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Optimal Location of Sectionners and Distributed Generation Resources to Improve Reliability in Distribution Networks

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ABSTRACT

In traditional distribution networks, due to the radial structure and subscriber power supply, in the event of errors in the main feeders, downstream subscribers experienced a long blackout, which reduced the reliability level of the network. With the expansion of the use of scattered generations, storage resources and the use of load response methods, load retrieval is provided in the downstream area. In this paper, a method is proposed for locating sectionners and distributed generations in distribution networks with the aim of creating flexible micro-grids. By creating an island, disassembling and restoring loads of more importance in the distribution network, on the one hand, it reduces the amount of fines paid by the distribution company to Subscribers and economic interests of the distribution company, and, on the other hand, by improving reliability, provides customer satisfaction.

1. INTRODUCTION

Reliability is one of the most important indicators of electrical networks. In recent years, this index has been instrumental in increasing social welfare. So the need for high quality and reliable electrical energy has become one of the important goals of power companies. The reason is the increase in the presence of sensitive loads, which could lead to financial, technical and security damage to the required electricity. In distribution networks, reliability can be improved in two ways:

- Reduce the frequency of errors
- Reducing the time needed to recover lost loads

In traditional networks, methods and strategies are set to implement the above programs. Cost / benefit studies that are considered as the core of a suitable strategy for enhancing reliability are required to consider the extent to which each method is effective against the cost involved. Different methods are selected with regard to determining the range of impact of each method and the cost of execution, and the expected level of reliability. Studies conducted to improve the reliability of distributed networks and studies carried out in various papers show that the use of distributed generation resources, the use of intelligent drag programs, and the improvement of positioning methods and the use of power key, can be the most effective factors in improving performance indicators in reliability indicators [1, 2]. In this paper, a new method for locating simultaneously distributed resources and sectionners is presented with the direct control of subscribers. In this way, the subscribers conclude a pre-paid contract with the distribution company based on their reliability, and the location of the distributors and the location and capacity of the distributed generation resources and the determination of the cut-offs will be based on the optimal profit. In this paper, based on the location of the error and the situation of the sectionners, the optimal micro-grid are formed, considering the total capacity of distributed generation sources, the capacity of the loads and in the case of emergency loading programs, by providing a new method, the optimal arrangement of recovery loads, based on the frequency stability of the network and the optimal profit of the distribution company. In the first part, a review is presented of the work done in the field of locating DG and sectionners. In the second section, we will introduce the micro-grid and the tools contained therein, in the third section, an overview of the reliability insurance rules in the distribution networks, and in the fourth section, the proposed method is presented with the objective function. In the fifth part of the proposed method in a sample network numerical results will be considered using numerically optimized genetic algorithms.

2. REVIEW OF STUDIES ON THE LOCATION OF DG RESOURCES AND SWITCHING DEVICES

The field of placement of DG units in the system has been studied a lot. The reference [3] reports the positive effects of the installation of the DG in Virginia, [4] using a genetic algorithm to provide a new method for locating DGs, in order to increase the reliability of subscribers and couriers [5]. It provides a network based approach to automation and consumption management programs to improve reliability. Also, the reference [6] performs location based on time-varying loads. A lot of methods have been considered in the field of locating the sectionners. In the reference [7], the problem of optimal placement of the sectionners has been investigated by using optimization of steel electroplating method. In this method, the subscribers are divided into categories including major, industrial, agricultural, commercial, household, governmental and administrative subscribers, and given the blackout time, the amount of damage to each group is obtained. Reference [8] provides a model for the problem of the placement of the sequencer in the distribution network, in which the energy costs are not sold, the investment required to install the key and the state in which the sectionners operate with error. Various articles have also been presented in the field of locating the sectionners and distributed generation sources in the distribution network. An innovative algorithm has been proposed in which the location of the sequencer takes into account the presence of distributed generation resources. In this study, considering two different modes for critical loads, a similar algorithm is proposed for locating the sequencers in both states. In these two situations, the behavior with the most important loads is different. In the first case, maximizing the feeding of the important load is considered as the target. In the latter case, with a harder view, feeding all critical loads are considered as customary [9, 10].

In [11-13], sectionner location is taken into account in the context of distributed generation resources. With the presence of the DG instead of separating the loads from the network, at the moment of the error, it is possible to retrieve the downstream area with the help of resources by opening the sectionners. Also, [14] shows that the use of off-load programs can help maintain optimum conditions.

3. PREPAID AND FINES FOR PRIORITIZATION SUBSCRIBERS

Conventional methods for regulating electrical distribution networks have weaknesses in financial discussions, risk allocation, subscriber performance, and reliability value. The rate of return and the PBR fully take on the risk of blackout and exclude the possibility of a joint presence in determining the quality of the service. Several methods have been developed to determine the fines of distribution companies for the duration of subscribers' blackouts. In this paper, reliability estimates have been proposed to determine the value of each charge and the amount of blackout loss for each subscriber group. Using reliability insurance in calculations, instead of conventional methods for determining the loss of blackout, increases the level of subscribers' ability to determine the energy value and expected reliability level. Reliability insurance is able to significantly improve the reliability of reliability service than traditional methods such as financial incentive schemes. In this way, subscribers reduce the risk of blackout risk by paying initial premium, and the reliability of the subscribers can vary with their performance in choosing an insurance plan. This feature eliminates the confusion of operators and legal bodies in determining the optimal level of service quality on the network; because in this way, the value of reliability and a desirable level of service can be clearly understood from subscriber insurance contracts [15-17]. Different subscribers, in view of their sensitivity to the power of their loads, conclude a contract with the respective distribution company, which determines the amount of prepayment as well as fines. Referring to the proposed relationship in reference [17] and given the level of reliability in the current network, the amount of prepayment of subscribers and fines of distribution companies in exchange for blackout hours will be derived from (1).

$$P = R(1 - r) \tag{1}$$

P: Premium paid by subscribers
R: Blackout penalty
r: reliability of network

4. THE PROPOSED METHOD

In locating DG resources and switching devices, it should be noted that the appropriate location of these two devices is not independent, and will be dependent on the final location of each, as well as the capacity of the distributed generation source, to another location, as well as the type of loads located on each network. Therefore, we have to solve the three factors of the location of the sectionners, the location of the installation of distributed generation resources and the capacity of each resource at the same time. If we are not at the design stage and there is a network of multiple sectionners, then also given that the distribution network is not designed to provide the reliability of each consumer, therefore, an open network development with the same goal should be adopted. In most cases, projects that electricity distribution companies are undertaking to locate switching devices or distributed generation resources is to develop or modify the network structure. In these networks, there are usually a number of switching devices already, although they are in non-optimal locations. Usually moving or removing some old devices is not economic. In these cases, the goal is not replacement of previous device and optimal location, but the goal is optimal placement of new equipment. Therefore, the optimal location for a network that has no sectionner is completely different with a network that already has these devices. An algorithm that is currently being offered will also include old devices if any, and locate newer devices with regard to previous devices. Distributed generation sources can cover a regional error in blackout time. The first requirement for this issue is the presence of a sequencer along the line to separate the error region. Given that the capacity of distributed generation sources is limited, in some cases, the whole downstream area cannot be assigned a fault; therefore, we need to have sectionners in different positions of the line so that we can provide a source for the resource by cutting off less important loads. In terms of capacity, it has the capacity to provide the load in that area. The cost function is considered in accordance with (2):

$$fo = \Big[\sum P_i \times Q_i - \sum((1 - r_i) \times R_i \times Q_i)) - InvCost \times [(1 + m)^n \times (\frac{m}{(1 + m)^n - 1})\Big] \tag{2}$$

In the cost function, the parameters used are as follows:
Q: The duration of blackout each time in a one-year period
P: Prepayment cost by subscribers to the distribution company
R: Penalty payment from distributor companies to subscribers per hour of blackout
Invcost: The cost of purchasing, installing, repairing and dismantling the jM source
m: interest rate
n: Operation Period

It should be noted that different subscribers, having regard to their sensitivity to the power of their loads, conclude a contract with the respective distribution company, which determines the amount of prepayment as well as fines. Distribution companies must, in each case, prioritize the provision of loads in the micro-grid, in light of the availability of power in each micro-grid, and benefits and losses caused by the blackout management. Also, considering the network conditions, the duration of the blackout due to events, the cost of installing sectionners and the source of the distributed generation, and fines from blackouts of sensitive subscribers, it should be noted in the location and capacity for DG resources and sectionners.

5. NUMERICAL RESULTS

Loads are divided into three categories: household, commercial, and industrial. Due to the reliability of network in the initial state and relationship (1), the prepayment is considered to be 1.3.5 kWh/$ and the fines are 80,280 and 400 kWh/$ respectively. The power factor for all loads is 0.95. The cost of installing and maintaining distributed discharges (per kilowatt) and sectionner respectively is 700 and 4000 $. The duration of the period is 10 years and the inflation rate is 20%. The average keying kit time is 15 minutes and the time required for the dispersion of distributed generation resources is 45 minutes. Distributed sources of resources are available in 500, 1000 and 1500 kilowatt groups. The network was selected based on the real network of Babolsar Beach Boulevard to simulate the proposed algorithm. Green Spots are Candidate Points for installing sectionner and Blue Spots are Candidate for installing distributed generation resource. The sample network is shown in Figure 1.

5.1 First scenario: The simultaneous allocation of distributed generation and sectionner in the current distribution network

In this scenario, all input information is the same as the initial information. Table 1 shows the installation costs and the profit generated by the reliability enhancement. In addition, Tables 4 and 5 show the location of the sectionner, the location and capacity of the DG.

5.2 Second scenario: The effect of reducing the duration of switching and launching of distributed generation sources

In this scenario, it is assumed that in the event of an increase in the level of technology in the design of sectionners, the time required for switching operations is reduced as well as distributed generation sources. The following tables show the half effect of switching and being on the circuit of distributed generation resources to the cost of reliability and profit of distribution companies.

Tables 4 and 5 show the location of sectionner, the location and capacity of the DG, and Table 2 shows the installation costs and the profit generated by the reliability enhancement.

The second experiment shows that, given the improved design of distribution network equipment and the reduction in the time required for the separation and commissioning of DGs, due to reduced time required to recover the load, as well as an increase in the level of service to the subscribers, which led to an increase the reliability of network under study, companies' profits from installing DG resources and sectionners, with a reduction in the duration of recovery operations, has an inverse relative. In the other word, the faster the operation takes place, the profits of companies will increase with a high coefficient.

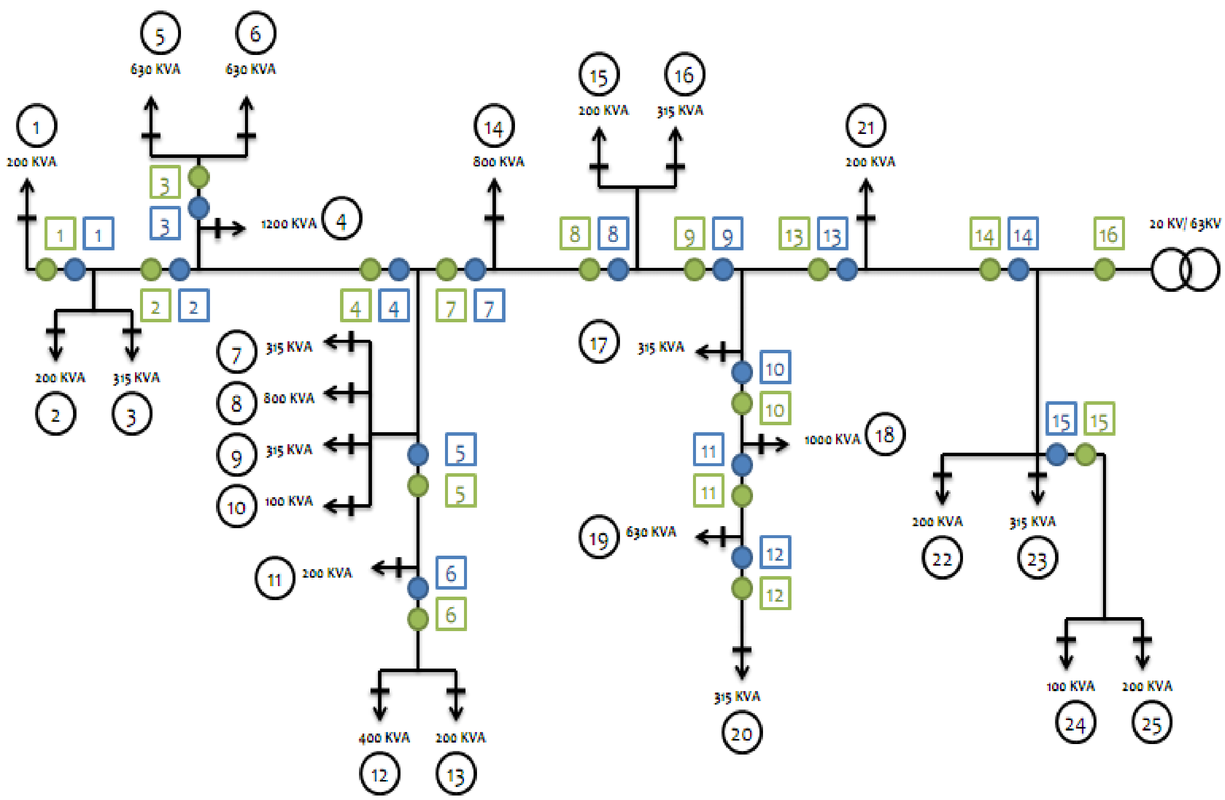

Figure 1. Case study network

Table 1. Equipment installation costs and profitability due to improved reliability

Cost	$
The cost of buying and installing sectionner	2400
The cost of buying and installing DG	63000
Profit from improved reliability	401330
Net Income Distribution Company	335930

Table 2. Equipment installation costs and profitability due to improved reliability

Cost	$
The cost of buying and installing sectionner	2800
The cost of buying and installing DG	42000
Profit from improved reliability	401800
Net Income Distribution Company	357000

5.3 Third scenario: The effect of reducing the number of failures

In this scenario, it is assumed that by implementing the measures in the planning and exploitation of the network studied, the number of errors in all sections will be halved. Regarding the information on the error rate in Table 2, in simulation for this scenario, all values are multiplied by 0.5. Tables 4 and 5 show the location of the sectionner, the location and capacity of the DG, and Table 3 shows the installation costs and the profit generated by the reliability enhancement.

The third experiment shows that by improving the reliability level in distribution networks or, in other words, reducing the number of errors, given that due to the optimum situation of the network, the total duration of the blackout has decreased and, consequently, the need for the equipment is also prescribed. The profits earned by companies by installing the equipment will be less than the network does not have a secure state. Figure 2 illustrates the benefit of improved reliability in the reviewed scenarios.

Table 3. Equipment installation costs and profitability due to improved reliability

Cost	$
The cost of buying and installing sectionner	1600
The cost of buying and installing DG	168000
Profit from improved reliability	392180
Net Income Distribution Company	222580

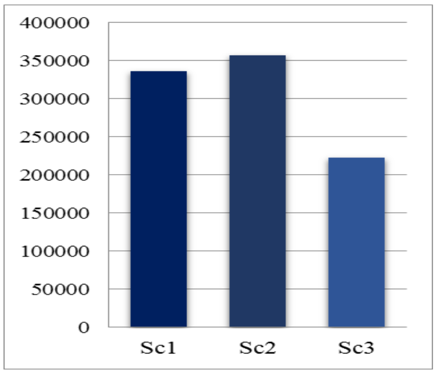

Figure 2. Distribution company profit from sectionner installation and DG in different conditions

In Tables 4 and 5, the optimum location of the sectionner, are presented as well as the location and capacity of the installation of distributed generation sources at the proposed candidate points.

Table 4. Locations of sectionners in different scenarios

Candidate points for installing sectionners	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
First scenario	0	0	0	1	1	0	0	1	0	1	0	0	0	1	1
Second scenario	1	0	0	1	1	0	0	1	1	1	0	0	0	0	1
Third scenario	0	0	0	0	0	1	0	0	1	0	0	1	0	0	1

Table 5. Location and capacity of distributed resources in different scenarios

Candidate points for installing DG	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
First scenario	500	0	0	0	0	0	0	0	0	0	0	0	500	0	500
Second scenario	0	0	0	0	0	0	0	0	0	1000	0	0	0	0	0
Third scenario	0	500	0	0	0	500	0	0	1000	500	0	0	1000	0	500

6. CONCLUSION

In recent years, with the restructuring of network management as well as the importance of decision-making and the need of consumers for the level of reliability they need, has caused that reduced number of blackout do not define as the sole target of the network's users. But reducing the amount of investment and increase the profit rate are considered as an effective and desirable goal. In this paper, with the optimal location of sectionner and DG and the creation of flexible microgrid, on the one hand, it reduces the amount of fines paid by the distribution company to the subscribers and, as a result, improves the economic benefits of the distribution company. And on the other hand, by improving the reliability level fits the common request, increases the satisfaction level of subscribers. With regard to the proposed model and its implementation in a real sample network, numerical results compare the profitability of distribution companies in different network conditions due to the installation of switching devices and distributed generation sources and has been confirmed the importance of the proposed method.

REFERENCES

[1] Senger, E.C., Manassero, G., Goldemberg, C., Pellini, E.L. (2005). Automated fault location system for primary distribution networks. IEEE Transactions on Power Delivery, 20(2): 1332-1340. http://doi.org/10.1109/TPWRD.2004.834871

[2] Fujisawa, A., Kurokawa, N. (2002). Oversea distribution automation system based on Japanese experience. IEEE/PES Transmission and Distribution Conference and Exhibition, 2: 1164-1169. http://doi.org/10.1109/TDC.2002.1177642
[3] Maurhoff, B., Wood, G. (2000). Dispersed generation-reduce power costs and improve service reliability. 2000 Rural Electric Power Conference. Papers Presented at the 44th Annual Conference (Cat. No.00CH37071), Louisville, KY, USA. http://doi.org/10.1109/REPCON.2000.848049
[4] Silvestri, A., Berizzi, A., Buonanno, S. (1999). Distributed generation planning using genetic algorithms. PowerTech Budapest 99. Abstract Records. (Cat. No.99EX376), Budapest, Hungary. http://doi.org/10.1109/PTC.1999.826689
[5] Dugan, R.C., McDermott, T.E., Ball, G.J. (2000). Distribution planning for distributed generation. 2000 Rural Electric Power Conference. Papers Presented at the 44th Annual Conference (Cat. No.00CH37071), Louisville, KY, USA. http://doi.org/10.1109/REPCON.2000.848048
[6] Zhu, D., Broadwater, R.P., Tam, K.S., Seguin, R., Asgeirsson, H. (2006). Impact of DG placement on reliability and efficiency with time-varying loads. IEEE Transactions on Power Systems, 21(1): 419-427. http://doi.org/10.1109/TPWRS.2005.860943
[7] Billinton, R., Jonnavithula, S. (2009). Optimal switching device placement in radial distribution systems. IEEE Transactions on Power Delivery, 11(3): 1646-1651. http://doi.org/10.1109/61.517529
[8] Levitin, G., Mazal-Tov, S., Elmakis, D. (2007). Genetic algorithm for optimal sectionalizing in radial distribution systems with alternative supply. Electric Power Systems Research, 35(3): 149-155. http://doi.org/10.1016/0378-7796(95)01002-5
[9] Griffin, T., Tomsovic, K., Secrest, D., Law, A. (2000). Placement of dispersed generation systems for reduced losses. Proceedings of the 33rd Annual Hawaii International Conference on System Sciences, Maui, HI, USA. http://doi.org/10.1109/HICSS.2000.926773
[10] Mao, Y., Miu, K.N. (2003). Switch placement to improve system reliability for radial distribution systems with distributed generation. IEEE Transactions on Power Systems, 18(4): 1346-1352. http://doi.org/10.1109/TPWRS.2003.818609
[11] Barker, P.P., DeMello, R.W. (2000). Determining the impact of distributed generation on power systems. I. Radial distribution systems. 2000 Power Engineering Society Summer Meeting (Cat. No.00CH37134), Seattle, WA, USA. http://doi.org/10.1109/PESS.2000.868775
[12] Brown, R.E., Freeman, L.A.A. (2001). Analyzing the reliability impact of distributed generation. 2001 Power Engineering Society Summer Meeting. Conference Proceedings (Cat. No.01CH37262), Vancouver, BC, Canada. http://doi.org/10.1109/PESS.2001.970197
[13] Powell, L.J. (1988). An industrial view of utility cogeneration protection requirements. IEEE Trans. Ind. Applicat, 24(1): 75-81. http://doi.org/10.1109/28.87254
[14] Ng, K.H., Sheble, G.B. (2008). Direct load control-a profit-based load management using linear programming. IEEE Trans. Power Syst, 13(2): 688-694. http://doi.org/10.1109/59.667401
[15] Divan, D., Johal, H. (2006). A smarter grid for improving system reliability and asset utilization. 2006 CES/IEEE 5th International Power Electronics and Motion Control Conference, Shanghai, China, pp. 1-7. http://doi.org/10.1109/IPEMC.2006.4777942
[16] Photovoltaics, D.G. (2007). IEEE Guide for Monitoring, Information Exchange, and Control of Distributed Resources Interconnected with Electric Power Systems. IEEE. http://doi.org/10.1109/IEEESTD.2007.4432408
[17] Fumagalli, E., Black, J.W., Vogelsang, I., Ilic, M. (2004). Quality of service provision in electric power distribution systems through reliability insurance. IEEE Transactions on Power Systems, 11(3): 1286-1293. http://doi.org/10.1109/TPWRS.2004.831294