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ORIGINAL PAPER

Energy storage system location selection for smart grid applications on distribution networks

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Abstract Every day, the evaluation of classical distribution networks (DNs) to smart grids (SGs) has become a necessity, and renewable energy sources (RESs) are an important part for smart grids. One of the most significant problems for RESs is the sustainability of energy, because the raw material storage is not possible for renewable energy sources as photovoltaic (PV), wind, etc. Therefore, energy storage systems (ESSs) have an important place for RESs and SGs. The aim of this paper is ESS location selection for selected distribution networks. In this paper, a PV array is modelled and connected to DN randomly as unlicensed manufacturers, and a location planning algorithm (LPA) for location selection of ESSs is studied for higher energy quality at DNs. The location is determined for optimum ESS usage connecting the ESS to the correct bus decreases the power losses and increases the voltage levels. Besides, energy can be stored at the peak-off time, and stored energy can be used at the peak times for the lower cost with the usage of ESSs. Thus, the optimum usage of ESSs will be provided for RESs and SGs.

Keywords Energy storage systems · PV arrays · Smart grid · Location planning · Distribution networks

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1 Introduction

Nowadays, smart grids are more popular than classical distribution networks because of high-power quality, automatic fault detection, dual energy transmission, renewable power integration, safe, economy, and efficiency. Electricity distribution companies can estimate the energy need in advance. Therefore, sustainable, safe, and cheaper energy can be supplied for customers [1–6].

RESs have an important place in the smart grid, because they can be installed closer to settlements. Thus, energy production will be cheaper than the conventional power plants and power losses, and the voltage drop can be decreased. The interest in RESs as distributed generation is growing, and PV panels are being used widely as RES [7–10].

PV cells produce DC voltage depending on ambient temperature and solar irradiation level. Most researchers are working on PV cell modeling. Mathematical model and electrical equivalent circuit of PV cell are investigated for the simulations in this works [11–18].

Another issue that needs development with RESs is energy storage systems. RESs widely used at smart grid applications and PV arrays cannot generate electricity all day and ESSs can store the extra power which is generated by PV array. Besides power demand is not always stable, and ESSs can be used for feeding the peak load. To meet this demand in an optimum way, ESSs must be located to correct bus. Therefore, ESSs can minimize voltage fluctuations and decrease power losses. Thus, connection to the correct bus for ESSs can help the aim of Smart Grid. The studies about the ESS location selection are generally about connection to the transformer secondary, connection to the same bus with the largest RES, or connection to the largest load bus [19–28].

The aim of this paper is ESS location selection for selected distribution networks. First, a location planning algorithm

(LPA) is improved to connect ESS to the correct bus for increasing the energy quality with lower cost. LPA is created based on the load flow algorithm. The forward–backward method is used for this purpose. The location is determined with voltage index for optimum ESS usage. Load flow results for the distribution network have been obtained. Then, the mathematical model of PV cell is created, PV arrays based on the mathematical model are connected to the bus randomly, and load flow results are recorded. After this section, LPA is optimized for determining the location of the ESS. Finally, load flow results are taken again, and power losses and voltage levels are compared with other results. RESs are widely used at SGs, and ESSs will be a solution for continuity problem of RESs. Optimum usage can be obtained for ESS with LPA. Energy quality based on voltage regulation can increase, and energy cost can decrease with lower power loss and higher voltage level by means of connecting the ESS to the correct bus.

2 Location selection for ESS

Energy storage systems play an important role in the integration of renewable energy sources to the distribution grid. ESSs can be a solution to the sustainability problem of RESs for energy supply, and in addition, the ESS can help about voltage control, power quality, economy, power losses, and peak shaving. Connecting to the correct bus is important to use the ESS more efficiently. The location of the ESS plays an important role for voltage stability and lower power loss. ESSs are generally connected to the transformer secondary, the same bus with the largest RES or the largest load bus in the studies.

We studied a new approach for determining the location, and an algorithm is prepared based on the load flow (LF) analysis. The forward–backward method is used as a load flow algorithm. Classical load flow algorithms as Newton Rapson, Gauss Siedel, and Fast Decoupled are developed for transmission lines. Distribution networks need different methods because of load profiles and network structures. Newton-based methods, forward–backward method, compensation methods, Kirchoff voltage rule, and direct methods can be used in DNs. One of the most widely used methods is the forward–backward method, and the basic steps of the algorithm are [29]:

Step 1: Assign initial values and calculate branch currents.
Step 2: Calculate the line currents with Kirchoff current law from the last line to the source.
Step 3: Calculate the bus voltages from the source to the last bus.
Step 4: Determine the voltage errors and if the error is lower than defined error value, finalize the process. Otherwise, calculate the load currents with the last voltage values and go to step 2.

Voltage levels of the busses can be increased, and power losses can be decreased by selecting the correct bus for ESS. LF algorithm is revised for this purpose to determine optimum bus for ESS. Bus voltage levels and active–reactive power losses are obtained from load flow. These results are used for ESS location selection. The LPA controls the IEEE limits for voltage levels, and LPA calculates a voltage index, as shown in Eq. (1). The bus which has the largest value of the voltage index is selected as ESS bus. The flowchart of the proposed algorithm can be found in Fig. 1:

$$v_i = \frac{\min(V_{\mathrm{lf}}(j)) * n}{\sum_{j=1}^{n} V_{\mathrm{lf}}(j)} \tag{1}$$

where n is bus number of DN, V_{lf} is the voltages of the load flow results, and v_i is the voltage index.

Table 1 Nomenclature

I	PV cell output current	T_{C}	Cell temperature
I_{ph}	Photon current	$T_{\mathrm{C,ref}}$	Reference cell temperature
I_{d}	Diode current	K_i	Short circuit current temperature coefficient
I_{p}	Parallel resistance current	K_{v}	Open circuit voltage temperature coefficient
I_{s}	Diode saturation current	R_{s}	Series resistance
$I_{\mathrm{s,ref}}$	Reference saturation current	R_{p}	Parallel resistance
$I_{\mathrm{ph,ref}}$	Reference photon current	N_{p}	Parallel module number
V	Output voltage	N_{s}	Series module number
G_{T}	Solar irradiation	N_{c}	Cell number
$G_{\mathrm{T,ref}}$	Reference solar irradiation	$V_{\mathrm{oc,ref}}$	Reference open circuit voltage
q	Electron charge—1.6021×10^{-19} C	$I_{\mathrm{sc,ref}}$	Reference short circuit current
k	Boltzmann's constant—1.38065×10^{-23} J/K	n	Ideality factor
E_{g}	Bandgap energy		

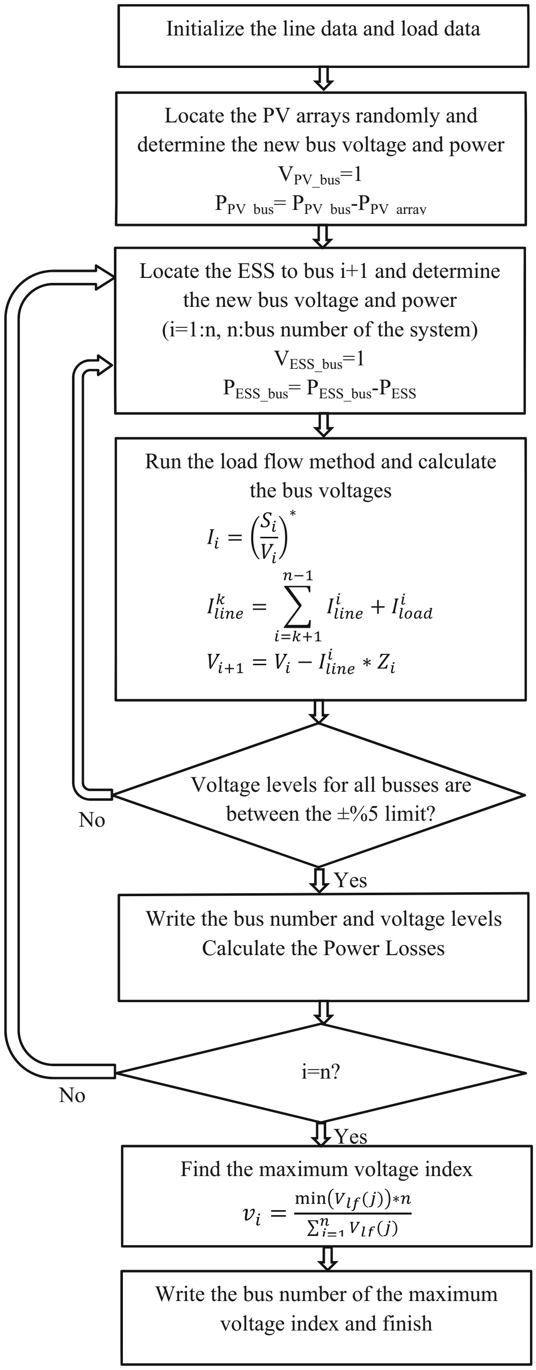

Fig. 1 Flowchart for the ESS location selection

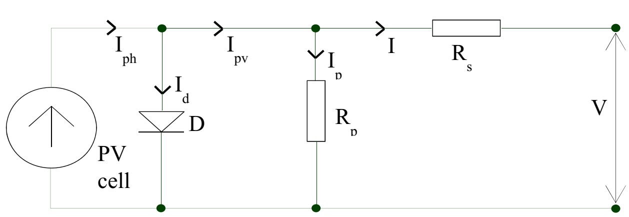

Fig. 2 PV cell electrical equivalent circuit

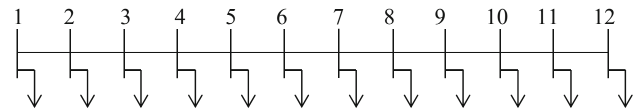

Fig. 3 12 bus distribution network [30]

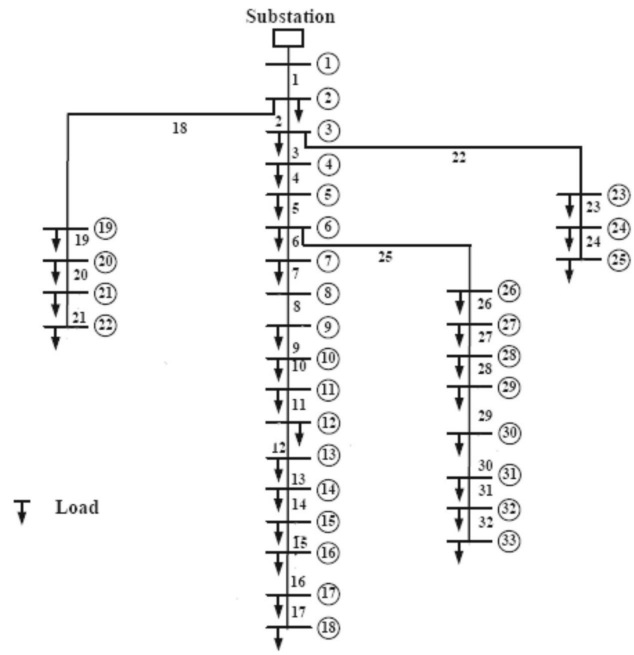

Fig. 4 33 bus distribution network [31]

3 PV array

PV cells consist of semiconductor materials and produce DC voltage depending on ambient temperature and solar irradiation. PV (photovoltaic) cells' operating principle is similar to the p–n junction diode. The sunlight is absorbed by the junction, and absorbed photon energy is transferred to the electron structure of the material. Electrical charge carriers are created in the junction gap, and these carriers generates potential. The current circulation is provided through an external circuit. The photon power which cannot transfer to the external circuit increases the PV cell temperature. PV cell can be modelled with the current source, parallel diode, and parallel and series resistances, as shown in Fig. 2. PV cell generates current (I_{ph}) depending on the solar irradiation and temperature. The equation of the output current statement of PV cell is given in (2).

$$I = I_{ph} - I_d - I_p. \tag{2}$$

Equations (3), (4), and (5) show the currents in (2), and Eqs. (6) and (7) are necessary to calculate these currents [11–18]:

$$I_{\mathrm{ph}} = N_{\mathrm{p}} * \frac{G_{\mathrm{T}}}{G_{\mathrm{T_{ref}}}} * [I_{\mathrm{ph_{ref}}} + K_i (T_{\mathrm{C}} - T_{\mathrm{C_{ref}}})] \tag{3}$$

$$I_{\mathrm{d}} = N_{\mathrm{p}} * I_{\mathrm{s}} * \left[\mathrm{e}^{\frac{q\left(V + I\frac{N_{\mathrm{s}}}{N_{\mathrm{p}}}R_{\mathrm{s}}\right)}{N_{\mathrm{s}} n k N_{\mathrm{c}} T_{\mathrm{C}}}} - 1 \right] \tag{4}$$

$$I_{\mathrm{p}} = \frac{V + I\frac{N_{\mathrm{s}}}{N_{\mathrm{p}}}R_{\mathrm{s}}}{\frac{N_{\mathrm{s}}}{N_{\mathrm{p}}}R_{\mathrm{p}}} \tag{5}$$

$$I_{\mathrm{s}} = I_{\mathrm{s_{ref}}} * \left[\left(\frac{T_{\mathrm{C_{ref}}}}{T_{\mathrm{C}}} \right)^3 * \mathrm{e}^{\frac{qE_g}{nk} * \left(\frac{1}{T_{\mathrm{C_{ref}}}} - \frac{1}{T_{\mathrm{C}}} \right)} \right] \tag{6}$$

Table 2 Verification table

12 BUS DN	Results	Reference results [30]
Bus no.	Voltage	Voltage
1	1.0000	1.00000
2	0.9944	0.99433
3	0.9892	0.98903
4	0.9808	0.98057
5	0.9702	0.96982
6	0.9670	0.96653
7	0.9643	0.96374
8	0.9560	0.95530
9	0.9482	0.94727
10	0.9455	0.94446
11	0.9446	0.94356
12	0.9444	0.94335
	Total power losses	
	$P_{\mathrm{L}} = 20.6891$, $Q_{\mathrm{L}} = 8.0319$	$P_{\mathrm{L}} = 20.71$ kW, $Q_{\mathrm{L}} = 8.04$ kVAr

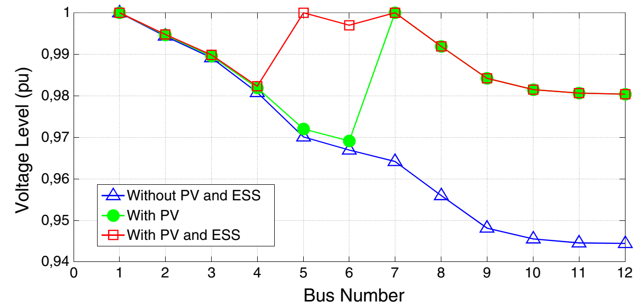

Fig. 5 Voltage-level comparison for 12 bus DN

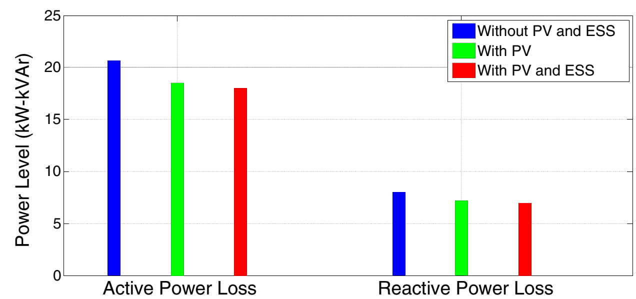

Fig. 6 Power loss comparison for 12 bus DN

$$I_{\mathrm{s_{ref}}} = \frac{I_{\mathrm{sc_{ref}}} + K_i (T_{\mathrm{C}} - T_{\mathrm{C_{ref}}})}{\mathrm{e}^{\frac{q(V_{\mathrm{oc_{ref}}} + K_{\mathrm{V}}(T_{\mathrm{C}} - T_{\mathrm{C_{ref}}}))}{nkN_{\mathrm{c}}T_{\mathrm{C}}}} - 1}. \tag{7}$$

The nomanclature of the PV array is given in Table 1.

4 Case studies

There is no need to have a license under the 1000 kW PV array in Turkey. The objective of this paper is to locate the ESS for

Table 3 Results of 12 bus distribution network

12 BUS DN	Without PV and ESS (a)		With PV (b)		With PV and ESS (c)	
Bus no.	Voltage	Angle	Voltage	Angle	Voltage	Angle
1	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
2	0.9944	0.0022	0.9947	0.0022	0.9948	0.0022
3	0.9892	0.0042	0.9897	0.0042	0.9899	0.0042
4	0.9808	0.0076	0.9819	0.0076	0.9823	0.0077
5	0.9702	0.0120	0.9721	0.0119	1.0000	0.0000
6	0.9670	0.0134	0.9692	0.0132	0.9970	0.0012
7	0.9643	0.0145	1.0000	0.0000	1.0000	0.0000
8	0.9560	0.0193	0.9919	0.0042	0.9919	0.0042
9	0.9482	0.0238	0.9843	0.0081	0.9843	0.0081
10	0.9455	0.0252	0.9816	0.0094	0.9816	0.0094
11	0.9446	0.0257	0.9807	0.0098	0.9807	0.0098
12	0.9444	0.0258	0.9805	0.0099	0.9805	0.0099
	Total power losses (kW − kVAr)		Total power losses (kW − kVAr)		Total power losses (kW − kVAr)	
	$P_{\mathrm{L}} = 20.6891$, $Q_{\mathrm{L}} = 8.0319$		$P_{\mathrm{L}} = 18.5502$, $Q_{\mathrm{L}} = 7.1831$		$P_{\mathrm{L}} = 18.0477$, $Q_{\mathrm{L}} = 6.9737$	

Table 4 Results of 33 bus distribution network

33 BUS DN	Without PV and ESS (a)		With PV arrays (b)		With PV arrays and ESS (c)	
Bus no.	Voltage	Angle	Voltage	Angle	Voltage	Angle
1	1.0000	0.0000	1.0000	0.0000	1.0000	0.0000
2	0.9960	0.0004	0.9965	0.0004	0.9965	0.0004
3	0.9770	0.0024	1.0000	0.0000	1.0000	0.0025
4	0.9668	0.0040	0.9912	0.0017	0.9914	0.0042
5	0.9568	0.0057	0.9825	0.0034	0.9830	0.0059
6	0.9318	0.0036	0.9608	0.0024	1.0000	0.0000
7	0.9271	−0.0020	0.9567	−0.0017	0.9960	−0.0044
8	0.9205	−0.0012	0.9516	−0.0006	0.9910	−0.0036
9	0.9119	−0.0032	0.9453	−0.0011	0.9848	−0.0047
10	0.9040	−0.0048	1.0000	0.0000	1.0000	−0.0055
11	0.9028	−0.0047	0.9991	0.0002	0.9991	−0.0053
12	0.9008	−0.0044	0.9975	0.0005	0.9975	−0.0050
13	0.8924	−0.0068	0.9910	−0.0006	0.9910	−0.0062
14	0.8894	−0.0089	0.9886	−0.0017	0.9886	−0.0073
15	0.8874	−0.0098	1.0000	0.0000	1.0000	0.0000
16	0.8856	−0.0105	0.9983	−0.0005	0.9983	−0.0005
17	0.8828	−0.0125	0.9959	−0.0020	0.9959	−0.0020
18	0.8820	−0.0127	0.9951	−0.0022	0.9951	−0.0022
19	0.9953	0.0001	0.9958	0.0002	0.9958	0.0001
20	0.9906	−0.0015	0.9910	−0.0014	0.9911	−0.0015
21	0.9896	−0.0019	0.9901	−0.0018	0.9902	−0.0019
22	0.9888	−0.0024	0.9893	−0.0023	0.9893	−0.0024
23	0.9722	0.0016	1.0000	0.0000	1.0000	0.0018
24	0.9632	−0.0005	0.9913	−0.0020	0.9913	−0.0003
25	0.9588	−0.0015	0.9870	−0.0030	0.9870	−0.0014
26	0.9292	0.0046	0.9584	0.0033	0.9977	0.0009
27	0.9257	0.0061	0.9553	0.0045	0.9946	0.0021
28	0.9101	0.0085	0.9413	0.0065	0.9807	0.0040
29	0.8989	0.0107	0.9313	0.0084	0.9708	0.0058
30	0.8941	0.0134	1.0000	0.0000	1.0000	0.0081
31	0.8884	0.0114	0.9949	−0.0017	0.9949	0.0064
32	0.8871	0.0109	0.9938	−0.0021	0.9938	0.0059
33	0.8867	0.0107	0.9935	−0.0023	0.9935	0.0057
	Total power losses (kW−kVAr)		Total power losses (kW−kVAr)		Total power losses (kW−kVAr)	
	$P_L = 281.5877$, $Q_L = 187.9595$		$P_L = 212.2384$, $Q_L = 141.3620$		$P_L = 204.7387$, $Q_L = 136.4772$	

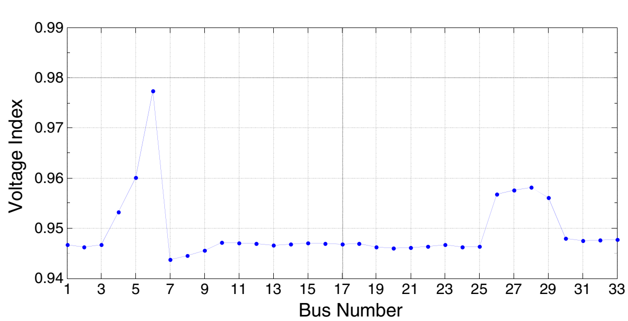

Fig. 7 Voltage index for 33 bus DN

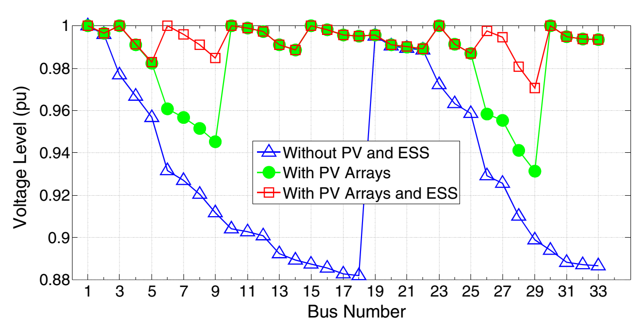

Fig. 8 Voltage-level comparison for 33 bus DN

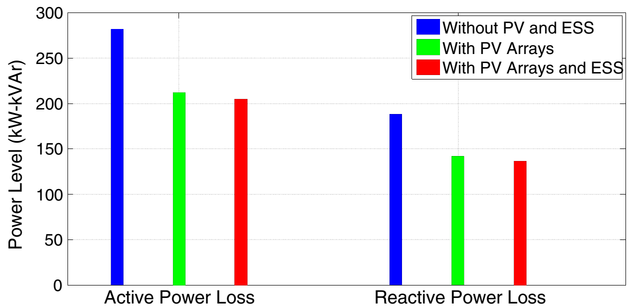

Fig. 9 Power loss comparison for 33 bus DN

the unlicensed PV arrays to decrease the power losses and to increase the voltage levels for lower energy cost. Besides, PV arrays cannot produce electricity in every hours of a day. ESSs store the energy which is produced by the PV arrays and the stored energy can be used at the peak time. Two distribution networks as 12 bus and 33 bus are used for case studies. Figure 3 shows the 12 bus DN, and Fig. 4 shows the 33 bus DN. Line data and load data are given in Tables 6 and 7 in the "Appendix" for distributions networks. The study is simulated in MATLAB. PV arrays based on Eq. (2) are added to the network randomly for the unlicensed manufac-

Table 5 Comparison of different ESS locations

33 BUS DN	Transformer secondary	Same bus with the largest PV array	Same bus with the largest load	Proposed algorithm
Bus no.	Voltage	Voltage	Voltage	Voltage
1	1.0000	1.0000	1.0000	1.0000
2	0.9960	0.9965	0.9965	0.9965
3	0.9770	1.0000	1.0000	1.0000
4	0.9668	0.9912	0.9912	0.9914
5	0.9568	0.9825	0.9825	0.9830
6	0.9318	0.9608	0.9608	1.0000
7	0.9271	0.9567	0.9567	0.9960
8	0.9205	0.9516	0.9516	0.9910
9	0.9119	0.9453	0.9453	0.9848
10	0.9040	1.0000	1.0000	1.0000
11	0.9028	0.9991	0.9991	0.9991
12	0.9008	0.9975	0.9975	0.9975
13	0.8924	0.9910	0.9910	0.9910
14	0.8894	0.9886	0.9886	0.9886
15	0.8874	1.0000	1.0000	1.0000
16	0.8856	0.9983	0.9983	0.9983
17	0.8828	0.9959	0.9959	0.9959
18	0.8820	0.9951	0.9951	0.9951
19	0.9953	0.9958	0.9958	0.9958
20	0.9906	0.9911	0.9911	0.9911
21	0.9896	0.9901	0.9901	0.9902
22	0.9888	0.9893	0.9893	0.9893
23	0.9722	1.0000	1.0000	1.0000
24	0.9632	0.9913	1.0000	0.9913
25	0.9588	0.9870	0.9957	0.9870
26	0.9292	0.9584	0.9584	0.9977
27	0.9257	0.9553	0.9553	0.9946
28	0.9101	0.9413	0.9413	0.9807
29	0.8989	0.9313	0.9313	0.9708
30	0.8941	1.0000	1.0000	1.0000
31	0.8884	0.9949	0.9949	0.9949
32	0.8871	0.9938	0.9938	0.9938
33	0.8867	0.9935	0.9935	0.9935
	Total power losses (kW)	Total power losses (kW)	Total power losses (kW)	Total power losses (kW)
	$P_L = 281.5877$, $Q_L = 187.9595$	$P_L = 210.8217$, $Q_L = 139.9223$	$P_L = 209.7123$, $Q_L = 139.9223$	$P_L = 204.7387$, $Q_L = 136.4772$

turers, and the location of ESS is planned with the proposed algorithm.

4.1 Case 1

12 bus distribution network is used for checking the algorithm, and load flow results are verified with [30], as shown in Table 2. Table 3a shows the base case for the 12 bus distribution network. In this case, there are no PV array and ESS. The results are belonged to the load flow results for the basic network. Then, a bus is selected randomly, and 20 kW PV array is located to the 7th bus. Load flow results are given in Table 3b. Then, the LPA is ran and 5th bus is found for the 10 kW ESS. The results are given in Table 3c. Voltage-level comparison can be seen in Fig. 5, and power loss comparison is in Fig. 6. Figure 5 shows that voltage levels change between 0.9444 and 1.0000 for 12 bus DN. After selecting the 5th bus with LPA and connecting ESS to the 5th bus, voltage levels changes between 0.9805 and 1.0000. Figure 6 shows that PV array helps to decrease the power losses from 20.6891 to 18.5502 kW and 8.0319–7.183110 kVAr, and power losses are decreased to 18.0477 kW and 6.9737 kVAr with ESS connection.

4.2 Case 2

In this case, a 33 bus distribution network is used for ESS location planning. Load flow results are given in Table 4a for the 33 bus DN. Then, the 50 kW PV array is connected to the 3th bus, 90 kW PV array is connected to 10th bus, 80 kW PV array is connected to 15th bus, 100 kW PV array is connected to 23th bus, 20 kW PV array is connected to 30th bus, and busses are selected randomly. Load flow algorithm is ran again, and the results are given in Table 4b. Then, the location planning algorithm is ran, 6th bus is determined for the 40 kW ESS based on voltage index, as shown in Fig. 7, and the load flow results are given in Table 4c.

Figure 8 shows that PV arrays help to increase voltage levels but still the results is not between the IEEE limits (±5 %) and minimum voltage level is 0.8820. All voltage levels are between the ±5 % limits after ESS connection, and minimum voltage level is increased to 0.9708 in Fig. 8. Power losses are decreased from 281.5877 to 212.2384 to 204.7387 kW and 187.9595 to 141.3620 to 136.4772 kVAr in Fig. 9.

4.3 Case 3

The works about the location selection are generally about connection to the transformer secondary, connection to the same bus with the largest RES, or connection to the largest load bus. The ESS is connected to these locations separately, and the voltage levels and power losses for these

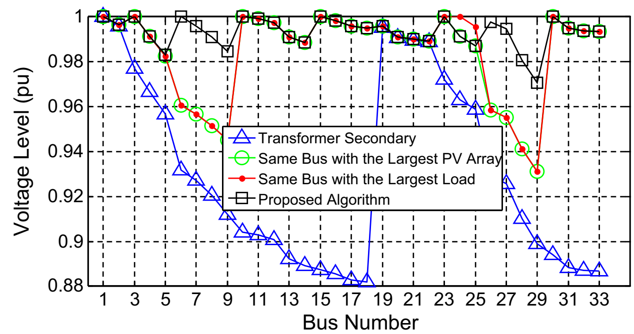

Fig. 10 Voltage-level comparison for different ESS locations

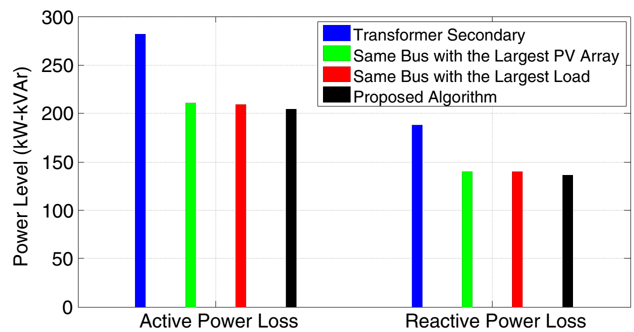

Fig. 11 Power loss comparison for different ESS locations

locations are compared in this case. The results are given in Table 5. The results show that LPA is successful about choosing the correct place for ESS. Voltage levels are higher than the other locations, and power losses are lower than the other locations. Figs. 10 and 11 belong to the voltage-level comparison and power loss comparison for different ESS location. Figures are showing the success of the algorithm about increasing the voltage levels and decreasing the power losses. Minimum voltage level is 0.8820 for transformer secondary, 0.9313 for the same bus with the largest PV and the largest load, and 0.9708 for LPA. Power losses are 281.5877 kW and 187.9595 kVAr for transformer secondary, 210.8217 kW and 139.9223 kVAr for the same bus with the largest PV, 209.7123 kW and 139.9223 kVAr for the same bus with the largest load, and 204.7387 kW and 136.4772 kVAr for LPA.

5 Conclusion

In this paper, PV array is modelled mathematically, and two distribution networks as 12 bus DN and 33 bus DN are chosen for planning work. Forward–backward load-flow-based LPA is prepared for selecting ESS location.

The accuracy of the PV array and load flow algorithm were tested separately. Then, unlicensed PV arrays are connected to distribution networks randomly, and the proposed algorithm was run. The results were evaluated by a voltage index, and the suggested location of the ESS was determined with these results. The algorithm was applied to the 12 bus DN and 33 bus DN. The proposed algorithm results which include the voltage levels for all busses, and total active and reactive power losses were compared with classical load flow results and the results of connected PV arrays network in case 1 and case 2.

ESSs are generally connected to the transformer secondary, connection to the same bus with the largest RES or connection to the largest load bus. In case 3, the proposed algorithm was compared with the results in these locations. Voltage levels and active–reactive power losses were used for this comparison.

ESSs are an important part of the smart grid because of the RES integration, low-cost and high-quality energy requirements, and lower power losses. ESS location selection is a significant process to provide these needs. This work proposes a new approach with LPA for optimum usage of ESS to decreasing line losses, reducing production cost, and improving energy quality. The results show the importance of the selecting correct bus for ESS. LPA is more successful than general approaches to location selection.

Appendix

See Tables 6 and 7.

Table 6 Line data and load data of 12 bus distribution network

12 Bus distribution network line data and load data [30]							
Line data					Load data		
Branch No.	Sending bus	Receiving bus	R	X	Bus no.	P_L (kW)	Q_L (kVAr)
1	1	2	1.093	0.455	2	60	60
2	2	3	1.184	0.494	3	40	30
3	3	4	2.095	0.873	4	55	55
4	4	5	3.188	1.329	5	30	30
5	5	6	1.093	0.455	6	20	15
6	6	7	1.002	0.417	7	55	55
7	7	8	4.403	1.215	8	45	45
8	8	9	5.642	1.597	9	40	40
9	9	10	2.89	0.818	10	35	30
10	10	11	1.514	0.428	11	40	30
11	11	12	1.238	0.351	12	15	15

Table 7 Line data and load data of 33 bus distribution network

33 Bus distribution network line data and load data [31]							
Line data					Load data		
Branch no.	Sending bus	Receiving bus	R	X	Bus no.	P_L (kW)	Q_L (kVAr)
1	1	2	0.0922	0.0470	2	100	60
2	2	3	0.4930	0.2511	3	90	40
3	3	4	0.3660	0.1864	4	120	80
4	4	5	0.3811	0.1941	5	60	30
5	5	6	0.8190	0.7070	6	60	20
6	6	7	0.1872	0.6188	7	200	100
7	7	8	0.7114	0.2351	8	200	100
8	8	9	1.0300	0.7400	9	60	20
9	9	10	1.0440	0.7400	10	60	20
10	10	11	0.1966	0.0650	11	45	30
11	11	12	0.3744	0.1238	12	60	35
12	12	13	1.4680	1.1550	13	60	35
13	13	14	0.5416	0.7129	14	120	80
14	14	15	0.5910	0.5260	15	60	10
15	15	16	0.7463	0.5450	16	60	20
16	16	17	1.2890	1.7210	17	60	20
17	17	18	0.7320	0.5740	18	90	40
18	2	19	0.1640	0.1565	19	90	40
19	19	20	1.5042	1.3554	20	90	40
20	20	21	0.4095	0.4784	21	90	40
21	21	22	0.7089	0.9373	22	90	40
22	3	23	0.4512	0.3083	23	90	50
23	23	24	0.8980	0.7091	24	420	200
24	24	25	0.8960	0.7011	25	420	200
25	6	26	0.2030	0.1034	26	60	25
26	26	27	0.2842	0.1447	27	60	25
27	27	28	1.0590	0.9337	28	60	20
28	28	29	0.8042	0.7006	29	120	70
29	29	30	0.5075	0.2585	30	200	600
30	30	31	0.9744	0.9630	31	150	70
31	31	32	0.3105	0.3619	32	210	100
32	32	33	0.3410	0.5320	33	60	40

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