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Evaluation of Electricity Supply System Selection at an Indonesian Upstream Oil and Gas Company's Power Plant Using the Ahp-Topsis Method to Improve Operational Performance in Oil Production Lifting

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ABSTRACT

The reliability of electricity supply systems is a critical factor in supporting continuous oil production operations in the upstream oil and gas industry, particularly for artificial lift facilities such as Electrical Submersible Pumps (ESP). Interruptions in electricity supply may lead to unplanned shutdowns, production losses, and operational inefficiencies. This study aims to evaluate alternative electricity supply systems for an upstream oil and gas company's power plant and develop an appropriate decision-making model based on technical, economic, and operational considerations. The study employed a quantitative decision-making approach using the Analytic Hierarchy Process (AHP) and Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) methods. Data were collected from operational reports, electricity supply alternatives, cost estimations, and expert assessments. The AHP method was applied to determine the priority weights of evaluation criteria, while TOPSIS was used to rank the available alternatives. The results indicate that cost was the most influential criterion in the decision-making process, followed by operational reliability, maintenance aspects, and failure impact. The TOPSIS analysis showed that the PLN electricity supply system integrated with Super Ultima service and Dynamic Rotary Uninterruptible Power Supply (DRUPS) achieved the highest preference value compared with other alternatives. This study contributes a structured evaluation model for selecting reliable electricity supply systems in upstream oil and gas operations. The proposed approach can support strategic decision-making to improve production continuity, operational resilience, and energy sustainability.

INTRODUCTION

The business processes of Indonesian oil and gas companies encompass integrated activities from upstream to downstream, beginning with oil and gas exploration and production activities in the upstream sector (Pieris & Widiarty, 2023). Figure 1 illustrates that the process of obtaining oil and gas production begins with exploration activities, including investigations of potential areas through geological surveys, geophysical surveys, and drilling methods. Following the exploration phase, development activities are conducted, and if the results are successful, production activities proceed. Oil and gas production originates from both onshore and offshore sources. The products derived from these exploration and production activities are subsequently processed in refineries to produce various oil and gas products. These processed products are then distributed and marketed through the downstream supply chain, which includes transportation, storage, distribution, and sales to end consumers. In their operational processes, Indonesian oil and gas companies have a vision of becoming energy companies that prioritize resilience, availability, and sustainability (Subagja, 2019; Mariana et al., 2024).

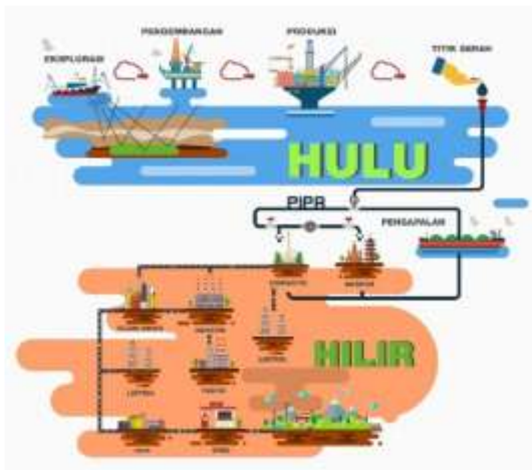

Figure 1. Flowchart of Oil and Gas Company Business in Indonesia from Upstream to Downstream (Source: SKK Migas Public Relations)

Indonesian upstream oil and gas companies are Cooperation Contract Contractors (Kontraktor Kontrak Kerja Sama [KKKS]) that conduct business activities in the upstream oil and gas sector, including exploration and exploitation. One of the fields operated by an Indonesian upstream oil and gas company is located in Bojonegoro Regency, East Java, and consists of SKW Pad A and SKW Pad B. The SKW field has two types of production wells, namely wells with natural flow and artificial lift systems, with total production of 9,200 Barrels of Oil Per Day (BOPD) of oil and 12 Million Standard Cubic Feet per Day (MMSCFD) of gas. SKW Pad A consists of three artificial lift wells and 11 natural flow wells, while SKW Pad B consists of seven artificial lift wells and 14 natural flow wells (Rendall et al. 2015; Rohadi et al. 2024; Simms et al. n.d.; Temizel et al. 2020).

In the oil production cycle of upstream oil and gas companies in Indonesia, the oil lifting process is an important stage because it enables production fluids from subsurface reservoirs and oil wells to be brought to the surface (Al-Ballam et al., 2022). The lifting process can occur naturally, known as Natural Flow, or through the use of mechanical assistance, known as Artificial Lift (Malatinszky & Marcu, 2022; Mahdi et al., 2024). The Natural Flow method is a condition in which reservoir fluids (oil, gas, and water) can flow naturally from the reservoir to the surface without the assistance of artificial lifting equipment. Meanwhile, the Artificial Lift method is a mechanical technique used to lift hydrocarbon fluids, particularly crude oil, from the wellbore to the surface (Mahdi et al., 2023). In addition, Artificial Lift serves as an artificial production enhancement method that assists in transporting well fluids to the surface by utilizing external mechanical energy (Hamdan Alibrahim, 2024). Examples of Artificial Lift applications at Pertamina EP include the Electrical Submersible Pump (ESP), Sucker Rod Pump (SRP), Progressive Cavity Pump (PCP), and several other technologies (Rahman & Kartohardjono, 2024; Wang, Zhuang, et al., 2025; Wang, Zhang, et al., 2025). Generally, in the implementation of Artificial Lift methods within Indonesian upstream oil and gas operations, electricity supply plays a critical role in ensuring the reliability and continuity of the oil lifting operation process (Petrochenkov, Lyakhomskii, et al., 2023; Petrochenkov, Ilyushin, et al., 2023; Song et al., 2024).

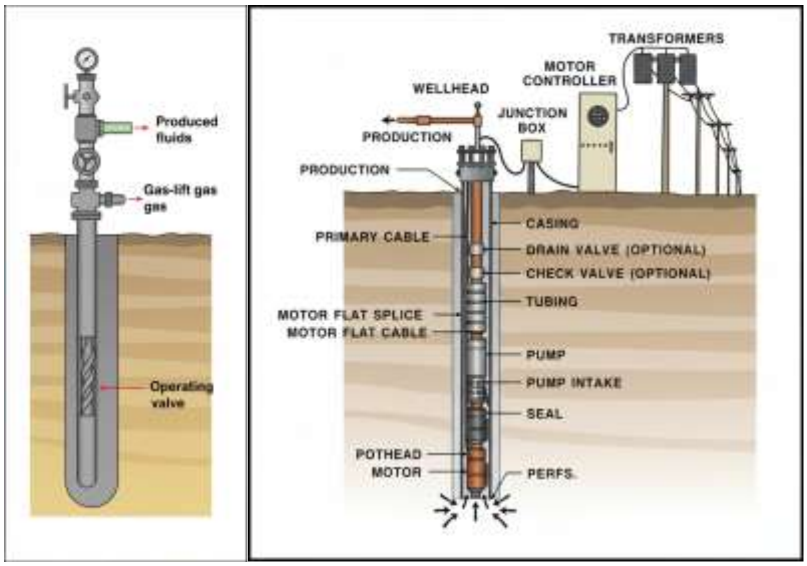

Figure 2. ***Natural Flow*** **and** ***Electrical Submersible Pump (ESP)*** **Methods (Clegg, J-1993– Image has been modified for the author)**

Based on data from SKK Migas in 2024, several challenges were identified in the operational processes of upstream oil and gas production, including emergency operation stoppages (Safety Stand Down), operational land permit issues, rig facility availability, unplanned shutdowns caused by pipe leaks and power supply disruptions, onstream project delays, extreme weather conditions, and other technical issues. One of the dominant problems was unplanned operational stoppages during the oil lifting process due to power supply disruptions, which generally occurred because of failures in power generation facilities or disturbances in the power grid supplying electricity to production areas. These disruptions caused critical equipment used in the oil lifting process, such as Electrical Submersible Pump (ESP) and Sucker Rod Pump (SRP) systems, to stop operating, resulting in decreased production rates or temporary production interruptions.

In every artificial lift well in the SKW field, the ESP system requires electrical power to operate the electric motor that assists in lifting oil and gas production fluids from the production well. During ESP operation, the electrical power supply is provided by a Diesel Engine Generator (DEG) installed together with a Variable Speed Drive (VSD) at each production well location. The DEG facility is provided by a third party (contractor) through a rental system due to the unavailability of permanent power generation facilities in the SKW Pad A and Pad B areas. The operation of DEG units requires high operational costs associated with fuel consumption for continuous 24/7 operation. In addition, DEG units require periodic maintenance intervals to ensure reliable operation, which may potentially lead to temporary production shutdowns. Under these conditions, alternative solutions are required to provide a reliable electricity supply capable of supporting continuous 24/7 operations. Based on several references, alternative electricity supply solutions include (i) DEG rental with operational redundancy, (ii) DEG investment, (iii) photovoltaic (PV) systems combined with a Battery Energy Storage System (BESS), (iv) connection to the Perusahaan Listrik Negara (PLN) power grid, and (v) a combined PLN and Dynamic Rotary Uninterruptible Power Supply (DRUPS) system.

In accordance with the company's vision of becoming an energy company that prioritizes resilience, availability, and sustainability, electricity supply system management oriented toward environmentally friendly technologies needs to focus on implementing energy solutions capable of reducing exhaust gas emissions, including CO (carbon monoxide), NOx (nitrogen oxides), SO_2 (sulfur dioxide), and CO_2 (carbon dioxide), improving operational cost efficiency, reducing production operational failures or Loss Production Opportunities (LPO), and ensuring sustainable electricity supply reliability (Ferlia et al., 2023). From a technical perspective, alternative electricity supply systems must be designed by considering durability, namely the ability of the system to withstand long-term operational and environmental conditions, as well as reliability, which focuses on maintaining uninterrupted electricity supply and minimizing disturbances such as voltage dips through the implementation of backup systems, including battery-based energy storage systems such as BESS (Battery Energy Storage System).

Gavade (2014) explains the theory of Multi-Criteria Decision Making (MCDM) and the effectiveness of various MCDM methods used to analyze problems and determine the most appropriate alternatives. Several methods discussed include (i) Analytic Hierarchy Process (AHP), (ii) Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), (iii) Vise Kriterijumska Optimizacija Kompromisno Resenje (VIKOR), (iv) Elimination Et Choix Traduisant la REalité (ELECTRE), and (v) Preference Ranking Organization Method for Enrichment Evaluation (PROMETHEE). Sánchez-Lozano et al. (2007) explained the determination of the most appropriate diesel engine component cleaning system by considering technical, economic, and environmental criteria using the Analytic Hierarchy Process (AHP) method as a multicriteria decision-making tool. According to Wong et al. (2011), AHP can accommodate decision-making processes involving multiple Subject Matter Experts (SMEs) or experts.

METHOD

This stage aimed to obtain references and theoretical foundations related to the research background. Information was collected from various sources, including academic journals, literature, and references related to the upstream oil and gas industry. Primary data consisted of information directly related to operational problems in upstream oil and gas companies, including unit reliability reports, operational failure reports, and unplanned shutdown reports. Secondary data were obtained from company records and other publications supporting the research, including PLN service proposals, Diesel Engine Generator (DEG) unit price quotations, and DEG rental offers.

In this study, the criteria weighting evaluation was conducted using the Analytic Hierarchy Process (AHP), in which the weighting process was performed through pairwise comparisons based on the Saaty scale. The collected and processed data were analyzed to determine the criteria and sub-criteria weights obtained from the AHP model, followed by simulations using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method in Microsoft Excel. The analysis evaluated the consistency values of the Consistency Index (CI) and Consistency Ratio (CR) to ensure that the results aligned with the evaluation criteria and actual field conditions.

RESULTS AND DISCUSSION

Technical Analysis

Based on the results of the AHP and TOPSIS methods, the PLN electricity supply system alternative with Super Ultima Service + DRUPS received the highest preference score. Technically, these results indicate that this alternative has the best ability to meet the need for a reliable, stable, and continuous electricity supply to support oil lifting operations in the SKW area.

In addition, ESP facilities also require a stable and continuously operating electricity supply, so the supply system needs to be protected from *trip conditions, voltage dips, undervoltage* and *blackouts* . In ESP facilities, power outages can cause pumps to stop operating and potentially be difficult to operate again. With the implementation of PLN with Super Ultima + DRUPS Services, these operational needs can be met, especially the existence of a back up or redundancy system, so the potential for production loss when the electricity supply is interrupted is very low.

Technically, the main advantage of the PLN Super Ultima + DRUPS alternative lies in the system's ability to maintain continuity of electricity supply when disruptions occur in the main grid. The DRUPS facility acts as a power buffer system that can respond quickly to voltage disturbances, thus minimizing the potential for *voltage dips, sags , and supply interruptions.*

When compared with other alternative solutions, there are several parameters that have limitations for each alternative solution. In the DEG rental or investment alternative, this alternative scheme has operational flexibility, but still depends on fuel, machine maintenance, operator readiness, and potential mechanical failures . In contrast, the PLTSS + BESS alternative has advantages from an environmental aspect, but has limitations due to weather factors, battery capacity, land requirements, and the complexity of BESS maintenance. Meanwhile, the PLN Premium Silver alternative, this system is simpler in terms of operation and maintenance, but still risks network disruptions, voltage dips, or conditions if the location is at the end of the feeder .

The decision results show that the selected alternative is not only superior in one aspect, but is a combination of several key technical parameters, such as technology reliability, power quality, system redundancy, availability, and recovery capability in the event of a disruption. Therefore, a power supply system capable of maintaining voltage stability and power continuity is crucial. An alternative solution using PLN Super Ultima + DRUPS is considered more suitable because it can minimize power supply disruptions that can directly impact ESP operations.

Based on its technical characteristics, this alternative selection model has the potential to be replicated in other upstream oil and gas areas that require continuous electricity supply, have critical production loads, and face the risk of production loss due to power outages. However, its implementation still needs to be adapted to the actual conditions of each location, such as load profile, PLN grid availability, energy sources, geographic conditions, and history of system outages.

Sensitivity Analysis

In this study, calculations and sensitivity analysis were conducted to ensure the consistency of the final decision chosen. The application of sensitivity analysis in this research Sensitivity analysis is conducted to test the stability and consistency of the final decision results. Through sensitivity analysis, changes in the weights of each criterion can be simulated in several scenarios, allowing for a clearer understanding of their impact on the ordering or ranking of alternatives. This analysis helps ensure that the selected alternative remains consistent when the assumed weights of the criteria change.

Sensitivity testing was conducted on the *Cost sub-criterion* , as this sub-criterion has the potential to experience changes in value due to the influence of external factors. Some factors influencing these changes include material prices, fuel prices, the rupiah exchange rate, and the dynamics of the developing economy, particularly in East Java. In this study, sensitivity testing was conducted with a deviation range of 10% to 30% with a testing interval of 5%. This testing aims to determine the extent to which changes in the cost sub-criterion can affect the assessment results, preference values, and the final ranking of each alternative solution.

Table 1. Simulation Value of Cost Subcriteria Sensitivity

Sub Criteria	Criteria Weight	+10%	-10%	+15%	-15%	+20%	-20%	+25%	-25%	+30%	-30%
Investment	0.086344782	0.095	0.078	0.099	0.073	0.104	0.069	0.108	0.065	0.112	0.060
Operational	0.280827854	0.309	0.253	0.323	0.239	0.337	0.225	0.351	0.211	0.365	0.197
Maintenance	0.051252419	0.056	0.046	0.059	0.044	0.062	0.041	0.064	0.038	0.067	0.036
Impact	0.581574945	0.640	0.523	0.669	0.494	0.698	0.465	0.727	0.436	0.756	0.407

Table 2. Rank Consistency Testing in Sensitivity Simulation

Subcriteria	+10%	-10%	+15%	-15%	+20%	-20%	+25%	-25%	+30%	-30%
Investment	3	3	3	3	3	3	3	3	3	3
Operational	2	2	2	2	2	2	2	2	2	2

Maintenance	4	4	4	4	4	4	4	4	4	4
Impact	1	1	1	1	1	1	1	1	1	1

Table 3. Sensitivity Weighting Calculation Values

Parameter	Criteria Weight	Min	Max	Difference in Value	Weight of Influence
Investment	0.086344782	0.060441	0.112248	0.051807	0.025903435
Operational	0.280827854	0.196579	0.365076	0.168497	0.084248356
Maintenance	0.051252419	0.035877	0.066628	0.030751	0.015375726
Impact	0.581574945	0.407102	0.756047	0.348945	0.174472483

The table above shows the magnitude of the change in the final score or criteria weight when each cost parameter changes in the sensitivity scenario. The goal is to determine which parameters have the greatest impact on the assessment results. In Table 3, the column labeled "influence weight" defines the maximum impact of the change on the initial weight. This value reflects the parameter's sensitivity level. The higher the influence weight, the greater the parameter's influence on the final result. The Impact parameter is the most sensitive, so small changes to it can have a relatively large impact on the final weight. Meanwhile, the Maintenance parameter has the lowest sensitivity, so changes to it have a smaller impact on the final result.

Economic Analysis

Based on the data references explained in the previous subchapter, the simulation of the economic value calculation will use the assumption of the analysis life of 10 years with the assumption of a discount rate of 10% per year. While the load usage data for each location uses the calculation simulation data, which is 468,000 kWH / month so that for the calculation of 2 locations (Pad A and Pad B) for 1 year is 11,232,000 kWH / year. In this study, the *Present Value Annuity Factor (PVAF)* value is 6.14457 based on the calculation of the analysis life value and the discount rate used.

In the *Life Cycle Cost Analysis* (LCCA) formula, the value of the impact of losses is specifically included in the category of Damage Costs or Risk Costs (*Failure Cost* / *Risk Cost*), generally the value of the impact of losses is merged or integrated into the Care & Maintenance Costs. *(Maintenance Cost)* especially in the unplanned */corrective maintenance section* . According to Ngapuli I. Sinisuka, Herry Nugraha (2013) lost production output (Lost Production Cost) is a loss due to the stopping of a machine/factory so that it fails to produce profits (*opportunity loss*).

Table 4. Simulation of *Life Cycle Cost Analysis* (LCCA) Calculation

Alternative Solutions	Investment Cost (Rp*10^6)	Operational Costs (Rp*10^6)	Maintenance Fee (Rp*10^6)	Cost of Failure Impact (Rp*10^6)	Total Value / year (Rp*10^6)
Alternative-1	46180	79020	651	3465	618,923
Alternative-2	78168	61740	1516	3465	537,824

Alternative-3	82801	11784	3301	2772	205,822
Alternative-4	46180	13716	651	691	149,932
Alternative-5	46180	18828	651	1	180,382

After obtaining the LCCA value for each alternative, a calculation simulation was carried out for *the Levelized Cost of Energy* (LCOE) method for each alternative solution.

Table 5. Simulation of *Levelized Cost of Energy* (LCOE) Calculation

Total energy power value per year	11,232,000 kWh		
Annuity Factor PV Value	6.88923		
PV Energy Value	77,379,776 kWh		
Alternative Solutions	**LCC (Rp*10^6)**	**Discounted LCOE (Rp / kWh)**	**Nominal LCOE (Rp / kWh)**
Alternative-1	618,923	7,999	11,513
Alternative-2	537,824	6,950	12,900
Alternative-3	205,822	2,660	8,962
Alternative-4	149,932	1,938	5,452
Alternative-5	180,382	2,331	5,846

If we refer to the calculation results in the table above, we can conclude as follows:

1. The lowest LCCA value was obtained by Alternative 4, namely PLN with Premium Silver Services
2. The lowest LCOE value was obtained by Alternative 4, namely PLN with Premium Silver Service

Thus, 4th alternative namely PLN with Premium Silver Services shows superiority in terms of life cycle cost efficiency and average energy costs .

Meanwhile, to determine the financial indicators related to the feasibility of this investment or alternative solution, *a Cost Benefit Ratio* (CBR) calculation was performed using reference data on the failure impact values of each alternative solution. In this simulation, the baseline reference data used the highest impact value, Alternative 1.

Table 6 Simulation of *Cost Benefit Ratio* (CBR) Calculation

Alternative Solutions	**Down Time Value (Rp*10^6)**	**PV Benefit (Rp*10^6)**	**PV Cost (Rp*10^6)**	**CBR**
Alternative-1	3465	0	595,051	0
Alternative-2	3465	0	513,953	0
Alternative-3	2772	4,774	186,725	0.0256
Alternative-4	693	19,065	145,157	0.1316
Alternative-5	1	23,864	180,375	0.1323

the Cost Benefit Ratio calculation , the highest CBR value was obtained by Alternative 5, namely PLN with Super Ultima + DRUPS Services. However, from the CBR calculation results, all alternatives have a CBR value below 1. This indicates that the calculated economic benefits, namely reducing the impact of electricity supply system failure, have not been able to cover the total investment, operational, and maintenance costs during the analysis period. Thus, if the assessment is only based on direct financial CBR indicators , then the electricity supply system alternative cannot be categorized as financially feasible to be implemented in the SKW area, Bojonegoro . However, the decision to select an electricity supply system is not only determined by direct financial aspects, but also needs to consider strategic operational needs if the electricity supply system is needed to maintain production continuity, reduce the risk of critical failures, meet reliability standards, or protect high-value production processes.

Replication Potential

In this study, an analysis was conducted regarding the potential replication of AHP + TOPSIS modeling for a similar problem, namely regarding the selection of electricity supply systems in upstream oil and gas production areas in Indonesia. This is because the AHP + TOPSIS method is able to accommodate various criteria and sub-criteria that are technical, economic, operational, and environmental in a structured manner. By compiling a clear decision hierarchy, this method can be used to compare several alternative solutions based on the level of importance of each parameter relevant to operational needs.

Referring to the data in Table 2, the distribution of implementation data for each alternative solution in Indonesia's Upstream Oil and Gas sector is known. Based on the data grouping, several potential areas, such as the Cepu location in Central Java and Tanjung in South Kalimantan, have similar patterns of electricity supply system implementation. Based on the survey results, it is known that the Kawangan area, Cepu, in Central Java, previously operated a *Diesel Engine Generator* (DEG)-based power plant. In its operational process, the power plant uses *its own facilities,* type 3512 DEG with a capacity of 1200 kVA per unit with a configuration of 2 operating units + 1 standby unit. The power plant has a track record of significant operational production failures when disruptions occur in the DEG unit, especially under *voltage conditions* **.** These disruptions impact the operation of the Sucker *Rod Pump (SRP)* **,** which has the potential to become *stuck* , causing the production operation to stop. In addition to the use of DEG, the implementation of PLN Premium Silver Services has also been carried out in the area. However, in its operational practice, this service still experiences several obstacles when there are disruptions to the electricity network, such as voltage *swings and voltage drops* . This condition is influenced by the position of the Kawengan area which is at the end of the electricity network from the feeder substation. As an effort to improve the reliability of the electricity supply system, in 2022, the PLN Super Ultima Service + DRUPS was installed with a capacity of 2 Mega Watts, where the DRUPS configuration used is 2 units x 1 Mega Watt. This implementation is expected to improve power quality, maintain continuity of electricity supply, and minimize the risk of operational disruptions at production facilities.

Figure 3. DRUPS facilities at the Kawengan Power Plant, Cepu Area

In addition to the Kawengan location in Cepu, Central Java, problems with the electricity supply system also occurred at the Tanjung location in South Kalimantan. The Tanjung power plant operates using *its own facilities. Gas Turbine Generator* (GTG) product Solar Turbine Centaur 40 with a capacity of 3.75 Mega Watts per unit, and *Gas Engine Generator* (GEG) product Caterpillar Cat G3520 - Dual Fuel with a capacity of 2 Mega Watts per unit. The operating configuration used is 3 operating units + 1 standby unit. Unlike the Cepu and Sukowati areas which previously operated with DEG, the main problem in Tanjung is related to the limited availability of gas fuel. In its operation, the power plant in Tanjung uses *Compressed Natural Gas (CNG)* sent from PT Badak LNG Bontang, and utilizes associated gas from the operating process.

However, in practice, delays in CNG deliveries from Bontang to Tanjung are one of the factors that reduce the operational reliability of GTG and GEG. These conditions require operators to combine fuel sources with associated gas. However, the quality of this associated gas falls below the minimum requirements for the GTG unit. Furthermore, the GEG unit also uses diesel fuel as an alternative when gas supplies are insufficient. This situation indicates that dependence on the natural gas fuel supply chain can be a risk factor in maintaining the continuity of the electricity supply system. In an effort to improve the reliability of the electricity supply system, PLN installed Super Ultima Service + DRUPS with a total capacity of 10 Mega Watts in 2020. The DRUPS configuration used consists of 5 units, each with a capacity of 2 Mega Watts. The implementation of PLN Super Ultima Service + DRUPS in the Tanjung area is the first application of this service for the upstream oil and gas industry. Based on survey data from engineer respondents in Tanjung, the operation of PLN's Super Ultima Service + DRUPS can potentially generate savings of up to Rp 120 billion per year. This successful implementation has become a benchmark for similar applications in other operational areas, such as Sukowati and Cepu.

Figure 4. DRUPS facilities at Tanjung Power Plant, South Kalimantan

CONCLUSION

The alternative PLN electricity supply system using the Super Ultima service combined with DRUPS was selected as the best solution based on the technological availability and operational conditions in Indonesia. The evaluation results showed that this alternative achieved the highest preference value compared with the other alternatives, indicating that it was the closest option to the ideal solution based on the criteria and subcriteria established in the study. Based on the simulation results using the Analytic Hierarchy Process (AHP) method, the Cost parameter ranked first with a weight value of 0.575 and demonstrated consistency. This result indicated that cost was the most dominant criterion in evaluating alternative electricity supply systems. The cost aspect, including investment costs, operational costs, maintenance costs, and potential losses caused by system failures, became the primary consideration in the decision-making process.

Furthermore, based on the simulation results using the Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) method, the highest-ranked alternative was Alternative 5, namely the PLN electricity supply system with Super Ultima service combined with DRUPS. Based on the analysis using the AHP-TOPSIS method, the PLN electricity supply system with Super Ultima + DRUPS was considered capable of supporting oil production lifting operations in the Indonesian upstream oil and gas industry, particularly those utilizing the Electrical Submersible Pump (ESP) method, with higher reliability and continuity. This capability was attributed to the high reliability level of the electricity supply system and the availability of redundancy and backup mechanisms. The implementation of this system minimized potential production losses caused by power supply failures. In addition, the continuity of ESP operations was better maintained, thereby improving the sustainability and optimization of oil production activities.

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