Optimization of the Belinyu solar power plant to reduce emissions of waste gas in diesel power plant

E M Siregar
PT PLN (Persero) UIW Bangka Belitung, Indonesia

E-mail: vancoenregar@gmail.com

Abstract. The operation of a diesel power plant not only improves reliability but also has an impact on the environment in the Belinyu sub-district. The purpose of this PLTD development is to meet the increasing electricity demand. Environmental aspects in the construction of this PLTD include exhaust gas emission factors which are pivotal to notice. Meanwhile, this low emission power plant located next to the diesel power plant has not yet had an optimal operating pattern because there is no energy storage system. By optimizing the design of the solar power plant and optimization the operating pattern of the diesel power plant, it has the potential to reduce the operating hours of the diesel power plant engine as well as the potential to reduce exhaust gas emissions in the amount of 0.0060264 mn tons CO$_2$/year.

1. Introduction
The Belinyu-solar power plant with an installed capacity of 1 MWp operated in 2013 which is assistance from the Directorate General of Renewable Energy and Energy Conservation (Ministry of Energy and Mineral Resources) to accommodate the addition of the New Renewable Energy mix in the Province of Bangka Belitung - Indonesia. Over time, because the operating pattern of the Belinyu solar power plant is considered not optimal, PLN UIW Bangka Belitung built a diesel power plant located next to the solar power plant. The construction of this diesel power plant at the same time responds to the increasing demand for electricity and optimizing the drop voltage in Belinyu Sub-district, Bangka Induk Regency. Besides the hope to improve the reliability of the electricity system, the construction of a diesel power plant also creates environmental problems [1-6]. Environmental problems here are related to exhaust gases resulting from burning fossil fuels to generate electricity. PLN UIW Bangka Belitung through its business unit, the Babel Generation Unit, has made efforts that are deemed necessary to minimize the environmental effects of this exhaust gas by applicable regulations. One of these efforts is to carry out routine exhaust gas testing which is regulated in the operating standard of a diesel power plant. In addition, optimizing the pattern of operation and maintenance of the engine is an important thing to do to keep this diesel power plant operating under environmental rules and regulations [7-13].

This article discusses the optimization of the operating pattern of the Belinyu solar power plant to reduce the exhaust gas produced by the diesel power plant. With this approach, it is hoped that it will reduce the operating hours of the diesel power plant engine as well as have a positive impact on the environment.
2. Method
The method used to improve the exhaust gas effect is carried out in several steps, namely data collection, system modelling, and providing selected scenarios that can be used as the basis for determining environmentally friendly operating patterns as the result of this journal.

3. Results and Discussion

3.1. Data of Belinyu diesel power plant
The exhaust gas test data on the Belinyu diesel power plant engine used is the test data in April 2020. The data for the diesel power plant exhaust gas test is shown in Table 1, as follows:

| Engine | Capacity (kVA) | NOx | SO2 | Partikulat | CO |
|--------|---------------|-----|-----|------------|----|
| Cum#1  | 1200          | 987.2 | 78.1 | 19.8 | 180.0 |
| Cum#2  | 1200          | 942.8 | 81.0 | 23.6 | 174.2 |
| Cum#3  | 1200          | 1004.4 | 94.8 | 39.7 | 185.5 |
| Cum#4  | 1200          | 1012.7 | 119.1 | 26.1 | 214.8 |
| Cum#5  | 1200          | 990.3 | 96.8 | 20.7 | 203.9 |
| Cum#6  | 1200          | 1012.3 | 115.7 | 26.4 | 142.9 |

In addition to the exhaust gas test results for the Belinyu diesel power plant, emission factor data is also used as a basis for comparisons related to solar power plant activities. The value of Indonesia's emission factor on Bangka Island is assessed at 0.93 tons CO\textsubscript{2} / MWh.

3.2. Data of Belinyu solar power plant
After the data related to exhaust emissions and emission factors, to calculate the system modeling, data on the Belinyu power plant specifications are needed which are shown in Table 2 as follows:

| Description | Explanation |
|-------------|-------------|
| Brand       | Isolar-1    |
| Type        | SPU-180M (monocrystalline) |
| Maximum Power (Pmax) | 200 Wp |
| Maximum Power Voltage (Vmp) | 38.7 V |
| Maximum Power Current (Imp) | 5.17 A |
| Open circuit voltage (Voc) | 45.9 V |
| Short circuit current (Isc) | 5.5 A |
| Efficiency | 16 % |
| Dimensions (mm) | 1580 x 808 x 35 |
| Operating temperature | -40\(^\circ\) C – 85\(^\circ\) C |
| Maximum system voltage | 1000 V |
| Maximum rated current series | 10 A |
| Power tolerance | ± 3 % |

To make a system model, some prominent data is needed, including the operating characteristics of the solar panel and inverter module. The characteristics of the solar panel and inverter module are shown in the following figure (Figure 1 and 2).
The solar module is installed in 5 groups where the specifications for each group are shown in Table 3.

**Table 3. Belinyu solar power plant grouping**

| Grup | Materials | Power (Wp) |
|------|-----------|------------|
| A    | 1 inc M V Cell (250 kVA) | 10 | 60 | 1080 | 216,000 |
| B    | 1 inc M V Cell (250 kVA) | 10 | 60 | 1080 | 216,000 |
| C    | 1 inc M V Cell (250 kVA) | 10 | 58 | 1044 | 208,800 |
| D    | 1 inc M V Cell (250 kVA) | 10 | 50 | 900  | 180,000 |
| E    | 1 inc M V Cell (250 kVA) | 10 | 50 | 900  | 180,000 |

3.3. System Modelling

For data uniformity and to facilitate analysis, the electrical system data used for modeling is the electrical system data in April 2020. The modeling approach for the Belinyu solar power plant uses ETAP 12.6 software. The electricity data in the Belinyu sub-district in April 2020 is shown in Table 4.

**Table 4. Belinyu electricity data (April 2020)**

| Source               | Feeder       | Average Load |
|----------------------|--------------|--------------|
|                      |              | Current (amper) | Power (MVA) |
| Sungailiat Substation| Gn. Muda     | 84.55         | 2.9          |
| Kelapa Substation    | Pangkal Niur | 40.33         | 1.4          |
| Belinyu Diesel PP    | Penyusuk     | 23.60         | 0.8          |
|                      | Jalan Baru   | 35.70         | 1.2          |
|                      | Bintet       | 55.00         | 1.9          |

The modeling of the Belinyu sub-district system is shown in Figure 3.
From the summary of data collection and modeling, a system condition approach is obtained where the Sungailiat substation, Kelapa substation, and Belinyu diesel power plant are in an on-grid position to supply feeders. From a reliability point of view, this pattern is already good, but from an environmental point of view, the Belinyu diesel power plant operates at full load, producing electricity at the same time and contributing to exhaust emissions.

From historical data, the Belinyu solar power plant can produce electricity of 200 kWp (on-grid), with a capable power range of 200 kW–750 kW. This capable power range is quite large because it is influenced by fluctuations in the intensity of sunlight. With the addition of BESS (battery energy storage system; Table 5), the Belinyu solar power plant can save energy as optimally as possible and during night conditions it can help reduce the operation of the diesel power plant. The expected load of the Belinyu solar power plant is 20% of the installed capacity. This is related to the lifetime of the equipment and the average intensity of the sun in the Belinyu District. With a total load of 200 kW, the BESS requirements are:

| Grup | Komponen inverter | Battery (Ah) |
|------|-------------------|--------------|
| A    |                   | 24000        |
| B    |                   | 24000        |
| C    |                   | 24000        |
| D    |                   | 24000        |
| E    |                   | 24000        |

From the evaluation results, the most optimal operating pattern can be selected for reliability and reduce environmental impact, namely Sungailiat substation on, Kelapa substation on, the solar power plant on, and diesel-power plants operating with 4 engines (2 engines off). In addition, the bus voltage which is still within the tolerance limit strengthens the reason why this scenario was chosen. Belinyu electrical operation scenario is shown in the Table 6.

From the change in the operating pattern of the Belinyu diesel power plant, which originally operated 6 engines to 4 engines, it has the potential to reduce exhaust emissions. The potential for reducing exhaust emissions can refer to the data from the Belinyu diesel power plant Exhaust Gas Test Results. Referring to Table 1, the recommended engines not to operate are Cummin#4 and Cummin#5 where these two engines have the worst test results, among all machines.

Assuming the annual generating capacity of the solar power plant is 6.48 GWh (200 kW/day electricity production for 180 days a year and 18 percent efficiency), and the emission factor of Bangka
Island is 0.93 tons CO$_2$/MWh, the potential to reduce exhaust gas emissions is 0.0060264 mn tons CO$_2$ /year.

Table 6. Belinyu operation scenario

| Source      | All Opr. | SLT Off | KLP Off | Diesel PP | Solar PP |
|-------------|----------|---------|---------|-----------|----------|
|             | 5 en. Off | 4 en. Off | 3 en. Off | 2 en. Off | 1 en. Off |
| Sungailiat  | 2.7      | 0       | 2.7     | 3.2       | 3        |
| Kelapa      | 1.5      | 1.5     | 0       | 2.2       | 1.9      |
| Diesel PP   | 2.4      | 2.4     | 2.4     | 1.2       | 1.8      |
| Solar PP    | 0.2      | 0.2     | 0.2     | 0.2       | 0.2      |
| Load        | 6.8      | 4.1     | 5.3     | 6.8       | 6.9      |
| Bus Voltage | 19.68    | 19.66   | 19.66   | 18.76     | 19.21    |

4. Conclusion
The optimization of the Belinyu solar power plant can reduce exhaust gas emissions. By optimizing the design of the solar power plant and optimization the operating pattern of the diesel power plant, it has the potential to reduce exhaust emissions by 0.0060264 mn tons CO$_2$ /year.

References
[1] Aprilianti K P, Baghta N A, Aryani D R, Jufri F H, and Utomo A R 2020 Potential assessment of solar power plant: A case study of a small island in Eastern Indonesia IOP Conf. Ser.: Earth Environ. Sci. 599 012026
[2] Baghta N A, Aprilianti K P, Aryani D R, Jufri F H, and Utomo A R 2020 Optimization of Battery Energy Storage System (BESS) sizing for solar power plant at remote area IOP Conf. Ser.: Earth Environ. Sci. 599 012030
[3] Bangun G M, Nabila N, Budiansyah M A, Alvianingsih G, and Utomo A R 2020 Study of Battery Sizing for Solar Power Plant IOP Conf. Ser.: Earth Environ. Sci. 353 012004
[4] Dawood F, Shafiullah G M, and Anda M 2020 Stand-Alone Microgrid with 100% Renewable Energy: A Case Study with Hybrid Solar PV-Battery-Hydrogen Sustainability 12 2047
[5] Kevin, Noor V P, Jufri F H, Naradhipa A M and Utomo A R 2020 Optimization and comparative analysis for a stand-alone hybrid model of PV, wind turbine, and natural gas generator system in remote area – A case study in Belu IOP Conf. Ser.: Earth Environ. Sci. 599 012028
[6] Nugroho O V, Pramono N F, Hanafi M P, Husnayain F and Utomo A R 2020 Techno-economic analysis of hybrid Diesel-PV-Battery system and hybrid Diesel-PV-Wind-Battery system in Eastern Indonesia IOP Conf. Ser.: Earth Environ. Sci. 599 012031
[7] PT Indoelectric Instruments 2013 Belinyu Solar Power Plant Technical Specifications
[8] PT PLN (Persero) 2018 Data on the Value of Greenhouse Gas Emission Factors in the Electricity System
[9] PT PLN (Persero) 2020 Certificate of Exhaust Emission Test Result for Belinyu diesel power plant
[10] Renaldhy Z R, Hutajulu A R, Husnayain F, Aryani D R, and Utomo A R 2020 Dynamic simulation of a hybrid PV/Wind/Diesel system using power factory IOP Conf. Ser.: Earth Environ. Sci. 599 012036
[11] Soefian W, Azka R, Jufri F H, Aryani D R, and Utomo A R 2020 Study of power flow and stability for a hybrid diesel-PV power system in Indonesia IOP Conf. Ser.: Earth Environ. Sci. 599 01203
[12] Sufyan M, Rahim N A, Aman M M, Tan C K, and Raihan S R S 2019 Sizing and applications of battery energy storage technologies in smart grid system: A review Journal of Renewable and Sustainable Energy 11 014105
[13] Tsany F N, Widayat A A, Aryani D R, Jufri F H, and Ardita I M 2020 Power system stability improvement using Battery Energy Storage System (BESS) in isolated grid IOP Conf. Ser.: Earth Environ. Sci. 599 012025

Acknowledgment
We gratefully acknowledge the support from PT PLN (Persero) UIW Bangka Belitung in publishing this article.