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Optimum Reserve Capacity Assessment and Energy and Spinning Reserve Allocation Based on Deterministic and Stochastic Security Approach

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Abstract: In this paper a new algorithm for determination of optimal active power reserve capacity requirements and energy and spinning reserve allocation in power system during the 24 hours is presented. In the proposed method, the optimum amount of reserve capacity per hour is determined proportional to network security level required by the system operator. In this way, it is essential to define a proper index for measuring system security. Thus, we have used Expected Load Not Served (ELNS) to evaluate system security in each hour. The proposed method has been implemented over the IEEE 24-bus test system and the results are compared with a deterministic security approach, which considers certain and fixed amount of reserve capacity in each hour. This comparison is done from economic and reliability points of view. The promising results show the effectiveness of the proposed model which is solved using mixed integer linear programming (MILP) and GAMS software is used.

Key words: ELNS, Optimal Reserve Capacity, Spinning Reserve Allocation, System Security, VOLL.

Nomenclature

Parameters

N_g	Number of generating units.
N_l	Number of blocks of the piece-wise linearization of the cost function.
N_b	Number of buses.
N_c	Number of contingencies.
p_{gi}^{min}	Lower bound on p_{gi} in megawatts.
P_{gi}^{max}	Upper bound on p_{gi} in megawatts.
L_j	Demand at bus j.
F_l^{max}	Maximum Power flow on line l.
T_i^{on}	Minimum up time to ith unit.
T_i^{off}	Minimum down time of ith unit.
RR	Power ramp rate in megawatt per minute.
q_i	Rate in dollars per megawatt-hour offered by ith unit to provide spinning reserve.
$VOLL_j$	Value of loss load in bus j.
$ELNS^{max}$	Maximum expected load not served determined by system operator.
FOR	Forced outage rate of network elements.
$P_r(k)$	probability of contingency k.

Functions

$C_i(p_{gi})$	Cost function in dollars per megawatt-hour offered by the ith generating unit to produce $p_{gi.}$

Variables

p_{gi}	power output in megawatts of the ith unit.
R_{gi}	Spinning reserve in megawatts provided by ith unit
u(I)	Binary variable, which is 1 if the ith unit is committed and 0 otherwise.
$X_{ion}(t-1)$	Duration that ith unit was online till t-1
$X_{ioff}(t-1)$	Duration that ith unit was online till t-1
F_l	Power flow on line l.
$D_{k,t}(j)$	Amount of involuntary load shedding in bus j as contingency k.

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ELNS	Network expected load not served.

Indices

I	Index of generators running from 1 to N_g
j	Index of buses running from 1 to N_b
l	Index of transmission lines running from 1 to N_l
k	Index of contingencies running from 1 to N_c
t	Index of times running from 1 to 24

INTRODUCTION

In recent years, extensive structural changes have occurred in the power system operation and planning; known as power system restructuring or deregulation. These changes introduced new chalenges in operation of deregulated power systems; since security and reliability are two important factors in operation of power system, so they need more attention and should be reviewed with considering the new structure of power networks and creating competitive markets for purchasing and selling the electricity energy. In general, power system security is provided by ancillary services. Among them, spinning reserve has significant role in providing system security after failure of power plant units or transmission lines (Kirschen, D. and G. Strbac, 2004).

One of the common methods to determine total or partial network power reserve capacity is deterministic method. In this method, the reserve capacity is often assumed to be equal to the largest power plant capacity in the network or considered area (Baughman, M.L., 1997); Baughman, M.L.,1997. For the sake of simplicity and computing speed of this method, many system operators such as REE in Spain and IESO in Ontario use it to determine their required power reserve capacity (http://www.ieso.com; www.ree.es.). Although this method is much faster and easier, it has some disadvantages like non-optimality of considered reserve capacity which may be less or more than network requirement. If it is less than network requirements, when system faces with its power plants or transmission lines failure, due to lack of reserve capacity, the operator has to shed involuntary load; this caused the system security reduced. Vice versa, considered reserve capacity may be more than the network requirements, this cause an unnecessary increase in network operation cost, so network social welfare decreases.

More over, although security of the system increases by increasing the amount of reserve capacity or spinning reserve considered in the system, providing spinning reserve imposes costs to the system. In other words, by purchasing a spinning reserve, safety and security of the system will increase, but simultaneously the system cost would increase. Thus, it is essential to equilibrate these two important quantities to reach an optimal point. Accordingly, Kirschen (2002) suggested that power system security analysis methods should evaluate the credibility of failures and their expected consequences by means of probabilistic methods. Since the outages are random unpredictable events, their probabilistic nature should be included in the optimization process. To achieve this purpose, the stochastic security approach is used. Unlike the deterministic security approach, the amount of active power reserve capacity is not definite and predetermined, but it assessed according to level of network security set by system operator. In (Arroyo, J.M. and D. Galiana, 2005), pricing of energy and reserve and their allocation among network generation units is done with full security constraint. This means that the amount of active power reserve capacity is determined in a way that if any single contingency (such as generation units or transmission lines outage) happens in the system, no load shedding will be occurred. In (Bouffard, F., 2005; Bouffard, F., 2005), pricing of energy and reserve and their allocation in each bus is done based on stochastic security approach. In these papers, the first step to determine optimum amount of security is to calculate system expected load not served (ELNS) in each period. Probability of each contingency is calculated based on network elements forced outage rate (FOR). In the second step, system value of loss load (VOLL) is allocated to the ELNS index as a load shedding cost. Their objective function is sum of cost of power production, reserve providing and load shedding. In this way, the optimum amount of the system security (ELNS value) is determined.

The model proposed in (Arroyo, J.M. and D. Galiana, 2005), may become infeasible due to lack of enough generation capacity. In other words, after occurrence of a contingency, there may be situation in which not all of network loads are supplied even when all generatin units are committed for producing energy. Moreover, probability of different contingencies has not been considered; this could result in unnecessary increase in system operation cost. In the algorithm presented in (Bouffard, F., 2005; Bouffard, F., 2005), value of security index (ELNS) is one of the goals of models and its optimal amount is achieved from solving the optimization problem. However, in operation of power network, security and reliability of the system have an outstanding importance that even if it result to impose an extra cost, the acceptable security level should be provided.

In this paper, a model for determining the optimum active power reserve capacity and allocating the energy and spinning reserve among the units in both deterministic and stochastic security approach is presented and the results are compared from economic and reliability points of view. In the first case, system reserve capacity is determined according to the deterministic security approach criteria in which a fixed amount of reserve capacity is considered in each hour. In the second case, system reserve capacity is determined according to the stochastic security approach criteria in which the predefined amount of ELNS is applied as one of the optimization problem constraint. In other words, in the second case, the amount of network ELNS is set by the system operator and then the optimum amount of spinning reserve that should be provided by each power plant is determined based on it. In comparison with (Arroyo, J.M. and D. Galiana, 2005; Bouffard, F., 2005; Bouffard, F., 2005), the proposed algorithm in this paper has more flexibility and it is able to solve the problem with different amount of ELNS set by operator. Furthermore, with keep this in mind that system security and reliability has priority to system operation cost, in the proposed algorithm the cost of system operation is calculated as a function of system security and its ELNS value.

Moreover, the algorithm proposed in this paper has the ability to review the role of VOLL in the system security and the allocation of load shedding in different buses. For this purpose, after determining the optimum amount of system active power reserve capacity, the amount of system ELNS and activated spinning reserve is calculated and compared in two different manners:

- The VOLL amount is less than spinning reserve cost
- The VOLL amount is more than spinning reserve cost

Also the allocation of load shedding in system buses is carried out in two different manners:

- The amounts of VOLL in system buses are equal
- The amounts of VOLL in system buses are different

The first case illustrates the allocation of load shedding based on technical issues while in the second case, in addition to technical issues, economic factors are also considered.

In section 2, the proposed algorithm formulation for both deterministic and stochastic approaches is presented and it more illustrated by relevant flowcharts in section 3. Section 4, presented data and results from IEEE 24-bus reliability test system over 24-hours horizon. In section 5, the main conclusions are summarized.

The Proposed Algorithm:

Assumptions considered in the proposed algorithm are:

1. Amount of load in each bus is constant and not affected by the energy price changes.
2. Energy and reserve are traded in power pool structure and bilateral contracts are not included.
3. Spinning reserve comes into operation in 10 minutes.
4. Power losses in transmission lines are neglected.

In the proposed algorithm, first the unit commitment (UC) with the aim of minimizing total cost and satisfying all network constraints is solve in order to determine the on/off status of generators and their power production. Since only the spinning reserve is considered in this algorithm and because no new units can be started and committed to the network in 10 minutes, so the on/off status of generators and their power production in each hour is supposed to be fixed. Hence, any changes in the amount of power produced by each generator are considered as spinning reserve provided by that generator. In the second step, in each hour, all the single probable contingencies are applied; for each contingency the DC-OPF program is run in order to determine the amount of reserve provided by each generator and load shedding in each bus. The formulation of the algorithm describes as following.

The objective function of UC in each hour is to minimized total generation cost.

$$Min\left\{\sum_{i=1}^{N_g} C_i^t(p_{g_i})\cdot u_i^t\right\} \tag{1}$$

The electricity power cost function for the generating unit in each hour is usually defined by quadratic function as follow:

$$C_i^p(t) = a_i p_i(t) + b_i p_i^2(t) + c_i u_i(t) \tag{2}$$

The cost function in (2) can be accurately approximated by a set of tangent lines as shown in Fig.1. The analytic representation of this linear approximation is as follow:

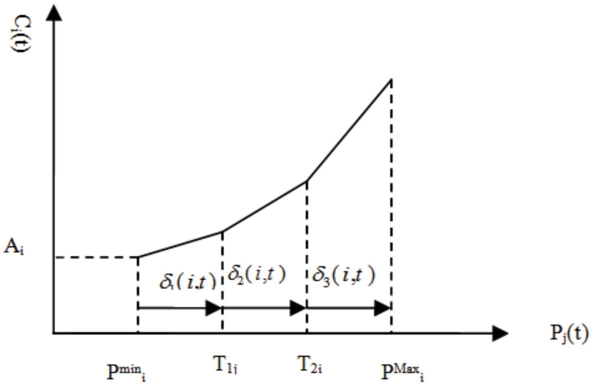

Fig. 1: Piece-wise linear approximation of cost function

$$C_i^p(t) = A_i u_i(t) + \sum_{m=1}^{NL_i} F_{mi}.\delta_m(i,t) \tag{3}$$

$$p_i(t) = \sum_{m=1}^{NL_i} \delta_m(i,t) + P_{\min} u_i(t) \tag{4}$$

$$\delta_1(i,t) \le T_{1i} - P_{\min_i} \tag{5}$$

$$\delta_m(i,t) \le T_{mi} - T_{m-1_i} \tag{6}$$

$$\delta_{NL_i}(i,t) \le P_{\max_i} - T_{NLJ-1} \tag{7}$$

Where F_{mi} denotes the slope of the cost curve in block m and $A_i=a_i.P_{\min}+b_i.P^2_{\min}+c_0$ is the cost at the point $p_i^{\min}$.

The UC problem is subjected to:

$$\sum_{i=1}^{N_g} P_{g_i} - \sum_{j=1}^{N_b} L_j = 0 \tag{8}$$

$$-F_l^{\max} \le F_l \le F_l^{\max} \tag{9}$$

$$P_{g_i}^{Min} \le P_{g_i} \le P_{g_i}^{Max} \tag{10}$$

$$-RR \times 60 \le P_{g_i}(t) - P_{g_i}(t-1) \le RR \times 60 \tag{11}$$

$$\left[T_i^{on}-X_i^{on}(t-1)\right]\times\left[u_i(t)-1\right]\geq 0 \tag{12}$$

$$\left[T_i^{off}-X_i^{off}(t-1)\right]\times\left[1-u_i(t)\right]\leq 0 \tag{13}$$

Unit commitment constraints will be completed by considering the reserve capacity criteria into the model. As mentioned, in deterministic approach, amount of reserve capacity is often considered equal to the largest generating unit capacity. Thus the reserve capacity constraint in deterministic approach is as follow:

$$\sum_{i=1}^{N_g} P_{g_i}^{\max} = \sum_{j=1}^{N_b} L_j^t + 400 \tag{14}$$

However in the stochastic approach, the amount of reserve capacity is determined proportional to desire network ELNS. Thus the reserve capacity constraint is modeled by the following equations:

$$\sum_{i=1}^{N_g} P_{g_i}^{\max} = \sum_{j=1}^{N_b} L_j^t + cap(t) \tag{15}$$

$$cap(t)=\frac{Max_k\left\{\sum_{j=1}^{N_b} d_{k,t}(j)\right\}+Min_k\left\{\sum_{j=1}^{N_b} d_{k,t}(j)\right\}}{2} \tag{16}$$

In (15) and (16), cap(t) reflects the amount of considered reserve capacity in each hour. In order to calculate the amount of load shedding in each hour, after fixing the on/off status of generating units and their power production, a DC-OPF problem is solved for all single contingencies. Because of fixing the $u_i(t)$ and $p_{gi}(t)$, decision variables are $R_{gi}(t)$ and $d_j(t)$; where R_{gi} and d_j represent the spinning reserve and load shedding respectively. The associated objective function and its constraints are presented by equations 17-21.

$$Min\left\{\sum_{i=1}^{N_g}\left[C_i(P_{g_i})+R_{g_i}\cdot q_i\right]\times u_i+\sum_{j=1}^{N_b} d_j\cdot VOLL_j\right\} \tag{17}$$

$$\sum_{i=1}^{N_g}\left(P_{g_i}^t+R_{g_i}^t\right)+\sum_{j=1}^{N_b} d_j^t=\sum_{j=1}^{N_b} L_j^t \tag{18}$$

$$d_j^t\leq L_j^t \tag{19}$$

$$P_g^{\min}\leq P_g\leq P_g^{\max}-R_g \tag{20}$$

$$-F_l^{\max}\leq F_l\leq F_l^{\max} \tag{21}$$

By determination of load shedding value, in order to calculate ELNS, we need to have the probability of each contingency, which is estimated based on network elements' FOR. FOR is probability of elements failure and calculated based on the statistical data of that element; by means of following equation:

$$FOR = \frac{MTTR}{MTTR + MTTF} \tag{22}$$

Where MTTR is mean time to repair and MTTF is mean time to failure. The probability of each contingency is then determined as follow:

$$\rho_r(k) = \frac{FOR_k}{1 - FOR_k} \cdot \prod_{i=1}^{N_c} \left(1 - FOR_k\right) \tag{23}$$

Finally ELNS in each hour is determined as follow:

$$ELNS_t = \sum_{k=1}^{N_c} \left\{ \rho_r(k) \times \left[\sum_{j=1}^{N_b} d_t(k,j) \right] \right\} \quad ; \forall t \in T \tag{24}$$

The obtained ELNS is compared with target value ($ELNS^{max}$) which is defined prior by the operator. If it is greater than $ELNS^{max}$, the amount of system reserve capacity will be increased based on equation (16) and then unit commitment and DC-OPF problems are resolved with modified cap(t) value. This process is repeated till the ELNS value becomes less than $ELNS^{max}$.

Methodology of Implemention:

ELNS calculation as one of the optimization constraint is shown by flowchart diagram in Fig.2.

Methodology of implementation the proposed Algorithm for deterministic security approach and stochastic security approach are shown in Fig.3 and Fig.4 respectively.

Fig.4 illustrates that in stochastic approach, the amount of network ELNS is compared with $ELNS^{max}$; if network ELNS is more than $ELNS^{max}$, reserve capacity will increase based on equation (16) and then again network ELNS will be calculated till its amount became less than $ELNS^{max}$.

IEEE-RTS Case Study:

Here the proposed algorithm is tested over the IEEE 24-bus test system (The IEEE Reliability Test System, 1996) for both deterministic and stochastic security approach. This network is chosen due to its similarity to a real network. It contains 32 generators and 34 transmission lines that all their parameters and load information are given in (The IEEE Reliability Test System, 1996). Value of parameters a_i, b_i, c_{0i} in equation (2) and parameter q in equation (17) are adopted from (Wang, J., 2003). In this section the result of implementation the proposed algorithm in both deterministic and stochastic approach for 3 amounts of ELNS is presented. The results are compared from economic and reliability points of view in order to determine the optimal approach. After determining the optimal approach, the effect of VOLL in system performance is reviewed.

Economic Point of View:

The amount of considered reserve capacity in deterministic approach and required reserve capacity in stochastic approach per hour and for 3 different amounts of ELNS are given in table (1). In presented tables in this section, column named by 1 refers to deterministic approach and column named by 2 refers to stochastic approach

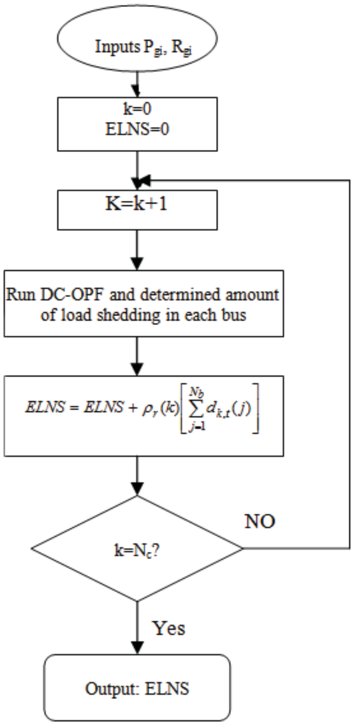

Fig. 2: ELNS calculation flowchart

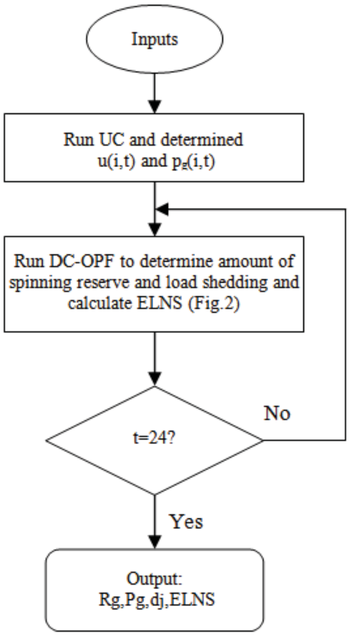

Fig. 3: Algorithm flowchart in deterministic approach

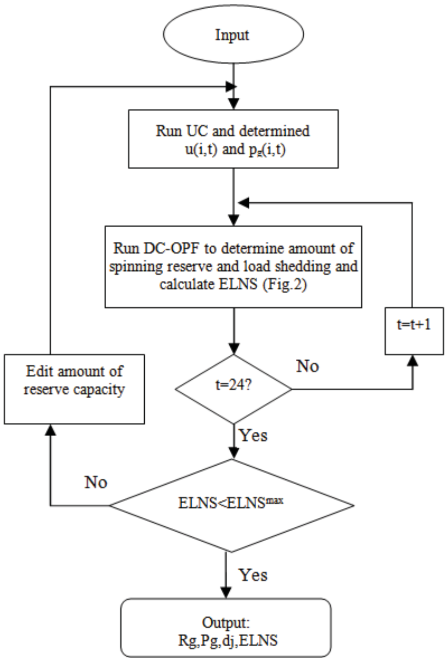

Fig. 4: Algorithm flowchart in stochastic approach

Table 1: Capacity requirement in 24 hours [MW]

	ELNS=0.5		ELNS=1.5		ELNS=15	
	1	2	1	2	1	2
1	400	583	400	466.4	400	161.4
2	400	364.9	400	364.9	400	145.9
3	400	56.3	400	56.3	400	0
4	400	295.1	400	295.1	400	248.3
5	400	260.6	400	260.6	400	260.6
6	400	137.5	400	137.5	400	46
7	400	318	400	318	400	271.5
8	400	468.1	400	468.1	400	345.3
9	400	461	400	461	400	379.6
10	400	448.6	400	448.6	400	373.1
11	400	466.3	400	466.3	400	390.7
12	400	448.6	400	448.6	400	373.3
13	400	479.2	400	479.2	400	408.3
14	400	397.7	400	397.7	400	331.7
15	400	287.2	400	287.2	400	287.2
16	400	248.7	400	248.7	400	248.7
17	400	287.3	400	287.3	400	287.3
18	400	368.4	400	368.4	400	302.3
19	400	453.8	400	453.8	400	367.3
20	400	483.2	400	483.2	400	412.9
21	400	513.5	400	513.5	400	367.1
22	400	466.7	400	466.7	400	344.8
23	400	536.4	400	536.4	400	452.9
24	400	521.9	400	521.9	400	521.9
total	9600	9235.6	9600	9352.2	9600	7328.4

Table (1) shown that as expected, in stochastic approach the amount of required reserve capacity is fully imitate the system ELNS value; with increasing ELNS (or decreasing system security), the amount of require reserve capacity will decrease, but in deterministic approach the amount of considered reserve capacity is constant and does not follow the ELNS values. So in deterministic approach in some cases system may face with surplus of reserve capacity; this lead to unnecessary commitment of some generating units in order to provide the extra capacity, in which not only increase the system operation cost, but also wear out the network equipment and could made some problems in system maintenance schedule. In order to review this problem, number of generators committe to network in both approaches during 24-hour are present in table (2). Numbers given in the table (2) are calculated as follow:

$$\sum_{i=1}^{N_g} u(i,t) \qquad (25)$$

Table 2: number of committed generators

	ELNS=0.5		ELNS=1.5		ELNS=15	
	1	2	1	2	1	2
1	15	15	15	15	15	15
2	15	15	15	17	15	15
3	16	17	16	16	16	15
4	16	19	16	18	16	17
5	16	19	16	18	16	17
6	18	19	18	18	18	18
7	19	20	19	21	19	18
8	25	22	25	22	25	19
9	27	23	27	24	27	21
10	27	26	27	27	27	25
11	28	26	28	28	28	24
12	27	25	27	25	27	24
13	22	24	22	24	22	23
14	22	22	22	21	22	21
15	22	22	22	21	22	21
16	21	22	21	21	21	21
17	21	22	21	21	21	21
18	22	22	22	21	22	22
19	27	22	27	23	27	26
20	27	27	27	26	27	27
21	27	26	27	24	27	25
22	25	25	25	23	25	23
23	23	23	23	21	23	19
24	18	18	18	18	18	18
total	523	521	523	513	523	495

Table 2 clearly illustrates that in first approach number of committed generators is independent of network ELNS value. However in second approach it affected by ELNS value.

Moreover, in table (3), daily system operation cost are shown and compared for both approaches. To calculate the operation cost, equation (26) is used:

$$Cost = \sum_{t=1}^{T} \sum_{i=1}^{N_g} C_i^t (P_{g_i}) \cdot u(i,t) \qquad (26)$$

Table 3: System operation COST ($)

	ELNS=0.5		ELNS=1.5		ELNS=15	
	1	2	1	2	1	2
cost	82273	82242	82273	81747	82273	80345

Tables (1-3) clearly prove that from economic point of view, the stochastic security approach is much better than deterministic approach.

Reliability Point of View:

In power system planning, not only an economic criterion is mentioned but also system security and reliability is considered. In deterministic approach, as mentioned, the amount of reserve capacity is determined regardless the required security (defined by ELNS), this may lead to some limits in providing spinning reserve and security. In other words, ELNS value could reduce to a certain amount that in the tested system it is equal to 0.123. Now if system operator asks for more security (ELNS less than 0.123), due to lack of reserve capacity, it is not possible to meet the operator request. However, if operator asks for less security (ELNS more than 0.123), an inelastic nature of this approach leads to surplus of reserve capacity which cause an extra cost.

But in stochastic security approach, reserve capacity is determined proportional to amount of ELNS set by operator. Thus, both two problems mentioned in former approach are solved. In order to examine this, the amount of used reserve capacity and network security (ELNS values) are depicted in Fig.5 and Fig.6 for 10 iterations based on methodology presented in Fig.4. These two figures clearly illustrate the relation between spinning reserve and system ELNS values.

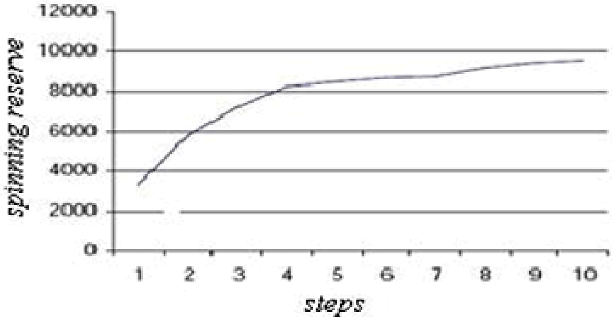

Fig. 5: Spinning reserve curve

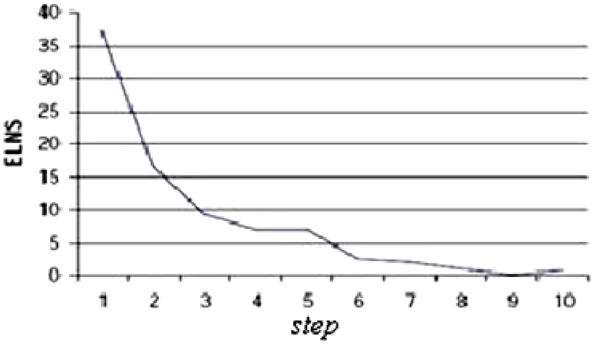

Fig. 6: ELNS curve

From what discused in this section, it is concluded that from reliability point of view, the stochastic security approach is better than deterministic one, too. Hence it is suggested that it is better to use the stochastic approach than the deterministic approach. Accordingly in the next sections, this approach is applied.

Energy and Spinning Reserve Allocation:

The allocation results for energy and spinning reserve in peak hour is reported in table (4). The spinning reserve values are obtained for failure of 23rd generating unit. It is supposed that ELNS is set equal to 0.5.

The Role of VOLL:

Another important factor which is considered in the proposed algorithm and has a determining role in a rate of spinning reserve activation and allocation of load shedding is value of loss load (VOLL). In order to examine effects of the VOLL, different senarioes are applied over the proposed algorithm. In the first senario, it is supposed that the VOLL values in tested system buses are less than spinning reserve cost. In this case, in order to minimize the cost of system, proposed algorithm prefer to shed the load instead of activate spinning reserve, thus ELNS value will reach to its maximum allowed amount. Vice versa, in the second senario the VOLL values considered to be more than spinning reserve cost. In this case, for the sake of minimizing the cost of system, proposed algorithm prefers to activate spinning reserve instead of sheddind the load, so ELNS value will be much lower than its amount in first senario. In this way, the low amounts of VOLL are considered as they presented in table (5) and the high amounts of VOLL supposed to be 1000 times greater than amounts in table (5). Also it is supposed that the maximum amount of ELNS set by operator is 15.

Table 4: Energy and reserve allocation

Generator ID	P_g	R_g
1	0	0
2	16	0
3	76	0
4	76	0
5	16	0
6	0	0
7	76	0
8	76	0
9	50	50
10	50	50
11	50	0
12	111.7	85.3
13	69	121
14	103.3	93.7
15	2	0
16	2	0
17	2	0
18	2	0
19	2	0
20	155	0
21	155	0
22	400	0
23	400	0
24	50	0
25	50	0
26	50	0
27	50	0
28	50	0
29	50	0
30	155	0
31	155	0
32	350	0

Table 5: VOLL value in each bus

Bus number	VOLL($/MWh)
1	2
2	1.85
3	1.6
4	2
5	2.75
6	1.5
7	1.65
8	1.03
9	1.5
10	2.2
11	3.1
12	1.65
13	1.9
14	0.95
15	3.2
16	2.5
17	2.05
18	1.5
19	1.5
20	2.3
21	1.58
22	2.6
23	2.3
24	1

In Fig.7 the amounts of ELNS during 24-hour operation for both senarios are shown

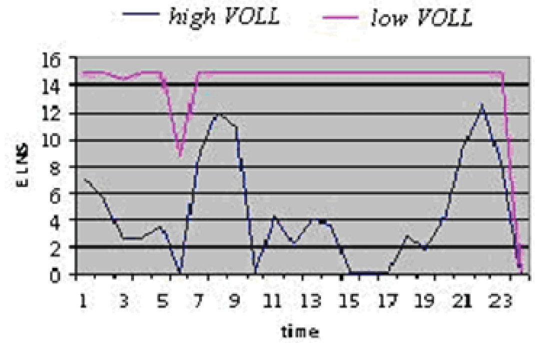

Fig. 7: ELNS curve for low and high value of VOLL

The amount of activated reserve in both senarios is represented in Fig.8.

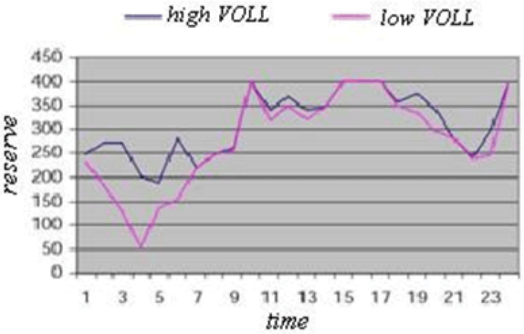

Fig. 8: Reserve curve for low and high value of VOLL

Moreover, the amount of load shedding in each bus can be affected by the VOLL in that bus. The proposed algorithm has this ability to consider the value of VOLL in each bus in order to impose minimum cost to system if it is necessary to shed loads. In this way, load will be shed in buses with lower VOLL value. For examine this matter, two more senarios defined. In the first senario, it is supposed that the amounts of VOLL in all buses are the same and equal to 1[$/MWh] and in the second senario the VOLL values supposed to be equal to amounts presented in table (5). Results are shown in Fig.9. In this figure column chart shows the amount of load shedding in each bus in peak hour as a result of all single contingency occurrence for two different defined senarios. In other words Fig.9 expresses that when just technical issues is concerned, load shedding will be done like blue column; but when economic issue is applied simultaneously, the load shedding will be done like red column.

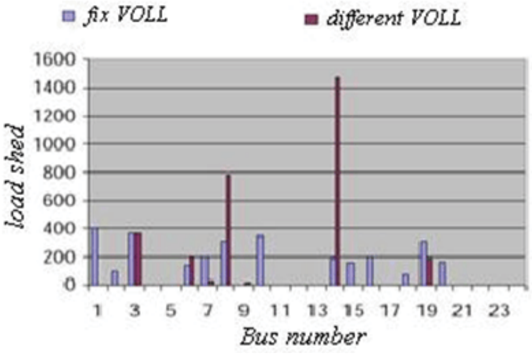

Fig.9- load shedding in each bus for different VOLL values

Conclusion:

In this paper an algorithm for determination of optimum amount of active power reserve capacity and allocation of energy and spinning reserve with considering the system security constraint is presented. In the proposed algorithm, all the system constraints such as demand and production equilibrium, generators production limits, Ramp-rates, minimum up/down times, transmission lines capacity, system security and reserve capacity are considered. In order to determine generator power production, we use UC and for determination of spinning reserve provided by each generator and amount of load shedding in each bus, DC-OPF is used. In order to assess system security, a probabilistic model is developed. Probability of each contingency is calculated based on equipment FOR values.

In this paper, active power reserve capacity is assessed based on deterministic and stochastic security approaches and ELNS as a security index is used to assess system security and reliability.

By comparing these two approaches from economic and reliability points of view, it is determined that the stochastic approach is better than the deterministic one. Finally the effects of VOLL are studied in the proposed model.

In the proposed algorithm, optimum system condition with aim of minimizing system cost and load shedding is achieved. Thus it can be used as a guideline for system operator in order to harness the system when probable contingencies occures.

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