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Assessing the Impact of Size and Site of Distributed Generations and Smart Meters in Active Distribution Networks for Energy Losses Cost

T. Sattarpour*, D. Nazarpour

Department of Electrical Engineering, Urmia University, Urmia, Iran

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ABSTRACT

Many approaches have been applied to study the capacity of distributed generation (DG). One aspect missing from existing methods is the capability to efficiently adaptive power factor (APF) of DGs to power system problems. Hence, this paper proposes a methodology for simultaneous allocation of DGs and smart meters (SMs) in active distribution networks (ADNs) with adaptive power factor of DGs in order to minimize the cost of energy losses. Allocation of SMs in the promising (ADNs) would definitely affect the power system problems such as distributed generations (DGs) studies. SMs are taken into consideration for the sake of successful implementation of demand response programs (DRPs) such as direct load control (DLC) with end-side consumers. To overcome the minimum losses cost, the optimization procedure is tackled with genetic algorithm (GA) and tested thoroughly on IEEE 33-bus distribution test system. In this paper, a probabilistic load model is assumed instead of utilizing time-series based models. The results certify considerable effect of DRPs and APF mode in determining the optimal size and site of DGs to be connected in ADN resulting in the lowest value of energy losses as well.

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1. INTRODUCTION

Power systems are now growing from the conventional controlled systems with centralized generation connected to the transmission networks, to a decontrolled structure that allow small generators to be connected directly to the distribution networks. Such networks, thus become active and are usually called “active distribution networks (ADNs)” [1]. Also, facing with the quick development of innovative technologies, the well-known technical features such as power losses minimization and energy losses cost minimization, as well as economic benefits such as reduction in long-term planning and short-term operational costs, drive the worldwide nations to provide the use of distributed generations (DGs) in their distribution networks. These units have become a motivating option for distribution network operators (DNOs) to meet the demands of their customers [2]. DGs are one of the promising technologies that can support the incorporation of smart grids due to their capacity to improve the system reliability and to facilitate the integration of high penetration levels of renewable energy sources (RESs) [3-5]. The most common types of DGs are the conventional diesel-based and renewable-based DGs [6-8]. Due to the innovative technologies, it has been made possible to install DGs in different methods such as adaptive power factor (APF) mode. In APF method, a DG unit is speculated to be suitable for both providing active and reactive power support to the network. So, it would have a remarkable effect in both active power loss reduction and energy losses cost minimization [9-15]. Because of fast improvement in technologies, transition is changing the passive distribution network to a more intelligent and well-organized one known as active distribution networks (ADNs), which are amongst the promising technologies, can support the information and communication technology. Therefore, different kinds of intelligent electronic devices (IEDs) that are used in power systems, such as smart meters (SMs) and distribution remote terminal units (DRTUs)

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*Corresponding Author’s Email: *t.sattarpur@yahoo.com* (T. Sattarpur)

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and some other devices developed to profit an online and well-organized control on different parts of ADNs. ADNs are described with responsive loads, renewable-based/diesel-based DGs, and flexible network structures realized with remotely controlled switches (RCS) [16, 17]. Different types of consumer such as residential, commercial and industrial consumers can participate in demand response programs (DRPs) in two bases including time-based programs and incentive-based programs [18, 19]. Time-based programs, with different electricity prices for different peak loads of day-ahead hours, are generally used through consumers, and there is no control on them by the DNOs.

There are different types of incentive-based program such as direct load control (DLC) that the DNO controls the customer's consumption through SMs with some contracts between customers and DNO.DLC programs are the top ways for DNOs to cope with the emergency situations such as feeders with low reliability and managing the peak load hours with high prices.

The developing of ADNs has emotional impact on the distribution system studies such as optimal location of DGs. In the passive distribution networks (PDNs), DGs are just organized in the peak load hour for different objects such as reliability enhancement, cost reduction, and voltage profile improvement [20-23]. More recently, some of the structures of ADNs such as automatic online reconfigurations realized by the RCSs have been implemented in DGs optimal sizing and siting problem. Rao et al. [24] have offered an optimal approach for DGs placement. Moreover, the optimal size and site of DGs define the optimal status of RCSs (as well which one is open or close). Also, they have proposed the extra benefits such as loss reduction and change in the size and location of DGs as the result of using RCSs. In [25], the author has proposed a top framework for concurrent placement of DGs and capacitors in active distribution networks with online reconfigurations. Also, he has proposed some remarkable outcomes in this context.

To the best of our knowledge, the existence of responsive loads and considering different peak loads with different electricity prices for each one have been ignored in the aforesaid papers. Direct load control program as one of the most effective DRPs for management in different percentages of peak load is considered to be communicated between the DNO and some types of customers that they participated in demand responses programs in the ADNs. Therefore, DNOs can reduce the consumption of these responsive loads up to the appropriate value at contracted prices for each special emergency situation through the signals released by SMs. Consequently, as an inventive point, this paper proposes the determination of installation locations at the system under study for specified number of SMs due to the definite investment capabilities of DNO with considering the problem of DGs idealizing and siting and considering different peak loads with different probabilities and prices for each peak load. By determination of optimum seats for SMs, the effect of DLC program in optimal placement of DGs would be analyzed in depth. Hence, it would be indispensable for DNOs to take into account the presence of DRPs in solving the DG placement problem and finding the best installation buses. Also, the effect of DLC in extra power loss reduction and minimizing the energy losses cost would be highlighted. By speculating the DNO to be apt for remotely controlling the DGs active and reactive power injections, APF mode has been considered for DGs, whereas, in most of the previous studies, DGs are treated in constant power factors. In this manner, the optimal power factor would be determined for DGs as well. The optimization procedure has been formulated as a non-linear problem (NLP) and tackled with genetic algorithm (GA) seeking to minimize total energy losses cost in the network. To validate the well performance of the proposed methodology, the IEEE 33-bus systems has been considered for numerical studies.

This paper is organized in five different sections as follows. Section 2 is about problem description. In section 3 the methodology is discussed in depth. Section 4 presents a case under study. The outcomes and conclusions are presented in sections 5 and 6, respectively. References used in this paper are listed in Section 7.

2. PROBLEM DESCRIPTION

The developing of SMs in ADNs would greatly affect the power system studies such as DGs optimal siting and sizing problem. Some of the features of ADNs such as voltage profile improvement, loss or cost reduction, and reliability improvement. However, the economic feasibility of DGs and SMs should be justified since these units are expensive in installation and maintenance costs. To achieve this task, the benefits from integrating DGs and SMs to attain load management need to be firstly enumerated as follows:

System promotion deferral: system promotions are usually essential in order to account for the annual load growth in a given distribution system. Through peak load shaving with DGs and SMs, system promotions can be deferred to later years. Energy losses reduction: another benefit for integrating DG and SM units into distribution systems is Energy losses reduction. By means of proper placement of these units, the cost of energy losses in distribution systems can be decreased.

Power loss reduction: Minimizing power loss in active distribution system depends on optimal DGs and SMs allocation. From the aforementioned discussion, the proposed work focuses on finding the optimal DG and SM sizing and siting in distribution systems that minimizes the energy losses cost.

3. METHODOLOGY

This section presents the general methodology implemented in this paper. The input to the methodology proposed is the different probabilistic models of load during a year, while the output of this methodology is the optimal size and location of DGs and SMs with APF operate for DGs units. In the following subsections, the main assumptions, genetic algorithm, load modeling, objective function considered to be optimized and also running constraints are introduced in more detail.

3. 1. Assumptions The proposed methodology is based on the following assumptions:

- ADN is assumed to be balanced;
- Total loads are modeled with constant powers and constant power factor for each load states;
- There is limited budget for placing of both DGs and SMs; hence, the number of DGs and SMs would be limited;
- The control of DGs and SMs is based on minimizing the energy losses.
- DGs are operated in APF mode allowing them possible to generate both active and reactive power.

3. 2. Genetic Algorithm The proposed optimal placement framework is a non-linear problem (NLP) which is solved using genetic algorithm (GA). GA as an intelligent search technique which imitates the biological selection process. In this process, the most eligible parents would be more likely to stay alive and replace their genetic code to the upcoming offspring. This procedure is known as evolution process implemented by specific operators namely recombination and mutation. By this way, GA would be apt to carefully probe the search space and then find the optimal solutions[26, 27].

3. 3. Problem Codification The main step of the methodology proposed is the chromosome encoding of GA. In the presented work, each chromosome consists of three parts as shown in Figure 1. The first part accounts for optimal site and size of DGs, the second part is for adaptive power factor of DGs and finally the third part determines the optimal site for smart meters. For every population generated by GA, some main steps are required to evaluate the objective function. The structure of the proposed optimization is shown in Figure 2. In the proposed study, K_1 and K_2 are 40 and 20, respectively. Probabilistic load model planning is proposed in this work in order to evaluate the losses cost of system.

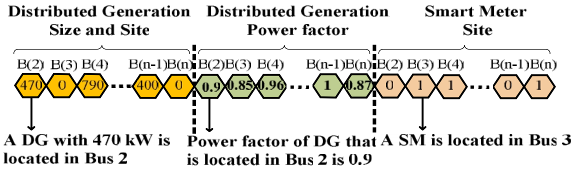


Figure 1. Structure of the proposed chromosome

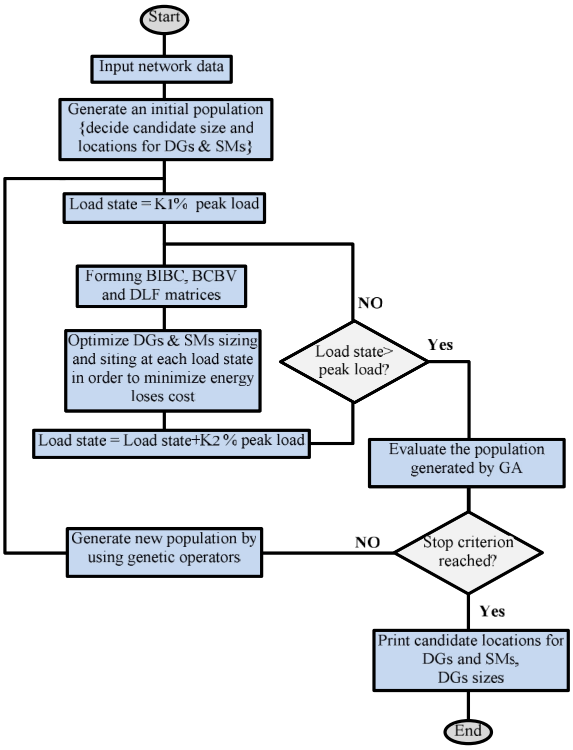


Figure 2. Structure of the proposed methodology

TABLE 1. Probabilistic load model

Load State	Peak Load (%)	Probability	Electricity Price ($/kWh)
Minimum	40	0.330	0.018
Medium	60	0.330	0.020
Normal	80	0.325	0.025
Maximum	100	0.015	0.030

3. 4. Load Modeling The loading at each bus is assumed to follow the hourly load shape. The hourly load data has been clustered into 4 distinct load states. The loading levels and electricity prices for each state are given in Table 1.

3. 5. Evaluate Objective Function In this step, the objective function is presented that minimizes the energy losses costs leading to improve the losses reduction and other benefits for distribution system. The problem constraints such as load flow equations, voltage limits, limit for substations capacity, flow limits for feeders, DGs Size and total capacity and limits on SMs and DLC responsive loads maximum reduction capacity are further added to the objective function using penalty terms. Basically, there are several techniques mentioned in the literature to handle constraints in evolutionary algorithms, e.g., eliminating or repairing infeasible chromosomes, and penalty terms applied to the objective function. On the other hand, the approach of penalty terms is simple and generally works well with all problems.

Each bus that is selected for placing SM would be exposed to reduce its load up to a prespecified amount denoted by $S_{DLC_i}^{\max}$. Also, DGs are considered to be installed at different buses injecting both active and reactive power to the network. DGs, due to their excellent capabilities, could be utilized to attain several objectives such as power loss minimization and voltage profile improvement. Herein, the most important purpose is to minimize the energy losses cost in the network represented in (1):

Minimize

$$CE_{loss} = 8760 \times \left\{ \sum_{Ls} \rho_{Ls} \times P_{loss_{Ls}} \times C_{Ls} \right\} \tag{1}$$

Here, CE_{Loss} represents the cost of energy losses, Ls is combined load-DG state index, ρ_{Ls} and C_{LS} are the probability and electricity price for each load state, respectively shown in Table 1 and $p_{Loss_{LS}}$ represents the total power losses for each state of load.

3. 6. Constraints

The problem of optimal siting and sizing of DGs and SMs in an ADN is subjected to the following equality and inequality constraints.

3. 6. 1. Load Flow Equations For each combined load-DG state (Ls), solve load flow equations as in (2) and (3). The equality of these constraints are taken for ensuring the governing of Kirchhoff's current and voltage laws in the network's load flow process. The presented load flow equations are modified to include the effect of DGs and SMs presence as follows:

$$P_{g_{i,Ls}} + P_{DG_{i,Ls}} + P_{DLC_{i,Ls}} - P_{L_{i,Ls}} = \sum_{j \in \Omega_i} P_{ij}\left(V_{i,Ls}, V_{j,Ls}, Y_{ij}, \theta_{ij}\right) \tag{2}$$

$$Q_{g_{i,Ls}} + Q_{DG_{i,Ls}} + Q_{DLC_{i,Ls}} - Q_{L_{i,Ls}} = \sum_{j \in \Omega_i} Q_{ij}\left(V_{i,Ls}, V_{j,Ls}, Y_{ij}, \theta_{ij}\right) \tag{3}$$

where, $P_{DG_{i,Ls}}$ and $Q_{DG_{i,Ls}}$ are active and reactive power generation by DG at bus *i* and state *Ls* respectively, $P_{DLC_{i,Ls}}$ and $Q_{DLC_{i,Ls}}$ active and reactive power reduction by DLC responsive load at state *Ls* respectively. $P_{L_{i,Ls}}$ and $Q_{L_{i,Ls}}$ represents active and reactive powers of distribution feeders at each load state respectively. $V_{i,Ls}$ and $V_{j,Ls}$ are bus voltages at bus i and bus *j* at each load state respectively. Finally Y_{ij} and θ_{ij} are magnitude and phase angle of feeder's admittance respectively.

3. 6. 2. Voltage Limits Proper constraints are required to guarantee the voltage magnitude to be kept at admissible range at each bus. The voltage magnitude for substation buses is maintained at 1 p.u.

$$V_{\min} \leq \left| V_{i,Ls} \right| \leq V_{\max}, \qquad i \in \Omega_B \tag{4}$$

$$\left| V_{i,s} \right| = 1 \text{ p.u.}, \qquad i \in \Omega_S \tag{5}$$

where V_{min} and V_{max} are minimum and maximum limits of bus voltages respectively, *i* is indices of buses, Ω_B and Ω_s are set of buses and set of substations, respectively and s is index of substations.

3. 6. 3. Limit for Substations Capacity The maximum allowable capacity of the transformer limits the maximum apparent power flow in each substation connecting the ADN to the upstream sub-transmission level:

$$\sqrt{P_S^2 + Q_S^2} \leq S_S^{\max}, \qquad s \in \Omega_S \tag{6}$$

where P_s and Q_s represent active and reactive power imported from s-th substation, respectively and $S_s^{\max}$ is maximum allowable apparent power that could be flowed through s-th distribution substation.

3. 6. 4. Flow limits for Feeders It is necessary to keep the apparent power flowing through each feeder in its admissible range:

$$\sqrt{P_k^2 + Q_k^2} \leq S_k^{\max}, \qquad k \in \Omega_{Br} \tag{7}$$

Here P_k and Q_k are active and reactive power flowing *k*-th branch, respectively and $S_k^{\max}$ is maximum allowable apparent power flowing in *k*-th branch. *K* and Ω_{Br} are index and set of branches, respectively.

3. 6. 5. DGs Size and Total Capacity

The limited budget available for DNO may confine the total capacity of installed DGs up to PER_{DG} (%), that is, the percent of total active load of the network. Also, by applying DGs in APF mode, they should also satisfy the permissible range for PF. Meanwhile, with the aim of limiting the maximum number of installed DGs, namely $N_{DG}^{\max}$, the following constraints should be satisfied:

$$P_{DG}^{\min} \le P_{DG_i} \le P_{DG}^{\max}, \qquad i \in \Omega_B \tag{8}$$

$$Q_{DG}^{\min} \le Q_{DG_i} \le Q_{DG}^{\max}, \qquad i \in \Omega_B \tag{9}$$

$$\left[\left(P_{DG_i}\right)^2 + \left(Q_{DG_i}\right)^2\right]^{1/2} \le S_{DG_i}^{\max}, \qquad i \in \Omega_B \tag{10}$$

$$\sum_{i \in \Omega_B} S_{DG_i}^{\max} \le \frac{PER_{DG}(\%)}{100} \times \sum_{i \in \Omega_B} S_{L_i}, \qquad i \in \Omega_B \tag{11}$$

$$PF_{\mathrm{DG}_i} = \frac{P_{\mathrm{DG}_i}}{\left(P_{\mathrm{DG}_i} + Q_{\mathrm{DG}_i}\right)^{1/2}}, \qquad i \in \Omega_B \tag{12}$$

$$PF_{\mathrm{DG}_i}^{\min} \le PF_{\mathrm{DG}_i} \le PF_{\mathrm{DG}_i}^{\max}, \qquad i \in \Omega_B \tag{13}$$

$$N_{DG} = N_{DG}^{\max} \tag{14}$$

here, $p_{DG}^{\min}$ and $p_{DG}^{\max}$ are minimum and maximum limits for DGs active power, respectively. $Q_{DG}^{\min}$ and $Q_{DG}^{\max}$ are minimum and maximum limits for DGs reactive power, respectively. $S_{DG}^{\max}$ and S_{L_i} are maximum apparent power limit for DGs and apparent power of distribution feeders, respectively. Finally $PF_{DG_i}^{\min}$ and $PF_{DG_i}^{\max}$ are minimum and maximum power factor for DGs, respectively.

3. 6. 7. Limits on SMs and DLC Responsive Loads Maximum Reduction Capacity

As the initial investment capital of DNO may be limited, there will be a maximum cap for installing SMs in the ADN and implementing DLC demand response between some large consumers. Determination of installation buses for SMs, itself will have a great effect on the optimal solutions for DGs sites and size. Hence, it should be modeled as a part of optimization procedure. The maximum number of installed SMs would be taken as $N_{SM}^{\max}$. Also, each candidate bus that is selected as a DLC responsive load should satisfy the maximum amount of permissible load reduction indicated by PER_{DLC} (%), that is, the percent of MVA reduction in each bus. The following constraints are taken to be observed:

$$N_{SM} = N_{SM}^{\max} \tag{15}$$

$$\left[\left(P_{DLC_i}\right)^2 + \left(Q_{DLC_i}\right)^2\right]^{1/2} \le \frac{PER_{DLC}(\%)}{100} \times S_{L_i}, \qquad i \in \Omega_B \tag{16}$$

$$PF_{L_i} = \frac{P_{\mathrm{L}_i}}{\left(P_{\mathrm{L}_i} + Q_{\mathrm{L}_i}\right)^{1/2}} = \mathrm{cte}, \qquad i \in \Omega_B \tag{17}$$

$$Q_{DLC_i} = \tan(\cos^{-1}(PF_{L_i}) \times P_{DLC_i}, \qquad i \in \Omega_B \tag{18}$$

here, PF_{Li} is constant power factor of load in each bus subjected to be equipped with SMs.

4. CASE STUDY

The system used for the case study is a 33-bus radial distribution system, as shown in Figure 3. The rated active and reactive power levels of the load points as well as the feeder data are taken from[28]. Test system specifications for each state are given in Table 2. The system peak demand is 3.715 MW and 2.3 MVA. For this case study the bus 1 is connected to the sub-transmission network and is assumed as the substation.

GA has been executed in several runs with different values for crossover and mutation rates. The setting parameters of GA are further given in Table 3. Even though there were not so remarkable differences, the best results are obtained with population size of 5 recombination rate equal with 0.5 and mutation factor adjusted at 0.01 respectively. DG and SM units conditions are given in Table 4. The acceptable range for voltage magnitudes in all buses has been determined to be between 0.95 p.u and 1.05 p.u respectively.

5. RESULTS

This section summarizes the findings of this study, optimal sizing and siting of DG and SM units in order to achieve minimum energy losses, and thus minimize the system losses. The impact of allocated DGs and SMs is studied in this section through three different cases: Placing DGs operated in unity power factor (UPF) mode and without placing SMs, placing DGs operated in APF mode and without placing SMs, and placing both DGs in APF mode and SMs to perform DLC demand response.

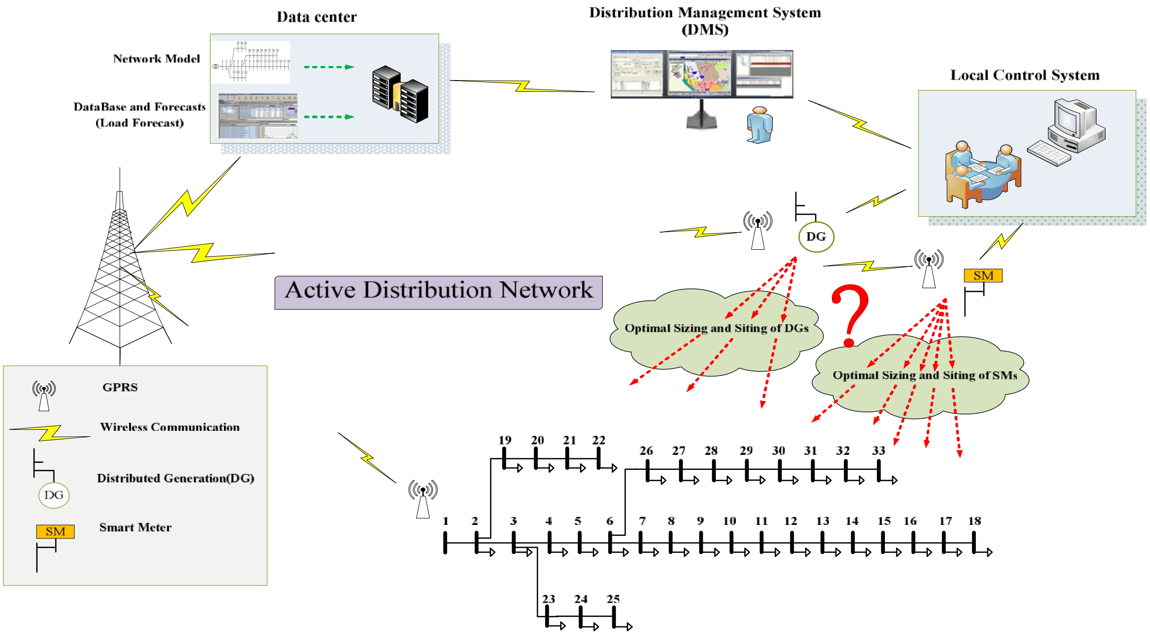


Figure 3. Single line diagram for IEEE 33-bus test system

TABLE 2. Original aggregate network loading and losses

Load State	Active Power (MW)	Reactive Power (MVA)	Losses (kW)
Minimum	1.486	0.920	30.78
Medium	2.229	1.380	71.30
Normal	2.972	1.840	130.71
Maximum	3.715	2.300	230.98

TABLE 3. GA parameters and stopping criteria

Population size	50
Selection criteria	Roulette wheel
Recombination probability	0.5
Mutation probability	0.01

TABLE 4. DGs and SMs specification

DGs specification		
Accessible size for DGs	Min	200kW
	max	2000kW
Power factor range for DGs	Min	0.85
	max	1
Number of buses to install the DGs	3	
Capacity of installed DGs (%)	50	
SMs specification		
Type of demand response contract with consumers to reduce their loads	DLC	
Number of buses to install the SMs	5	
Maximum amount of permissible load reduction (%)	10	

Table 5 shows the results for the test system in different cases where the optimal site and size of DGs and also the optimal site of installation for SMs have been determined. Note that, the percentage of savings in each case is calculated with respect to the corresponding base case. Also, the energy losses cost histogram at each case and each load state are given in Table 5.

Note that GA, as one of the heuristic algorithms, does not guarantee the same answer even after running the same problem numerous times. Consequently, in this study GA run was repeated ten times with different initial populations and recorded optimal solution results.

In the following, simulation results are obtained for each case and discussed in depth.

5.1. Placing DGs in UPF mode and without placing SMs.

In this case, the system is assumed to allocate DGs in UPF mode without placing SMs.

The optimal size and site of DGs are given in Table.5. The yearly energy losses cost reduced from $15859 (base case) to $6318, thus resulting in 60.16% saving. Also, as it is obvious in Table.5, total power loss at each load state has reduced. For example, the real power loss is 210.98 kW (base case) reduced to 87.66 kW.

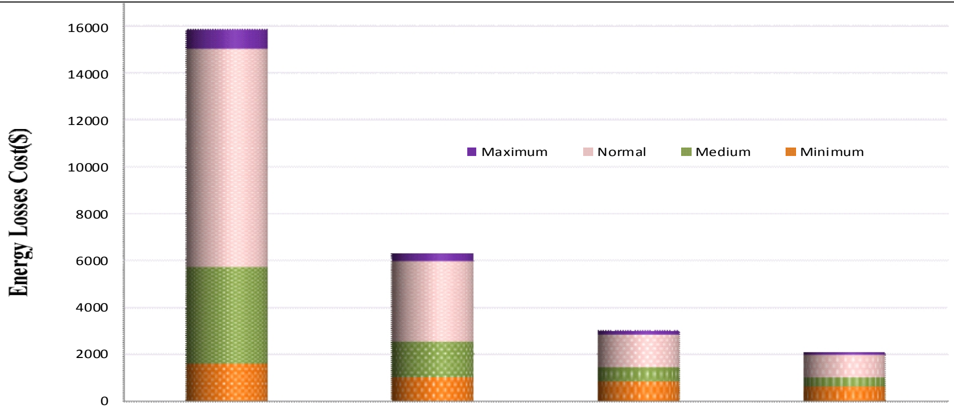
5.2. Placing DGs operated in APF mode and without placing SMs

Considering DG units in APF mode to be installed has resulted to 81.06% saving in total energy losses cost and power losses have decreased remarkably at each load state. These achievements are due to applying DGs in APF mode, DG units are allocated to be suitable for both providing active and reactive power support. Other results of this case are given in Table 5.

5.3. Placing both DGs in APF mode and SMs.

It is obvious with respect to Table 5, considering DLC demand response program through installation of SMs, would affect both the optimal site and size of DGs to be installed. In this case, by simultaneous placement of DGs and SMs, there has been an extra cost saving (86.82%) and also loss reduction from 210.98 kW (base case) to 35.14 kW. Optimal size, site and power factor of DGs and optimal location of SM units are given in Table.5. The optimal results obtained for the test system in the third case has been illustrated in Figure 5 visually.

TABLE 5. Optimal results for IEEE 33-bus test system.



Case			Base	DGs with PF=1	DGs with APF	DGs with APF & SMs
Energy Losse Costs ($)	Minimum		1601.4	1019.2	844.60	635.62
	Medium		4122.2	1511.3	606.16	375.35
	Normal		9303.5	3442.6	1378.6	958.80
	Maximum		831.9	344.9	173.64	138.23
	Total Cost		15859	6318	3003	2090
Power Losses (kW)	Minimum		30.78	19.59	16.23	12.21
	Medium		71.30	26.14	10.48	6.18
	Normal		130.71	48.37	19.37	13.47
	Maximum		210.98	87.66	44.11	35.14
Inistalled DG Units Size (kW)	DG1	Size	-	541	713	553
		Site	-	Bus 14	Bus 12	Bus 13
		PF	-	-	0.85	0.85
	DG2	Size	-	682	624	713
		Site	-	Bus 24	Bus 24	Bus 24
		PF	-	-	0.92	0.9
	DG3	Size	-	680	663	704
		Site	-	Bus 30	Bus 30	Bus 30
		PF	-	-	0.95	0.88
Inistalled SM Units	SM1	Site	-	-	-	Bus 7
	SM2	Site	-	-	-	Bus 8
	SM3	Site	-	-	-	Bus 25
	SM4	Site	-	-	-	Bus 30
	SM5	Site	-	-	-	Bus 32
Cost Saving (%)			-	60.16	81.06	86.82

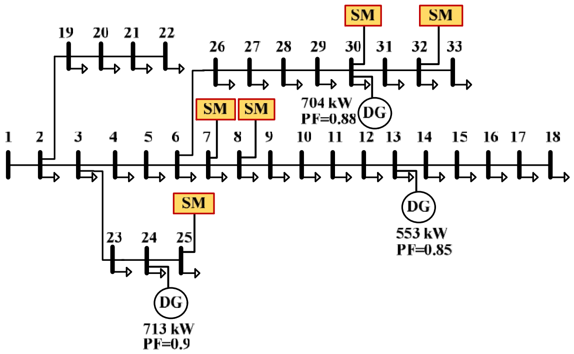


Figure 4. The optimal size and site of DGs and SMs in IEEE 33-bus test system.

6. CONCLUSION

In this paper, by presenting a comprehensive mathematical formulation for the non-linear problem, concurrent allocation of SMs and DGs has been modeled and tackled based on GA. A sample case study was presented, and three different cases are discussed. Moreover, a probabilistic approach, rather than time-series models used in the literature, was adopted in order to minimize the losses cost at each load state, and thus to achieve the maximum saving. It was shown that applying DG units in APF mode that results in higher reactive power support would have a considerable effect on energy losses cost and power loss reduction as well. By this way, the optimal value of PF for each DG unit has been assigned as well. Consequently, the effect of DLC demand response between large consumers, has been investigated by optimal placing of SMs in the network.

By reducing up to 10 percent of optimally determined consumers through SMs, the regime of optimal siting and sizing of DG units has been altered.

Performing DLC demand response has resulted in the change of both size and site of DGs to be installed. Additionally, the results showed that integrating both DG and SM units with distribution systems reduces the total losses costs because of their capacity to shave peak load. Thus, it is necessary for DNOs to consider the DRPs in the expansion planning problems as well as siting and sizing issues in the future ADNs.

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Assessing the Impact of Size and Site of Distributed Generations and Smart Meters in Active Distribution Networks for Energy Losses Cost

T. Sattarpour, D. Nazarpour

Department of Electrical Engineering, Urmia University, Urmia, Iran

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چکیده

شیوه های زیادی برای بررسی ظرفیت منابع تولید پراکنده (DG) استفاده شده است. یک جنبه ای که در شیوه های موجود دیده نشده است، توانایی تاثیر ضریب قدرت تطبیقی(APF) منابع تولید پراکنده بر مسائل سیستم‌های قدرت است. این مقاله شیوه‌ای برای جایابی همزمان DGs و ادوات اندازه‌گیری هوشمند (SMs) در شبکه های توزیع فعال (ADN) با ضریب قدرت تطبیقی DGs برای کاهش هزینه تلفات ارائه می‌کند. جایابی SMs در(ADNs) نوظهور، قطعاً بر مسائل سیستم‌های قدرت از جمله مطالعات مربوط به DGs تأثیر خواهد گذاشت. SMs در واقع برای پیاده‌سازی موفق برنامه‌های پاسخگویی بار (DRPs) همانند برنامه‌ی کنترل مستقیم بار (DLC) برای مصرف کنندگان نهایی در نظر گرفته شده است. برای رسیدن به کمترین هزینه تلفات، مساله بهینه‌سازی توسط الگوریتم ژنتیک مورد ارزیابی قرار گرفته و به طور کامل بر روی شبکه توزیع نمونه ۳۳ شینه‌ی IEEE مطالعه شده است. در این مقاله مدل بار احتمالی به جای استفاده از مدل زمانی فرض شده است. نتایج به دست آمده گواه تاثیر قابل توجّه برنامه‌های پاسخگویی بار و ضریب قدرت تطبیقی در تعیین اندازه و محل بهینه منابع تولید پراکنده برای اتصال به شبکه های توزیع فعال و تاثیر قابل توجه آن روی تلفات انرژی است.

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