Journal of Applied Sciences

ISSN 1812-5654

science alert

ANSInet
an open access publisher
http://ansinet.com

Journal of Applied Sciences 9 (7): 1248-1257, 2009
ISSN 1812-5654

Dynamical Joint Energy and Spinning Reserve Dispatch Considering Transmission Network Constraint

M. Asadi Bazardeh and M. Rashidi-Nejad
Department of Electrical Engineering, Shahid Bahonar University of Kerman, Kerman, Iran

Abstract: This study is dealing with ancillary services procurement and pricing in the new environment of electricity market. Spinning reserve is one of the most important ancillary services needed for satisfying reliability requirements as well as desired level of security in power systems. In deregulated power markets, generally two methods for energy and spinning reserve dispatching are addressed the so-called sequential dispatch and joint dispatch. It can be said that the sequential dispatch method may not be even feasible as well as optimal because of the coupling between spinning reserve and energy capacity. Therefore, in this study, a new method is proposed for dynamical joint energy and reserve dispatch that can solve the bottling of reserve problem by considering transmission limits. A genetic algorithm as an evolutionary optimization technique is used to solve such a complicated and non-convex problem. The proposed methodology is applied to a typical IEEE 30-bus system, while simulation studies show the effectiveness of joint energy and spinning reserve dispatch in comparison with the sequential dispatch.

Key words: Power market, restructuring, economic dispatch, ancillary services

INTRODUCTION

Among ancillary services which should be procured in a power system, Spinning Reserve (SR) has a significant importance to support system reliability. Spinning Reserve (SR) is considered to satisfy the system loads in a sudden outage in generating units and/or transmission lines as well as unforeseen increase in load demand (Shahidehpour and Alomoush, 2001). In deregulated power markets, satisfying a desired level of reliability; unit's contribution for energy production and SR procurement should be based upon minimizing total costs of energy and SR dispatching. Generally two methods for energy and SR dispatching are addressed the so-called Sequential Dispatch (SD) and Joint Dispatch (JD). In SD regardless of considering the price of SR, at first energy is dispatched optimally and then from the remained capacity of all units, SR can be dispatched (Song and Wang, 2003). It might be said that SD method may conclude two problems in satisfying real power demand and Spinning Reserve Requirement (SRR). Since in SD method at first energy is dispatched, maximum capacity of some units might be allocated only to energy and there is no more capacity for allocating to SR. Under this condition although the other units may have enough capacity for allocating to SR but because of their ramp up rate constraint, they cannot satisfy system SRR which is infeasible. In some units, where their energy prices are very closed while their SR prices are significantly different, SD method will allocate most of energy to the cheaper units those cannot have any chance to contribute for SR. Under this condition SR will be procured by some expensive units where it may cause a non-economic outcome. In fact, the optimal allocation of energy and SR would be through a Joint Dispatch (JD) technique, where in order to achieve a feasible as well as optimal solution JD will consider the total procurement costs of energy and SR concurrently.

Transmission limit is one of the most important constraints which can be considered in energy and SR dispatch problem in a real environment. When energy and SR are dispatched without considering transmission limit and only by minimizing the generation costs two problems may be happened. It is according to achieve a particular pattern of energy production and SR procurement. Firstly, based upon the prescribed allocated values for energy and SR; in time of energy delivery some transmission lines might be faced with an overload. Secondly, bottling of reserve can be occurred in satisfying the allocated SR of all units that should guarantee system reserve requirement. In bottling of reserve problem, sum of allocated energy and SR to a typical unit may be bigger than the transmission lines capacities that connect this unit to the system. Since there is a reserve capacity that

Corresponding Author: Dr. Masoud Rashidi-Nejad, Department of Electrical Engineering, Shahid Bahonar University of Kerman, 22 Bahman Blvd., Kerman, Iran Tel: 00983412221636 Fax: 00983412237240

cannot be delivered, therefore the energy generation and SR procurement pattern without considering transmission limit seems to be infeasible.

A hybrid real genetic algorithm method is proposed by Baskar *et al*. (2003) for solving the economic dispatch problem with multiple fuel options. A method proposed by Chen *et al*. (2003) addresses a joint dispatch for energy and SR considering a conventional optimal power flow. A hybrid deterministic/probabilistic approach is proposed for SR allocation by Fotuhi-Firoozabad and Rashidi-Nejad (2004). Energy and SR joint dispatch technique based upon a dynamic optimal power flow is proposed by Costa and Costa (2007). A comprehensive memetic algorithm is applied for solving joint energy and SR dispatch by Hazrati *et al*. (2007). A method is also presented for solving the infeasibility problem of SD technique by Asadi *et al*. (2008).

In this study, a new methodology is proposed for solving such a non-convex problem via JD-based technique using genetic algorithm as an evolutionary optimizer. In this study transmission limit constraint is considered to prevent bottling of reserve problem by implementing a DC power flow.

PROBLEM DEFINITION AND MATHEMATICAL FORMULATION

Joint energy and spinning reserve dispatch (JD) can be formulated as a constrained optimization problem. The objective function of JD is considered as minimization of joint energy production and SR procurement costs (Rashidi-Nejad *et al*., 2002). A competitive day-ahead market is assumed where suppliers may offer their active power associated with prices both for energy and SR through a quadratic scheme for energy and a single-part bid scheme for SR, respectively. The objective function of such an optimization problem can be written as:

$$\text{Min}\sum_{t=1}^{T}\sum_{i=1}^{N} C_i(P_i^t) + C_i(R_i^t) \tag{1}$$

where, $C_i(P_i^t)$ and $C_i(R_i^t)$ are energy generation and reserve provision costs, respectively, T is the scheduling time horizon and N is the No. of generating units.

Energy price is assumed to be quadratic while SR price is assumed to be linear. Therefore energy and reserve costs are expressed by Eq. 2 and 3, respectively.

$$C_i\left(P_i^t\right) = a_i + b_i \times P_i^t + c_i \times \left(P_i^t\right)^2 \tag{2}$$

$$C_i\left(R_i^t\right) = d_i \times R_i^t \tag{3}$$

where, a_i, b_i and c_i are generation cost coefficients and P_i^t is energy amount of generator i at hour t. R_i^t and d_i are reserve amount and its price for generator i at hour t, respectively (Kothari and Dhillon, 2004). The optimization problem is subjected to some constraints in which Eq. 4 is the balance between supply and demand.

$$\sum_{i=1}^{N} P_i^t = P_D^t \tag{4}$$

where, P_D^t is forecasted demand for hour t. Some physical constraints also can be written as follows:

$$P_i^{min} \le P_i^t \tag{5}$$

$$P_i^t + R_i^t \le P_i^{max} \tag{6}$$

where, P_i^{max} and P_i^{min} are maximum and minimum generation capacity of generator i, respectively. Spinning reserve limits are defined by Eq. 7 and 8.

$$0 \le R_i^t \le \min\left\{\left(\Delta t \times RR_i^{up}\right), R_i^{max}\right\} \tag{7}$$

$$\sum_{i=1}^{N} R_i^t \ge R_{req}^t \tag{8}$$

where, RR_i^{up} and R_{req}^t are ramp up rate of generator i and SR requirement at hour t, respectively. Δt is response time for SR while R_i^{max} is maximum reserve capacity that is defined by Eq. 9.

$$R_i^{max} = P_i^{max} - P_i^t \tag{9}$$

Transmission limit constraint is considered as fallows:

$$\left|P_{ij}\right| \le \overline{P}_{ij} \tag{10}$$

where, P_{ij} is active power flow from bus i to bus j and $\overline{P}_{ij}$ is maximum power flow limit of ijth transmission line. In fact, by considering transmission constraint, the generation strategy is determined which pattern of energy generation and SR procurement has minimum costs while overload would not be happened in any transmission line.

SOLUTION METHODOLOGY

Genetic algorithm is a random and robust search technique that guides a population of encoded solutions towards an optimum using the principles of natural evolution. This process is facilitated through a fitness

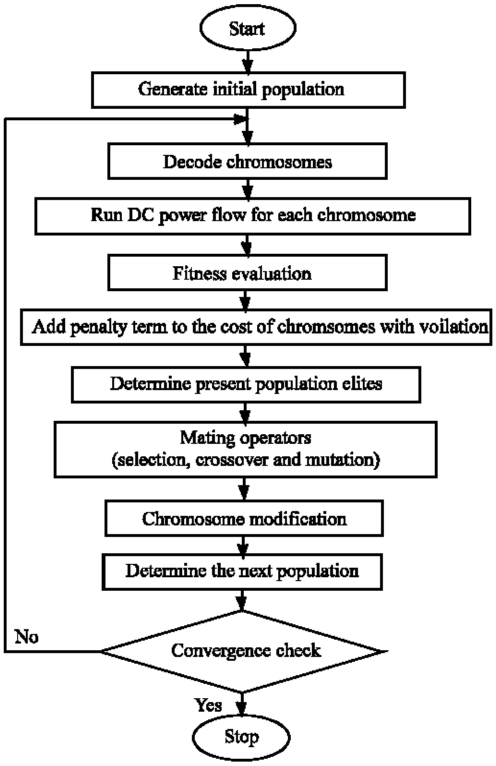

Fig. 1: The flowchart of proposed solution approach for DJESD

evaluation procedure, which determines the fitness value of each member of the population the so-called chromosome. The robustness of GA and its capability across a broad range of problems make GA as general problem solving techniques in many applications (Swarup and Yamashiro, 2002). So, in this study according to the complexity of dynamical joint energy and SR dispatch (DJESD), GA is used to solve this complicated and non-convex optimization problem. The flowchart of the proposed GA-based solution approach for DJESD is shown in Fig. 1 that includes the following steps:

Step 1: Initialization and coding: In this step goal, constraint and variable ranges will be defined while continuous variables should be converted to discrete variables. Then the range of discrete variables must be indexed. Finally, based on the problem requirement, genomes, chromosomes and population must be created. In this study, every chromosome is a random case of unit's energy production and SR procurement. In fact, the major difference between the proposed dispatching technique and other GA based dispatching methods is chromosomes coding. In the proposed method, chromosomes are coded randomly based upon the allocated energy and SR such that all constraints should be satisfied.

Step 2: Decoding: In this step, binary values of each chromosome are decoded while real equivalent of energy production and SR procurement are calculated for all chromosomes.

Step 3: Feasibility checking: In this step, according to the allocated energy and SR for each chromosome, DC power flow will be executed considering two different conditions both for checking an overload. Firstly, it is considered that each unit will produce just the amount of its allocated energy. Secondly, it is considered that the allocated amount of energy as well as SR will be produced. Then for each chromosome according to the results of DC power flow, the number of violated transmission lines (n) can be determined.

Step 4: Fitness evaluation: In this step, the fitness value of each chromosome should be calculated. Some constrains associated with the optimization problem that has proper form, might be incorporated into the objective function as penalty function.

Step 5: Defining penalty factor: In this step, for those chromosomes which have violations, penalty term will be added to their costs (obtained from step 4). At first the overloaded lines will be specified and then a penalty term is calculated by using Eq. 11.

$$\text{Penalty} = \sum_{m=1}^{n}\left(1-2\times e^{-\frac{|P_m|}{\overline{P}_m}}\right)\times \text{Chromosome cost} \tag{11}$$

where, P_m is power flow of overloaded line m and $\overline{P}_m$ is its maximum power flow limit.

Step 6: Elitism: To prevent of missing the best chromosomes of present population after mating operators (selection, crossover and mutation), elitism is used (Reily *et al*., 2005). Hence, 5% of the present population with the best fitness will be selected as elites.

Step 7: Mating: The mating process consists of three operators: selection, crossover and mutation (Haupt and Haupt, 2004).

Step 8: Chromosomes modification: Since after mating process there are some chromosomes which do not satisfy problem constraints, in this step those chromosomes should be modified such that all constraints are satisfied.

Step 9: New population: At this step, the present population must be renewed. Five percent of new population is consisted of elites while 95% is consisted from the produced offspring.

Step 10: Convergence check: The end step will be terminated if the tour counter reaches the maximum predefined number of iterations and if it is not satisfied then it goes to step 2.

CASE STUDIES AND RESULTS ANALYSIS

The proposed methodology is implemented to a typical IEEE 30-bus test system (Fig. 2) with six generators. Generation data and system lines data are shown in Table 1-3. Forecasted demand curve for 24 h is shown in Fig. 3. SRR for each hour is considered as 10% of total demand in that hour. The response time for SR is assumed 10 min incorporated with Ten Minute Spinning Reserve (TMSR).

Applying SD method: Here, SD method is applied on the above mentioned test system. In SD method which is used in this study, lambda iteration technique is used for energy dispatch which is a suitable when cost functions are quadratic. On the other hand, a merit order technique is used for SR dispatch (Shahidehpour and Alomoush, 2001). The results of applying SD method on the IEEE 30-bus system are shown in Fig. 4.

As it is shown in Fig. 4, SD method cannot obtain a feasible pattern for energy production and SR procurement from 15 to 21 h. The exact values of the allocated energy and SR using SD method are shown in Table 4. In those hours, the maximum capacity of units A, E and F is allocated to energy, while units B, C and D according to their ramp up rate constraint cannot satisfy the SRR.

Applying JD method without transmission limit constraint: Here, proposed JD method is applied to the IEEE 30-bus system but transmission limit constraint is neglected. The solution methodology of JD without

Table 1: Generation data for IEEE 30-bus system

Unit	P_{max} (MW)	P_{min} (MW)	a	b	c	Ramp up rate (MW min^{-1})	TMSR price ($/MWh)
A	80	20	240	7.0	0.0065	1.0	3.2
B	155	20	260	10.4	0.0095	1.5	5.0
C	170	30	185	9.1	0.0085	2.0	4.7
D	145	20	255	8.0	0.0085	1.2	4.0
E	100	25	160	6.8	0.0065	1.7	2.0
F	110	35	180	6.6	0.0062	2.2	1.7

Table 2: The percentage of system load at each bus

Bus	Percentage	Bus	Percentage
1	0.00	16	1.24
2	7.66	17	3.18
3	0.85	18	1.13
4	2.68	19	3.35
5	33.20	20	0.78
6	0.00	21	6.18
7	8.05	22	0.00
8	10.50	23	1.13
9	0.00	24	3.07
10	2.05	25	0.00
11	0.00	26	1.24
12	3.95	27	0.00
13	0.00	28	0.00
14	2.19	29	0.85
15	2.89	30	3.74

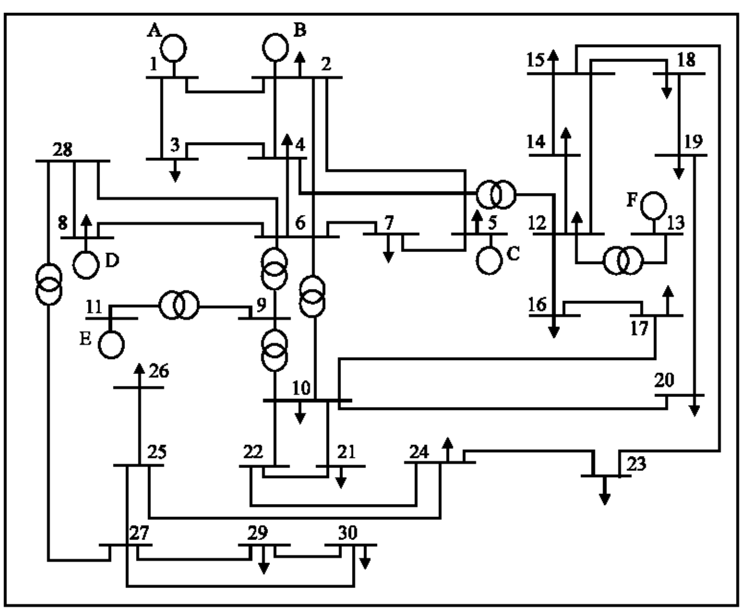

Fig. 2: IEEE 30-bus system

Table 3: Line data

From bus	To bus	Reactance	$\bar{P}_{ij}$ (MW)	From bus	To bus	Reactance	$\bar{P}_{ij}$ (MW)
1	2	0.0575	130	15	18	0.2185	16
1	3	0.1652	130	18	19	0.1292	16
2	4	0.1737	65	19	20	0.0680	32
3	4	0.0379	130	10	20	0.2090	32
2	5	0.1983	130	10	17	0.0845	32
2	6	0.1763	65	10	21	0.0749	60
4	6	0.0414	90	10	22	0.1499	32
5	7	0.1160	90	21	22	0.0236	32
6	7	0.0820	130	15	23	0.2020	16
6	8	0.0420	130	22	24	0.1790	32
6	9	0.2080	65	23	24	0.2700	16
6	10	0.5560	32	24	25	0.3292	16
9	11	0.2080	90	25	26	0.3800	16
9	10	0.1100	95	25	27	0.2087	16
4	12	0.2560	65	28	27	0.3960	65
12	13	0.1400	95	27	29	0.4153	16
12	14	0.2559	32	27	30	0.6027	32
12	15	0.1304	44	29	30	0.4533	16
12	16	0.1987	32	8	28	0.2000	130
14	15	0.1997	16	6	28	0.0599	32
16	17	0.1923	16				

Table 4: Allocated energy and SR to the units by using SD method from 15 to 21 h

	Hour						
Unit	15	16	17	18	19	20	21
A							
Energy (MW)	80	80	80	80	80	80	80
Reserve (MW)	0	0	0	0	0	0	0
B							
Energy (MW)	20	20	41.8056	46.0556	58.3333	52.1944	39.9167
Reserve (MW)	15	15	15	15	15	15	15
C							
Energy (MW)	51.1471	54.1471	123.1944	127.9444	141.6667	134.8056	121.0833
Reserve (MW)	20	20	20	20	20	20	20
D							
Energy (MW)	115.8529	118.8529	145	145	145	145	145
Reserve (MW)	12	12	0	0	0	0	0
E							
Energy (MW)	100	100	100	100	100	100	100
Reserve (MW)	0	0	0	0	0	0	0
F							
Energy (MW)	110	110	110	110	110	110	110
Reserve (MW)	0	0	0	0	0	0	0
SR requirement (MW)	47.7	48.3	60	60.9	63.5	62.2	59.6
Sum of allocated reserve (MW)	47	47	35	35	35	35	35

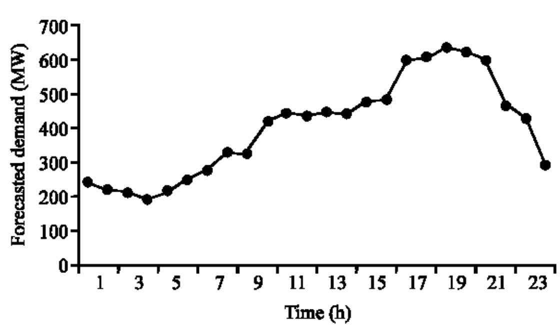

Fig. 3: Forecasted demand curve for 24 h

transmission limit is the same as the algorithm with transmission limit without considering step 3 and 5. The results of applying this method are shown in Fig. 5. The exact values for the allocated energy and SR to the units from 15 to 21 h are shown in Table 5. The obtained results show that when JD method is used, infeasibility problem is not happened.

Energy production and SR procurement costs at each hour are shown in Table 6 both for SD method and proposed JD method without transmission limit. Because SD cannot find a feasible solution for energy and SR dispatch from 15 to 21 h, therefore energy production and

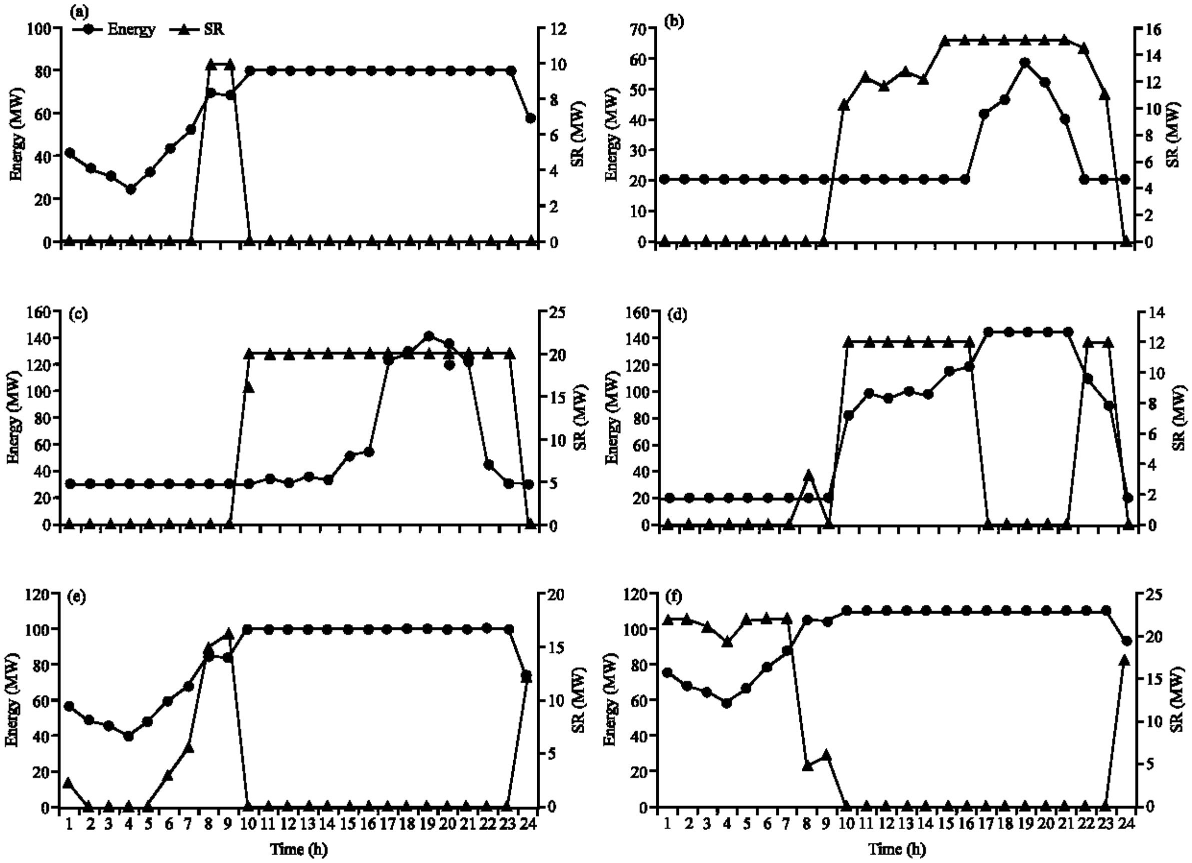

Fig. 4: Scheduling of energy production and SR procurement by using SD method, (a) generator A, (b) generator B, (c) generator C, (d) generator D, (e) generator E and (f) generator F

Table 5: Allocated energy and SR to the units by using JD method from 15 to 21 h

	Hour						
Unit	15	16	17	18	19	20	21
A							
Energy (MW)	80	80	80	80	80	80	80
Reserve (MW)	0	0	0	0	0	0	0
B							
Energy (MW)	20	20	53.7534	58.2408	78.5289	65.0935	51.5729
Reserve (MW)	0	0	14.9997	15	15	14.9999	15
C							
Energy (MW)	69.7326	76.3203	136.2469	141.6592	149.9711	149.1066	134.0272
Reserve (MW)	0	0	20	20	20	20	20
D							
Energy (MW)	132.9683	132.9797	133.0019	133.0006	133.0056	133.004	133.003
Reserve (MW)	11.9991	12	11.9981	11.9994	11.9944	11.996	11.9969
E							
Energy (MW)	86.2415	85.6993	100	99.6701	98.1161	99.0371	99.9995
Reserve (MW)	13.7585	14.3007	0	0.3299	1.8839	0.9629	0.0005
F							
Energy (MW)	88.0576	88.0007	96.9978	96.4293	95.3783	95.7588	97.3974
Reserve (MW)	21.9424	21.9993	13.0022	13.5707	14.6217	14.2412	12.6026
SR requirement (MW)	47.7	48.3	60	60.9	63.5	62.2	59.6
Sum of allocated reserve (MW)	47.7	48.3	60	60.9	63.5	62.2	59.6

SR procurement costs of those hours could not be calculated and shown by NF (not feasible). As shown in Table 6, energy production and SR procurement costs of the proposed JD method is lower than SD method except for 1-7 h that costs of both methods are equal.

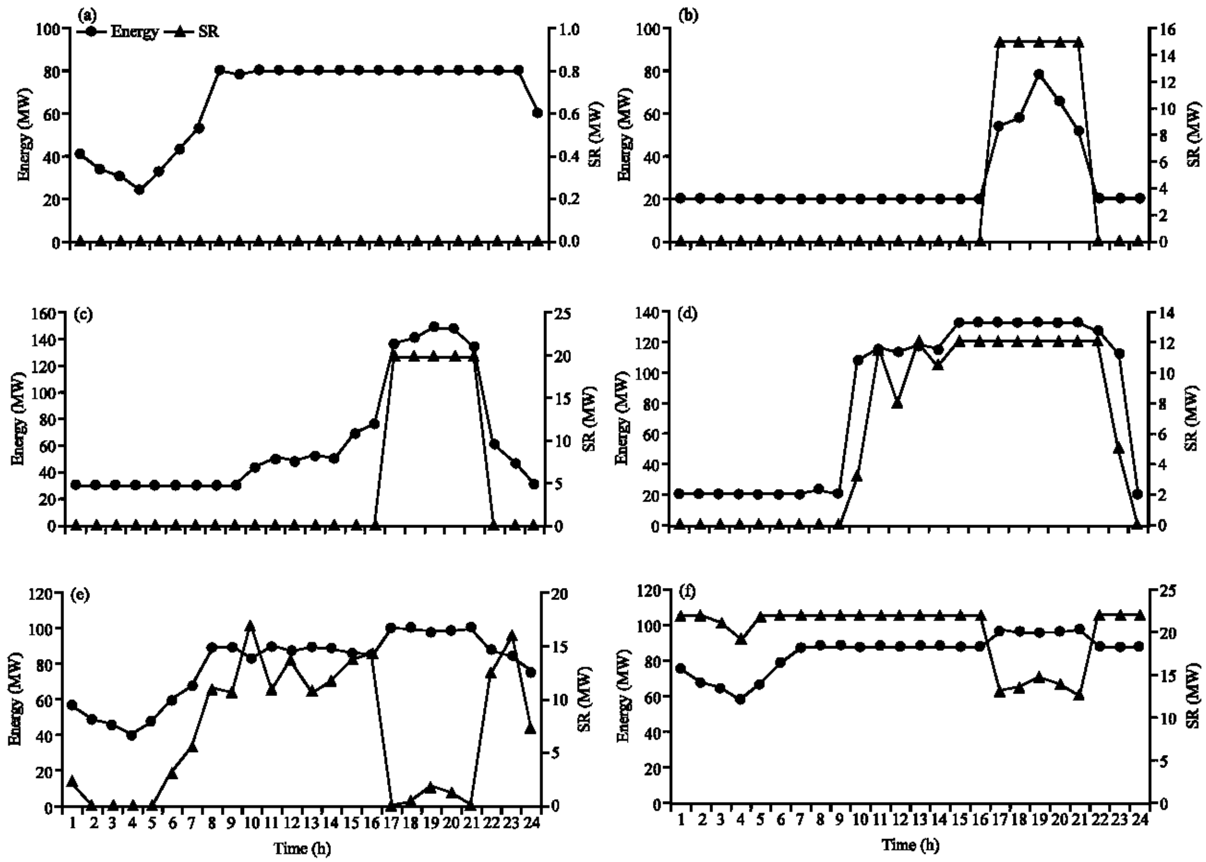

Fig. 5: Scheduling of energy production and SR procurement by using JD method without transmission limit, (a) generator A, (b) generator B, (c) generator C, (d) generator D, (e) generator E and (f) generator F

Table 6: Energy production and SR procurement cost

	Cost ($) of method	
Time (h)	SD	JD
1	3214.368	3214.368
2	3045.239	3045.239
3	2969.314	2969.314
4	2826.289	2826.289
5	3014.800	3014.800
6	3268.614	3268.614
7	3479.809	3479.809
8	3927.279	3907.452
9	3888.303	3873.492
10	4826.224	4785.752
11	5037.454	5002.118
12	4966.399	4929.728
13	5078.244	5043.621
14	5017.110	4981.409
15	NF	5360.188
16	NF	5424.886
17	NF	6762.708
18	NF	6870.703
19	NF	7188.477
20	NF	7028.259
21	NF	6714.995
22	5253.119	5221.851
23	4905.920	4867.880
24	3615.858	3614.606

Applying JD method with transmission limit constraint: Here, proposed JD method with transmission limit is applied on the IEEE 30-bus system. The results of applying this method are shown in Fig. 6. According to Table 3, maximum capacity of lines 9-11 and 12-13 which connect units E and F to the system are 90 and 95 MW, respectively. Therefore sum of the allocated energy and SR to these units should not be more than transmission limits of connection lines, otherwise bottling of reserve might be happened. By comparison between Fig. 5 and 6 it is shown that when transmission limit constraint is neglected, in the most hours sum of allocated energy and SR to units E and F is bigger than their connection transmission line limit but this problem was not happened in any hours when transmission limit is considered. In other word, these results show that the proposed JD method with transmission limit can prevent bottling of reserve in all hours.

In peak load hour, the allocated energy and SR to the units by using the proposed JD without/with transmission limit are shown in Table 7 for 19 h. According to these

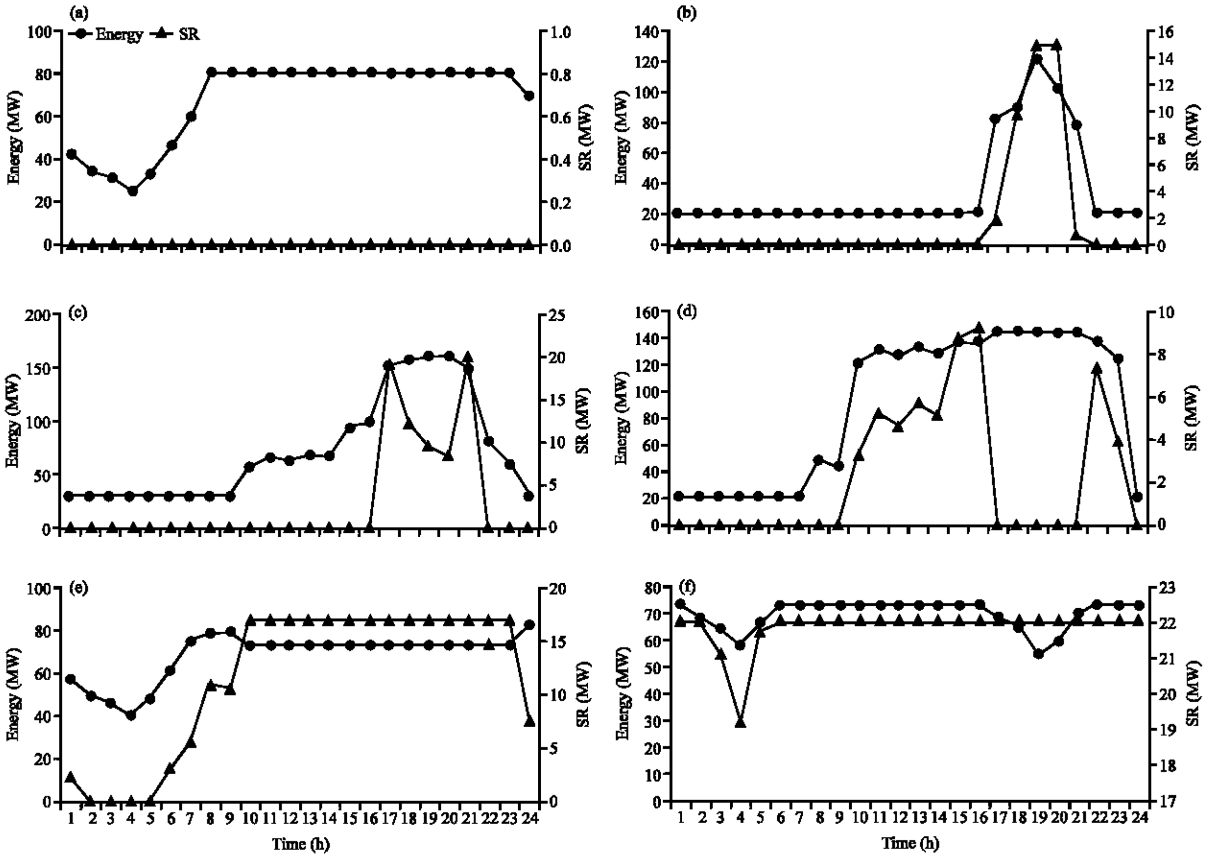

Fig. 6: Scheduling of energy production and SR procurement by using JD method with transmission limit, (a) generator A, (b) generator B, (c) generator C, (d) generator D, (e) generator E and (f) generator F

Table 7: Allocated energy and SR using JD method with/without transmission limit for peak load hour

	Without transmission limit		With transmission limit	
Unit	Energy (MW)	Reserve (MW)	Energy (MW)	Reserve (MW)
A	80.00	0.00	80.00	0.00
B	78.5289	15.00	121.5454	14.9985
C	149.9711	20.00	160.4985	9.5015
D	133.0056	11.9944	145.00	0.00
E	98.1161	1.8839	72.9999	17.00
F	95.3783	14.6217	54.9562	22.00

values, DC power flow is executed in two cases both with and without transmission limit. Firstly, it is considered that each unit will produce just the amount of its allocated energy. Secondly, it is considered that the allocated amount of energy as well as SR will be produced. Results of applying DC power flow are shown in Table 8 and 9, where, P_{ij}^{oe} is power flow from bus i to bus j only for energy production, P_{ij}^{ses} is power flow from bus i to bus j for sum of energy and SR and $\bar{P}_{ij}$ is transmission limit of this line.

As shown in Table 8 and 9, when energy and SR are dispatched without transmission limit, if generators tend to produce just their allocated energy, overload is happened in lines of 9-11 and 12-13. Also when they want to produce their allocated SR, overload is happened in lines of 12-15, 15-18 and 15-23 as well. By comparing Table 8 and 9, it is observed that this problem is solved by using the proposed JD method even having transmission line limits.

Total costs of energy production and SR procurement in 24 h is 113396.56 $ when transmission limits are neglected and it is 114825.11 $ when transmission limits are considered. It is seen that when transmission limits are considered, total costs is increased in about 1.26%. On the other hand, because of transmission limit it is impossible for the cheap generators (E and F) to use their maximum capacity for energy generation and SR procurement. Therefore, we must allocate more energy to the expensive generators in order to satisfy demand in all hours.

Table 8: DC power flow results for 19 h considering energy and SR pattern via JD method without transmission limit

From bus	To bus	$\bar{P}_{ij}$ (MW)	P_{ij}^{oe} (MW)	P_{ij}^{ses} (MW)
1	3	130	28.4825	30.1939
2	4	65	15.0719	17.5216
3	4	130	23.0850	24.2567
2	5	130	48.7851	51.7309
2	6	65	17.5485	20.5775
4	6	90	11.4930	14.1135
5	7	90	-12.0639	-10.2001
6	7	130	63.1814	66.4294
6	8	130	-50.2092	-54.0863
6	9	65	-13.0726	-10.5675
6	10	32	12.4275	14.2695
9	11	90	-98.1162	-100.0000
9	10	95	85.0435	89.4325
4	12	65	9.6459	8.9450
12	13	95	-95.3783	-110.0000
12	14	32	18.4307	20.6689
12	15	44	43.0974	48.7876
12	16	32	18.4137	21.8978
14	15	16	4.5242	5.3717
16	17	16	10.5397	13.2364
15	18	16	14.5547	16.9724
18	19	16	7.3792	9.0794
19	20	32	-13.8933	-14.3204
10	20	32	18.8463	19.7687
10	17	32	9.6533	8.9759
10	21	60	37.4945	40.6941
10	22	32	18.4594	19.9441
21	22	32	-1.7485	-2.4732
15	23	16	14.7154	17.0003
22	24	32	16.7109	17.4709
23	24	16	7.5399	9.1072
24	25	16	4.7563	5.1342
25	26	16	7.8740	8.6614
25	27	16	-3.1177	-3.5272
28	27	65	32.2642	35.5883
27	29	16	13.6024	14.9627
27	30	32	15.5441	17.0985
29	30	16	8.2049	9.0254
8	28	130	15.5499	16.9425
6	28	32	16.7143	18.6458

Table 9: DC power flow results for 19 h considering energy and SR pattern via JD method with transmission limit

From bus	To bus	$\bar{P}_{ij}$ (MW)	P_{ij}^{oe} (MW)	P_{ij}^{ses} (MW)
1	2	130	40.9291	40.6001
1	3	130	39.0708	39.3999
2	4	65	30.9574	31.3333
3	4	130	33.6733	33.4626
2	5	130	50.2585	57.8780
2	6	65	32.6526	34.4279
4	6	90	9.1632	15.1463
5	7	90	-0.0907	-4.0240
6	7	130	51.2082	60.2533
6	8	130	-59.6013	-53.4802
6	9	65	10.4377	2.1061
6	10	32	20.9765	19.6005
9	11	90	-72.9997	-89.9997
9	10	95	83.4375	92.1058
4	12	65	38.4495	30.9298
12	13	95	-54.9561	-76.9561
12	14	32	16.9510	19.2986
12	15	44	37.9276	43.9999
12	16	32	13.4445	16.9967

Table 9: Continued

From bus	To bus	$\bar{P}_{ij}$ (MW)	P_{ij}^{oe} (MW)	P_{ij}^{ses} (MW)
14	15	16	3.0445	4.0014
16	17	16	5.5705	8.3353
15	18	16	11.8515	14.2412
18	19	16	4.6760	6.3482
19	20	32	-16.5965	-17.0516
10	20	32	21.5495	22.4999
10	17	32	14.6225	13.8770
10	21	60	37.0543	40.9186
10	22	32	18.1702	20.0916
21	22	32	-2.1887	-2.2487
15	23	16	10.7692	13.5735
22	24	32	15.9815	17.8429
23	24	16	3.5937	5.6804
24	25	16	0.0806	2.0794
25	26	16	7.8740	8.6614
25	27	16	-7.7934	-6.5820
28	27	65	36.9399	38.6432
27	29	16	13.6024	14.9627
27	30	32	15.5441	17.0985
29	30	16	8.2049	9.0254
8	28	130	18.1453	17.5486
6	28	32	18.7946	21.0945

CONCLUSION

In this study, two general methods for energy and SR dispatch are presented. It is shown that SD method is not a proper technique for energy and SR dispatch because of two fundamental problems might be encountered. Therefore, in this study a new joint algorithm associated with a GA-based technique is proposed for energy and SR joint dispatch, while transmission line limit is considered. The results of applying the proposed method for scheduling a 6 unit show that the proposed method can offer a better solution in comparison with the sequential dispatch method. It is also shown that the proposed method can prevent happening the bottling of reserve problem and overload in the lines properly. Significant simulation results presents the effectiveness of the proposed methodology especially in a restructured electricity environment.

REFERENCES

Asadi, B.M., M. Rashidi-Nejad and M. Pourakbari, 2008. A modified sequential optimal dispatch for energy and spinning reserve in restructured electricity industry. International Conference on Power Control and Optimization, Chiang May, Thailand, Jul. 18-20.

Baskar, S., P. Subbaraj and M. Rao, 2003. Hybrid real coded genetic algorithm solution to economic dispatch problem. Comput. Elect. Eng., 29: 407-419.

Chen, J., J.S. Thorp, R.J. Thomas and T.D. Mount, 2003. Locational pricing and scheduling of an integrated energy-reserve market. Proceedings of the 36th Annual Hawaii International Conference on System Sciences (HICSS'03), Jun. 6-9, IEEE Computer Society, Washington, DC, USA., pp: 54-63.

Costa, A.L. and A.S. Costa, 2007. Energy and ancillary service dispatch through dynamic optimal power flow. Elect. Power Syst. Res., 77: 1047-1055.

Fotuhi-Firuzabad, M. and M. Rashidi-Nejad, 2004. Allocation of spinning reserve among generating units using a hybrid deterministic/probabilistic approach. Proceedings of the 2004 Large Engineering Systems Conference on Power Engineering (LESCOPE04), Jul. 28-30, Nova Scotia, Canada, pp: 81-87.

Haupt, R.L. and S.E. Haupt, 2004. Practical Genetic Algorithms. 2nd Edn., John Wiley and Sons, IEEE, New Jersey, ISBN: 0471671754.

Hazrati, N., M. Rashidi-Nejad and A. Gharaveisi, 2007. Joint energy and reserve dispatching in restructured power systems. Proceedings of the 2007 Large Engineering Systems Conference on Power Engineering, Montreal, Canada, Oct. 10-12.

Kothari, D.P. and J.S. Dhillon, 2004. Power System Optimization. PHI Learning Pvt. Ltd., India, ISBN: 8120321979.

Rashidi-Nejad, M., Y.H. Song and M.H. Javidi Dashti-Bayaz, 2002. Contingency reserve pricing via a joint energy and spinning reserve dispatching approach. Energy Conver. Manage., 43: 537-548.

Reily, U., T. Yu, R. Riolo and B. Worzel, 2005. Genetic Programming Theory and Practice II. Springer Science Business Media, USA, ISBN: 978-0-387-23253-9.

Shahidehpour, M. and M. Alomoush, 2001. Restructured Electrical Power Systems: Operation, Trading and Volatility. CRC Press, UK., ISBN: 082470620X.

Song, Y.H. and X.F. Wang, 2003. Operation of Market-Oriented Power Systems. 1 Edn., Springer, USA., ISBN: 1852336706.

Swarup, K.S. and S. Yamashiro, 2002. Unit commitment solution methodology using genetic algorithm. IEEE Trans. Power Syst., 17: 87-91.