Implementation of Harris Hawks optimization for load frequency control of hydropower plant

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Article Info

ABSTRACT

Hydropower has been used for many years and is essential to meet the renewable energy ambition of the world at present. In a hydroelectric power plant, voltage and frequency control are required, but, the voltage control could be done on the load side. In the present paper, frequency control using Harris Hawks optimization (HHO) for improved performance has been presented. Simulations are performed on the dynamic model of the hydropower plant and results are compared with the conventional PID that is designed using the Ziegler-Nichols method. The efficacy of the proposed algorithm is also tested at dynamic conditions of the hydropower plant.

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1. INTRODUCTION

Hydropower is clean and lowers costs in long run. It is a great contributor to renewable energy these days and is also used as a spinning reserve. Typically, a hydropower plant comprises different subsystems as shown in Figure 1 [1]. Frequency control in the good range is crucial for hydropower plants as power demand is increasing these days. However, the technologies involved in the hydropower plant are conventional, people still prefer gain scheduling for load frequency control but this is not suitable for more range of operating points. Many researchers proposed load frequency controllers with optimization methods for interconnected power systems [2]−[10]. Some works have been presented on load frequency control of hydropower plants using nonlinear controllers [11]−[14]. Artificial intelligence-based controllers using fuzzy and ANN controllers are proposed for load frequency control in [15]−[23]. A nonlinear load frequency controller is developed in [8], also with sliding mode controller in [24], [25], however, they have more mathematical intricacies. More new optimization methods are implemented for this problem in [20]−[23].

In literature, very few of them are based on nature-inspired optimization methods for control of frequency in a typical hydropower plant to the best of the knowledge of the authors. In the present paper, Harris Hawks optimization (HHO) for improved performance of frequency control for a hydropower plant has been presented. The benefits of the proposed method are: i) simple control strategy with lesser

mathematical complexities, ii) easy to implement the control parameters like PID values in off-line for the real-time system, iii) cost-effective and consume less time in implementation, and iv) effective working on non-linear hydropower plant. The remaining paper is structured as follows: the dynamic equations of hydropower plant are described in section 2, proposed Harris Hawks optimization (HHO) is detailed in section 3, the result analysis and conclusions are described in section 4 and section 5 respectively.
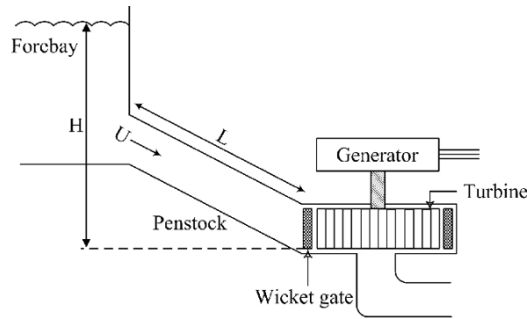

Figure 1. Hydropower plant and its subsystems

2. THE DYNAMIC EQUATIONS GOVERNING THE HYDRO-ELECTRIC POWER PLANT

The equations which are governing the liquid flow penstock and output power of the turbine are detailed as below to represent the dynamic model of the Hydropower plant.

$$\frac{d\bar{u}_t}{dt} = \frac{1}{t_w}\left(\bar{h}_o - \left(\frac{\bar{u}_t}{g}\right)^2\right) \tag{1}$$

$$\bar{h}_t = \left(\frac{\bar{u}_t}{g}\right)^2 \tag{2}$$

$$\bar{p}_m = (\bar{u}_t - \bar{u}_{nl})\left(\frac{\bar{u}_t}{g}\right)^2 \tag{3}$$

The transfer function model of the servo system that is used to control the motion of the wicket gate system is shown below. Where, the gate position change due electric servo system is given by (6). In (7) represents the generator model and (8) represents the state-space model of the entire hydropower plant.

$$\frac{\Delta\bar{x}_e(s)}{u(s)} = \frac{1}{t_p s + 1} \tag{4}$$

$$\frac{\Delta\bar{g}(s)}{\bar{x}_e(s)} = \frac{1}{t_g s + 1} \tag{5}$$

$$\Delta\bar{g} = \bar{g} - \bar{g}_o \tag{6}$$

$$M\frac{d\bar{\omega}}{dt} = \bar{p}_m - \bar{p}_e - D\bar{\omega} \tag{7}$$

$$\dot{x} = f(x) + g(x)u \tag{8}$$

Where,

$$f(x) = \begin{bmatrix} \frac{1}{M}\frac{x_2^3}{x_3^2} - \frac{\bar{u}_{nl}}{M}\frac{x_2^2}{x_3^2} - \frac{D}{M}X_1 - \frac{D}{M}\bar{\omega}_{ref} - \frac{\bar{p}_e}{M} \\ -\frac{1}{t_w}\frac{x_2^2}{x_3^2} + \frac{1}{t_w}\bar{h}_0 \\ \frac{1}{t_g}X_4 - \frac{1}{t_g}X_3 + \frac{\bar{g}_0}{t_g} \\ -\frac{1}{t_g}X_4 \end{bmatrix} \tag{9}$$

$$g(x) = \begin{bmatrix} 0 & 0 & 0 & \frac{1}{t_p} \end{bmatrix}^T \tag{10}$$

$$x(t) = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \\ x_4 \end{bmatrix} = \begin{bmatrix} \Delta\overline{\omega} \\ \overline{u}_t \\ \overline{g} \\ \overline{x}_e \end{bmatrix} \tag{11}$$

Where, $\Delta\overline{\omega} = \overline{\omega} - \overline{\omega}_{ref}$ (12)

3. HARRIS HAWKS OPTIMIZATION (HHO)

This algorithm is realized by imitating the capture of prey by harries hawks and their behavioral steps during this process. One may find its image in Figure 2. It involves exploratory and exploitative phases such as exploring prey, surprise pounce, and various ways of attacking the prey. This method is successful as it has main features of: (i) population-based approach and (ii) gradient-free method. The main behavior steps are described as given in [26]. In the proposed HHO algorithm, the position of the hawk and its best position is expressed in (13).

$$f(t+1) = \begin{cases} f_{rand}(t) - m_1|f_{rand}(t) - 2m_2 f(t)| & x \geq 0.5 \\ f_{rabbit}(t) - f_m(t) - m_3(Lb + m_4(Ub - Lb) & x < 0.5 \end{cases} \tag{13}$$

Where, $f(t+1)$ is next iteration position, $f_{rabbit}(t)$ is rabbit position at instant t, current position is $f(t)$, m_1, m_2, m_3, m_4, and x are random numbers updated in each iteration step and they lie in between {0,1}, Lb & Ub are lower and upper bound of the variable respectively, randomly a hawk being selected from the population is represented by $f_{rand}(t)$, and the average position is f_m. It is calculated using (14). Energy-related to prey is mathematically described as in (15) and will decrease during escaping considerably. It will also randomly vary in every iteration and lies in {-1,1}. When energy increases towards 1 from 0 indicates that the prey (or rabbit) is physically strengthening and is decreasing from 0 to -1, indicating that the prey is flagging. This aforesaid energy variation in the prey and its behavior for every iteration is mathematically shown by (16).

$$f_m(t) = \frac{1}{N}\sum_{i=1}^{N} f_i(t) \tag{14}$$

The energy of prey, $E = 2E_o(1 - \frac{t}{T})$ (15)

$$f(t+1) = \Delta f(t) - E|Jf_{rabbit}(t) - f(t)| \tag{16}$$

Where, $\Delta f(t) = f_{rabbit}(t) - f(t)$, in which $\Delta f(t)$ is position difference of prey with respect to previous position and randomly lies between {0, 1}. The J = 2(1 − m_5), is the movement of the rabbit (prey) in each iteration. Hard encircle of the prey will happen when x ≥0.5 and |E|<0.5, it indicates the low energy level of the prey and very difficult to escape. Hence harries hawks do not encircle and implement the surprise pounce at this condition. Then the present positions are updated as given in (17).

$$f(t+1) = f_{rabbit}(t) - E|\Delta f(t)| \tag{17}$$

For |E| ≥0.5 but x <0.5, the prey will have sufficient energy to escape. Thus, harries hawks execute a plan of soft besiege just before deciding the surprise pounce. Now the concept of levy flight (LF) is used to mathematically model this intelligent behavior in the HHO algorithm as in (18). When the prey is moving more irregular and deceptive then movements are described mathematically in (19).

$$y = f_{rabbit}(t) - E|Jf_{rabbit}(t) - f(t)| \tag{18}$$

$$z = y + s \times LF(D) \tag{19}$$

Where, $LF(f) = 0.01 \times \frac{u \times \sigma}{|v|^{\frac{1}{\beta}}}$ (20)

$$\sigma = \left(\frac{\Gamma(1+\beta) \times \sin(\frac{\pi\beta}{2})}{\Gamma(\frac{1+\beta}{2}) \times \beta \times 2^{(\frac{\beta-1}{2})}} \right)^{\frac{1}{\beta}} \tag{21}$$

Where the random values u, v in the range between {0, 1}, β=1.5. Hence, the final soft besiege phase position is modelled as (22). When |E| < 0.5, the prey has very low energy to escape and it is a hard besiege stage to catch and kill the prey. It is governed by (23).

$$f(t+1) = \begin{cases} y \ if \ g(y) \ less \ than \ g(f(t)) \\ z \ if \ g(z) \ less \ than \ g(f(t)) \end{cases} \tag{22}$$

$$f(t+1) = \begin{cases} y \ if \ g(y) < g(x(t)) \\ z \ if \ g(z) < g(x(t)) \end{cases} \tag{23}$$

$$\text{Where, } y = f_{rabbit}(t) - E|Jf_{rabbit}(t) - f_m(t)| \tag{24}$$

$$z = y + s \times LF(D) \tag{25}$$

Figure 2. Harris Hawk

HHO algorithm [10]

```
Inputs: Enter total population (N) and iterations (T)
Outputs: Prey position and fitness value
```
$$f_i \ (i = 1, 2. \ . \ . \ N)$$

```
While (terminate when the statement is failed) do
Compute the fitness of position
Keep f_rabbit as best location of the prey
        for (every hawk (f(i)) do
        Update the E₀ and J
        E₀ =2*rand-1;
        J=2*(1-rand)
        Update the E if (|E|≥ 1)
```
$$E = 2E_o(1 - \tfrac{t}{T})$$
```
        Update the current location vector using below equations
```

$$f(t+1) = \begin{cases} f_{rand}(t) - \text{m}_1|f_{rand}(t) - 2\text{m}_2 f(t)| \ x \geq 0.5 \\ f_{rabbit}(t) - f_m(t) - m_3(LB + m_4(UB - LB) \ x < 0.5 \end{cases}$$

```
   if (|E|< 1) then < <exploitation_phase >>
   if (x ≥0.5 & |E|≥ 0.5) then << Soft_ besiege> >
        Update the position using the following equation
```

$$f(t+1) = \Delta f(t) - E|Jf_{rabbit}(t) - f(t)|, \text{ where } \Delta f(t) = f_{rabbit}(t) - f(t)$$
```
   else if (r ≥0.5 and |E|< 0.5) then << Hard_besiege>>
   else if (r < 0.5 and |E|≥ 0.5) then < <Soft besiege> >
```
$$f(t+1) = \begin{cases} y \ if \ g(y) < g(f(t)) \\ z \ if \ g(z) < g(f(t)) \end{cases}$$
```
   else if (r < 0.5 and |E|< 0.5) then <Hard besiege>
   Position update using the following equation
```

$$f(t+1) = \begin{cases} y \ if \ g(y) < g(f(t)) \\ z \ if \ g(z) < g(f(t)) \end{cases}$$

```
Return f_rabbit
```

In this paper, an objective function is the minimization of the integral square error of frequency deviation as shown in (26), and the remaining optimization parameters are with lower bound (lb) =-1; upper bound (ub=100) and with number iterations are 50.

$$f = min\left(\int_0^{t_s}(\omega_r - \omega)^2 dt\right) \tag{26}$$

4. RESULT ANALYSIS

Harris Hawks optimization (HHO) for frequency control of a hydropower plant has been executed and tested comprehensively for frequency control. In MATLAB/Simulink environment, the proposed method is tested at different conditions with parameters shown in Table 1. In frequency control, the controller is mostly PID control and the gains of this controller are tuned using Ziegler Nichols (ZN) method. However, it will not provide better control for dynamic changes and is a tedious procedure. The HHO is used to optimally tune the PID gains in this paper and thereby, control the frequency effectively. The PID gains obtained while running the algorithm are k_p =100; k_i =100 and k_d= 79.94717, with convergence shown in Figure 3. Figure 4 illustrates the frequency deviation (normalized) value during control and the remaining figures show the variation of the other variables, i.e., Figure 5, Figure 6, and Figure 7 shows the normalized gate opening, water velocity in turbine, and change in the pilot actuator position respectively during this operation. In comparison to the conventional (ZN) technique, the frequency deviation is lower and the steady-state is reached within less than 2 seconds as shown in Figure 4. The traditional method took longer, taking more than 20 seconds to reach negligee frequency deviation. At the same time, the proposed control technique causes relatively little disruption in gate opening, turbine water velocity, and change pilot location.

The usefulness of the proposed work is also tested for ±10% dynamic change in the normalized water velocity. Figure 8 and Figure 9 shows the $\Delta\bar{\omega}$ plot for +10% sudden increments in the normalized water velocity and its zoomed view. Similarly, Figure 10 shows the $\Delta\bar{\omega}$ plot for -10% sudden decrement in the normalized water velocity and the corresponding zoomed view is shown in Figure 11. From Figure 8 to Figure 11, when this system is subjected to dynamic conditions, such as a sudden change in water velocity, the frequency deviation is greatly reduced using the proposed control approach. In addition, as compared to the traditional ZN technique, the turbine water velocity is within the safe range. When comparing the suggested HHO algorithm based frequency controller to the ZN-based controller, the dynamic functionality of the presented technique is superior with the proposed HHO algorithm based frequency controller.

Table 1. Simulation parameters

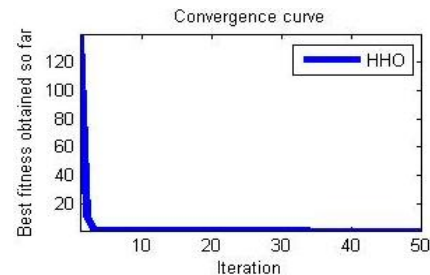| Parameter	Value
Equivalent damping (D)	1
Net head of water ($\bar{h}_0$)	1 pu
Equivalent inertia constant (M)	6
Normalized output power ($\bar{p}_e$)	0.05 pu
Servo time constant of the main gate (t_g)	0.2 sec
Time constant of the pilot actuator (t_p)	0.02 sec
Time constant of water starting (t_w)	1.3 sec
Velocity water at no load($\overline{u_{nl}}$)	0.068 pu

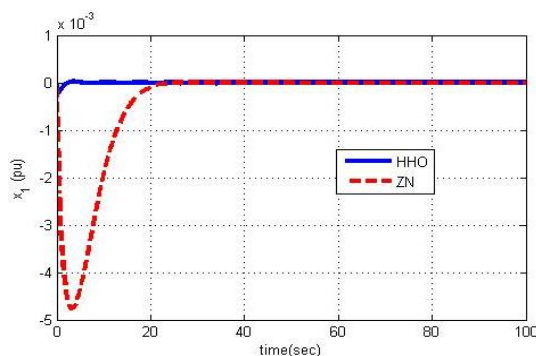Figure 3. Convergence curve during the control of Hydropower plant
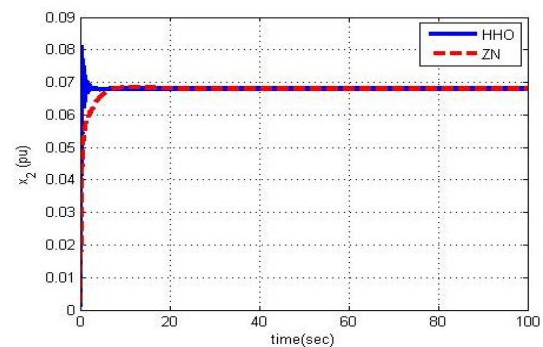

Figure 4. Frequency deviation $\Delta\bar{\omega}$
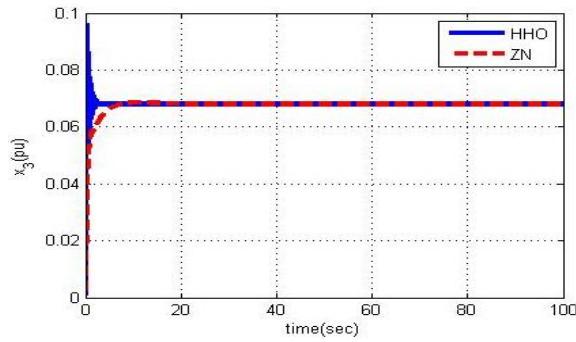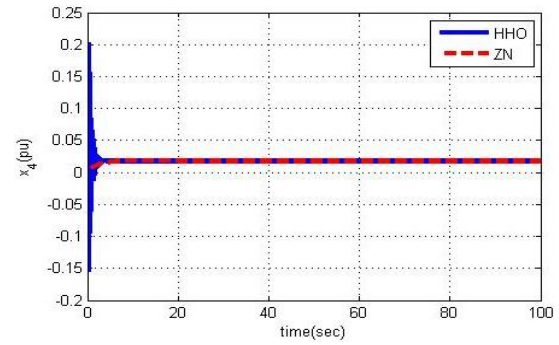

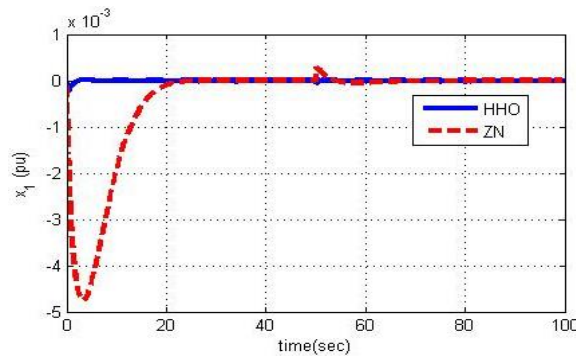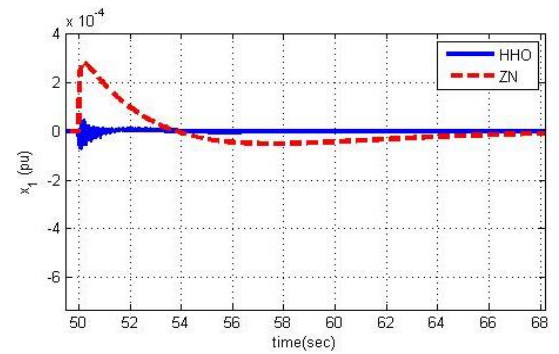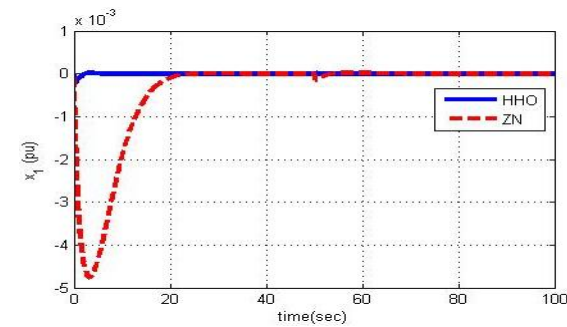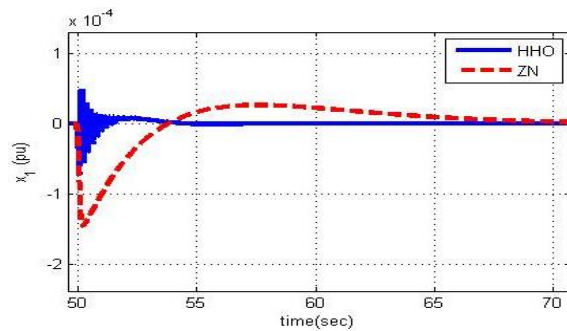Figure 5. Normalized gate opening ($\bar{g}$)

Figure 6. Normalized water velocity in turbine ($\bar{u}_t$)

Figure 7. Normalized change in pilot actuator position

Figure 8. $\Delta\bar{\omega}$ for sudden increment in $\bar{u}_t$

Figure 9. Zoomed view $\overline{\Delta\omega}$ for sudden increment in $\bar{u}_t$

Figure 10. $\Delta\bar{\omega}$ for the sudden decrement in $\bar{u}_t$

Figure 11. Zoomed view $\overline{\Delta\omega}$ for the sudden decrement in $\bar{u}_t$

5.   CONCLUSION

Frequency control using Harris Hawks optimization (HHO) for improved performance has been successfully presented in this paper. The hydropower plant is simulated using its dynamic model and PID gains of load frequency controller are optimally tuned using the HHO algorithm. The efficacy of the proposed frequency controller is tested at dynamic conditions on the hydropower plant and is also compared with the conventional ZN method. It is experiential that the efficacy of the proposed approach is better than the conventional ZN method for frequency control of Hydropower plants.

REFERENCES

[1]   Prabha Kundur, "Power system stability and control," *Power System Engineerign Series*, 1ˢᵗ ed., McGraw Hill, 1994.
[2]   C. Li *et al*., "Continuous Under-Frequency Load Shedding Scheme for Power System Adaptive Frequency Control," *IEEE Transactions on Power Systems*, vol. 35, no. 2, pp. 950-961, 2020, doi: 10.1109/TPWRS.2019.2943150.

[3]   Y. Jia, Z. Y. Dong, C. Sun and K. Meng, "Cooperation-Based Distributed Economic MPC for Economic Load Dispatch and Load Frequency Control of Interconnected Power Systems," in *IEEE Transactions on Power Systems*, vol. 34, no. 5, pp. 3964-3966, Sept. 2019, doi: 10.1109/TPWRS.2019.2917632.

[4]   H. Chen, R. Ye, X. Wang and R. Lu, "Cooperative Control of Power System Load and Frequency by Using Differential Games," *IEEE Transactions on Control Systems Technology*, vol. 23, no. 3, pp. 882-897, 2015, doi: 10.1109/TCST.2014.2346996.

[5]   F. Liu, Y. Li, Y. Cao, J. She and M. Wu, "A Two-Layer Active Disturbance Rejection Controller Design for Load Frequency Control of Interconnected Power System," *IEEE Transactions on Power Systems*, vol. 31, no. 4, pp. 3320-3321, 2016, doi: 10.1109/TPWRS.2015.2480005.

[6]   K. Sun, H. Xiao, S. Liu and Y. Liu, "Machine learning-based fast frequency response control for a VSC-HVDC system," *CSEE Journal of Power and Energy Systems*, vol. 7, no. 4, pp. 688-697, 2021, doi: 10.17775/CSEEJPES.2020.01410.

[7]   L. V. S. Kumar, D. V. N. Ananth, Y. V. P. Kumar, D. J. Pradeep, Ch. P. Reddy, and E. Ariwa, "Use of Super Conductor Magnetic Energy Storage System and FACTS Devices for Two-Area Load Frequency Control Having Synchronous Generators and DFIG Wind Generators," *International Journal of Computing and Digital Systems*, vol. 10, no. 1, pp. 1227–1238, 2021, doi: 10.12785/ijcds/1001110.

[8]   K. S. Xiahou, Y. Liu and Q. H. Wu, "Robust Load Frequency Control of Power Systems Against Random Time-Delay Attacks," *IEEE Transactions on Smart Grid*, vol. 12, no. 1, pp. 909-911, 2021, doi: 10.1109/TSG.2020.3018635.

[9]   M. H. Syed, E. G. Sansano, A. M. Sani and G. M. Burt, "Load Frequency Control in Variable Inertia Systems," *IEEE Transactions on Power Systems*, vol. 35, no. 6, pp. 4904-4907, 2020, doi: 10.1109/TPWRS.2020.3014778.

[10]   V. Gholamrezaie, M. G. Dozein, H. Monsef and B. Wu, "An Optimal Frequency Control Method Through a Dynamic Load Frequency Control (LFC) Model Incorporating Wind Farm," *IEEE Systems Journal*, vol. 12, no. 1, pp. 392-401, 2018, doi: 10.1109/JSYST.2016.2563979.

[11]   S. Doolla and T. S. Bhatti, "Load Frequency Control of an Isolated Small-Hydro Power Plant With Reduced Dump Load," *IEEE Transactions on Power Systems*, vol. 21, no. 4, pp. 1912-1919, 2006, doi: 10.1109/TPWRS.2006.881157.

[12]   B. Singh and V. Rajagopal, "Neural-Network-Based Integrated Electronic Load Controller for Isolated Asynchronous Generators in Small Hydro Generation," *IEEE Transactions on Industrial Electronics*, vol. 58, no. 9, pp. 4264-4274, 2011, doi: 10.1109/TIE.2010.2102313.

[13]   C. K. Sanathanan, "A frequency domain method for tuning hydro governors," *IEEE Transactions on Energy Conversion*, vol. 3, no. 1, pp. 14-17, 1988, doi: 10.1109/60.4193.

[14]   J. Zou, M. Pipattanasomporn, S. Rahman and X. Lai, "A Frequency Regulation Framework for Hydro Plants to Mitigate Wind Penetration Challenges," *IEEE Transactions on Sustainable Energy*, vol. 7, no. 4, pp. 1583-1591, Oct. 2016, doi: 10.1109/TSTE.2016.2569560.

[15]   Y. V. P. Kumar and R. Bhimasingu, "Fuzzy logic based adaptive virtual inertia in droop control operation of the microgrid for improved transient response," *IEEE PES Asia-Pacific Power and Energy Engineering Conference (APPEEC)*, 2017, pp. 1-6, doi: 10.1109/APPEEC.2017.8309006.

[16]   H. Bevrani and S. Shokoohi, "An Intelligent Droop Control for Simultaneous Voltage and Frequency Regulation in Islanded Microgrids," *IEEE Transactions on Smart Grid*, vol. 4, no. 3, pp. 1505-1513, 2013, doi: 10.1109/TSG.2013.2258947.

[17]   A. D. Shakibjoo, M. Moradzadeh, S. U. Din, A. Mohammadzadeh, A. H. Mosavi and L. Vandevelde, "Optimized Type-2 Fuzzy Frequency Control for Multi-Area Power Systems," *IEEE Access*, vol. 10, pp. 6989-7002, 2022, doi: 10.1109/ACCESS.2021.3139259.

[18]   R. Umrao and D. K. Chaturvedi, "Load frequency control using polar fuzzy controller," *TENCON 2010 - 2010 IEEE Region 10 Conference*, 2010, pp. 557-562, doi: 10.1109/TENCON.2010.5686740.

[19]   X. J. Liu and J. W. Zhang, "CPS compliant fuzzy neural network load frequency control," *American Control Conference*, 2009, pp. 2755-2760, doi: 10.1109/ACC.2009.5160181.

[20]   B. Khokhar, S. Dahiya, and K. P. S. Parmar, "A Novel Hybrid Fuzzy PD-TID Controller for Load Frequency Control of a Standalone Microgrid," *Arabian Journal for Science and Engineering*, vol. 46, no. 2, pp. 1053–1065, 2021, doi: 10.1007/s13369-020-04761-7.

[21]   A. Safari, F. Babaei, and M. Farrokhifar, "A load frequency control using a PSO-based ANN for micro-grids in the presence of electric vehicles," *International Journal of Ambient Energy*, vol. 42, no. 6, pp. 688–700, 2021, doi: 10.1080/01430750.2018.1563811.

[22]   A. H. Yakout, H. Kotb, H. M. Hasanien and K. M. Aboras, "Optimal Fuzzy PIDF Load Frequency Controller for Hybrid Microgrid System Using Marine Predator Algorithm," *IEEE Access*, vol. 9, pp. 54220-54232, 2021, doi: 10.1109/ACCESS.2021.3070076.

[23]   Z. Li, X. Li and B. Cui, "Cloud Neural Algorithm based Load Frequency Control in Interconnected Power System," *24th International Conference on Automation and Computing (ICAC)*, 2018, pp. 1-6, doi: 10.23919/IConAC.2018.8749027.

[24]   H. Kondo, Y. Suzuki and S. Iwamoto, "A load frequency control design using the sliding mode control theory with a VSS observer," *IEEE Power & Energy Society General Meeting*, 2009, pp. 1-5, doi: 10.1109/PES.2009.5275519.

[25]   Y. Mi, Y. Fu, C. Wang and P. Wang, "Decentralized Sliding Mode Load Frequency Control for Multi-Area Power Systems," *IEEE Transactions on Power Systems*, vol. 28, no. 4, pp. 4301-4309, 2013, doi: 10.1109/TPWRS.2013.2277131.

[26]   A. A. Heidari, S. Mirjalili, H. Faris, I. Aljarah, M. Mafarja, and H. Chen, "Harris Hawks optimization: Algorithm and applications," *Future Generation Computer Systems*, vol. 97, pp. 849–872, 2019, doi: 10.1016/j.future.2019.02.028.

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