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Techno-Economic Analysis of Diesel Rotary UPS Implementation in Power Supply of Pertamina EP Zona 9

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Abstract

This study evaluates power supply design options at PT Pertamina EP Zona 9, focusing on the Tanjung and Sangatta Fields, by analyzing technical and economic performance before and after the implementation of a Diesel Rotary Uninterruptible Power Supply (DRUPS). The research was conducted from December 2024 to February 2025 using a mixed-methods approach, incorporating field observations, interviews, document analysis, and power system simulations using ETAP. Power reliability indices and investment feasibility parameters were used for evaluation. The results indicate that DRUPS implementation significantly improved power reliability and operational efficiency, with electricity cost savings of 63% and a reduction in System Average Interruption Frequency Index (SAIFI) from 10.1 to 6.6 interruptions per month. Economic analysis confirms high investment feasibility, with a Benefit–Cost Ratio of 58.61, Net Present Value of IDR 473 billion, Internal Rate of Return of 117,18%, and a payback period of one month. These findings demonstrate that DRUPS is a technically reliable and economically viable solution for enhancing long-term power system sustainability in Pertamina EP Zona 9.

Keywords: Index Terms— Diesel rotary uninterruptible power supply, economic analysis, power supply reliability, SAIFI.

1. Introduction

Since 1966, the Production Sharing Contract (PSC) has been the primary form of cooperation with foreign oil companies in Indonesia's oil exploration and production. However, in August 2016, the Minister of Energy and Mineral Resources introduced a new paradigm for upstream oil and gas management with Government Regulation No. 52 of 2017 on the Gross Split Contract. Both PSC and Gross Split share a common requirement for feasibility studies, covering technical and financial aspects. As fossil energy resources (oil, coal, and gas) continue to deplete, and new reserves take time to discover, this poses a significant challenge for the oil and gas industry, particularly in meeting power supply needs for daily operations, such as in Pertamina EP Zona 9. Several fields in Zona 9, including Tanjung and Sangatta, face challenges with inadequate gas supply to generate electricity, resulting in the use of oil (diesel) as an alternative fuel. Pertamina Zona 9, which includes Fields Tanjung, Sangatta, Sangasanga, and PHSS, has different characteristics, with Fields Tanjung and Sangatta facing the highest operational costs for electricity generation. Before implementing the DRUPS system at Field Sangatta from 2021 to September 2022, the average monthly electricity consumption was 3,681,958 kWh, costing approximately Rp 6,879,985,510, with an average cost per kWh of Rp 1,871. This high operational cost, primarily from diesel-powered generators, highlighted inefficiencies, making the implementation of a more efficient electrical system like DRUPS a crucial consideration. Meanwhile, in 2022, the cost per kWh at Field Sangatta was Rp 2,622.

Fields Tanjung and Sangatta in Pertamina EP Zona 9 face challenges with gas fuel availability, resulting in high electricity generation costs. In 2021, electricity generation costs at Field Tanjung were Rp 1,871 per kWh, while at Field Sangatta in 2022, it was Rp 2,622 per kWh. To reduce operational costs and improve electricity supply reliability, Pertamina EP Zona 9 Tanjung switched from Gas Turbine Generator (GTS) to PLN's Premium Super Ultima service, with a 10,380 kVA capacity, projected to save up to Rp 12 billion per month, or around Rp 144 billion per year. Data shows a consistent rise in electricity costs at Tanjung from 2020 to 2022, with monthly costs fluctuating between Rp 2.3 trillion to Rp 7.1 trillion. This increase is likely due to higher consumption, rising electricity tariffs, and changes in energy usage patterns. Additionally, power disruptions like voltage sag, undervoltage, harmonics, and blackouts at both fields cause significant operational inefficiencies, including equipment damage and increased fuel consumption for backup generators. These issues prompted the planning of a Diesel Rotary UPS (DRUPS) project in collaboration with PT PLN, with the aim to maintain power reliability and production targets [1]. The project will be implemented first at Field Tanjung, followed by Field Sangatta.

The implementation of Diesel Rotary Uninterruptible Power Supply (DRUPS) at Pertamina EP Tanjung Field has proven effective in stabilizing power supply and reducing the risk of electrical disruptions that directly impact operational efficiency. DRUPS works by storing kinetic energy in a flywheel, ensuring a stable power supply even during electrical disturbances, allowing for seamless transition from PLN power to generators without downtime, unlike conventional generators which require start-up time. If implemented at Field Sangatta, DRUPS could reduce electrical disruptions by up to 99%, as seen at Field Tanjung. Additionally, it has the potential to lower electricity costs to Rp 1,800 – 1,900 per kWh and improve system resilience against external disruptions. A comparative analysis of various power supply options, including solar-powered gensets, LNG-powered gensets, PLN supply with capacitor banks, and PLN supply with DRUPS, highlights that PLNisation with DRUPS is the most optimal solution. It offers high reliability, cost savings of over Rp 100 billion per year, and increased operational efficiency of over 99% compared to the existing system, all while reducing carbon emissions and fossil fuel consumption. Despite higher initial investment, DRUPS provides substantial long-term savings and is a strategic move for Pertamina EP Zona 9 to ensure sustainable power supply, lower operational costs, and enhance competitiveness in the industry. The results after conducting the DRUPS design simulation showed optimization of the option, which provided the best value from both a technical and financial analysis perspective. Ultimately, this outcome provided input to the management, considering that the DRUPS design was more cost-efficient.

2. Material and methods

This research will be conducted at Field Tanjung and Field Sangatta, which are part of Pertamina EP Zona 9, from December 2024 to February 2025. These locations were chosen due to their differing operational characteristics, particularly concerning gas fuel availability and electricity generation costs. The primary focus of this research is the analysis of the implementation of Diesel Rotary Uninterruptible Power Supply (DRUPS) to improve power supply reliability. Data will be collected through direct observation, internal Pertamina EP document studies, and direct measurements of technical parameters such as energy consumption, power supply disruptions, and generation efficiency. This study adopts a descriptive and analytical quantitative design, enabling both technical and economic analysis, as well as the operational impacts of implementing DRUPS compared to existing electricity generation methods, such as diesel and LNG-powered generators, and electricity supply from PLN with capacitor banks. Additionally, an experimental approach based on simulations will be used to model the reliability of the electrical system with and without DRUPS using ETAP software.

Data collection will involve both primary and secondary data. Technical data on electricity consumption, power supply disruptions, and energy efficiency will be gathered through direct measurements and observations of Pertamina EP Zona 9's electrical systems. Power reliability data, such as SAIFI, SAIDI, MTBF, MTTR, voltage sag, and harmonics, will be obtained through historical studies and disruption analysis in operational reports. Economic data, including DRUPS investment costs, operational costs, and cost efficiency, will be gathered through document studies and interviews with relevant stakeholders. Regulatory data will be obtained from literature reviews on electricity reliability standards and energy efficiency policies in the oil and gas industry. Case study data on DRUPS implementation in other industries will be collected through literature reviews and benchmarking to evaluate the impact of implementation in similar sectors. Data analysis will be conducted using both quantitative and qualitative approaches. Technical and power reliability data will be analysed through technical calculations such as SAIFI, SAIDI, MTBF, MTTR, as well as ETAP simulations or manual calculations to assess voltage sag, harmonics, and power supply stability. Economic data will be analysed using cost analysis methods such as LCC, NPV, IRR, and Payback Period to assess investment feasibility and operational cost efficiency. Meanwhile, qualitative data will be analysed through a descriptive approach, including interviews, document studies, and policy reviews to interpret external factors influencing the decision to implement DRUPS, such as energy policies and related regulations.

3. Results and discussion

3.1 *DRUPS Implementation Technology Analysis*

The implementation of Diesel Rotary Uninterruptible Power Supply (DRUPS) at Pertamina EP Zona 9 has led to significant changes in monthly electricity consumption and related operational costs. Before DRUPS was implemented, the average monthly electricity consumption was 3,681,958 kWh, with an average cost per kWh of Rp 1,871. Although electricity consumption increased to 3,974,554 kWh after DRUPS implementation, this actually reflects better energy efficiency. In theory, technologies like DRUPS, which integrate flywheels and diesel generators, should optimize energy use, reduce power wastage, and eliminate downtime associated with power disturbances. In this context, the increase in electricity consumption, followed by a decrease in cost per kWh, illustrates more efficient and optimal energy use. This aligns with energy efficiency concepts in energy management theory, which asserts that improvements in efficiency are not always directly related to reducing energy consumption but rather to achieving better output with less energy waste.

In energy economics theory, operational efficiency can be achieved through investments in technologies that reduce energy waste and optimize energy distribution across operations. DRUPS, with its ability to reduce power disruptions and maintain power supply continuity, enables energy savings by reducing power waste that previously occurred due to frequency fluctuations and power outages [2], [3]. Despite an increase in electricity consumption (kWh), the reduction of Rp 101 per kWh indicates that DRUPS improves power supply quality at a more cost-efficient rate. This is based on the principles of energy cost economics, where the cost per unit of energy (in this case, cost per kWh) becomes cheaper with more advanced technology, even if total energy consumption is slightly higher [4], [5]. The reduction in cost per kWh reflects a decrease in waste within an inefficient power distribution system.

Resource management and sustainability theories are also relevant for analyzing these results. In sustainability approaches, any increase in energy consumption must be offset by reductions in waste and more environmentally friendly energy use [6]. DRUPS offers a solution that aligns with these sustainability principles, as the system is more energy-efficient and less dependent on fossil fuels compared to traditional generator systems. The reduction in operational costs following DRUPS implementation contributes to reduced emissions and more environmentally friendly energy consumption, which is a key aspect of sustainability theory in industry [7]. Therefore, although electricity consumption increased, the reduction in cost per kWh and overall system efficiency improvements indicate that DRUPS not only benefits cost-wise but also supports the company's sustainability goals by enabling more efficient and controlled energy use [8], [9].

As shown in Table I, prior to the implementation of the Diesel Rotary Uninterruptible Power Supply (DRUPS), the electrical system at Pertamina EP Zone 9 experienced a relatively high level of supply interruptions, with an average SAIFI of 10.1 incidents per month over a 21-month observation period. This indicates that the system had limited resilience in maintaining power continuity and remained highly dependent on conventional backup mechanisms. Generator-based backup systems require mechanical start-up, synchronization, and stabilization time, which increases the risk of temporary power loss during transition periods. As a result, disturbances in the upstream network or operational switching processes frequently translated into measurable supply interruptions that affected production stability and operational efficiency.

An examination of the individual disturbance categories shows that blackout events contributed the largest share of interruptions, averaging 3.2 incidents per month, indicating a significant vulnerability to complete loss of supply. Frequency instability also played a major role, with both over-frequency and under-frequency conditions contributing substantially to the total SAIFI value. These disturbances suggest limited capability of the existing system to maintain frequency stability during load variations or external grid fluctuations. Additional interruptions were associated with feeder transfer operations, diesel synchronization processes, and occasional transformer maintenance, further reflecting operational limitations in handling switching events and equipment servicing without affecting supply continuity.

Table 1. SAIFI Comparison Before and After DRUPS Implementation

SAIFI Causes	Before DRUPS Implementation		After DRUPS Implementation	
	Total	Average/month	Total	Average/month
Blackout	68	3.2	56	2.7
Diesel Sync Mode	25	1.2	25	1.2
Frequency Above 50.52 Hz	41	2.0	21	1.0
Frequency Below 49.6 Hz	43	2.0	22	1.0
Transformer Maintenance	2	0.1	-	-
Feeder Transfer	16	0.8	14	0.7
Total SAIFI (21 Months)	213	10.1	138	6.6

After DRUPS was implemented, there was a significant reduction in disruption frequency, with SAIFI dropping to 6.6 incidents per month. This reduction clearly demonstrates the effectiveness of DRUPS technology in improving power supply reliability. As shown in Table II, the integrated flywheel technology in DRUPS helps maintain power stability during transition periods, reducing response time from 1.41 seconds to just 0.17 seconds. This indicates that DRUPS can address power disruptions almost instantly, accelerate power recovery, and minimize production downtime. With fewer disruptions and faster recovery times, operations can run more smoothly and efficiently.

Table 2. Comparison of the System Before and After DRUPS Implementation

Aspek	Before DRUPS	After DRUPS
Power Capacity	5-8 MW	10 MVA
SAIDI: Supply Stabilitation Time	33.24 seconds (range from 5 seconds to 3 minutes	15.14 seconds
SAIDI : Transition Time from Blackout	1.41 seconds (range from 1 to 2.5 seconds)	0.17 seconds (less than 0.2 seconds)
Frequency of Disruption (SAIFI)	10.14 times/month	6.57 times/month

The significant improvement in transition time and power supply stabilization after DRUPS implementation shows that the electrical system has become much more responsive [10], [11]. The reduction in the number of disruptions and faster power recovery speeds suggests that DRUPS has successfully addressed many weaknesses in the previous system. Previously, reliance on conventional generators and UPS batteries resulted in longer response times, causing more disruptions and affecting productivity. Now, with DRUPS, the power supply is more reliable, faster, and more stable, which directly reduces downtime and operational losses. Overall, DRUPS provides a more efficient solution, reducing dependence on slower and more costly backup systems.

Before DRUPS implementation, the Loss Production Opportunity (LPO) was recorded at 8.37%, indicating that power disruptions had a significant impact on operations and production. With such a high LPO, more than 8% of production capacity was lost due to electrical disruptions causing downtime. Issues like frequency fluctuations and power outages hindered the production process, resulting in energy waste and the need to shut down machinery or equipment for extended periods. As a result, production was disrupted, and the company faced substantial financial losses, both in terms of wasted capacity and additional operational costs to address the disruptions.

After DRUPS implementation, the LPO showed a significant reduction to 1.63%. This decrease demonstrates DRUPS's success in mitigating the impact of power disruptions on operations and production. With DRUPS's ability to maintain power stability, production processes that were previously disrupted by downtime became more stable and efficient. DRUPS reduced downtime caused by power fluctuations or sudden outages, allowing machines and equipment to operate without major interruptions. Production efficiency improved as energy wastage from power disruptions was minimized, which also positively impacted lower operational costs.

The reduction in LPO after DRUPS implementation shows that this technology not only improves power supply reliability but also has a direct impact on productivity improvement [12]. By reducing losses from downtime, the company can maximize production capacity, increase output, and reduce energy waste. Moreover, the decrease in LPO also cuts costs previously incurred to address power disruptions, such as repair costs, replacement of damaged equipment, and costs associated with downtime [13]. Overall, DRUPS contributes significantly to improving operational efficiency, reducing financial losses, and enhancing the company's competitiveness in the market [14].

3.2 *Economic Analysis of DRUPS Implementation*

The implementation of Diesel Rotary Uninterruptible Power Supply (DRUPS) has had a positive impact on electricity operational cost savings. As shown in Table III, the total electricity cost for Super Ultima II, which includes the Premium Platinum system and DRUPS, was recorded at Rp 8,349,315,811.20 per month. This reflects an annual saving of approximately Rp 127,745,234,265.60, equivalent to 63% of the previous higher electricity costs. This cost saving demonstrates that DRUPS has successfully enhanced electricity generation efficiency, even with an increase in electricity consumption. The reduction in costs is crucial for industries that rely on stable power supply, as it decreases reliance on more expensive electricity sources and enhances long-term profitability.

Table 3. Economic Analysis

Description	Amount (Rp)
Super Ultima II Monthly Bill	8,349,315,811.20
Super Ultima II Annual Bill	100,191,789,734.40
Existing BPP (Tanjung)	1,871 Rp/kWh
Monthly BPP (for 5.6 MW load) (30 days)	18,994,752,000
Annual BPP (for 5.6 MW load) (12 months)	227,937,024,000
Potential Annual Savings	127,745,234,265.60
Annual Savings Percentage	56%

In addition to significant operational cost savings, DRUPS implementation also succeeded in lowering the cost per kWh from Rp 1,871 to Rp 1,770. This decrease reflects higher efficiency in electricity generation, where DRUPS optimizes energy use and reduces waste caused by power disturbances or fluctuations [15]. With a lower cost per kWh, the company not only saves on operational costs but also reduces the financial impact of large energy demands. This efficiency is achieved because DRUPS reduces reliance on more expensive backup systems, such as generators, and lowers the use of more costly fossil fuels [16].

As shown in Table IV, the BCR is calculated at 58.61, indicating that for every Rp 1 invested in DRUPS, Rp 58.61 in benefits are generated. This is a very high ratio, showing that the investment is highly profitable. A BCR greater than 1 indicates that the benefits of the project outweigh the costs, providing confidence that investing in DRUPS delivers a significant return. This figure strengthens the decision to continue implementing DRUPS, as it demonstrates that the project will not only cover the investment costs but also generate significant financial benefits for the company.

Table 4. Benefit Cost Ratio (BCR)

Present Value Benefit (PV) of operational cost savings using DRUPS over 5 years is calculated as: PV = Rp 127,745,234,265.60 x 5 = Rp 638,726,171,328.00
Total Initial Investment Cost: Rp 10,898,024,000
$\mathrm{BCR}=\frac{638{,}726{,}171{,}328}{10{,}898{,}024{,}000}= 58.61$

Based on the Net Present Value (NPV) calculation presented in Table V, the DRUPS investment generates a consistently positive discounted cash flow over the five-year evaluation period. With an assumed annual net cash flow of Rp 127,745,234,265.60 and a discount rate of 10%, the present value of future benefits shows a gradual decline over time due to the time value of money, yet remains substantial in each year of analysis. The discounted cash inflows range from Rp 116.13 billion in the first year to Rp 79.32 billion in the fifth year, resulting in a cumulative present value of Rp 484.25 billion. After deducting the initial investment cost of Rp 10.90 billion, the project yields a total NPV of IDR 473.36 billion, indicating that the financial benefits generated by the system significantly exceed the capital expenditure required for implementation.

From an investment feasibility perspective, a large positive NPV reflects strong economic value creation and confirms that the DRUPS implementation provides substantial long-term financial returns. The magnitude of the NPV indicates not only that the project recovers its initial investment but also generates considerable net economic benefits over its operational life. This outcome demonstrates that the operational cost savings produced by improved power reliability and efficiency have a significant present-value impact when evaluated using standard capital budgeting principles. Consequently, the DRUPS project can be classified as highly financially viable, as the discounted future cash inflows comfortably surpass the initial capital outlay, reinforcing its attractiveness as a strategic infrastructure investment for improving both operational performance and long-term cost efficiency.

Table 5. Net Present Value (NPV)

Year	Net Cash Flow (Rp)	Discount Formula	Present Value (Rp)
1	127,745,234,265.60	127,745,234,265.60 / (1.1)^1	116,132,030,241.45
2	127,745,234,265.60	127,745,234,265.60 / (1.1)^2	105,574,572,037.68
3	127,745,234,265.60	127,745,234,265.60 / (1.1)^3	95,976,892,761.53
4	127,745,234,265.60	127,745,234,265.60 / (1.1)^4	87,251,711,601.39
5	127,745,234,265.60	127,745,234,265.60 / (1.1)^5	79,319,743,147.08
		Subtotal	484,254,950,788.13
	Initial Investment		–10,898,024,000.00
		Total NPV	473,356,926,788.13

The calculated IRR of 117.18% that presented in Table VI shows a very high rate of return, far exceeding the discount rate typically expected in investment projects. An IRR higher than the discount rate (such as the common 10%) indicates that the DRUPS project is highly profitable and delivers quick returns. This high return rate also suggests that the investment in DRUPS carries low risk and can generate profitable results, even with a significant initial investment. This is a strong indicator that DRUPS is a profitable investment choice for the company.

Tabel 5. Internal Rate of Return (IRR)

Year	Cash Flow (Rp)	Discount Formula	Present Value (Rp)
0	-10,898.024,000.00	-10,898,024,000.00 / (1+11.7189)^0	–10,898,024,000.00
1	127,745,234,265.60	127,745,234,265.60 / (1+11.7189)^1	10,899,507,231.82
2	127,745,234,265.60	127,745,234,265.60 / (1+11.7189)^2	927,466,612.84
3	127,745,234,265.60	127,745,234,265.60 / (1+11.7189)^3	78,908,090.45
4	127,745,234,265.60	127,745,234,265.60 / (1+11.7189)^4	6,715,303.88
5	127,745,234,265.60	127,745,234,265.60 / (1+11.7189)^5	571,815.02
		Total Present Value	≈ Rp0 (NPV ≈ 0)
		IRR	117,18%

With a Payback Period of just 1.02 months as presented in Table VII, meaning the investment in DRUPS can be recouped in a very short time, this demonstrates an exceptionally fast return on investment, which is highly advantageous for the company. In comparison, most long-term investments have a much longer Payback Period, often exceeding a year. This rapid payback time indicates a very high investment efficiency, allowing the company to quickly realize profits and reduce financial risks associated with long-term investments.

Table 7. Payback Period (PP)

I0 = Initial investment (IDR 10,898,024,000)
Annual Cash Flow = Annual savings obtained (IDR 127,745,234,265.60)
$PP = \frac{10{,}898{,}024{,}000}{127{,}745{,}234{,}265.60} = 0{,}085 \text{ years}$
PP×12=0.085×12= 1.02 months

Such an extremely short Payback Period also indicates that the financial exposure associated with the DRUPS investment is minimal, as capital recovery occurs within a very limited time horizon. This condition significantly reduces investment risk, particularly in industrial environments where operational continuity and cost stability are critical. Rapid capital recovery improves cash flow flexibility, enabling the company to reallocate financial resources toward other strategic initiatives, such as system expansion, reliability enhancement, or energy efficiency programs. Furthermore, a short payback period provides strong financial resilience against uncertainties such as fluctuations in operational costs, energy prices, or future economic conditions. From a strategic investment perspective, this level of financial responsiveness strengthens the justification for DRUPS implementation, as the project not only delivers operational benefits but also enhances the company's financial agility and long-term capital efficiency.

3.3 *Simulation of Tanjung and Sangatta*

The DRUPS (Diesel Rotary Uninterruptible Power Supply) connection design with a dual supply approach involves separate connections at GS-1 and GS-2 in the Sangatta Field. As shown in Fig.1, this configuration ensures operational independence between the two main substations, accommodating specific load requirements based on the characteristics and capacities of each point. It provides greater flexibility in load management and maintenance, offering more reliable power supply redundancy by avoiding reliance on a single centralized supply point. This approach is ideal for installations with high local disruption risks or varying operational needs at each distribution point. The system includes 1.5 MVA step-down transformers (20/6.6 kV) at each point, reducing voltage from the PLN network, which is then supplied to 1,000 kVA DRUPS units and distributed to the substations. The design also features Normally Open (NO) panels for automatic power source switching in emergencies. This separation ensures that disturbances at one point will not directly affect the other, enhancing system reliability and enabling rapid response to local disruptions without compromising overall operational continuity.

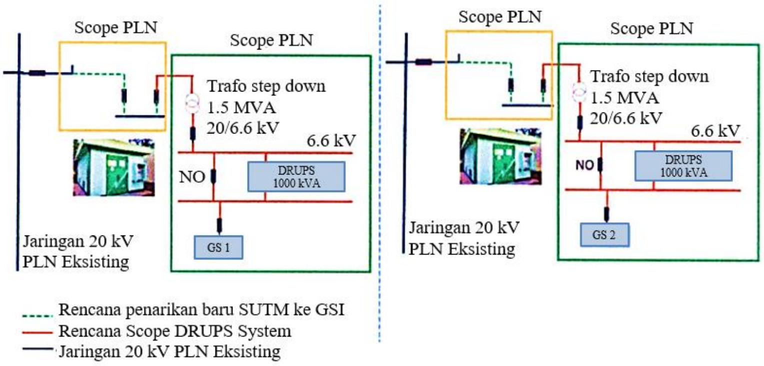

Fig. 1. Scheme 1 DRUPS Connection of 2 Points in Separate GS-1 & GS-2

The DRUPS (Diesel Rotary Uninterruptible Power Supply) connection system with a single centralized supply configuration is located at Power Plant GS-1 to serve both GS-1 and GS-2 simultaneously that presented in Fig.2. This approach simplifies the electrical infrastructure by integrating power supply into one large-capacity DRUPS system, supported by the existing 20 kV PLN network and a 2.5 MVA step-down transformer. The system aims to enhance operational efficiency and investment savings by minimizing the number of DRUPS units, while centralizing electrical control and monitoring. This configuration is ideal for operations with stable load coordination and high reliability needs from a single main power source. The design uses a 2,500 kVA DRUPS, with power distributed to both substations through Normally Open (NO) panels for control. Although this model reduces infrastructure costs and simplifies control, it requires high reliability from the single DRUPS system, as any disruption at this point may affect both substations simultaneously. This setup is suitable for systems with well-coordinated operations and a need for optimal investment efficiency.

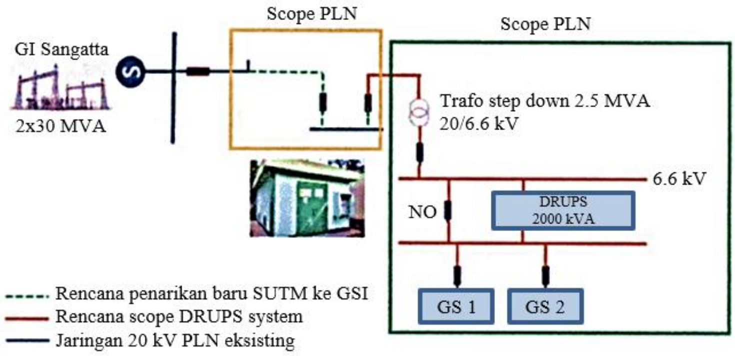

Fig. 2. Scheme 2 DRUPS 1 Point Connection at GS-1

The Fig.3 shows the planned tapping points for the PLN power supply to the GS#1 and GS#2 substations at the Sangatta Field. This scheme illustrates the configuration of the main electrical panels, including incoming, outgoing panels, and the step-down transformer system, which will be integrated with the PLN 20 kV network. At GS#1, the PLN supply will pass through a 20 kV/6.6 kV transformer, then be distributed through several panels such as the outgoing GS-1 panel and share. At GS#2, a similar scheme is applied with the addition of a dedicated panel for the DC commins system (1100 kVA), as well as a 250 kVA step-down transformer for smaller loads. This connection plan enables the direct and efficient integration of the PLN system with the internal electrical infrastructure of the substations, facilitating more stable and segmented power distribution according to the operational needs of each substation. This approach is part of efforts to enhance the reliability and efficiency of the power supply system in the oil and gas production environment.

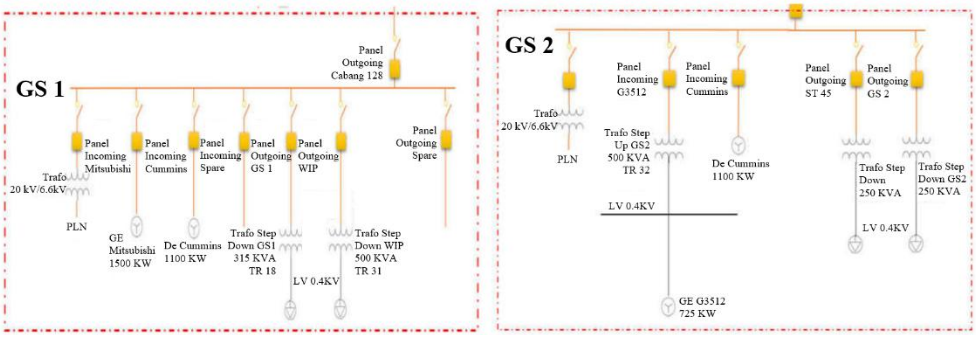

Fig. 3. Tapping Point Plan for PLN Electricity Connection in GS#1 and GS#2

The Switchgear Panel and Synchronization Panel configuration presented in Fig. 4 illustrates the integrated power supply architecture that combines multiple energy sources into a unified electrical distribution system. The configuration interconnects the existing generator units, consisting of a 1500 kW gas generator (GG) and a 1100 kW diesel generator (DG) operating at 6.6 kV, with the PLN utility supply at 24 kV, as well as the Diesel Rotary Uninterruptible Power Supply (DRUPS) system. The output of the existing generators is managed through the 6.6 kV switchgear (SWGR GS1), which distributes power to outgoing feeders while also enabling controlled synchronization with external and backup power sources. To support system expansion and improve operational control, the design incorporates new metal-clad switchgear units at both 24 kV and 7.2 kV levels, complete with synchronization facilities and spare feeder provisions. This arrangement enables coordinated power transfer and seamless switching among gensets, PLN supply, and DRUPS, ensuring stable operation during both normal and contingency conditions.

In addition to power source integration, the system includes a 1250 kVA step-down transformer that converts incoming medium-voltage supply to the required distribution voltage level for operational loads within the field. The synchronization infrastructure allows automatic coordination between multiple power sources, minimizing transfer time and preventing supply interruptions during switching events. Furthermore, the incorporation of dedicated synchronization facilities and spare feeder capacity enhances operational flexibility, enabling maintenance activities or load redistribution without compromising system reliability. Overall, the configuration improves switching efficiency, strengthens supply redundancy, and enhances voltage stability, thereby ensuring continuous and reliable power delivery to critical production facilities in the Sangatta Field.

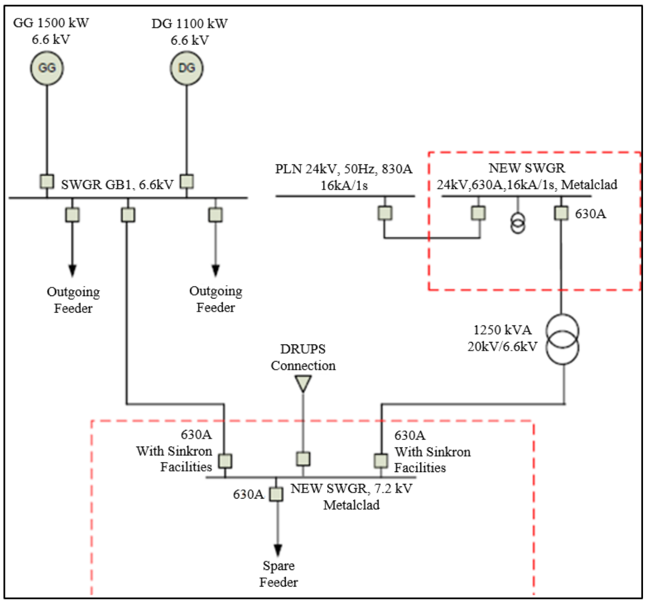

Fig. 4. Switchgear and Synchronous Panel Plan

The electrical system design at GS 1 and GS 2 Sangatta, integrated with the main power supply from PLN and equipped with a Diesel Rotary Uninterruptible Power Supply (DRUPS), offers significant advantages in maintaining high reliability and uninterrupted power supply. The integration ensures that critical loads receive a stable electricity supply even during main grid disturbances. Under normal conditions, the primary power supply is provided by PLN through a 20 kV/6.6 kV transformer, distributed to each substation (GS) via a comprehensive protection and control system, including outgoing and incoming relays and circuit breakers. The 47.5 kW DRUPS, connected to each GS system, remains in standby mode, ensuring a seamless transition to backup power if required. This setup guarantees no downtime, even in milliseconds, making it ideal for supporting operations that cannot afford disruptions, such as in the oil and gas industry. Simulations using ETAP demonstrate that presented in Fig.5, the system's ability to maintain voltage stability at 6.6 kV and 0.4 kV with minimal voltage deviation, optimal energy efficiency (power factor above 0.95), and no significant phase imbalance or overcurrent. The protection system functions flawlessly, with no interlocking failures or delays during switching. The DRUPS, connected through a 4 MVA transformer, ensures the system's readiness to automatically handle primary supply loss, reinforcing both technical efficiency and operational reliability, crucial for supporting oil and gas production continuity at Pertamina EP Zona 9.

In addition to the overall system configuration, the single-line diagram explicitly illustrates the symmetrical architecture of GS 1 and GS 2, each supplied through independent incoming feeders from the PLN 20 kV network and stepped down to 6.6 kV distribution buses via dedicated transformers. Each GS is equipped with clearly defined incoming and outgoing circuit breakers, coordinated protection relays, and monitored load buses, enabling sectionalized operation and selective isolation during disturbances. The diagram also presents steady-state load flow values along the feeders, including power transfer, voltage magnitude at the 6.6 kV and 0.4 kV levels, and transformer loading conditions, confirming balanced operational distribution between the substations. The DRUPS units at both GS locations are interfaced through 4 MVA coupling transformers to the low-voltage buses, forming an electrically synchronized backup path capable of immediate load support. This arrangement establishes parallel-ready infrastructure, controlled switching sequences, and defined power flow directions, ensuring structured interconnection between utility supply, local distribution, and dynamic backup generation within each substation.

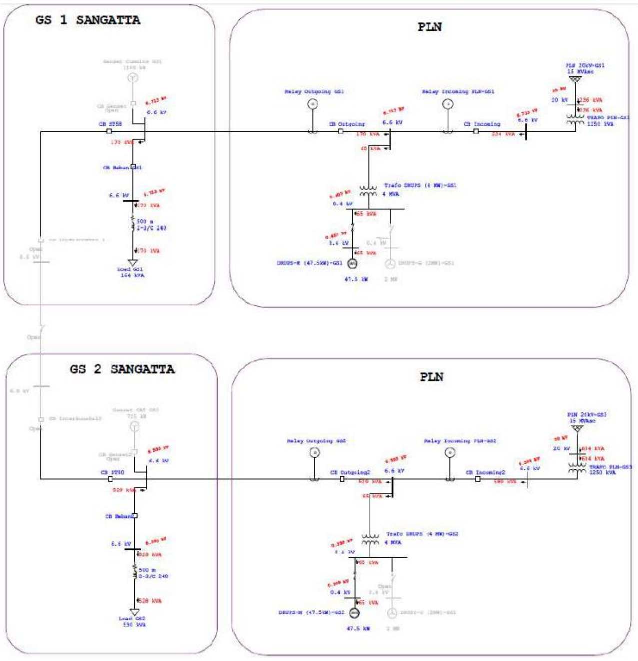

Fig. 5. ETAP Simulation Design for Normal Condition (PLN) - Sangatta

The electrical system design at Sangatta, featuring a Diesel Rotary Uninterruptible Power Supply (DRUPS) configuration, excels in handling power supply disruptions from PLN. ETAP simulation as shown in Fig.6 results show that during PLN network outages (indicated by the open position on the incoming CB), the system automatically switches to DRUPS mode with zero transfer time, ensuring no power interruption. The 4 MVA DRUPS transformer transfers power to the 47.5 kW DRUPS unit, which supplies the entire load through a 0.4 kV distribution bus. Both GS 1 (164 kVA) and GS 2 (530 kVA) loads are effectively served by DRUPS without any issues. The kinetic energy stored in the DRUPS flywheel bridges the transition from the PLN network to the diesel engine in real time, with no voltage fluctuations or frequency drops. The system performs stably during this mode, with output voltage and current remaining within safe nominal limits, and actual power values at each DRUPS unit nearing 464 kVA (GS1) and 822 kVA (GS2), matching the loads. There is no sign of overload or phase imbalance, indicating that the DRUPS capacity is sufficient for critical loads. The power factor remains optimal, and the relay system operates without unwanted trips, demonstrating effective protection and control. This design ensures high reliability, providing comprehensive protection against PLN outages without disrupting operations, particularly for critical oil and gas units that cannot tolerate downtime. It is ideal for industrial facilities requiring continuous power supply and high stability.

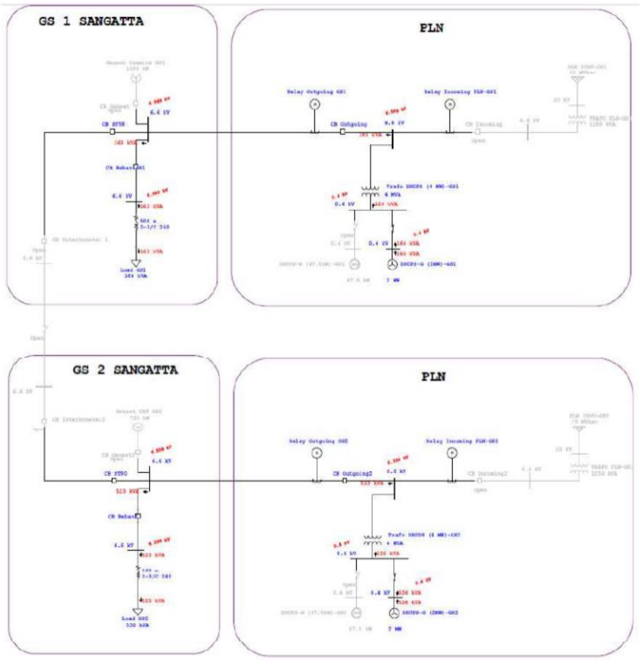

Fig. 6. ETAP Simulation Design for Normal Condition (PLN) - Sangatta

The detailed capital expenditure (CAPEX) required for the DRUPS implementation is presented in Table VIII, consisting of three main cost components: engineering, procurement, and construction and installation. Engineering activities include system design, project management, and on-site supervision, representing the initial technical preparation of the project. The procurement component constitutes the largest portion of the investment, covering major electrical equipment such as 20 kV and 6.6 kV switchgear, power transformers, medium-voltage cabling, fire protection systems, and supporting bulk materials. In addition, costs for PLN grid interconnection are included as part of infrastructure integration. Construction and installation expenses comprise physical installation works and certification for operational approval (SLO). The total investment cost derived from these components represents the initial capital outlay used as the basis for the subsequent economic feasibility analysis, including NPV, Benefit/Cost Ratio, and Profitability Index calculations. All cost estimates are based on vendor quotations, standard market pricing, and typical engineering implementation practices for industrial electrical infrastructure projects. The cost structure also reflects equipment capacity requirements, system redundancy considerations, and compliance with applicable safety and operational standards. Furthermore, the CAPEX distribution provides an overview of the primary cost drivers of the project, which are dominated by major electrical equipment procurement and grid integration works. This structured investment framework ensures that the economic evaluation reflects realistic implementation conditions and supports reliable long-term operational planning

Table 8. Cost Estimation of DRUPS Implementation in Sangatta Field

	Description	Qty.	IDR	Total (IDR)	Total (USD)
	Engineering				
1.	Engineering design	2	705,624,500	1,411,249,000	98,345
2.	Project management & supervision	2	197,000,000	394,000,000	27,456
			Total engineering work	1,805,249,000	125,801
Procurement					
1.	JTM network connection fee to PLN	1	1,425,260,000	1,425,260,000	99,321
2.	Switchgear 20 KV	2	1,115,000,000	2,230,000000	155,401
3.	SWGR 20kV & 6.6kV building	2	1,125,000,000	2,250,000,000	156,794
4.	Switchgear 6.6 KV	2	965,000,000	1,930,000,000	134,495
5.	Stepdown transformer 20kV/6.6V, 1250 kVA	2	870,000,000	1,740,000,000	121,254
6.	Medium-voltage cable 20 kV	1000	352,200	352,200,000	24,544
7.	Medium-voltage cable 6.6 kV	1500	647,000	970,500,000	67,631
8.	Fire protection system	2	235,167,800	470,335,600	32,776
9.	Bulk material	2	224,179,956	448,359,912	31,245
			Total procurement	11,816,655,512	823,460
Construction & installation					
1.	Construction & installation cost	2	786,669,000	1,573,338,000	109,640
2.	SLO sertification fee	2	100,000,000	200,000,000	13,937
	Total Construction & installation cost			1,773,338,000	123,578

The economic analysis of the project shows that DRUPS is feasible to implement, with a NPV calculation of IDR 473.36 billion, a Benefit/Cost Ratio of 58.61, and a Profitability Index (PI) of 4.57. These figures indicate that the project will provide significant economic benefits compared to the investment costs. From an investment theory perspective, particularly the capital budgeting approach developed by Brealey & et al. [17], projects with a positive NPV, a B/C ratio greater than one, and a PI above one is considered viable because they can create value for the company. Additionally, the use of DRUPS also reflects a sustainable power management approach, which not only emphasizes long-term cost efficiency but also supports the reduction of operational risks, carbon emissions from diesel-powered generators, and dependency on fuel supply. Therefore, the combination of technical advantages and financial feasibility makes this project a strategic model for transforming the electrical system in the upstream oil and gas sector into a more reliable, efficient, and sustainable system.

4. Conclusion

The implementation of Diesel Rotary Uninterruptible Power Supply (DRUPS) at Pertamina EP Zona 9 has significantly improved operational efficiency and power supply reliability. Data shows a 63% annual reduction in electricity operational costs, with a decrease in cost per kWh despite increased consumption, reflecting improved energy efficiency. The System Average Interruption Frequency Index (SAIFI) dropped from 10.1 to 6.6 incidents per month, indicating enhanced power supply reliability, while the transition time from blackouts was reduced, showcasing faster response to power disruptions. Economically, DRUPS offers strong investment feasibility, with a Benefit Cost Ratio (BCR) of 58.61, a Net Present Value (NPV) of IDR 473,356,926,788.13, and an Internal Rate of Return (IRR) of 117,18%, ensuring quick returns with a Payback Period of just one month. In simulations for Field Sangatta, DRUPS integration through a Step-Down GS#1 substation (Scheme 2) proved the most effective, reducing power disruption risks by 99%, improving voltage stability, and reducing voltage sag and harmonics. This option also demonstrated the highest NPV and fastest Payback Period, with savings exceeding Rp 100 billion annually and electricity costs dropping from Rp 2,622/kWh to around Rp 1,800–1,900/kWh, confirming that DRUPS is both a reliable and cost-effective long-term investment for supporting the region's oil and gas production.

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