Optimal Scheduling of Hydro-Thermal-Wind Generation Using Heuristic Search Optimization Technique

Ombeer Saini[1], Abdul Kadir[1]
Department of Electrical, Institute of Technology, Gopeshwar, Chamoli-246424, INDIA

Department of Electrical, B.S.M. College of Engineering and polytechnic Roorkee -247667, INDIA

ombeer2009@gmail.com, kadirbsmpoly@gmail.com

Abstract-: This paper develops the Hybrid Hydro-Thermal-Wind system optimization and Heuristic search Optimization techniques that are used for cracking the optimal organize of hydro-thermal-wind generation organize difficulty. A heuristic hydrothermal organization considering the uncertain behavior of wind power generation mainly depends on the wind speed, which is unresolved in the environment. To tackle the uncertainty related to wind energy, the 5m point estimate method is used. The optimization of hybrid hydro-thermal-wind power generation systems can be achieved technically and economically according to the system reliability requirement. the overall efficiency of the proposed optimization techniques is confirmed on short-term variable head hydro – thermal and wind Generation test systems including two thermal units and two hydro plants and one wind unit. A test system has been taken to justify the ability to solve the problem and examine the effect of wind energy in a hydrothermal system. To make difficulty much more practical the valve-point loading effect is contemplated too. A positive session of the strategy is reported in this paper and outcomes for one sample test system are given.

Keywords: Hybrid Hydro-Thermal-Wind system; Heuristic Search Method, valve-point loading effect.

I. INTRODUCTION

The role of optimal generation organization of a thermal-renewable power generation system aiming at economic and environmental benefits is vital in the current scenario of increasing power demand, escalating fuel prices, and high contamination rates. The optimized generation organize of a Hydro-Thermal-Wind system aims to distribute the power demand among the generating plants in such a way that the net energy cost and emission of pollutants are minimized while satisfying the various constraints of power plants. Untimely, the marge operation of Hydro-Thermal plants was successfully scheduled to reduce the fuel cost, as well as the secretion of contaminations. Now, with the evaluation and preparedness of new and cost-effective automation, the penetration test of wind power plants in the energy sector has become noteworthy, requiring its inclusion in the scheduling process. But analysis declaration expresses the optimal generation scheduling of such hybrid energy sources is scanty.

Hydrothermal scheduling (HTS) is a vital problem in the power scenario of the world. The main goal of the HTS problem is to minimize the fuel cost of generation by using the water of hydro reservoir as much as possible and also satisfying several equality and inequality constraints related to hydro and thermal plants. As an important issue, various methods have been already tested to solve this problem. These are namely: Gradient Search (GS) [1], dynamic programming (DP) [2], Lagrange relaxation (LR) [3] and decomposition and coordination [4]. All these techniques have some advantages as well as disadvantages. In the case of the GS method, the problem needs to be presented in a piecewise linear function. This may not be practical in nature. Dimensionality is a big problem in the case of the DP method and it increases as the system size suit expands. LR method has faced difficulty during the convergence process because of dual problem formulation. Decomposition and coordination methods have faced problems while dealing with non-convex objective functions as well as constraints.

Recently some advanced methods based on artificial intelligence have been introduced to rectify the problems of the above-mentioned methods these include simulated annealing (SA) [5], differential evolution (DE) [6], and (AIS) [7] put in. Later on, (PSO) [8] and some other PSO-based methods [9] have been successfully implemented to solve the HTS problem. The real coded chemical reactionbased optimization (RCCRO) [10] method has been proposed by Bhattacharjee *et al.* for the solution of optimizing organize of hydrothermal systems. The cuckoo search algorithm [11] was implemented by Nguyen *et al.* and checked on a hydro-thermal system and found higher results. Das *et al.* prospective symbiotic organisms search algorithm [12] for the solution to the HTS problem.

Recently renewable energy sources like wind and solar are gaining more attention in most parts of the world. These energy sources are very eco-friendly and very cheap compared to other sources. Researchers are trying to utilize renewable sources as much as feasible. For this ambition, renewable power sources are being incorporated with hydro and thermal units to solve the SHTS problem [13-14]. To deal with the uncertain behavior of solar and wind, several approaches have been taken so far. Among them, the point evaluation procedure 15] has been used widely due to certain advantages like less simulation time and deterministic approaches to solving probabilistic problems. Based on the PEM method various problems [16-17] have been solved.

The focal objective of the short-term variable head hydro-thermal and wind generation system arrangement problem is to find the optimum generation of the thermal and hydropower units to minimize the total production cost over the arrangement time horizon (typically a single day or one week) subjected to a diversity of thermal and hydro units' coercion. The hydro-thermal-wind generation system unit scheduling is mainly worried about both hydro units, thermal units, and wind unit dispatching. The short-term variable head hydro-thermal generation problem is more problematic than the generation arrangement of the thermal power unit systems. In short-term variable head hydro, thermal, and wind generation arrangement problems, the hydro and thermal unit limits and the load demand over the generation adaption interim. Several mathematical optimization procedures have been used to solve short-term variable head hydro-thermal-wind generation arrangement problems [3].

II. METHODS

More recently, Pereira and pinto [4] demonstrated an efficient optimization technique for cracking the coordination problem using decomposition techniques [5]. The heuristic search technique is not found the greatest solution but guaranteed the find a decent solution in a reasonable time, and rises the efficiency, valuable in solving problems that, could not be solved any other way, and Solutions take an infinite time or very long time to compute.

III. ASSUMPTIONS

The elementary problem considered involves the short-term optimal economic process of an electric power system that comprises both hydro – thermal - wind generation resources. The purpose is to reduce the total scheme operational cost, marked by the fuel cost strained for the system's thermal generation units, over the optimized interim. individually hydropower unit is constrained by the amount of water accessibility for draw-down in some interval. A prediction of the system's future water source and power demand is expected to be accessible for the optimum interim. The output power of each hydro unit varies with the real hydraulic head and the rate of water released through the turbines. For enormous capacity reservoirs, it is empirical to assume that the real head is constant over the optimized interim.

IV PROBLEM FORMULATION

To objective of the problem is to minimize the total generation cost while satisfying all the constraints related to hydro, thermal, and wind.

A.

Minimum cost =

$$\sum_{i=1}^{TI}[\sum_{k=1}^{Mi} Tp(k,i)+\sum_{n=1}^{Mw} Wp(n,i)*Cw(n)+OEC(n,i)+UEC(n,i)---(1)$$

Where TI represents the total time interim. T_p and Wp indicate hydro-wind power sequentially. Mt and Mw indicate the total number of thermal and wind plants. α_j, β_j, χ_j, δ_j, ε_j are the fuel cost coefficient of the thermal generator.

OEC and UEC indicate the overestimation and underestimation cost of wind power. C_w represents the direct cost coefficient of wind power.

B. Hydraulic Continuity equation

$$EV_h(j,t)=EV_h(j,t-1)+I_h(i,t)-D_h(j,t)+\sum_{meRu(i)} R_h(n,t-tm)--(2)$$

where, EV_h, I_h, and D_h represent the water storage volume, inflow, and water discharge of the hydro reservoir. m represents the number of upstream reservoirs and τ_m indicates the water time delay.

C. Hydro reservoir storage volume and discharge limits

$$EV_h^{\min}(j) \le EV_h(j,t) \le EV_h^{max}(j) - - - (3)$$

$$R_h^{\min}(j) \le R_h(j,t) \le R_h^{\max}(j) - -(4)$$

where, EV_h^{min} and EV_h^{max} indicate the minimum and maximum reservoir volume limit. D_h^{min} and D_h^{max} represent the upper and lower discharge limit.

D. Initial and terminal reservoir storage volume limits:

$$EV_h(j,0) = EV_h^{begin}(j) - -(5)$$

$$EV_h(j,t) = EV_h(j) - -(6)$$

where EV_h^{start} and EV_h^{end} specify the starting and terminal reservoir volume.

E. Generation limits:

$$T_p^{\min}(k) \le T_p(k,t) \le T_p^{\max}(k) - -(7)$$

$$H_p^{\min}(i) \le H_p(i,t) \le H_p^{\max}(i) - -(8)$$

where T_p^{min} and T_p^{max} indicate the minimum and maximum limit of thermal power generation. H_p^{min} and H_p^{max} indicate the minimum and maximum hydropower generation limits. Hydropower output can be calculated using the following equation:

$$H_p(i,t) = k_{1i}.EV^2{}_h(i,t) + k_{2i}R_h^2(i,t) + k_{3i}EV_h(i,t).R_h(i,t) - -(9)$$

where, J_{1i} and J_{2i} represent the hydro cost coefficients.

F. Power balance constraint:

Total power should be equal to the total demand and loss and can be represented below:

$$\sum_{k=1}^{M_t} T_p(k,t) + \sum_{i=1}^{M_h} H_p(i,t) + \sum_{n=1}^{M_i} W_p(n,t) = P_D(t) + P_{loss}(t) - -(10)$$

V. WIND POWER MODELING

Wind power output is highly dependent on the variation of wind speed. So, in accord with the deceptive of wind power 5m PEM has been used [15]. The steps of 5m PEM are mentioned in [16]. The wind speed characteristics mostly follow the Weibull probability density function (PDF) according to [17]. So, the PDF can be expressed as below:

$$PDF(v) = \frac{k}{c}(\frac{v}{c})^{k-1}.\exp[-(\frac{v}{c})^k]v > 0) - -(11)$$

where v indicates the current wind speed. k and c are the shape and scale factors of the wind turbines. The output power of wind is basically calculated based on the wind velocity and can be determined using its speed-power curve as below:

$Wp = 0$ $(v < v_{in}$ or $v \ge v_{out})$

$w_r(v-v_{in})/v_r-v_{in}$ $(v_{in} \le v \le v_r)$ ---(12)

0 $v < vin$ $(v_r \le v \le v_{out})$

where, v_r , v_{in} and v_{out} indicate the rated, cut-in, and cutouts speed of the wind turbine. w_r represents the rated power of a wind turbine.

As wind power generation is associated with the unreliability of wind speed, so it is very burdensome to appraise the genuine wind power output. If the real wind power generation is fewer than the scheduled output, convey the wind power is overestimated. On the other hand, if the actual wind power output is more than the planned wind power output, convey wind power is underrated.

VI. RESULT

A test system has been considered to examine the effect of wind power on the test system as well as to analyze the performance of the heuristic search method. All the coding has been done in MATLAB 2020a. The configuration of the laptop is as follows: 16GB RAM 1.80 GHz core i7. A total number of population and iteration are taken as 20 and 100 respectively for the test system.

A. Test system

The system comprises two hydro, two thermals, and one wind unit. The scheduling period is taken 1 day at 24 intervals. The period of each interval is taken 1 hour. To make the problem formulation much more realistic, the valve point loading effect of the thermal generator is taken into consideration. As it is well-known fact that wind power generation depends on wind velocity which is unpredicted in nature. So, it is quite difficult to schedule the power for the next day. To accurately model the wind behavior, an efficient 5m PEM is used. The input data related to hydro and thermal plants is contracted from [14]. The shape and scale parameters are contracted as 1.7 and

17 systematically. The cut-in, cut out and rated speeds of wind are taken as 5, 15, and 45 m per second systematically. The apprize power of wind is contracted at 12 MW. The optimal generation of hydro–thermal–a wind has been depicted in fig 1. The value of hydro is in Table 2. Table 2 reveals the heuristic method. The hourly generation of wind power has been depicted in Table 3. The concurrence graph of the heuristic optimization method is related to fig 2.

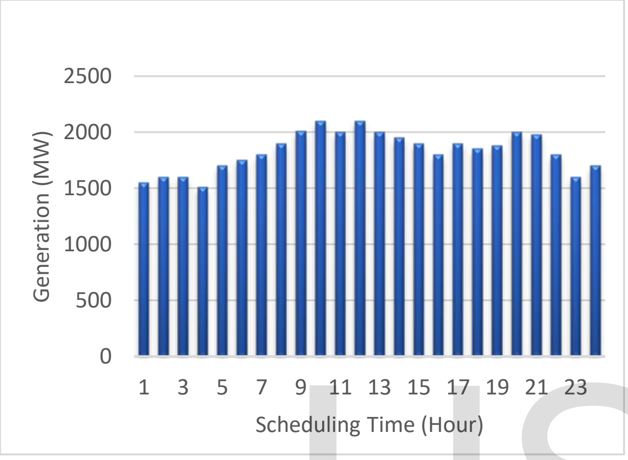

Fig.1: Optimal generation of hydro, thermal and wind power.

TABLE 1 OPTIMAL SOLUTION OF HYDRO DISCHARGES.

Hour	H_1 (m^3x10^5)	H_2 (m^3x10^5)
1	0.765451079	0.9352018589
2	0.863276999	0.6660166497
3	1.106508539	1.214908562
4	0.862577371	0.760299217
5	1.120183023	0.995102102
6	0.5895903736	0.655289257
7	0.8583735598	0.975921030
8	0.7636643721	0.895351654
9	0.792868780	0.769005331
10	0.937406555	0.854380405
11	0.841428050	0.688652121
12	0.576419398	0.848510069
13	0.895765196	0.786987146
14	0.674266742	0.754900596
15	0.651063437	0.865498995
16	1.053228968	0.779611069
17	0.558030212	0.724769266
18	0.547912666	0.797215604
19	1.022102038	0.839623056
20	0.832260055	0.9321200609
21	0.825051275	0.734437440
22	0.519847297	1.022272016
23	0.994192607	0.768290954
24	0.71469825	1.278623993

Table2: Comparative Study Among Different Methods.

Methods	Min Cost ($)	Std. Deviation ($)	Iteration Time(s)
Newton Raphson Method	202505.9548	2.8051	40.48
Practical Swarm Optimization Method	201403.8512	2.6048	32.26
Heuristic Search Method	201201.4310	2.0142	19.48

Table 3: Hourly Generation of Wind power Output

Hour	Wp (MW)	Hour	Wp (MW)	Hour	Wp (MW)
1	0	9	0	17	10.5448
2	0	10	12.0000	18	0.5436
3	12.0000	11	0	19	0
4	0	12	0	20	6.390
5	3.8642	13	9.0713	21	0
6	12.0000	14	0	22	12.0000
7	12.0000	15	0.8621	23	0
8	8.7421	16	0.91542	24	0

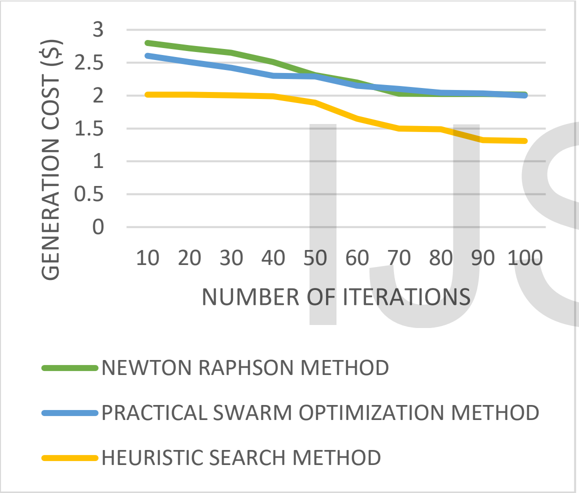

Fig: 2 Convergence Characteristics of Heuristic Search Method

VII. CONCLUSION

This paper presented the solution methodology to solve the short-term hydrothermal-wind scheduling problem. To model the unresolved related to wind power, a 5m PEM method is used. A heuristic optimization method is applied for cost minimization. The results obtained by the heuristic optimization method have been compared with the newton raphson method and practical swarm optimization method. The results reassert the superiority of the heuristic optimization method over other mentioned methods. Moreover, it takes less time to get converged compared to others. So, in the future, this method may be used as an effective tool to solve other power system optimization problems.

Nomenclature

the following symbolization used in this paper is primarily presented:

TI → Total time interval.

T_P and Wp →Hydro and wind power.

m_t and m_w → Total number of thermal and wind plant.

$\alpha_j, \beta_j, \chi_j, \delta_j, \varepsilon_j$ → Fuel cost coefficient of the thermal generator.

OEC→ Overestimation cost.

OEC → Underestimation cost.

Cw → Direct cost coefficient of wind power

EVh → Water storage Volume.

I_h → Inflow of water.

D_h → Water discharge of hydro reservoir.

m → Number of upstream reservoir.

τ_m → Water time delay.

J_{1i} and J_{2i} → Represent the hydro cost coefficients.

T_p^{min} → Minimum limit of thermal power generation

T_p^{max} → Maximum limit of thermal power generation.

References:

[1] Damodaran Suresh and Kumar T.K. Sunil “Hydro-Thermal-Wind Generation Scheduling Consideration Economic and Environmental Factors Using Heuristic Algorithms” in energies 2018,11,352, doi:10.3390

[2] O. Saini and A. Sandhu Arun “Differential Evolutionary Search Method for Hydrothermal Scheduling”, in *proc. Journal of Engineering Computer & applied Science(JECAS)*., vol 4, no 6, june 2015

[3] H. T. Kahraman, M. K. Dosoglu, U. Guvenc, S. Duman and Y. Sonmez, "Optimal scheduling of short-term hydrothermal generation using symbiotic organisms search algorithm," *2016 4th International Istanbul Smart Grid Congress and Fair (ICSG),* Istanbul, 2016, pp. 1-5.

[4] Sandhu Arun, Saini Ombeer and Shalini "Steepest decent method for economic load dispatch using matlab in *proc. Journal of Engineering Computer & applied Science(JECAS).*, vol 4, no 6, june 2015

[5] El-Hawary and I.A. Farhat "Optimization methods applied for solving the short-term hydrothermal coordination problem" Elsevier, 2009.

[6] Damodaran Suresh and Kumar T.K. Sunil "Hydro-Thermal-Wind Generation Scheduling Consideration Economic and Environmental Factors Using Heuristic Algorithms" in energies 2018,11,352, doi:10.3390

[7] O. Saini and A. Sandhu Arun "Differential Evolutionary Search Method for Hydrothermal Scheduling", in *proc. Journal of Engineering Computer & applied Science(JECAS).*, vol 4, no 6, june 2015

[8] H. T. Kahraman, M. K. Dosoglu, U. Guvenc, S. Duman and Y. Sonmez, "Optimal scheduling of short-term hydrothermal generation using symbiotic organisms search algorithm," *2016 4th International Istanbul Smart Grid Congress and Fair (ICSG),* Istanbul, 2016, pp. 1-5.

[9] Sandhu Arun, Saini Ombeer and Shalini "Steepest decent method for economic load dispatch using matlab in *proc. Journal of Engineering Computer & applied Science(JECAS).*, vol 4, no 6, june 2015

[10] El-Hawary and I.A. Farhat "Optimization methods applied for solving the short-term hydrothermal coordination problem" Elsevier, 2009.

[11] E.B.Dahlin and D.W.Shen, "Application of Dynamic Programming to Optimization of Hydro-Steam Power System Operation", *Proc. IEE.*, vol 112, no 12, 1965.

[12] T.G.Werner and J.F.Verstege "An Evolution Strategy For Short- Term Operation Planning Of Hydro Thermal Power Systems", *Proc. IEEE.*, vol 14, no 4, november1999.

[13] M.E.El-Hawary and K.M.Ravindranath "Combining Loss and Cost Objective In Daily Hydro- Thermal Economic Scheduling" *Proc IEEE. Trans. of Power Systems*, vol 6, no 3.1991.

[14] M.Farid Zaghlool and F. C. Troot, "Efficient Methods for Optimal Scheduling Of Fixed Head Hydro Thermal power System", *IEEE Trans of PWRS,* vol 3, no.1, pp.24-30. feb 1988.

[15] J. Wood and B.F. Wollenberg, "Power Generation, Operation and Control ", *John Wiley and sons*, New York, 1984.

[16] Abdul Halim, Abdul Rashid and Khalid Mohamed Nor, "An Efficient Method for Optimal Scheduling of Fixed Head Hydro Thermal Plants", *IEEE Trans of PWRS*, vol 6, no 2, may 1991.

[17] Yong-Hua Song, Malcom R.Lrving "Optimization Techniques for Electrical Power Systems Part 2 Heuristic Optimization Methods", *Power Engineering Journal* june 2001.

[18] N. Sinha, R. Chakrabarti and R.K Chattopadhyay, "Evolutionary Programming Techniques for Economic Load Dispatch", in *IEEE trans. on evolutionary computation*, vol 7, no.1, feb. 2003.

[19] N.Sinha, R.Chakrabarti, and P.K.Chattopadhyay "Improved Fast Evolutionary Program for Economic Load Dispatch with Non-Smooth Cost Curves", *IE (I) journal –EL* november 2004.

[20] Wood, A.J. and Wallenberg, "Power Generation Operation and Control" 2nd ed., *John Wiley & Sons,* New York, USA. B.F. [1996],

[21] Venkatesh, P. and R. Gnanadass, and N. P. Padhy, [2003], “Comparison and Application of Evolutionary Programming Techniques to Combined Economic Emission Dispatch with Line Flow Constraints”, *IEEE Transactions on Power Systems,* vol. 18, pp. 688-697.

[22] Vaishakh, K. and Srinivas, L.R. [2008], “Differential evolution approach for optimal power flow solution, Journal of theoretical and applied Information Technology”, *A.P. (India),* pp. 261-268.

[23] Thitithamrongchai, C. and Eua-arporn, “Self adaptive differential evolution based optimal power flow for units with non-smooth fuel cost functions”, *Journal of electrical systems regular paper Thailand,* pp. 88-99. [2007],

[24] Takriti, S.and Birge, J. R. “Using Integer Programming to Refine Lagrangian – Based Unit Commitment Solutions”, *IEEE Transactions on Power Systems* vol. 15 no. 1 pp. 151-156. [2000],

[25] Rahimullah, B.N.S. and Abdul Rahman T.K. [2006], “Short-term Hydrothermal Generation Scheduling Using Evolutionary Computing Technique” *4th Student Conference on Research and Development Shah Alam, Selangor, Malaysia*, pp. 27-28(SCO).