Research Journal of Recent Sciences ISSN 2277-2502
Vol. **3(8),** 74-79, August **(2014)** *Res.J.Recent Sci.*

Estimating Optimal Size of GenCos in a Restructured Power System, in order to Improve Reliability Based on Monte Carlo and Sensitivity Analysis Methods

Mohammad Reza Behmaneshfar[1], Shahrokh Shojaeian[1] and Ali Behmaneshfar[2*]
[1]Department of Electrical Engineering, Khomeinishahr Branch, Islamic Azad University, Isfahan, IRAN
[2]Young Researchers and Elite Club, Najafabad Branch, Islamic Azad University, Najafabad, Isfahan, IRAN

Available online at: www.isca.in, www.isca.me
Received 7th February 2014, revised 5th April 2014, accepted 4th June 2014

Abstract

In this paper, an algorithm is proposed in order to optimal sizing of the GenCos in a restructured power system based on well-known reliability indices. The proposed method uses Monte Carlo simulation to find indices after connecting each GenCo in an appropriate bus which has been found by sensitivity analysis. To show the validation and effectiveness of the proposed method simulation on IEEE reliability test system (IEEE-RTS) are presented.

Keywords: Monte Carlo simulation, sensitivity analysis, power system reliability, GenCosizing.

Introduction

The main objective of a power system is to provide reliable and continuous electricity for its customers. In a restructured power system, it is possible to plan a suitable generation program for individual GenCos which can reduce the effects of contingencies. Because of the probabilistic nature of the contingencies, it is clean that such a plan has to be done with a probabilistic point of view. Well-known reliability indices are used for taking into account direct and indirect of the contingencies[1, 2, 3].

Wang and Billinton present a technique for evaluating the customer load point reliability in a regulated power system considering customer choice on reliability. In this technique, a generation company (GenCo) is represented by an equivalent multistate generation provider (EMGP) and an equivalent multistate reserve provider (EMRP) based on the market function of a GenCo. A GenCo, which has reserve agreements with other GenCos, is represented by an equivalent multistate generation provider with reserve agreement (EMGPWR). The transmission system between a GenCo and its customer considering reserve agreements is represented by an equivalent multistate transmission provider with reserve agreement (EMTPWR). Reliability network equivalent techniques have been extended and combined with the equivalent assisting unit approach to determine the reliability model of the EMGPWR[4].

Pilo and Gelli improve an algorithm for the optimal allocation of automatic sectionalizing switching devices for the maximum exploitation of intentional islanding[5]. Line faults and overloads have been considered as causes of interruptions. Stochastic models have been adopted to assess the probability of overloads and of properly functioning intentional islands. The application to real world case studies has highlighted the benefits achievable with intentional islanding as well as the inability of common reliability indexes (e.g. SAIFI, SAIDI) to properly perceive advantages that are inherently local.

Billinton and Bai propose a methodology for capacity adequacy evaluation of power system including wind energy. The results and discussions on two representative systems containing both conventional generation units and wind energy conversion systems (WECS) are presented. A Monte Carlo simulation approach is used to conduct the analysis. The study shows that the contribution of a WECS to the reliability performance of a generation system can be quantified and is highly dependent on the wind site conditions[6].

In this paper, the most economical size of the GenCos which have been installed in a restructured power system is investigated using combination of Monte Carlo method and sensitivity analysis. Simulations are made on IEEE-RTS to show the effectiveness of the proposed method.

Material and Methods

In a restructured power system each power generation scheduling that can reduce loss of load expectation (LOLE) of the system will improve its reliability. Then size of GenCos in the IEEE-RTS is obtained by sensitivity analysis so that minimum LOLE to be obtained. There are 32 generation units in this power system, which of them can be considered in up or down state. The Down State probability is known as Forced Outage Rate (FOR).

For all units, it is possible to consider 2^{32} states that each can result in its individual total Capacity. 2^{32} is about 4.3 billion and can cause a heavy computation load even for modern digital computers.

In all 4.3 billion cases, total capacity has to be calculated and compared with the total load of the system. If the load demand can be supply, this state will be a success state, and else it will be a fail state. In practical power systems, number of generation units is considerably higher. It can complicate the system simulation intensively. To overcome this problem, Monte Carlo method has been proposed.

Monte Carlo Simulation: In recent decades, Monte Carlo method is used in different fields of sciences and engineering[7-10]. As a simple example to show how this method works, a simple one unit constant load power system can be considered. A random number between 0 and 1 is generated. If the generated number is greater than or equal to the unit FOR, this state will be a success state else it is a fail. Repeating this process more and more, results in a converged loss of load probability (LOLP) which is equal to the ratio of the number of fail states in the total number of iterations.

Results and Discussion

IEEE-RTS is shown in figure 1. Network parameters are mentioned in IEEE-reliability test system[11]. To simulate the system generation states, a 1*32 matrix with random components between 0 and 1 is generated. If each component is greater than or equal to the FOR of the corresponding unit, this unit is considered on, else it is off.

Consequently, total generation capacity can be calculated and compared with the total load demand. If total capacity can meet the total demand this state is a success state else it is fail. This process is repeated as needed to convergence.

The LOLE is calculated as follow:

$$LOLE = 365 * \frac{number\ of\ fail\ states}{number\ of\ total\ iterations} \quad (1)$$

Simulating IEEE-RTS with this method is converged after $7*10^6$ iterations as shown in figure 2.

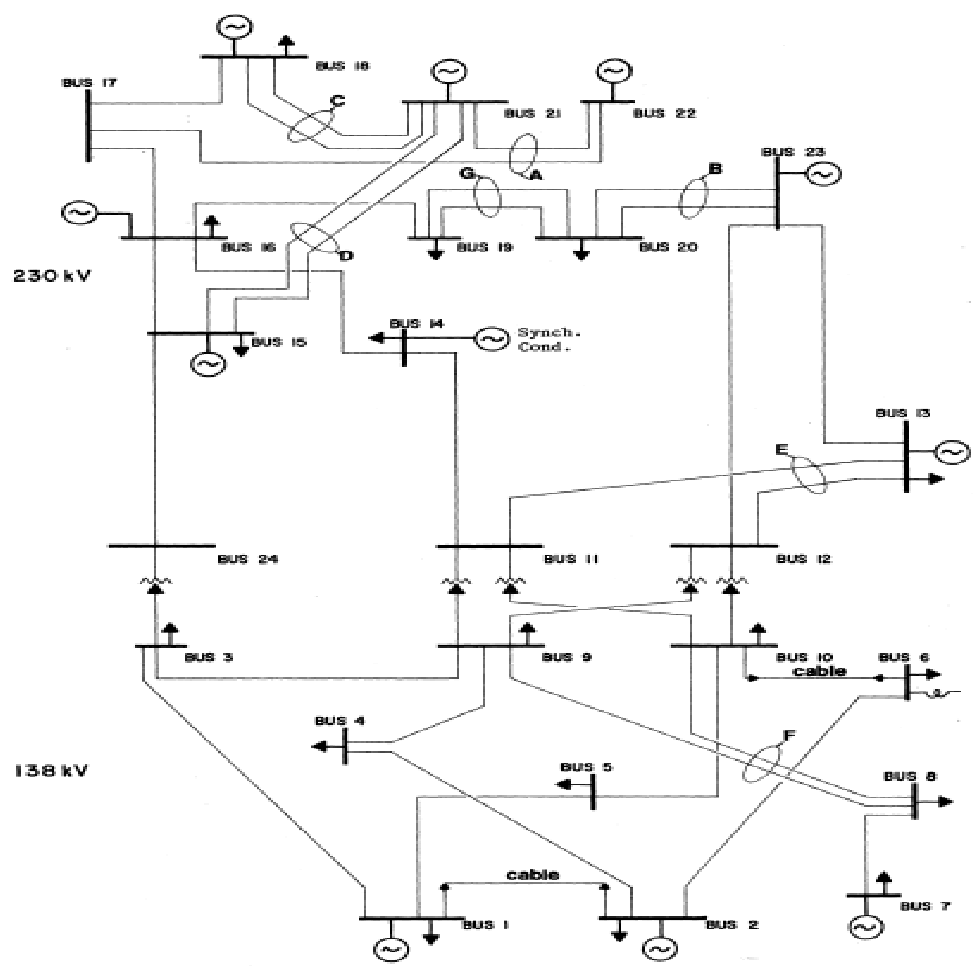

Figure-1
IEEE-RTS network[7]

Here LOLE is about 43.84 day/year. To determine optimal size of GenCos, it is needed to find unserved demand for each of $7*10^6$ states which mentioned above. All these states are saved. Then, a typical capacity for each GenCo is considered and number of the fail states which after coming this GenCo to the system can be changed into the success state are obtained. By dividing the number of the changed state to the number of all states ($7*10^6$), probability of improving the system LOLP can be calculated.

This calculation is repeated for different GenCo sizes to find the sensitivity. Table 1 and figure 3 show the results.

As the results show, improving in system LOLE has a saturated form. Thus, increasing the GenCo size from 600 to 1300 MW and even more, has a negligible effect on the system LOLP improvement and then it is not economical. Optimal GenCo size is one which can get the maximum reduction in LOLP as well as the minimum cost. Figure 4 shows sensitivity in the function of GenCo size. It is clear that the maximum sensitivity is for the sizes lower than 150 MW. Then, the figure is zoomed for this section in figure 5 and figure 6.

The sizes of 25, 30 and 50 MW have the higher sensitivity respectively. On the other hand, from (1):

$$\Delta LOLP = \frac{\Delta LOLE}{365} \qquad (2)$$

Then, if it is aimed to reduce LOLE, for example for 7 days, it is needed to decrease the LOLP by 1.9178%. Therefore, as table 1 shows, it is needed to use a GenCo by the Capacity of 40 MW or more. Also, from figure 6 GenCo with 50 MW Capacity will be the final choice, which can improve the LOLP with economical cost. With this choice LOLE is become 33.142 days which is 10.7 days lower with respect to the original network (with no GenCo).

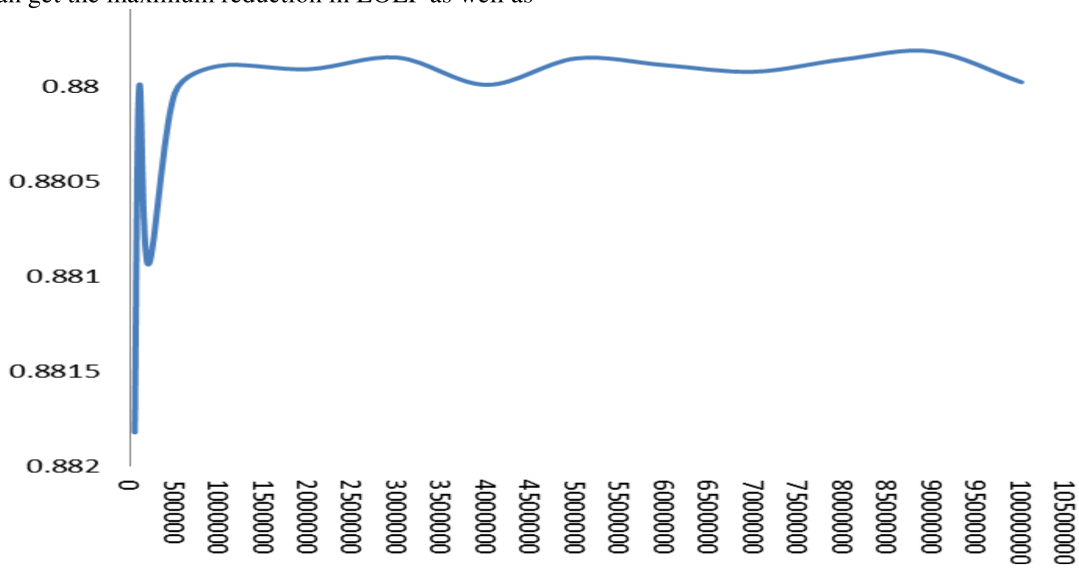

Figure-2
Convergence of system success probability in Monte Carlo method

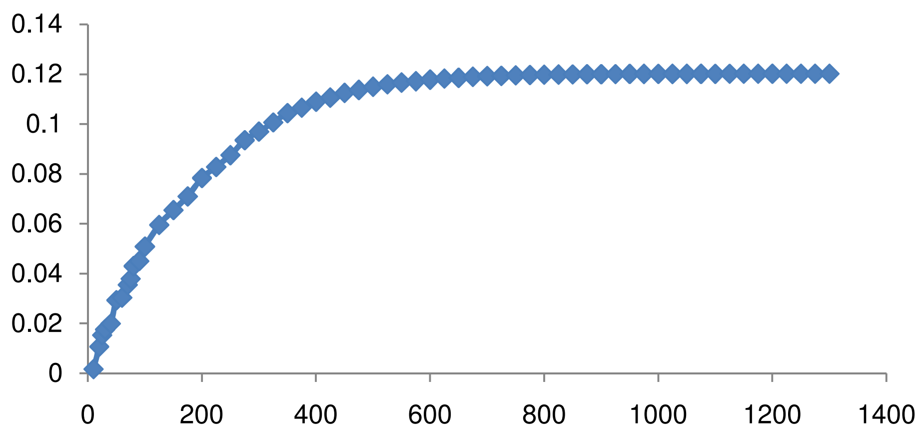

Figure-3
Probability of reliability improvement based in function of GenCo value in HLI level

Table-1
Calculation probability of production lack in HLI Level

Generation curtailment	Number of curtailed generation, less than X	Variation of probability in ideal conditions	Sensitivity
10	11901	0.0017	0.000170
20	74679	0.010668	0.000533
25	107215	0.015316	0.000613
30	122899	0.017557	0.000585
40	139293	0.019899	0.000497
50	205187	0.029312	0.000586
60	212676	0.030382	0.000506
70	248494	0.035499	0.000507
75	265135	0.037876	0.000505
80	300877	0.042982	0.000537
90	315080	0.045011	0.000500
100	355819	0.050831	0.000508
125	416397	0.059485	0.000476
150	458135	0.065448	0.000436
175	496716	0.070959	0.000405
10	11901	0.0017	0.000170
20	74679	0.010668	0.000533
200	548303	0.078329	0.000392
225	579232	0.082747	0.000368
250	612338	0.087477	0.000350
275	654443	0.093492	0.000340
300	678470	0.096924	0.000323
325	704379	0.100626	0.000310
350	730290	0.104327	0.000298
375	745652	0.106522	0.000284
400	762558	0.108937	0.000272
425	774148	0.110593	0.000260
450	787367	0.112481	0.000250
475	795511	0.113644	0.000239
500	804519	0.114931	0.000230
525	811286	0.115898	0.000221
550	816273	0.11661	0.000212
575	820083	0.117155	0.000204
600	824543	0.117792	0.000196
625	827695	0.118242	0.000189
650	829644	0.118521	0.000182
675	832437	0.11892	0.000176
700	834239	0.119177	0.000170
725	835269	0.119324	0.000165
750	836522	0.119503	0.000159
775	837534	0.119648	0.000154
800	838215	0.119745	0.000150
825	838683	0.119812	0.000145
850	839318	0.119903	0.000141
875	839704	0.119958	0.000137
900	839931	0.11999	0.000133
925	840203	0.120029	0.000130
950	840426	0.120061	0.000126
975	840543	0.120078	0.000123
1000	840631	0.12009	0.000120

1025	840727	0.120104	0.000117
1050	840783	0.120112	0.000114
1075	840819	0.120117	0.000112
1100	840860	0.120123	0.000109
1125	840884	0.120126	0.000107
1150	840902	0.120129	0.000104
1175	840913	0.12013	0.000102
1200	840921	0.120132	0.000100
1225	840930	0.120133	0.000098
1250	840933	0.120133	0.000096
1275	840936	0.120134	0.000094
1300	840938	0.120134	0.000092

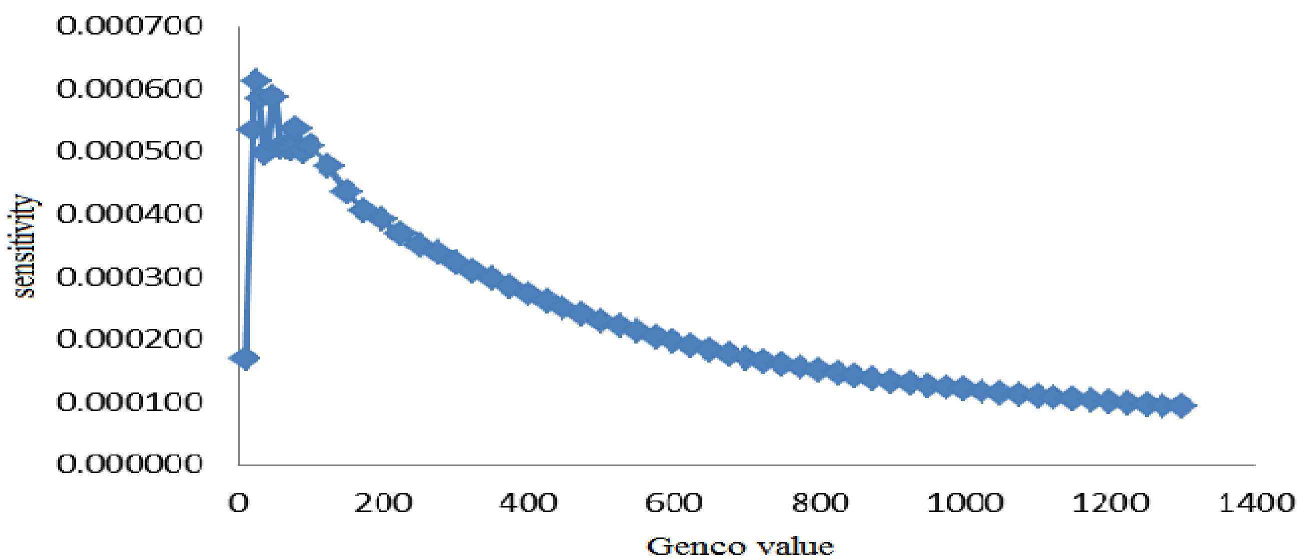

Figure-4
Sensitivity analysis based on GenCo value

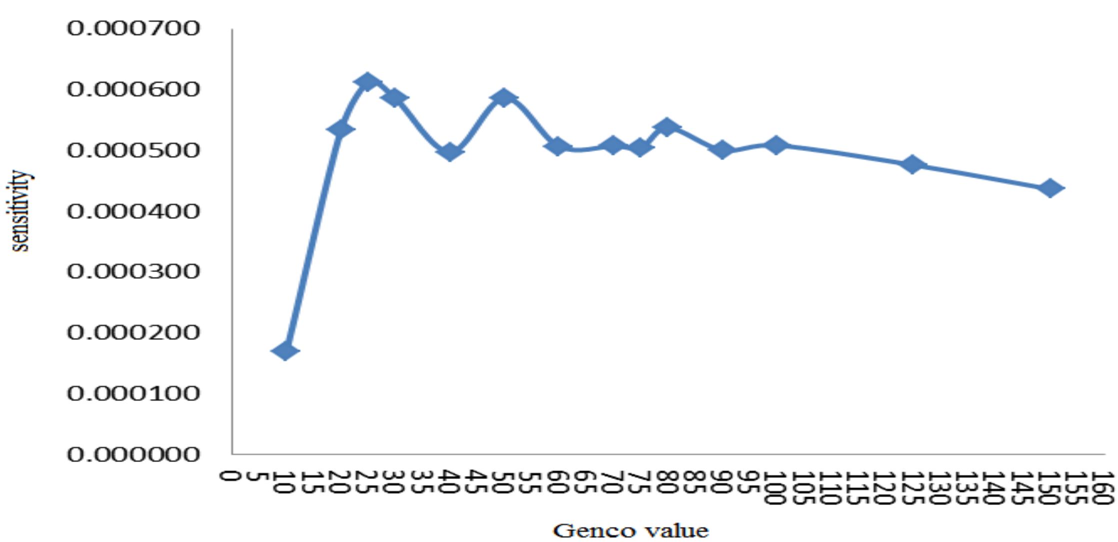

Figure-5
Sensitivity analysis based on GenCo value for less than 150 M.W.

Conclusion

In this paper, a simple and relatively fast method is presented to find optimal size of GenCos in a restructured power system. Sensitivity analysis and Monte Carlo method are used to find reliability indices and they are selected as the essential measures for determining the system performance with individual sizes of GenCos. Simulation of the proposed method for IEEE-RTS shows its capability to improve system reliability.

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