International Journal of Electrical, Electronic and Communication Sciences
ISSN: 2517-9438
Vol:8, No:7, 2014

Optimal Simultaneous Sizing and Siting of DGs and Smart Meters Considering Voltage Profile Improvement in Active Distribution Networks

T. Sattarpour, D. Nazarpour

Abstract**—**This paper investigates the effect of simultaneous placement of DGs and smart meters (SMs), on voltage profile improvement in active distribution networks (ADNs). A substantial center of attention has recently been on responsive loads initiated in power system problem studies such as distributed generations (DGs). Existence of responsive loads in active distribution networks (ADNs) would have undeniable effect on sizing and siting of DGs. For this reason, an optimal framework is proposed for sizing and siting of DGs and SMs in ADNs. SMs are taken into consideration for the sake of successful implementing of demand response programs (DRPs) such as direct load control (DLC) with end-side consumers. Looking for voltage profile improvement, the optimization procedure is solved by genetic algorithm (GA) and tested on IEEE 33-bus distribution test system. Different scenarios with variations in the number of DG units, individual or simultaneous placing of DGs and SMs, and adaptive power factor (APF) mode for DGs to support reactive power have been established. The obtained results confirm the significant effect of DRPs and APF mode in determining the optimal size and site of DGs to be connected in ADN resulting to the improvement of voltage profile as well.

Keywords**—**Active distribution network (ADN), distributed generations (DGs), smart meters (SMs), demand response programs (DRPs), adaptive power factor (APF).

NOMENCLATURE

Indices and Sets

i, j, Ω_B	Indices and set of buses.
k, Ω_{Br}	Index and set of branches.
s, Ω_S	Index and set of substations.
Ω_i	Set of buses connected to bus *i*.

Parameters

R_k	Resistance of *k-th* branch.
P_L, Q_L	Active and reactive powers of distribution feeders.
Y_{ij}, θ_{ij}	Magnitude and phase angle of feeder's admittance.
$S_s^{\max}$	Maximum allowable apparent power that could be flowed through *s-th* distribution substation.
$S_k^{\max}$	Maximum allowable apparent power flowing each substation.
$P_{DG}^{\min}, P_{DG}^{\max}$	Minimum and maximum limits for DGs active power.
$Q_{DG}^{\min}, Q_{DG}^{\max}$	Minimum and maximum limits for DGs reactive power.
$S_{DG}^{\max}$	Maximum apparent power limit for DGs.
S_L	Apparent power of distribution feeders.
$PF_{DG}^{\min}, PF_{DG}^{\max}$	Minimum and maximum power factor for DGs.
$V_{\min}, V_{\max}$	Minimum and maximum limits of bus voltages.
I_k	Current magnitude in *k-th* branch.
N_{DG}	Number of DGs installed in the network.
N_{SM}	Number of SMs to be installed in the ADN
PF_L	Constant power factor of load in each bus subjected to be equipped with SMs

Functions and Variables

P_{Loss}	Total power losses.
x, u	Vector of dependent and independent variables.
V	Bus voltage.
P_s, Q_s	Active and reactive power imported from *s-th* substation.
P_{DLC}, Q_{DLC}	Active and reactive power reduction by DLC responsive load.
P_k, Q_k	Active and reactive power flowing *k-th* branch.
P_{DG}, Q_{DG}	Active and Reactive power generation by DG at bus *i*.
PF_{DG}	Power factor for DGs.

T. Sattarpour and D. Nazarpour are with the electrical engineering department, Urmia University, Urmia 57148 Iran (e-mail: t.sattarpur@yahoo.com, d.nazarpour@urmia.ac.ir).

I. INTRODUCTION

NOWADAYS, distributed generation (DG) is in increasing concentration in power systems as a solution to economical challenges, hence the famous scientific features such as voltage profile improvement as well as economical benefits such as reduction in long-term planning and short-term operational costs are some of the main factors encouraging the worldwide nations to provide the employment of distributed generations (DGs) in their networks [1], [2]. DGs are usually located near load centers and accommodate the electrical requirements of consumers locally. Therefore, DG would reduce distribution losses and improve the system voltage profile. There are different types and sizes of DGs, but the most common types are the conventional diesel-based and renewable-based DGs, renewable-based such as solar, biomass, wind, small hydro turbines, micro turbines, and CHP [3]. DGs ranging are between 1 W to 300 MW that can also be categorized based on the power ratings, proposed in [1]. Due to the technological improvements, it has been made possible to deploy DGs in different modes such as adaptive power factor (APF) mode. In APF mode, a DG unit is speculated to be suitable for both providing active and reactive power support to the network. Consequently, it would have a more remarkable effect in both voltage profile improvement and active power loss reduction [4]-[5].

On the other hand, there is now a common intelligence between the industry and academia on the ongoing transition is changing the passive distribution network to a more intelligent and efficient one known as active distribution networks (ADNs). In passive distribution networks, the electrical power is supplied by the general grid system to the consumers fixed in the distribution networks, but in ADNs, DG units are added to the distribution system leading to bidirectional power flows in the networks. ADNs are generally benefitting from the rapid development in the information and communication technology (ICT). General packet radio services (GPRS) is one of the most useful media in the wireless and online engineering control actions. In this way, flexible types of intelligent electronic devices (IEDs) such as distribution remote terminal units (DRTUs) and smart meters (SMs) have been developed to yield an online and efficient control on ADNs ingredients. ADNs are characterized with both renewable-based and controllable diesel-based DGs, responsive loads and flexible network structures realized with remotely controlled switches [6], [7]. The active participation of end-side consumers in demand response programs (DRPs) could be divided mainly in two folds encompassing incentive-based programs and time-based programs [8], [9]. In incentive-based programs such as direct load control (DLC), the distribution network operator (DNO) controls the consumers demand up to a prespecified contracted value and prices through SMs. DLC is voluntary program, and if consumers do not limit utilization, this is not penalized. These programs are the best tools for DNOs to handle the crisis such as peak load hours and forced outages in some feeders. Time-based programs, with respect to the forecasted price of electricity in different hours of next 24-hour ahead, are mainly activated by the consumers themselves and there is no any direct control on them by the DNOs.

The developing of ADNs would deeply change the power system studies such as DGs optimal siting and sizing problem. In the passive distribution networks, DGs are exclusively handled in the peak load hour considering voltage profile improvement, loss or cost reduction, and reliability enhancement [10]-[13]. More recently, some of the features of ADNs such as automatic online reconfigurations realized through remotely controlled switches (RCSs), has been adopted in DGs optimal placement problem. The author in [14] has developed an optimal framework for concurrent allocation of DGs and capacitors in ADNs making use of online reconfigurations. He has also provided some remarkable consequences in this context. However, the presences of responsive loads and DRPs have ignored in the abovementioned studies.

Keeping the foregoing discussions in mind, this study initiates to examine the effect of DRPs effect in optimal placement of DGs in ADNs. DLC as one of the most effective DRPs in peak load management is considered to be contacted between the DNO and some large consumers in the network. By this way, DNO can reduce the utilization of these loads up to a prespecified value at contracted prices by the signals released through SMs. Thus, as an innovative point, this paper coordinates the determination of installation buses for limited number of SMs due to the limited investment capabilities of DNO with the problem of DGs optimal placement. To do so, different scenarios have been devised which investigate both the individual and simultaneous placement of DGs and SMs. By determination of installation buses for SMs, the effect of DLC responsive loads in optimal siting and sizing of DGs would be analyzed in depth. It will be discussed that the inclusion of DLC buses as DRPs, would affect both the size and site of DGs to be installed in the future ADNs. Therefore, it would be necessary 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 voltage profile improvement and extra power loss reduction 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 paper, DG is also capable to supply reactive power in addition to real power since DG units with reactive power control can give better voltage profile. 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 solved with genetic algorithm (GA) looking for improve voltage profile in the network. The proposed methodology is applied on IEEE 33-bus distribution test system. The remainder of the paper is organized as follows. The problem statement and mathematical formulation is presented in section II. In the sequel, Section III addresses the GA fundamentals and introduces the proposed chromosome for the problem. Afterwards, different scenarios have been devised and simulated numerical results are provided in section IV. Eventually, concluding remarks are presented in Section V.

II. Problem Formulation

This section is dedicated to present the mathematical formulation for optimal placing of DGs and SMs in ADN. In the following subsections, the main assumptions, objective function considered to be optimized and running constraints are introduced in more aspects.

A. Assumptions

The following assumptions are made as the main features envisaged in the optimal placement of DGs and SMs in the ADN:

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

B. Objective Function

Each bus that is selected for placing SM would be exposed to reduce its load up to a prespecified amount denoted by $S_{DLC_i}^{\max}$. In addition, 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 voltage profile improvement and power loss minimization. Herein, the most important purpose is to improve the voltage profile in the network. Voltage Profile Improvement (VPI) is considered using (1).

Minimize

$$\left[VPI(x,u) = \sum_k \left(|V(i) - 1| \right)^2 \right], \qquad i \in \Omega_B \tag{1}$$

Subject to $h(x,u) = 0$

$g(x,u) \leq 0$

C. Constraints

The problem of optimal siting and sizing of DGs and SMs in an ADN is subjected to the following equality and inequality constraints namely, h(x,u) and g(x,u).

D. Load Flow Equations:

The equality constraints (2) and (3) 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 amended to include the effect of DGs and SMs presence as follows:

$$P_{g_i} + P_{DG_i} + P_{DLC_i} - P_{L_i} = \sum_{j \in \Omega_i} P_{ij}(V_i, V_j, Y_{ij}, \theta_{ij}) \tag{2}$$

$$Q_{g_i} + Q_{DG_i} + Q_{DLC_i} - Q_{L_i} = \sum_{j \in \Omega_i} Q_{ij}(V_i, V_j, Y_{ij}, \theta_{ij}) \tag{3}$$

E. Voltage Limits:

Proper constraints are required to guarantee the voltage magnitude to be kept at permissible range at each bus. The voltage magnitude for substation buses is maintained at 1 p.u.:

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

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

F. Limit for Substations Capacity:

The maximum acceptable capacity of the transformer limits the maximum apparent power flow in each substation connecting the ADN to the upstream sub-transmission level:

$$\sqrt{P_s^2 + Q_s^2} \leq S_s^{\max}, \qquad s \in \Omega_s \tag{6}$$

G. Flow Limits for Feeders:

It is necessary to keep the apparent power flowing each feeder in its allowable range:

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

H. 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:

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

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

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

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

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

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

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

I. Limits on SMs and DLC Responsive Loads Maximum Reduction Capacity:

As the primary 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. Purpose of installation buses for SMs, itself will have an enormous consequence 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 $N_{SM}^{\max}$. In addition, each candidate bus that is selected as a DLC responsive load should suit the maximum amount of allowable load reduction indicated by PER_{DLC} (%), that is, the percent of MVA decrease in each bus. The following constraints are taken to be observed:

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

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

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

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

III. Optimization Technique Based On 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 imitates the biological selection process. In this process the most qualified 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 crossover and mutation. By this way, GA would be apt to carefully probe the search space and then find the optimal solutions [15]. However, based on ordinary selection theory, GA is an influential solving engine for complex non-differentiable engineering problems such as simultaneous placing of both DGs and SMs in distribution systems.

A. Problem Codification

The problem codification denotes establishing of a probable candidate solution surrounding one chromosome. The set of unknown variables, as the constituting genes, embrace a chromosome in GA. The proposed coding strategy for DGs and SMs optimal placement is illustrated in Fig. 1. It can be observed that the implemented chromosome is composed of three strings. The first string accounts for optimal site and size of DGs, the second string is for adaptive power factor of DGs and finally the third string determines the optimal site for smart meters.

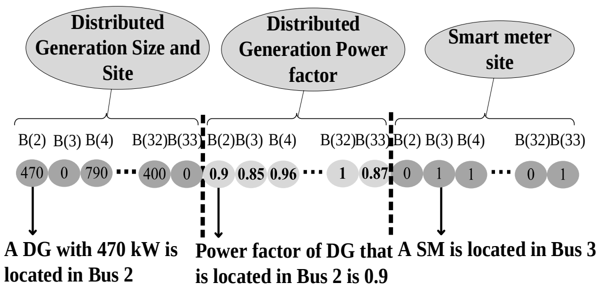
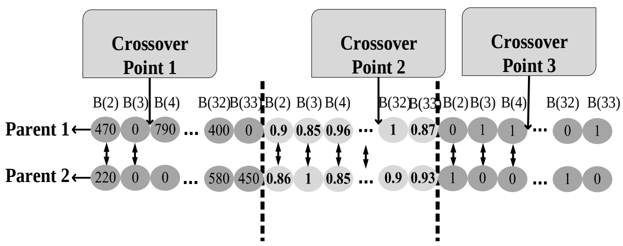


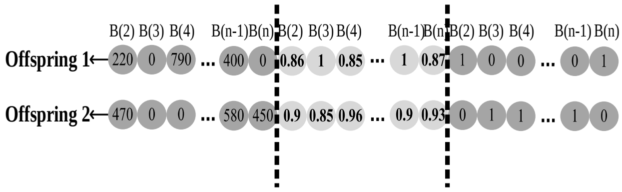
Fig. 1 Structure of the proposed chromosome

B. Crossover and Mutation

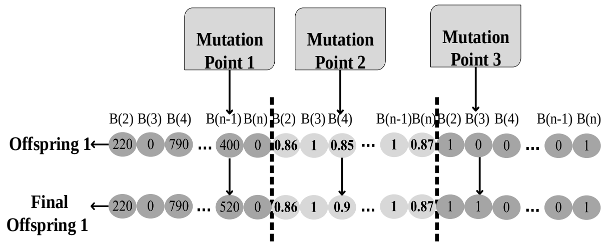
Crossover stage refers to a stochastic process in which some of the chromosomes are randomly selected, and from stochastically determined crossover points (CPs), are combined together to create new offspring. Therefore, each offspring would possess a portion of its parent's coding. Afterwards, some of the genes in the produced offspring are exposed to random mutations to remain the stochastic temper of duplicate process. Figs. 2 (a)-(c) display the multi-point crossover and mutation process for the proposed chromosome.



(a)



(b)



(c)

Fig. 2 (a) Selected parents, (b) Recombination process, (c) Mutation process

IV. Numerical Results and Discussion

A. Test System Specifications

To investigate the validity and outperformance of the proposed methodology, the well-known IEEE 33-bus system has been considered as the test beds here. Fig. 3 demonstrates the single line diagram for this system. Bus 1 is connected to the sub-transmission network and is assumed as the substation. The essential network data including impedance of branches and the active and reactive loads for all buses could be found in [16], [17]. The allowable range for voltage magnitudes in all buses has been determined to be between 0.95 p.u and 1.05 p.u respectively. The maximum possible investment capital, available for DNO, limits the maximum penetration of DGs up to PER_{DG}= 50% of the peak load of the network with a maximum number of three DGs.

The minimum and maximum available size for DGs has been assumed as 200 and 2000 kW. With respect to APF mode, DGs are permissible to operate with power factors between 0.85 and 1. Also, the maximum number of buses that DNO initiates to install the SMs is taken to be equal with 5 to establish DLC demand response contracts with consumers to reduce their loads up to 10%, say PER_{DLC}=10%. GA has been executed in several runs with different values for crossover and mutation rates. Even though there were not so significant differences, the best results are obtained with population size of 50, crossover rate equal with 0.5 and mutation factor adjusted at 0.01 respectively.

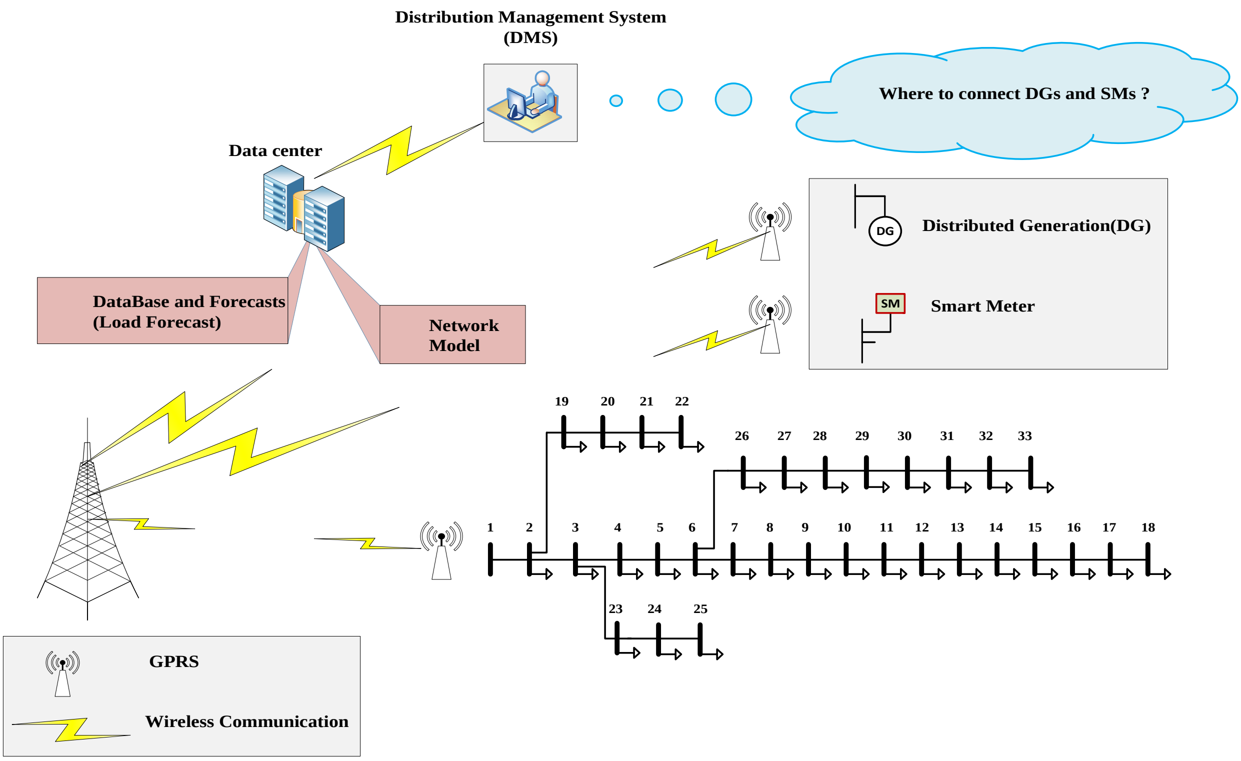


Fig. 3 Single line diagram for IEEE 33-bus test system

B. Multi-Scenario Optimal Sizing and Siting of DGs and SMs

To present a comprehensive analysis, four different scenarios have been devised as the following:

- Scenario 1: Base plan;
- Scenario 2: Optimal placing of only 1 DG and SMs;
- Scenario 3: Optimal placing of 2 DGs and SMs;
- Scenario 4: Optimal placing of 3 DGs and SMs.

Base plan represents the basic construction of the test cases without any DGs and SMs. For each of the second, third and fourth scenarios there have been designated three different cases including:

- Placing DGs operated in unity power factor (UPF) mode and without placing SMs, designated with Case-I;
- Placing DGs operated in APF mode and without placing SMs, designated with Case-II;
- Placing both DGs in APF mode and SMs to perform DLC demand response, designated with Case-III.

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

V. Numerical Results for IEEE 33-Bus Test System

For the test system and in its base structure, the total load of the network is equal with 3.72 MW and 2.3 MVAr. The minimum voltage value is 0.9038, which occurs at bus 18 and the power loss without any installation of DGs and SMs is attained as 210.98 kW.

Table I gathers the obtained results for the test system in different scenarios where the optimal site and size of DGs and the optimal site of installation for SMs have been determined. For the case of second scenario, the minimum voltage value corresponds to Case-III is 0.9589 and the minimum power loss is 64.19% reduction in total power losses. Also, as it is obvious with respect to Table I, considering DLC demand response program through installation of SMs, would affect both the optimal site and size of DGs to be installed. In the third scenario, considering two DG units in APF mode to be installed has resulted to 74.41% reduction in total power losses and minimum voltage value is 0.9721; although the total size of DGs has only increased by 0.035 MW from 1.960 MW to 1.995 MW. In addition, the worst bus voltage value has increased from 0.9589 p.u to 0.9721 p.u., which signifies a very influential improvement in voltage profile. Meanwhile, power losses have decreased remarkably by 10.22% too. These achievements are due to applying DGs in APF mode and affecting more than one DG units in the most impressive parts of the network. By concurrent placement of DGs and SMs in the fourth scenario, there has been an influential voltage profile improvement and extra loss reduction with respect to second and third scenarios. However, as the fourth scenario reports in Table I, the most important effect of DLC demand response is through SMs returns back to the change in the optimal site and size of DGs to be installed.

In addition, Fig. 4 demonstrates the voltage profile for three different cases. As it is seen, the best voltage profile is obtained for the Case-III wherein DGs are in APF mode and through optimal placement of SMs, the DNO has contracted

DLC demand response with the most suitable consumers. Considering DGs in APF mode, would result to reactive power support too, and hence, the voltage profile has been improved remarkably. The optimal PFs for the three DGs has been achieved as 0.98, 0.98 and 0.85. It is worth noting that the concurrent placement of SMs with DGs affects the installation buses of SMs too. The optimal results obtained for the test system in the fourth scenario has been illustrated in Fig. 5 visually. Also, Fig. 6 represents the reduction in both active and reactive power losses in different scenarios. It can be observed that the maximum reduction in power losses is occurred in scenario4.

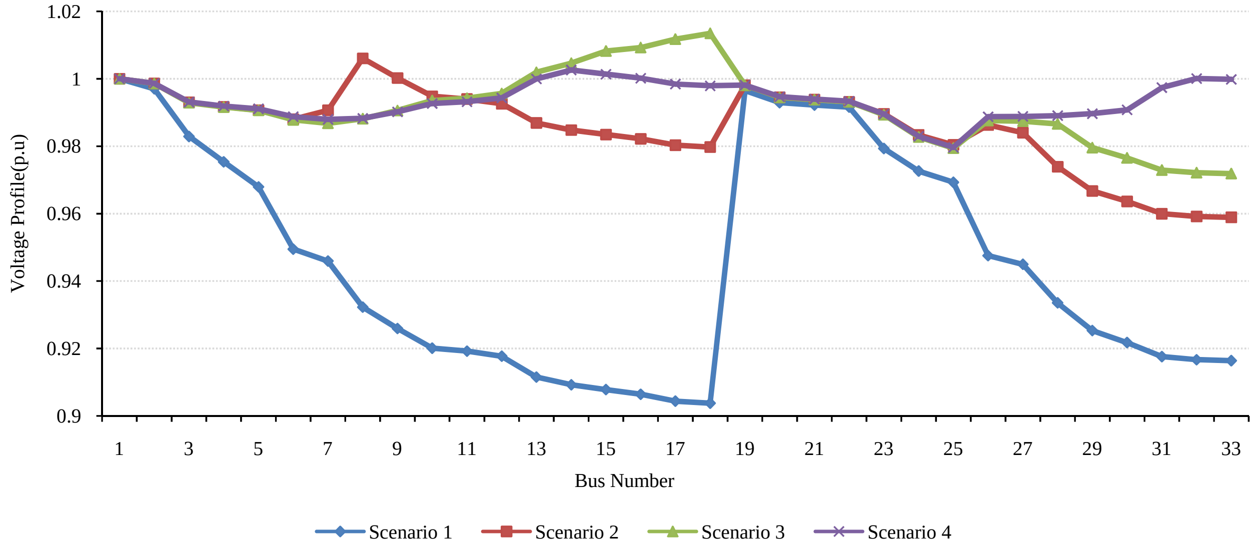


Fig. 4 Voltage profile for IEEE 33-bus test system in different scenarios

TABLE I
OPTIMAL RESULTS FOR IEEE 33-BUS TEST SYSTEM

Scenario	Cases	Minimum Voltage (p.u.)	Power Losses (kW)	Loss Reduction (%)	DGs Optimal Size (MW) and Site	Optimal Power Factor	Buses for Installing SMs
Scenario 1	Base Case	0.9038(B18)	210.98	–	–	–	–
Scenario 2	Case-I	0.9456(B33)	143.77	31.87	2.0(B12)	1.00	–
	Case-II	0.9545(B33)	83.91	60.22	1.998(B8)	0.85(B8)	–
	Case-III	0.9589(B33)	75.55	64.19	1.960(B8)	0.9(B8)	B6, B25, B30, B31, B32
Scenario 3	Case-I	0.9615(B31)	110.71	47.52	1.444(B14), 0.556(B33)	1.00(B14), 1.00(B33)	–
	Case-II	0.9700(B25)	63.51	69.9	0.966(B17), 1.033(B33)	0.95(B17), 0.95(B33)	–
	Case-III	0.9721(B33)	54.00	74.41	0.953(B14), 1.042(B32)	0.95(B14), 0.85(B32)	B7, B14, B18, B20, B32
Scenario 4	Case-I	0.9687 (B31)	108.34	48.65	0.959(B13), 0.507(B16), 0.534(B33)	1.00(B13), 1.00(B16), 1.00(B33)	–
	Case-II	0.9789(B25)	54.08	74.37	0.719(B15), 0.417(B18), 0.862(B33)	0.98(B15), 0.98(B18), 0.85(B33)	–
	Case-III	0.9796(B25)	39.76	81.15	0.700(B15), 0.430(B18), 0.870(B28)	0.98(B15), 0.98(B18), 0.85(B28)	B8, B29, B30, B31, B32

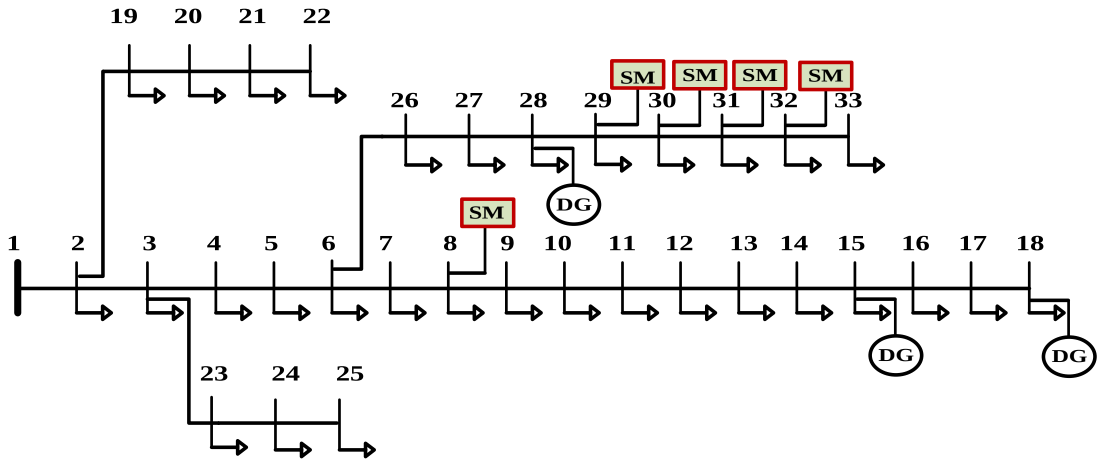


Fig. 5 The optimal size and site of DGs and SMs in IEEE 33-bus test system

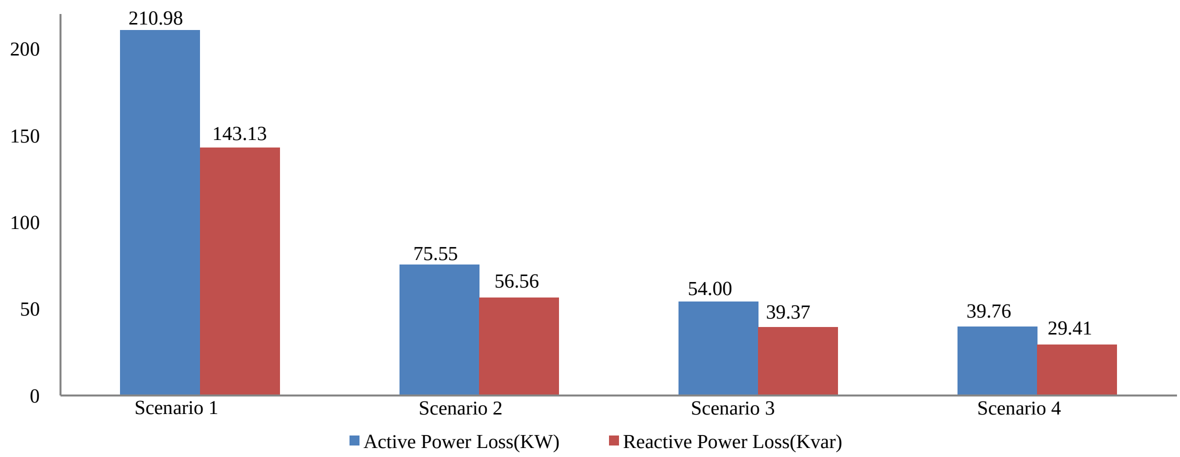


Fig. 6 Total active and reactive power losses for IEEE 33-bus test system in different scenarios

VI. Conclusion

The presence of well promising DRPs such as DLC demand response programs in the future ADNs has been tailored in the problem of optimal siting and sizing of DG units. By presenting an inclusive mathematical formulation for the non-linear problem, simultaneous allocation of SMs and DGs has been modeled and solved with GA. Different scenarios has been put under examination on IEEE standard 33-bus test system. It was shown that applying DG units in APF mode, which results in higher reactive power support, would have a considerable effect on voltage profile improvement and power loss minimization too. By this way, the optimal value of PF for each DG unit has been assigned as well. In the sequel, the effect of DLC demand response between large consumers was 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 changed. Performing DLC demand response has resulted in the change of both size and site of DGs to be installed. There has been voltage profile improvement as well. 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.

References

[1] M.M. Aman, G.B. Jasmon, A.H.A. Bakar, H. Mokhlis, “A new approach for optimum DG placement and sizing based on voltage stability maximization and minimization of power losses,” *Energy Conversion and Management*, vol. 70, pp. 202–210, 2013.

[2] R.P. Payasi, A. K.Singh, D. Singh, “Review of distributed generation planning: objectives, constraints, and algorithms,” *International Journal of Engineering, Science and Technology*, vol. 3, no. 3, pp. 133-153, 2011.

[3] W. El-Khattam, M.M.A. Salama, “Distributed generation technologies, definitions and benefits,” *Electric Power Systems Research*, vol. 71, pp. 119–128, 2004.

[4] S. Gopiya Naik, D.K. Khatod, M.P. Sharma, “Optimal allocation of combined DG and capacitor for real power loss minimization in distribution networks,” *Electr Power Energy Syst*, vol. 53, pp. 967–973, 2013.

[5] D.Q. Hung, N. Mithulananthan, R. C. Bansal, “Analytical expressions for DG allocation in primary distribution networks,” *IEEE Tran Energy Conversion*, vol. 25, no. 3, September 2010.

[6] Z. Hu, F. Li, "Cost-Benefit analyses of active distribution network management, part I: annual benefit analysis," *IEEE Tran Smart Grid*, vol. 3, no. 3, September 2012.
[7] P. MacDougall, P. Heskes, P. Crolla, "Fast demand response in support of the active distribution network," *in Proc. 22nd International Conference on Electricity Distribution,* Paper1024, Stockholm, 10-13 June 2013.
[8] B. Chakrabarti, D. Bullen, C. Edwards, C. Callaghan, "Demand response in the New Zealand electricity market," *in Proc. Transmission and Distribution Conference and Exposition (T&D), IEEE PES,* pp. 1–7, 2012.
[9] P. Palensky, D. Dietrich, "Demand side management: demand response, intelligent energy systems, and smart loads," *IEEE Tran Industrial Informatics*, vol. 7, no. 3, August 2011.
[10] S. Kansal, B.B.R. Sai, B. Tyagi, V. Kumar, "Optimal placement of distributed generation in distribution networks," *International Journal Engineering, Science & Technology,* vol. 3, no. 3, pp. 47-55, 2011.
[11] M.H. Hemmatpour, M. Mohammadian, M. Rezaie Estabragh, "A novel approach for the reconfiguration of distribution systems considering the voltage stability margin," *Turk J Elec Eng & Comp Sci,* vol. 21, pp. 679-698, 2013.
[12] M.M. Aman, G.B. Jasmon, H. Mokhlis, A.H.A. Bakar, "Optimal placement and sizing of a DG based on a new power stability index and line losses," *Electr Power Energy Syst,* vol. 43, pp. 1296–1304, 2012.
[13] S. Ghosh, S.P. Ghoshal, S. Ghosh, "Development of smart distribution grid," *in Proc. Electr Power Energy Syst,* vol. 32, pp. 849–856, 2010.
[14] S. Golshannavaz, "Optimal simultaneous siting and sizing of DGs and capacitors considering reconfiguration in smart automated distribution systems," *J Intelligent Fuzzy Syst,* vol. 10, 2014.
[15] H. E.A, Talaat, E. Al-Ammar, "Optimal allocation and sizing of distributed generation in distribution networks using genetic algorithms," *in Proc. 11th International Conference on Electrical Power Quality and Utilisation (EPQU),* pp. 1–6, 2011.
[16] S. Chandramohan, N. Atturulu, R.P. Kumudini Devi, B. Venkatesh, "Operating cost minimization of a radial distribution system in a deregulated electricity market through reconfiguration using NSGA method," *Electr Power Energy Syst*, vol. 32, pp. 126–132, 2010.
[17] N. Rugthaicharoencheep, S. Sirisumrannukul, "Feeder reconfiguration for loss reduction in distribution system with distributed generators by Tabu search," *GMSARN International Journal,* vol. 3, pp. 47–54, 2009.

Tohid Sattarpur received the B.Sc. degree in electrical engineering from Urmia University, Urmia, Iran, in 2012. Currently, he is pursuing M. Sc. degree in electrical engineering, Urmia University, Urmia, Iran. His research interests are in smart grid technologies, optimal operation and expansion planning of active distribution networks as well as renewable energies.

Daryoosh Nazarpour received the B.Sc. degree from Iran University of Science and Technology, Tehran, Iran, in 1982 and the M.Sc. and Ph.D. degrees from Tabriz University, Tabriz, Iran in 1988 and 2005, respectively, all in electrical engineering. He is now an Associate Professor in Urmia University, Urmia, Iran. His research interests are primarily in advanced power electronics, FACTS applications in power system and smart grid concepts, specifically active distribution networks planning and operation.