Optimum Design of Islanded Microgrid Based on Life Cycle Cost for Office Building in Myanmar

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Abstract: *Renewable energy sources in energy generation can decrease the costs of system fuel and also can have desirable impact on reliability of system. According to the weather condition in Myanmar, solar energy is the best renewable energy source to provide electricity for both urban and rural areas. The islanded microgrid system optimization that is composed of the photovoltaic (PV) system, battery energy storage system (BESS), and diesel generation system (DGS) is proposed for fulfilling the continuous power supply of the office buildings which is situated in Hlaing Tharyar Township, Yangon division of Myanmar. To evaluate the optimum cost of the islanded microgrid system Hybrid Optimization Model of Electric Renewable (HOMER) software is used. In addition to, the simulation results of HOMER are compared with the outcomes of the other optimization method, Particle Swarm Optimization (PSO). According to the comparative results of HOMER and PSO, the PSO provides less life cycle cost (LCC) than that of HOMER.*

Key Words: *Islanded Microgrid, Photovoltaic System, HOMER, Particle Swarm Optimization, Life Cycle Cost*

1. INTRODUCTION:

A microgrid is made up of various renewable distributed generators, non-renewable distributed generators, energy storage devices, different types of microgrid loads, interfaced distributed energy resources (DERs), interconnected microgrids, stability and control systems, and communication systems. The technical features of a Microgrid make it suitable for supplying power to remote area of a country where supply from the national grid system is either difficult to avail due to the topology or frequently disrupted due to severe climatic conditions or man-made disturbances. Microgrids can supply uninterruptible power, improve local reliability, reduce feeder losses and provide local voltage support. Microgrids reduce environmental pollution and global warming through utilization of low-carbon technology. The microgrid is operated in two modes: (1) gird-connected and (2) stand-alone. A more cost-effective approach of electrifying an off-grid community is to use a stand-alone microgrid power generation system that utilizes the available renewable energy resources (RERs)[1].

In this paper, islanded microgrid system is considered in order to supply the continuous power with the optimum cost for the office buildings which is situated in Hlaing Tharyar Township, Yangon division of Myanmar. According to the collected data, the load demand of the proposed area is approximately about 150 kW and the load demand varies throughout the day. After that, the stand-alone microgrid system is designed regarding to the levelized cost of energy. The simulation, sensitivity analysis and optimization of microgrid system have been performed by using HOMER software and Particle Swarm Optimization (PSO) and the two simulation results are compared to achieve the optimum cost of the proposed system.

2. ISLANDED MICROGRID:

A more cost-effective approach of electrifying an off-grid community is to use a stand-alone microgrid power generation system that utilizes the available renewable energy resources (RERs). Such isolated power generation and distribution systems, which embed distributed energy resources (DERs), are known as islanded microgrids (IMGs). An IMG energized mainly by RERs not only reduces the life-cycle cost (LCC) but it also enhances renewable energy penetration (REP) and thus decreases greenhouse gas emissions [3]. IMGs are categorized based on a number of factors such as installation capacity, peak load, and daily average load (DAL). Considering all kinds of off-grid system/remote community has divided the IMGs based on their installation capacity and the categories are presented in Table 1[2].

Table 1. Categories of IMG based on installed power [2]

Installed Power(kW)	Estimated DAL(kWh)	Types	Descriptions	Remarks
< 1	1-20	Micro power system	Single point DC based system	Mostly energy storage and PV system
1-100	21-400	Village power systems	Small power system both DC and AC bus	The diesel generators are helped by wind and PV system
101-10,000	401-50,000	Island power systems	Isolated grid systems mostly AC bus	Mostly augmented the diesel generators by wind power and/or PV power integrated with energy storage
>10,000	-	Large inter-connected systems	Large remote power system	Big wind and/or solar farm integrated with BES

3. OPTIMIZATION TECHNIQUES FOR ISLANDED MICROGRID:

A. Particle Swarm Optimization Method

Particle swarm optimization (PSO) is an exciting new methodology in evolutionary computation that is similar to a genetic algorithm(GA). The algorithm is initialized with a population of random solutions. Unlike other algorithms, each potential solution (called a particle) is also assigned a randomized velocity and then flown through the problem hyperspace. Particle swarm optimization has been found to be extremely effective in solving a wide range of engineering problems. It is very simple to implement (the algorithm comprises two lines of computer code) and solves problems very quickly [3]. Advantages of PSO method are:

- PSO is one of the modern heuristic algorithms capable to solve large-scale non convex optimization problems like Economic Dispatch.
- The main advantages of Particle Swarm Optimization algorithms are simple concept, easy implementation, relative robustness to control parameters and computational efficiency.
- The prominent merit of PSO is its fast convergence speed.
- PSO algorithm can be realized simply for less parameter adjusting.
- PSO can easily deal with non differentiable and non convex objective functions.
- PSO has the flexibility to control the balance between the global and local exploration of the search space.

B. Hybrid Optimization Model of Electric Renewable

Hybrid Optimization Model of Electric Renewable (HOMER) is a computer model that simplifies the task of evaluating design options for both off-grid and grid-connected power systems for remote, stand-alone, and distributed-generation (DG) applications. HOMER's optimization and sensitivity analysis algorithms allow one to evaluate the economic and technical feasibility of a large number of technology options and to account for variation in technology costs and energy resource availability for both conventional and renewable-energy technologies. HOMER models a power system's physical behavior and its life-cycle cost, which is the total cost of installing and operating the system over its life span. It allows the modeler to compare many different design options based on their technical and economic merits. It also assists in understanding and quantifying the effects of uncertainty or changes in the inputs [5].

As it is HOMER's aim to minimize the total net present cost (TNPC) both in finding the optimal system configuration and in operating the system, economics play a critical role in the simulation. The indicator is chosen to compare the life style costs (LCC) and the TNPC in the economic simulation.

This LCC is determined with the help of TNPC, which expresses all costs and proceeds occurring during the system life span in one total sum (in dollars). Future earnings are discounted back to the present using the discount rate, which is just as the system life span set by the designer [4].

4. EXPLANATION OF RESEARCH:

The proposed microgrid system consists of PV array and Diesel Generator as main power generating components, System converter, Battery Storage and electrical load. The Diesel generator in the system is used as a load follower. The system is simulated in such a way that there will be no electricity shortage to the consumer.

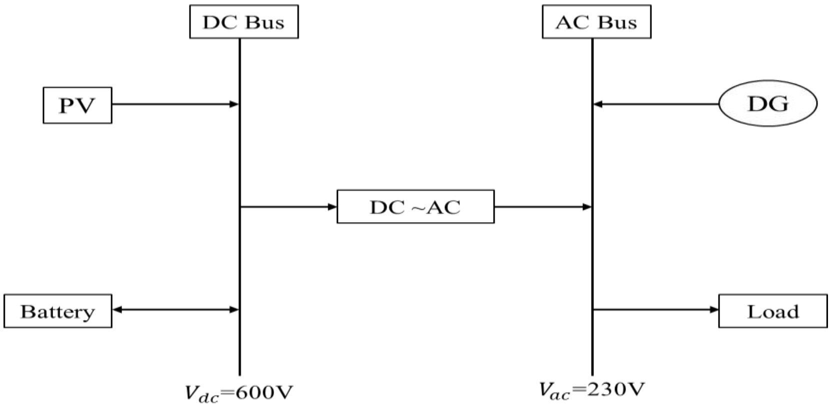

Figure 1. Block diagram of the proposed system

In this paper, the load demand of the buildings is collected and the islanded microgrid system is designed to supply the continuous power with the optimum cost for the office buildings which is situated in Hlaing Tharyar Township, Yangon division of Myanmar. It is located at latitude 16° 17' N and longitude 96° 97' E. According to the collected data, the daily energy consumption of the buildings is about 150kW. Fig 2 shows the daily profile of the buildings. At 1am to 8am and 6pm to 12am, the load demand is the lowest and then at 8am to 5pm, the load demand is the highest because the proposed area is the office building.

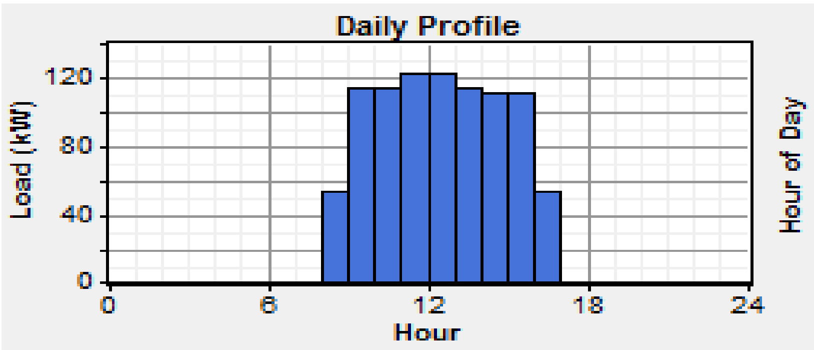

Figure 2. Daily load profile

April is the highest radiation month as in value of 6.45 kWh/m^2/day and August is the lowest radiation month for the case study area as in value of 3.23 kWh/m^2/day. The average annual solar radiation for Yangon is 4.698 kWh/m^2/day [6].

5. OPTIMIZATION RESULTS:

A. HOMER Simulation Results

HOMER performs 72 simulations in order to get the best optimum power system based on the optimization and sensitivity results. According to the results, proposed power system with 150kW PV arrays, 100 kW diesel generator, 750 batteries and 150kW inverter shows the best optimum configuration in technical and economical ways. The levelized cost of energy (LCOE) is 0.237 $/kWh that is the lowest price among 72 simulated systems and also the total net present cost is 688,823 $. The renewable energy fraction is 0.78. And, the liter of fuel usage is 34,669 L for the whole year.

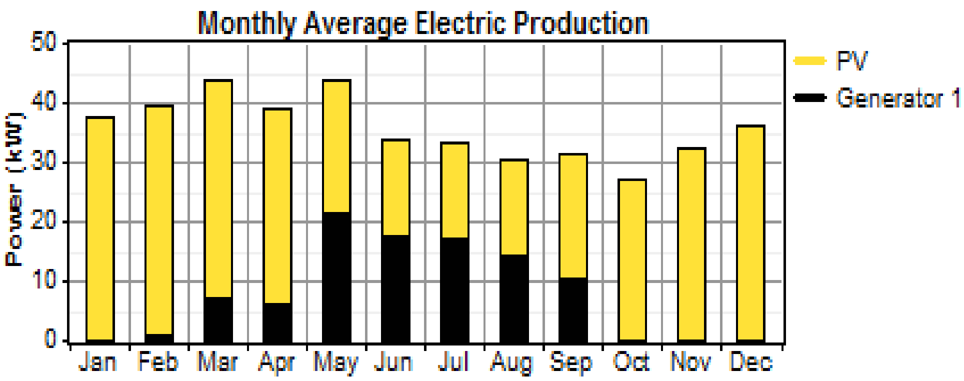

Figure 3. Monthly average electric production

The total energy production of the proposed system is 313,503kWh/yr and the required load demand is 227,760kWh/yr. therefore, the proposed system can provide enough power to the load with excess electricity of 50,922kWh/yr. And there is no capacity shortage by the use of the proposed hybrid system.

Table 2. System configuration and energy output of system components

Energy Production	***(kWh/yr)***	***(%)***
PV Array	243,244	78
Diesel Generator	70,259	22
Total Energy Production	313,503	100
Energy Consumption	(kWh/yr)	(%)
AC Primary Load	227,760	100
Excess Electircity	50,922	16.2
Unmet Electric Load	0.000903	0.0
Capacity Shortage	0.0	0.0

Table 3. Cost summary of the components in microgrid system

Component	***Capital ($)***	***Replacement ($)***	***O&M ($)***	***Fuel ($)***	***Salvage ($)***	***Total ($)***
PV Array	150,000	41,158	7,670	0	-23,067	175,761
Generator	16,667	21,455	9,110	221,592	-1,560	267,264
Battery	127,500	83,694	9,588	0	-24,028	196,754
Converter	40,000	11,849	3,835	0	-6,640	49,043
System	334,167	158,156	30,203	221,592	-55,295	688,823

B. PSO Simulation Results for the Proposed Microgird System

For the load profile, the daily load demand is approximately 626kWh/day. The input parameters are tabulate in Appendix B. The Particle Swarm Optimization (PSO) method is applied in order to obtain the best configuration of the system and for sizing the components. The Cost of Electricity (COE) and Loss of Power Supply Probability (LPSP) are defined as objective functions.

Table 4. Simulation results by using PSO

Station	***Microgrid System***
Number of Iterations	40
Number of particles	40
Power of PV panels (kW)	150
Power of diesel generator (kW)	100
LPSP (%)	0
COE ($/kWh)	0.205

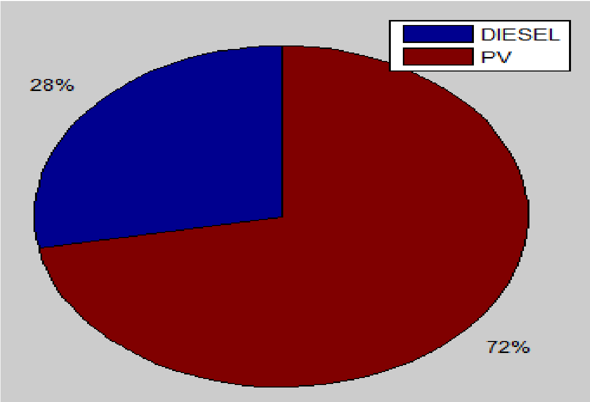

Figure 4. Percentage of energy provided by PV and diesel generator through a year

According to the results from PSO, the PV provides 72% of energy and the diesel generator supplies the 28% of the energy. It can be recommended that the system that is given by HOMER is more suitable than the system that is given by PSO when the environmental impacts are considered.

Table.5 Comparison Results of PSO and HOMER

	PV (kW)	Gen: (kW)	Batt: (kWh)	Con: (kW)	LPSP -	LCC ($)	COE ($/kWh)	Demand (kW)
PSO	150	100	2040	150	0	323,552.967	0.205	150
HOMER	150	100	2040	150	0	332,263.745	0.237	150

For PSO, Life Cycle Cost (LCC) = $ 323,552.967 (or) 44.0 billion kyats
For HOMER, Life Cycle Cost (LCC) = $ 332,263.745 (or) 45.2 billion kyats

6. CONCLUSION:

A cost optimized standalone microgrid system for office buildings at the Yangon division of Myanmar is proposed in this study. In this research, the islanded microgrid system including solar power, diesel generator and storage batteries is designed regarding to the levelized cost of energy. The simulation, sensitivity analysis and optimization of microgrid system have been performed by using HOMER software. In addition to, the Particle Swarm Optimization (PSO) is applied to compare with the simulation results of HOMER. The best optimum system of HOMER consists of 150 kW PV (78% of energy production) and 100kW diesel generator (22% of energy production) and its levelized cost of energy is 0.237 $ /kWh. According to the simulation results of PSO, LCOE is 0.205 $/kWh which is the most optimal cost in 40 iterations where the PV provides 72% of energy and the diesel generator also provides 28% of energy. According to the comparative results of HOMER and PSO, the PSO provides less LCC than that of HOMER. In conclusion, these two systems recommend that the use of renewable energy offers substantial environment credit, better reliability and lowest cost compared to conventional alternatives.

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