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Investigating New Method for Power Reservation by Multi Objective Optimization and Considering Risk Factor

Farhad Abolhasani[1], Alireza Sedaghati[2]
[1]MS student of Electrial Engineering, Shahabdanseh Institute of Higher Education, Qom,Iran
[2]PhD in Electrial Engineering, Shahabdanseh Institute of Higher Education, Qom,Iran

***Abstract*— The ancillary services market is formed alongside the energy market and the transmission lines market due to the growing need and importance of ancillary services the most important of which is reserve. Determining the amount of reserve and how it functions and the ancillary services market settlement is one of the most important discussions in the field of ancillary services. There are, in general, two major ways for reserve and energy settlement. The first method is to settle the ancillary services one by one and successively with the energy market. The second method is to examine the market for ancillary services simultaneously and simultaneously with an energy market. In this study, after studying the principles of this method, we examine its function. In general, despite the advantages of the second method, due to its complexity, few studies have been done in this regard. Also, consideration of risk criteria in the mechanism of providing, designing and the simultaneous settlement of reserve and energy markets is also extremely important.**

***Keywords* — Multi Objective Optimization, power market, Risk factor, power reservation**

I. INTRODUCTION

Electricity is an important option in the development and development of a modern society. Typically, everyday life issues involve the use of electrical energy and the performance of electricity companies in the field of servicing this product to consumers. The optimal and suitable level of servicing of power companies is measured by the level of quality and reliability of electrical energy provided to consumers.

Establishing a balance between "the consumers' need for good quality electrical energy and uninterruptible power supply" and "the cost that buyers or consumers can pay for this type of electrical energy" is always associated with many problems. Since the growth of the load and output of equipment in the power system is a probabilistic phenomenon, there is the possibility of such equipment being removed from the system at any time. Therefore, the output of the equipment in the system can't be completly eliminated, but the power system can be designed and operated with a high level of reliability, and the equipment and the load interruption in the system can be reduced.

Designing and operating a power system with a high level of reliability requires the consideration of a series of reserve capacity in the system to cover the effect of the output of a production unit or a transmission line in the system.

Calculating the reserve using the definitive indices of the largest unit in the circuit is a percentage of the peak load, or a combination of these two cases. Considering that the minimum reserve requirement for a different area of operation is different, it is calculated separately for each region. Definitive indicators have many uses because of their simple and rational computation, and in most power systems in the world, such indicators are used. But due to the randomness of the elements of power systems, the equipment is always subject to probable events. Definitive methods to determine the reserve don't consider the probabilistic nature of the behavior of power systems and equipment in this system, therefore, the probabilistic method is used to solve the problem.

The probability indicators that are used to determine the amount of reserve required in the system, in addition to the benefits expressed, considering the random nature of the elements in the power system, are facing with problems such as the lack of accurate statistical information and the function of the elements and the actual curve of the system's load, and the high volume of computations, and these to some extent make it impossible the practical use of these methods to determine the amount of reserve required in the system. For this reason, many electricity companies are looking to use definitive methods at any moment to determine the amount of reserve required by the system in addition to calculating probabilistic indexes. Therefore, they combine probabilistic methods and definitive methods and use it as a technique in the form of deterministic / probabilistic measures to keep the system risk less than possible and predetermined risk At all times.

II. MODELING

The objective is to provide a new method for simultaneous settlement of energy and reserve based on cost / benefit analysis taking in to account the risk factor.

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Reducing investment and low production margin will reduce the reliability of the power system, while increased investment and high operating costs will lead to a non-economic decision. In order to increase economic efficiency and optimize the reliability of the power system, we need to analyze the cost / benefit of the money earned by improving system reliability and the costs incurred to make this improvement.

A. Load interruption algorithm

Generally, in power systems, when the load in the system is higher than the ready-made energy in the system, the system suffers from a lack of production, and when there is no effort to overcome this problem, in the most optimistic mode, the load of A number of consumers will be interrupted. However, in the most pessimistic mode, the system suffers from a loss of frequency and voltage, and if this frequency and voltage reduction is not compensated, the rate of decrease will increase and eventually can cause blackout in the system. Therefore, in order to protect the system against the blackout phenomenon, it is necessary to consider sufficient storage in the system as well as a load interruption algorithm for the system. The load interruption algorithm helps to interrupt the loads of consumers who in such circumstances prefer to disconnect their consumption before they a heavy sum for power supply. This algorithm helps to reduce and limit the costs caused by of consumers load interruption. Considering the above issues and assuming that consumers of electrical energy demand different levels of reliability considering the importance of load consumption, they make reserving in the power system somewhat difficult. Because providing the same reliability is not economical for all of them, and, on the other hand, calculating the load-interruption algorithm in the system must be fair and in accordance with the demand for reliability of consumers. Therefore, assuming that consumers loads can be interrupted independently of each other, and given the differentiation of reliability levels for them, the risk of load interruption can be determined in such a way that:

$$ECOST = \min \sum_{i=1}^{N} VOLL * EENS_i \qquad \sum_{i=1}^{N} EENS_i = EENS \tag{1}$$

Where, N is the total number of consumers in the desired load area.

B. The proposed algorithm for determining the spinning reserve and resolution of the energy and spinning reserve

Spinning Reserve is one of the most important ancillary services that are purchased to maintain reliability and response to various advances in the power system. Although there's plenty of spinning reserve on the power system will increase the reliability of the system, but the purchase of this product will be very expensive. In general, definitive methods for providing spinning reserve in the power system will not eventually lead to economical results, and examples of such deterministic measures are the capacity of the largest production units or a percentage of the system's load as a spinning reserve.

In contrast to the methods, the probabilities based on recursive calculations are abundant and do not consider the economic criteria well. Examples of such methods are methods based on calculating LOLP. Here, a new method is proposed for simultaneously analyzing the energy market market and reserve based on cost / profitability analysis. Generally, cost / profitability analysis methods will lead to economic responses. These methods purchase this type of reserve based on analyzing the cost of purchasing a spinning reserve and the profit from the presence of this type of reserve. Therefore, methods based on this kind of analysis are expected to eventually lead to economic solutions. References [15], [16], and [17] have proposed ways to optimize the amount of spinning reserve in power systems based on cost / profitability analysis. The reference [8] uses a sequential method to provide the needed spinning reserve, so the final solution will not be optimal. References [16] and [17] also do not consider the market structure for energy and reserve, and solve only a mathematical problem, regardless of the physical constraints, such as the minimum on being on or off, while The methods presented in this project, while taking into account the structure of the market for energy and the spinning reserve, settle these two commodities simultaneously and taking into account this physical constraints by performing cost / profit analysis. In this study, the total cost at time t is equal to TCt as defined in Equation (2), and definitive energy cost for hour t is calculated according to Equation (3).

$$TC_i = \sum_{i=1}^{N} \left[f_{g,it}(P_g(i,t)) + f_{s,it}(S_r(i,t)) \right] I(i,t) + \sum_{i=1}^{N} \left[S(i,t) + ECOST_i \right] \tag{2}$$

$$ECOST_i = VOLL_{system} * EENS_i \tag{3}$$

Indicators and parameters used in the above equations are as follows:

N: Number of production units
I: Indices for production units
Fg, it is the unit cost proposed of the i-th unit for the hour t
Fs, it is the cost function proposed for spinning reserve of the i-th unit at time t ($)
Pg (I, t)) the amount of energy generated by the ith unit for hour t in MWh
Sr (I, t)) the volume of the spinning reserve purchased of ith unit for hour t in MW
I (I, t)) the status of being on and off of ith unit at hour t (0 off, 1 on)
S (I, t)) The cost of being on and off of ith unit at hour t in $
ECOST Final energy cost per hour t
EENSi is the expected non-supplied energy of the system in hour t in MWh
VOLLsystem Value of interrupted load of whole system in MWh / $

In order to calculate EENSt, we use the formation of the COPT table. Here, we assume that a definitive investigation of one or two production units is sufficient to calculate the EENSt index. Here we define the parameter sj, k. The values 0 and 1 can be considered. In fact, if the interruptions of the production unit j and k lead to energy interruption in the system, this parameter is equal to 1 otherwise 0. This parameter is determined by equation (4).

$$\frac{D_g(t)-\sum_{=1}^{N}(P_g(i,t)+S_r(i,t)}{\sum P_{\max}(i)} * s_{jk} < \frac{P_g(t)-\sum_{=1}^{N}(P_g(i,t)+S_r(i,t)}{\sum P_{\max}(i)} \qquad (4)$$

Dg (t) The amount of energy demanded for hour t and Pmax is the maximum amount of energy produced by the i-th unit. The probability of j and k units faces with interruption at hour t and the rest of the units do not, Probt (j, k), is calculated by the equation (5).

$$\Pr ob_t(j,k) = I(i,t)I(k,t)U_j U_k(1-I(i,t)) \qquad (5)$$

In the above equation, Ui represents the inaccessibility of the ith unit. If one production unit is being investigated and the j index is deleted from equations 4 and 5. In fact, the EENSt index is calculated by equation (6).

$$EENS_i = \sum_{j=1}^{N} s_j \Pr ob_{t,j} *(P_g(i,t)+S_r(i,t)-D_s(t)) + \sum_{j=1}^{N}\sum_{k>j}^{N} \Pr ob_{j,k} *(P_g(i,t)+S_r(i,t)+P_g(k,t)+S_r(k,t)-D_g(t)) \qquad (6)$$

In this regard (6) Ds (t), is the spinning reserve value for hour t, and in fact, to calculate EENSt, the definite energy level is considered due to the interruption of one or two production units and the probability of their interruption. This method of calculating EENSt is very fast and at the same time has a fairly good accuracy.

In general, there are a number of constraints on the amount of spinning reserve and energy purchased. These constraints are illustrated by equations (7).

$$\begin{aligned} &\sum_{i=1}^{N} P_g(i,t) = D_g(t) \\ &\sum_{i=1}^{N} S_r(i,t) = D_s \\ &P_{\min}(i) < P_g(i,t) < P_{\max}(i) \\ &0 < S_r(i,t) < RR_s \end{aligned} \qquad (7)$$

In the above equations, RRs are the capacity of increasing the spinning reserve of the ith unit in MW / min.

In the following, we describe the problem-solving method of finding the optimum solution. The Pg parameter is obtained for each power system based on load prediction. In fact, this parameter has a specific value for each hour. But the discussion for the Ds parameter will be different. In fact, in order to simultaneously settle the energy market and reserve, there is a tangible need for a specific number for Ds. In fact, the riddle of this chapter is to find Ds based on cost / profitability analysis and the simultaneous settlement of energy market and spinning reserve. In other words, we seek the optimal value of Ds. The optimal Ds is the amount of spinning reservation, for which the total cost of the tth hour is calculated by the equation (6). The method used in this project to find the optimal Ds level is the Pareto optimal method based on the NSGAII algorithm. In the Pareto method, instead of finding an optimal jumper, a range of optimal answers is first obtained. Then, using the modified genetic algorithm (NSGAII), an optimal final solution is obtained. Finally, the NSGAII method is fully investigated to find the optimal solution from the Pareto optimal.

III. SIMULATION

The single-mode diagram of the IEEE reliability test is shown in Fig. 1. This system has 11 bass generators, 13 consumer buses, 33 transmission lines and 5 transistors. There are 22 production units ranging from 12 megawatts to 40 megawatts in this sample system. The system consists of two 400 MW nuclear units and six 50 MW water units and six 20 MW combined units. The rest of the units in this system are steam units.

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It is assumed here that water units do not participate in the energy market, and only 26 units out of these 32 units participate in the energy market and spinning reserve. Water units can only participate in the ten- minute non-spinning reserve market [18].

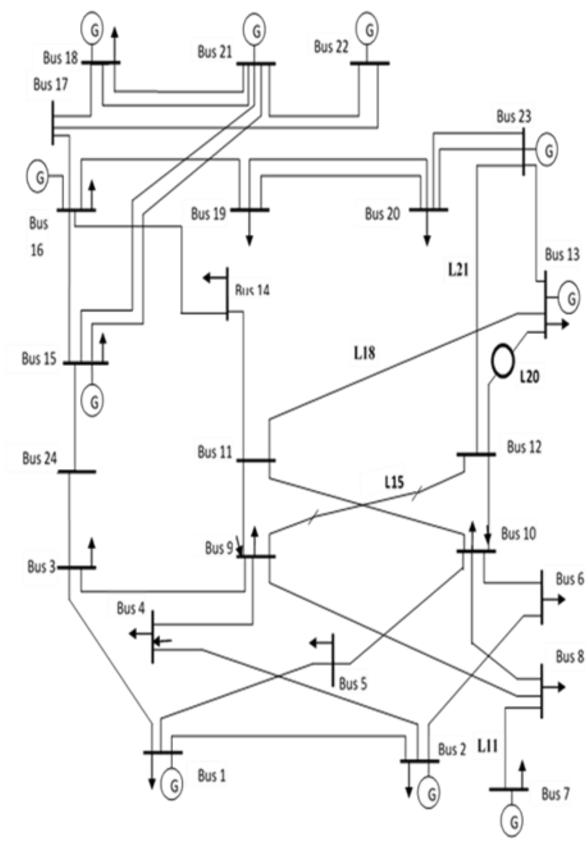

Fig. 1. The single-mode diagram of the IEEE reliability test

In this section, the proposed method has been simulated for determining the optimal spinning reserve, the simultaneous settlement of the energy market and spinning reserve on the RTS-IEEE reliability test system.

At the simultaneous energy market and spinning reserve, it is assumed that GenCo simultaneously offers their offerings for energy and spinning reserve to the ISO. Their suggestions for each product include the amount and cost. We assume in this paper that GenCoS have proposed their suggestions on energy prices in accordance with the cost functions provided in reference [19].

The load level for the around the clock is assumed as reference information [19]. This level of load is shown in Fig. 2. Here we assume that the system's definite load value is 2000 MW /$.

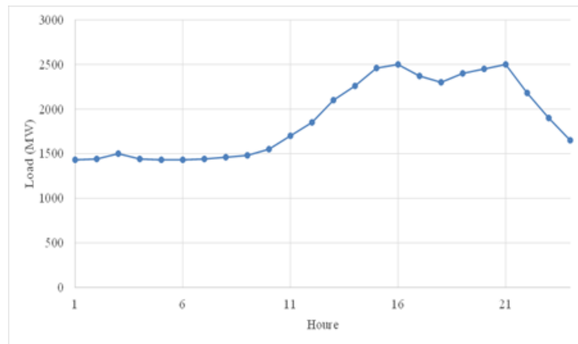

Fig. 2. The load level for the around the clock

First, we assume that the proposed method only applies for an hour. We apply our proposed method for the first, fourteenth and twenty fourth hours. The load of these hours is 1430, 2260 and 1650 megawatts, respectively. Here, to evaluate the performance of the proposed method, we compare our method with the method for determining definitive spinning reserve. Our assumption is that the definitive criterion for spinning reserve is the capacity of the largest production unit (400MW). To illustrate the concept and mechanism of performance of the proposed method, Figure 3 shows the overall cost based on the function of the spinning reserve for the 1430MW load level.

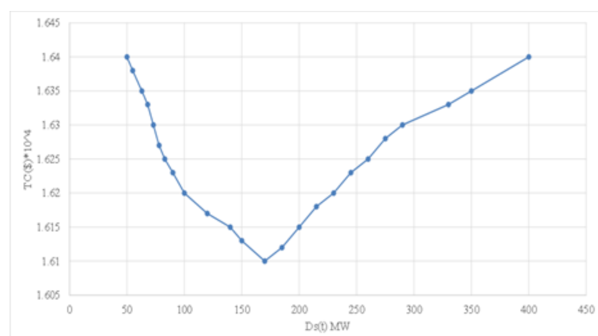

Fig. 3. the overall cost based on the function of the spinning reserve for the 1430MW load level

As previously explained, the total cost of the energy and the spinning reserve purchased, is the cost of turning on or off the production units and the final cost of the system. As shown in Figure 3, the optimal rate of spinning reserve for this load level based on the proposed cost / benefit analysis is 170MW. Meanwhile, the cost of turning on or off the production units is in accordance with the costs given in reference [15].

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To better understand the performance of the proposed method, the amount of spinning reserve obtained for different hours, based on the definitive method and the coupling method, is shown in Figure 4. As this figure shows, the value of spinning reserve obtained based on the proposed method, NSGAII algorithm is less than 400MW at all hours. It is important to note that we consider the number of test points in this algorithm based on Pareto optimal.

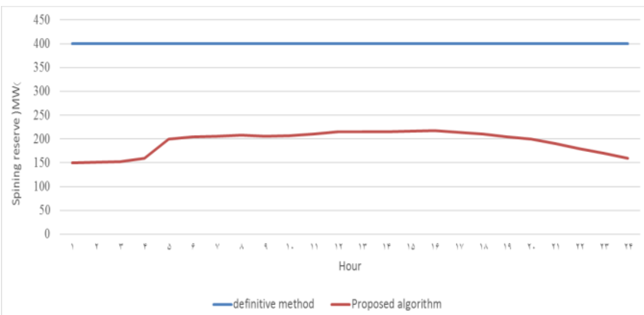

Fig. 4. the amount of spinning reserve obtained for different hours, based on the definitive method and the coupling method

Also, the risk obtained from the proposed method is shown in Figure 5.

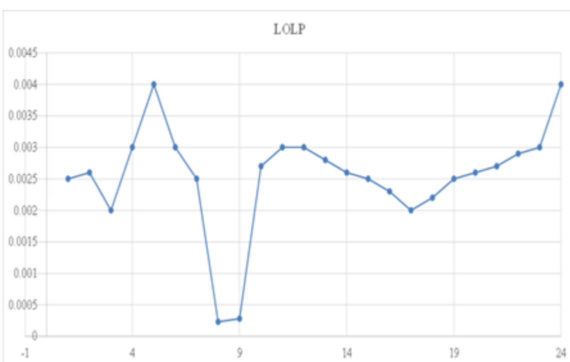

Fig. 5. the risk obtained from the proposed method

As is shown in Figure 5, due to the reduction in the value of spinning reserve in all hours, the risk level for all the hours in the proposed method is higher than the equivalent rate in the definitive method. It is important to note that if the risk level of the system increases, but because of our method is based on cost / profitability analysis, this risk will be more economical.

IV. CONCLUSION

This study focuses on spinning reserve as one of the most important ancillary services after completing structural studies in the ancillary services market.

As shown in this article, the definitive methods for determining the spinning reserve in the power system, despite the great simplicity, do not take Into account the probabilistic nature of the system and lead to non-economic responses. In contrast, among the probabilistic methods of determining spinning reserve, the cost / profit analysis is the most optimal method economically. For this reason, the analysis of this study is based on this method.

In fact, this study, by settlement of the energy market and spinning reserve simultaneously based on cost / profit analysis and considering the risk factor in exploiting the power grid, takes a effective step in system reliability studies. In this type of analysis, obtaining the optimal solution is important due to the multi-purpose objective function. A conventional way to solve such problems is to use the Pareto optimal method. In this method, after obtaining a set of optimal solutions for the problem, it is necessary to select an optimal solution using another algorithm from the set of the obtained solutions. In this study, the genetic algorithm method with a non-dominated selection (NSGAII) has been used. The results show that this method, while obtaining optimal solution, has a good speed to solve the problem.

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