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SOLVING UNIT COMMITMENT PROBLEM IN MICROGRIDS BY HARMONY SEARCH ALGORITHM IN COMPARISON WITH GENETIC ALGORITHM AND IMPROVED GENETIC ALGORITHM

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Abstract- This article presents a Harmony Search Algorithm to solve the unit commitment (UC) problem. A micro grid includes various types of smart distributed generators, renewable generators, storage devices and controllable load. A micro grid must satisfy its local needs and should be under the hierarchical control of management system. Due to this combination of conventional and renewable sources, the unit commitment becomes more crucial and more complicated in the management of a micro grid. In this paper, a harmony algorithm based method is proposed for unit commitment in a micro grid. The objective is to minimize micro grid's operational cost when it is isolated and maximize its revenue when it is connected to networks.

Keywords: Harmony Search, Unit Commitment, Micro Grid, Meta-Heuristic Algorithm.

I. INTRODUCTION

In the past decade, the traditional energy network has been facing a gradual evolution from the centralized network to a distributed and localized network, where smart grids and micro grids have surfaced and are playing a key role in the countrywide main network. A micro grid is a localized low voltage distributed network, which is capable of managing its own operation by an intelligent control system. It can be operate as a part of the main grid, known as interconnected mode, or as an isolated system separated from the main grid, known as island mode.

In addition, a micro grid possesses various generation sources including renewable sources, which can also supply the main grid. Therefore, to the main grid, a micro grid can be treated as a single controlled load entity within the power system or as an intelligent source supporting the main grid. Because of its localized smart control system and renewable sources, a micro grid is able to provide consumers a high quality and reliable energy with lower price and less carbon emissions [1-3]. Generation scheduling is one main function of the micro grid's intelligent control system, which is to decide the Unit Commitment and the Economic Dispatch.

The Unit Commitment (UC) is generally defined as a scheduling of power generation over a daily to weekly period to achieve optimization objectives while respecting various constraints from individual units and the overall grid. The UC is one of the most challenging problems in power system optimization. Usually it has to work out hundreds of continuous and discrete variables from one to several quadratic objective functions and numerous linear and quadratic constraints within a very limited time window. And the variety in unit characteristics will add the complexities and challenges of solving the UC [4, 5].

The micro grid normally consists of classical thermal generators and several renewable sources like wind turbines (WTs) and solar panels (photovoltaic, or PVs), and intelligent storage battery banks as well. The characteristics of the renewable generators and intelligent storage devices are very different from the conventional generators, which would increase the burden of solving the UC. Moreover, the maximum output of renewable sources cannot be controlled and they normally would not follow the normal trend of load demand. In addition, the operation and performance of the main grid would affect the UC decision in a micro grid in interconnected mode, as it has to decide whether to sell energy to the main grid or to buy energy from the main grid [1-5].

In this paper, an application of Harmony Search is proposed to solve unit commitment problem [4, 5]. The objective used herein is to minimize the total production cost by optimizing the control variables within their limits. Therefore, no violation on other quantities (e.g. MVA flow of transmission lines, load bus voltage magnitude, generator MVAR) occurs in normal system operating conditions.

A simulated micro grid model is selected for testing the new algorithm and the results show a steady improvement in solving UC for micro grids compared with those of the conventional solutions.

II. UNIT COMMITMENT

The UC is an optimization process to decide the running status and output power of multiple generation sources. The optimization is subject to several global constraints such as power balance, spinning reserve and several individual constraints such as unit output limits, maximum output ramp rates and minimum up/down hours [5]. In this paper it is assumed that the schedule periods are 24 hours and divide into 24 sub-intervals. The total cost is the sum of the running cost and startup cost for all units over the whole scheduling periods. In addition. The shutdown cost is usually given a constant value for each unit. The shutdown cost has been taken equal to 0 for each unit. In micro grids, the objective can be minimizing the total generation cost, denoted by C_{run}, while the micro grid is in island mode, as follows [14]:

$$\text{Min } C_{run} = \sum_t \sum_n \sum_k (\alpha_{k,n} P_{t,n,k} + \beta_{k,n} V_{t,n,k}) + \\ + \sum_t \sum_n (S_{t,n} CS_n) \quad (1)$$

where t, n and k represent time, unit index and segment index of the cost function respectively, $P_{t,n,k}$ and $V_{t,n,k}$ represent power output and on/off status of unit n at time t, and at segment k. $\alpha_{k,n}$ and $\beta_{k,n}$ represent the cost coefficients of segment k of unit n, $S_{t,n}$ indicates the startup status of unit n at time t, and CS_n represents the startup cost of unit n.

When the micro grid operates in interconnected mode, it is able to buy electricity from the main grid to cover its shortage and sell its electricity back to the main grid. In this operation mode, the objective of UC is to maximize total revenue of micro grid, denoted by Rev. The revenue based objective function is presented as follows [14]:

$$\max\ Rev = (w_s E_s) - (w_b E_b) - C_{run} \quad (2)$$

where, C_{run} denotes the total unit running cost on Equation (1), E_b and E_s denote the total energy bought from the main grid and sold to the main grid, and ω_b and ω_s are the respective contractual electricity price. Many constraints can be applied on the unit commitment problem. Each individual power system may cause different rules and change the scheduling of the units, depends on the output generations curves and load characteristics. In this paper, the assumed constraints are:

1- Demand: the total power output must satisfy the demand of that time:

$$\sum_n \sum_k P_{t,n,k} \geq D_t \quad (3)$$

where, D_t is the total power demand at time t.

2- Spinning reserve: the total spinning reserve must be larger than 10% of demand, within which the 2.5% comes from the online (running) units,

$$\sum_t \sum_n \left((U_n V_{t,n}) - P_{t,n} \right) \geq 2.5\% D_t \quad (4)$$

And the rest 7.5% comes from the offline (resting) units.

$$\sum_t \sum_n \left(U_n (1 - V_{t,n}) \right) \geq 7.5\% D_t \quad (5)$$

where, U_n is the maximum output of unit n. Spinning reserve describes the total amount of generation available from all units synchronized on the system, minus the present load supplied and losses being considered. Spinning reserve must be presented in such a way that the loss of one or more units does not cause too far a drop in the system frequency.

3- Unit min/max output:

$$L_n V_{t,n} \leq P_{t,n} \leq U_n V_{t,n} \quad (6)$$

where, L_n and U_n are the lower limits and the upper limits of unit n.

4- Unit max ramp up/down rate:

$$-MRU_n \leq P_{t,n} - P_{t+1,n} \leq MRD_n \quad (7)$$

where, MRU_n and MRD_n denote the maximum power ramp up amount and maximum ramp down amount of unit n within the time interval.

III. UNIT COMMITMENT IN MICROGRIDS

The unit commitment involves the selection of units that will supply the predicted load of the system at minimum cost over a required period of time as well as providing a specified amount of the operating reserve, known as the spinning reserve. Unit Commitment problem in micro grids is very different with the one in classical power system. Besides the conventional dispatch able sources with relatively small capacity, the micro grid normally possesses several renewable sources such as wind turbines (WTs) and solar panels (photo-voltaic, or PVs), which have very different characteristics from those of the conventional thermal or hydro generators [1-3]. The models of these devices are shown as follows.

A. Wind Turbine

The power output of a wind turbine (WT) is most related to the ambient wind speed V_w, which can be presented as [14]:

$$P_{wt} = \begin{cases} 0 & V_w < V_{in} \\ aV_w^2 + bV_w + c & V_{in} \leq V_w < V_{rate} \\ P_{rate} & V_{rate} \leq V_w < V_{out} \\ 0 & V_{out} \leq V_w \end{cases} \quad (8)$$

where, V_{in} and V_{out} denote the turbine's cut-in and cutout wind speed for safety reasons. P_{rate} and V_{rate} denote the rated power and corresponding wind speed. a, b and c are coefficients which present the turbine characteristic curves and are provided by manufacturer.

B. Solar Panel

The solar panel converts the sun energy into electricity. Its power output depends on the sun insolation G and is also affected by the ambient temperature. For convenience, we assume a fixed normal operating temperature. Therefore, output can be presented as [14]:

$$P_{pv} = \begin{cases} 0 & G < G_{in} \\ \mu G & G_{in} \leq G < G_{rate} \\ P_{rate} & G_{rate} \leq G \end{cases} \quad (9)$$

where, G_{in} and G_{rate} denotes the minimum and rated insolation and μ is a coefficient of the solar panel. Renewable sources like WTs and PVs are all expected to work at maximum output condition at all time. Therefore, their outputs only depend on the ambient environment and are not controllable. We have to predict their time-based output curve in order to include them into the UC calculation for micro grids.

The inclusion of renewable sources and a battery bank and the interconnection with the main grid make the UC of micro grid much more complex than the one for the conventional system. There are solutions published in recent years, which are based on Lagrangian Relaxation (LR), Dynamic Programming (DP), Genetic Algorithm (GA), and Harmony Search (HS).

IV. PURPOSED ALGORITHM

The harmony search (HS), which was proposed by Zong Woo Geem et al. in 2001 [6], is a music-inspired evolutionary algorithm, mimicking the improvisation process of music players. In jazz music, the different musicians try to adjust their pitches, such that the overall harmonies are optimized due to aesthetic objectives. At the beginning, they start with some harmonies and then they attempt to achieve better harmonies by improvisation. This analogy can be used to derive search heuristics, which can be used to optimize a given objective function instead of harmonies. Here the musicians are identified with the decision variables and harmonies correspond to solutions.

The HS is presenting several advantages with respect to traditional optimization techniques such as the following [16]: 1- HS is simple in concept, 2- HS needs only few parameters, and 3- HS is easy in implementation, with theoretical background of stochastic derivative. These features increase the flexibility of the HS algorithm and produce better solutions. The algorithm was originally developed for discrete optimization, later expanded for continuous optimization.

HS has been applied to a wide spectrum of optimization problems in several disciplines such as the design of water pipeline networks [7], the so called Switch Location Problem (SLP) [8], multicast routing [9], vehicle routing [10], scheduling of multiple dam system [11], spectrum channel allocation in cognitive radio networks [12], or even as an efficient means to solve the Sudoku puzzle [13]. The meta-heuristic HS search process consists of five steps [16].

A. Initializing Problem

In step 1, the discrete optimization problem is specified as follows:

$$\min \; f(x) \quad \text{s.t.} \quad x_i \in \boldsymbol{X}_i \,,\; i = 1, 2, \cdots, N \tag{10}$$

B. Initializing Harmony Memory

In step 2, harmony memory (HM) matrix shown in Equation (10) is randomly filled with as many solution vectors as harmony memory size (HMS).

C. Improvising New Harmony

In step 3, a New Harmony vector $x' = (x_1', x_2', \ldots, x_N')$, is improvised. There are three rules to choose one value for each decision variable memory consideration, pitch adjustment, and random selection. In memory consideration, the value of the first decision variable x_1' can be chosen from any discrete values in the specified HM range $\left\{x_1^1, x_1^2, \ldots, x_1^{HMS-1} . x_1^{HMS}\right\}$ with the probability of HMCR, which varies between 0 and 1.

Values of the other decision variables x_i' can be chosen in the same manner. However, there is still a chance where the new value can be randomly chosen from a set of entire possible values with the probability of (1-HMCR). Any component of the New Harmony vector, whose value was chosen from the HM, is then examined to determine whether it should be pitch-adjusted. This operation uses pitch adjusting parameter (PAR) that sets the rate of pitch-adjustment decision as follows.

If the pitch adjustment decision for x_i' is Yes, x_i' is replaced with (the *k*th element of $\boldsymbol{X}_i$) and the pitch adjusted value of $x_i(k)$ becomes: The algorithm chooses -1 or 1 for neighboring index *m* with the same probability.

D. Updating Harmony Memory

If the New Harmony $x' = \left(x_1', x_2', \ldots, x_N'\right)$ is better than the worst harmony in the HM in terms of objective function value, the New Harmony is included in the HM and the existing worst harmony is excluded from the HM.

E. Checking Termination Criterion

In step 5, the computation is terminated when the termination criterion is satisfied. Otherwise, steps 3 and 4 are repeated.

V. SIMULATION TEST

A simulated micro grid model is set up in this section to test the proposed UC algorithm. The simulated micro grid consists of a wind turbine (WT) and a solar panel (PV), storage devices, and four dispatchable conventional generation sources (denoted by S1-S4). The operational costs of all sources are to be calculated Equation (1), and the coefficients and start-up costs are listed in Table 1.

Table 1. Parameter of generation sources

	S1	S2	S3	S4	WT	PV
α (\$/kWh)	0.018	0.02	0.015	0.021	0.001	0.001
β (\$/h)	0.15	0.12	0.09	0.12	0	0
CS (\$)	3	3.5	2.8	2.5	0.001	0.001
$P_{\min}$	5	3	2	4	0	0
$P_{\max}$	8	7	6	8	5	1.05

To include the renewable sources into the UC calculation, their time-based (e.g. next 24-hour) power outputs are to be predicted based on weather forecasting. In this experiment, the 24-hour predicted output of WT and PV is shown in Figure 1 [14].

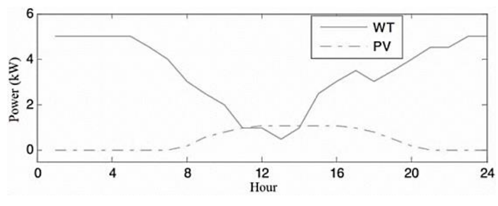

Figure 1. Predicted output of WT and PV

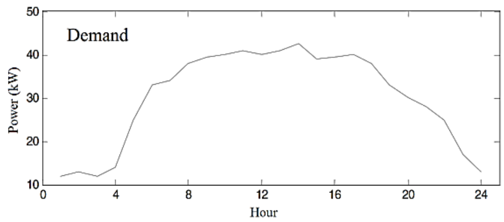

Figure 2. The simulated 24h load demand

The UC of this simulated micro grid model is solved by the conventional GA algorithm, the improved GA algorithm, and the purposed HS algorithm. Table 2 shows the unit on/off status, purchase and sale of electricity in the next 24 hours is shown in this table. As it can be observed from Table 2, because of using storage devices with solar panels (PV), the status of PV can be considered "ON" even at dark hours of a day.

Figure 2 shows the simulated load demand [14]. "Sell electricity" operations always happen in non-peak hours to store electricity and make profit by selling electricity to upstream networks, while the "buy electricity" operations always happen in peak hours to cover the demand in the micro grid. Table 3 shows the difference of calculation time in three purposed method [14] in the unit commitment problems. An HS algorithm is coded in Matlab Editor and the test is conducted in a workstation with 2.6 GHz Quad CPU and 3.25 GB Ram memory.

Table 2. Simulation results, ON/OFF status

H	S1	S2	S3	S4	WT	PV	Buy	Sell
1	1	1	1	1	1	1	0	1
2	0	1	1	0	1	1	0	1
3	1	1	1	0	1	1	0	1
4	1	1	1	1	1	1	0	1
5	1	0	1	1	1	1	0	1
6	1	1	0	0	1	1	1	0
7	0	1	1	0	1	1	1	0
8	0	1	1	0	1	0	1	0
9	1	1	1	0	0	1	1	0
10	1	0	0	0	1	1	1	0
11	1	1	1	1	1	1	1	0
12	0	1	1	0	1	1	1	0
13	0	1	1	1	1	1	1	0
14	0	0	1	1	1	1	1	0
15	1	1	0	1	1	0	1	0
16	0	1	1	1	1	0	1	0
17	1	0	1	1	1	1	1	0
18	1	1	1	1	1	0	1	0
19	0	1	0	1	1	0	1	0
20	0	0	1	1	1	0	1	0
21	0	1	0	1	1	1	1	0
22	1	1	1	0	1	0	1	0
23	1	0	1	1	1	1	0	1
24	1	0	1	1	1	0	1	0

Table 3. Comparison of methods

	GA	Improved GA	HS
Objective value	-38.2 $	-38.5 $	-39.16 $
Iteration	113250	2974	1000
Time	50 min 11 sec	2 min 43 sec	1.53 sec

VI. CONCLUSIONS

The UC problem is one of the most complex optimization problems in power generation and transmission system. Due to the large size of objective functions and constraints, some algorithms will take extremely long time to converge, which is not acceptable for the real world practice. In micro grids, the UC problem becomes more challenging because of renewable sources, and the ability of purchase and sale of electricity, which will definitely prolong the UC calculations. For real world practice, it is worthy to put in efforts to experiment the faster approaches.

In this paper, the proposed HS algorithm is efficiently implemented to solve the UC problem. The test in a simulated system shows that the proposed algorithm has an advantage in convergence time and approximately in economic compared with the conventional and improved GA. Numerical results demonstrate the effectiveness of the HS algorithm in searching global or near global optimal solution to the UC problems.

NOMENCLATURES

$P_{t,n,k}$: Power output of segment k of unit n at time t
$V_{t,n,k}$: ON/OFF Status of segment k of unit n at time t
$\alpha_{k,n}, \beta_{k,n}$: Cost coefficients of segment k of unit n
$S_{t,n}$: Start-up status of unit n at time t
CS_n: Start-up cost of unit n
C_{run}: Total unit running cost
E_b: Total energy bought from the main grid
ω_b : Contractual electricity price for buying
E_a: Total energy sold to the main grid
ω_s : Contractual electricity price for selling
D_t: Total power demand at time t
U_n: Maximum output of unit n
L_n: Minimum output of unit n
MRU_n: Maximum power ramp up amount of unit n within the time interval
MRD_n: Maximum ramp down amount of unit n within the time interval
V_{in}: Turbine's cut-in wind speed
V_{out}: Turbine's cut-out wind speed
P_{rate}: The rated power
V_{rate}: Corresponding wind speed
V_w: Wind Speed
a, b, c: Coefficients which present the turbine characteristic curves
G: Sun insolation
G_{in}: Minimum sun insolation
G_{rate}: Rated sun insolation
μ : Coefficient of the solar panel

REFERENCES

[1] C.A. Hernandez Aramburo, T.C. Green, N. Mugniot, "Fuel Consumption Minimization of a Microgrid", IEEE Transactions on Industrial Applications, Vol. 41, No. 3, pp. 673-681, 2005.
[2] T. Logenthiran, D. Srinivasan, "Short Term Generation Scheduling of a Microgrid", IEEE Conference of TENCON, 2009.

[3] M.Y. Nguyen, Y.T. Yoon, N.H. Choi, "Dynamic Programming Formulation of Microgrid Operation with Heat and Electricity Constraints", IEEE Conference of Transmission & Distribution Asia, 2009.
[4] N.P. Padhy, "Unit Commitment - A Bibliographical Survey", IEEE Transactions on Power Systems, Vol. 19, No. 2, pp. 1196-1205, 2004.
[5] B. Venkatesh, T. Jamtsho, H.B. Gooi, "Unit Commitment - A Fuzzy Mixed Integer Linear Programming Solution", IET Journal of Generation, Transmission and Distribution, Vol. 1, No. 5, pp. 836-846, 2007.
[6] Z.W. Geem, J.H. Kim, G.V. Loganathan, "A New Heuristic Optimization Algorithm - Harmony Search", Simulation, Vol. 76, No. 2, pp. 60-68, 2001.
[7] Z.W. Geem, "Optimal Cost Design of Water Distribution Networks Using Harmony Search", Engineering Optimization, Vol. 38, No. 3, pp. 259-277, 2006.
[8] S. Gil Lopez, J. Del Ser, I. Landa, L. Garcia Padrones, S. Salcedo Sanz, J.A. Portilla Figueras, "On the Application of a Novel Grouping Harmony Search Algorithm to the Switch Location Problem", 2nd International Conference on Mobile Lightweight Wireless Systems, Barcelona, Spain, May 2010.
[9] R. Forsati, A.T. Haghighat, M. Mahdavi, "Harmony Search Based Algorithms for Bandwidth Delay Constrained Least-Cost Multicast Routing", Computer Communications, Vol. 31, No. 10, pp. 2505-2519, 2008.
[10] Z.W. Geem, K.S. Lee, Y. Park, "Application of Harmony Search to Vehicle Routing", American Journal of Applied Sciences, Vol. 2, No. 12, pp. 1552-1557, 2005.
[11] Z.W. Geem, "Optimal Scheduling of Multiple Dam System Using Harmony Search Algorithm", Springer Lecture Notes on Computer Science, Vol. 4507, pp. 316-323, 2007.
[12] J. Del Ser, M. Matinmikko, S. Gil Lopez, M. Mustonen, "A Novel Harmony Search based Spectrum Allocation Technique for Cognitive Radio Networks", IEEE International Symposium on Wireless Communication Systems, September 2010.
[13] Z.W. Geem, "Harmony Search Algorithm for Solving Sudoku", Springer Lecture Notes on Computer Science, Vol. 4692, pp. 371-378, 2008.
[14] H.Z. Liang, H.B. Gooi "Unit Commitment in Micro Grids by Improved Genetic Algorithm", pp. 842-847, 2010.
[15] A. Safari, H.A. Shayanfar, R. Jahani, "Optimal Unit Commitment of Power System Using Fast Messy Genetic Algorithm", International Journal on Technical and Physical Problems of Engineering (IJTPE), Iss. 3, Vol. 2, No. 2, pp. 22-27, June 2010.
[16] Z.W. Geem, K.S. Lee, C.L. Tseng, "Harmony Search for Structural Design", Conference on Genetic and Evolutionary Computation, pp. 651-652, 2005.
[17] K.S. Lee, Z.W. Geem, "A New Meta-Heuristic Algorithm for Continues Engineering Optimization - Harmony Search Theory and Practice", Comput. Meth. Appl. Mech. Eng., Vol. 194, pp. 3902-3933, 2004.
[18] H.A. Shayanfar, E.S. Barazandeh, S.J. Seyed Shenava, A. Ghasemi, O. Abedinia, "Solving Optimal Unit Commitment by Improved Honey Bee Mating Optimization", International Journal on Technical and Physical Problems of Engineering (IJTPE), Iss. 13, Vol. 4, No. 4, pp. 38-45, December 2012.

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