Optimal Placement and Operation of BESS in a Distribution Network Considering the Net Present Value of Energy Losses Cost

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Abstract

In recent years, penetration of battery energy storage systems in distribution networks is increased. This is because of increasing interest to integrate energy storage devices into the power system smart grid. Integrating energy have simultaneously goal with smart grid, which are improve the reliability and satisfactory operation of power system. Battery energy storage system is as one kind of energy storage devices have some advantage can satisfy these goals. One of the main challenges in use of these devices is the optimal placement of them. In this paper, optimal placement of battery energy storage is obtained by evaluating genetic algorithm for minimizing net present value related to power losses in addition to its best operation during faced different percentage of load levels with specific electricity price for each level. In this paper in spite of most of research in the field of placement of battery energy storage, the load characteristic is considered multi-level to approach realty optimization. In addition, in this paper cost benefit of energy storage installation respect to the energy losses cost is optimized and arbitrage benefits of this installation did not considered. By considering this, yet the total benefit in presented scheme is higher than homogeneous works. To evaluate this optimization challenge IEEE-33 bus standard distribution network is chosen and to validation of efficiency of presented scheme, results are compared with previous similar works.

1. Introduction

Nowadays, Electrical distribution systems are going to be smart grids as a main part of an intelligent network that can control itself. One of the main factors change conventional distribution networks toward smart distribution networks is integrating of energy. Integration in power system driven by several factors; avoid excess electricity production, carbon reduction targets for the implementation climate change, voltage control and power flow management. In papers [1, 2], it is discussed about energy storage done toward their benefits in distribution networks, which are based on load acid-battery technology. In [3] the impact on the tasks of voltage control and power flow management operating of battery energy storage system (BESS) penetrated in the distribution network is shown. Some investigations have been done in papers like [4], [5] to show the important role of usage battery energy storage besides discussing about the various storage technologies. In addition, the reviews, which are carried out in these papers, suggest that so far the battery technology is the most widely used storage device for power system applications.

In papers for planning, management and integrating energy, several efforts have been done. Some researchers try to plane different type of distributed energy resources (DERs) such as Distribution Generations (DGs), and Demand Responses (DRs) in to distribution systems in order to changing the passive distribution network to a more intelligent and efficient one known as active distribution networks (ADNs) [6]. In some of these papers, researchers try to planning by siting and sizing distributed generations (DGs) in distribution networks [7-9]. In [9] focused on sizing and siting of DG considering demand respond to minimize power losses in distribution networks. In [11] the objective function tries to minimize total costs. In [12], [13] authors' goal is optimal sizing and siting of DGs and capacitors simultaneously. Nowadays extra of generation units, storage units are also considered to investigation and study. In [14] probability using the storage tools are investigate, also in [15] the advantage and disadvantage of these tools are considered and shown the beneficial ways of using them. Optimal siting of these units is one of the fundamental research challenges for active management of distribution networks. Many efforts have been done in this subject area. Some researchers are focused on optimization methods. Trial and error methods and deterministic approaches need several efforts and are time-consuming. Today's heuristic methods like as genetic algorithm (GA) and particle swarm optimization (PSO) are commonly used to find optimal locate. In this paper optimization tools is GA. In some other researches, different objective functions are studied [16]. Like improving voltage profile and reliability, minimizing power loss, minimizing total cost and so on. In [17] the market-clearing price is tracked profit is produced by exploiting the differences between peak and off-peak prices. This is because of considering electricity arbitrage through the rule of 'buy low, sell high'. In [18] energy storage allocation in distribution network for load management is considered. Load by their probability in 10 levels are considered. In addition, the arbitrage benefit of this installation is considered.

In this paper optimal placement of energy storage is taken to reduction net present value (NPV) related to power losses cost. During solve of this optimization problem load are multi levels. In other words, there are different percentages of load levels that have specific electricity price for each level to approach more reality. Herein numbers of states for loads are four. This optimize location is considered for 5 years planning. Also through this optimization problem, there is no DG to investigate that, how usage of storage unit in distribution networks is beneficial without DG. It is noted that arbitrage benefits of this installation did not considered, this is a while, evaluating numerical analyses on IEEE 33 bus test standard system, shows the total beneficial is positive and considerable.

This paper is organized in six sections. The problem depiction is presented in section 2. Section 3 is prepared to explain methodology. Case study and numerical results are provided in section four and 5 respectively. Eventually, concluding remarks are presented in section 6.

2. Problem Explanation

The goal of using BESS is simultaneously with demand side management programing, because both of them shift demand use of energy from peak to off-peak periods. In the other words BESSs shave peak load by charging in off peak period and discharging in peak load, this is the same policy for demand side management programing. In this policy, although the installation of storage units are expensive but it is just able when the benefits from integrating of BESSs to attain demand side management need to be considered arbitrage benefits, system upgrade deferral, and energy loss reduction [18]. Arbitrage benefits is buying and storing power electricity energy in cheap price time (off-pick) and selling power electricity energy in expensive price time (pick) have economic beneficial to the storage unit owner. In this deal, economic beneficial counted after accounting loss of storage units. As said before, electrical energy has different prices and deferent periods of time have been considered in this paper. In addition, installing storage units in maximum load state could shave the peak load, therefore it can be said that part of flowing power in distribution network shift from expensive price time to cheap price time in the planning period. Hence, energy price losses is reduced and brought saving money that called energy losses cost reduction. This is while this benefit is considered as a secondary benefit from integrating BESSs into distribution systems. In distribution network, there is an annually load grows which usually needs to upgrade the system. This upgrading needs some costs, however by installation storage unit the pick load is shaved and upgrading can shift and deferral to the latter years.

Keeping the foregoing comments in mind, in this paper the main goal is sitting a battery storage unit to investigate economic justification without considering arbitrage benefits. It is clear that pretermit arbitrage benefits make justification about economic feasibility of storage units hard. This is a while, in this paper will be shown that the total benefits with pretermit arbitrage benefits is positive and considerable. In addition, the proposed comparison with pervious papers reveals more aspects of profitability. Therefore the proposed work try to find optimal location of BESS in planning period with different load states and specific duration of time and electricity prices for each state in distribution network under study and catch the optimum output power of BESS in this planning period in each state of load in order to minimize the NPV related to power losses cost.

3. Methodology

The proposed approach is described in this section. Firstly, assumptions will be discussed, and then model of load will be introduced and explained in this section. In sequel optimization tools and problem formulation as running constraints are prepared.

3.1. Assumptions

This optimization problem normally needs to be considered basically assumptions as follows:

- Distribution system is redial and balanced;
- Controlling the operation of BESS is based on achieving specified goals.
- Buses 2 up to bus 33 are candidate buses. In other words, except bus 1 all buses can be targeted bus for BESS allocation;
- Annual load growth is considered constant rate;
- Interest rate and inflation rate for financial parameters are assumed constant too;
- the BESS in this paper is not ideal and has the specific round trip efficiency (η) ;

It is noted that in most of researches in this area annual load growth are considered 5%, but herein it considered 7% to find out feasibility of this work in harder situations.

3.2. Load Modeling

Loads, in this paper, are considered in four state; minimum, medium, normal, and maximum. Data of these four states are given in Table. 1. The first column specifies load state, second column specifies that in each state loads are in what percentage of pick loads. Third column give duration time of each state, energy price is given in forth column for each state and in last column is defined operation status of BESS in each state. As shown in this table, BESS in minimum and medium states is in charging status because these states are supposed to be off-peak states and in normal and maximum states is in discharging status because these states are supposed to be peak states.

4. Optimization Technique

One of the most important parts in distribution system planning is to plan a suitable solution scheme, the objective function under study is a non-linear problem (NLP) which is solved using genetic algorithm (GA). GA as an intelligent search technique reproduces the biological selection process.

In this way, GA would be suitable to attentively analysis the search space and then find the optimal solutions. GA has been used in some papers as in [19], [20] and it has shown superior performance compared to other meta-heuristic algorithm in terms of the solution error. The advantage of this algorithm is that use multipoint search. Thus, they can produce a set of non-dominated solutions during the optimization. Therefore, GA has been used to solve the objective function under study. GA parameters that are used in this paper to catch the optimum planning and operation such as mutation rate, crossover rate, population, and so on; are shown in Table. 2.

Table 1. Load modeling and BESS operation.

Load state	Peak load (%)	Duration (h)	Energy price ($/kWh)	BESS operation status
Minimum	40	2890	0.018	Charging
Medium	60	2890	0.020	Charging
Normal	80	2847	0.020	Discharging
Maximum	100	173	0.090	Discharging

Table 2. GA parameters and stopping criteria

GA parameters	description
Inertia	100
Population Size	50
Mutation function	Gaussian
Initial population	random
Stopping criteria	20 generations unchanged
Mutation rate	0.01
Crossover rate	0.95

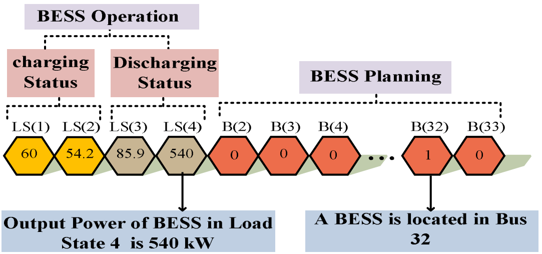

Fig. 1. Construction of the suggested chromosome.

As it seen in this table, stopping criteria considered 20. It means that after 20 generation if the answer is unchanged, the GA optimization will be stopped.

The main step of the methodology proposed is the chromosome encoding of GA. In this process, the most eligible parents would be more likely to survive on their genes to following generations and then replace their genetic code to the upcoming offspring [21]. At first, the initial population of possible solutions is generated, and then other solutions are evaluated in order to optimize the objective function. This technique is known as development process implemented by specific operators namely crossover and mutation. Crossover operator, which produces offspring that will replace some of the old individuals of the population, and mutation, which involves selecting, with partial probability, a string element and altering the gens contained therein with a different gens being used.

In the presented work, each chromosome contains three parts as presented in Fig.1. The first part accounts for optimal charging status of BESS, the second part accounts for optimal discharging status of BESS and finally the third part determines the optimal site for BESS.

5. Problem Formulations

In presented scheme, the optimization goal is to minimize NPV to approach minimum energy losses cost. Herein to achieve this task, objective function is defined as follows:

$$\text{OF} = \text{Minimize } \{NPV_{Loss}\} \tag{1}$$

Here, The NPV is related to power losses cost in planning period under study. The NPV is defined as follow:

$$NPV_{Loss} = \sum_{yr=1}^{N_{yr}} \frac{M_{yr}}{(1+(\frac{IR-IF}{1+IF}))^{yr}} \tag{2}$$

Where, IR and IF identifies interest rate and inflation rate, respectively. N_{yr}, identifies number of years in planning period. Also, M_{yr} is the yearly energy loss cost is defined as follows:

$$M_{yr} = \sum_{LS=1}^{N_{LS}} D_{LS} \times PLoss_{LS} \times EP_{LS} \tag{3}$$

Here, N_{Ls} is abbreviation of load states number, D_{LS} is duration of each load state for each year, EP_{LS} identify the energy price at load state LS, and $PLoss_{LS}$ is the power loss at load state LS.

During tackle this optimization problem, there are some constrains must be satisfied. Firstly, it is important to consider that; there are not any battery storage units with 100% efficiency ($\eta = 1$), it means that there are some losses in charging and discharging process. Therefore the following constrain is established;

$$\sum_{Ls\in Ls_{ch}} D_{Ls} \times P^{ch}_{BESS_{Ls}} \times \eta = \sum_{Ls\in Ls_{dis}} D_{Ls} \times P^{dis}_{BESS_{Ls}} \tag{4}$$

Where, $P^{ch}_{BESS_{Ls}}$ and $P^{dis}_{BESS_{Ls}}$ are power losses of load states in charging and discharging statuses, respectively. In sequel, the other important constrain which must be satisfied is Maximum Energy Capacity (MEC) of BESS, this constrain established as follows:

$$\sum D_{LS} \times P^{ch}_{BESS} \times \eta \le BESS_{MEC} \tag{5}$$

As it obvious, the size of BESS is constant and through this problem solvation, this constrain is brought in (6). In the last load state, because of maximum power loss in the distribution network, the output power of BESS in the discharging status must be equal to BESS power size in order to reduce the energy losses cost and discharge the total capacity of BESS to the network completely with peak electricity price.

$$P^{MLS}_{BESS} = BESS_{Size} \tag{6}$$

Here, P^{MLS}_{BESS} is output power for BESS in the maximum load state and $BESS_{Size}$ is the total power size of BESS. In the following, charging/discharging constrains are provided. The value of charging at each state must be less than total size of BESS and discharging value at each state must be positive as shown in following:

$$\begin{cases} P^{ch}_{BESS} \le BESS_{Size} \\ P^{dis}_{BESS} \ge 0 \end{cases} \tag{7}$$

Solving this optimization problem needs to satisfy power flow constrain. As shown in the following equations, Power flow for charging and discharging states are described as:

$$P_{g_{i,LS}} - P^{ch}_{BESS_{i,LS}} - P_{L_{i,LS}} = \sum_{j\in \Omega_i} P_{ij}(V_{i,LS}, V_{j,LS}, Y_{ij}, \theta_{ij}) \tag{8}$$

$$P_{g_{i,LS}} + P^{dich}_{BESS_{i,LS}} - P_{L_{i,LS}} = \sum_{j\in \Omega_i} P_{ij}(V_{i,LS}, V_{j,LS}, Y_{ij}, \theta_{ij}) \tag{9}$$

$$Q_{g_{i,LS}} - Q_{L_{i,LS}} = \sum_{j\in \Omega_i} Q_{ij}(V_{i,LS}, V_{j,LS}, Y_{ij}, \theta_{ij}) \tag{10}$$

In these equations, $P^{ch}_{BESS_{i,LS}}$ and $P^{dich}_{BESS_{i,LS}}$ are charging and discharging power generation by BESS at bus i and state Ls respectively. $P_{L_{i,Ls}}$ and $Q_{L_{i,Ls}}$ identified respectively active and reactive powers of distribution feeders for each load state, $V_{i,Ls}$ and $V_{j,Ls}$ are bus voltages at bus i and bus j at each load state, finally Y_{ij} and θ_{ij} are represented magnitude and phase angle of feeder's admittance respectively.

5.1. Voltage Limits

To guarantee for keeping the voltage magnitude at admissible range at each bus proper constraints are required. It is noted that the voltage magnitude for substation bus is one p.u.

$$V_{min} \leq \left| V_{i,\ Ls,\ yr} \right| \leq V_{max}, \qquad i \in \Omega_B \tag{11}$$

$$\left| V_{i,s} \right| = 1 \text{ p.u.}, \qquad i \in \Omega_S \tag{12}$$

Where, V_{Min} and V_{Max} are the upper and lower limits of state variable. Herein, i is number of bus, Ω_B and Ω_s are set of buses and set of substations, respectively.

5.2. Substations Capacity Limit

Maximum capacity of transformer is limited the upper apparent power flow in each substation connecting the distribution network to the upstream sub-transmission level. So the following constrain must be established:

$$\sqrt{P_s^2 + Q_s^2} \leq S_s^{max}, \qquad s \in \Omega_S \tag{13}$$

Here P_s and Q_s are active and reactive power imported from S^{th} substation. S_s^{max} is maximum capacity apparent power that could be flowed through S^{th} distribution substation.

5.3. Limit for feeder flows:

This constrain is established as follows:

$$\sqrt{P_k^2 + Q_k^2} \leq S_k^{max}, \qquad k \in \Omega_{Br} \tag{14}$$

Here, K shows the branch number and S_k^{max} is maximum allowable apparent power respected to K^{th} branch. Also, Ω_{Br} is set of branches.

6. Numerical Results

This section represented numerical analyses, which have started with introducing standard test network, then case study are presented consist of simulation part. After all, results of simulation are studied in more depth.

A 33-bus radial distribution system is considered to study as a test distribution network. This system consists of 33 bus and 32 branches. Total loads are 3.72 MW and 2.3 MVar. The load data, transmission line details, and data of load in detail are presented in [22]. Fig. 2 shows the single line diagram of this distribution network under study. The real power loss and reactive power loss in this network without considering BESS is 210.98 kW and 143 kVar, respectively. Furthermore, respected calculation of using the load flow method, in detail, is reported in [23]. It is noted that these losses in the network respect to the condition at the peak load state without BESS.

As said before, GA is used tackle this sitting of BESS. Battery energy storage is selected as candidate storage battery because of suitable output power and sufficient discharge time for the system under study. Energy storage system specifications and condition of the system are given in Table 3. In this table, the first part is for storage unit data and second part is for condition of the system.

After running 15 times, trying to achieve the best location for BESS, bus 14 is chosen as the best. Therefore, network power losses considering optimum allocation of BESS in planning period are given in Table. 4. In this table, the second column is power losses without BESS for first year. Each year are depicted in four level; minimum, medium, normal, and maximum load states. It can be seen that power losses in the first year condition without BESS in maximum load state is 210.98 kW, and power losses considering BESS in this state is reduced to 146.84 kW. The continued of this paper is the same as the part of explained, but each pair is for each year of the five years planning. As it seen in this table, percentages of loss reduction for minimum and medium load state are negative. Moreover, in the next two states loss reductions are positive. The reason is, in minimum and medium state BESS is connected as load for charging, and in the two next states, it is appear as generators with injection the power to the system. Total loss reduction during each year is calculated in this table. As shown in this table, because of annual load growth, there are different loss reductions during planning period.

As it is clear in this table, loess reductions in pick load state for each year is 30.4 %, 23.08 %, 28.41 %, 27.20 %, and 26.53 % respectively, as important load states for loss reduction for pick shaving.

As discussed in introduction section, the objective function is considered in this paper is; minimizing the NPV of energy losses cost. In Table. 5 the efficiency of the scheme for optimum planning which is presented in this paper is shown. This table consists of results; NPV of energy losses cost in two condition for comparing, also optimum location of BESS is allocated at bus 14.

As it seen in column 2 and row 2; the NPV of energy losses cost for the condition without BESS is 92001$, and this value for the condition when BESS is connected is reduced to 90586$. The difference among these two values is 1415$ which is show that there is a considerable total energy losses cost reduction. Also the percentage of total saving is shown in this table.

Table. 6 is prepared to investigate of output for operation of BESS in the optimal planning.

This table is depicted in four load state to show the BESS operation in each state considered in this paper.

Table. 3. Data of BESS and condition of system

BESS Specification	
Capacity of BESS	600 kW- 600 kWh
Round-trip efficiency of BESS (%)	80
Planned Technique Condition	
Inflation rate (%)	1.5
Interest rate (%)	6
Annual Load growth (%)	7
planning period duration	5 years
candidate buses for BESS installation	2-33
Number of BESS	1

Table. 4. Network power losses in planning period.

Planning Period	Year 1		Year 2		Year 3		Year 4		Year 5	
Network Condition	Without BESS	With BESS	Without BESS	With BESS	Without BESS	With BESS	Without BESS	With BESS	Without BESS	With BESS
Load State 1 (kW)	30.77	32.73	35.38	37.48	40.32	42.57	45.61	48.01	51.25	53.86
Loss Reduction	-6.36 %		-5.93 %		-5.58 %		-5.26%		-5.09 %	
Load State 2 (kW)	71.30	76.38	82.15	87.64	93.85	99.75	106.41	112.74	119.86	126.62
Loss Reduction	-7.12 %		-6.68 %		-6.29 %		-5.95 %		-5.64 %	
Load State 3 (kW)	130.71	125.22	150.99	145.00	172.95	166.45	196.65	189.62	222.13	214.55
Loss Reduction	4.2 %		3.38 %		3.76 %		3.57 %		3.41 %	
Load State 4 (kW)	210.98	146.84	244.43	172.64	280.84	201.05	320.32	233.18	363.02	266.72
Loss Reduction	30.4 %		23.08 %		28.41 %		27.20 %		26.53 %	
Total Loss Reduction	21.12 %		13.85 %		20.03 %		19.56 %		19.21 %	

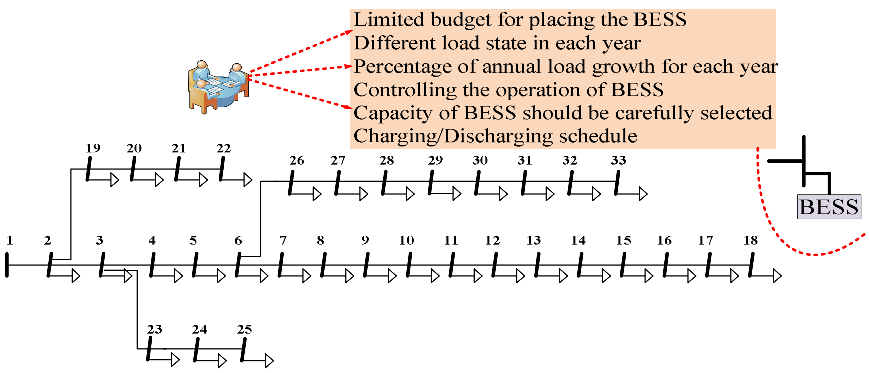

Fig. 2. IEEE-33 bus test system.

Table. 5. Optimum planning results.

Results	Condition of system	
	Without BESS	With BESS
NPV of Losses ($)	92001	90586
Total saving (%)	----------	1.54
BESS optimal site	----------	Bus (14)

Table. 6. Optimum operation result.

Load state	BESS operation	BESS output power (kW)
Minimum	Charging	35.923
Medium	Charging	58.800
Normal	Discharging	48.894
Maximum	Discharging	600.000

It was clear, BESS in the first two states must be charged and in the next load states must be inject its energy to the system. The value of charging and discharging of the BESS in bus 14, in the specific sate are given in third column.

Validation of optimal operation needs to satisfy all constrains which are considered before. Optimal operation of BESS for charging and discharging are obtained from constraints and assumptions that are explained. As it seen in this table, the value of BESS power generation in discharging statue in the last load state is 600 Kw.

As said before, this is equal to maximum capacity of BESS because of achieving the maximum power loss in the distribution network. The proposed operation scheme, satisfied constrain which is shown in (6). It is noted that the maximum discharging in this state can help pick shaving in distribution network in peak load duration of a year.

7. Conclusion

Nowadays, present of battery energy storage in distribution networks is increased rapidly. The reason of this increment is, increasing interest in smart grids to integrate energy storage devices in the power system. Parallel goal of integrating energy and smart grid to improve the reliability and satisfactory operation of power system increase this interest more and more. The reason is; the battery energy storage systems are prepared the fundamental feature to achieve this purpose suitably. In this paper an optimal placement of BESS in order to minimize the NPV respect to power losses cost during the planning period is done. BESS is chosen as energy storage unit to tackle the optimization problem. In this paper, GA is used as optimization tools. In addition, in this paper, cost benefit of energy storage installation respect to the energy losses cost is optimized and arbitrage benefits of this installation did not considered to made optimization problem harder.

During solvation of this optimization problem loads of system are considered in four states. Depicted loads on 4 states help to approach reality in planning and operation. This planning is considered for 5 years to show the efficiency of using storage unit in distribution networks. The secondary purpose of this paper was presenting optimal operation for BESS to these four states.

This new scheme is applied on IEEE 33 bus standard radial distribution test system. Results showed that benefits of minimizing the NPV of power losses cost without considering arbitrage benefits is considerable too and total saving percentage in presented scheme is high. Also in this paper, optimal operation was presented and for validation of this operation all constrains was checked again.

References

[1] Anderson, Max D., and Dodd S. Carr. "Battery energy storage technologies"*Proceedings of the IEEE* 81.3 (1993): 475-479.

[2] Lachs, W. R., and D. Sutanto. "Application of battery energy storage in power systems" *Power Electronics and Drive Systems, 1995., Proceedings of 1995 International Conference on*. IEEE, 1995.

[3] Wade, Neal S., et al. "Evaluating the benefits of an electrical energy storage system in a future smart grid" *Energy policy* 38.11 (2010): 7180-7188.

[4] Amin, S. Massoud, and Bruce F. Wollenberg. "Toward a smart grid: power delivery for the 21st century" *Power and Energy Magazine, IEEE* 3.5 (2005): 34-41.

[5] Joseph, Ami, and Mohammad Shahidehpour. "Battery storage systems in electric power systems" *Power Engineering Society General Meeting,* IEEE, 2006.

[6] Harrison, Gareth P., Antonio Piccolo, and Pierluigi Siano. "Exploring the tradeoffs between incentives for distributed generation developers and DNOs" *IEEE Transactions on Power Systems,* 22.2 (2007): 821-828.

[7] Zou, Kai, et al. "Distribution system planning with incorporating DG reactive capability and system uncertainties" *IEEE Transactions on Sustainable Energy*, 3.1 (2012): 112-123.

[8] Celli, Gianni, et al. "A multiobjective evolutionary algorithm for the sizing and siting of distributed generation" *IEEE Transactions on Power Systems,* 20.2 (2005): 750-757.

[9] Liu, Zhipeng, Fushuan Wen, and Gerard Ledwich. "Optimal siting and sizing of distributed generators in distribution systems considering uncertainties" *IEEE Transactions on Power Delivery,* 26.4 (2011): 2541-2551.

[10] Faria, Pedro, et al. "*Modified particle swarm optimization applied to integrated demand response and DG resources scheduling*." *IEEE Transactions on Smart Grid,* 4.1 (2013): 606-616.

[11] Fini, A. Sheikhi, M. Parsa Moghaddam, and M. K. Sheikh-El-Eslami. "An investigation on the impacts of regulatory support schemes on distributed energy resource expansion planning" *Renewable Energy* 53 (2013): 339-349.

[12] Naik, S. Gopiya, D. K. Khatod, and M. P. Sharma. "Optimal allocation of combined DG and capacitor for real power loss minimization in distribution networks" *International Journal of Electrical Power & Energy Systems* 53 (2013): 967-973.

[13] S. Golshannavaz, "Optimal Simultaneous Siting and Sizing of DGs and Capacitors Considering Reconfiguration in Smart Automated Distribution Systems" *J Intelligent Fuzzy Syst*, vol. 27, no. 4, pp. 1719-1729, 2014.

[14] Awad, Ahmed S., Tarek HM El-Fouly, and Magdy M. Salama. "Optimal ESS Allocation for Load Management Application." *IEEE Transactions on Power Systems,* 30.1 (2015): 327-336.

[15] Xiao, Jun, et al. "Method, implementation and application of energy storage system designing" *International Transactions on Electrical Energy Systems,* 24.3 (2014): 378-394.

[15] Exarchakos, Lazaros, Matthew Leach, and Georgios Exarchakos. "Modelling electricity storage systems management under the influence of demand-side management programmes" *International Journal of Energy Research* 33.1 (2009): 62-76.

[17] Haessig, Pierre, et al. "Energy storage sizing for wind power: impact of the autocorrelation of day-ahead forecast errors" *Wind Energy* 18.1 (2015): 43-57.

[18] Awad, Ahmed S., Tarek HM El-Fouly, and Magdy M. Salama. "Optimal ESS Allocation for Load Management Application" *IEEE Transactions on Power Systems,* 30.1 (2015): 327-336.

[19] Pregelj, Aleksandar, Miroslav Begović, and Ajeet Rohatgi. "Recloser allocation for improved reliability of DG-enhanced distribution networks" *IEEE Transactions on Power Systems,* 21.3 (2006): 1442-1449.

[20] Salehi, Javad, and Mahmood-Reza Haghifam. "Determining the optimal reserve capacity margin of Sub-Transmission (ST) substations using Genetic Algorithm" *International Transactions on Electrical Energy Systems*, 24.4 (2014): 492-503.

[21] Sattarpour, T., et al. "An Optimal Procedure for Sizing and Siting of DGs and Smart Meters in Active Distribution Networks Considering Loss Reduction" *Journal of Electrical Engineering & Technology* 10.3 (2015): 804-811.

[22] Sood, V. K., et al. "Developing a communication infrastructure for the smart gri." *Electrical Power & Energy Conference (EPEC*), 2009 IEEE. IEEE, 2009.

[23] BaranME, Wu FF. "Optimum sizing of capacitor placed on radial distribution systems" *IEEE Trans PWRD* 4 (1989): 735-743.