ISBN 978-602-53531-8-5

Hybrid System Solution for Off-Grid and Rural Energy Access in Indonesia

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Abstract

Based on a recent study in 2016, there are still 12.659 underdeveloped villages or 16% of the total number of villages in Indonesia are still lacking in electric power from PT PLN (persero). To fulfill the electricity target in these villages, the government has issued the Program Indonesia Terang (PIT/Electrification Program). This program consists of efforts to extend the grid (for villages where PT PLN is present), install mini grid/off grid/hybrid systems, and implement solar home systems. It is hoped that this program will contribute to the penetration of renewable energy into the national energy mix to reach 25% in 2025. Regulation No. 38/2016 published by the Ministry of Energy and Mineral Resources (ESDM) titled ACCELERATION of ELECTRIFICATION IN UNDERDEVELOPED, SOLITARY, BORDER RURAL AREAS, AND INHABITED SMALL ISLAND THROUGH the BUSINESS OF PROVIDING A SMALL-SCALE POWER, outlines how to structure rural electrification projects.

In order to support these programs, an off-grid hybrid power system is a viable option, depending on the available resource at the project location. Whether a mix of one or more renewables with one or more non-renewable generators, a hybrid system is considered when it can achieve a higher cost-benefit compared with just using one generation independently. Existing hybrid power systems in Indonesia, including the Baron Technopark_Gunung Kidul Regency and Pantai Baru_ Bantul Regency are good examples of how an off-grid hybrid power plant can be constructed. Overall, this paper will assess the current trends in hybrid and off-grid electricity generation and determine why an off-grid hybrid system could be a better option compared to a single generation method.

Keywords: off grid, hybrid system, renewable energy, energy mix, rural energy

1. Introduction

1.1 Background Information on Electrification Ratio in Indonesia

Indonesia, a nation with more than 17,000 islands spanning 5,000 km is no stranger to issues in electrification. Having a coastline of more than 80,000 km, rural development in remote areas are impeded due to the degree of difficulty of interconnecting all the islands in the country into major electrical grids. Although smaller diesel powered systems are common in remote areas in the country, increasing oil price, along with major logistical problems are hindering villages to have full and reliable access to electricity. Solely responsible for providing electricity, including for customers in remote areas, is state-owned utility PT Perusahaan Listrik Negara (Persero)/ (PT PLN) along with ongoing support from the Ministry of Energy and Mineral Resources (MEMR).

According to data provided by the Directorate General of Electricity of the MEMR in the Book of Electricity Statistics No. 29/2016 (Directorate General of Electricity, 2016), the total electrification ratio in Indonesia is approximately 88%. The remaining 12% non-electrified households account for approximately 12,659 villages. Fortunately, over the past few years, electrification of remote areas in the country has been a key focus of the national electrical utility company, PLN, and the Ministry of Energy and Mineral Resources. The following figure below, taken from the Directorate General of Electricity of the MEMR, shows the increase in electrification in Indonesia, following the efforts by PLN and MEMR.

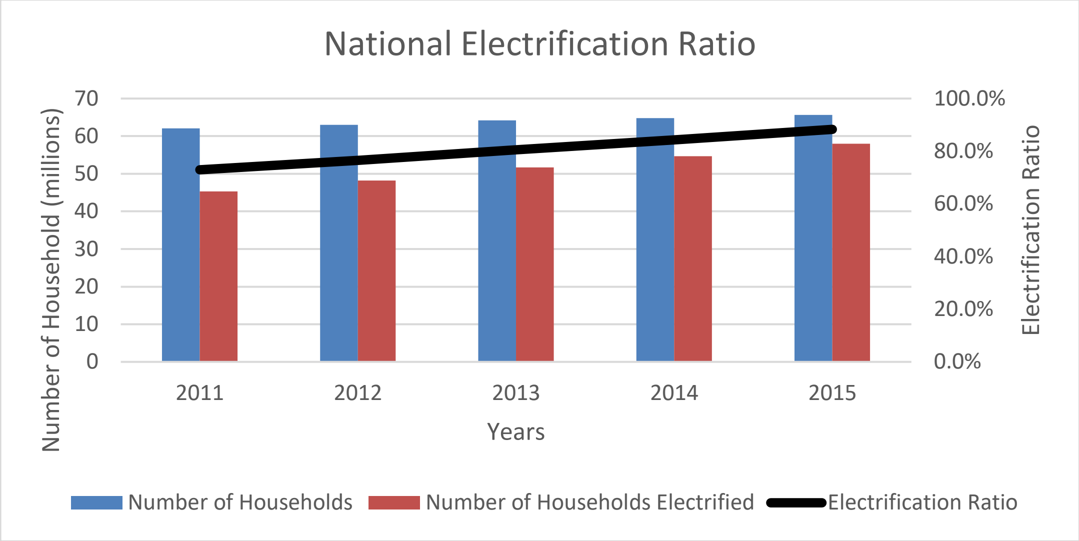

Fig. 1: National Electrification Ratio Graph (Source: Directorate General of Electricity, MEMR, 2016)

As seen from Figure 1 above, there is significant effort from PLN and MEMR to drive remote electrification programs. Recently, due to the difficulty of providing non-renewable electricity in remote regions, PLN and MEMR has turned their attention towards more sustainable and renewable energy solutions. Due to the rapid maturity of renewable energy technology, along with the steep decrease in costs, programs conducted by both PLN and the MEMR have provided facilities for stakeholders to go hand-in-hand to develop a cheaper, cleaner energy access for the country.

1.2. Existing Policy Support for Rural Electrification

As a sign of commitment to provide electricity to rural areas of the country, and to integrate more renewable energy into the electricity system, the MEMR launched a rural electrification program in April 2016, targeted specifically to eastern Indonesian regions where electricity access is usually much more difficult to find. Formally titled the Electrification Program (Program Indonesia Terang, PIT), is a part of the country's ambitious 35,000 MW program to fulfill the rapidly growing electricity demand in the country. This program has the vision of increasing the national electrification ratio from 88% in 2015 to 97% in 2019 via off-grid or mini-grid solar and micro-hydro power plants with a total capacity of approximately 9.4 MW to electrify 12,659 villages untouched by PT PLN, (Ministry of Energy and Mineral resources, 2016).

The following Table 1 below outlines the six provinces in Eastern Indonesia which are considered to be the main targets of this program, along with their expected total installed capacity and the budget the MEMR has allocated for each region.

Table 1: Provinces targeted by the PIT (Source: MEMR, 2016)

Province	Total Capacity (MW)	Budget (Rp Milllion)
Papua	5,4	198,9
West Papua	3,3	91,8
Maluku	0,3	42,8
North Maluku	0,1	11,1
East Nusa Tenggara	1,1	77,2
West Nusa Tenggara	0,3	19,2

Furthermore, in support of providing clean electricity for remote areas, in 2016, the MEMR has recently released a Minister Regulation (Peraturan Menteri) ESDM No. 38 year 2016, titled Acceleration of Electrification in Underdeveloped, Solitary, Border Rural Areas, And Inhabited Small Island through the Business of Providing a Small-Scale Power Plant, which outlines how to structure rural electrification projects.

Governing projects of up to 50MW for underdeveloped villages to small islands, MEMR Minister Regulation No. 38/2016 states that for rural electrification projects, whether developed by a regional government body, a private entity, or a local union, must first prioritize local and readily available renewable energy resources ahead of non-renewable fuels. Upon getting approval from the Minister of Energy and Mineral Resources, the project owner might also be eligible for subsidy on the electricity price. The following equation outlines the amount of subsidy that can be provided by the government.

$$S = -(TTL - BPP(1 + M)) \times V \quad (1)$$

Where:

- S = Subsidy (Rp)
- TTL = PLN Electricity tariff for households rated at 450VA (Rp/kWh)
- BPP = Cost of electricity generation locally (Rp/kWh)
- M = Margin (%)
- V = Volume of electrical energy usage per connection per month (kWh/month). This is limited to a maximum of 84 kWh per connection per month.

On the other hand, projects which are not eligible for subsidies will have the electricity selling price determined by the Minister or the local governor, in accordance with the prevailing laws.

2. Hybrid System and its Applications

A hybrid power system is defined by PLN as a system with two or more power generation sources, either renewable or non-renewable sources or a combination of both. A system with only one generation source and a storage is not considered a hybrid. There are various ways of configuring a hybrid power system, depending on a lot of external factors that are usually making the project more feasible by going hybrid, such as: cost considerations, geographical considerations, fuel or resource availability, etc. A hybrid system can consist of a combination of solar, wind or hydro power in conjunction with diesel and even may or may not be coupled with energy storage systems, such as batteries. Figure 2 below is an example of a wind-PV-diesel hybrid configuration.

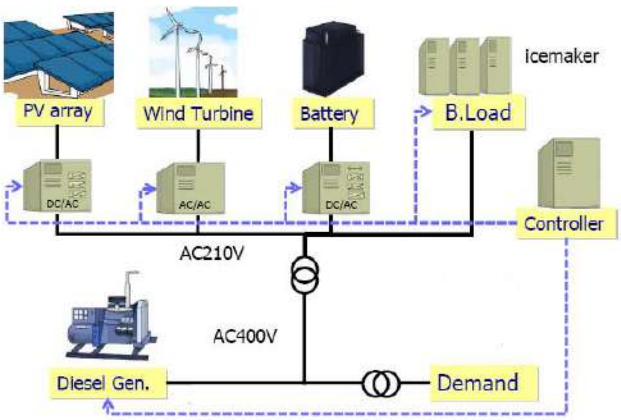

Fig. 2: Simple wind-PV-Diesel Hybrid Configuration diagram

Benefits of a Hybrid System

A hybrid system is usually implemented to reduce the weakness of its individual power source which is being offset by the other power sources. For example, an intermittent but renewable power source (e.g. solar PV) can have its intermittency offset by a stable but non-renewable power source (e.g. diesel). The high and fluctuating cost of diesel, especially in remote locations, can be compensated on certain periods of time using readily available sunlight through solar PV technology. However, for periods that solar PV are unable to operate, such as at night or when there is minimum sunlight, the diesel can take over and provide reliable electricity to the demand.

For illustration purposes, the following Figure 3 shows an example of a 4 kWh/day household's electricity demand being met by a hybrid system consisting of a solar PV system and a diesel generator. During the night, where the peak load is reached, the solar PV is not operational so the diesel will provide all the electricity needed for the house. In this example, a 130Wp PV system can reduce approximately 22% of the electricity consumed from a 300W diesel system during the day when the sun is shining. This 22% of electricity generation from diesel reduced is linearly correlated to the price of electricity that is charged to the house, hence when the price of diesel increase, the benefit in using a hybrid system with the solar PV will be much more apparent.

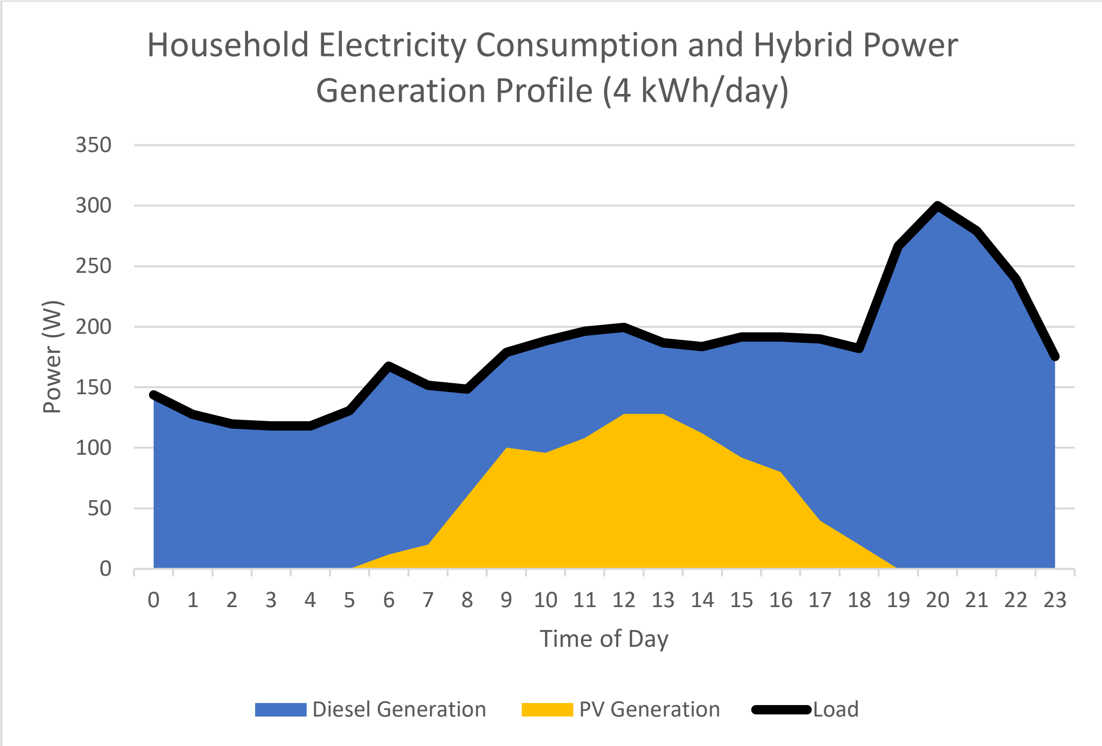

Fig. 3: 4kWh/day Household Electricity Consumption and Hybrid Power Generation (example)

Off-Grid Hybrid System

Due to the reliability and accessibility of hybrid power systems, it is usually more suitable for off-grid remote electrification systems without electricity access from PLN compared to its individual components separately. For an off-grid system, a base load power source is usually very much needed. An already relatively stable renewable energy source, like a hydro or geothermal powered system, which can be turned on and off as needed, is typically sufficient to provide electricity for an off-grid load, depending on resource. However, for systems like hydro and geothermal, resources are much more location dependent, unlike intermittent but more readily-available solar or wind, which may be inaccessible for remote villages.

To determine the most suitable mix for an off-grid hybrid system, it is important to also perform an economic analysis of the model by comparing the cost of each technology on per kWh generated basis. The Levelized Cost of Electricity (LCOE) is a common term of assessing the cost-benefit of different generation sources and their combinations. According to a study conducted in 2013 (Blum et al, 2013), a hybrid system for an Indonesian village grid is a more cost-efficient system compared with a solar PV coupled with a battery system, or a stand-alone conventional diesel system. The study assesses two scenarios; Scenario A, is a basic scenario, whereby electricity is demanded only at night time and zero electricity is needed during the day, therefore making PV obsolete. Scenario B, is a more advanced scenario where power generation is smoother during the day due to small commercial activities and the system never reduces to an idle state, although higher demand from the household sector is still the peak during night time. The following Figure 4 shows the LCOE for the different system configurations for both scenarios.

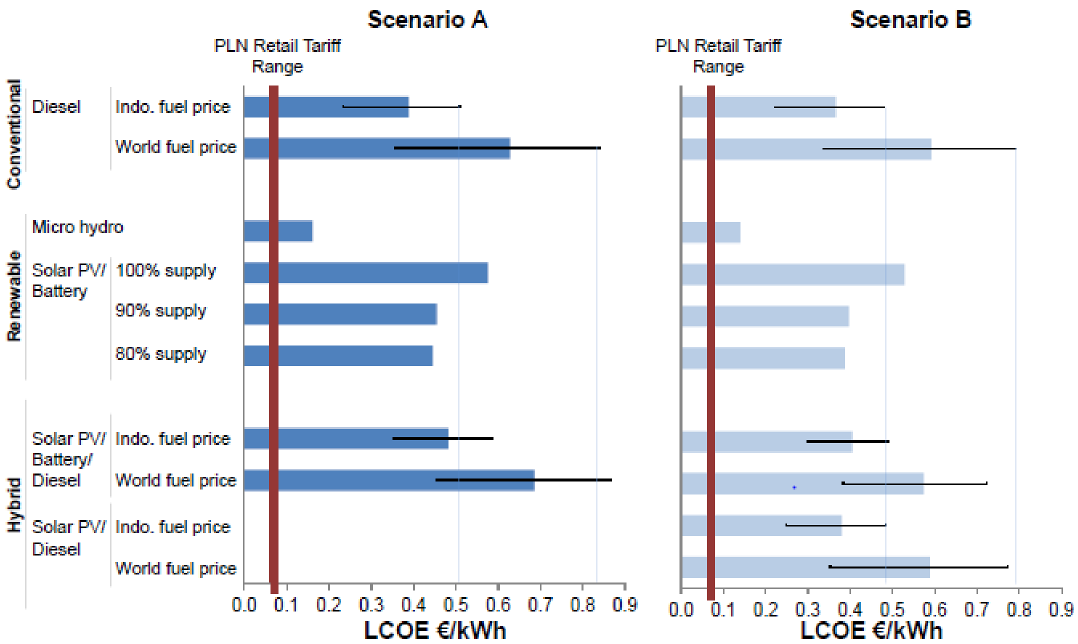

Fig. 4: LCOE of different renewable energy technologies (Source: Blum et al, 2013)

Hybrid Resource Maps in Indonesia

As mentioned in the previous section, determining the available renewable energy resource at the proximity of the location is critical in determining the viability of possible combinations of hybrid systems. In spirit of MEMR Minister Regulation No. 38/2016 above, assessment of the available renewable energy resource in a specific location must first be done. For renewable energy sources, such as wind and solar, there are already maps available publicly online based on satellite measurements, which can be used for preliminary project prospecting. For wind power generation, the MEMR has worked together with the Danish aid agency Danida to create an online portal for available wind data throughout the country on a 3x3 grid. This can be accessed through the following link: http://indonesia.windprospecting.com/. There are also various solar resource maps available online for free which covers Indonesia. Companies, such as SolarGIS (https://solargis.info/) provides high resolution solar data on their online global atlas. The International Renewable Energy Agency (IRENA) has also published an online wind and solar atlas for Indonesia, which can be accessed from the following link; https://irena.masdar.ac.ae/gallery/. During project prospecting phase, it is critical to identify the available resources at the specific site and whether access to harness these sources is possible.

3. Existing Hybrid Power Plants in Indonesia

Hybrid System in Baron Technopark – Gunung Kidul Regency

Indonesia has established a number of pilot off-grid small-scale hybrid power plants in Indonesia. Mostly developed, constructed and operated by the Agency for Assessment and Application of Technology (Badan Pengkajian dan Penerapan Teknologi, BPPT) and its extensions, the hybrid power plants (Pembangkit Listrik Tenaga Hibrid, PLTH) are scattered throughout the country, both in remote areas and in places where there is enough resources.

One project that was successfully developed by BPPT and is still operational up to today is the Baron Technopark Hybrid Power Plant located on Baron beach in Jogjakarta. Originally constructed in 2010 together with the Norwegian Agency for Development Cooperation (NORAD), Baron Technopark has been a long-standing showcase on the implementation of hybrid power plants in Indonesia. The power plant generates electricity using a combination of 36 kWp mono-crystalline PV modules produced by PT LEN Industri and 2 wind turbines, rated at 10 kW and 5 kW. These two intermittent sources are then used to power the loads in the vicinity of the power plant along with a battery bank with a total capacity of 1000Ah that can supply 240 kWh/day and a 25kVA diesel generator (Badan Pengkajian dan Penerapan Teknologi. BPPT, 2010). The following diagram in Figure 5 dan Figure 6 shows the single line diagram and photograph for this hybrid power plant and the flow of energy through its components.

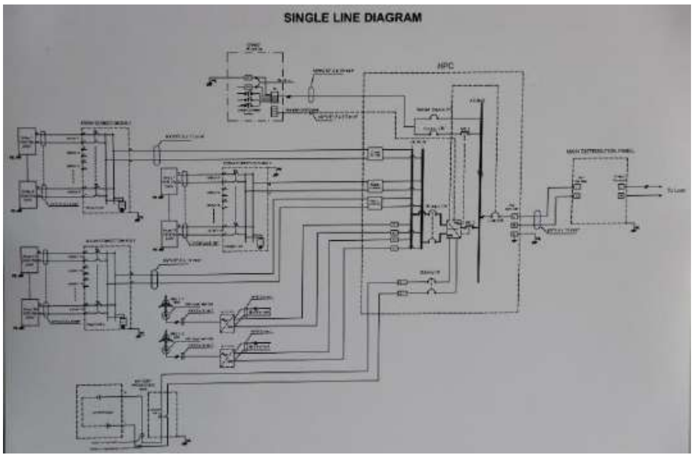

Fig. 5: Single line diagram for Baron Technopark (Source: BPPT, 2013)

Fig. 6: Baron Technopark, wind-PV-Diesel (Source: Soeripno)

Hybrid System in Pantai Baru Bantul Regency

A wind-PV-battery hybrid system in Pantai Baru – Pandansimo, Bantul was constructed by the Ministry of Research and Technology (Kementrian Riset dan Teknologi) of Indonesia supported by the Indonesian National Institute of Aeronautics and Space (Lembaga Penerbangan dan Antariksa Nasional, LAPAN), BPPT, the Ministry of Marine Affairs and Fisheries (Kementrian Kelautan dan Perikanan Indonesia) and the local Bantul government. The project was initiated in an effort to utilize the energy resource available in the region to increase the livelihood of the local community and as a hybrid power plant showcase for coastal areas. The Pantai Baru hybrid power plant supplies electricity to local farmers and fishermen also to a nearby icemaking plant, which supplies ice to local fishermen, eateries, and irrigation for farms and fisheries.

The hybrid power plant is a combination of two renewable power generation sources, wind power and solar power, totaling a rated capacity of 77.5 kW. The electricity produced by the hybrid power plant is used to operate the ice making machine, water pumps, blowers, street lighting, electronic equipment, etc. Aside from the availability of both the wind and solar resource at the site, the hybrid power plant, the hybrid power plant is equipped with an energy storage system and a hybrid control system. The wind turbine used in the wind farm consists of several types of small wind turbines: 21 x 1 kW, 6 x 2,5 kW dan 2x 10 kW, The solar part of the plant consists of 100 Wp solar panels with a total capacity of 15 kWp. Figure 7 shown the part of hybrid system plant in Pantai Baru

Fig. 7: Pantai Baru hybrid system of Wind-PV-Diesel for ice making (Source: Soeripno)

4. Challenges and Opportunities in Hybrid Power Development

The Baron Technopark pilot project, among other hybrid projects in Indonesia are meant to be a guideline for all stakeholders involved in the power generation industry. However, many of these pilot projects are not performing for as long as it was initially thought to be. There are various learning points from the operations of these hybrid plants over the past few years. These include:

- Operation and maintenance is critical to ensure the longevity of hybrid power plants. Since most off-grid hybrid power plants are projects done by international aid organizations, there are budgetary issues for keeping the plants running
- Capacity building. Due to the remote locations of these power plants and the complexity of combining different types of power generation, local expertise is scarce.
- Spare parts for replacement. Hybrid power plants, especially those utilizing batteries need parts replacement every several years. Shortage of spare parts in rural areas are becoming a hindrance to the operation of hybrid power plants

Nonetheless, there is still room for growth for hybrid power plants in Indonesia, especially with the recent regulations and government programs which incentivizes the development of off-grid hybrid power plants in Indonesia for rural electrification. From an economic point of view, hybrid systems are becoming much more attractive now with the rapid reduction in costs of generating renewable energy and energy storage in the past few years. From a technical point of view, with all the available resource maps and existing hybrid power plants that are operational, it is now easier than ever to develop off-grid hybrid power plants for remote electrification.

5. Conclusion

Off-grid hybrid power plants are now very viable options due to recent techno-economic trends in the renewable energy industry in Indonesia. Along with regulatory support from the Government, off-grid hybrid power plants are expected to penetrate regions untouched by PLN in order to push development in remote regions. However, it is recommended that operation and maintenance of these power plants are to be performed rigorously to prevent unwanted breakdowns.

Usually, off-grid hybrid power plants are located in remote areas with difficult access and low electricity load demand. Due to these challenges, hybrid systems are typically not economically viable as a venture and can be constructed together with support from the Government together with ministries such as the Ministry of Villages, Disadvantaged Regions and Transmigration (Kementrian Desa, Pembangunan Daerah Tertinggal dan Transmigrasi), or the Ministry of Marine Affairs and Fisheries. Without support from the Government, off-grid hybrid power systems will have difficulties in penetrating the commercial market.

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