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A Deterministic Hopfield Model To Dynamic Economic Dispatch With Ramp Limit And Prohibited Zones

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Abstract: *A solution to the dynamic economic dispatch (DED) for 24-hour dispatch intervals (one day) with practical constraints using a Hopfield neural network (HNN) is proposed in this paper. The HNN is a deterministic model with mutual coupling and of non-hierarchical structure. A continuous and monotonically increasing transfer function is adopted in this model. The DED in this paper must satisfy the following constraints: (1) the system load demand, (2) the spinning reserve capacity, (4) the ramping rate limits and (5) finally the prohibited operating zone. The line losses are included in the algorithm using an iterative procedure where the load demand is augmented in each time interval with a maximum estimation of line losses. The feasibility of the proposed approach is demonstrated using two power systems, and it is compared with the other methods in terms of solution quality and computation efficiency.*
Keywords: *Dynamic economic dispatch, Hopfield Neural Network, prohibited operating zone, ramping rate limits.*

1. Introduction

The DED is used to determine the optimal schedule of generating outputs so as to meet the load demand at the minimum operating cost under various system and operating constraints over the entire dispatch periods. DED is an extension of the conventional economic dispatch (ED) problem that takes into consideration the limits on the ramp rate of generating units to maintain the life of generation equipment [1, 2]. In general, the DED is solved by discrete the entire dispatch period into a number of small time periods. Therefore, the static ED in each dispatch period is solved subject to the power balance constraints and generator operating limits. Previous efforts on solving static ED problems have employed various mathematical programming methods and optimization techniques (lambda-iteration, gradient method and dynamic programming (DP) [3]. Unfortunately, for generating units with non-linear characteristics, such as prohibited operating zones and non-convex cost functions, the conventional methods can hardly obtain the optimal solution. Furthermore, for a large-scale mixed-generating system, the conventional methods often oscillate which result in a local minimum solution or a longer solution time [4].

Earlier period, the global optimization techniques known as genetic algorithms (GA), simulated annealing (SA), tabu search (TS), evolutionary programming (EP), and particle swarm optimization (PSO) have been successfully used to overcome the non-convexity problems of the constrained ED [5, 6, 7], but the greater CPU time/iteration was its drawback.

Artificial intelligent techniques, such as Hopfield neural networks (HNN), have also been employed to solve DED problems [8]. However, an unsuitable transfer function adopted in the Hopfield model may suffer from excessive numerical iterations, resulting in huge calculations [9]. To overcome these drawbacks, we have attempted to construct and implement of a HNN, which employs a linear transfer function.

2. Problem Formulation of DED Problem

ED planning must perform the optimal generation dispatch among the operating units to satisfy the system load demand, spinning reserve capacity, and practical operation constraints of generators that include the ramp rate limit and the prohibited operating zone [7].

2.1. Practical Operation Constraints of Generator

For convenience in solving the DED problem, the unit output is usually assumed to be adjusted smoothly and instantaneously. Practically, the operating range of all online units is restricted by their ramp rate limits [3, 4]. In addition, the prohibited operating zones in the input-output curve of generator are due to steam valve operation or vibration in a shaft bearing. The best economy is achieved by avoiding operation in areas that are in actual operation. Hence, these two constraints must be taken into account to achieve true economic operation.

1) Ramp Rate Limit: According to [5, 10, 11], the inequality constraints due to ramp rate limits for unit generation changes are given as follow:

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$$P_i^t - P_i^{t-1} \le R_i^{up} \quad (1)$$

$$P_i^{t-1} - P_i^t \le R_i^{down} \quad (2)$$
$$i = 1,...,N \text{ and } t = 1,...,T$$

where P_i^t is the output power at interval t; P_i^{t-1} is the previous output power; R_i^{up} is the up-ramp limit of i-th generator at period t, (MW/time-period); and R_i^{down} is the down-ramp limit of the i-th generator (MW/time period).

2) Prohibited Operating Zone: Fig. 1 shows the input–output performance curve for a typical thermal unit with prohibited zone. The operating zones of unit can be described as follows:

$$P_i^t \in \begin{cases} P_i^{\min} \le P_i^t \le P_{i,1}^l \\ P_{i,j-1}^u \le P_i^t \le P_{i,j}^l \quad , j = 2,3,...,n_i \\ P_{i,n_i}^u \le P_i^t \le P_i^{\max} \end{cases} \quad (3)$$

where n_i is the number of prohibited zones of generator i.

$P^l_{i,j}$, $P^u_{i,j}$ are the lower and upper power output of the prohibited zones j of the generator i, respectively.

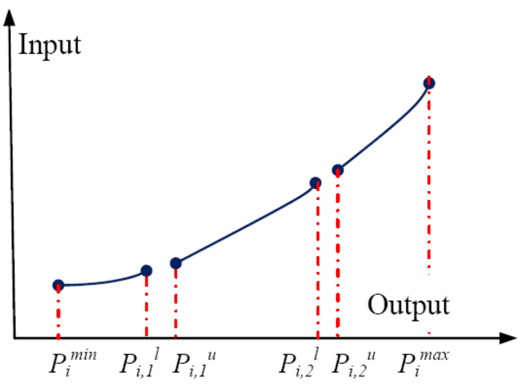

Figure 1. The input–output performance curve for a typical thermal unit with Prohibited Zone

2.2. The DED Objective Function

The objective of DED is to simultaneously minimize the generation cost rate and to meet the load demand of a power system over some appropriate period while satisfying various constraints. To combine the above two constraints into a DED problem, the constrained optimization problem at specific operating interval can be modified as:

$$C_T = \sum_{t=1}^{T}\sum_{i=1}^{N} C_i^t(P_i^t) = \sum_{t=1}^{T}\sum_{i=1}^{N} a_i + b_i P_i^t + c_i (P_i^t)^2 \quad (4)$$

where: C_T is the total generation cost; C_i^t (P_i^t) is the generation cost function of i-th generator at period t, which is usually expressed as a quadratic polynomial; a_i, b_i, and c_i are the cost coefficients of the i-th generator; P_i^t is the power output of the i-th generator, N is the number of generators and T is the total periods of operation.

Subject to the following constraints

i) Power balance

$$\sum_{i=1}^{N} P_i^t = D^t + L^t \quad (5)$$

where D^t is the load demand at period t and L^t is the total transmission losses, which is a function of the unit power outputs that can be represented using the B-coefficients:

$$L^t = \sum_{i=1}^{N}\sum_{j=1}^{N} P_i^t B_{ij} P_j^t + \sum_{i=1}^{N} B_{0i} P_i^t + B_{00} \quad (6)$$

where B, B_0 and B_{00} are the loss-coefficient matrix, the loss-coefficient vector and the loss constant, respectively.

ii) System spinning reserve constraints

$$\sum_{i=1}^{N}\left[\min\left(P_i^{\max} - P_i^t, R_i^{up}\right)\right] \ge SR^t, \; t = 1,2,...,T \quad (7)$$

iii) generator operation constraints

$$\max(P_i^{\min}, P_i^{t-1} - R_i^{down}) \le P_i^t \le \min(P_i^{\max}, P_i^{t-1} + R_i^{up}) \quad (8)$$

where P_i^{min} and P_i^{max} are the minimum and maximum outputs of the ith generator respectively.

The generation output P_i^t must fall in the feasible operating zones of unit i *by* satisfying the constraint described by Eq. (3).

3. An improved HNN applied to ED

The ED Problem has been widely studied and reported by several authors in books and journals on power system analysis. Many techniques have been developed to solve this problem, e.g. the lambda-iterative method, gradient technique, Interior Point, Lagrange technique, linear programming, Quadratic Programming, Dynamic Programming, Simulated Annealing, Genetic algorithm (GA), Evolutionary Programming (EP), Neural Network and methods combining two or more of the above methods [2]. Most of these methods often suffer from the large amount of computational requirement or give just a good estimate (near optimal) of the solution to the ED problem.

The continuous or deterministic model of the Hopfield Neural Network is based on continuous variables. The output variable of neuron i has the range $y_i^0 < y_i < y_i^1$ and the input-output function is a continuous and monotonically increasing function of the input x_i to neuron i. The model is a mutual coupling neural network and of non-hierarchical structure. Architecture of a HNN of three neurnes sample is shown in figure 2 The processing elements are modeled as a neurone in conjunction with feedback circuits to model the basic computational features of neurons and synapses connecting different neurons. Usually the neurones have sigmoidal monotonic input-output relations.

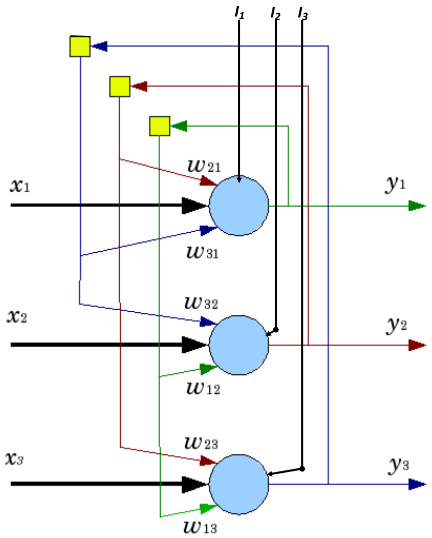

Figure 2. Architecture of the Hopfield Neural Network

The continuous model of the HNN is based on continuous output variables, and the transfer function is a continuous and monotonically increasing function. The model is a mutual coupling and of non-hierarchical structure. The dynamic characteristic of each neuron can be described by:

$$\frac{dU_i}{dt'} = I_i + \sum_{j=1}^{N} T_{ij} V_j \tag{9}$$

where ($U_i = x_i$) is the total input of neuron i; ($V_i = y_i$) is the output of neuron i; ($T_{ij} = \omega_{ij}$) is the interconnection conductance from the output of neuron j to the input of neuron i; ($T_{ii} = \omega_{ii}$) is the self-connection conductance of neuron i and I_i is the external input to neuron i.

It should be noted here that t' is not representing real time, it is a dimensionless variable.

The energy function of the continuous Hopfield model can be defined as:

$$E = -\frac{1}{2}\sum_{i=1}^{N}\sum_{j=1}^{N} T_{ij} V_i V_j - \sum_{i=1}^{N} I_i V_i \tag{10}$$

In the computation process the model state always moves in such a way that energy function gradually reduces and converges to a minimum [12].

3.1. The Hopfield Model for ED Problem

To solve the ED problem using the HNN, energy function is defined as follows:

$$E = \frac{W_{PM}}{2}\left(D + L - \sum_{i=1}^{N} P_i\right)^2 + \frac{W_F}{2}\sum_{i=1}^{N} a_i + b_i P_i + c_i P_i^2 \tag{11}$$

where the positive weighting factors W_{PM} and W_F introduce the relative importance of power mismatch P_m and total fuel cost F, respectively.

To avoid saturation, a linear model is used to describe the transfer function, where U_{min} and U_{max} are the minimum and maximum input of neurons.

$$V_i = f(U_i) = P_i = Z_{1i} U_i + Z_{2i}, \quad \forall U_{\min} \le U_i \le U_{\max} \tag{12}$$

$$V_i = f(U_i) = P_i = P_i^{\max}, \quad \forall U_i \ge U_{\max} \tag{13}$$

$$V_i = f(U_i) = P_i = P_i^{\min}, \quad \forall U_i \le U_{\min} \tag{14}$$

$$\text{with } Z_{1i} = \left(P_i^{\max} - P_i^{\min}\right) / \left(U_{\max} - U_{\min}\right) \tag{15}$$

$$\text{and } Z_{2i} = P_i^{\min} - Z_{1i} U_{\min} \tag{16}$$

Comparing the energy function Eq. (11) with the Hopfield energy function Eq. (10), by replacing V_i and V_j with P_i^t and P_j^t respectively thus we get

$$T_{ii} = -W_{PM} - W_F . c_i \tag{17}$$

$$T_{ij} = -W_{PM} \tag{18}$$

$$I_i = W_{PM}(D + L) - W_F(b_i / 2) \tag{19}$$

Substituting Eq. (17), Eq. (18) and Eq. (19) into Eq. (8), the dynamic equation becomes,

$$dU_i / dt' = W_{PM} P_m - (W_F/2)(dC_i / dP_i) \tag{20}$$

$$\text{with } P_m = D - \sum_{i=1}^{N} P_i$$

Substituting Eq. (12) in Eq. (20) the dynamic equation becomes:

$$dU_i / dt' = W_{PM} P_m - (W_F/2)\left(b_i + 2c_i\left(Z_{1i} U_i + Z_{2i}\right)\right) \tag{21}$$

Solving Eq. (21) for the neuron's input function

$$U_i(t') = \left(U_i(0) + \left(Z_{4i}/Z_{3i}\right)\right) e^{K_{3i} t'} - \left(Z_{4i}/Z_{3i}\right) \tag{22}$$

$$\text{with } Z_{3i} = -W_F c_i Z_{1i}$$

$$\text{and } Z_{4i} = -W_F c_i Z_{2i} - (W_F/2) b_i + W_{PM} P_m$$

From Eq. (12), the neuron's output $P_i(t')$ is obtained as:

$$\begin{aligned} P_i(t') &= \left(2W.P_m - b_i\right)/2c_i + \ldots \\ &\ldots\left(Z_{2i} + Z_{1i} U_i(0) - \left(2W.P_m - b_i\right)/2c_i\right) e^{Z_{3i} t'} \end{aligned} \tag{23}$$

with $W = W_{PM} / W_F$

By setting (t' = inf), the second term in Eq. (23) decays exponentially and finally becomes insignificant and gives,

$$P_i(\text{inf}) = \left(2.W.P_m - b_i\right)/2c_i \tag{24}$$

In Eq. (24), $P_i(\inf)$ represents the final generation output (optimal) of unit i and present the output of neuron i at (t' = inf) which is the required solution.

A simple formula for the generation function can be done by back substituting of Eq. (24) in Eq. (23), to give

$$P_i(t') = P_i(\inf) + \left(P_i(0) - P_i(\inf)\right) e^{Z_{3i}t'} \quad (25)$$

where $P_i(0) = Z_{1i}U_i(0) + Z_{2i}$ (26)

We can derive the power mismatch from Eq. (24) as follow:

$$P_m = \left(\left((1/2)\sum_{i=1}^{N}(b_i/c_i)\right) + D\right) \Big/ \left(1 + W.\sum_{i=1}^{N}(1/c_i)\right) \quad (27)$$

4. Inclusion of Transmission Losses by Augmenting Power Demand

To include transmission losses, a classical dichotomy solution method is combined to the HNN which is proposed in [9]. For each time period t, a maximum forecast of transmission losses is supposed to not exceed 10 % of the total load demand at the same time interval, then a HNN algorithm is run to determine the optimal generators' power outputs by augmenting the total power demand by the estimated line losses. Then an iterative procedure is started unless error between the transmission losses calculated using the B-coefficients method and the estimated one are insignificant. Reference [9] gives more details about this procedure.

5. Ramp Rate Limit and Prohibited Zone Constraints

In the proposed algorithm, the ramp rate limit and the prohibited zone constraints are taken into account during the dispatching process.

Due to the ramp rate limit constraint, and for each period t, a minimum and maximum outputs $P_i^{min,t}$ and $P_i^{max,t}$ of the i-th generator is allowed, as follow:

$$\begin{cases} P_i^{\min,t} = \max(P_i^{\min}, P_i^{t-1} - R_i^{down}) \\ P_i^{\max,t} = \min(P_i^{\max}, P_i^{t-1} + R_i^{up}) \end{cases} \quad (28)$$

Then, and to satisfy the constraints of Eq. (24), three possible cases are given in figure 3. The fourth case is impossible where:

$$P_i^{t-1} - R_i^{down} < P_i^{\min} \wedge P_i^{t-1} + R_i^{up} > P_i^{\max} \quad (29)$$

and to prohobit the units from falling in the such prohibited operating zones, we introduce a medium incremental cost, $IC_{i,j}^{m}$, for each j-th prohibited zone for each unit i where the corresponding generation point is $P_{i,j}^{m}$,

$$P_{i,j}^{m} = \left(P_{i,j}^{u} + P_{i,j}^{l}\right)/2 \quad (30)$$

$IC_{i,j}^{m}$ is defined by:

$$IC_{i,j}^{m} = \left.\frac{\partial F_i(P_i)}{\partial P_i}\right|_{P_i = \frac{P_{i,j}^{u}+P_{i,j}^{l}}{2}} = b_i + c_i(P_{i,j}^{u} + P_{i,j}^{l}) \quad (31)$$

We have the following possible cases for satisfying the constraints of Eq. (3) and Eq. (29), as given in Fig. 2.

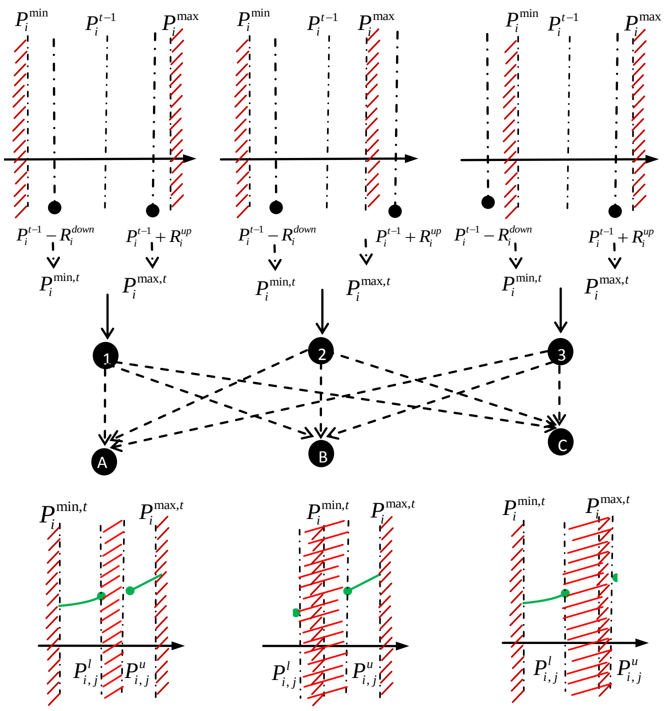

Figure 3. Cases of ramp rate limits and prohibited zones with respect to the minimum and maximum generator's outputs

which can be devided in two categories:

5.1. Dealing with ramp rate limit constraints

Case 1: The ramp rate limit is within the minimum and maximum generator's outputs. Let the minimum and maximum generator's outputs at period t equal to P_i^{t-1}-R_i^{down} and P_i^{t-1}+R_i^{up}, respectively

Case 2: The maximum generator's outputs allowed is less than the upper bound forced by the ramp up limit at the period t. Do not change the maximum generator's outputs and let the minimum generator's outputs at period t equal to P_i^{t-1}- R_i^{down}.

Case 3: The minimum generator's outputs allowed is greater than the lower bound forced by the ramp down limit at the period t. Do not change the minimum generator's outputs and let the maximum generator's outputs at period t equal to P_i^{t-1}+ R_i^{up}.

5.1. Dealing with Prohibited Zone Constraints

Case A: The prohibited zone is within the minimum and maximum generator's outputs of the period t.

Dispatch unit i with generation level at or above $P_{i,j}^{u}$ if the system incremental cost exceeds $IC_{i,j}^{m}$, by setting $P_{i,j}^{min,t} = P_{i,j}^{u}$.
Conversely, dispatch unit i with generation level at or below $P_{i,j}^{l}$, if the system incremental cost is less than $IC_{i,j}$, by setting $P_{i,j}^{max,t} = P_{i,j}^{l}$.
Case B: The minimum generator's outputs allowed of the period t exceeds the lower bound of the prohibited zone. Dispatch unit i by setting $P_{i,j}^{min,t} = P_{i,j}^{u}$.
Case C: The maximum generator's outputs allowed of the period t is less than the upper bound of the prohibited zone. Dispatch unit i by setting $P_{i,j}^{max,t} = P_{i,j}^{l}$.

When a unit operates in one of its prohibited zones, the idea of this strategy is to force the unit either to escape from the left subzone and go toward the lower bound of that zone or to escape from the right subzone and go toward the upper bound of that zone.

6. Computational Procedures

The proposed approach for solving the constrained DED with 24-hour dispatch intervals (one day) have the following computational steps:
Step 0: Specify the power generation for dispatchable units at interval t = 0. This step can be escaped if no data are avalaible for the power generation for this stage.
Step 1: Let the dispatch interval t = 1, specify the lower and upper bound generation power of each unit using Eq. (24), by satisfying the ramp rate limit according to section 5 strategy.
Pick the hourly power demand D^t.
Apply the algorithm of section 3, based on HNN model to determine the optimal generation for all units.
Step 2: To include transmission losses, apply the algorithm of section 3, based on dichotomy method to adjust the optimal generation of step 1for all units,.
Step 3: If prohibited zone constraints are satisfied, the power generation obtained in Step 2 is the solution, go to Step 5; otherwise, go to Step 4.
Step 4: Apply the strategy of section 5 to escape from the prohibited zones, and redispatch the units having generation falling in the prohibited zone.
Step 5: Let $t=t+1$ and if $t \leqq 24$, then go to Step 1. Otherwise,
Terminate the computation.

7. Numerical Examples and Results

To demonstrate the application and verify the feasibility of the proposed hybrid HNN method, a 6-unit and a 15-unit power systems [7, 11, 13] was tested.
Example 1: The 6-unit test system [13] characteristics are given in Table I and Table II. Total power capacities were committed to meet the 24-hour load demands from 930 MW to 1263 MW that was shown in Table III.

Example 2: The system is a 15-units whose characteristics are given in Table IV and Table V . Total power capacities were committed to meet the 24-hour load demands from 2215 MW to 2953 MW that was shown in Table VI. The loss coefficients B matrices are given in [13].

In normal operation of the system, the loss B-coefficients matrices with the 100 MVA base capacity for both examples are given in [11]. The spinning reserve was requested to be greater than 5% of the load demand.

The ramp rate limits, prohibited zones of units and spinning reserve constraints were taken into account, so the proposed Hybrid HNN method can be compared with other methods. The results of the proposed HNN are compared with those obtained by the FEP and IFEP and PSO algorithms from [7, 13] in terms of generation cost and average computational time as shown in Table VII for the two example. The software was written in LabVIEW language and executed on a Pentium V, 2.00 GHz personal computer with 1G of RAM. The linear model parameters of deterministic Hopfield are chosen as follow: U_{min} = -0.4, U_{max}= 0.4, W_{PM} = 2 W_F = 1 and P_m = 0.0001 MW as shown in figure 4.

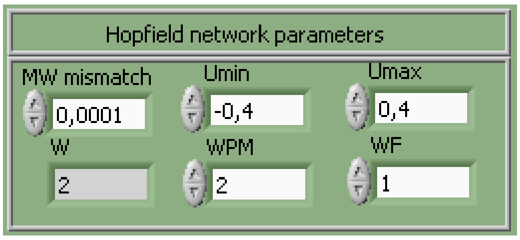

Figure 4. A part of front panel of virtual instrument showing Hopfield parameters

The simulation results given in Table VII showed that the proposed methods could obtain good solutions satisfying both the spinning reserve, ramp rate limit and the prohibited operating zones limit of generators. In a small-scale system as in the 6-units power system, though the advantage of HNN method was not very obvious, it could still have the fastest computation efficiency and the minimum daily total generation cost. For a medium system of 15-units, the advantage of the proposed HNN method was very obvious, and it could obtain both the fastest computation efficiency and the minimum daily total generation cost.

Table 1. Generating unit capacity and cost coefficients of example 1

Unit	P_i^{max}	P_i^{min}	a_i (\$/h)	b_i (\$/MWh)	c_i (\$/MW^{2}h)
1	500	100	240	7.0	0.0070
2	200	50	200	10.0	0.0095
3	300	80	220	8.5	0.0090
4	150	50	200	11.0	0.0090
5	200	50	220	10.5	0.0080
6	120	50	190	12.0	0.0075

Table 2. Ramp rate limits and prohibited zones of generating units of example 1

Unit	P_i^0	R_i^{up} (MW/h)	R_i^{down} (MW/h)	*Prohibited zone* (MW)

1	340	80	120	[210 240] [350 380]
2	134	50	90	[90 110] [140 160]
3	240	65	100	[150 170] [210 240]
4	90	50	90	[80 90] [110 120]
5	110	50	90	[90 110] [140 150]
6	52	50	90	[75 85] [100 105]

Table 3. The daily load demand (MW) of example 1

Hour	1	2	3	4	5	6	7	8	9	10
Load	955	942	935	930	935	963	989	1023	1126	1150
Hour	11	12	13	14	15	16	17	18	19	20
Load	1201	1235	1190	1251	1263	1250	1221	1202	1159	1092
Hour	21	22	23	24						
Load	1023	984	975	960						

Table 4. Generating unit data of example 2

Unit	P_i^{max}	P_i^{min}	a_i ($/h)	b_i ($/MWh)	c_i ($/MW^{2}h)	P_i^0	R_i^{up} (MW/h)	R_i^{down} (MW/h)
1	455	150	671	10.1	0.000299	394.44	80	120
2	455	150	574	10.2	0.000183	450.27	80	120
3	130	20	374	8.8	0.001126	50.111	130	130
4	130	20	374	8.8	0.001126	113.36	130	130
5	470	150	461	10.4	0.000205	426.35	80	120
6	460	135	630	10.1	0.000301	207.10	80	120
7	465	135	548	9.8	0.000364	286.51	80	120
8	300	60	227	11.2	0.000338	262.88	65	100
9	162	25	173	11.2	0.000807	94.579	60	100
10	160	25	175	10.7	0.001203	133.78	60	100
11	80	20	186	10.2	0.003586	66.78	80	80
12	80	20	230	9.9	0.005513	29.90	80	80
13	85	25	225	13.1	0.000371	46.25	80	80
14	55	15	309	12.1	0.001929	15.01	55	55
15	55	15	323	12.4	0.004447	51.49	55	55

Table 5. Prohibited zones of generating units of example 2

Unit	*Prohibited zone* (MW)
2	[185 225] [305 335] [420 450]
5	[180 200] [305 335] [390 420]
6	[230 255] [365 395] [430 455]
12	[30 40] [55 65]

Table 6. The daily load demand (MW) of example 2

Hour	1	2	3	4	5	6	7	8	9	10
Load	2236	2215	2226	2236	2298	2316	2331	2443	2651	2728
Hour	11	12	13	14	15	16	17	18	19	20
Load	2783	2785	2780	2830	2953	2950	2902	2803	2651	2584
Hour	21	22	23	24						
Load	2432	2312	2261	2254						

Table 7. The summary of the daily generation cost and CPU time

Method	Total Generation Cost ($)		CPU time/interval	
	6-Units	15-Units	6-Units	15-Units
FEP [7]	315,634	796,642	357.58	362.63
IFEP [7]	315,993	794,832	546.06	574.85
PSO [13]	314,782	774,131	2.27	3.31
Hybrid HNN	313,579	759,796	1.52	2.22

8. Conclusion

The increase of competition in power generation may enhance the importance of the DED problem in power system. The DED planning is a complex optimization problem which must perform the optimal generation dispatch at the minimum operating cost among the operating units to satisfy the system load demand, spinning reserve capacity and practical operation constraints of generators that include the ramp rate limit and the prohibited operating zone. In this paper, we have successfully employed a HNN method to solve the constrained DED problem taking into account most of the practical operation constraints of generators. The proposed HNN algorithm is a deterministic model with mutual coupling and of non-hierarchical structure coupled with a classical mathematical method iteratively to include transmission line losses. The algorithm has been demonstrated to have superior features, including high-quality solution and good computation efficiency. The results showed that the proposed HNN method was indeed capable of obtaining higher quality solution efficiently in constrained DED problems. Future research focus may be directed to DED for Microgrids which integrate distributed renewable energy resources, controllable loads and energy storage in a more economic and reliable fashion.

9. References

[1] X. S. Han, H. B. Gooi, D. S. Kirschen, "Dynamic economic dispatch: feasible and optimal solutions", *IEEE Trans. Power Syst.*, vol.16, no.1, pp.22-28, 2001.

[2] X. Xia, A.M. Elaiw, "Optimal dynamic economic dispatch of generation: A review", *Elect. Power Syst. Res.*, vol.80, pp.975-986, 2010.

[3] D. L. Travers and R. J. Kaye, "Dynamic dispatch by constructive dynamic programming", *IEEE Trans. Power Syst.*, vol.13, no.1, pp.72-78, 1998.

[4] F. N. Lee, A. M. Breipohl, "Reserve constrained economic dispatch with prohibited operating zones", *IEEE Trans. Power Syst.*, vol.8, no.1, pp.246-254, 1993.

[5] D. C. Walters, G. B. Sheble, "Genetic algorithm solution of economic dispatch with valve point loading", *IEEE Trans. Power Syst.*, vol.8, no.3, pp.1325-1332, 1993.

[6] P. Venkatesh, R. Gnanadass, N. P. Padhy, "Comparison and application of evolutionary programming techniques to combined economic emission dispatch with line flow constraints", *IEEE Trans. Power Syst.*, vol.18, no.2, pp.688-697, 2003.

[7] Z. -L. Gaing, et al. "Constrained dynamic economic dispatch solution using particle swarm optimization", *IEEE Power Eng. Soc. Gen. Meet.*, vol.1,pp.153–158, 2004.

[8] R. H. Liang, "A Neural-based redispatch approach to dynamic generation allocation", *IEEE Trans. Power Syst.*, vol.14, no. 4, pp.388-1393. 1999.

[9] F. Benhamida et al. "Generation allocation problem using a hopfield-bisection approach ıncluding transmission losses", *Elect. Power and energ. Syst.*, vol.33, no.5, pp.1165-1171. 2011.

[10] S. Pothiya et al., "Application of multiple tabu search algorithm to solve dynamic economic dispatch considering generator constraints", *Ener. Conv. Manag.*, vol.49, pp.506-5162, 2008.

[11] P. H. Chen, H. C. Chang, "Large-scale economic dispatch by genetic algorithm", *IEEE Trans. Power Syst.*, vol. 10, no.4, pp.1919-1926, 1995.

[12] J. M. Zurada, "Introduction to artificial neural network systems", *Jaiko Publishing house,* Mumbai, 1996.

[13] C.-T. Su, G.-J. Chiou, "An enhanced hopfield model for economic dispatch considering prohibited zones", *Elect. Power Syst. Res.*, vol.4, pp. 71-76, 1997.

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