Generation Scheduling of Thermal Units Integrated with Wind-Battery System Using a Fuzzy Modified Differential Evolution Approach

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***Abstract*—This paper presents a fuzzy methodology for solving thermal unit commitment problem integrated with wind power system using differential evolution approach. Wind power facility is coupled with an equivalent battery to compensate with frequency and voltage fluctuations. Wind energy system is integrated with the system due to lower electric cost and positive effect on the environment. But due to the uncertainty of wind speed and hence wind power generation and load forecasting, a crisp optimization method may fail short providing the effective solution. Therefore, to solve the problem effectively, this model handles such imprecision by fuzzyfication. Then the unit commitment problem is solved by using a modified differential evolution approach. Trivial differential evolution method is modified to work with thermal scheduling problem which is a mixed-integer problem requiring discrete optimization. Several simulations are presented in order to demonstrate the effectiveness of the proposed method.**

***Index Terms*—Unit Commitment, Wind Power, Fuzzy System, Differential Evolution.**

I. INTRODUCTION

OPTIMAL scheduling of generating units plays a prominent role in cost and profit concerns of power economics. A good schedule points out which units to operate and the amount to generate at each online unit in order to achieve the minimum production cost. This generation scheduling problem is commonly known as unit commitment problem. Thermal unit commitment in a power system requires determining the on/off schedules of thermal units over a particular schedule horizon. Apart from determining the on/off states, this problem also involves deciding the hourly thermal output power (known as economic load dispatch; ELD) as well as satisfying a large set of system and operational constraints while keeping the fuel cost as minimum as possible. A good number of discrete (on/off status of thermal units) and continuous (hourly thermal power output) variables are required to be solved in unit commitment (UC) problem. These attributes define the higher dimensionality, non-linearity nature of UC problem and hence introduce it as one of the most complex combinatorial optimization problems in power system economics [1]. A bibliographical survey on UC discloses that a good amount of numerical optimization techniques and meta-heuristic methods $[2-9]$ have been applied to achieve efficient and near optimal solutions for UC problem. Thermal unit generation requires extensive use of burning fossil fuels which is expensive since the price of fuel is increasing. Moreover, fuel burning produces emission of gases such as CO_2, SO_2 which have negative effect on environment. Therefore, concerns regarding alternative sources of energy and power which are cheaper in price, stamp environmental friendly feature are growing. Renewable energy sources are therefore, receiving significant importance in recent researches and studies due to lower electricity generation price and positive effect on environment. However due to their highly unpredictable nature and fluctuating power production, these sources are not yet in the position of fully replace the thermal generation. Among these energy sources, wind power is widely investigated and the integration with thermal power systems has been studied.

However, wind power is highly fluctuating due to its cubic relationship with wind speed. Therefore a crisp method for determining the generation schedule of thermal units coupled with wind power system may not be effective. Moreover, the forecasted power demand is also more likely to be erroneous since the consumer demand varies abruptly with the weather factors. Taking account of such scenarios fuzzy methodologies have been successfully applied to stand-alone thermal power system as well as with power system with renewable sources.

Differential evolution approach was introduced by Kenneth Price primarily dedicated to solve continuous problem. It has also been successfully applied on power system economics problems such as economic load dispatch [2]. However its application as a discrete optimizer especially in generation schedule v.i.z. unit commitment is still unexplored. This paper proposes a short term thermal unit commitment strategy integrated with wind power system by comprising a modified differential evolution approach. In this model, a battery system is incorporated with wind system to supply power in case of peak load shaving and also to facilitate the load levelling. Since UC depends on the forecasted load demand and forecasted wind speed, conventional methods contain errors determining the UC schedule. Moreover deterministic injection of wind power is highly likely to be erroneous

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due to the fluctuating nature of wind speed. Therefore the proposed method applies fuzzy formulations considering load forecasting and consequently spinning reserve and total fuel cost along with wind speed. Finally the whole process is fed into an differential evolution based algorithm to find the global minimum production cost. The simulations show the effectiveness of the proposed method.

II. FORMULATION

This section details about the formulation of UC problem including the notations used throughout the paper. The considered constraints also presented here.

A. Notation

N	number of generating units.
T	total scheduling period.
$P_i(t)$	generation of unit i at hour t.
SC_i	Start-up cost of i-th unit.
$P_{loss}(t)$	network loss at hour t.
$I_i(t)$	off/on [0,1] status of unit i at hour t.
$D_k(t)$	load in bus k at hour t.
$P_w(t)$	power output from wind energy system at hour t.
$P_b(t)$	power output from the battery system at hour t.
UR_i/DR_i	Ramp up/down limits for i-th unit.
$\bar{F}_l$	real power flow limit on transmission line l.
Γ_l	the matrix relating generator output to power flow on transmission line l.
$D_k(t)$	load in bus k at hour t.
T_i^{on}	minimum up time of unit i.
T_i^{off}	minimum down time of unit i.
X_i^{on}	duration of unit i being continuously on.
X_i^{off}	duration of unit i being continuously off.
μ_{LD}	fuzzy membership for load demand.
μ_{SR}	fuzzy membership for spinning reserve.
μ_{WS}	fuzzy membership for wind speed.
μ_{TC}	fuzzy membership for production cost.

B. Objective Function

The objective function of thermal unit commitment problem is to minimize the total production cost (TC) while satisfying several constraints.

$$\begin{aligned} Min\ TC = \sum_{i=1}^{N}\sum_{t=1}^{T}[F(P_i(t)) + \\ SC_i(1 - I_i(t-1))]I_i(t) \end{aligned} \tag{1}$$

where $F(P_i) = a + bP_i + cP_i^2$, is the quadratic fuel cost function; a, b and c are the fuel coefficients.

C. Constraints

UC problem requires handling a number of constraints while minimizing the production cost. The constraints considered in this study are described in following sections.

1) System power balance: The total power output from the thermal generators and wind-battery should exactly satisfy the load demand for that hour and corresponding network loss. Thus the system power balance equation for hour t can be expressed as

$$\sum_{i=1}^{N} P_i(t) + P_w(t) + P_b(t) = D(t) + P_{loss}(t). \tag{2}$$

In this study, the network loss is calculated as approximate and simple functions of units' output using a coefficient matrix.

2) System spinning reserve requirements: In order to ensure reliability, the system spinning reserve requirement must be satisfied. Spinning reserve is typically defined as the base component and additional fraction of the load demand. Since the amount of reserve is highly system and country oriented, for the sake of generalization this study uses an approximation of reserve amount (10% of the load demand). Hence the spinning reserve requirement is expressed by following equation

$$\sum_{i=1}^{N} I_i(t)P_i^{max}(t) \geq 1.1D(t) + P_{loss}(t). \tag{3}$$

3) Generation limit: The power output of each generating unit must be limited within a specified range.

$$P_i^{min} \leq P_i(t) \leq P_i^{max}. \tag{4}$$

4) Unit minimum up/down time: Due to operational limitations, once a unit is committed/decommitted it should be kept stable for a minimum period of time before a transition. This leads to following equation

$$\left.\begin{array}{lcl} T_i^{\text{on}} & \leq & X_i^{\text{on}}(t) \\ T_i^{\text{off}} & \leq & X_i^{\text{off}}(t) \end{array}\right\}. \tag{5}$$

5) Ramp constraint: For each unit in each hour output is limited by the following ramp constraint:

$$P_i^{min}(t) \leq P_i(t) \leq P_i^{max}(t). \tag{6}$$

where $P_i^{min}(t) = max(P_i(t-1) - DR_i, P_i^{min})$ and $P_i^{max}(t) = min(P_i(t-1) + UR_i, P_i^{max})$.

6) Transmission line constraint: To provide the security and reliability of the system, transmission line flow constraint is incorporated in this model. The following equation is thus defined

$$-\bar{F}_l \leq F_l(t) = \sum_{i=1}^{N} \Gamma_{l,i}P_i(t) - \sum_{k=1}^{K} \Gamma_{l,k}D_k(t) \leq \bar{F}_l. \tag{7}$$

7) Power output from wind energy system: The wind power generation is calculated from a conditional quadratic function of forecasted wind speed and several wind turbine related speed such as cut in/out and rated speed. The following equations are used for the calculation

$$P_w(t) = \begin{cases} 0 & : v_w(t) \leq v_1\ or \\ & \quad v_w(t) \geq v_3 \\ \psi(v_w(t)) & : v_1 \leq v_w(t) \leq v_2 \\ P_{wn} & : v_2 \leq v_w(t) \leq v_3 \end{cases} \tag{8}$$

where $v_w(t)$ is forecasted wind speed at hour t; v_1, v_2 and v_3 are cut in, rated and cut out wind turbine speed; $\psi(v_w(t))$

is wind to energy conversion function and P_{wn} is equivalent rated power output for wind power generation. $\psi(v_w(t))$ is approximated as a quadratic equation by assuming $P_w(t)$ varies as $v_w(t)$ between cut-in and rated wind speed. $\psi(v_w(t))$ is expressed by the following equation

$$\psi(v_w(t)) = j_0 + j_1 v_w(t) \tag{9}$$

$$j_0 = \frac{P_{wn} v_1^2}{v_1^2 - v_2^2}, j_1 = \frac{P_{wn}}{v_2^2 - v_1^2}.$$

8) Fuel constraint: The fuel cost and start-up cost must be limited for a specified range for each hour in time period. The equation is expressed as

$$FL_i \leq \sum_{t=1}^{T} [I_i(t) F_i(P_i(t)) + SC_i(t)] \leq FU_i. \tag{10}$$

9) Emission constraint: Burning fuel emit contaminated gases which should be limited by the following equation

$$\sum_{i=1}^{N} \sum_{t=1}^{T} H_i(P_i(t)) \leq E_{limit}. \tag{11}$$

where $H_{P_i(t)}$ is a quadratic function associated with several emission types.

D. Fuzzy formulations

Depending on the nature of the variables, the followings are expressed as fuzzy notations.

1) Load demand membership function: Since the actual load demand may differ from the forecasted load, the load demand is taken into the wings of fuzzy variables. The following membership function is defined for load demand

$$\mu_{LD} = \begin{cases} \frac{1}{1+(\frac{\Delta D}{D^+})^2}, & \Delta D \geq 0 \\ \frac{1}{1+(\frac{\Delta D}{D^-})^2}, & \Delta D < 0 \end{cases} \tag{12}$$

where

$$\Delta D = \frac{Actual\ demand - Forecasted\ demand}{Forecasted\ demand} \times 100\% \tag{13}$$

and $D^{+/-}$ are the average error percentage when the actual load demand is greater/lower than the forecasted one.

2) Spinning reserve membership function: Since the load demand can be represented as fuzzy, spinning reserve can also be represented as fuzzy set as per following equation

$$\mu_{SR} = \begin{cases} 1, & if\ Eq.\ (15) \\ \frac{R - R_{min}}{R_{sat} - R_{min}}, & otherwise \end{cases} \tag{14}$$

considering

$$\sum_{i=1}^{N} I_i(t).P_i^{max} \geq 1.1 D(t) \tag{15}$$

where $I_i(t)$ is the UC on/off schedule, $D(t)$ is the forecasted load demand at hour t and P_i^{max} is the maximum power for unit i. R_{sat} is the satisfactory spinning reserve.

3) Wind speed membership function: Since the wind speed is forecasted, it can be presented as fuzzy variables. The following equation points this scenario.

$$\mu_{WS} = \begin{cases} \frac{1}{1+(\frac{\Delta WS}{WS^+})^2}, & \Delta WS \geq 0 \\ \frac{1}{1+(\frac{\Delta WS}{WS^-})^2}, & \Delta WS < 0 \end{cases} \tag{16}$$

where

$$\Delta WS = \frac{Actual\ w.speed - Forecasted\ w.speed}{Forecasted\ w.speed} \times 100\% \tag{17}$$

4) Cost membership function: The fuzzy membership function for production cost Eq.(1), is defined as

$$\mu_{TC} = \begin{cases} e^{-w \Delta TC}, & \Delta TC \geq 0 \\ 1, & \Delta TC < 0 \end{cases} \tag{18}$$

where

$$\Delta TC = \frac{TC - \sigma.TC_{max}}{\sigma.TC_{max}} \tag{19}$$

where w is the weighting factor, σ is the cost tolerance factor and TC_{max} is the highest fuel cost.

III. DIFFERENTIAL EVOLUTION APPROACH FOR UC

Differential evolution (DE) is a powerful heuristic method for solving non-linear, non-differential and multi-modal problems. DE can be treated as an extension of genetic algorithm. However unlike GA, it maintains a dummy vector which is created by mutating the individuals from current population. Then a crossover operation is performed between the target vector and the mutated vector. The crossover creates a trial vector. Finally the selection process selects elements from the trial vector based on the fitness function.

A. Individual structure

The structure of each individual is a binary matrix of on/off schedule. The dimension of the matrix is $N \times T$ where N is the number of units and T is the generation schedule horizon.

$$[I] = \begin{vmatrix} I_{11} & I_{12} & \dots & I_{1T} \\ I_{21} & I_{22} & \dots & I_{2T} \\ \vdots & \vdots & \vdots & \vdots \\ I_{N1} & I_{N2} & \dots & I_{NT} \end{vmatrix} \tag{20}$$

B. Mutation operation

The mutation operation creates a new vector for mutation purpose. For each target vector $X_{i,G}$ (where i is the solution index and G is the generation index) of dimension $D = N \times T$, the mutation vector ($MV_{i,G+1}$) for next generation is defined as the following random discrete Boolean functions for all of the dimensions d.

$$\begin{aligned} TV_{i,G+1}^d = {} & X_{r1,G}^d\ AND\ (X_{r2,G}^d\ OR\ X_{r3,G}^d) \\ & OR\ (X_{r2,G}^d\ AND\ X_{r3,G}^d) \end{aligned} \tag{21}$$

$$MV_{i,G+1}^d = \begin{cases} TV_{i,G+1}^d & rand(0,1) \leq 0.8 \\ X_{r1,G}^d & otherwise \end{cases} \tag{22}$$

where $r1 \neq r2 \neq r3 \neq i$ and solution $X_{r1,G}$ contains the better fuzzy acceptance probability than $X_{r2,G}$ and $X_{r3,G}$.

C. Crossover operation

The diversity of the solution is ensured by introducing crossover between the mutated vector and target vector. The resultant vector CV is defined as follows

$$CV_{i,G+1}^{d} = \begin{cases} TV_{i,G+1}^{d} & if\ (rand(0,1) \leq CC) \\ & OR\ d = rnb(i) \\ X_{i,G}^{d} & otherwise \end{cases} \quad (23)$$

where CC is the crossover constant between $[0,1]$, $rnb(i)$ is a randomly chosen index from $1, 2, \ldots, D$ to ensure the resultant vector CV gets at least one element from the mutated vector.

D. Selection operation

The resultant vector from the crossover operation ($CV_{i,G+1}$) is compared with the target vector ($X_{i,G}$). The comparison is carried by the following probability function (for solution X)

$$PF_X = \mu_{LD} \cap \mu_{SR} \cap \mu_{WS} \cap \mu_{TC}(X) + 1/(viol(X)) \quad (24)$$

Therefore,

$$X_{i,G+1} = \begin{cases} U_{i,G+1} & if\ PF(CV_{i,G+1}) < PF(X_{i,G}) \\ X_{i,G} & otherwise \end{cases} \quad (25)$$

where $viol(X)$ represents the constraints violation of solution X.

IV. ALGORITHM OUTLINE

The flow chart of the proposed method is briefed in Fig 1. The outline of the fuzzy strategy with wind-battery system using modified differential evolution is listed bellow.

Step 1: Generate the initial population with a number of solutions using a weighted priority list. For each hour the units are committed in the order of priority list until the spinning reserve requirements are not met. The achieved solution is called the base solution. The priority list is created by the maximum power output and minimum per unit cost. Best per unit cost is the function of fuel cost coefficients and is derived as follows (for unit i)

$$2\sqrt{a_i c_i} + b_i \quad (26)$$

Multiple solutions are generated randomly committing the intact units of base solution. More base solutions are created by changing the weights of priority list attributes, which are maximum power output and per unit cost.

Step 2: Repair the solutions for any constraint violation. Minimum up/down constraint violations for each solution are repaired in this step.

Step 3: Calculate the ELD operation for each solution. ELD is calculated using system lambda iteration method. Since the wind power system includes the battery, the constraints related to the battery are also considered in this step. Then the membership degrees of load demand, spinning reserve, wind speed and production cost are also evaluated using the equations from (12) to (19).

Step 4: If the maximum number of iteration is encountered, the best performed solution (which contains the minimum production cost) is the potential UC schedule and the algorithm stops. Repair the solution for constraints violation, otherwise continue to the next step.

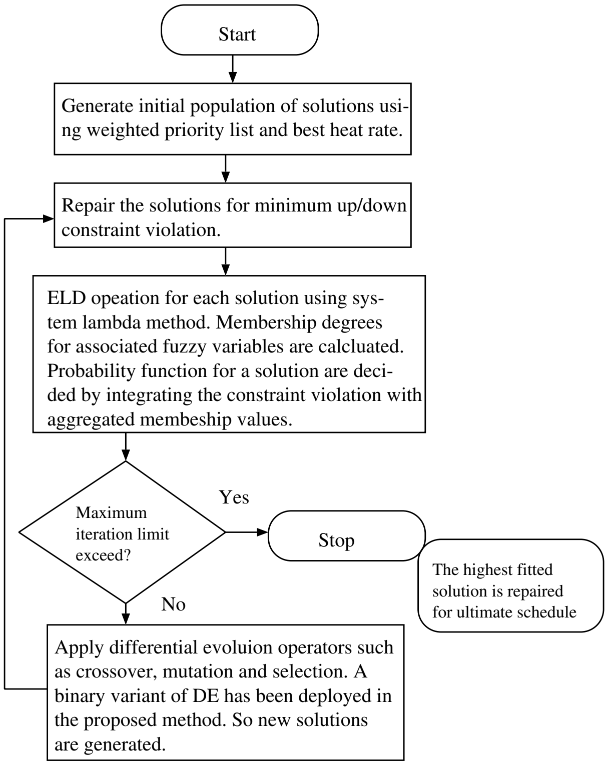

Fig. 1. Flowchart of the proposed fuzzy DE method.

Step 5: Now apply the differential evolution operators described in section III.B to III.D. The constraint violation of a solution X is calculated by taking account of the equal and in-equal constraints by using the following equation.

$$viol(X) = \frac{S}{M_1}\sum_{j=1}^{M_1} C_j \times ECD^2 + \frac{S}{M_2}\sum_{j=1}^{M_2} C_j \times min(ULD, LLD)^2 \quad (27)$$

where M_1 and M_2 are the number of equality and inequality constraints, respectively. ECD is the amount violation for equality constraints, ULD is the upper limit difference and LLD is the lower limit difference for inequality constraints. C_j is the weight of associated constraints and varies from 0 to 1. S is the combined penalty factor associated with each population (g) and expressed as (initially g is set to 0)

$$S = 100 + \log(g + 1) \quad (28)$$

Return to step 2.

V. NUMERICAL SIMULATION

The method is implemented in Visual C++ 6.0 and PHP 5.0.1 environment on an Intel Pentium IV machine with 512 MB of RAM. The simulation is run by considering a base ten units system and assuming 10% spinning reserve requirements.

TABLE I

TEST RESULT OF THE PROPOSED METHOD WITH EXECUTION TIME.

	Best cost (NT$)	Average cost (NT$)	Worst cost (NT$)	Max. execution time (NT$)	Min. execution time (NT$)	Avg. execution time (NT$)
With wind-battery	185.37	187.80	189.91	12.78	9.47	11.20
Without wind-battery	199.04	201.34	203.61	10.40	8.94	9.69

TABLE II

RESULT COMPARISON WITH OTHER METHODS.

	Proposed DE	DP	LR	SA	CLP	FA
Cost (NT$)	185.37	215.5	214.5	215.6	213.8	213.9
Average Execution time (s)	11.20	199	29	2589	17	3.56

TABLE III

CRISP, FUZZY LOAD DEMANDS AND MEMBERSHIP DEGRESS OF FUZZY LOAD.

Hour	Crisp load (MW)	Fuzzy load (MW)	μ_{LD}	Hour	Crisp load (MW)	Fuzzy load (MW)	μ_{LD}
1	5700	5803.40	0.96747	13	6900	6906.90	0.99999
2	5400	5497.58	0.96747	14	8150	8143.48	0.99998
3	5150	5243.90	0.96747	15	8250	8243.40	0.99998
4	4850	4932.30	0.96747	16	8000	7993.60	0.99998
5	4950	5039.10	0.96747	17	7800	7793.76	0.99998
6	4800	4804.80	0.99999	18	7100	7094.32	0.99998
7	4850	4854.85	0.99999	19	6800	6794.56	0.99998
8	5400	5405.40	0.99999	20	7300	7294.16	0.99998
9	6700	6694.64	0.99998	21	7100	7094.32	0.99998
10	7850	7843.72	0.99998	22	6800	6794.56	0.99998
11	8000	7993.13	0.99998	23	6550	6544.76	0.99998
12	8100	8093.52	0.99998	24	6450	6457.46	0.99999

TABLE IV

TEST RESULT AND COMPARISON FOR BASE 10 AND HIGHER POWER SYSTEM (WITHOUT WIND-POWER SYSTEM).

Unit	Cost (USD)	Average Time (Sec)	Load Error	ICGA Cost	ICGA Average Time
10	564,936	8.10	69.55	566,404	7.40
20	1,125,742	15.53	142.85	1,127,244	22.40
40	2,244,843	25.03	262.08	2,254,123	58.30
60	3,367,008	36.84	415.39	3,378,108	117.30
80	4,489,780	55.36	554.10	4,498,943	176.00
100	5,611,352	74.70	689.25	5,630,838	242.50

The generation units' operator data and load are taken from 38-units Taiwan power system. The scheduling period is fixed as 24 hours. It is assumed that there is no prior information to calculate the forecasted error except the errors are random, positively biased and have the central tendency to the average points. The simulation is run for 10 times to achieve the result. The maximum iteration is set to 300.

Table I shows the results of the proposed method by considering with (and without) Wind-Battery system. The production cost reported in New Taiwan dollar. From this table, it can be shown that the method is capable of finding near optimal solutions in an affordable time. Moreover, the differences between best, average and worst cost are not significant which recons that the solution quality of the proposed method is good. The cost and time comparisons of the proposed method with other established methods are shown in Table II. The comparing methods considered in this study are dynamic programming (DP) penned on [3], Largrangian Relaxation (LR) penned on [4], simulated annealing (SA) [5], fuzzy (FA) [6] and constraint logic programming (CLP) reported on [7]. The proposed differential evolution method outperforms the other methods in terms of production cost. However, since this method integrates wind-battery system with the thermal units, less fuel is consumed which in turn reduce the production cost. But without the integration of wind-battery system, proposed DE method is still able to generate solutions with optimized cost (NT$ 199.04). So this method is also useful for a stand alone thermal power system.

Table III shows the crisp and fuzzy load demands of the optimum solution. The crisp load demand has been modified in the fuzzy UC problem by taking the potential uncertainties into account. Depending on the error statistics, some hours the fuzzy load is lower while other hours it is higher than the forecasted crisp load. However the total fuzzy loads are higher than the total crisp load.

In order to provide the scalability of the proposed method, the algorithm is run under a different environment (as per Table IV). The generators' data are collected from reference [8]. The base 10 units are extended to 20, 40, 60, 80 and 100 units by multiplying the generators' data and hence the load demand. The load error is calculated from [8]. The result is also compared with integer coded genetic algorithm (ICGA) reported in [9]. The table shows that the execution time is quite acceptable since the amount is not grown exponentially with the number of units. Rather the relation between number of units and execution time is nearly linear. So the method is capable of handling larger units and thus scalable.

Table V shows the thermal units' status for 24 hours for the

TABLE V
24-HOURS UNIT SCHEDULE FOR 10 UNITS.

	1	2	3	4	5	6	7	8	9	10
H1	1	1	0	0	0	0	0	0	0	0
H2	1	1	0	0	0	0	0	0	0	0
H3	1	1	0	0	1	0	0	0	0	0
H4	1	1	0	0	1	0	0	0	0	0
H5	1	1	0	1	1	0	0	0	0	0
H6	1	1	1	1	1	0	0	0	0	0
H7	1	1	1	1	1	0	0	0	0	0
H8	1	1	1	1	1	0	0	0	0	0
H9	1	1	1	1	1	1	1	0	0	0
H10	1	1	1	1	1	1	1	1	0	0
H11	1	1	1	1	1	1	1	1	1	0
H12	1	1	1	1	1	1	1	1	1	1
H13	1	1	1	1	1	1	1	1	0	1
H14	1	1	1	1	1	1	1	0	0	0
H15	1	1	1	1	1	0	0	0	0	0
H16	1	1	1	1	1	0	0	0	0	0
H17	1	1	1	1	1	0	0	0	0	0
H18	1	1	1	1	1	0	0	0	0	0
H19	1	1	1	1	1	0	0	0	0	0
H20	1	1	1	1	1	1	1	1	0	0
H21	1	1	1	1	1	1	1	0	0	0
H22	1	1	0	1	1	1	1	0	0	0
H23	1	1	0	1	0	1	1	0	0	0
H24	1	1	0	0	0	0	0	0	0	0

base 10 units system (without the wind-battery). Considering the generators data and Eq. (26) the units are prioritized from 1 to 10 (unit 1 having the highest priority). The table depicts that higher priority units are committed first. However when the load demand is higher (on hour 12) all the units are ON. Inclusion of wind-battery system helped the thermal generators to achieve load levelling.

VI. CONCLUSIONS

A methodology for solving thermal unit commitment problem integrated with wind-battery system is presented in this paper. Since the load demand and wind speed is forecasted, the forecasting error becomes severe for large scale power system. For this reason, the proposed method applies a fuzzy model where load demand, wind speed, spinning reserve and production cost are presented as fuzzy variables. The errors are taken from a priory statistics due to the absence of actual data. Then a modified differential evolutionary method is deployed to solve the UC problem. DE is a very popular method which is frequently used to solve continuous problem. But in this paper, DE is modified to solve a mixed integer based problem. The modification is carried by changing the mutation operator. The effectiveness of the proposed method is shown by comparing the performances in two different kinds of power system; the 38-units' Taiwan power system and a 10-units' system. To show the scalability of the method, 10 units system is being multiplied upto 100 units. The provided solution quality is relatively higher than the persistent methods.

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