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Table of Content

Economic Aspect of Hybrid Renewable Energy System for Base Transceiver Station

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***Abstract*—Economic aspect of hybrid renewable energy system for Base Transceiver Station (BTS) in Indonesia is analyzed in this paper. This analysis is very useful to examine the feasibility of the hybrid renewable system, compare to existing power supply of utility or diesel generator. Firstly, the design for hybrid renewable energy system for on-grid and off-grid BTS is proposed, to be the basis for economic analysis. Economic analysis is conducted based on Levelized Cost of Energy (LCOE) and Life Cycle Cost (LCC). It can be shown that the resulted LCOE is still higher than utility charge, but much lower than diesel generator operation. Although hybrid renewable energy system has higher initial cost, but in the longtime span it has lower future cost.**

***Keywords*—renewable energy, base transceiver station, economic, LCOE, LCC**

I. Introduction

Indonesia as an archipelagic country located in equator has abundant source of renewable energy. Among many renewable energy sources, solar, wind, and biofuel are the most potential energy sources to be developed in Indonesia. Those renewable energy sources potentially to be utilized as alternative energy to reduce fossil-based energy source consumption[1].

The geographical nature of Indonesia also possess challenge that in many islands, the utility company must supply the electricity through small grid system based on diesel genset, not to mention many of the remote islands have not been reached by the electricity from the utility. Diesel generator utilization has consequences of higher electricity cost, while also suffers environmental impact from producing CO_2[2]. Renewable energy sources are very applicable to solve such situation.

Application of renewable energy sources to generate electricity for residential customer has been in progress for last several years, especially in the rural and remote areas of Indonesia. Apart from electricity, another basic needs for people nowadays is communication access. The telecommunication provider must construct base transceiver station (BTS) to expand the range of coverage to reach all people[3][4]. For rural and remote areas in Indonesia, this situation is more difficult because the electricity for powering the BTS is not always available from the utility. The current solution is by installing diesel genset for powering the BTS[5]. This solution has consequence that the telecommunication provider must pay higher electricity cost[6]. Higher energy cost will affect the total operation cost for providing telecommunication access for rural or remote areas, which eventually will slow down the expansion of range of coverage.

This paper proposes the application of hybrid renewable system for powering the BTS. Firstly, the existing power supply configuration of BTS is analysed. Then, basic design of the integration of the existing BTS system and the renewable energy source is shown. An economic assessment based on cumulative cost is conducted to evaluate the feasibility of the proposed system.

II. Power Supply Topology of Base Transceiver Station

In Indonesia, typically the power supply for BTS can be classified into two types, the on-grid BTS and off-grid BTS, depends on the availability of the supply from the utility.

A. On-Grid Base Transceiver Station

On-grid BTS has utility supply for powering the telecommunication equipment. However, the availability of the utility supply is not fully available to supply all the time in the rural or remote areas in Indonesia. To overcome this situation, it is common practice for telecommunication provider to install its own diesel generator as backup power. Automatic Transfer Switch (ATS) is used to change over between utility supply and the diesel generator.

The existing power supply configuration for on-grid BTS is shown in Fig. 1. Two main DC buses are used, 48VDC bus and 24VDC bus. Each bus has its own rectifier from the common ac bus provided either by utility or diesel generator. The batteries are also available for emergency backup, each bus has its own battery bank. Fig. 1(a) is typically is the most commonly found power topology of BTS, but some other topologies are also available which are 48VDC only bus (Fig. 1(b)), and 24 VDC only bus (Fig. 1(c)).

The authors have conducted survey and site visit to 8 sample of locations of on-grid BTS in remote areas in Indonesia. The typical existing power supply capacity are shown in Table 1. Existing BTS uses 20kVA power source for powering the telecommunication loads and charging the battery. Autonomy time provided by battery typically is very long, at least 9 hours of autonomy mode during utility and diesel generator are not available to supply.

B. Off-Grid Base Transceiver Station

Off-grid BTS does not have utility supply for powering the telecommunication equipment. Commonly, two redundant diesel generators are used to act as supply and backup interchangeably, connected by ATS to transfer the power. Fig. 2 shows typical power supply topology for off-grid BTS under study. Single DC bus of 48VDC is used for powering the equipment. The AC bus receives power from the diesel generator to supply the DC rectifier and AC loads.

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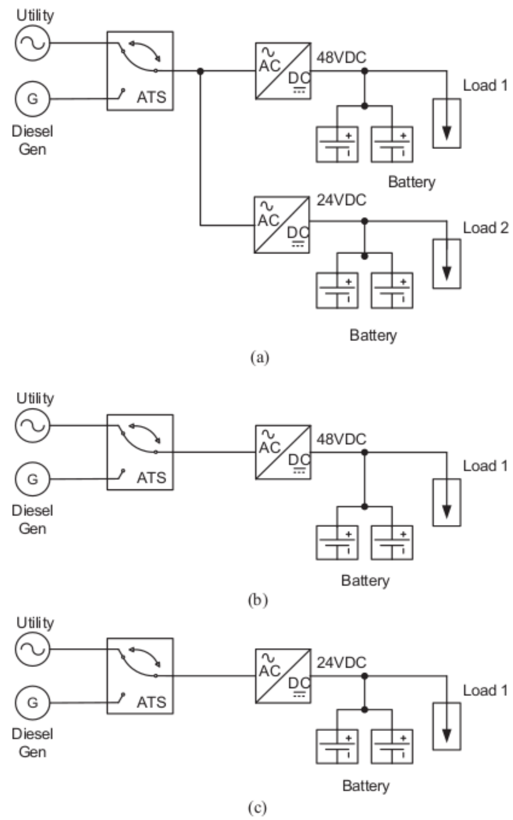


Fig. 1. Typical power supply topology of on-grid base transceiver station. (a) 48VDC and 24 VDC dual bus (b) 48VDC only bus (c) 24VDC only bus

Table 1. Typical existing power supply capacity of on-grid BTS in Indonesia

	Utility (kVA)	Diesel Gen (kVa)	Battery autonomy (hours)	Load (kW)
BTS A	20	20	12	6.5
BTS B	20	20	12	9
BTS C	20	20	24	4
BTS D	20	20	25	1.5
BTS E	20	20	17.5	5
BTS F	20	20	9	6
BTS G	20	20	12	7
BTS H	20	20	10	6

The authors also have conducted survey and site visit to 3 sample of locations of off-grid BTS in remote areas in Indonesia. The typical existing power supply capacity are shown in Table 2. Off-grid BTS has bigger load due to in the remote locations the non-equipment loads are dominant, for example the living support for the stand-by officer. Existing BTS uses larger diesel generators for powering the telecommunication loads and charging the battery. Autonomy

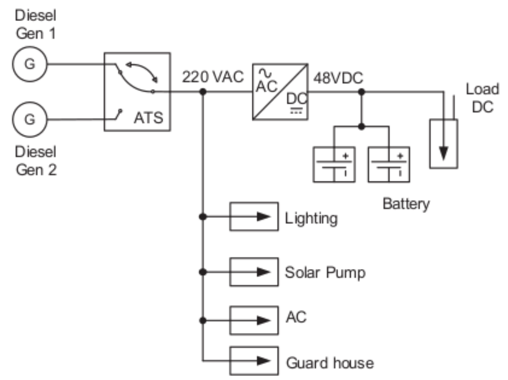


Fig. 2. Typical power supply topology of off-grid base transceiver station

Table 2. Typical existing power supply capacity of off-grid BTS in Indonesia

	Diesel Gen 1 (kVA)	Diesel Gen 2 (kVa)	Battery autonomy (hours)	Load (kW)
BTS I	35	35	4	11
BTS J	50	50	4	16
BTS K	30	30	4	11

time provided by battery typically is very small, only 4 hours of autonomy mode during both diesel generators are not available to supply.

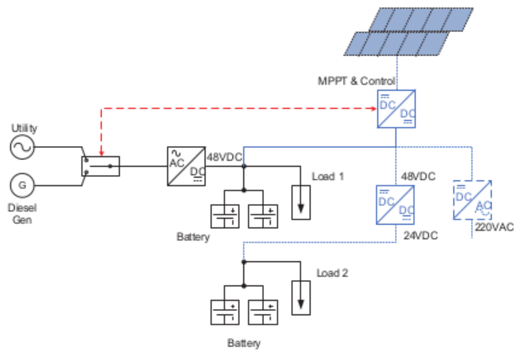
III. Hybrid Renewable Energy System for Base Transceiver Station

Integrating renewable energy source to the existing topology shown in Fig. 1 and 2 will reduce the fuel consumption of diesel generator. Solar energy is the potential source for rural and remote locations in Indonesia. However, space availability is the main factor on how much energy from solar can be harvested in BTS.

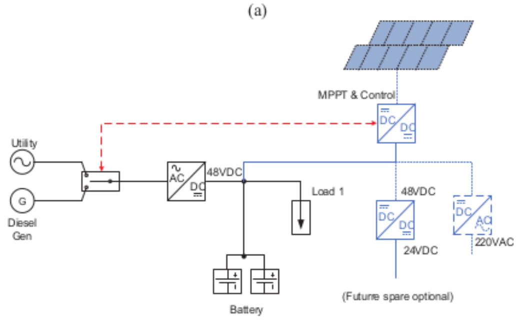
Table 3 shows the total space and the space available for implementing solar power in the vicinity of rural and remote BTS. Most of BTS under study has enough space to be implemented with solar power as hybrid renewable energy system. Based on the space availability and the BTS loading, the estimated PV capacity is shown in Table 5.

To implement hybrid renewable energy system by using solar power in BTS, it is desired to do minimal modification from the existing power supply topology. Fig. 3 and 4 show the proposed hybrid renewable energy system for BTS based on the existing topology as shown in Fig. 1 and 2.

In general, the proposed hybrid renewable energy system for BTS comprises of solar charge controller, a DC-DC converter which has maximum power point tracking feature. Solar charge controller converts the output voltage of photovoltaic (PV) panel to the DC bus voltage, either 48 VDC (as in Fig. 3(a) and (b)) or 24 VDC (as in Fig. 3(c)). Solar charge controller has function to send the generated power to the load and charge the battery. Solar charge controller is also able to send command for operating either utility supply or diesel generator in the case of on-grid BTS, or diesel generators in



(a)



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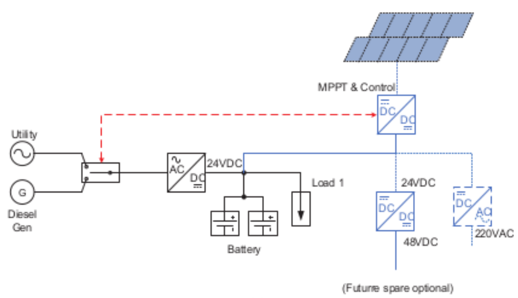

(c)

Fig. 3. Proposed hybrid renewable energy system for on-grid base transceiver station (a) 48VDC and 24 VDC dual bus (b) 48VDC only bus (c) 24VDC only bus

the case of off-grid BTS. The level of priority of the power supply is shown in Table 4 for on-grid and off-grid BTS. In the case of solar power is unavailable, utility power is prioritized instead of battery in the case of on-grid BTS. Since utility power is unavailable in the off-grid BTS, the priority level for battery is increased to supply the load in the case of solar power unavailable. In both on-grid and off-grid BTS, diesel generator has less priority due to high energy cost.

Dc-dc converter then is used to convert 48 VDC in the main bus to 24 VDC bus, therefore the existing 24 VDC rectifier is no longer required (as in Fig. 3(a)). An inverter is also required to convert 48 VDC to 220 VAC to supply local AC loads, if available. Similar concept is applied to implement hybrid renewable energy system to the off-grid BTS, as shown in Fig. 4. While the level of priority is also shown in Table 4.

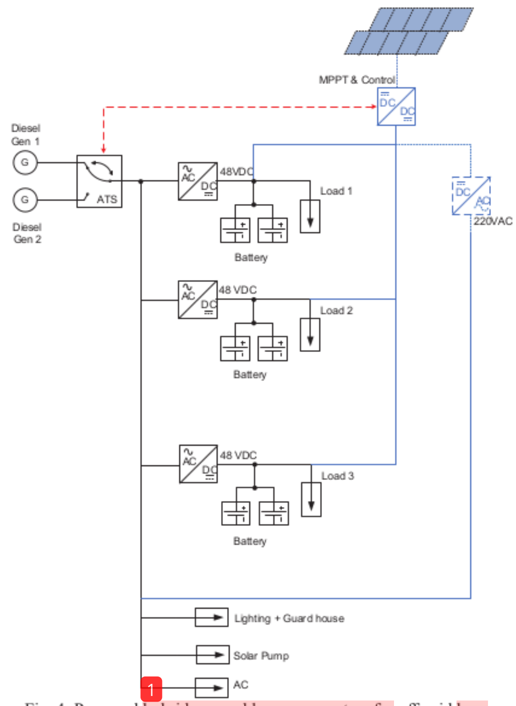

Fig. 4. Proposed hybrid renewable energy system for off-grid base transceiver station

Table 3. the total space and the space available for implementing solar power

	Total space (m2)	Available space (m2)	Available space (%)
BTS A	300	160	53
BTS B	300	150	50
BTS C	300	100	33
BTS D	300	112	37
BTS E	300	150	50
BTS F	300	150	50
BTS G	300	100	33
BTS H	300	150	50
BTS I	2572	974	38
BTS J	3060	1472	48
BTS K	2400	780	32

On-grid BTS is designed to keep the utility and diesel generator as the backup source, while install sufficient capacity of PV to be the main source. In this analysis, it is assumed that the equivalent sun hour (ESH) for the locations in Indonesia is 4 hours, to take into account the performance ratio of a PV plant. The availability of the utility in the remote areas in Indonesia is assumed only 12 hours per day in average. Therefore, the rest of the time must be supplied from the battery, while diesel generator is less prioritized due to the expensive fuel cost.

Table 4. Priority level of power supply

	On-grid BTS	Off-grid BTS
Level 1	Solar	Solar
Level 2	Utility	Battery
Level 3	Battery	Diesel Generator
Level 4	Diesel Generator	-

Table 5. Proposed design of hybrid renewable energy system for BTS

	Existing design	Proposal design	PV Capacity (kWp)	Battery autonomy (hours)
BTS A	Fig. 1a	Fig. 3a	21	9
BTS B	Fig. 1a	Fig. 3a	31	9
BTS C	Fig. 1a	Fig. 3a	14	9
BTS D	Fig. 1b	Fig. 3b	6	9
BTS E	Fig. 1c	Fig. 3c	17	9
BTS F	Fig. 1b	Fig. 3b	23	9
BTS G	Fig. 1a	Fig. 3a	24	9
BTS H	Fig. 1a	Fig. 3a	24	9
BTS I	Fig. 2	Fig. 4	60	20
BTS J	Fig. 2	Fig. 4	90	20
BTS K	Fig. 2	Fig. 4	60	20

Similar concept is applied for off-grid BTS, however since no utility available, the battery must be longer to cover the loads. Diesel generator is also less prioritized. Table Y shows the design proposal for each BTS under study. Based on the space availability and the BTS loading, the estimated PV capacity is also shown in Table 5.

IV. Economic Aspect of Hybrid Renewable Energy System for Base Transceiver Station

The ownership of the hybrid renewable energy system of BTS is owned by the telecommunication company itself, therefore no definitive energy price is set by the buyer. To adapt with this situation, two parameters of economic feasibility are used in this study, namely Levelized Cost of Energy (LCOE) and accumulation cost to predict the payback time.

A. *Levelized Cost of Energy*

Levelized Cost of Energy (LCOE) is a measure of lifetime cost of an energy plant divided by its energy production during the life span[7][8]. The LCOE calculates the present value of the total investment and operation cost over an assumed lifetime span. This approach allows the comparison of different technology or energy sources, even for unequal lifetime span, capital cost, risk, return. Simplified expression for calculating LCOE is shown in Eq. (1). Where I_t is the investment in year t, M is operation and maintenance cost in year t, F_t is the fuel expense in year t, E_t is electricity generation in year t, r is the discount rate, and n is the lifetime span of the project.

$$LCOE = \frac{\sum_{t=1}^{n} \frac{I_t + M_t + F_t}{(1+r)^t}}{\sum_{t=1}^{n} \frac{E_t}{(1+r)^t}} \quad (1)$$

LCOE analysis was run in all the BTS understudy based on the design shown in Table Y. Based on the current price, the assumptions for cost analysis for this study is shown in Tabel 6.

Fig. 5 shows the LCOE for on-grid BTS in comparison with the utility charge. The expected cost for hybrid renewable energy for BTS is in the range of 0.485 – 0.5 USD/kWh. Much higher than utility charge which cost only 0.1 USD/kWh. From the economic point of view, higher LCOE means the hybrid renewable energy system is not feasible for BTS. However, if we take into account the reliability of the utility supply that is not 100%, hybrid renewable energy system for BTS is an option that can be considered since the estimated LCOE will surely below the LCOE of diesel generator operation.

Fig. 6 shows the LCOE for off-grid BTS in comparison with LCOE of diesel generator operation. The LCOE for off-grid BTS by using hybrid renewable energy system is similar with the LCOE on-grid BTS. However, the expected cost is much lower than the LCOE based on diesel generator operation. In the case of off-grid BTS, the hybrid renewable energy system is potential solution from the economic point of view.

B. *Life Cycle Cost*

Life Cycle Cost (LCC) analysis is the approach to know the total cost of owning, operating, and maintaining a facility[9]. Different technology applied for a solution has a different combination of initial cost and future cost. This will bring difficulty in making consistent comparison between two or more solutions. LCC is preferred to evaluate different solutions with different initial and future cost. LCC considers the total cost of a solution by accumulating the discounted annual costs over its lifetime span.

Fig. 7 and 8 shows a case of life-cycle cost of hybrid renewable energy system for on-grid and off-grid BTS, respectively. These selected cases are representative since the size is relatively similar for on-grid or off-grid BTS. Since comparison with the utility will not produce competitive situation, in this study comparison with diesel generator operation is analysed under assumption that the reliability from utility supply is not fully available. The hybrid renewable energy system has higher initial cost, but less future cost, compare to the diesel generator operation. This analysis provides insight that in the long run, the hybrid renewable energy system uses less cost than diesel generator supply system. The long-term saving opportunity is the attractive

Table 6. Cost assumptions

	Cost Assumptions	
Fuel Price	1	USD/litre
Interest rate	12	%/year
PV Investment	8000	USD/kWp
Battery Investment	400	USD/kWh
Utility Charge	0.1	USD/kWh

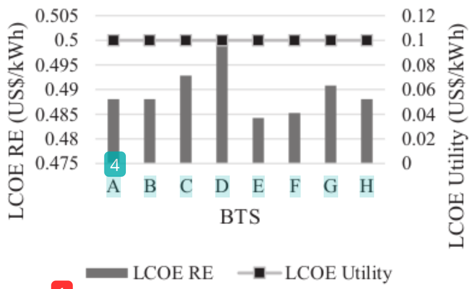

Fig. 5. LCOE of hybrid renewable energy system for on-grid BTS.

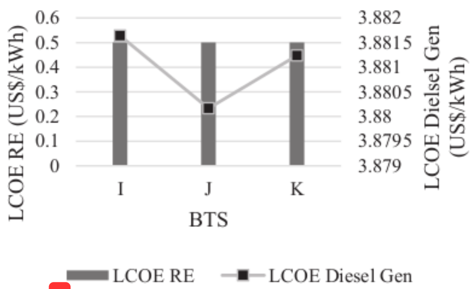

Fig. 6. LCOE of hybrid renewable energy system for off-grid BTS.

point for the provider, although it must invest to install hybrid renewable energy system in the beginning.

Simple payback time can be deduced based on the intersection between cumulative cost of hybrid renewable energy system and diesel generator operation. Fig. 9 and 10 shows the estimated simple payback time of the BTS understudy, both for on-grid and off-grid, respectively. To put into perspective, the capacity of PV for each BTS is also shown as the reference. Hybrid renewable system for on-grid BTS has simple payback time in the range of 6-11 years, while off-grid BTS has 20 years. These results are understandable since the capacity of PV installed in the off-grid BTS is larger than PV in on-grid BTS.

V. Conclusions

In this paper, economic analysis of hybrid renewable energy system for Base Transceiver Station is conducted. LCOE analysis show that hybrid renewable energy system of on-grid BTS has higher cost of energy compare to utility charge, but the risk of using costly diesel generator is exist due to the reliability of the utility supply. In contrast, LCOE of hybrid renewable energy system of off-grid BTS is much lower than LCOE of diesel generator operation. In the case of off-grid BTS, the hybrid renewable energy system is potential solution from the economic point of view. Life Cycle Cost analysis is used to obtain the total cost of the proposed hybrid renewable energy solution for BTS. In the lifetime span, hybrid renewable energy system uses less cost than diesel generator supply system.

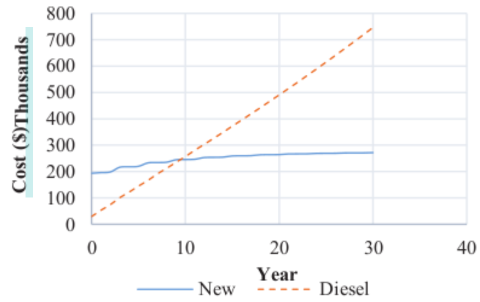

Fig. 7. Cumulative cost of on-grid BTS: Case BTS A

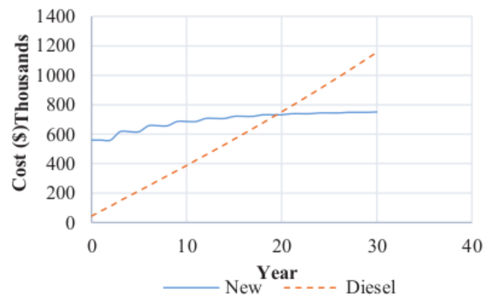

Fig. 8. Cumulative cost of off-grid BTS: Case BTS I

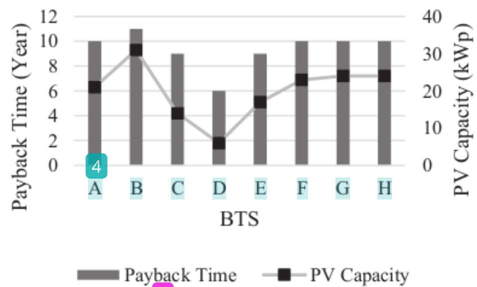

Fig. 9. Payback time for hybrid renewable energy system for on-grid BTS

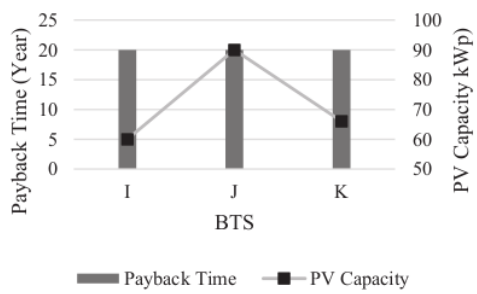

Fig. 10. Payback time for hybrid renewable energy system for off-grid BTS

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