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## **Grid Analysis of Timpah Isolated ULD System ni the de-Dieselization Program of PT PLN (Persero) UID Kalselteng – UP3 Kuala Kapuas**

**Eko Bagus Aribawa**

Universitas 17 Agustus 1945 Jakarta, Indonesia

Email: ekobagusaribawa@gmail.com

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### **ABSTRACT**

*The de-dieselization program has become a key strategy of PT PLN (Persero) in reducing dependence on diesel power plants in isolated areas, including ULD Timpah, Kapuas Regency, Central Kalimantan. This study aims to analyze the effectiveness of the grid system performance after the implementation of de-dieselization, focusing on technical, operational, and financial aspects. The method used is a descriptive quantitative approach with a case study, supported by primary and secondary data, as well as system simulations using the ETAP application. The results show that the electricity distribution voltage remained stable within operational standards, both before and after the project (20.54 kV to 19.17 kV). Operationally, the electricity service hours increased from 16 hours to 24 hours per day, improving the quality of service to customers. Initial financial analysis indicated that the project was not feasible; however, an avoided cost analysis resulted in a positive Net Present Value (NPV) of IDR 162.55 billion, demonstrating significant cost efficiency compared to diesel-based operations. In conclusion, the de-dieselization program at ULD Timpah successfully improved the efficiency, reliability, and sustainability of the electricity system in remote areas, providing positive impacts technically, operationally, and financially to support national electrification goals.*

### **KEYWORDS**

De-dieselization, Energy Efficiency, Grid System, ULD Timpah, Remote Area Electrification



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### **INTRODUCTION**

Indonesia is the largest archipelagic country in the world. Although the population is mainly concentrated on the main islands, it is undeniable that more than 67% of districts in Eastern Indonesia are underdeveloped and isolated areas (Herawati et al., 2020), resulting in limited access to electricity sources. In the guidelines for the 2021-2030 Electricity Supply Effort Plan (RUPTL), it is stated

that PLN still relies on diesel power plants (PLTD) (Rahmat & Umar, 2024). When the RUPTL was prepared in 2021, there were 5,200 diesel generators spread across 2,130 locations in Indonesia (PLN, 2021).

In addition to problems related to PLTD, electrification of isolated grids is considered an affordable option to expand access to electricity in disadvantaged and isolated areas (Solangi et al., 2021), but maintenance of these difficult systems needs to be considered (Mahendra & Liliana, 2023). Isolated grids also have limited scalability (Jacobson, 2021). PLTDs in remote areas tend to have high fuel consumption, large operational costs, and significant energy distribution losses (Bowes et al., 2017).

The role of interconnection systems is significant in the process of de-dieselization or decarbonization, as it can reduce dependence on coal and shows that with an interconnection of 115 GW, renewable energy penetration can increase up to 2.5 times compared to isolated systems (Alves et al., 2019; Aribawa & Rofii, 2025; Jin, 2023). This interconnection also allows a reduction in coal use by about 33% (Reyseliani et al., 2024). Grid systems, both centralized and microgrid, have their own challenges in the context of integration in remote areas (Siregar et al., 2024). Interconnection and de-dieselization programs also impact the socio-economy. (Farghali et al., 2023), in their research related to electricity integration, note that an increasing population leads to increased electricity needs, which affects productivity when electricity supply is limited.

This article discusses efforts to improve electricity services on Buluh Island by replacing PLTD with electricity supply from the PLN Batam network. Technical studies show that this interconnection system is technically feasible and able to maintain voltage stability according to standards; as a result, Buluh Island now enjoys electricity 24 hours a day (Manalu et al., 2024).

This article discusses the analysis of interconnection planning of the electric power system through submarine cables between the islands of Ambon, Haruku, and Saparua in Maluku Province (Tumiran et al., 2022). The main objective is to improve the performance and stability of the power system in the archipelago (Tupalessy et al., 2015).

Reflecting on the results of studies on several de-dieselization and interconnection processes with grid systems, it was found that most transitions from PLTD to interconnection between regions resulted in significant changes (Aribawa & Rofii, 2025). The de-dieselization program is a strategic effort made by PT PLN (Persero) to reduce dependence on diesel-based power plants in isolated areas (Susanto & Rasgianti, 2023). De-dieselization is directed to replace diesel power plants (PLTD) with new and renewable energy-based plants (NRE). Based on the 2021–2030 Electricity Supply Business Plan (RUPTL), de-dieselization not only targets operational cost efficiency and carbon emission reduction but also aims to

improve the quality of electricity supply in areas that previously lacked adequate electricity infrastructure.

The effectiveness of the de-dieselization program depends on successful technical integration between the new generation system and the existing distribution network (Suparman et al., 2024). The main technical parameters used to evaluate this effectiveness include the level of distribution losses, voltage and frequency stability, load matching, and power grid reliability as measured through interference indices such as SAIDI (System Average Interruption Duration Index) and SAIFI (System Average Interruption Frequency Index) (Eteruddin et al., 2021). A high level of system losses or instability can indicate suboptimal grid integration and require further technical adjustments (Seck et al., 2020).

Therefore, this study aims to analyze the effectiveness of grid system performance in *Timpah* ULD after the implementation of the de-dieselization program, focusing on energy distribution efficiency, voltage and frequency stability, and electricity supply reliability using ETAP simulations, so as to contribute practical technical recommendations for electricity system optimization in remote areas.

The working area of PLN Customer Service Implementation Unit (UP3) Kuala Kapuas, in a 2021 report, stated that the de-dieselization of 11 ULDs spread across South Kalimantan is underway, converting diesel to more environmentally friendly primary energy sources. One of the ULDs to be de-dieselized is *Timpah* ULD, which has an engine capacity of 1,200 kilowatts with a peak load of approximately 730 kilowatts running 14 hours daily. Monthly fuel consumption for *Timpah* ULD operations is 100,000 liters of diesel. The *Timpah* ULD is in *Timut Village*, Kuala Kapuas Regency, approximately 95 km from the Palangkaraya-Buntok axis road. Completion of de-dieselization at *Timpah* ULD is expected to positively impact seven surrounding villages, connecting a total of 1,138 customers to 24-hour PLN electricity.

## RESEARCH METHODOLOGY

This study used a descriptive quantitative approach with a case study method, focusing on the technical analysis of grid system performance in the Timut ULD area, Timmah District, Kapuas Regency, Central Kalimantan. A quantitative approach was chosen to enable objective measurement of technical parameters such as energy distribution efficiency, voltage and frequency stability, and power grid reliability. The case study method was selected to evaluate the specific phenomenon occurring at this location after the implementation of the de-dieselization program.

Data collection combined primary and secondary sources. Primary data came from interviews with PLN technicians at ULP Kuala Kapuas, field observations of electrical infrastructure, and direct measurement of voltage, current, frequency, and

distribution losses. Secondary data included PLN's internal documents on the de-dieselization project, daily load reports, network disruption reports, and supporting data from the 2021-2030 Electricity Supply Business Plan (RUPTL). Network system modeling was performed using ETAP software, while statistical processing and visualization used Microsoft Excel.

Data analysis compared system performance before and after de-dieselization using technical indicators. Distribution efficiency was calculated with the formula  $\eta = \frac{P_{\text{load}}}{P_{\text{input}}} \times 100\%$ . System stability was assessed by voltage and frequency deviations against operating standards (voltage  $\pm 5\%$ , frequency 49.5–50.5 Hz). Reliability was measured using SAIDI and SAIFI indices, indicating average outage duration and frequency. The results were interpreted to determine the program's success in improving grid system performance. This study also analyzed financial feasibility for building an interconnection via a 41 km medium voltage distribution network (SUTM).

## RESULTS AND DISCUSSION

### Research Results

The implementation of the de-dieselization program at ULD Timpah is carried out through the construction of a 41 km medium voltage distribution network (SUTM) connected to the BTK 02 feeder from the Buntok Substation (GI).

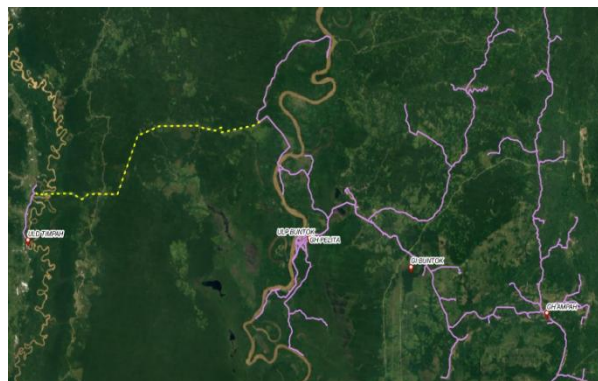


Figure 3 Construction of SUTM for Dedieselization through BTK02

Based on the results of the power flow simulation using the ETAP application, it is known that before the project was implemented, the voltage at the end of the system (Simpang Pendang) was recorded at 20.54 kV, which is still within the standard operating range of  $+5\%$  /  $-10\%$  of the nominal voltage of 20 kV. After the construction of the network and the integration into the grid system, the voltage at that point became 19.17 kV, which is also still within the standard tolerance limit. This shows that technically, the voltage quality of the system is maintained after dedieselization.

Figure 4 Transformer Inputs in Etap Applications

Figure 5 Conductor Inputs in the Etap Application

Figure 6 Load Quantity Input in the Etap Application

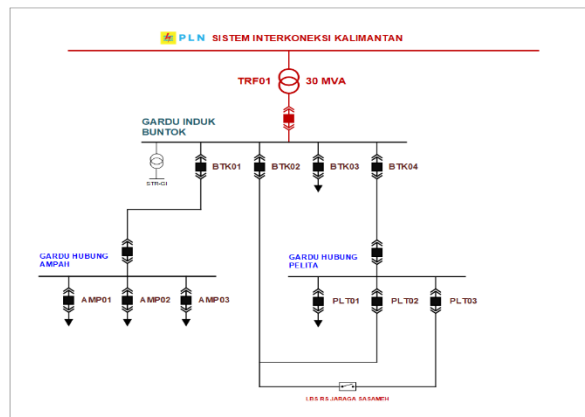


Figure 7 Single line diagram GI Buntok interconnection system

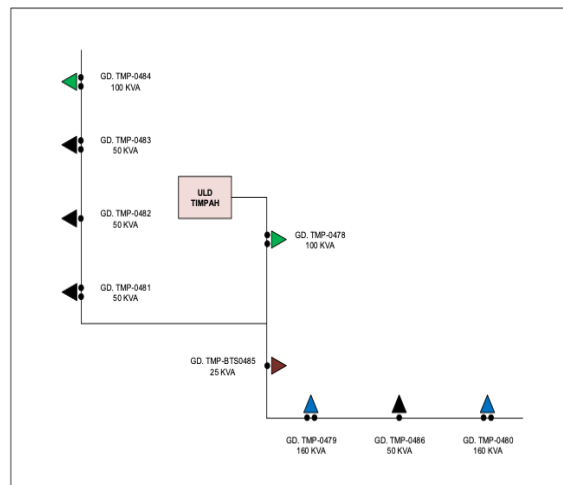


Figure 8 Single Line Diagram system isolated ULD Timpah

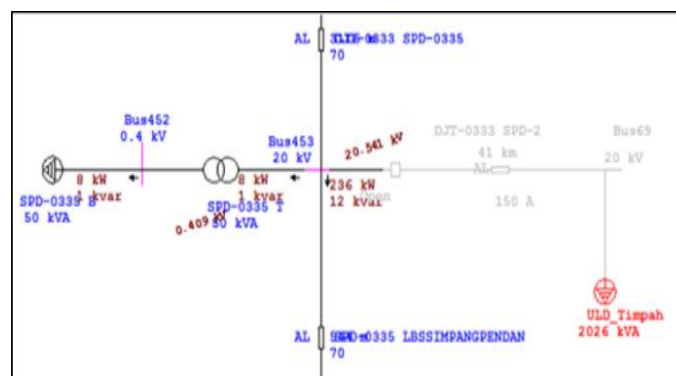


Figure 9 Power Flow Simulation Results in Etap Applications Before De-de-isolation Project

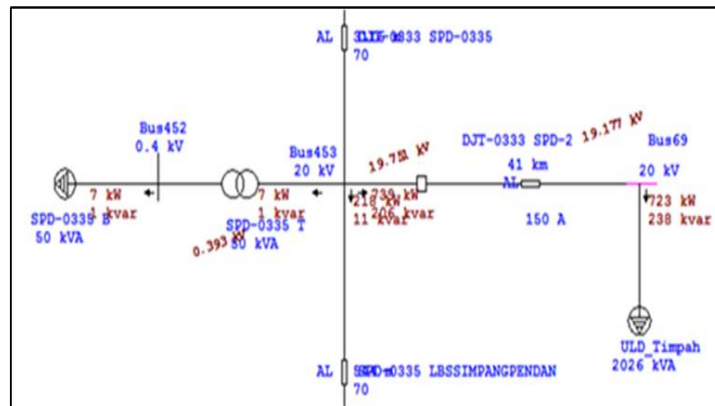


Figure 10 Power Flow Simulation Results in Etap Applications After De-dieselization Project

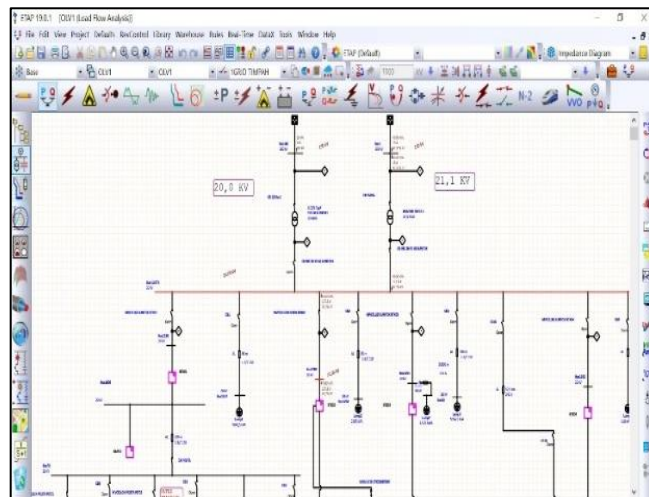


Figure 11 Power Flow Simulation Results in Etap Applications After Inlet System / De-dieselization Project

**Table 1.** Report on Timpah ULD Power Plant until December 2024

| ELECTRICITY CENTRAL |                   |        | POWER |          |            | FUEL USAGE |            |       | LUBRICATING OIL APPLICATION |         |       |
|---------------------|-------------------|--------|-------|----------|------------|------------|------------|-------|-----------------------------|---------|-------|
| CENTRAL NAME        | SU M              | TER    | CAN   | HOUR     | KWH        | REAL       | SHRIN K    | SUM   | REA L                       | SHR INK | SU M  |
|                     | CEN TRA L COD E   | U NI T | PAIR  | MAXIM UM | OPERATIO N | TOTAL      | NEW        |       |                             |         |       |
|                     |                   |        | (kW)  | (kW)     |            |            | (LTR)      | (LTR) | (LTR)                       | (LTR)   | (LTR) |
| 2                   |                   | 4      | 5     | 6        |            |            | 4          | 5     | 6                           | 4       | 5     |
| TIMPAH              | 2E+10             | 7      | 2,378 | 1,696    |            | 1,766,268  | 370,956.95 | -     | 370,956.95                  | 3,927   | 3,927 |
| 1                   | Deutz / F 5 L-413 | 2E+10  | 1     | 40       | 36         | 14         | 0.00       | 0.00  | -                           | -       | -     |



|   |                                              |       |   |     |     |    |         |             |             |        |   |        |   |
|---|----------------------------------------------|-------|---|-----|-----|----|---------|-------------|-------------|--------|---|--------|---|
|   | FR / 8048168                                 |       |   |     |     |    |         |             |             |        |   |        |   |
| 2 | Deutz / F 6 L - 912 / 8681917                | 2E+10 | 1 | 40  | 35  | 14 | -       | 0.00        | 0.00        | -      | - | -      | - |
| 3 | D- MWM/T BD 616- V12/220 5186                | 2E+10 | 1 | 528 | 315 | 14 | 569,554 | 120,183 .05 | 120,183 .05 | 1,68 6 | - | 1,68 6 | - |
| 4 | Deutz / TCD 2013 L06 4V / 1202167 6          | 2E+10 | 1 | 200 | 180 | 14 | 132,452 | 29,607. 50  | 29,607. 50  | 596    | - | 596    | - |
| 5 | Deutz / TCD 2013 L06 4V / 1202165 8          | 2E+10 | 1 | 250 | 180 | 14 | 31,108  | 7,108.4 0   | 7,108.4 0   | 160    | - | 160    | - |
| 6 | SCANIA (Mobile Genset) / DC09 072A / 6933336 | 2E+10 | 1 | 264 | 250 | 14 | 142,564 | 31,453. 50  | 31,453. 50  | 406    | - | 406    | - |
| 7 | D- MWM/T BD 616- V12/220 3515                | 2E+10 | 1 | 528 | 350 | 14 | 720,909 | 149,283 .55 | 149,283 .55 | 1,07 9 | - | 1,07 9 | - |
| 8 | Sewa/Do ssan/PT. Gala                        |       | 1 | 528 | 350 | 14 | 169,681 | 33,320. 95  | 33,320. 95  | -      | - | -      | - |

**Table 2.** Timpah ULD Reliability Performance Realization Report until June 2024

| NO | UNIT               | SAIDI (MINUTES /CUSTOMER) |                        |        | SAIFI (TIMES/CUSTOMERS) |                        |        |
|----|--------------------|---------------------------|------------------------|--------|-------------------------|------------------------|--------|
|    |                    | Target 2024               | The Realization of Sd. | %      | Target 2024             | The Realization of Sd. | %      |
| 1  | ULP BUNTOK         | 299,64                    | 507,57                 | 59,03  | 5,41                    | 5,61                   | 96,43  |
| 2  | ULP KPS KOTA       | 455,08                    | 154,23                 | 295,07 | 5,19                    | 3,72                   | 139,52 |
| 3  | ULP MUARA TEWEH    | 1098,26                   | 1083,28                | 101,38 | 11,3                    | 10,3                   | 109,71 |
| 4  | ULP PULANG PISAU   | 437,48                    | 626,67                 | 69,81  | 8,12                    | 9,12                   | 89,04  |
| 5  | ULP PURUK CAHU     | 847,27                    | 821,55                 | 103,13 | 2,47                    | 4,17                   | 59,23  |
| 6  | ULP TAMIANG LAYANG | 359,64                    | 165,13                 | 217,79 | 8,84                    | 6,8                    | 130,00 |
| 7  | ULD TIMPAH         | 787,04                    | 1072,02                | 73,42  | 8,95                    | 12,68                  | 70,58  |
| 8  | ULD PUJON          | 874,03                    | 884,65                 | 98,80  | 8,67                    | 11,34                  | 76,46  |

**Table 3.** ULD Timpah Reliability Performance Realization Report until December 2024

| NO | UNIT               | SAIDI (MINUTES /CUSTOMER) |             |        | SAIFI (TIMES/CUSTOMERS) |             |        |
|----|--------------------|---------------------------|-------------|--------|-------------------------|-------------|--------|
|    |                    | Target 2024               | Realization | %      | Target 2024             | Realization | %      |
| 1  | ULP BUNTOK         | 299,64                    | 402,99      | 74,35  | 5,41                    | 5,98        | 90,47  |
| 2  | ULP KPS KOTA       | 455,08                    | 354,44      | 128,39 | 5,19                    | 4,54        | 114,32 |
| 3  | ULP MUARA TEWEH    | 1098,26                   | 983,13      | 111,71 | 11,3                    | 11,13       | 101,53 |
| 4  | ULP PULANG PISAU   | 437,48                    | 516,34      | 84,73  | 8,12                    | 8,92        | 91,03  |
| 5  | ULP PURUK CAHU     | 847,27                    | 721,11      | 117,50 | 2,47                    | 3,45        | 71,59  |
| 6  | ULP TAMIANG LAYANG | 359,64                    | 215,22      | 167,10 | 8,84                    | 7,24        | 122,10 |
| 7  | ULD TIMPAH         | 787,04                    | 772,02      | 101,95 | 8,95                    | 8,78        | 101,94 |
| 8  | ULD PUJON          | 874,03                    | 899,65      | 97,15  | 8,67                    | 12,76       | 67,95  |

As a more detailed overview of the condition of the plant before dedieselization, the operational report of ULD Timpah until December 2024 shows that there are 9 units of diesel engines with a total installed capacity of 2,378 kW, and a peak load of 1,340 kW. Energy production was recorded at 535,426.85 kWh with diesel fuel consumption reaching 64,713.95 liters and lubricant of 3,927 liters (table 1). This high fuel consumption reflects the characteristics of PLTD which is energy-intensive and high-cost.



In addition to maintaining voltage stability, the de-dieselization program also has an impact on improving the reliability of the distribution system at the Timat ULD. Before dedieselization, ULD Timpah was only able to serve electrical operating hours for 16 hours per day, while with the system's connection to the regional grid, the operating hours were increased to a full 24 hours. This change is expected not only to improve services to the community, but also have a direct impact on increasing electricity sales revenue. Based on PLN data, the annual revenue projection increased from IDR 1.83 billion to IDR 2.67 billion after extended operating hours and energy supply capacity increased.

In addition to increasing electricity service hours, the technical performance of the plant can also be measured through the Equivalent Availability Factor (EAF) indicator, which reflects the operational availability of the plant to its maximum capacity. Based on data on the realization of EAF PLTD in 2024 in the UID Kalselteng area, including ULD Timpah (within the scope of UP3 Kuala Kapuas), the average monthly EAF ranges from 87% to 94%, with the rate of achievement of the target ranging from 0.87 to 1.10 times the target. This shows that in general, diesel plants remain fairly reliable, but de-dieselization provides opportunities for further efficiency improvements and reduction of the operational load of high-cost PLTDs. This EAF value is also an important reference for evaluating performance before and after the transition of an isolated system to a grid.

**Table 4.** The Results of the Financial Analysis

| Financial Projection |        |               |              |
|----------------------|--------|---------------|--------------|
| Parameter            | Value  | Criterion     | Result       |
| NPV                  | -30,47 | >0 (Positive) | Not Eligible |
| IRR                  | #NUM!  | > Disc Rate   | #NUM!        |
| BC Ratio             | 0,82   | >1            | Not Eligible |
| PayBack Period       | -39,38 | < Asset Age   | Not Eligible |
| profitability Index  | -1,42  |               |              |

**Table 5.** Cost Avoidance Financial Analysis

| Financial Projection |        |               |        |
|----------------------|--------|---------------|--------|
| Parameter            | Value  | Criterion     | Result |
| NPV                  | 162,55 | >0 (Positive) | Proper |
| IRR                  | 58,47% | > Disc Rate   | Proper |
| BC Ratio             | 1,78   | >1            | Proper |
| PayBack Period       | 1,82   | < Asset Age   | Proper |
| Profitability Index  | 59,23  |               |        |

In terms of system efficiency, operational analysis shows that the construction of a new distribution network has reduced dependence on local diesel plants which previously had a very high Cost of Production (BPP), which was Rp 2,859 per kWh. After de-dieselization and integration into the grid system, the BPP target was lowered to Rp 1,381 per kWh. This efficiency contributed to a decrease

in annual operating costs which previously reached IDR 7.3 billion. Although from the initial financial analysis of this project it was declared unfeasible (because the Net Present Value (NPV) value was negative), but based on the avoided cost analysis, this safe analysis was carried out to compare with alternative solutions whether it can produce Avoided cost, if there is an avoided cost, then there is efficiency obtained from this project, then in the avoided cost financial study by comparing the operation of PLTD for 24 hours with the Grid through a 20kV sstem. From table 3 above, it can be seen that when compared to the operation of PLTD for 24 hours, this project is worthy of being marked with a Positive NPV value (162.55 billion), so that this project produces efficiency when compared to the operation of PLTD for 24 hours.

## **Discussion**

### **1. Technical Aspects**

The implementation of the dedieselization program at ULD Timpah shows improvements in the technical aspects of the electricity system, especially in maintaining the stability of the distribution voltage. Based on the results of the power flow simulation using the ETAP 19 application, the base voltage of the BTK 02 feeder GI is 21.5 KV, the voltage at the farthest point of the distribution substation in Timpah Village system before the project drops the voltage is 20.54 kV and after the grid is carried out to the GI Buntok system, the voltage drop is obtained to 19.17 kV. These two values are still within the standard operating range of  $\pm 5\%$  of the nominal voltage of 20 kV. This proves that despite the change in system configuration from isolated to grid, the voltage quality can still be controlled. This voltage stability is important to ensure user comfort, safety of consumer electrical equipment, and the efficiency of the distribution system.

In addition, the analysis of the power flow shows that the distribution of electrical energy through the new grid provides good performance in terms of power quality and reliability. No indication of significant short-circuit interference or harmful load imbalance was found. The results of the evaluation show that the technical requirements for power flow, system reliability, and electrical power quality were entirely met after the implementation of the new network. Thus, dedieselization through the construction of a new network successfully meets the technical criteria needed to improve the performance of the electricity system in the Timpah ULD area.

### **2. Operational Aspects**

Dedieselization at the Timpah ULD not only has an impact on the technical side, but also brings major changes to the operational aspects of the electricity system. One of the most obvious improvements is the increase in electrical operating hours. Before dedieselization, the isolated system was only capable of

supplying electricity for 16 hours per day, while after the project, the system was planned to be able to fully operate for 24 hours.

This extension of operating hours is essential to improve the quality of life of local communities, expand economic activity, and increase productivity in important sectors such as trade and education based on research from Farghali et al., (2023).

In addition, the number of customers served also has the potential to increase along with the increase in the reliability of electricity supply. With more reliable electricity services as seen from the performance table of SAIDI SAIFI ULD Timpah in 2024, it is seen that there is a significant decrease in the frequency of customer disruption SAIDI performance from the target of 787.04 times/plg to 772.02 times/plg as well as the performance of SAIDI from the target of 8.95 hours/plg to 8.78 hours/plg until December 2025 (table 3) compared to when using the Isolated Network until June 2024 where SAIFI's performance from the target is 787.04 times/plg only achieved 1072.02 hours/plg or 73.42 % of the set target and SAIDI's performance target was only achieved 12.68 hours/plg from the target of 8.95 hours/plg or 70.58% (Table 2), with this increase in reliability it is expected to increase the electrification ratio in the region which is more sustainable. Overall, from an operational aspect, the dedieselization program brings a significant transformation in improving services to customers in Timpah District and its surroundings.

### **3. Financial Aspects**

From the financial side, the results of the analysis show interesting dynamics. In the initial financial feasibility analysis without considering the avoided cost, the Timpah ULD dedieselization project was declared unfeasible because it produced a negative Net Present Value (NPV) and an unfavorable payback period. However, when an avoided cost analysis was carried out, which compared the operational costs of 24-hour PLTD versus the operating costs of the grid system, this project was considered feasible. The analysis shows that with an investment of IDR 22.67 billion, this project can generate significant savings, reflected in a positive NPV of IDR 162.55 billion.

These results show that dedieselization is not only about cost savings in the short term, but rather operational cost efficiency in the long term. By reducing the Cost of Production (BPP) from Rp 2,859 to Rp 1,381 per kWh, PLN not only reduces the burden of energy subsidies but also increases operational profitability in the future. In addition, this positive impact is also in line with PLN's strategic goals in supporting cleaner and more sustainable energy. Thus, from a financial aspect, the Timpah ULD dedieselization project has proven to bring substantial economic added value when calculated with the right approach.

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