

Combined Economic Environment Unit Commitment by Using Modified Water Evaporation Optimization Algorithm

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ABSTRACT: Unit commitment which is considered as a large scale, nonlinear, mixed-integer optimization problem plays a very important role in optimal operation of power systems. Solving the UC problem is a complex decision-making process since multiple constraints must be satisfied and a good UC solution method can substantially contribute to annual savings of production cost. In this paper combined economic environment unit commitment by using modified water evaporation optimization algorithm has been proposed. In order to show the feasibility of the proposed algorithm it has been tested with 10 unit system and the results are compared with existing method.

KEYWORDS: Unit commitment, water evaporation optimization, Emission, Generation dispatch

I. INTRODUCTION

The objective of the UC problem is to minimize the total cost of thermal generating units while maintaining sufficient spinning reserve and satisfying the operational constraints of generating units over a given schedule time horizon [1]. Due to the increasing environmental protection the emission is also added to UC problems.

Over the years, extensive research has been conducted on developing efficient UC algorithm that can be mainly grouped as numerical based techniques and Heuristic search based techniques [2-27]. In this paper, combined economic environment unit commitment has been proposed using modified water evaporation optimization algorithm [26] are implemented to handling ramp rates with the aims of achieving the desired solution accuracy and to reduce the cost and emission computational effort in 24 hr time horizon.

II. PROBLEM FORMULATION

Multi-objective UC Model

$$\text{Min } F = \sum_{t=1}^T \sum_{i=1}^N [FC_i(P_i^t) + SC_i^t + SD_i^t + h * E_i(P_i^t)] \quad (2.1)$$

SD_i^t is the Shutdown cost of the i^{th} generator at t hour. F is the combined Fuel cost and Emission with penalty factor h .

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Constraints

1. Power balance constraint

Power balance constraint states that, the generated power should be sufficient enough to meet the power demand and is given by,

$$\sum_{i=1}^N U_i^t P_i^t \quad t = 1, 2, \dots, T \quad (2.2)$$

2. Generated power limits constraint

The generated power of online generating units should lie between its upper and lower limits as given by,

$$P_{i,\min} U_i \leq P_i^t \leq P_{i,\max} U_i^t \quad (2.3)$$

Where $P_{i,\min}$ and $P_{i,\max}$ are the minimum and maximum thermal output power at i_{th} unit.

3. Spinning reserve requirement constraint

Spinning reserve is essential to maintain system reliability; sufficient spinning reserve must be available at every time period. Usually, the spinning reserve is given as some percentage of the total power demand.

$$\sum_{i=1}^N U_i^t P_{i,\max} \geq LD_t + SR_t \quad (2.4)$$

Where SR_t spinning reserve at hour t , LD_t load demand during hour t .

4. Minimum up and down time constraint

This constraint helps to determine shortest time periods during which a unit must be on or down.

$$\begin{aligned} HR_i^{t,on} &\geq MU_i \\ HR_i^{t,off} &\geq MD_i \end{aligned} \quad (2.5)$$

Where $HR_i^{t,on}$ and $HR_i^{t,off}$ are number of hours at unit i is continuously online and offline unit until t_{th} hour. MU_i is the minimum up time hours and MD_i is the minimum down time hours.

5. Ramp rate limit constraint

Because of the physical restrictions on thermal generating units, the rate of generation changes must be limited within certain ranges. The ramp rate limits confine the output movement of a generating unit between adjacent hours.

$$\begin{aligned} P_i^t - P_i^{t-1} &\leq RU_i \\ P_i^{t-1} - P_i^t &\leq RD_i \end{aligned} \quad (2.6)$$

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III. WATER EVAPORATION OPTIMIZATION ALGORITHM

The evaporation of water is very important in biological and environmental science. The water evaporation from bulk surface such as a lake or a river is different from evaporation of water restricted on the surface of solid materials. In this WEO algorithm water molecules are considered as algorithm individuals. Solid surface or substrate with variable wettability is reflected as the search space. Decreasing the surface wettability (substrate changed from hydrophilicity to hydrophobicity) reforms the water aggregation from a monolayer to a sessile droplet.

Such a behavior is consistent with how the layout of individuals changes to each other as the algorithm progresses. And the decreasing wettability of surface can represent the decrease of objective function for a minimizing optimization problem. Evaporation flux rate of the water molecules is considered as the most appropriate measure for updating individuals which its pattern of change is in good agreement with the local and global search ability of the algorithm and make this algorithm have well converged behavior and simple algorithmic structure. The details of the water evaporation optimization algorithm are well presented in (Kaveh and Bakhshpoori, 2016).

In the WEO algorithm, each cycle of the search consists of following three steps (i) Monolayer Evaporation Phase, this phase is considered as the global search ability of the algorithm (ii) Droplet Evaporation Phase, this phase can be considered as the local search ability of the algorithm and (iii) Updating Water Molecules, the updating mechanism of individuals.

(i) Monolayer Evaporation Phase

In the monolayer evaporation phase the objective function of the each individuals Fit_i^t is scaled to the interval [-3.5, -0.5] and represented by the corresponding $E_{sub}(i)^t$ inserted to each individual (substrate energy vector), via the following scaling function.

$$E_{sub}(i)^t = \frac{(E_{max} - E_{min}) \times (Fit_i^t - Min(Fit))}{(Max(Fit) - Min(Fit))} + E_{min} \quad (3.1)$$

Where E_{max} and E_{min} are the maximum and minimum values of E_{sub} respectively. After generating the substrate energy vector, the Monolayer Evaporation Matrix (MEP) is constructed by the following equation.

$$MEP_{ij}^t = \begin{cases} 1 & \text{if } rand_{ij} \leq \exp(E_{sub}(i)^t) \\ 0 & \text{if } rand_{ij} \geq \exp(E_{sub}(i)^t) \end{cases} \quad (3.2)$$

where MEP_{ij}^t is the updating probability for the j^{th} variable of the i^{th} individual or water molecule in the t^{th} iteration of the algorithm. In this way an individual with better objective function is more likely to remain unchanged in the search space.

(ii) Droplet Evaporation Phase

In the droplet evaporation phase, the evaporation flux is calculated by the following equation.

$$J(\theta) = J_o P_o \left(\frac{2}{3} + \frac{\cos^3 \theta}{3} - \cos \theta \right) (1 - \cos \theta) \quad (3.3)$$

where J_o and P_o are constant values. The evaporation flux value is depends upon the contact angle Θ , whenever this angle is greater and as a result will have less evaporation. The contact angle vector is represented the following scaling function.

$$\theta(i)^t = \frac{(\theta_{max} - \theta_{min}) \times (Fit_i^t - Min(Fit))}{(Max(Fit) - Min(Fit))} + \theta_{min} \quad (3.4)$$

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Where the min and max are the minimum and maximum functions. The Θ_{\min} & Θ_{\max} values are chosen between $-50^\circ < \Theta < -20^\circ$ is quite suitable for WEO. After generating contact angle vector $\Theta(i)^t$ the Droplet Probability Matrix (DEP) is constructed by the following equation.

$$DEP_{ij}^t = \begin{cases} 1 & \text{if } rand_{ij} < J(\theta_i^{(t)}) \\ 0 & \text{if } rand_{ij} \geq J(\theta_i^{(t)}) \end{cases} \quad (3.5)$$

where DEP_{ij}^t is the updating probability for the j^{th} variable of the i^{th} individual or water molecule in the t^{th} iteration of the algorithm.

(iii) Updating Water Molecules

In the WEO algorithm the number of algorithm individuals or number of water molecules (nWM) is considered constant in all t^{th} iterations, where t is the number of current iterations. Considering a maximum value for algorithm iterations (t_{\max}) is essential for this algorithm to determine the evaporation phase and for stopping criterion. When a water molecule is evaporated it should be renewed. Updating or evaporation of the current water molecules is made with the aim of improving objective function. The best strategy for regenerating the evaporated water molecules is using the current set of water molecules ($WM^{(t)}$). In this way a random permutation based step size can be considered for possible modification of individual as:

$$S = rand \cdot (WM^{(t)}[permute1(i)(j)] - WM^{(t)}[permute2(i)(j)]) \quad (3.6)$$

where $rand$ is a random number in $[0,1]$ range, $permute1$ and $permute2$ are different rows of permutation functions. i is the number of water molecule, j is the number of dimensions of the problem. The next set of molecules ($WM^{(t+1)}$) is generated by adding this random permutation based step size multiplied by the corresponding updating probability (monolayer evaporation and droplet evaporation probability) and can be stated mathematically as:

$$WM^{(t+1)} = WM^{(t)} + S \times \begin{cases} MEP^{(t)} & t \leq t_{\max} / 2 \\ DEP^{(t)} & t > t_{\max} / 2 \end{cases} \quad (3.7)$$

Each water molecule is compared and replaced by the corresponding renewed molecule based on objective function. It should be noted that random permutation based step size can help in two aspects. In the first phase, water molecules are more far from each other than the second phase. In this way the generated permutation based step size will guarantee global and local capability in each phase.

IV. IMPLEMENTATION OF WEO ALGORITHM TO SOLVE UC PROBLEM

The detailed algorithmic steps for proposed MWEO algorithm to solve an UC problem are presented below.

Step 1: Initialize total no of generating units, generator power limits, ramp rate limits, minimum uptime, minimum downtime, load demand, number of water molecules, maximum number of algorithm iteration (t_{\max}), MEP_{\min} , MEP_{\max} , DEP_{\min} , DEP_{\max} .

Step 2: Randomly initialize all water molecules.

Step 3: Obtain the ON/OFF status of generating units by applying priority list method and compute the objective function given by Eq. (2.1), Eq. (2.4) and Eq. (2.8) for all water molecules.

Step 4: Check whether t (current iteration) $\leq t_{\max}/2$.

Step 5: If step 4 is satisfied, then, water molecules are globally evaporated based on monolayer evaporation probability MEP using Eq. (3.2).

Step 6: For $t > (1+t_{\max}/2)^2$, Based on DEP (Eq. 3.5), in the modified evaporation occurs.

Step 7: Generate random permutation based step size matrix according to Eq. (3.6).

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Step 8: Generate evaporated water molecules by adding the product of step size matrix and evaporation matrix to the current set of molecules $MWM^{(t)}$ by using Eq. (3.7) and update the matrix of water molecules.

Step 9: Compare and update the water molecules.

Step 10: Return the best water molecule (generator outputs corresponding to the minimized value of CF or E).

Step 11: If the number of iteration of the algorithm (t) becomes larger than the maximum number of iterations (t_{max}), the algorithm terminates. Otherwise go to step 3.

V. SIMULATION RESULTS AND DISCUSSION

The application of WEO algorithm is extended to solve the combined UC and Emission problem in 10-unit system with 10% spinning reserve and without considering ramp rate constraint. The WEO algorithm parameters for all test systems are shown in **Table 5.1**. The test system particulars are adopted from [27]. **Table 5.2** presents the 24h committed schedule for the 10-unit case and **Table 5.3** shows the comparison of the proposed method to other popular method. The dispatch of each generating unit shows that the generating capacity limit constraint as well as minimum up and down constraints is satisfied. As comparison shows, the best total cost obtained using MWEO is \$ **1111845.12** and emission of 43732.15 which is lesser than compared to RCGWO [27].

TABLE 5.1 PROBLEM PARAMETERS OF WEO ALGORITHM

Problem Parameters	WEO	MWEO
Water Molecules (nWM)	10	10
Maximum Number of Algorithm Iteration (t_{max})	100	100
MEP_{min}	0.03	0.03
MEP_{max}	0.6	0.5
DEP_{min}	0.6	0.5
DEP_{max}	1	1

TABLE 5.3 COMPARISON RESULTS OF TEST SYSTEM 16

Method	Total Cost \$	Emission, lb
RCGWO	1111956	43732.98
WEO	1111845.35	43732.82
MWEO	1111845.12	43732.15

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TABLE 5.2 TEST RESULTS OF 10-UNIT SYSTEM FOR COMBINED UC AND EMISSION MINIMIZATION

Hour	Generation Schedule, MW										SC, \$	Fuel cost, \$	Emission, lb
	P ₁	P ₂	P ₃	P ₄	P ₅	P ₆	P ₇	P ₈	P ₉	P ₁₀			
1	455	244	0	0	0	0	0	0	0	0	0	13682.07	955.21
2	455	295	0	0	0	0	0	0	0	0	0	14554.39	1055.02
3	455	265	0	130	0	0	0	0	0	0	560	16891.91	1077.33
4	455	235	130	130	0	0	0	0	0	0	550	19261.36	1249.78
5	455	285	130	130	0	0	0	0	0	0	0	20132.39	1343.76
6	455	360	130	130	25	0	0	0	0	0	900	22387.15	1549.72
7	455	410	130	130	25	0	0	0	0	0	0	23262.03	1704.26
8	455	455	130	130	30	0	0	0	0	0	0	24150.13	1863.08
9	455	455	130	130	85	20	25	0	0	0	860	27251.14	2183.28
10	455	455	130	130	140	55	25	10	0	0	60	30057.64	2599.12
11	455	455	130	130	162	73	25	10	10	0	60	31916.25	2945.22
12	455	455	130	130	162	80	25	43	10	10	60	33889.41	3229.37
13	455	455	130	130	140	55	25	10	0	0	0	30057.64	2599.12
14	455	455	130	130	85	20	25	0	0	0	0	27251.14	2183.28
15	455	455	130	130	30	0	0	0	0	0	0	24150.13	1863.08
16	455	310	130	130	25	0	0	0	0	0	0	21513.8	1424.18
17	455	260	130	130	25	0	0	0	0	0	0	20641.92	1318.57
18	455	360	130	130	25	0	0	0	0	0	0	22387.15	1549.72
19	455	455	130	130	30	0	0	0	0	0	0	24150.1	1863.08
20	455	455	130	130	140	55	25	10	0	0	490	30057.64	2599.12
21	455	455	130	130	85	20	25	0	0	0	0	27251.23	2191.28
22	455	315	130	130	25	20	25	0	0	0	0	23627.49	1718.82
23	455	245	0	130	25	20	25	0	0	0	0	19497.97	1346.83
24	455	276	0	0	25	20	25	0	0	0	0	17159.45	1319.1

VI. CONCLUSION

The effective unit commitment saves fuel costs and is a necessary contribution to the operating on/off plans of the generating units. In this paper, a modified water evaporation optimization based solution algorithm for solving the combined economic environment unit Commitment problem is presented. The proposed algorithm uses global search and local search to select the committed units and give the economic schedule for each specific hour. This new algorithm produces better results than the existing methods in addition to satisfaction of the system constraints. From the results, it is clear that the proposed method provides the quality solution with low cost and has a potential for on-line implementation.

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REFERENCES

1. Wood A. J, and Wollenberg B. F, (1996), Power generation, operation and control, Second Edition, *John Wiley and Sons*, New York
2. Virmani S, Adrian E. C, and Imhif, K, (1989), Implementation of Lagrangian based unit commitment problem, *IEEE Transaction on Power System*, Vol. 4, No. 4, pp. 1373–1380.
3. Ongsakul W, and Petcharak N, (2004), Unit commitment by enhanced adaptive Lagrangian relaxation, *IEEE Transaction on Power System*, Vol. 19, No. 1, pp. 620–628.
4. Chandram K, Subrahmanam N, and Sydulu M, (2011), Unit commitment by improved pre-prepared power demand table and Muller method, *Electric Power and Energy System*, Vol. 33, pp. 106–114.
5. Hobbs W. J, Hermon G, Warner S, and G. B. Sheble, (1988), An enhanced dynamic programming approach for unit commitment, *IEEE Transaction on Power System*, Vol. 3, No. 3, pp. 1201-1205.
6. Marian Marcoveccio G, Augusto Novals Q, and Ignacio Grossmann E, (2014), Deterministic optimization of the thermal unit commitment problem: a branch and cut search, *Computers and Chemical Engineering*, Vol. 67, pp. 53–68.
7. Han D, Jian J, and Yang L, (2014), Outer approximation and outer-inner approximation approaches for unit commitment problem, *IEEE Transaction on Power System*, Vol. 29, No. 2, pp. 505–513.
8. Roy P. K, (2013), Solution to the unit commitment problem using gravitational search algorithm, *Electrical Power and Energy Systems*, Vol. 53, pp. 85–94.
9. Burns R. M, and Gibson C. A, (1975), Optimization of priority lists for a unit commitment program, *IEEE PES proceedings*, Vol. 75, pp. 453-461.
10. Patra S, Goswami S. K, and Goswami B, (2008), Differential evolution algorithm for solving unit commitment with ramp constraints, *Electrical Power and Components System*, Vol. 36, No. 8, pp. 771–787.
11. Kazarlis S. A, Bakirtzis A. G, and Petridis V, (1996), A genetic algorithm solution to the unit commitment problem, *IEEE Transaction on Power System*, Vol. 11, No. 1, pp. 83–92.
12. Juste K. A, Kita H, and Tanaka E, (1999), An evolutionary programming solution to the unit commitment problem, *IEEE Transaction on Power System*, Vol. 14, pp. 1452–1459.
13. Zhuang F, and Galiana F. D, (1990), Unit commitment by simulated annealing, *IEEE Transaction on Power System*, Vol. 5, pp. 311–317.
14. Ebrahimi J, Hosseini S. H, and Gevorg B, (2011), Unit commitment problem solution using shuffled frog leaping algorithm, *IEEE Transaction on Power System*, Vol. 26, No. 2, pp. 573–581.
15. Roy P. K, (2013), Solution to the unit commitment problem using gravitational search algorithm, *Electrical Power and Energy Systems*, Vol. 53, pp. 85–94.
16. Roy P. K, and Sarkar R, (2014), Solution of unit commitment problem using quasi-oppositional teaching learning based algorithm, *Electrical Power and Energy System*, pp. 96–106.
17. Eslamian M, Hosseini S, and Vahidi B, (2009), Bacterial foraging based solution to the unit commitment problem, *IEEE Transaction on Power System*, Vol. 24, No. 3, pp. 1478–1488.
18. Saber A. Y, Senjyu T, and Miyagi T, (2006), Fuzzy Unit commitment scheduling using absolute stochastic simulated annealing, *IEEE Transaction on Power System*, Vol. 21, No. 2, pp. 955–964.
19. Damousis I. G, Bakirtzis A. G, and Dokopoulos P. S, (2004), A solution to the unit commitment problem using integer coded genetic algorithm, *IEEE Transaction on Power System*, pp. 1165–1172.
20. Zhao B, Guo C. X, and Bai B. R, (2006), An improved particle swarm optimization algorithm for unit commitment, *Electric Power and Energy System*, Vol. 28, No. 7, pp. 482–490.
21. Cheng C. P, Liu C. W, and Liu G. C, (2000), Unit commitment by Lagrangian relaxation and genetic algorithms, *IEEE Transaction on Power System*, Vol. 15, No. 2, pp. 707–714.
22. Kumar N, Panigrahi B. K, Bhim Singh, (2016), A solution to the ramp rate and prohibited operating zone constrained unit commitment by GHS-JGT evolutionary algorithm, *Electrical power and Energy system*, Vol. 81, pp. 193-203.
23. Lau T. W, Chung C. Y, and Wong K. P, (2009), Quantum inspired evolutionary algorithm approach for unit commitment, *IEEE Transaction on Power System*, Vol. 24, No. 3, pp. 1503–1512.
24. Jeong Y. W, Park J. B, and Jang S. H, (2010), A new quantum inspired binary PSO: application to unit commitment problems for power systems, *IEEE Transaction on Power System*, Vol. 25, No. 3, pp. 1486–1495.
25. Quan R, Jian J, and Yang L, (2015), An improved priority list and neighborhood search method for unit commitment, *Electric Power and Energy System*, Vol. 67, pp. 278–285.
26. Kaveh A, and Bakhshpoori T, (2016), Water Evaporation Optimization: A novel physically inspired optimization algorithm, *Computer and Structures*, Vol. 167, pp. 69–85.
27. Rameshkumar J, Ganesan S, Abirami M, and Subramanian S, (2015), cost, emission and reserve pondered pre dispatch of thermal generating units coordinated with real coded grey wolf optimization, *IET generation Transmission and Distribution*, Vol. 45, pp. 1-14.