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# Simultaneously Optimal Placement and Operation Scheduling of BESSs and DGs in Distribution Networks in order to minimizing net present value related to power losses

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***Abstract:*** *In recent years, because of increasing interest to integrate energy storage devices as one of the main goals into the power system smart grid, penetration of battery energy storage and distribution generation in distribution networks is increased. The integration of battery energy storages and distribution generations are improve the reliability and satisfactory operation of power system. The deployment of distributed generations and battery energy storages has led to a revolution in the use of distribution systems to improve many concepts of smart grid. This paper prepared to optimal palacement and optimal operation of distributed generations and battery energy storages to improved net present value reduction related to power losses as one of the main factors in smart grids. This placement is evaluated based on genetic algorithm in order to achieve the best operation during faced different percentage of load levels with specific electricity price for each level. In this paper in spite of most of researches which are proposed in literatures in this fields, the placement problem is done simultaneously for distribution generation and battery energy storages, in addition, the load characteristic is considered multi-level to approach realty in optimal scheduling. In this paper to show the superiority of using distribution generation and battery energy storages, cost benefit of energy storage installation respected to the energy losses cost is calculated toward optimal costs. This is a while, in this paper, arbitrage benefits of this installation did not considered. By considering this, yet the results show that, the total benefit in presented scheduling is higher than homogeneous works. During this scheduling, a comprehensive investigation is done to describe of combination structure of distribution generation and battery energy storage systems. To evaluate this optimization challenge, IEEE 33 bus standard distribution network test is chosen to implement presented scheme. To validation of efficiency of presented scheme, results are compared with previous similar works.*

***Keywords:*** *BESS, DGs, net present value, and power losses.*

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## 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.

Many concepts of distribution generations (DGs) in distribution networks, especially utilization of them in efficiency with time-varying loads make them as the inseparable part of networks. DGs are increased reliably, improved voltage profile, reduced power losses, utilized for pick shaving and so on [6-9]. Many efforts have been done in papers, for planning, management to persuade the efficiency of integrating energy especially with using DGs. Some researchers try to plane different type of distributed energy resources (DERs) such as Distribution Generations (DGs), and Demand Responses (DRs) in distribution systems in order to changing the passive distribution network to a more intelligent and efficient one known as active distribution networks (ADNs) [10]. In sequential, researchers try to planning by siting and sizing distributed generations (DGs) in distribution networks to show the necessity and requisiteness of hosting DGs in distribution networks [11-13]. In [14] authors focused on sizing and siting of DG considering demand respond to minimize power losses in

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distribution networks. In [15] the objective function tries to minimize total costs. In [16], [17] 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 [18] probability using the storage tools are investigate, also in [19] the vast advantage and disadvantage of these tools are considered to discussed and is 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. Like the subject of utilization of DGs many research works have concerned 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 during solving the optimization problem. Today's heuristic methods like as genetic algorithm (GA) and particle swarm optimization (PSO) are commonly used as optimization machine. Therefore, in this paper optimization tools is GA. In some other researches, different objective functions are studied [20]. In [21] 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 [22] energy storage allocation in distribution network for load management is considered. Also, the probability load form by 10 separet levels are considered. But, herein the challenge is the simultaneously placement of DGs and BESSs and optimal operation of them in distribution system. Therefore, in this paper optimal placement of energy storage and DGs 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, in this paper to describe of combination structure of distribution generation and battery energy storage systems a comprehensive analysis is investigated. In order words, in this paper investigate that, to reduction of NPV related to power losses cost using one BESS is efficient or other combination structure. It is worth to 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 just by using one BESS.

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 [23]. 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. In addition, 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. In sequential, for more investigation, placement of DGs and BESSs are simultaneously is done besides presenting the best operation of them.

## 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 through the 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 ( $\eta$ ) ;

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 [24], [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 |

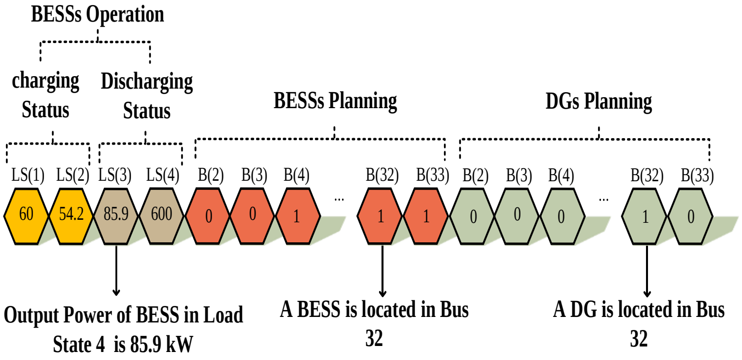

Fig. 1. Construction of the suggested chromosome.

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 [25]. 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:

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

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

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

Where, $IR$ and $IF$ identifies interest rate and inflation rate, respectively. Nyr, 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:

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

The limited budget available for distribution system may confine the total number and size of installed DGs. Likewise, applying DG unit by power factors rather than unity makes them possible to generate both active and reactive power. These notations are considered through constraints (8)-(13) as follows:

$$\left[\left(P_{DG}\right)^2 + \left(Q_{DG}\right)^2\right]^{1/2} \le S^{\max}_{DG} \tag{8}$$

$$P_{DG} \le P^{\max}_{DG} \tag{9}$$

$$Q_{DG} \le Q^{\max}_{DG} \tag{10}$$

$$Q_{DG} = \tan(\cos^{-1}(PF_{DG}) \times P_{DG} \tag{11}$$

$$PF_{DG} = \frac{P_{DG}}{\left(P_{DG} + Q_{DG}\right)^{1/2}} \tag{12}$$

$$N_{DG} = N^{\max}_{DG} \tag{13}$$

Here, $p_{DG}$ and $Q_{DG}$ are DGs' active and reactive power generation at each load state, respectively. $P^{\max}_{DG}$ and $Q^{\max}_{DG}$ are the maximum limits for DGs' active and reactive power generation, respectively. $S^{\max}_{DG}$ is the maximum apparent power limit for DG. Also, $PF_{DG}$ represents the designated power factor of DG which is equal to 0.9 in this work.

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:

$$P_{g_{i,LS}} + P_{DG,Ls} - P^{ch}_{BESS_{i,LS}} - P_{L_{i,LS}} = \sum_{j\in\Omega_i} P_{ij}(V_{i,LS}, V_{j,LS}, Y_{ij}, \theta_{ij}) \tag{14}$$

$$P_{g_{i,LS}} + P_{DG,Ls} + P^{dich}_{BESS_{i,LS}} - P_{L_{i,LS}} = \sum_{j\in\Omega_i} P_{ij}(V_{i,LS}, V_{j,LS}, Y_{ij}, \theta_{ij}) \tag{15}$$

$$Q_{g_{i,LS}} + Q_{DG,Ls} - Q_{L_{i,LS}} = \sum_{j\in\Omega_i} Q_{ij}(V_{i,LS}, V_{j,LS}, Y_{ij}, \theta_{ij}) \tag{16}$$

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. $P_{DG,Ls}$ and $Q_{DG,Ls}$ are output active power and reactive power of DG at load 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 $\theta_{ij}$ 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.

$$V_{\min} \le \left|V_{i,\text{ Ls, yr}}\right| \le V_{\max}, \qquad i \in \Omega_B \tag{17}$$

$$\left|V_{i,s}\right| = 1 \text{ p.u.}, \qquad i \in \Omega_S \tag{18}$$

Where, $V_{Min}$ and $V_{Max}$ are the upper and lower limits of state variable. Herein, $i$ is number of bus, $\Omega_B$ and $\Omega_s$ 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:

$$\sqrt{P_s^2 + Q_s^2} \le S_s^{\max}, \qquad s \in \Omega_s \tag{19}$$

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

### 5.3. Limit for feeder flows:

This constrain is established as follows:

$$\sqrt{P_k^2 + Q_k^2} \le S_k^{\max}, \qquad k \in \Omega_{Br} \tag{20}$$

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

## 6. Numerical Results

This section represented numerical analyses, which have started with introducing standard test network, then different scenarios are presented consist of simulation part. After all, results of simulation are studied in more depth. In this paper, there are considered four scenarios with different combination structure of using DG and BESS. Scenario-1 is placement of one BESS with 600 kWh capacity, scenario-2 is placement of 3 BESSs with capacity of 200 kWh. In this scenario the total capacity of BESSa are 600 kWh. Scenario-3 is placement of one 1000 kW DG with one 600 KWh BESS. This is while scenario-4 is for placement of one 1000 kW DG and 3, 200 kWh BESSs. Data of BESSs, DG and condition of system are given in table. 3.

**Table. 3**. Data of BESS and condition of system

| BESSs & DG Specification | | | | |
|---|---|---|---|---|
| | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
| Capacity of BESSs | 600 kW-<br>600 kWh | BESS1: 200 kW- 200 kWh<br>BESS2: 200 kW- 200 kWh<br>BESS3: 200 kW- 200 kWh | 600 kW- 600 kWh | BESS1: 200 kW- 200 kWh<br>BESS2: 200 kW- 200 kWh<br>BESS3: 200 kW- 200 kWh |
| Round-trip efficiency of BESSs (%) | 80 | BESS1: 80<br>BESS2: 80<br>BESS3: 80 | 80 | BESS1: 80<br>BESS2: 80<br>BESS3: 80 |
| Capacity of DG | ------- | ------ | 1000 Kw – PF=0.9 | 1000 Kw – PF=0.9 |
| Number of BESS | 1 | 3 | 1 | 3 |
| Number of DG | ------ | ------- | 1 | 1 |

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 in this test system, are 3.72 MW and 2.3 MVar. The load data, transmission line details, and data of load in detail are presented in [26]. 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 [27]. It is important to noted, these losses in the network respect to the condition at the peak load state without BESS.

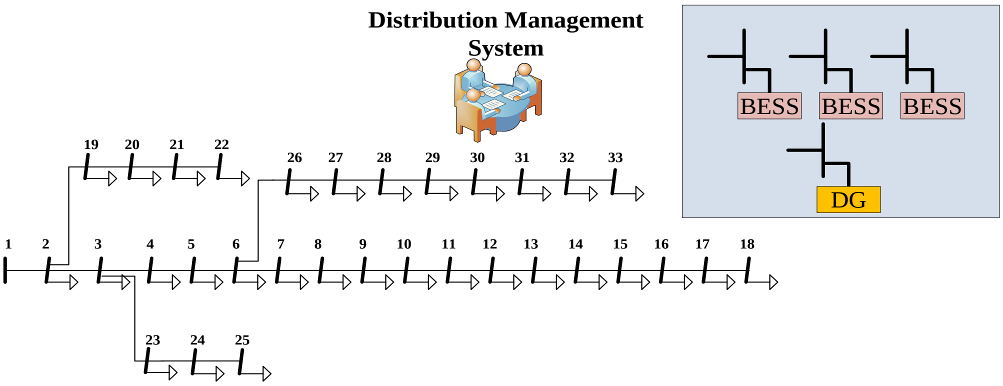

**Fig. 2.** IEEE-33 bus test system.

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 4. As it seen in this table, Inflation rate (%) is 1.5, Interest rate (%) is 6. Candidate buses for BESSs and DG installation are bus 2-33.

**Table. 3**. Data of BESS and condition of system

| | |
|---|---|
| Inflation rate (%) | 1.5 |
| Interest rate (%) | 6 |
| Annual Load growth (%) | 7 |
| planning period duration | 5 years |
| candidate buses for BESSs and DG installation | 2-33 |

After running 15 times, trying to achieve the best location for BESS, bus 14 is chosen as the best in scenario-1. Therefore, network power losses considering optimum allocation of BESS in planning period are given in Table. 4. NPV related to power loss cost ($) in based plan is 92001 $ which is reduced to 90586 $ in scenario-1 with one BESS. NPVs related to power loss cost ($) are 90323 $, 48964 $ and 48820 $ respectively to scenario-2, scenario-3 and scenario-4. For one BESS with 600 kWh capacity, candidate bus is 14 as scenario-1. Total saving in this scenario is 1.54 %. Charging and discharging of BESS in each state ate given in Table. 5 as best operation scheduling. For example in scenario-1, BESS in state 1 is charged 35.923 and in maximum load state discharge 600 Kw.

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. The total saving in scenario-2 as stated in Table. 5 is 1.82 %. In this scenario 3 BESSs are conceded to find optimal operation. Buses 14, 17 and 32 are candidate bus in this scenario. As it seen here, although total capacity of BESSs is equal scenario-1 but total saving in this scenario in higher than scenario1.

In scenario-3, in addition BESSs one DG is added to placement problem. In this scenario total saving is increased too which is show the efficiency of integrating of BESSs and DGs. In this scenario the total saving is 46.78 % which is very high. The optimal charging and discharging of BESS in different load states are 34.78, 59.82, 15.946 and 200 for minimum, medium, normal and maximum load state respectively. In Table. 5 in column 4 and 5, the optimal active and reactive power injection of DG is given for each load state. For example, in normal state DG inject 668 kW to distribution networks.

In scenario-4, instead of using one BESS with 600 kWh capacity, 3 BESSs is used. Each BESS is 200 kWh in this scenario. The total saving is 46.93 % which is the high total saving between these four scenario. Like pervious scenarios, optimal operation in charging and discharging of BESSs are given in Table. 5. Also for this scenario DG operation is consisted in Table for like scenario-3. From these scenarios, it can conclude that, the best combination structure of distribution generation and battery energy storage systems is done in scenario-1 and scenario 4.

**Table. 4.** Results in different scenarios.

| Network condition | Base plane | Scenario 1 | Scenario 2 | Scenario 3 | Scenario 4 |
|---|---|---|---|---|---|
| NPV related to power loss cost ($) | 92001 $ | 90586 $ | 90323 $ | 48964 $ | 48820 $ |
| BESSs optimal site | ---- | Bus (14) | BESS1: Bus (14)<br>BESS2: Bus (17)<br>BESS3: Bus (32) | Bus (15) | BESS1: Bus (14)<br>BESS2: Bus (18)<br>BESS3: Bus (33) |
| DGs optimum active power (kW) | ---- | --- | --- | Minimum: 343<br>Medium: 524<br>Normal: 668<br>Maximum: 677 | Minimum: 347<br>Medium: 520<br>Normal: 669<br>Maximum: 674 |
| DGs optimum reactive power (kVA) | ---- | --- | --- | Minimum:166.12<br>Medium:253.78<br>Normal:323.52<br>Maximum:327.88 | Minimum:168.06<br>Medium:251.85<br>Normal:324.01<br>Maximum:326.43 |
| DG optimal site | ---- | --- | --- | Bus (6) | Bus (6) |
| Total saving (%) | 0 % | 1.54 % | 1.82 % | 46.78 % | 46.93 % |

**Table. 5.** Optimum planning results.

| Load state | BESS operation | Scenario 1 | Scenario 2 | | | Scenario 3 | Scenario 3 | | |
|---|---|---|---|---|---|---|---|---|---|
| | | | BESS 1 | BESS 2 | BESS 3 | | BESS 1 | BESS 2 | BESS 3 |
| Minimum | Charging | 35.923 | 19.160 | 17.30 | 10.20 | 34.78 | 13.35 | 15.43 | 11.32 |
| Medium | Charging | 58.800 | 11.890 | 14.340 | 21.40 | 59.82 | 17.79 | 16.78 | 20.43 |
| Normal | Discharging | 48.894 | 16.3023 | 16.3510 | 16.319 | 48.794 | 15.946 | 16.81 | 16.442 |
| Maximum | Discharging | 600.000 | 200 | 200 | 200 | 600 | 200 | 200 | 200 |

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 Table 5.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.

BESS location in this paper is considered as scenario-1 in this paper. To investigation combination structure of distribution generation and battery energy storage systems, three order scenario is considered in this paper. Also extra of solving optimization problem for one BESS, optimization problem is defined to simultaneously placement and operation scheduling of BESSs and DGs in distribution networks in order to minimizing net present value related to power losses.

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.

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