L, Diabat A. Advances in Sine Cosine Algorithm: A comprehensive survey. *Artificial Intelligence Review*. 2021;54(4):2567–2608. Available from: https://doi.org/10.1007/s10462-020-09909-3.
5) Kumar A, Asim M, Shadab MM, Akhtar I. Review of Various Load Frequency Controllers. In: Iqbal, A, Malik, H, Riyaz, A, et al., editors. Lecture Notes in Electrical Engineering;vol. 723. Springer Singapore. 2021;p. 275–283. Available from: https://doi.org/10.1007/978-981-33-4080-0_26.
6) Sarwar A, Yadav RK, Asim M, Saxena D, Jain CP, Mewara HS. Most Valuable Player based selective harmonic elimination in a cascaded H-bridge inverter for wide operating range. *International Journal of Emerging Electric Power Systems*. 2023;24(5):619–634. Available from: https://doi.org/10.1515/ijeeps-2022-0041.
7) A MM, Ramli HREH, Bouchekara. Wind Farm Layout Optimization Considering Obstacles Using a Binary Most Valuable Player Algorithm. *IEEE Access*. 2020;8. Available from: https://doi.org/10.1109/ACCESS.2020.3009046.
8) Mohamed TH, Abubakr H, Hussein MM, Salman GS. Adaptive Load Frequency Control in Power Systems Using Optimization Techniques. *AI and Learning Systems - Industrial Applications and Future Directions*. 2021. Available from: https://doi.org/10.5772/intechopen.93398.
9) Anwar MN, Pan S. A new PID load frequency controller design method in frequency domain through direct synthesis approach. *International Journal of Electrical Power & Energy Systems*. 2015;67:560–569. Available from: http://dx.doi.org/10.1016/j.ijepes.2014.12.024.
10) Padhan DG, Majhi S. A new control scheme for PID load frequency controller of single-area and multi-area power systems. *ISA Transactions*. 2013;52(2):242–251.
11) Gundes AN, Chow LC. Controllers for interconnected systems with communication delays. *2015 54th IEEE Conference on Decision and Control (CDC)*. 2015. Available from: https://doi.org/10.1109/CDC.2015.7403336.