J. Basic. Appl. Sci. Res., 2(2)1147-1151, 2012
© 2012, TextRoad Publication

ISSN 2090-4304
Journal of Basic and Applied Scientific Research
www.textroad.com

Optimal Operating Strategy for Distributed Generation Considering Reliability Index of SAIDI

M. Karami[1], S. A. Hosseini[2], R. Karam Beigi[3], S. S. Karimi Madahi[4]
F. Razavi[*5], *Member IEEE*, A. A. Ghadimi[6], *Member IEEE*

[1,2] Department of Electrical Engineering, Golpayegan Branch, Islamic Azad University, Golpayegan, Iran,
[3] Department of Electrical Engineering, Khoramshahr Branch, Islamic Azad University, Khoramshahr, Iran,
[4] Department of Electrical Engineering, Islamshahr Branch, Islamic Azad University, Islamshahr, Iran,
[5] Department of Electrical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran,
[6] Department of Electrical Engineering, Science and Research Branch, Islamic Azad University, Arak, Iran

ABSTRACT

Deciding the optimal operation mode for Distributed Generation (DG) is of a crucial importance in increasing the efficiency of these resources. This paper presents a method to determine optimal operating strategy for distributed generation (DG) according to the improvement of SAIDI reliability index. The considered operation modes of this paper includes, peak shaving and standby. The use of DG for peak shaving could reduce the overall system operating cost and its use as standby power could reduce the customer interruption cost. The SAIDI index is used in the strategy proposed in this paper to determine the optimal operating decision for the DG. In addition, Monte Carlo method is incorporated, in order to determine the occurrence and duration of the failure of each distribution network elements. Using the approach proposed in this paper, the distribution companies could determine the optimal operating strategy for their DG. To validate the proposed strategy, bus 2 of the standard distribution network of RTBS is simulated in DIgSILENT software and the simulation results are presented and discussed.
KEY WORDS: Distributed Generation (DG), Distribution System, Monte Carlo method, SAIDI Index, Reliability Indices.

INTRODUCTION

DG is usually defined as electrical power resources, which are directly connected to the system [1]. Nowadays, DG plays an increasingly significant role in the electrical power systems due to the developments in DG technologies, the increase in the electricity demand, the importance of reliability of the system, and the increasing attention to the environmental issues [2].

The applications of DG include combined heat and power, standby power, islanding mode, peak shaving, and grid support. Nowadays, customers are interested in having electricity with a reduced cost and increased reliability. Power system reliability, is defined as ability of a system to provide electrical energy for costumers. In addition, the issue of reliability of distribution networks is becoming one of the most important problems in electrical industry due to its impacts on electricity price and the satisfaction of the costumers [3]. In the other hand, on the most important benefits of having a high reliability is the reduction of interruptions. Since the electrical companies have to pay dues for interruptions, reduce in interruption amount is desired for both customers and utilities [4].

Many studies have been carried out regarding the impacts of DG on reliability of system. Authors in [5] discussed the negative impacts of DG on distribution system reliability. Dynamic behavior and transient states associated with DG are considered in this paper. The work of [4] has considered the hourly reliability worth to determine the optimal operation strategy of DG. This study considered peak shaving and standby modes. Authors in [6] presented an analytical method to evaluate the reliability of the power system having DG resources considering the peak shaving and backup modes. This study proposes connectivity matrixes to state the condition of connectivity of resources and costumers. Ref. [7] has discussed the impacts of DG on distribution networks reliability. In addition, the impact of the location of DG on the reliability of distribution system is analyzed in this paper. Ref. [8] and [9] proposed a reliability model to identify DG equivalent to use DG instead of adding a new feeder in peak load. In these studies, reductive transformers and fuses are assumed to have the reliability of 100%. In the other hand, the interruptions due to simultaneous failures and the impacts of DG modes on reliability of system are not considered. The applications of DG with old technologies such as diesel are discussed in [10] and the benefits of islanding mode of operation are presented. Authors in [11] expressed intentional islanding mode as an option to improve the reliability of power system. In this study, the other operational modes of the DG are not considered. Studies [12] and [13] proposed a method to identify the optimal location and capacity of DG in order to improve reliability, voltage profile and reduce the power losses.

Analyzing the reliability indexes is carried out in these studies based on the modified analytical methods in order to manage number of generators. DG unit is considered in backup unit and the peak shaving and islanding modes are ignored. The problem of reducing the loading of the distribution feeders due to installing DG units in distribution

***Corresponding Author:** Farzad Razavi, Department of Electrical Engineering, Qazvin Branch, Islamic Azad University, Qazvin, Iran, phone: +98 912 1773241, Email: farzad.razavi@qiau.ac.ir

networks and its impact on system reliability is analyzed in [14]. The reliability index of SAIDI is used to evaluate the reliability of system.

In this paper, a technique is proposed to identify the optimal operational mode of DG, according to the reliability index of SAIDI of the distribution system including DG. The SAIDI index is calculated hourly for every load point of the distribution network for different considered operational modes and the optimal operational mode is decided according to the improvement of this index in each mode. The considered operation modes are peak shaving mode and backup mode.

Namely, the optimal operational mode is the mode in which the SAIDI index is improved more. In addition, Monte Carlo method in incorporated in order to determine the time of the failure of each of the distribution network elements. To carry out the simulation, bus 2 of the standard distribution network of RTBS is selected and simulated, using DIgSILENT software and the simulation results are presented and discussed.

The structure of the paper is the following. In the second section, the model of the DG and distribution network are presented and considered DG modes and transitions between them are explicated. The reliability index of SAIDI which is applied in this paper is presented in the third section. The fourth section presents the proposed method, and the 5th section presents the case study. Simulation results are presented and discussed in section 6.

THE MODEL OF THE DGANDDISTRIBUTION NETWORK

To simulate the arbitrarily nature of the faults, outages and failures of distribution network, Monte Carlo method is incorporated. Using the Monte Carlo results, the chronological waveform of each element is obtained according to the reliability information of [15].

In this paper, to determine the interference of the failure of different modes of DG and the distribution network, six-state model of DG operated in peak shaving and standby is proposed [4]. Different parameters of Fig. 1 are explained in the Table I.

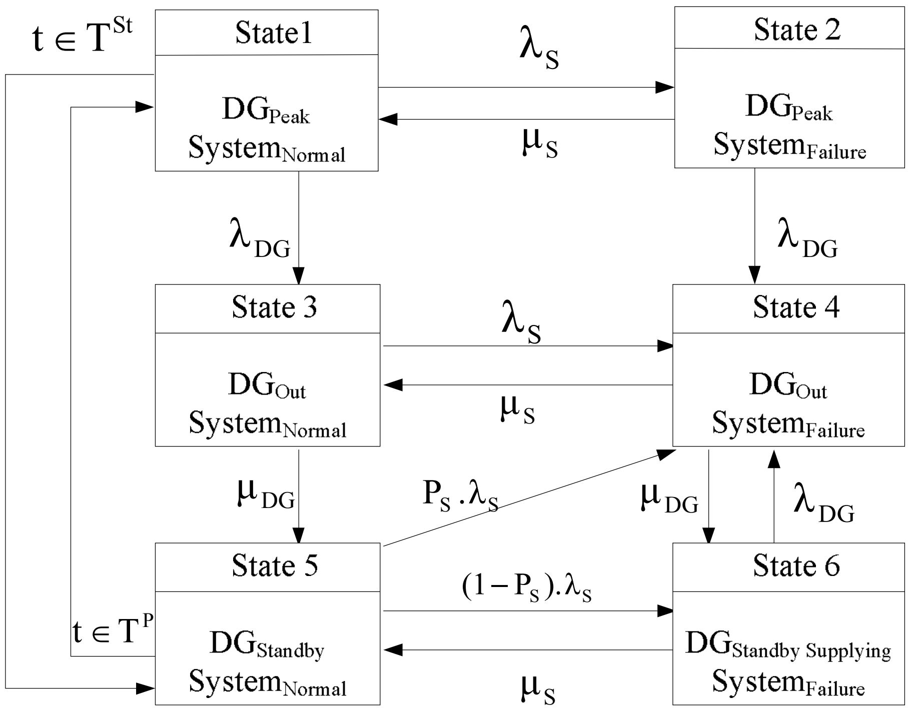

Fig. 1. Six-state model of DG operated in peak shaving and standby

Arrows in Fig. 1 show the possible transitions between states. In state 1 DG is in peak mode. When a failure occurs in transmission system, the system goes to state 2 and if a failure occurs in DG it would go to state 3. When the peak period is finished the system goes to state 5. If the failure resolves in state 2, the system returns to state 1. When the failure of DG resolves in state 3 the system goes to state 5. In state 4, both the DG and the network have problems. If the problem of distribution system resolves the system goes to state 3 and if the problem of DG resolves it goes to state 6. The state 5 is a condition when the DG is ready to operate but out of service. In the state 6, DG is in back up mode and supplies all or part of the interrupted load [4].

TABLE I : Explanation of the parameters, used in Fig. 1

Parameter	Definition	Parameter	Definition
DG_{Peak}	DG is employed in peak shaving mode	T^P	Scheduled time of transition between standby to peak-shaving
P_S	The probability of the start of failure in DG	λ_S	Rate of the occurrence of system outage
$DG_{Standby}$	DG is employed in standby mode, but it does not inject any power to the network	T_{St}	Scheduled time of transition between peak-shaving to standby
$DG_{Standby\ Supplying}$	DG is in the standby mode and after the system outage, it starts to inject power to the network		
DG_{Out}	DG is unavailable due to failure	λ_{DG}	Rate of occurrence of DG failure
$System_{Normal}$	No outage has occurred in distribution system	μ_S	Repair rate of distribution system
$System_{Failure}$	Outages has occurred in some parts of distribution system	μ_{DG}	Repair rate of DG

SAIDI RELIABILITY INDEX

The purpose of this paper is to identify the optimal operation mode of DG with respect to the improvement of SAIDI index. SAIDI stands for system average interruption duration index. This index shows the summation of customer interruption time, divided into the total number of customers and is calculated by the Eq. 1.

$$SAIDI = \frac{\sum_{i=1}^{LP} U_i . N_i}{\sum_{i=1}^{LP} N_i} \left(\frac{hours}{\cos tumer.year}\right) \tag{1}$$

Where LP is number of load points, U_i is the annual average of interruption time, N_i is the number of customers which are located at i. The less the value of this index is, the duration of interruption during a year is less.

The Hourly System Average Interruption Duration Index is also defined as follow. Since U_i is the average interruption duration, hSAIDI(t) can be calculated as Eq. 2 and the annual value of SAIDI is calculated by adding up the hSAIDI for a year.

$$hSAIDI(t) = \sum_{i=1}^{CLP} hSAIDI_i(t) \tag{2}$$

In this equation, $hSAIDI_i(t)$ is the average hourly interruption duration of load i for all the incidents of j at t time and is calculated by Eq. 3. CLP is the total number of interruptions at customers load points. $N_{i,j}(t)$ stands for all disconnected customers of i load point for j incident and at t time. $r_{i,j}(t)$ is the duration of the interruption of i load point for j incident and at t time and N_k is the total number of customers of k point.

$$hSAIDI_i(t) = \frac{\sum_{\forall j} N_{i,j}(t).r_{i,j}(t)}{\sum_{K=1}^{LP} N_K} \tag{3}$$

According to these equations, if the number of interrupted customers be minimized by operating in optimal operation mode, the hSAIDI(t) index minimizes at each hour which results in reduction of SAIDI index for a year. Hence, the objective function can be defined as Eq. 4.

$$Min\left(\sum_{t=1}^{8760} \text{hSAIDI(t)}\right) \tag{4}$$

PROPOSED METHOD

DG unit can be employed in different operation modes. The considered operation modes of this paper are peak shaving and islanding. The use of DG for peak shaving could reduce the overall system operating cost and its use as standby power could reduce the customer interruption cost.

To obtain the optimal operation strategy, as the DG unit is employed at each mode, the value of SAIDI index is calculated. Namely, three different scenarios are considered. In the first scenario, the DG unit is considered to be employed as a peak shaving unit and $SAIDI^P$ is calculated for this scenario. In the second scenario, the DG unit is considered to be employed as a standby unit and $SAIDI^S$ is calculated for this scenario. In the last scenario, which is the proposed method of this paper, the SAIDI values of each operation mode are calculated and the operation mode, in which the SAIDI index is minimized, is selected as the employed mode. Accordingly, the last scenario can be written as the Eq. 5.

$$U_{DG}(t) = hSAIDI^P(t) - hSAIDI^S(t) \tag{5}$$

There are two possibilities in Eq. 5, if $U_{DG}(t)$ was positive, DG should operate in backup mode and if it was negative, DG should operate in peak shaving mode.

Comparing the SAIDI index for these different scenarios can clarify whether the proposed method can result in the reduction of SAIDI index or not.

CASE STUDY

To test the proposed strategy, bus 2 of the standard distribution network of RTBS is simulated in DIgSILENT software, presented in Fig. 2 and the simulation results are presented and discussed. Further information of this network is available in [15].

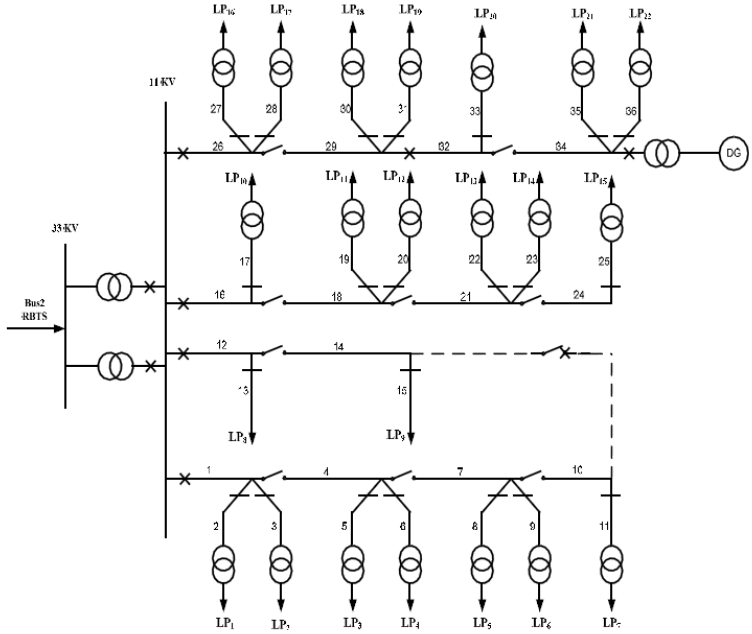

Fig. 2. Bus 2 of the standard distribution network of RTBS

SIMULATION RESULTS

Discussed scenarios are simulated and applied in this part and the results are presented and discussed. The Fig. 3 shows the obtained values of the SAIDI index for different operation modes of DG.

As Fig. 3 shows the value of SAIDI index for the 3th scenario, which is the optimal state, is so close to the 2nd scenario, which is the state that DG is employed in standby mode. The reason is that when the DG is employed in standby mode, it is ready to operate in system failures. So the interruption time diminishes to the time of connecting the DG to distribution system.

As it is clear, the SAIDI index of the proposed method is the least value among different states. Therefore, it can be concluded that applying the proposed method will result in the most possible reduction of SAIDI index. Hence, operation in the proposed method is suggested when the aim of the electrical companies is to reduce SAIDI index.

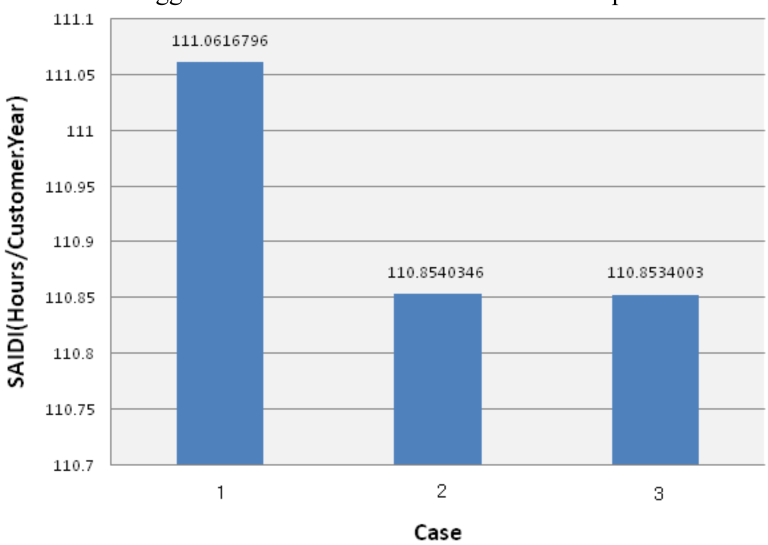

Fig. 3. The values of the SAIDI index for different scenarios

CONCLUSION

In this paper a new method for determining the optimal operating strategy for the DG has been presented. This approach takes into consideration the improvement of the SAIDI index in the distribution system. A six-state DG model including the DG operating strategy, the distribution system state, and the transition relationship between each state, has been used and described. Three different scenarios are presented to compare the efficiency of the proposed method. In the first scenario, the DG unit is considered to be employed as a peak shaving unit and $SAIDI^{P}$ is calculated for this scenario. In the second scenario, the DG unit is considered to be employed as a standby unit and $SAIDI^{S}$ is calculated for this scenario. In the last scenario, which is the proposed method of this paper, the SAIDI values of each operation mode are calculated mode and the operation mode, which the SAIDI index is minimized, is selected as the employed mode. Simulation results and the different values of SAIDI index shows that employing the DG in the proposed method will decrease the SAIDI index the most.

REFRENCES

[1] Mohab M. Elnashar, Ramadan El Shatshat and Magdy M.A. Salama, “Optimum siting and sizing of a large distributed generator in a mesh connected system”, Electric Power Systems Research (2009).

[2] Gianni Celli, Emilio Ghiani, May 2005, "A multi-objective evolutionary algorithm for the sizing and siting of distributed generation", IEEE Transactions on Power Systems, Vol. 20, No. 2.

[3] R.E.Brown, “Electric Power Distributionf Reliability”, Marcel Dekker, Inc, New York, Basel, (2002).

[4] I-S.Bae, J-O Kim, J-C.Kim, C.Singh, “Optimal Operating Strategy for Distributed Generation Considering Hourly Reliability Worth”, IEEE Transactions on power systems VOL. 19, NO. 1, pp. 287-292, (Feb. 2004).

[5] P.Jahangiri, M.Fotuhi–Firuzabad, “Reliability assessment of distribution system with distributed generation”, 2nd IEEE International Conference on Power and Energy (PECon 08), pp.1551-1556, December 1-3, Malaysia, 2008.

[6] I.S.Bae, J.O.Kim, “Reliability Evaluation of Distributed Generation Based on Operation Mode”, IEEE Transactions on power systems, Vol. 22, NO. 2, pp.785-790, (May 2007).

[7] S.X.Wang, W.Zhao, Y.Y.Chen, “Distribution System Reliability Evaluation Considering DG Impacts”, IEEE DRPT2008 Nanjing China, pp. 2603-2607, 6-9, (April 2008).

[8] A.A.Chowdhury, K.Agarwal, D.Koval, “Reliability Modeling of Distributed Generation in Conventional Distribution Systems Planning and Analysis”, IEEE Transactions on industry applications, VOL. 39, NO. 5, pp.1493-1498, (September/October 2003).

[9] A. A. Chowdhury, S. K. Agarwal, D.O. Koval, “Reliability Modeling of Distributed Generation in Conventional Distribution Systems Planning and Analysis”, pp. 1089-1094, IEEE (2002).

[10] J. C. Gomez, M. M. Marcos, “Distributed Generation: Exploitation of Islanding Operation Advantages”, IEEE, pp. 1-5, (2008).

[11] P.Fuangfoo, T.Meenual, W-J.Lee, C.Chompoo-inwai, “PEA Guidelines for Impact Study and Operation of DG for Islanding Operation”, IEEE Transactions on industry applications, VOL. 44, NO. 5, pp. 1348-1353, (September/October 2008).

[12] C.L.T.Borges, D.M.Falcao, “Optimal Distributed Generation Allocation for Reliability, Losses, and Voltage Improvement”, ELSEVIER, Electrical Power and Energy Systems 28, pp. 413–420, (2006).

[13] C.L.T.Borges, D.M.Falcao, “Impact of Distributed Generation Allocation and Sizing on Reliability, Losses and Voltage Profile”, IEEE Bologna PowerTecb Conference, June 23-26, Bologna, Italy, (2003).

[14] R.E.Brown, “Reliability Benefits of Distributed Generation On Heavily Loaded Feeders”, IEEE (2007).

[15] L.F. Pozzatti, A.Barin, L.N. Canha, R.Q. Machado, A.R. Abaide, F.A. Farret, C.G.Carvalho, “Simulation of Transient State Impacts from Low Power DG Aiming at Improving Power Quality and Reliability of Distribution Networks”, PowerENG 2007, pp. 702-706, April 12-14, (2007).