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Renewable Energy Sources constrained Generation Scheduling of Thermal Units in a Regulated Power Industry

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ABSTRACT

Abstract: Renewable energy production technologies use resources directly from the environment to generate electric power. These energy sources such as sunshine, wind, tides and biomass are some of the more popular gifts from the nature. The renewable energy resources emit nothing into atmosphere or never produce green house gas or pollute the environment at all. Even if the renewable energy sources are safe to the atmosphere, these resources meet out smaller percent of power requirement internationally This paper a population based optimization algorithm of Corona Virus Herd Immunity Optimizer (CVHIO) is proposed to solve the renewable energy constrained generation scheduling problem. The objective function of the problem is to minimize the total operating cost of hybrid system with satisfying standard operating constrains of thermal, wind and solar power plants. Initially the variables of the problem are effectively optimized using CVHIO algorithm. . Numerical example with IEE 39 bus test system (ten thermal twenty four hour) with an equivalent Solar and Wind generators are considered to prove the performance of CVHIO approach.

Keywords—Renewable energy, Generator sheduling, CVHIO,

1. INTRODUCTION

Earlier, the power system was dominated by Vertically Integrated Electric Utilities (VIEU) that owned most of the generation, transmission and distribution sub-systems [1] Recently, most of the electric power utilities are unbundling these sub-systems as part of deregulation process. Deregulation is unbundling of vertically integrated power system into generation (GENCOs), transmission (TRANSCOs) and distribution (DISCOs) companies..The foremost objective of deregulation is to create competition among generating companies and to provide different choice of generation options at cheaper price to consumers.

In the regulated power industry, unit commitment refers to strategic planning of scheduling of generating units over a periodical time horizon to meet the system demand at minimum operating cost while satisfying the standard system and unit constraints such as power balance, spinning reserve, minimum/maximum of generator limits, minimum ON/OFF time constraints and ramp rate limits. The Unit Commitment is therefore a process of determining the minimum operating cost and referred as cost based unit commitment (CBUC).

In power industry, several methods for solving the problem of short-term generation scheduling

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have been proposed, the classical methods such as Dynamic programming (DP) [2], Lagrangian relaxation (LR) [3], Mixed-integer programming (MIP) [4], benders decomposition [5], network flow with Newton's method [6, 9] Linear programming (LP) [7] and Nonlinear programming (NLP) [8].

Recently the researchers have proposed different evolutionary techniques like Genetic Algorithm (GA) [10,11], Evolutionary Programming (EP) [12], Particle swarm optimization (PSO) [13], improved PSO(IPSO) [14], adaptive particle swarm optimization(APSO) [15], Differential Evolution (DE) [16], modified differential evolution(MDE) [17], Modified hybrid differential evolution(MHDE) [18], Teaching learning based optimization (TLBO) [19] improved flower pollination algorithm (IFPA) [20], ABC algorithm [21], Gravitational Search Algorithm [22] and Symbiotic Organisms Search Algorithm [23] have been successfully employed to solve the SHTS problem.

In this article, an efficient methodology of CVHIO algorithm is planned for solving complicated optimization problem of generation scheduling with a view to obtaining global optimal solution with best computational effort and high reliability. The suggested algorithm is desired to minimize the total thermal generation cost of thermal units.

2. PROBLEM FORMULATION

2.1 Prime objective function

The main objective of the problem is to minimize the total operating cost of the thermal generators. It includes fuel cost start-up cost and shown cost of the system. The total cost of the proposed system are mathematically defined as

$$TC = \sum_{t=1}^{T}\sum_{i=1}^{N}\left(FC_i\left(P_i^t\right)\cdot u(t)\right) + SU_T + SD_T \qquad (1)$$

where SU_T is the start-up cost modeled as a two-valued (hot start/cold start) staircase function and SD_T is the shut-down cost which is assumed zero.

$$SU_i = \begin{cases} CS_i, & if \quad DT_i > MDT_i + CSH_i \\ HS_i, & if \quad MDT_i \le DT_i \le MDT_i + CSH_i \end{cases} \qquad (2)$$

where DT_i is the down time of unit *i*.

Generally the fuel cost function are represented in the quadratic function and mathematically formulated as follows

$$FC_i\left(P_i^t\right) = A_i + B_i.P_i^t + C_i.(P_i^t)^2 \qquad (3)$$

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2.2 Standard system and unit constraints

$$P_{i\min} < P_i^t < P_{i\max} \tag{4}$$

- Ramp up/down constraints:

$$P_{i\max}^t = \min\left\{P_{i\max}, P_i^{t-1} + \tau.RU_i\right\} \tag{5}$$

$$P_{i\min}^t = \max\left\{P_{i\min}, P_i^{t-1} + \tau.RD_i\right\} \tag{6}$$

- Minimum up/down time constraints.

This constraint represents the minimum time for which a unit must remain on/off before it can be shut down or restarted, respectively:

$$\begin{aligned} T_{ion}^c &> MUT_i \\ T_{ioff}^c &> MDT_i \end{aligned} \tag{7}$$

- Power balance: constraints

$$\sum_{i=1}^{N} u_i(t).P_i^t + P_{C,RES}(t) = D^t \tag{8}$$

- Spinning reserve constraints

$$\sum_{i=1}^{N} u_i(t).P_{i\max}^t \geq D^t + R^t \tag{9}$$

3. SOLUTION METHODOLOGY

3.1 Overview of Corona Virus Herd Immunity Optimizer (CVHIO)

A new nature-inspired human-based optimization algorithm of Corona Virus Herd Immunity Optimizer (CVHIO) is proposed in this research work [15]. The motivation of CVHIO is originated from the herd immunity concept as a way to tackle corona virus pandemic (COVID- 19). The speed of spreading corona virus infection depends on how the infected individuals directly contact with other society members. In order to protect other members of society from the disease, social distancing is suggested by health experts. Herd immunity is a state the population reaches when most of the population is immune which results in the prevention of disease transmission. Here, three types of individual cases are utilized for herd immunity: susceptible, infected, and immuned. This is to determine how the newly generated solution updates its genes with social distancing strategies. The structure of Herd immunity and Population hierarchy of CVHIO are represented fig. 1 and fig. 2.

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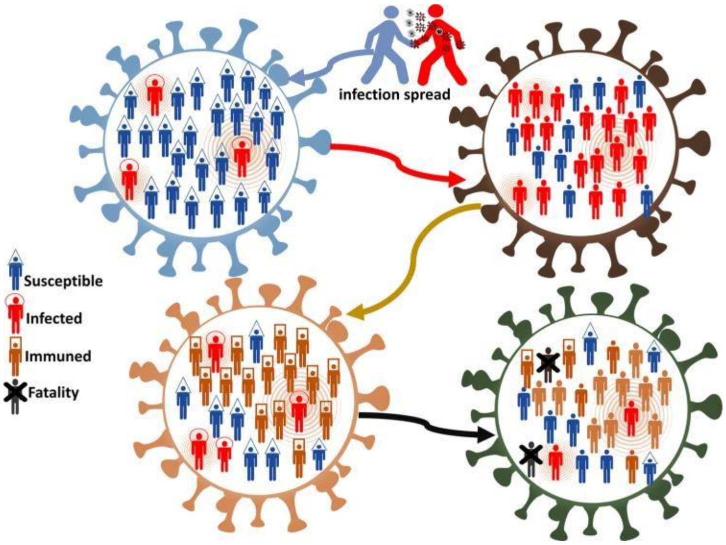

Fig 1. Herd immunity of CVHIO

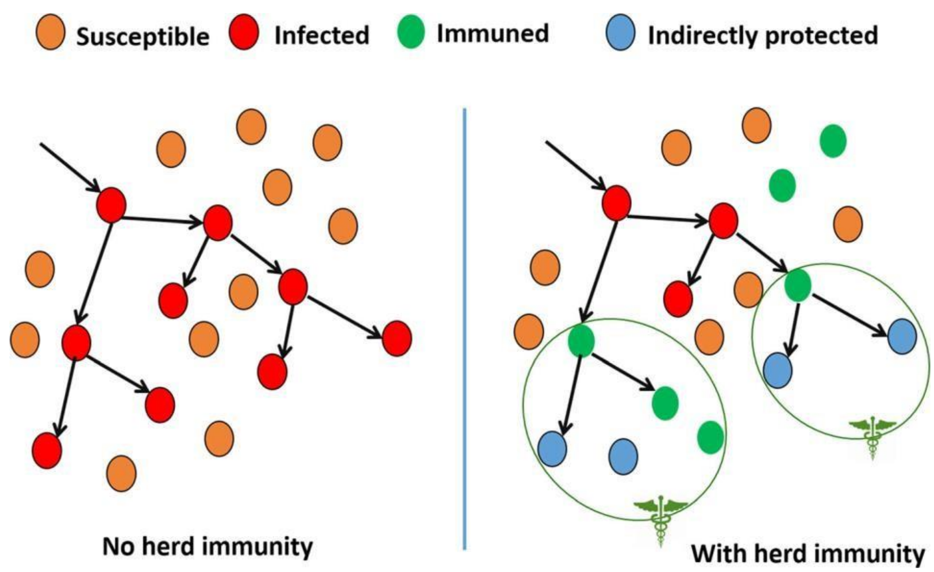

Fig 2 Opulation hierarchy of CVHIO

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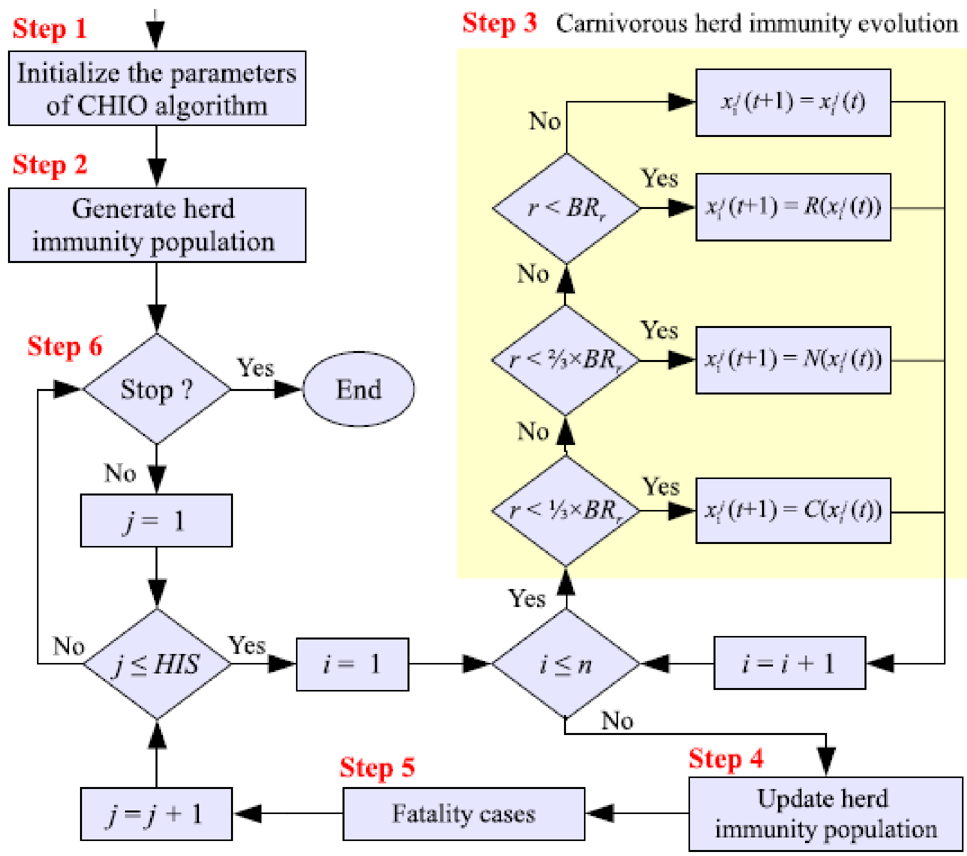

Fig 3. Flow diagram of proposed CVHIO algorithm

4. RESULTS AND DISCUSSION

This section discusses the simulation results of proposed standard test system. An applicability and superiority of the described CVHIO is tested on ten thermal, one solar and one wind units with 24 hour test system. The unit data and forecasted load demand of ten thermal units are taken from reference [12]. The spinning reserve requirement is assumed to be 10% of the total load. The proposed algorithm is programmed in MATLAB 14.0 and numerical simulations are carried out in a computer with i3 processor, Intel (R), core (i3), is 2.40 GHz, 4GB RAM. The proposed CVHIO method is especially having common control parameters such as population size and maximum number of iteration 50 and 500 respectively

Table 1 UC schedule of wind, solar and ten thermal integrated 24 hour test system

H (h)	Unit Commitment Schedule											
	Thermal Units										Wind Unit	Solar Unit
	U1	U2	U3	U4	U5	U6	U7	U8	U9	U10		

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1	1	1	0	0	0	0	0	0	0	0	1	0
2	1	1	0	0	0	0	0	0	0	0	1	0
3	1	1	0	0	0	0	0	0	0	0	1	0
4	1	1	0	0	0	0	0	0	0	0	1	0
5	1	1	0	0	0	0	0	0	0	0	1	0
6	1	1	0	0	1	0	0	0	0	0	1	0
7	1	1	0	0	1	0	0	0	0	0	1	0
8	1	1	0	0	1	0	0	0	0	0	1	1
9	1	1	0	1	1	0	0	0	0	0	1	1
10	1	1	1	1	1	0	0	0	0	0	1	1
11	1	1	1	1	1	0	0	0	0	0	1	1
12	1	1	1	1	1	0	0	0	0	0	1	1
13	1	1	1	1	1	0	0	0	0	0	1	1
14	1	1	0	1	1	0	0	0	0	0	1	1
15	1	1	0	1	1	0	0	0	0	0	1	1
16	1	1	0	1	0	0	0	0	0	0	1	1
17	1	1	0	1	0	0	0	0	0	0	1	1
18	1	1	0	1	0	0	0	0	0	0	1	1
19	1	1	0	1	0	0	0	1	0	0	1	0
20	1	1	1	1	0	0	0	1	0	1	1	0

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21	1	1	1	1	0	0	0	0	0	0	1	0
22	1	1	0	1	0	0	0	0	0	0	1	0
23	1	1	0	0	0	0	0	0	0	0	1	0
24	1	1	0	0	0	0	0	0	0	0	1	0

Fig.4. Unit status of ten thermal units with/without renewable energy sources

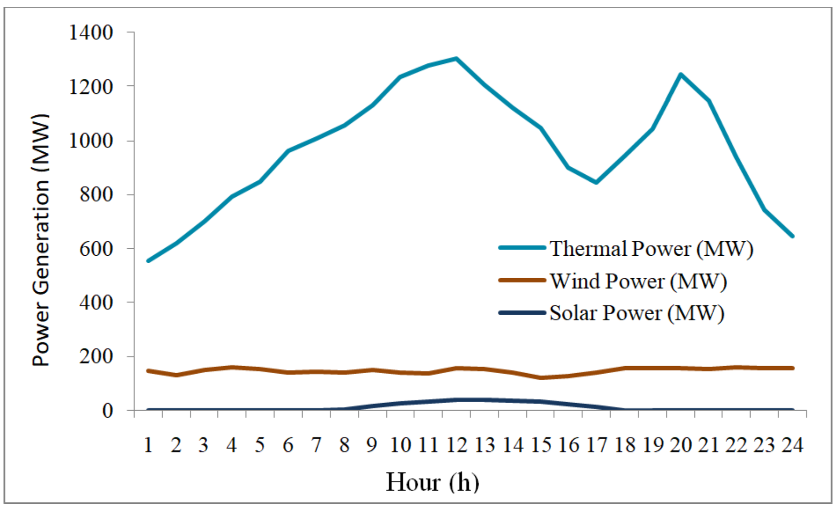

Fig 5. Power generation of thermal, wind and solar system

A wind and solar units are interconnected with standard ten thermal units test system and CVHIO algorithm is applied to solve this problem. Now the algorithm identifies the committed units of hybrid power system. The best UC schedule of wind, solar and thermal integrated system is reported in Table 1. The unit status of thermal units with/without renewable energy is graphically represented and displayed in fig 4.

Table 2 Simulation results of proposed hybrid test system

H (h)	PD (MW)	Thermal Power (MW)										Wind Power (MW)	Solar Power (MW)
		P1	P2	P3	P4	P5	P6	P7	P8	P9	P10		
1	700	455	99.01	0	0	0	0	0	0	0	0	145.994	0

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2	750	455	163.46	0	0	0	0	0	0	0	0	131.515	0
3	850	455	246.88	0	0	0	0	0	0	0	0	148.156	0
4	950	455	336.22	0	0	0	0	0	0	0	0	158.981	0
5	1000	455	392.24	0	0	0	0	0	0	0	0	152.758	0
6	1100	455	405	0	0	100.44	0	0	0	0	0	139.557	0
7	1150	455	455	0	0	96.61	0	0	0	0	0	143.393	0
8	1200	455	455	0	0	146.09	0	0	0	0	0	140.825	3.09
9	1300	455	455	0	62.62	160	0	0	0	0	0	150.843	16.54
10	1400	455	455	32.48	130	162	0	0	0	0	0	138.672	26.85
11	1450	455	455	77.95	130	162	0	0	0	0	0	137.723	32.33
12	1500	455	455	102.45	130	162	0	0	0	0	0	157.096	38.45
13	1400	455	455	36.66	130	130	0	0	0	0	0	153.591	39.75
14	1300	455	455	0	82.72	130	0	0	0	0	0	139.299	37.99
15	1200	455	455	0	37.54	100.55	0	0	0	0	0	120.375	31.54
16	1050	455	335	0	108.63	0	0	0	0	0	0	128.372	22.99
17	1000	455	385	0	106.02	0	0	0	0	0	0	141.455	12.52
18	1100	455	405	0	103.03	0	0	0	0	0	0	156.282	0.69
19	1200	455	455	0	120	0	0	0	14.01	0	0	155.994	0
20	1400	455	455	130	130	0	0	0	55	0	19.1	155.904	0
21	1300	455	455	106.25	130	0	0	0	0	0	0	153.255	0
22	1100	455	455	0	30.45	0	0	0	0	0	0	159.548	0
23	900	455	289.71	0	0	0	0	0	0	0	0	155.799	0
24	800	455	188.75	0	0	0	0	0	0	0	0	156.236	0
Total cost ($) = 466903.50													

Table 3 Comparison of total cost of proposed with existing methods

Methods	Total Operating Cost ($)	
	Without renewable energy Sources	**With renewable energy Sources**
GA	565825.00	509320
DE	564735.00	475310
CVHIO (Proposed Method)	**545523.50**	**466903.50**

The optimized thermal, solar and wind power, fuel cost, start-up cost and total cost of hybrid system are reported in Table 2. Power generation of hybrid test system is graphically represented in fig. 5. The obtained total operating cost is compared with other intelligence technique of GA and DE as shown in Table 3. The Table 2 and 3 clearly denotes that the proposed approach efficiently minimizes the fuel cost, start-up cost with less computational time when compared with existing soft computing methods such as GA and DE.

5. SUMMARY

The renewable energy sources of wind and solar constrained generation scheduling with thermal units are presented in this work. The major objective of the work is to minimize the total operating cost of thermal generator satisfying the standard operating constrains of thermal, wind and solar system. The total operating cost of the system includes fuel cost and start-up cost of the thermal generators. A best optimization algorithm of CVHIO is applied to solve this problem. In the proposed algorithm, the search extent is first explored and examined by the ant lion optimization and after that the domain is discovered by the PSO algorithm in every one iteration sequence. The proposed algorithms properly identify the committed thermal, wind and solar units to form UC schedule based on the forecasted load demand.

References

[1] A. J. Wood and B. F. Wollenberg, "Power generation, operation and control", John Wiley & Sons, New York, 1996.
[2] S. Ruzic, N. Rajakovic and A. Vuckovic, "A flexible approach to short term hydro-thermal coordination", IEEE Transactions on Power Systems, Vol. 11, No. 3, pp. 1564-1571, August 1996.
[3] X. Guan, E. Ni, R. Li, and P. B. Luh, "An optimization-based algorithm for scheduling hydrothermal power systems with cascaded reservoirs and discrete hydro constraints", IEEE Transactions on Power Systems, Vol. 12, No. 4, pp. 1775–1780, November 1997.
[4] M. Giuntoli and D. Poli, "A novel mixed-integer linear algorithm to generate unit commitment and dispatching scenarios for reliability test grids", International Review of Electrical Engineering, Vol. 6, No. 4, pp. 1971–1983, August 2011.
[5] S. Sifuentes and A. Vargas, "Hydrothermal scheduling using benders de- composition: Accelerating techniques", IEEE Transactions on Power Systems, vol. 22, No. 3, pp. 1351– 1359, August 2007.
[6] L. Guangyi, Q. Jinlong, Y. Erkeng and B. Xiaomin, "Convex flow programming and its application to the economic scheduling of hydro-thermal power systems", Proceeding Chinese Society for Electrical Engineering, Vol. 8, pp. 9-18, 1988.
[7] M. F. Zaghlool and F. C. Trutt, "Efficient methods for optimal scheduling of fixed head hydrothermal power systems", IEEE Transactions on Power Systems, Vol. 3, No. 1, pp. 24- 30, February 1988.
[8] T. N. Saha and S. A. Khapade, "An application of a direct method for the optimal scheduling of hydro-thermal power systems", IEEE Transactions on Power Apparatus and Systems, Vol. PAS-97, No. 3, pp. 977-983, May 1978.
[9] X. Qing, X. Niande, W. Shiying, Z. Boming and H. Mei, "Optimal daily scheduling of cascaded plants using a new algorithm of non-linear minimum cost network flow concept", IEEE Transactions on Power Systems, Vol. 3, No. 3, pp. 929-935, 1988.
[10] Padmini, S., C. Christober Asir Rajan, Subhronil Chaudhuri, and Arkita Chakraborty. "Optimal Scheduling of Short Term Hydrothermal Coordination for an Indian Utility System Using Genetic Algorithm." In Proceedings of the International Conference on Frontiers of Intelligent Computing: Theory and Applications (FICTA), pp. 453-459. Springer, Berlin, Heidelberg, 2013.
[11] Orero, S.O., Irving, M.R.: A genetic algorithm modeling framework and solution technique for short-term optimal hydrothermal scheduling. IEEE Trans. Power Syst. 13(2), 501–518 (1998).
[12] Sinha, N., Chakrabarti, R., Chattopadhyay, P.K.: Fast evolutionary technique for short- term

hydrothermal scheduling. IEEE Trans. Power Syst. 18(1), 214–220 (2003)
[13] Yuan, X., Wang, L., Yuan, Y.: Application of enhanced PSO approach to optimal scheduling of hydro system. Energ. Convers. Manag. 49(11), 2966–2972 (2008)
[14] Hota, P.K., Barisal, A.K., Chakrabarti, R.: An improved PSO technique for short-term optimal hydrothermal scheduling. Electr. Power Syst. Res. 79(7), 1047–1053 (2009)
[15] Amjady, N., Soleymanpour, H.R.: Daily hydrothermal generation scheduling by a new modified adaptive particle swarm optimization technique. Electr. Power Syst. Res. 80(6), 723–732 (2010)
[16] Mandal, K.K., Chakraborty, N.: Differential evolution technique-based short-term economic generation scheduling of hydrothermal systems. Electr. Power Syst. Res. 78(11), 1972–1979 (2008)
[17] Lakshminarasimman, L., Subramanian, S.: Short-term scheduling of hydrothermal power system with cascaded reservoirs by using modified differential evolution. IEE Proc. Gener. Transm. Distrib. 153(6), 693–700 (2006)
[18] Lakshminarasimman, L., Subramanian, S.: Modified hybrid differential evolution for short-term scheduling of hydrothermal power system with cascaded reservoirs. Energ. Convers. Manag. 49(10), 2513–2521 (2008)
[19] Roy, P.K.: Teaching learning based optimization for short-term hydrothermal scheduling problem considering valve point effect and prohibited discharge constraint. Electr. Power Energ. Syst. 53,10–19 (2013)
[20] Dubey, Hari Mohan, Bijaya K. Panigrahi, and Manjaree Pandit. "Improved flower pollination algorithm for short term hydrothermal scheduling." In International Conference on Swarm, Evolutionary, and Memetic Computing, pp. 721-737. Springer, Cham, 2014.
[21] Basu M. Artificial Bee Colony Optimization for Short-Term Hydrothermal Scheduling. Journal of The Institution of Engineers (India): Series B. 2014 Dec 1;95(4):319-28.
[22] Gouthamkumar, N., Sharma, V. and Naresh, R., 2016. Hybridized gravitational search algorithm for short-term hydrothermal scheduling. IETE Journal of Research, 62(4), pp.468-478.