Optimal distributed generation in green building assessment towards line loss reduction for Malaysian public hospital.

AMRAN, M.E., MUHTAZARUDDIN, M.N., BANI, N.A., KAIDI, H.M., HASSAN, M.Z., SARIP, S., MUHAMMAD-SUKKI, F.

2019

Bulletin of Electrical Engineering and Informatics
Vol. 8, No. 4, December 2019, pp. 1180~1188
ISSN: 2302-9285, DOI: 10.11591/eei.v8i4.1524

Optimal distributed generation in green building assessment towards line loss reduction for Malaysian public hospital

Mohd Effendi Amran[1], Mohd Nabil Muhtazaruddin[2], Nurul Aini Bani[3], Hazilah Mad Kaidi[4], Mohamad Zaki Hassan[5], Shamsul Sarip[6], Firdaus Muhammad-Sukki[7]
[1]Engineering Services Division, Ministry of Health Malaysia, 62590 Putrajaya, Malaysia
[1,2,3,4,5,6]Razak Faculty of Technology and Informatics, Universiti Teknologi Malaysia, 54100 Kuala Lumpur, Malaysia
[7]School of Engineering, Robert Gordon University, Garthdee Road, Aberdeen, AB10 7GJ Scotland, United Kingdom

Article Info

Article history:

Received Apr 30, 2019
Revised Jun 14, 2019
Accepted Jul 3, 2019

Keywords:

Artificial bee colony (ABC)
Distributed Generation (DG)
Green building rating system (GBRS)
Maximum demand (MD)
Photovoltaic-type DG (PV-DG)
Renewable energy (RE)

ABSTRACT

This paper presents an optimization approach for criteria setting of Renewable Distributed Generation (DG) in the Green Building Rating System (GBRS). In this study, the total line loss reduction is analyzed and set as the main objective function in the optimization process which then a reassessment of existing criteria setting for renewable energy (RE) is proposed towards lower loss outcome. Solar photovoltaic (PV)-type DG unit (PV-DG) is identified as the type of DG used in this paper. The proposed PV-DG optimization will improve the sustainable energy performance of the green building by total line losses reduction within accepted lower losses region using Artificial bee colony (ABC) algorithm. The distribution network uses bus and line data setup from selected one of each three levels of Malaysian public hospital. MATLAB simulation result shows that the PV-DG expanding capacity towards optimal scale and location provides a better outcome in minimizing total line losses within an appropriate voltage profile as compared to the current setting of PV-DG imposed in selected GBRS. Thus, reassessment of RE parameter setting and the proposed five rankings with new PV-DG setting for public hospital provides technical justification and give the best option to the green building developer for more effective RE integration.

Corresponding Author:

Mohd Effendi Amran,
Engineering Services Division,
Ministry of Health Malaysia,
Level 3-7 Block E3, Parcel E, Precinct 1, 62590 Putrajaya, Malaysia.
Email: meffendi.amran@gmail.com

1. INTRODUCTION

The green building developments are remarkably significant to the design of advanced and efficient integrated energy technologies to reduce electricity loads such as heating, cooling, etc. in the form of energy demand and the consumptions through the on-site RE sources approach [1, 2]. Based on the essence of sustainable developments, the RE usage such as photovoltaic (PV) generator is one of the most influentially common principles [3] and consequential approach in reducing the energy consumption in buildings [4] while having considered as a key component of the green building-based design of electricity generation capability [5]. RE setup such as PV-DG in current GBRS, for instance, Malaysian Carbon Reduction Environmental Sustainability Tool (MyCREST), Green Building Index (GBI), and Leadership in Energy and Environmental Design (LEED v4) were still lack in adopting optimization baseline approach via total line losses reduction as objective function for initial simulating stage. Relatively, simultaneous optimization criteria for RE-based DG location and capacity was found to be more effective to be observed via minimal losses outcome [6] and also implemented in many recent kinds of literature [6-9], however, this mechanism in estimating the possible RE impact, was lack of use in current GBRS assessment criteria. By adopting this approach, the extensiveness of RE utilization in current GBRS can be improvised for more justified and effective outlook measure subjected to early-stage design.

Thus, leaving a gap for the needs in simulated optimization approach at the initial stage in GBRS to meet the improved total line losses as the objective function for the desired outcome. This paper proposes an optimal reassessment criterion which focuses on reducing the total line losses as the main objective function for selected one in every three levels of public hospital i.e. national, state and district hospital. Subsequently, a ranking of five segregation output generated power and location of the PV-DG, simultaneously, is formed. The five assessment ranking (i.e. 1 to 5 scoring) for RE parameter setting has been practiced by most of GBRS worldwide including GBI and LEED v4 [10, 11]. Therefore, segregation of five rankings was following the current setting, except the percentage value for determining the capacity of the PV-DG in each rank is newly formed via a random figure setting in 5% increment order and proposed towards an optimal outcome in terms of power loss reduction. Only single PV-DG for a single location is considered in this paper. The rest of this paper: Section 2 touch on ABC optimization. Section 3 describes the problem formulation for the optimization and proposed method. Section 4 presents the twelve different case studies experimental results that were utilized to test in terms of power losses reduction and voltage profile as well as the performance of the suggested techniques for the distribution system. Section 5 concludes the paper.

2. OPTIMIZATION APPROACH FOR LOSS REDUCTION

As a part of the objective in proposing the right parameter setting for single PV-DG integration specifically in minimal power losses within voltage regulation, the analytical approach of optimization is needed [12]. Distribution system dissipated approximately 13% of losses from power generation and these losses are categories as active power loss and reactive power loss as given by (1) and (2) [13];

$$P_{Loss} = I_{ij}^{2} . R_{ij} \tag{1}$$

$$Q_{Loss} = I_{ij}^{2} . X_{ij} \tag{2}$$

Where, I_{ij} is current flowing between i_{th} and j_{th} bus, R_{ij} and X_{ij} are resistance and reactance of branch ij respectively. As solution, optimization is a procedure of identifying the value of minimum or maximum of a function by specifying several numbers of constraints known as the ‘variables’ [14]. Via simulation tools, the optimization function is called cost or fitness, or objective function is sequentially calculated [15]. Based on [16], separate and simultaneous analysis are two identical ways for the solution in power losses mitigation by DG. Using separate analysis, location and capacity of DG identification are calculated separately using sensitivity factor [17] followed by optimization technique respectively. While, in the simultaneous analysis (offer better results than separate analysis [18]), this method determining the capacity and the DG location simultaneously by using optimization techniques such as Artificial Bee Colony (ABC) [16, 19]. From the analogy of ABC according to [20], the flow and the cycle of three assigned groups i.e. employed, onlookers and scouts’ bees in the colony of artificial bees, can translated into three formulas as described in (3), (4) and (5). The ABC flowchart as illustrated in [21].

$$F_i = \frac{1}{(1+Obj.Func_i)} \tag{3}$$

Where, F_i is the fitness for the objective function and $Obj.Func_i$(Total power loss) is the target of study.

$$prob_i = \frac{F_i}{\sum_{i=1}^{N} F_i} \tag{4}$$

Where, $prob_i$ is the probability and N is a number of employed bees.

$$x_{ij}^{new} = x_{ij}^{old} + range(0,1) \times \left(x_{ij}^{old} - x_{kj}\right) \tag{5}$$

Where, x_{ij}^{new} and x_{ij}^{old} represent the new and old (previous) value of a variable (either DG location or DG size) respectively. x_{kj} is a neighbour value that is selected randomly from j^{th} dimension and $range(0,1)$ is a random value between 0 and 1.

3. RESEARCH METHOD

The simulation processes are performed into twelve case studies as determined in Table 1 uses selected distribution network of three Malaysian public hospitals representing selected one from each level hospital i.e. national level, state level, and district level, as illustrated in Figure 1(a), Figure 1(b) and Figure 1(c) respectively. The distribution network also comprises of six actual power system parameters, consist of distribution bus identification, active power load (*P*), reactive power load (*Q*), resistance (*R*) and reactance (*X*) for laid cables (Ω/Km) and voltage level (V) as shown in Appendix A–Appendix C. The distribution network in National level hospital is fed by three intake supplies (i.e. from utility provider) through its' radial network, however, the bus arrangement for simulation only divided and performed into two main zones named as 'Zone A' and 'Zone B'. While State and District level hospital had set division of zoning into two zones (Zone A and Zone B) and one zone (Zone A) respectively. DG size and location are identified simultaneously. 'Type 3 DG' is set in MATLAB coding according to major types of DG category [22-26], where the only real power is being injected into the distribution network by PV-DG.

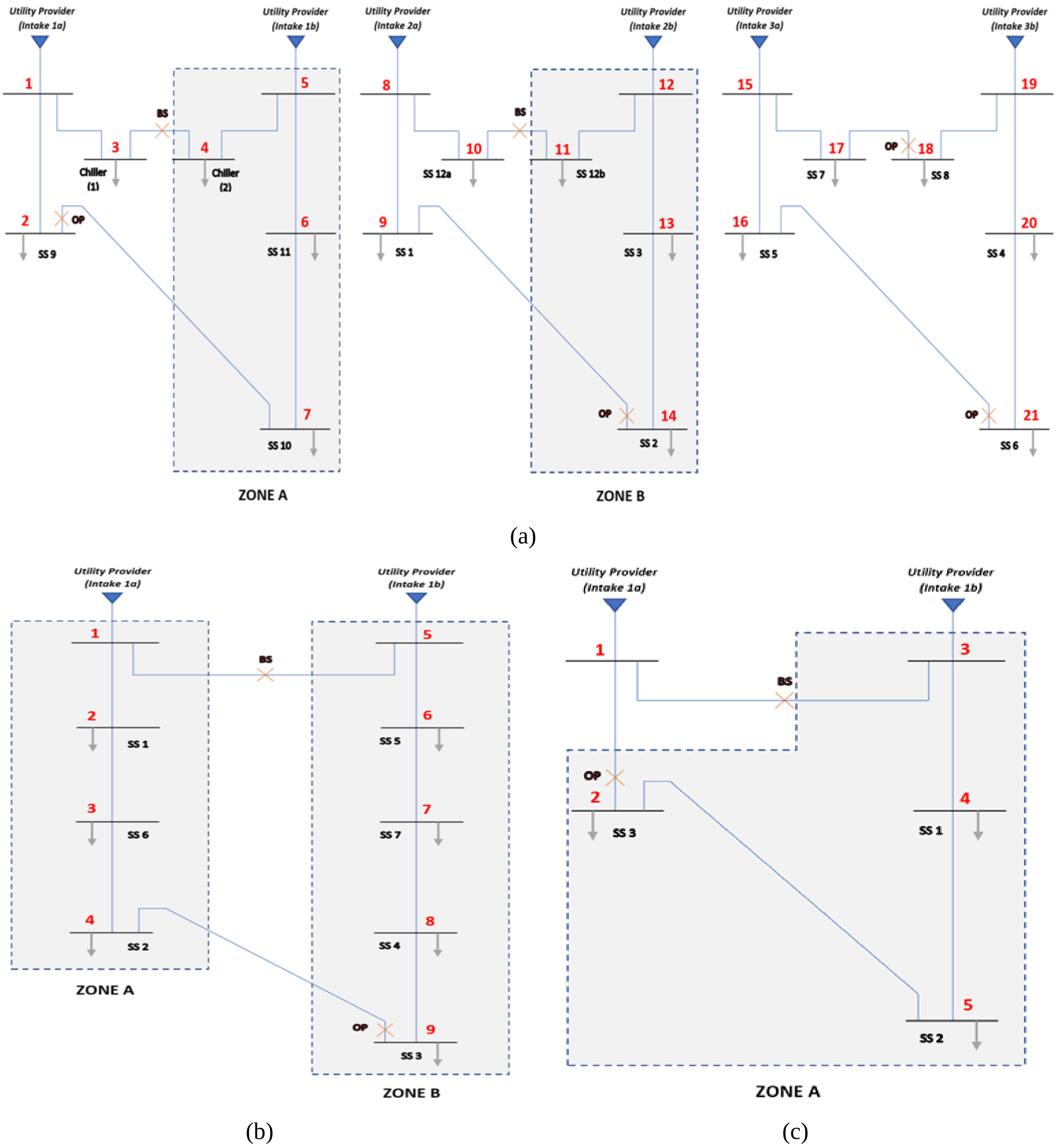


Figure 1. The distribution network of, (a) National level hospital in two zones, (b) State level hospital in two zones, and (c) District level hospital in one zone

ABC is proposed in this research paper to alleviate such problems. Consequently, the proposed PV-DG assessment is examined by simulation on the distribution network of three selected public hospitals i.e. national, state and district hospital and the results obtained are graphically plotted for U-shape trajectory determination. The P load and Q load sample data of distribution network are represented the highest value within a period of 6 consecutive months considering the MD and maximum irradiation adopted from timeline used in collecting energy trend via Efficient Management of Electrical Energy Regulation 2008, published by Energy Commission of Malaysia [27]. Total Power Losses (TPL) in this distribution network is selected as a main target i.e. objective function, in ABC optimization. The (6) represents the formula for objective;

$$TPL = \sum_{L=1}^{n}(|I_L|^2 \times R_L) \quad (6)$$

Where, L is a number of branches, I_L is branch current, and R_L is the branch resistance

All processes are examined for National level, State level, and District level hospital. In the first process, the initial power loss, L_1 is identified which represented the original losses of distribution network without the integration of PV-DG. L_1 is recorded for further comparison. Next, based on the ABC algorithm setup, the optimal capacity (unlimited capacity) of DG, P_{DG1} is obtained together with the optimal location (distribution network bus). At this stage total line losses, L_2 shall be much lower than L_1. For reassessment stage, five (5) ranking of scoring is remained (1 to 5 scoring) as practiced by GBI and LEED [10, 11]. The only element that being examined are the assessment criteria of DG capacity percentage, P_{DG2} (limitation capacity) and its' total line losses, L_3 value. Optimization process with all constraints as listed below:

a. Size of DG constraint

$$P_{DG(min)} \leq P_{DG1} \leq P_{DG(max)} \quad (7)$$

The minimum and maximum size of unlimited DG ($P_{DG(min)}$ and $P_{DG(max)}$) is set between 0.3 MW and 3 MW respectively as determined in Case 6 of Table 1.

Table 1. Case by case studies

Case	Description
1	Original test system without PV-DG.
2	Determine optimal PV-DG capacity and location (15% of MD), simultaneously
3	Determine optimal PV-DG capacity and location (25% of MD), simultaneously
4	Determine optimal PV-DG capacity and location (35% of MD), simultaneously
5	Determine optimal PV-DG capacity and location (45% of MD), simultaneously
6	Determine optimal PV-DG capacity and location (unlimited capacity), simultaneous
7-12	Further increase of PV-DG (random value) beyond optimal capacity ($P_{DG2} > P_{DG1}$)

$$P_{DG(min)} \leq P_{DG2} \leq P_{DG(max)} \quad (8)$$

The minimum and maximum size of proposed limited DG ($P_{DG(min)}$ and $P_{DG(max)}$) is set between 0-15% MD, 0-25% MD, 0-35% MD, and 0-45% MD as determined in Case 2, Case 3, Case 4 and Case 5 respectively in Table 1. These PV-DG percentage are randomly selected criteria before reaching P_{DG1}.

b. Power balance constraint

$$P_{DG} + P_{substation} = P_{Load} + TPL \quad (9)$$

The summation of the total power supply by substation and power output from the DG must be equal to the total size of load plus total power losses.

c. Voltage bus constraint

$$0.90 \leq V_n \leq 1.05 \quad (10)$$

where n is a number of buses in the distribution system.

d. Radial circuit constraint

For national, state and district level hospital, the distribution network in each case studies shall remain its radial circuit, i.e. maintaining the original condition of all off point (OP) switchgear shown in Figure 1(a), Figure 1(b) and Figure 1(c). In further process, the result L_2 from the simulated optimization (with limitation capacity) is observed and if the condition of $L_2 \leq L_3 \leq L_1$ is true, the DG value is effectively achieved, where this value is kept in the list of new assessment criteria. Then, the process repeated by increasing the percentage level of limitation to obtain remaining PV-DG output generated until the result of total line losses L_3 becoming higher than L_1, where at this stage, the value of PV-DG for integration with these selected distribution networks is no longer effective for power loss reduction. All data related to the test system can be obtained in Appendix A–Appendix C.

4. RESULTS AND DISCUSSION

From the results in Table 2(a), 2(b) and 2(c), original total power losses in the system (without PV-DG integration) as in Case 1 for National level hospital, State level hospital, and District level hospital represent the initial losses and used as a base case in the comparable making with further loss reduction outcome. Subsequently in National level for Case 2, imposing PV-DG with limitation capacity (P_{DG2}=15% from MD), resulting with 4% and 7% of total line losses reduction for Zone A and Zone B respectively. Whereas, for State level, the power losses outcome is reduced to 3% and 9% (Zone A and Zone B), finally, for District level, the output power loss is reduced to 4% (Zone A). At this 15% MD limited PV-DG value, the overall range of percentage reduction are gained between 3% to 9% (Case 2 for all level hospital).

Table 2. Simulation result for (a) National level, (b) State level, and (c) District level hospital

Case		1	2	3	4	5	6
Zone A MD=1097kW	Optimal DG in kW (Bus)	-	165 (5)	274 (4)	384 (4)	494 (4)	546 (7)
Total Power Losses (kW)		464	446	285	136	62	53
Percentage Reduction (%)			4%	39%	71%	87%	89%
Proposed RE Scoring		-	1	2	3	4	5
Zone B MD=1590kW	Optimal DG in kW (Bus)	-	239 (14)	398 (14)	557 (14)	716 (13)	840 (13)
Total Power Losses (kW)		577	536	351	282	193	169
Percentage Reduction (%)			7%	39%	51%	67%	71%
Proposed RE Scoring		-	1	2	3	4	5

(a)

Case		1	2	3	4	5	6
Zone A MD=1248kW	Optimal DG in kW (Bus)	-	187 (5)	312 (5)	437 (5)	562 (4)	654 (3)
Total Power Losses (kW)		350	338	195	113	82	70
Percentage Reduction (%)			3%	44%	68%	77%	80%
Proposed RE Scoring		-	1	2	3	4	5
Zone B MD=2584kW	Optimal DG in kW (Bus)	-	388 (6)	646 (6)	904 (5)	1163 (5)	1600 (4)
Total Power Losses (kW)		1466	1327	784	533	431	270
Percentage Reduction (%)			9%	47%	64%	71%	82%
Proposed RE Scoring		-	1	2	3	4	5

(b)

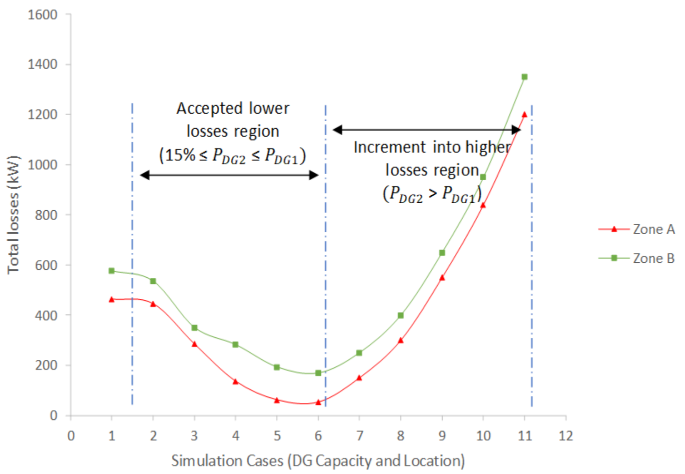
Case		1	2	3	4	5	6
Zone A MD=1232kW	Optimal DG in kW (Bus)	-	185 (2)	308 (2)	431 (2)	554 (2)	885 (5)
Total Power Losses (kW)		648	620	511	313	193	60
Percentage Reduction (%)			4%	21%	52%	70%	91%
Proposed RE Scoring		-	1	2	3	4	5

(c)

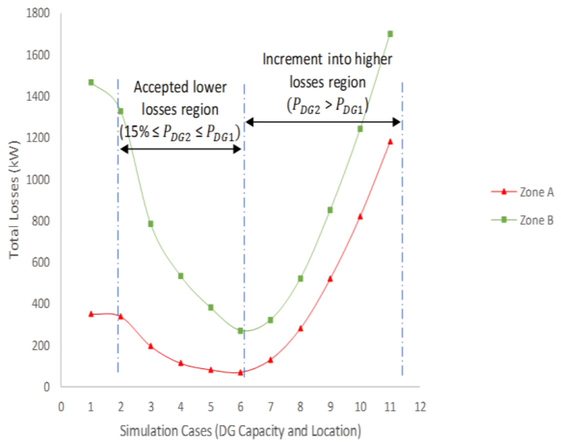
The reduction value of losses also achieved in Case 3 (P_{DG2}=25% from MD), Case 4 (P_{DG2}=35% from MD) and Case 5 (P_{DG2}=45% from MD) for all level hospital since these are still in the curve of lower losses region as described in [28]. The percentage range of loss reduction are as shown in Table 3. Without limiting the PV-DG in the optimization of Case 6 ($P_{DG2} = P_{DG1}$) it provides the best outcome in loss reduction, where these optimal PV-DG resulting in 71% to 91% of loss reduction in overall level. This optimal PV-DG value also vary from 53% (minimum) to 72% (maximum). In order to make it more firm with wider applicable criteria, a minimum value i.e. 53% is set into the round up figure, i.e. 55% and is made as the maximum scoring in new proposed RE assessment. Consequently, further increased PV-DG beyond the optimal capacity ($P_{DG2} > P_{DG1}$) as in case 7 to 12, the total line losses are rising back towards greater than optimal losses ($> L_2$) values, and moving beyond the base case value ($L_3 > L_2 > L_1$) as illustrated in Figure 2(a), Figure 2(b) and Figure 2(c).

Table 3. New RE criteria setting (capacity) based on its' potential in total loss reduction

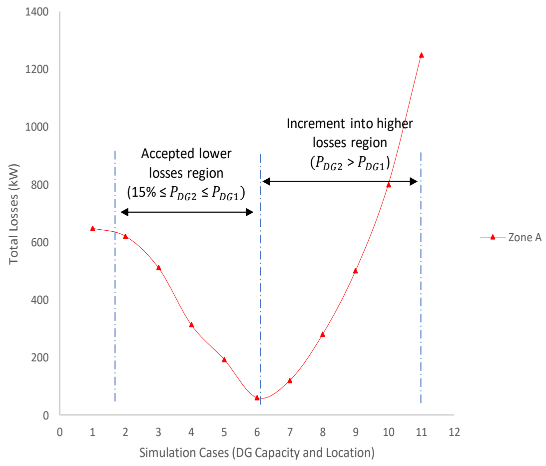
Case	1	2	3	4	5	6
RE capacity (% from MD)		15%	25%	35%	45%	Approx. 55%
Range of loss reduction (%) for all level		3%-9%	21%-47%	51%-71%	67%-87%	71%-91%
Proposed RE Scoring	-	1	2	3	4	5



(a)



(b)



(c)

Figure 2. Variation of power loss curve for, (a) National level hospital, (b) State level hospital, and (c) District level hospital

From the above analysis, the values of total losses versus simulation cases (DG capacity and location) were graphically plotted as in Figure 2(a) to Figure 2(c) and the results confirmed the energy losses variation as a function of the penetration level of DG forms a U-shape trajectory in all the situations according to [29] and [30] which also supported by a study in [31] and [28]. Other supported literature also obtained from [32] where power flow in a traditional distribution network was unidirectional and determined by the load profile due to centralized and passive with radial topology in the traditional development of the distribution networks. With the present of DG, the power system is changing, i.e. a large number of DG units are commonly connected to a distribution network which transformed into active modern distribution network with bidirectional power flows defined by the load profile and the DG generation units [33].

Based on the graph in Figure 2, five range of proposed assessment criteria (i.e. Case 2 to Case 6) reduced total line losses and in the range of lower region curve which laid between the base case and the optimal loss value. Therefore, new assessment for RE criteria is proposed, and the current setting comparison from three different GBRS by [28] is referred to differentiate this new proposed setting as shown in Table 4, thus, it is clearly observed that none of GBI, LEED, and MyCREST provide the RE criteria within this range of lower loss region as compared to the proposed new assessment criteria.

Table 4. Proposed new RE criteria and comparison with GBI, LEED, and MyCREST

Proposed New Assessment Criteria		GBI		LEED v4		MyCREST	
Parameter setting for PV-DG capacity	Score	Parameter setting for PV-DG capacity	Score	Parameter setting for PV-DG capacity	Score	Parameter setting for PV-DG capacity	Score
15% of MD or total electricity consumption	1 (min)	0.25% of MD or total electricity consumption or 2kWp	1 (min)			RE of 0.5% from total building energy use	1 (min)
25% of MD or total electricity consumption	2	0.5% of MD or total electricity consumption or 5kWp	2			RE of 1% from total building energy use	2
35% of MD or total electricity consumption	3	1.0% of MD or total electricity consumption or 10kWp	3	Points = $\frac{RE\ generated\ \%}{1.5\%} + \frac{Energy\ offset\ \%}{25\%}$	0 to 5 (max)	RE of 2% from total building energy use	3
45% of MD or total electricity consumption	4	1.5% of MD or total electricity consumption or 20kWp	4			RE of 3% from total building energy use	4 (max)
55% of MD or total electricity consumption	5 (max)	2.0% of MD or total electricity consumption or 40kWp	5 (max)				

From the whole analysis, optimization of PV-DG location and output simultaneously and reassessment of RE parameter setting give the best option to the green building developer through GBRS to provide the lowest line loss impact in the existing network. This can be seen by choosing the first five criteria (Case 2–Case 6) from graph in Figure 2 as well as establishment of new assessment criteria in Table 4, which has been proven on the effectiveness in reducing total line losses, hence, is proposed to be applied in GBRS for more justified and effective outcome. However, the optimal location for PV-DG placement needs to be simulated differently for other different public hospital application.

5. CONCLUSION

This paper presents the simulated outcome-based for the worth application of PV-DG imposed in green building development for selected Malaysian public hospitals. The objective function representing total line losses contribution gives a better justified measure for expanding capacity towards optimal DG setting, thus, the PV-DG assessment criteria in current GBRS is proposed to be reviewed into new parameter setting as in Table 4 specifically for application within selected Malaysian public hospitals due to their high energy demand [19] and distinctive electrical load profile [28].

ACKNOWLEDGEMENT

The authors would like to express their appreciation to the Universiti Teknologi Malaysia (UTM) and Ministry of Education for funding this study via grants R.K130000.7740.4J315 and Q.K130000.2540.16H95.

REFERENCES

[1] Lund, H., A. Marszal, and P. Heiselberg, "Zero energy buildings and mismatch compensation factors". *Energy and Buildings*, 2011. 43(7): p. 1646-1654.
[2] Mwasha, A., R.G. Williams, and J. Iwaro, "Modeling the performance of residential building envelope: The role of sustainable energy performance indicators". *Energy and buildings*, 2011. 43(9): p. 2108-2117.
[3] Shi, L. and M. Y. L. Chew, "A review on sustainable design of renewable energy systems". *Renewable and Sustainable Energy Reviews,* 2012. 16(1): p. 192-207.
[4] GhaffarianHoseini, A., et al., "Sustainable energy performances of green buildings: A review of current theories, implementations and challenges". *Renewable and Sustainable Energy Reviews*, 2013. 25: p. 1-17.
[5] Deng, S., et al., "Case study of green energy system design for a multi-function building in campus". *Sustainable Cities and Society*, 2011. 1(3): p. 152-163.
[6] Nguyen, T. T., A. V. Truong, and T. A. Phung, "A novel method based on adaptive cuckoo search for optimal network reconfiguration and distributed generation allocation in distribution network". *International Journal of Electrical Power & Energy Systems,* 2016. 78: p. 801-815.
[7] R. S. Rao, K. Ravindra, K. Satish and S. V. L. Narasimham, "Power Loss Minimization in Distribution System Using Network Reconfiguration in the Presence of Distributed Generation," in *IEEE Transactions on Power Systems*, vol. 28, no. 1, pp. 317-325, Feb. 2013.
[8] Sultana, U., et al., "A review of optimum DG placement based on minimization of power losses and voltage stability enhancement of distribution system". *Renewable and Sustainable Energy Review*s, 2016. 63: p. 363-378.
[9] Usman, M., et al., "Losses management strategies in active distribution networks: A review". *Electric Power Systems Research*, 2018. 163: p. 116-132.
[10] LEED, U.v., LEED v4 for Building Operations and Maintenance. Acedido em: http://www.usgbc. org/resources/leed-v4-building-operations-and-maintenance-current-version, 2016.
[11] Index, G.B. and G. Malaysia, "Green Building Index". 2013, Retrieved.
[12] Prabha, D.R. and T. Jayabarathi, "Optimal placement and sizing of multiple distributed generating units in distribution networks by invasive weed optimization algorithm". *Ain Shams Engineering Journal*, 2016. 7(2): p. 683-694.
[13] M. Dixit, P. Kundu and H. R. Jariwala, "Optimal placement of PV array in distribution system for power loss minimization considering feeder reconfiguration," *2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC)*, Florence, 2016, pp. 1-6.
[14] Banos, R., et al., "Optimization methods applied to renewable and sustainable energy: A review". *Renewable and Sustainable Energy Reviews*, 2011. 15(4): p. 1753-1766.
[15] Bhowmik, C., et al., "Optimal green energy planning for sustainable development: A review". *Renewable and Sustainable Energy Reviews*, 2017. 71: p. 796-813.
[16] M. N. B. Muhtazaruddin, N. D. Tuyen, G. Fujita and J. J. B. Jamian, "Optimal Distributed Generation and capacitor coordination for power loss minimization," *2014 IEEE PES T&D Conference and Exposition*, Chicago, IL, 2014, pp. 1-5.
[17] Z. M. Yasin, T. K. A. Rahman, I. Musirin and S. R. A. Rahim, "Optimal sizing of distributed generation by using quantum-inspired evolutionary programming," *2010 4th International Power Engineering and Optimization Conference (PEOCO)*, Shah Alam, 2010, pp. 468-473.
[18] Muhtazaruddin, M. N. B., J. J. B. Jamian, and G. Fujita, "Determination of optimal output power and location for multiple distributed generation sources simultaneously by using artificial bee colony". *IEEJ Transactions on Electrical and Electronic Engineering*, 2014. 9(4): p. 351-359.
[19] E. K. Bawan, "Distributed generation impact on power system case study: Losses and voltage profile," *2012 22nd Australasian Universities Power Engineering Conference (AUPEC)*, Bali, 2012, pp. 1-6.
[20] Lalitha, M. P., N. S. Reddy, and V. V. Reddy, Optimal DG placement for maximum loss reduction in radial distribution system using ABC algorithm. International journal of reviews in computing, 2010. 3: p. 44-52.
[21] Muhtazaruddin, M. N. B., et al., "Distribution Power Loss Minimization via Distributed Generation, Capacitor and Network Reconfiguration*". Indonesian Journal of Electrical Engineering and Computer Science,* 2017. 5(3): p. 488-495.
[22] Krueasuk, W. and W. Ongsakul. "Optimal placement of distributed generation using particle swarm optimization". in *Australian Universities Power Engineering Conference*. 2006.

[23] J. A. Sa'ed, M. K. Jubran, S. Favuzza and F. Massaro, "Reassessment of voltage stability for distribution networks in presence of DG," *2016 IEEE 16th International Conference on Environment and Electrical Engineering (EEEIC)*, Florence, 2016, pp. 1-5.

[24] D. Q. Hung and N. Mithulananthan, "Multiple Distributed Generator Placement in Primary Distribution Networks for Loss Reduction," in *IEEE Transactions on Industrial Electronics*, vol. 60, no. 4, pp. 1700-1708, April 2013.

[25] N. C. Hien, N. Mithulananthan and R. C. Bansal, "Location and Sizing of Distributed Generation Units for Loadabilty Enhancement in Primary Feeder," in *IEEE Systems Journal*, vol. 7, no. 4, pp. 797-806, Dec. 2013.

[26] Syahputra, R., I. Robandi, and M. Ashari, "Performance Improvement of Radial Distribution Network with Distributed Generation Integration Using Extended Particle Swarm Optimization Algorithm". *International Review of Electrical Engineering (IREE)*, 2015. 10(2): p. 293-304.

[27] EMEER 2008, E., Efficient Management of Electrical Energy Regulation 2008 (EMEER 2008).

[28] Amran, M.E. and M.N. Muhtazaruddin, "Assessment of renewable Distributed Generation in Green Building Rating System for public hospital". *International Journal of Engineering and Technology(UAE)*, 2018. 7(3): p. 40-45.

[29] V. H. M. Quezada, J. R. Abbad and T. G. S. Roman, "Assessment of energy distribution losses for increasing penetration of distributed generation," in *IEEE Transactions on Power Systems*, vol. 21, no. 2, pp. 533-540, May 2006.

[30] Van Thong, V., J. Driesen, and R. Belmans, "Interconnection of distributed generators and their influences on power system". *International Energy Journal*, 2005. 6.

[31] Mahdad, B. and K. Srairi, "Adaptive differential search algorithm for optimal location of distributed generation in the presence of SVC for power loss reduction in distribution system". *Engineering Science and Technology, an International Journal*, 2016. 19(3): p. 1266-1282.

[32] Ho, W., et al., "Design of distributed energy system through electric system cascade analysis (ESCA)." *Applied energy*, 2012. 99: p. 309-315.

[33] Savić, A. and Ž. Đurišić, "Optimal sizing and location of SVC devices for improvement of voltage profile in distribution network with dispersed photovoltaic and wind power plants". *Applied Energy*, 2014. 134: p. 114-124.

Appendix A: Bus and line data for National Hospital level

Zone	Zone A				Zone B			
Input data	Bus 4	Bus 5	Bus 6	Bus 7	Bus 11	Bus 12	Bus 13	Bus 14
Voltage (kV)	11.2	11.2	11.2	11.2	11.2	11.3	11.2	11.2
P Load (kW)	100	472	105	420	499	465	539	87
Q Load (kVAR)	52	170	-46	240	-68	157	111	52
Resistance, R (Ω/Km)	Bus 4-5=0.049, Bus 5-6=0.098, Bus 6-7=0.0686				Bus 11-12=0.049, Bus 12-13=0.0686, Bus 13-14=0.049			
Reactance, X (Ω/Km)	Bus 4-5=0.0377, Bus 5-6=0.0754, Bus 6-7=0.0528				Bus 11-12=0.0377, Bus 12-13=0.0528, Bus 13-14=0.0377			

Appendix B: Bus and line data for State Hospital level

Zone	Zone A				Zone B				
Input data	Bus 1	Bus 2	Bus 3	Bus 4	Bus 5	Bus 6	Bus 7	Bus 8	Bus 9
Voltage (kV)	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9	10.9
Real Power, P (kW)	710	187	151.5	199	1190	465	457	283	189
Reactive Power, Q (kVAR)	22.5	98	77	125	20.9	130	175	137	63
Resistance, R (Ω/Km)	Bus 1-2=0.049, Bus 2-3=0.0196, Bus 3-4=0.0294				Bus 5-6=0.0294, Bus 6-7=0.0196, Bus 7-8=0.049, Bus 8-9=0.0294				
Reactance, X (Ω/Km)	Bus 1-2=0.0377, Bus 2-3=0.0151, Bus 3-4=0.0226				Bus 11-12=0.0377, Bus 12-13=0.0528, Bus 13-14=0.0377				

Appendix C: Bus and line data for District Hospital level

Zone	Zone A			
Input data	Bus 2	Bus 3	Bus 4	Bus 5
Voltage (kV)	10.9	10.9	10.9	10.9
Real Power, P (kW)	217	50	479	485
Reactive Power, Q (kVAR)	33.42	10	181	198
Resistance, R (Ω/Km)	Bus 3-4=0.0196, Bus 4-5=0.0686, Bus 5-2=0.049			
Reactance, X (Ω/Km)	Bus 3-4=0.0151, Bus 4-5=0.0528, Bus 5-2=0.0377			