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Research paper

Assessment of Renewable Distributed Generation in Green Building Rating System for Public Hospital

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Abstract

This paper presents an optimization solution for renewable Distributed Generation (DG), as imposed in the Green Building Rating System (GBRS) for a public hospital. Solar photovoltaic DG unit (PV-DG) is identified as a type of DG used in this paper. The proposed optimization via PV-DG coordination will improve the sustainable energy performance of the green building by power loss reduction within accepted lower losses region using Artificial Bee Colony (ABC) algorithm. The setup input data from one of Malaysian public hospitals' power distribution system is been adopted and simulation results via MATLAB programming show that the optimization of DG forming into bigger-scale imposed system provides a better outcome in minimization of total power losses within appropriate voltage profile as compared to current PV-DG imposed in GBRS. The objective function representing total power losses which also supported by related literature give a measure that forming sufficient and optimal PV-DG assessment criteria is highly important, thus, current PV-DG assessment in GBRS is proposed to be reviewed into new parameter setting for public hospital due to its' high energy demand and distinctive electrical load profile.

Keywords: *Green Building Rating System (GBRS); Artificial Bee Colony (ABC); Power Loss Minimization; Solar Photovoltaic (PV); and Distributed Generation (DG).*

1. Introduction

The new trend to design and build or even operating existing hospital guided with environmental technology in sustainability, renewable based resources, and systems designed towards reducing consumption of energy as well as reducing carbon emissions in making it possible in achieving higher building performance. Sustainability incorporates three fundamental bottom-line, i.e. environmental, economic and socio-cultural segments while the respectively specified parts are considerably bound up with the conditions of improvement of prosperity for the occupants [1].

Moreover, environmental factors and conflicting of the price of oil at the international market, the concept of low energy building and green building are emphasized by Malaysian government [2]. Based on data from Ministry of Health, 28 hospitals have been identified as consuming more than 3,000,000kWh of electricity over a consecutive period of not more than six months. According to the TNB figures, these 28 hospitals alone account for approximately 13% of the government's 2009 energy bill. This makes the hospital building sector a significant contributor to the high-energy use and an important focus for sustainability measures. As such, the reliable determination of load characteristics becomes an important engineering task since the consumers were responsible by the Regulation in power system assessment and maintenance on users' side [3,4]. In this case, the hospital could react to energy consumption reduction, enhancing indoor air quality and a supportive healing condition. As the earth's future becoming the focus of global and the concern about the environment, increasing number of projects have made a closer movement to the sustainable goal in recent years. A sustainable approach is winding up to be more attractively in a growing number of hospitals [5].

In addition, sustainability has been formally embraced in Malaysia Eleventh Plan where green growth will be a fundamental shift especially in the human capital, policy, and regulatory framework, green technology investment and financial instruments [6]. In line with the said initiative, The Ministry of Energy, Green Technology, and Water upheld by significant Agencies among respective Ministries will advance the development for green products and services in domestic market where measures to be undertaken which include of implementing Government green procurement for at least 20% by year 2020, encouraging the *green building developments* and industries greening to stimulate green growth [6].

1.1. Green Building Rating System – Energy Assessment

The green buildings are remarkably correlated 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 renewable energy sources approach [7,8]. According to [9], Environmental Assessment (EA) has been put forward by previous studies as the end-focus by the performance of green buildings, therefore, it is a high necessity to ensure the measurement of indicators for sustainable energy performance were fully considered in any green implementations and the environmental evaluation. Besides, [8] stated performance evaluations shall up-bring the significant parameters of sustainable energy performance indicators which

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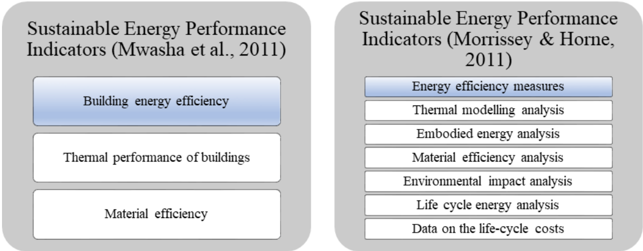
comprises energy efficiency of building, the material efficiency and thermal performance of buildings. While according to [10], analyses and evaluations within sustainable energy performance indicators shall include with the participation of embodied energy analysis, energy efficiency measures, environmental impact analysis, thermal modeling analysis, material efficiency analysis, the life cycle of energy analysis and data on the life-cycle costs in performance assessment of the building. Fig. 1 (a) and (b) shows the detailed assessment under sustainable energy performance indicators between these two (2) authors.



(a) (b)

Fig. 1: Assessment by [8] (a) and [10] (b) under sustainable energy performance indicators

By picking up energy and efficiency as focus, comparison study of green building assessment criteria by [5] between four (4) sets of different Green Building Rating system (GBRS), i.e., Green Building Index (GBI), Leadership in Energy and Environmental Design (LEED), Building Research Establishment Environmental Assessment Method (BREEAM) and Green Star has been reviewed which confirmed in defining the energy efficiency as dominant criteria in each GBRS. Obviously for BREEAM and Green Star, due to having considered of another criterion in their rating systems, they are not as high as of GBIs and LEED. However, BREEAM still prioritized energy efficiency in the assessment criteria. Overall comparison is shown in Table 1. The result also identifies energy criterion as the highest intensity of concern in green development for hospital building by the establishment of GBI for non-residential existing building (NREB): Hospital [11] and LEED v4 [12].

However, different Green Building Rating System (GBRS) affect building assessment methods differently in different climates and must also represent the geographical location and climatic condition of its origin country [13,14]. Moreover, as mentioned by [15], many types of research have concluded that developing countries are necessary to analyze the local situation at first, in terms of the different environmental focus and socio-economic needs, before customized and identify the adaptability of sustainable energy performance indicators in building assessment tools originated from developed countries. The GBI based on [16], was designed for the tropical climate of Malaysia. On the other option from local GBRS, i.e. Malaysian Carbon Reduction Environmental Sustainability Tool (MyCREST), had appeared into the mainstream and been made as a compulsory requirement by Public Work Department (PWD) for Malaysian governments' projects above RM50 million value [17]. In this paper, these two local GBRS will be used for referral on renewable energy assessment criteria. In addition, this paper will also consider a referral from LEED, since it has a great influence on newer GBRS for all over the world [16]. A Comparison of three (3) different GBRS focusing on renewable energy assessment criteria as shown in Table 2 [11,12].

1.2. Issues Related to Solar Photovoltaic DG (PV-DG) Imposed Under Energy Assessment

Due to the highest weight determinant point in energy and efficiency criterion, it attributes the building owners in gaining the highest possible scoring for that region to achieve higher GBRS certification level in overall assessment criteria, including theimposed of renewable energy (RE), since RE laid as part of assessment under energy efficiency category in many GBRS worldwide including [11], [12] and MyCREST. Since utilizing of renewable energy as one of the most key elements of green buildings [18], this significantly increases the imposed of solar photovoltaic (PV) system to the highest possible capacity into power system network. Based on the essence of sustainable developments, the renewable energy usage such as solar photovoltaic (PV) is one of the most influentially common principles [19] and consequential approach in reducing the energy consumption in buildings [9] while having considered as key component of green building-based design of electricity generation capability [20]. However, solar photovoltaic (PV) as one of various type of DG (PV-DG) can worsen the system performance [21] and lead to power losses and contribute to inefficiency of renewable energy transmitting if the proper assessment is not well considered. Due to that, there is lacking in right-sizing and right-locating of renewable DG unit within GBRS assessment, thus, leaving a gap of improper application.

Table 1: Comparison of assessment criteria between four (4) sets of different green building rating system (GBRS)

Green criteria / elements	GBI NRNC	GBI NREB	BREEAM	BREEAM	LEED	LEED	GSTAR	GSTAR
	100%	100%	110%	100%	110%	100%	172	100%
Energy efficiency	35	38	19	17.27	39	35.45	29	16.86
Indoor environment quality	21	21	15	13.64	18	16.36	32	18.60
Sustainable site planning& mgmt.	16	10	12	10.91	18	16.36	17	9.88
Materials & resources	11	9	12.5	11.36	16	14.55	35	20.35
Water efficiency	10	12	6	5.45	9	8.18	14	8.14
Innovation	7	10	10	9.09	6	5.45	5	2.91
Land use and ecology			10	9.09			20	11.63
Transport			8	7.27			12	6.98
Regional priority credits					4	3.64		
Pollution			10	9.09			20	11.63
Waste			7.5	6.82				

Table 2: Renewable energy criteria comparison between GBI, LEED, and MyCREST

GBI		LEED v4 (EBOM)		MyCREST (O&M)	
Parameter setting for RE capacity	Scoring	Parameter setting for RE capacity	Scoring	Parameter setting for RE capacity	Scoring
0.25 % of the M.D. or total electricity consumption, or 2 kWp (PV or equiv) whichever is the greater	1 (Min)	0% renewable energy generated	1 (Min)	Renewable Energy of 0.5% from Total Building Energy Use	1 (Min)
0.5 % of the M.D. or total electricity consumption, or 5 kWp (PV or equiv) whichever is the greater	2	Points = $\frac{\frac{\text{Renewable energy generated \%}}{1.5\%} + \text{Energy purchased or offset\%}}{25\%}$		Renewable Energy of 1% from Total Building Energy Use	2
1.0 % of the M.D. or total electricity consumption, or 10 kWp (PV or equiv) whichever is the greater	3			Renewable Energy of 2 % from Total Building Energy Use	3
1.5 % of the M.D. or total electricity consumption, or 20 kWp (PV or equiv) whichever is the greater	4				
2.0 % of the M.D. or total electricity consumption, or 40 kWp (PV or equiv) whichever is the greater	5 (Max)	1.5% renewable energy generated	5 (Max)	Renewable Energy of 3 % from Total Building Energy Use	4 (Max)

The injected DG in distribution system may increase or decrease power losses level, subjected with dependability to the type of DG technology, penetration, level of dispersion, characteristics of distribution network and load demand levels [22]. This also even may lead to greater losses compare to losses without DG [23], while, the improper sized and placement of DG may increase the system losses [24,25]. A study by [26] indicated that the higher system losses caused by this improperly sized and placement of this DG units are due to the effect of reverse power flow from larger DG units. According to [23], loss reduction via DG is most effective when feeder has a highly loaded of high resistance with a low load of power factor, whereas, feeder reactance is negligible unless the DG unit operates in voltage control mode [27]. Therefore, insertion of DG in distribution network shall consider the loss reduction element as the most important factor in its' planning and operation [28].

1.3. Optimization Approach for Loss Reduction Element

Optimization as a solution is the procedure in identifying the value of minimum or maximum of a function by specifying several numbers of constraints known as the 'variables' [29]. Using simulation tools, the optimization function is called cost or fitness or objective function is sequentially calculated [30].

Based on [21], separate analysis and simultaneous analysis are two identical ways of the solution in power losses mitigation by DG. Using separate analysis, location and capacity of DG identification are calculated separately using sensitivity factor [31] followed by optimization technique respectively. Whereas, in the simultaneous analysis which offer better results than separate analysis [32], this method determining the capacity and the DG location at the same time (simultaneously) by using optimization techniques, for instance, Particle Swarm Optimization (PSO), Genetic Algorithm (GA) and Artificial Bee Colony (ABC) [21,23].

Known as a population-based meta-heuristic algorithm, particle swarm optimization (PSO) works in two steps, of which, calculating the particle velocity and then updating the position [34]. PSO requires little memory and reduces the computation time, however, based on [34], a study by [35], [36] and [37] indicate that PSO easily suffers from partial optimization. Genetic algorithm (GA) on the other optimization technique, can be used to solve the non-dimensional, non-differential and non-continuous problems which also easy to understand [34]. There is a limitation in GA applications in real time performance due to less convergence speed and random solutions approach [38]. On the other hand, a study by [39] observing a combination of GA and PSO algorithm for DG optimal capacity and location.

Karaboga in 2005, has introduced the artificial bee colony (ABC) algorithm [40], where this optimization algorithm initially was proposed for unconstrained problems. Then, in dealing with constrained problems in optimization, an extended version of the ABC algorithm was established [41]. Based on [42], the analogy of ABC is that three groups i.e. employed, onlookers and scouts' bees are assigned in the colony of artificial bees. An 'onlooker' is the decision maker to choose the source of food source while an 'employed' is a bee of which going to the food source visited by it previously bee. The third one namely as 'scout', is a bee which carries out random of search. The algorithm of ABC assigned employed artificial bees in the first half of the colony, consequently, the onlookers, which constitutes in the second half. It is specified that only one employed bee assigned for every food source. Whereby, in the case of an exhausted food source by the employed bee and onlooker bees becomes a scout. In initialize stage, the bees select sets of food source positions randomly and determined their nectar amounts. Within the hive, the nectar sources information is shared among the bees waiting on the dance area by the coming bees into the hive. By this initial information, the existence of food source is kept in memory, of which, all employed bees make a way to previously visited cycle food source. Concurrently, a new source of food is also being visualized in the neighborhood of the present path via comparison-based positions of food source. Next, preferable food source area by an onlooker is depending on the distributed nectar information by the employed bees on the dance area. The probability of which an onlooker chooses that food source increases as the nectars' amount of food source increases. Once reached its limit, these bees left the nectar of a food source, where a new food source is randomly identified by a scout bee and superseded with the leaving one. The ABC flowchart as illustrated in Fig. 2 [33].

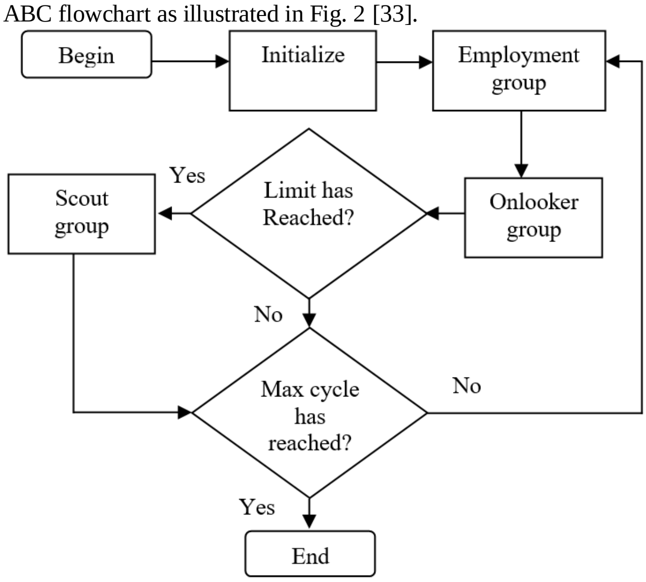


Fig. 2: Flowchart of ABC

2. Research Method

In this paper, the DG costing and the other associated financial worth analysis is not being considered in solving the sizing and location problem. The simulation processes are performed into three (3) groups, i.e. Group A, Group B, and Group C, whereas each of this group will be made comparable between four (4) case studies as determined in Table 3. All simulations are performed by MATLAB R2013b using six (6) actual power system parameters adopted from one of the Malaysian public hospital's distribution network as illustrated in Fig. 3. These power system parameters consist of distribution bus identification, active power dissipation (P), reactive power consumed (Q), resistance (R) and reactance (X) for laid cables (Ω/Km) and voltage level (V) as shown in Table 4. The sample data of P and Q are represented of the highest value within a period of 6 consecutive months considering the peak-load and maximum irradiation, which adopted from timeline used in collecting energy trend via Efficient Management of Electrical Energy Regulation 2008, published by Energy Commission of Malaysia [4]. The optimization process is done by using the ABC algorithm.

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

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

$$x_{ij}^{new} = x_{ij}^{old} + range(0,1) \times (x_{ij}^{old} - x_{kj}) \quad (2)$$

Where, x_{ij}^{new} and x_{ij}^{old} represent the new and old (previous) value of 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.

$$prob_i = \frac{F_i}{\sum_{i=1}^{N} F_i} \quad (3)$$

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

2.1. Mathematical Formulation

Total Power Losses (TPL) in this distribution network is selected as a main target i.e. objective function, in ABC optimization. As appointed in (4) represents the formula for objective

$$TPL = \sum_{L=1}^{n} (|I_L|^2 \times R_L) \quad (4)$$

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

Optimal selection of parameters that have been determined by the ABC must fulfill all constraints while striving the main objective to reduce the power losses. This important procedure needs to be observed during optimization process to ensure violation of any limit is not occur in the solution. Optimization process without with all constraints as listed below:

a) Size of DG constraint

The minimum and maximum size of DG is set between 0.3 MW and 3 MW respectively for unlimited optimized capacity value as determined in Case 4 of Table 3. Whereby, DG limit value in Case 2 and Case 3 are determined according to GBRS maximum score value as shown in Table 2 in previous Section 1.1.

b) Power balance constraint

$$P_{DG} + P_{substation} = P_{Load} + TPL \quad (5)$$

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

$$0.90 \le V_n \le 1.05 \quad (6)$$

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

d) Radial circuit constraint

For each of case studies, the distribution network must remain its radial circuit, i.e. maintaining original condition of all off point (OP) switchgear shown in Fig. 3.

Table 3: Case by case studies

Case	Description	Case	Description
1	Original test system without DG.	3	Determine optimal values of location and size for DG (limited capacity based on assessment criteria), simultaneously
2	Determine fixed values of location and size for DG, Based on GBRS common practice	4	Determine optimal values of location and size for DG (unlimited capacity), simultaneously

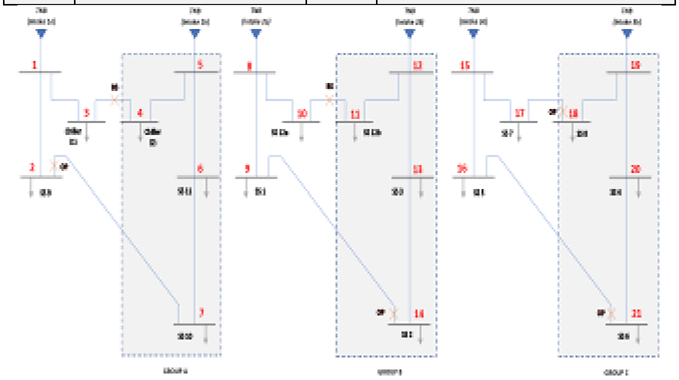


Fig. 3: Distribution network which split into three (3) groups

Table 4: Power system input parameter

Input data	Bus 4	Bus 5	Bus 6	Bus 7	Bus 11	Bus 12	Bus 13	Bus 14	Bus 18	Bus 19	Bus 20	Bus 21
Voltage (kV)	11.2	11.2	11.2	11.2	11.2	11.3	11.2	11.2	11.1	11.2	11.1	11.1
Real Power, P (kW)	100	472	105	420	490	465	539	87	941	216	348	635
Reactive Power, Q (KVAR)	52	170	-48	240	-68	157	111	52	307	83	115	251
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				Bus 18-19=0.0686, Bus 19-20 =0.0392, Bus 20-21=0.0490			
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				Bus 18-19=0.0528, Bus 19-20=0.0302, Bus 20-21=0.0377			

3. Results and Discussion

From the results in Table 5 (a), (b) and (c), original total power losses in the system (without imposed of PV-DG) as in Case 1 are equal to 464 kW, 577kW and 1069kW for Group A, Group B, and Group C respectively. Subsequently for Case 2, Imposing PV-DG for Group A in MyCREST, GBI, and LEED, however, increased total power losses by 897kW, 921kW, and 929kW respectively. The incremental loss figures also similarly occurred in Group B and Group C for Case 2 with values as in Table 5. From these values, an observation confirmed the impact of improper size and location of DG, which could cause in worsening the system performance as accorded to [21-26] in Section 1.2. Subsequently, optimization in Case 3 (both Group A, Group B, and Group C) via MyCREST, GBI and LEED were seen capable to reduce total power losses value from Case 2, but still, these outcome values are greater than original total power losses (Case 1). DGs in Case 3 are considered small, insufficient and optimized within limited DG constraint in highly losses region as shown in Fig. 4 (a), (b) and (c) which also coincide with power losses curve as in the study by [43]. Thus, bigger PV-DG capacity for loss reduction beyond this unnecessary region is needed for practical application in public hospital and worth financial investment for installation. Finally, without limiting the PV-DG in optimization (Case 4), it provides much better outcome in loss reduction (lower losses region), where these optimal DGs resulting in much lower output losses as compared with original total power losses (Case 1), as a result, benefiting the overall distribution network performance.

Table 5: Simulation result prior to (a) MyCREST, (b) GBI-NREB and (c) LEED v4 EBOM

Group		A				B				C			
Case		1	2	3	4	1	2	3	4	1	2	3	4
Description													
Control Parameters (NOB=Number of Bees, LMT=Limit)			NOB=40, LMT=50	NOB=40, LMT=50	NOB=40, LMT=50		NOB=40, LMT=58	NOB=40, LMT=50	NOB=40, LMT=50		NOB=40, LMT=58	NOB=40, LMT=50	NOB=40, LMT=58
Fixed DG (Solar PV) Coordination	Fixed Location (Bus)	-	5, 6, 7, 4	-	-	-	12, 13, 14, 11	-	-	-	18, 20, 21, 18	-	-
	Fixed Maximum Output Power (kW)	-	14, 8, 18, 3	-	-	-	14, 16, 8, 15	-	-	-	6, 10, 15, 28	-	-
Optimized DG (Solar PV) Coordination	Optimal Location (Bus)	-	-	4	7	-	-	14	13	-	-	19	21
	Optimal Output Power (kW)	-	-	32	546	-	-	48	840	-	-	30	1205
Total Power Losses (kW)		464	897	510	53	577	1384	912	169	3068	3364	2022	641
Percentage of loss reduction / addition		-	93%	15%	775%	-	136%	58%	341%	-	121%	88%	67%

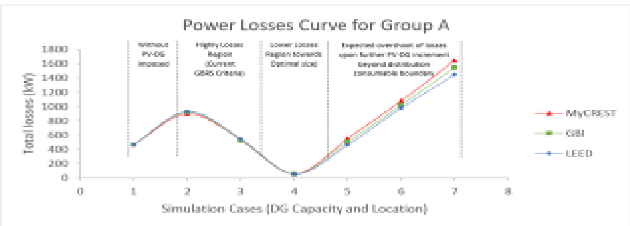
(a)

Group		A				B				C			
Case		1	2	3	4	1	2	3	4	1	2	3	4
Description													
Control Parameters (NOB=Number of Bees, LMT=Limit)			NOB=40, LMT=50	NOB=40, LMT=50	NOB=40, LMT=50		NOB=40, LMT=50	NOB=40, LMT=58	NOB=40, LMT=50		NOB=40, LMT=50	NOB=40, LMT=50	NOB=40, LMT=50
Fixed DG (Solar PV) Coordination	Fixed Location (Bus)	-	5, 6, 7, 4	-	-	-	11, 13, 14, 11	-	-	-	19, 20, 21, 18	-	-
	Fixed Maximum Output Power (kW)	-	8, 3, 8, 2	-	-	-	9, 11, 2, 10	-	-	-	4, 7, 17, 19	-	-
Optimized DG (Solar PV) Coordination	Optimal Location (Bus)	-	-	4	7	-	-	14	13	-	-	19	21
	Optimal Output Power (kW)	-	-	40	546	-	-	48	840	-	-	47	1155
Total Power Losses (kW)		464	831	528	53	577	1311	932	169	3069	3444	3057	641
Percentage of loss reduction / addition		-	98%	14%	775%	-	131%	61%	241%	-	129%	92%	67%

(b)

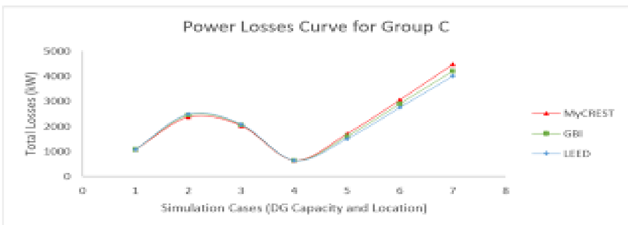
Group		A				B				C			
Case		1	2	3	4	1	2	3	4	1	2	3	4
Description													
Control Parameters (NOB=Number of Bees, LMT=Limit)			NOB=40, LMT=50	NOB=40, LMT=50	NOB=40, LMT=58		NOB=40, LMT=58	NOB=40, LMT=50	NOB=40, LMT=50		NOB=40, LMT=50	NOB=40, LMT=50	NOB=40, LMT=50
Fixed DG (Solar PV) Coordination	Fixed Location (Bus)	-	5, 6, 7, 4	-	-	-	12, 13, 14, 11	-	-	-	18, 20, 21, 18	-	-
	Fixed Maximum Output Power (kW)	-	7, 2, 8, 2	-	-	-	7, 8, 3, 7	-	-	-	3, 5, 13, 14	-	-
Optimized DG (Solar PV) Coordination	Optimal Location (Bus)	-	-	4	7	-	-	14	13	-	-	19	21
	Optimal Output Power (kW)	-	-	17	546	-	-	23	840	-	-	35	1115
Total Power Losses (kW)		464	929	547	53	577	1450	974	169	3069	3487	3075	641
Percentage of loss reduction / addition		-	100%	18%	775%	-	151%	69%	243%	-	133%	94%	67%

(c)



(a)

(b)



(c)

Fig. 4: Power losses curve for (a) Group A, (b) Group B and (c) Group C

4. Conclusion

This paper presents the simulated outcome-based for the worth application of solar photovoltaic DG (PV-DG) imposed in Malaysian public hospital as stimulated to current assessment criteria in MyCREST, GBI, and LEED. As a conclusion from guide reference in Fig. 4, the total losses can be reduced upon an increment of sufficient DG capacity until an optimal DG size at the identified location. Further increase of the DG size will subsequently increase back the losses which then may possibly trespass beyond the base case of total losses. The objective function representing these contributed total power losses give a measure that forming a sufficient and optimal DG setting is of essence, thus, the PV-DG assessment criteria in current GBRS is proposed to be reviewed into new parameter setting specifically for public hospital application due to its' high energy demand [23] and distinctive electrical load profile.

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