JP&M Engineering
Journal of Petroleum and Mining Engineering
http://jpme.journals.ekb.eg/

Minimizing Losses on Distribution System by PV and Compensating Capacitors

El-Mahdy,A. A. [1], Megahed, M.G. [2], Seleym, A.[2], Sweif, R. A.[3], Abdel-Salam, T. S.[1,3]

1. Faculty of Energy and Environmental Engineering, The British University in Egypt, Cairo, Egypt
2. Faculty of Engineering, British university in Egypt, Cairo, Egypt
3. Department of Electrical Engineering, Ain Shams University, Cairo, Egypt
* asmaa.ashraf@bue.edu.eg

Article Info

Received 10 Sept. 2019

Revised 24 Dec. 2019

Accepted 2 Feb. 2020

Keywords

Distributed generation; Cuckoo Search; Ant lion; Genetic algorithm; Power losses reduction; Voltage profile.

Abstract

Electric power has become an essential measure of the structure of modern society with most of today's daily activity based on the proposition that the desired electric power constantly exists. In the Electrical Distribution System (EDS), each component is essential to the process of distributing power from the site where it is generated then supplied to the customer who utilizes it. Distribution system plays an utmost role in providing the electrical energy from its generation point to the consumers' end by the use of transmission system. Since the R/X -Where R is the Resistance and X denotes for the impedance- ratio in the distribution network is high, the losses in the distribution system is more. In other words, since Electricity is so important, In addition, since there is losses in the networks where electricity is generated and transmitted to the end users, so it is typically wise to think of solutions to reduce such losses. One of the solutions is installing Distributed Generators (DGs) in the network. The DGs employed in this work is a mix of Photovoltaic panels (PVs) for active power compensation and capacitors for reactive power compensation. Location, range and type of capacitors used in the system manipulate the amount of compensation provided by the capacitors. To decide the location and size of the DGs, a load flow will be used and losses in the radial network are considered. The backward-forward sweep load flow technique is used on the IEEE 69 bus standard network. Also, the Genetic algorithm, antlion technique and Cuckoo search algorithm (CS) are used as optimization techniques. The results are tested on the IEEE 69-bus standard test network to validate the proposed algorithms. The proposed algorithms showed enhanced results compared to the genetic algorithms.

Introduction

The configuration of an Electrical Distribution System (EDS) is adjusted to diminish the real losses. Principally, the losses in an EDS arise due to two factors:

- Mistake in the network
- Burden on the feeders.

The losses taking place as a result of the overload or uneven load are dealt with in this paper. EDS is normally unevenly loaded and hereafter frequently require load balancing, which can also be done by reconfiguring the network using PV to substitute for active power and capacitors for reactive power.

Capacitor employment and network reconfiguration have been extensively employed to lessen power losses, and to maintain voltage profiles within allowable limits in distribution systems. Reconfiguration method proposed in this paper is based on loop elimination technique. In this method, the tie switches and sectionalized switches are operated, and network is reconfigured. The Optimal capacitor placement is carried out using Genetic Algorithm (GA). Furtherly, a united optimization algorithm is projected for merging network reconfiguration and capacitor placement. IEEE-69 bus test system and 85 standard bus structures are used as trials to make sure that the combined optimization technique and the loss reduction are computed and working successfully, the obtained results shows the effectiveness of the proposed method. The location of placing the capacitors in the distribution system is obligatory as of the load existing in the system [1]. There are many ways to reduce the active power losses of distribution network. Two important ways of solving the problem are:

- feeder reconfiguration, and
- capacitor placement.

The DG systems are constructed on a diversity of diverse technologies, which are founded on either renewables or fossil fuels sources. Solar, wind, geothermal and hydro-energies are some systems of those different technologies, which are founded on renewables. These technologies are more cost effectual for long-term strategies and more reliable with a smaller amount of environmental effects compared to the traditional centralized systems. Figure 1 demonstrates the diverse technologies for DG. It could be classified into Renewable or Non-renewable technology.

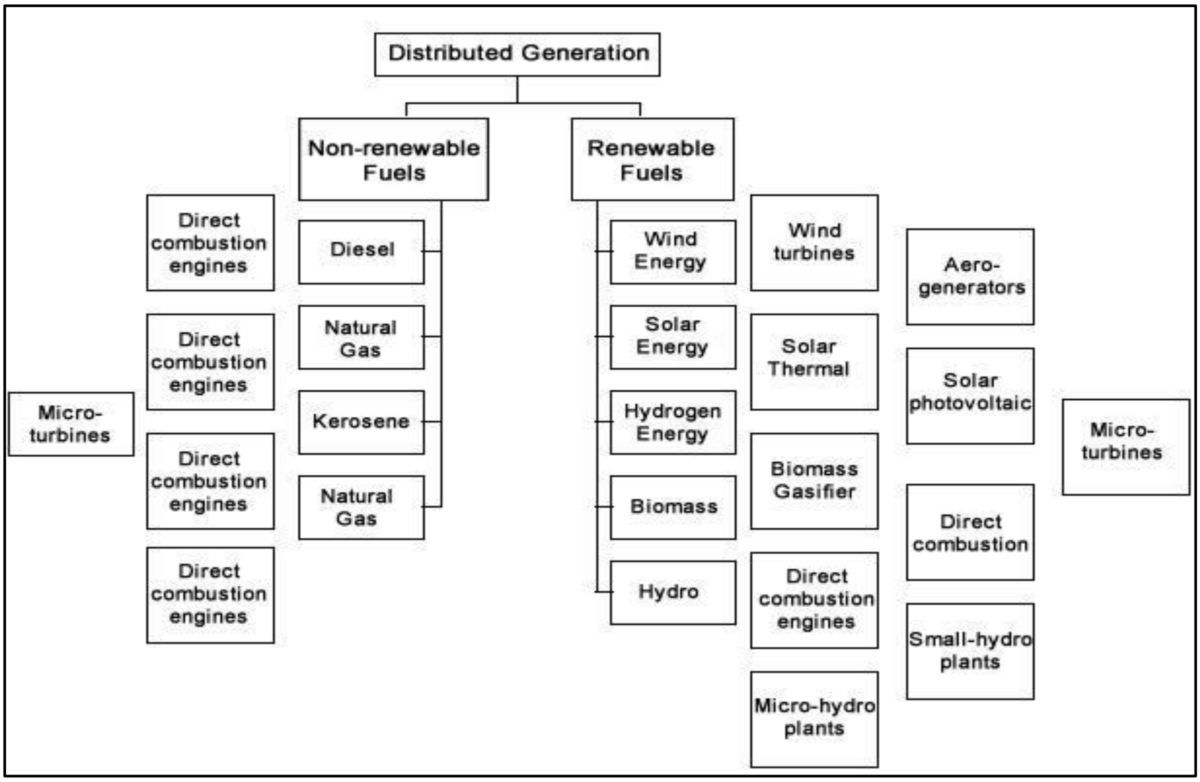

Figure 1 Distribution Generation technologie

In this thesis thesis, PV technology is considered as the distribution generation source. PV panels are used for whichever viable or local applications. They simply have the ability to convert light emissions into electricity. PV panels are made of smaller cells (range < 5 kW) linked together creating a system of any size. The PV produces DC power output, which has to be changed into AC for consumers' to be able to use by the use of inverters. Even if PVs are environmentally friendly and have greater reliability with lowest care requirements, they are considered to be very costly. To avoid this high cost, cheaper components may be used in the industrial process. A PV cell is the basic building unit of PV modules and panels. The cells are prepared using doped silicon crystals. These building units are linked in series/parallel connections to build up the module or panel. Lastly, the PV arrays are formed by connecting those modules or panels to generate the electrical power. The basic maneuver of PV is that solar energy is taken from the sunlight by the PV cells. The sunlight's photons urge the electrons of the cells to become free and stream. Hence, it is converted to dc electrical power. Each cell offers from 2A to 4A and 0.5V dependent on its size. In the array arrangements, cells are allied in series normally providing 12V as the output voltage permitting battery charging. There are some restrictions such as the low generated power, high costs of plots or areas where PV systems placed and restrictions because of the geographic and weather deviations.[12]

Genetic Algorithm is selected to unravel the network reconfiguration issue as well as the capacitor placement issue. These two ways will be merged together to reach the best effect of reducing losses. This will be better than using one method on its own. The correctness of the obtained ways has been inspected by means of 2 standard distribution networks and results are presented in this work [1]. A suggested load flow technique is used for solving radial distribution systems using backward forward sweep technique. This method is demonstrated through 69-node test systems. The final test results reveal verifies that the suggested methods give optimal configuration with reduced losses [2].

The topic of harmonizing the load in distribution systems has gained an excessive amount of attention since the cost of electricity is so high, and as a result, a big amount of the current research on distribution automation has been directed to focus on the network reconfiguration for loss minimization and load balancing. Other than economic attentions, electric power loss is seen as the heat energy dissipated which rises the temperatures of the linked electric components and can result in insulation catastrophe on overburdening of the feeders. Unequal load balancing of the feeders may lead to overloading of some of the feeders. In practical systems, the method employed for reduction of losses and load balancing is network reconfiguration, which is the selection of the proper topological structure of the network for minimum load balancing index. [3]

To check the efficiency and the performance of the mentioned algorithms in choosing the ideal location and size of DGs or Capacitors in radial distribution power system, three test systems were used [4].

In this paper, IEEE 69-bus test systems are used to verify the proposed algorithms [5]. Excluding the base case, three groups of cases are considered while three different types of generation are used. [13]

- Group 1 using PV DGs only
- Group 2 using compensating capacitors only
- Group 3 using both compensating capacitors and PV DGs

Three different penetration levels of DG/capacitor placement are used for the different cases were:

5% 10%,15%, 20% ,25%and 30% of the total active/reactive power in both networks.

While studying distributed networks, the most important challenge faced is power-flow problem of the network. The power-flow equations are nonlinear, which makes it hard to use traditional optimization techniques.

Examining the power flow of a certain network in any radial distribution-system is considered to be the life-line of the network. It demonstrates the active and reactive power losses in each branch of the networks in addition to the demonstrations of the voltage magnitudes of each bus of the network under the steady state. So examining the load flow of any network is a must in order to plan, optimize and control the power system. To start with, analyzing the power flow is the first process to be finished taking into consideration whether the voltage-profiles are within the limits throughout the system or not. Moreover, in the operation process, load flow analysis is used to discover diverse arrangements to lessen the system's power-loss plus improving the voltage-profiles in the system. Several power flow methods are used for the transmission-systems like Gauss Seidel and Newton Raphson [6]. Throughout this paper, we are applying the load flow on a distribution network not a transmission network. Distribution networks are architecturally weakly meshed but well-thought-out as radially operating. These networks have the advantage of being simpler in design and cheaper in cost as a result. [14] The Backward-forward sweep technique is used. Once we know all currents and voltages everywhere in the network, one can easily calculate the power to be able to calculate the power losses. Next chapter will discuss the proposed algorithm to minimize power losses by adding DGs. The Cuckoo search algorithm will determine the size and location of the DGs.[15]

The algorithm is done on "MATLAB© R2017b coding". Work is done on an A1278 Macbook 2.0 GHz Core 2 Duo (P7350) 2GB RAM, 256 MB VRAM 160GB GHH storage and 8X DL "SuperDrive"

Load Flow

Case Study

Cuckoo are breathtaking birds, besides their beautiful sounds, they have an aggressive reproduction attitude.

We will first initiate by describing the reproduction performance of cuckoos and the features of L´evy flights of certain birds and fruit flies, then express the new CS, and how to implement it. Like other meta-heuristic optimization procedures, it is an optimization that is inspired from nature. It is established upon the "obligate brood parasitism" of some cuckoo kinds in the environment which put their eggs in the nests of other birds. Those birds are called the host birds. Some Cuckoos have developed in a way that the lady parasitic Cuckoos can copy the colors and the pattern of the host eggs in order to not be revealed by the host eggs, thus the population of the cuckoos increases. If under circumstances the host bird discovered that the eggs are not its own, it does action of two [7].

- Throw the eggs away
- Abandon the nest build new one

If it did not realize that the eggs are not of its own, once the first cuckoo egg hatches, it starts to blindly throw the other eggs out of the nest as it usually hatches earlier than the other eggs. This instinct action helps the cuckoo get the most share of food provided by the host. Not only that, studies had proven that the baby cuckoos can imitate the sound of the host babies to always gain more feeding chances. The Cuckoo Search which overemphasizes such breeding performance was propositioned by Xin-She Yang and Suash Deb in 2009. From that time, the Cuckoo search algorithm technique has been applied widely to numerous engineering optimization

 DOI: 10.21608/jpme.2020.19110.1017

problems like data blending in wireless networks [8], and to project a multi objective designs as consistent embedded system designs [8]. It was also combined with quantum computing principles [9], and with power series [10] to obtain better performance. In the CS, each laid egg in a host's nest symbolizes a solution to our optimization problem, and a cuckoo egg symbolizes a new solution. The goal is to replace the "not so good" solution "egg" with a better solution which is the "cuckoo's egg"in the nest. Figure 2 shows a flow chart explaining the steps of the cuckoo search optimization algorithm. A simple way to understand CS we assume that each nestonly one egg. The CS is assembled in 3 rules as follows:

- Every cuckoo bird lay 1 egg separately, and place its egg in an arbitrary nest;
- The finest nests that have the high-standard eggs will continue to the subsequent generation;
- The number of existing host nests, n is fixed, and the cuckoo egg is exposed by the host bird probably by Pa ∈ (0,1). When the host bird realizes that the egg is not hers, however it is the Cuckoos, this causes that some nests (eggs) will be thrown away as they are "worst nests" and as a result the related solutions will be rejected and thrown away from next calculations.

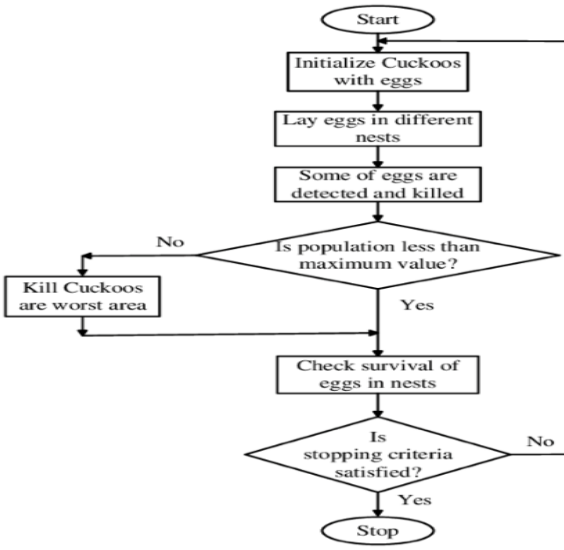

Figure 2 shows a flow chart explaining the steps of the cuckoo search optimization algorithm.

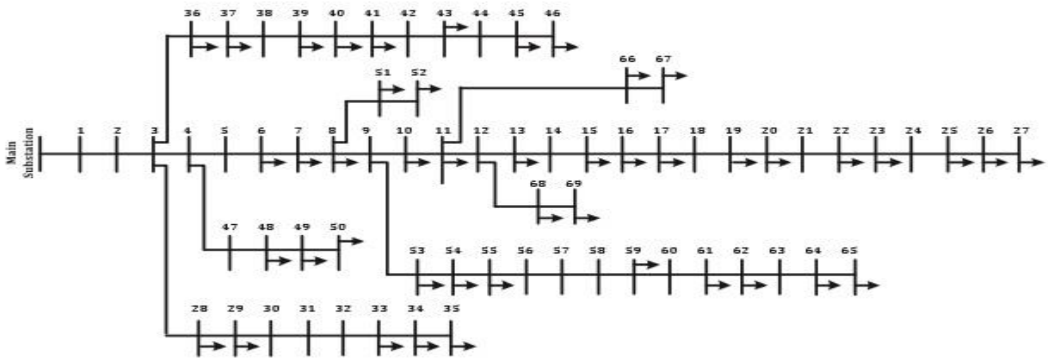

Figure 2 Single line diagram of IEEE 69 bus network

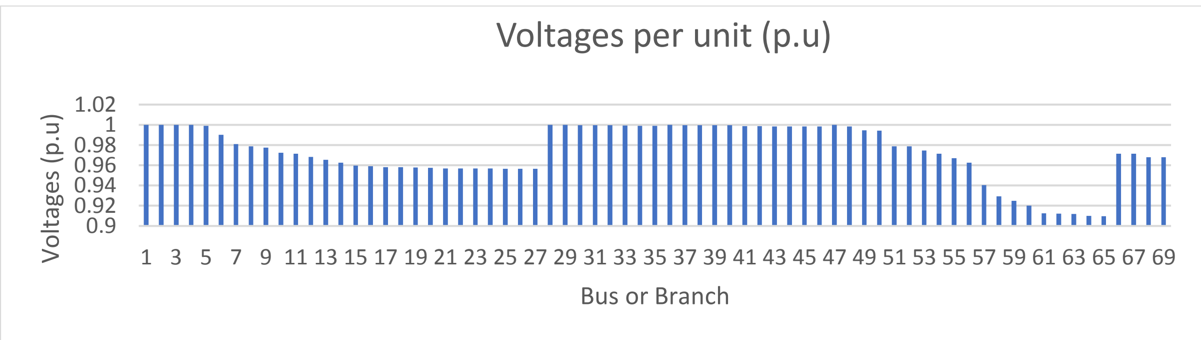

Figure 3 Node Voltage magnitudes of the base case of the IEEE 69-bus

Results

This section will be divided into 2 sections. One for the load flow results after using the backward-forward technique that was proposed by SherMohammady [11] and showed reliable results. The other section will be a table of comparison between the GA in finding the size and location of the DGs, the antlion algorithm and the Cuckoosearch algorithm.

1- Load Flow Results

The Backward Forward Sweep algorithm load flow is executed for the “IEEE 69-Bus” network whose data is proposed in [11] and is shown in the Appendix. The overall loads of the network are 4.660 MW which is shared 3.80189MW active power and 2.6941MVAR reactive power).

The “IEEE 69-bus” network has 69 nodes and 68 branches. Figure 2 shows the 69-bus network Single line diagram with all 69 nodes and 68 branches. The 69-bus network has the following base values:

- Voltage magnitude = 12.66KV

Base-apparent power = 100MVA. The results display that the IEEE 69 bus has a weak voltage-profile from bus “57” to “65” due to the bus “61” high load.

The results reveal that:

All the bus voltages lie within the range of (0.8713 – 1) p.u.

The minimum-voltage = 0.8713 p.u. at node “54”

The maximum branch current is 0.0404 p.u at the first branch

Comparison between GA, CS and AL

Table 1 shows a comparison between Different optimization techniques. The Genetic Algorithm, The antlion and the Cuckoo Search Algorithms. The Antlion and Cuckoo Search Algorithms have very near values to those of the GA. The Antlion and CuckooSearch algorithms are verified and validated as Optimization techniques.

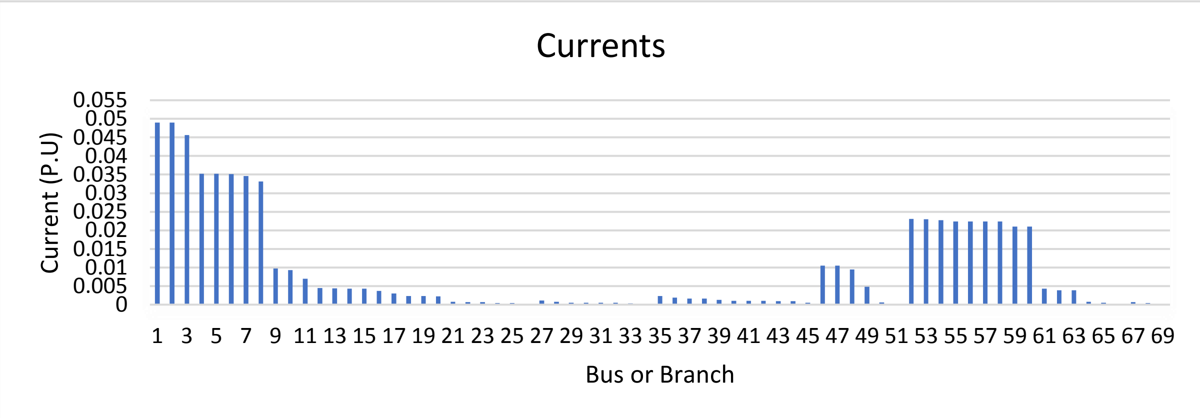

Figure 4 Branch current Magnitude of the base case of the IEEE 69-bus

Conclusions

The Genetic Algorithm (GA), Cuckoo search optimization algorithm and the Antlion Optimizer algorithm (ALO) techniques are presented in this paper to solve the problem of selecting the optimal size and location of DG placement in in the radial distribution system IEEE-69 bus system as a radial distribution system in order to minimize the total power losses. Backward/forward sweep load flow method is used for the load flow study of the radial distribution networks. The proposed DGs are compensating capacitors for improving the reactive power and using the PVs for enhancing the active power. The results prove validation of the applied algorithms GA, Cuckoo algorithm and antlion algorithm. The simulation results showed that the proposed algorithms are able to maximize the power losses reduction percentage.

Acknowledgements

The authors would also like to show their gratitude to the Prof. Tarek Saad Abdel-Salam and Dr. Rania Sweif for sharing their pearls of wisdom during this paper.

Table 1 A comparison between different Optimization algorithms

	GA	Cuckoo	Antlion
Penetration Level 5% Active Power= 190.095KW and Reactive Power= 134.705KVAR			
Location and Size	64 190.095 134.705	64 190.095 134.705	64 190.095 134.705
Plosses (KW)	179.2603	179.2603	180.8487
Qlosses (KVAR)	82.674	82.674	83.3512
Penetration Level 10% Active Power= 380.19KW and Reactive Power= 269.41KVAR			
Location and Size	64 380.19 269.41	64 380.19 269.41	64 380.189 269.41
Plosses (KW)	142.3634	142.3634	143.8337
Qlosses (KVAR)	66.9468	66.9467	67.574
Penetration Level 15% Active Power= 570.285KW and 4 Reactive Power= 404.115KVAR			
Location and Size	62 570.285 404.115	62 570.285 404.11	64 570.285 404.115
Plosses (KW)	111.8128	111.8127	112.9642
Qlosses (KVAR)	53.9172	53.9172	54.4127
Penetration Level 20% Active Power= 760.38KW and Reactive Power= 538.82KVAR			
Location and Size	61 760.38 538.82	61 760.38 538.82	61 760.38 538.82
Plosses (KW)	85.7325	85.733	86.8228
Qlosses (KVAR)	42.6791	42.6793	43.1611
Penetration Level 25% Active Power= 950.475KW and Reactive Power= 673.525KVAR			
Location and Size	61 950.475 673.525	61 950.47 5 673.5250	61 950.47 5 673.5250
Plosses (KW)	64.5433	64.5433	65.341
Qlosses (KVAR)	33.4675	33.4675	33.8191
Penetration Level 30% Active Power= 1140.57KW and Reactive Power= 808.23KVAR			
Location and Size	61 1140.57 808.229	61 1140.569 808.23	61 1140.57 808.23
Plosses (KW)	47.9962	47.9962	48.6136
Qlosses (KVAR)	26.1821	26.1821	26.4588

References

[1] [1] S. Segura, R. Romero, M.J. Rider Efficient heuristic algorithm used for optimal capacitor placement in distribution systems. Int J Electric Power Energy Syst, 32 (1) (2010), pp. 71-78.

[2] [2] D. B. Prakash, C. Lakshminarayana, "Optimal siting of capacitors in radial distribution network using Whale Optimization Algorithm", Alexandria Engineering Journal 56, 499-509 ElSevier, (2017).

[3] [3] Mohamed G. Z. Fouly, A. A. El-Mahdy, I. M. Mahmoud, Ashraf Seleym, R. A. Sweif, T. S. Abdel-Salam "Power System Improvement using Different AI Optimization Techniques", The Future of Electricity Grids Challenges and opportunities Cigre Egypt, March 2019.

[4] [4] H. HassanzadehFard and A. Jalilian, "A novel objective function for optimal DG allocation in distribution systems using meta-heuristic algorithms", International Journal of Green Energy, vol. 13, no. 15, pp. 1615-1625, 2016.

[5] [5] S. Devi and M. Geethanjali, "Application of Modified Bacterial Foraging Optimization algorithm for optimal placement and sizing of Distributed Generation," Expert Systems with Applications, vol. 41, no. 6, pp. 2772–2781, 2014.

[6] [6] R. Prakash and B. Sujatha, "Optimal placement and sizing of DG for power loss minimization and VSI improvement using bat algorithm," 2016 National Power Systems Conference (NPSC), 2016.

[7] Available online 2 October 2018. https://www.mdpi.com/1996-1073/11/10/2547

[8] [7] R. B. Magadum and D. Kulkarni, "Power loss reduction by optimal location of DG using fuzzy logic," 2015 International Conference on Smart Technologies and Management for Computing, Communication, Controls, Energy and Materials (ICSTM), 2015.

[9] [8] S. Gopiya Naik, D. Khatod and M. Sharma, "Analytical approach for optimal siting and sizing of distributed generation in radial distribution

networks", IET Generation, Transmission & Distribution, vol. 9, no. 3, pp. 209-220, 2015.

[10] [9] A. Rezaee Jordehi, "Allocation of distributed generation units in electric power systems: A review", Renewable and Sustainable Energy Reviews, vol. 56, pp. 893-905, 2016.

[11] [10] Lei Zhang, Kaoshe Zhang and Gang Zhang, "Power distribution system reconfiguration based on genetic algorithm," 2016 IEEE Advanced Information Management, Communicates, Electronic and Automation Control Conference (IMCEC), Xi'an, 2016, pp. 80-84.

[12] [11] R. Al Abri, E. El-Saadany and Y. Atwa, "Optimal Placement and Sizing Method to Improve the Voltage Stability Margin in a Distribution System Using Distributed Generation", IEEE Transactions on Power Systems, vol. 28, no. 1, pp. 326-334, 2013.

[13] [12] R. A. Swief, T. S. Abdel-Salam, and Noha H. El-Amary, "Photovoltaic and Wind Turbine Integration Applying Cuckoo Search for Probabilistic Reliable Optimal Placement", Energies 2018, Vol. 11, Issue 1, 139. doi: 10.3390/en11010139. Available online 6 January 2018. http://www.mdpi.com/1996-1073/11/1/139

[14] [13] Peter Makeen, R. A. Swief, T. S. Abdel-Salam, Noha H. El-Amary, "Smart Hybrid Micro-Grid Integration for Optimal Power Sharing-Based Water Cycle Optimization Technique", Energies 2018, Vol. 11, Issue 5, 1083, 2018. doi: 10.3390/en11051083. Available online 27 April 2018. http://www.mdpi.com/1996-1073/11/5/1083

[15] [14] Heba-Allah I. ElAzab, R. A. Swief, Noha H. El-Amary, and H. K. Temraz, "Unit Commitment Towards Decarbonized Network Facing Fixed and Stochastic Resources Applying Water Cycle Optimization", Energies 2018, Vol. 11, Issue 5, 1140, 2018. doi: 10.3390/en11051140. ISSN 1996-1073. Available online 3 May 2018. http://www.mdpi.com/1996-1073/11/5/1140

[16] [15] Heba-Allah I. ElAzab, R. A. Swief, Hanady H. Issa, Noha H. El-Amary, Alsnosy Balbaa, H. K. Temraz, "FPGA Eco Unit Commitment Based Gravitational Search Algorithm Integrating Plug-in Electric Vehicles", Energies 2018, Vol. 11, Issue 10, 2547, 2018. doi: 10.3390/en11102547. ISSN 1996-1073.

Appendix: IEEE 69-bus Networks' Data

In this Appendix, Table 2 shows the bus data for the "IEEE 69-bus system" while 3 shows the line data for "IEEE 69-bus system"

Table 2 69 Bus Data

Bus Number	P (KW)	Q (KVAr)	Bus Number	P (KW)	Q (KVAr)
1	0	0	**36**	26	18.55
2	0	0	**37**	26	18.55
3	0	0	**38**	0	0
4	0	0	**39**	24	17
5	0	0	**40**	24	17
6	2.6	2.2	**41**	1.2	1
7	40.4	30	**42**	0	0
8	75	54	**43**	6	4.3
9	30	22	**44**	0	0
10	28	19	**45**	39.22	26.3
11	145	104	**46**	39.22	26.3
12	145	104	**47**	0	0
13	8	5	**48**	79	56.4
14	8	5.5	**49**	384.7	274.5
15	0	0	**50**	384.7	274.5
16	45.5	30	**51**	40.5	28.3
17	60	35	**52**	3.6	2.7
18	60	35	**53**	4.35	3.5
19	0	0	**54**	26.4	19
20	1	0.6	**55**	24	17.2
21	114	81	**56**	0	0
22	5	3.5	**57**	0	0
23	0	0	**58**	0	0
24	28	20	**59**	100	72
25	0	0	**60**	0	0
26	14	10	**61**	1244	888
27	14	10	**62**	32	23
28	26	18.6	**63**	0	0
29	26	18.6	**64**	227	162
30	0	0	**65**	59	42
31	0	0	**66**	18	13
32	0	0	**67**	18	13
33	14	10	**68**	28	20
34	19.5	14	**69**	28	20
35	6	4			

Table 3 line Data for bus 69 system

From	To	R(ohms)	X(ohms)	From	To	R(ohms)	X(ohms)
1	2	0.0005	0.0012	3	36	0.0044	0.0108
2	3	0.0005	0.0012	36	37	0.064	0.1565
3	4	0.0015	0.0036	37	38	0.1053	0.123
4	5	0.0251	0.0294	38	39	0.0304	0.0355
5	6	0.366	0.1864	39	40	0.0018	0.0021
6	7	0.381	0.1941	40	41	0.7283	0.8509
7	8	0.0922	0.047	41	42	0.31	0.3623
8	9	0.0493	0.0251	42	43	0.041	0.0478
9	10	0.819	0.2707	43	44	0.0092	0.0116
10	11	0.1872	0.0619	44	45	0.1089	0.1373
11	12	0.7114	0.2351	4	46	0.0009	0.0012
12	13	1.03	0.34	46	47	0.0034	0.0084
13	14	1.044	0.345	47	48	0.0851	0.2083
14	15	1.058	0.3496	48	49	0.2898	0.7091
15	16	0.1966	0.065	49	50	0.0822	0.2011
16	17	0.3744	0.1238	8	51	0.0928	0.0473
17	18	0.0047	0.0016	51	52	0.331	0.1114
18	19	0.3276	0.1083	9	53	0.174	0.0886
19	20	0.2106	0.069	53	54	0.203	0.1034
20	21	0.3416	0.1129	54	55	0.2842	0.1447
21	22	0.014	0.0046	55	56	0.2813	0.1433
22	23	0.1591	0.0526	56	57	1.59	0.5337
23	24	0.3463	0.1145	57	58	0.7837	0.263
24	25	0.7488	0.2475	58	59	0.3042	0.1006
25	26	0.3089	0.1021	59	60	0.3861	0.1172
26	27	0.1732	0.0572	60	61	0.5075	0.2585
3	28	0.0044	0.0108	61	62	0.0974	0.0496
28	29	0.064	0.1565	62	63	0.145	0.0738
29	30	0.3978	0.1315	63	64	0.7105	0.3619
30	31	0.0702	0.0232	64	65	1.041	0.5302
31	32	0.351	0.116	11	66	0.2012	0.0611
32	33	0.839	0.2816	66	67	0.0047	0.0014
33	34	1.708	0.5646	12	68	0.7394	0.2444
34	35	1.474	0.4873	68	69	0.0047	0.0016