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Comparative simulation analysis of the economics of unit commitment to determine the cost of supplying electricity in simple generating systems in the Bengkulu region

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Abstract: An efficient electrical system is essential to meet the energy needs of the community without incurring high operational costs. This study aims to compare the total operational costs of power plants during three extreme time periods: low load (00:00–05:00), medium load (06:00–18:00), and high load (19:00–23:00), and to determine the most efficient combination of power plants using the Unit Commitment (UC) method based on priority list techniques. The study was conducted on the Bengkulu regional power system with the assumption of zero startup costs due to data limitations. Simulation results show that coal-fired power plants (IPP), hydroelectric power plants, and micro-hydro power plants serve as the base load power plants that are always active due to their low operational costs, while diesel power plants are only used as supplements when load exceeds the capacity of the main power plants. The lowest total operational cost occurs during low-load periods at Rp 40,936,446/hour, while the highest cost occurs during peak-load periods at Rp 65,040,329/hour. This finding confirms that optimizing the combination of power plants based on cost efficiency can significantly reduce operational expenses. In the future, it is expected that the electricity system can adopt smart grid technology to reduce, even eliminate, the use of inefficient diesel power plants.

Keywords: electrical system; unit commitment; priority list; operating costs

1. Introduction

Electricity is a vital element in life. Electricity plays an important role in various aspects of life, both in the household environment and public facilities. The availability of reliable and sufficient electricity is the main support for various activities, both in domestic, office and industrial environments. Electricity is a form of energy that is very important and inseparable from everyday life (Ngafifi, 2014). Therefore, the management of the power generation system must be done as efficiently as possible so that the cost of electricity production can remain low but the fulfilment of community needs can take place safely and stably. Almost all devices and supporting needs in people's lives today depend on electrical energy as a driving source, this has an impact on the continued increase in electricity consumption from year to year (Oktaviani et al., 2019).

In an electricity system, power plant regulation is not just about turning on or off the engine. The main priority is to determine the time and amount of power required from each plant to be supplied to the system. To support this decision making, in the world of electricity, a commonly used method is Unit Commitment (UC). Constraints in a Unit Commitment (UC) model capture the fundamental features of a power system, although the specific constraints and characteristics incorporated can differ depending on the model formulation (Wuijts et al., 2024). Concluded that the main challenge in is maintaining economic and operational stability in the power system under high demand conditions (Aryani et al., 2025). This study proposes a novel and comprehensive approach to the Unit Commitment (UC) problem by addressing uncertainty through a real-time data-driven sequential decision-making process. By introducing a robustness level variable controlled by a double Q-learning algorithm, the model enables adaptive and efficient UC solutions (Jiménez-Cordero et al., 2022). The unit commitment (UC) problem is solved daily by the Independent System Operator (ISO) to determine the operating status and production level of each plant, with the aim of minimizing the total cost of power system operations while meeting load demand constraints, reserve requirements, transmission capacity, regional constraints, and technical constraints of generating units (Raghunathan et al., 2022).

Unit commitment is the process of scheduling the on and off operation of power generation units in the power system over a period of time. It is this scheduling process that can minimize the cost of electricity generation over a predetermined period of time. Over the past century, the Unit Commitment Problem (UCP) has remained a significant topic along with various developments and transformations in the electricity industry. These changes are influenced by environmental policies, restructuring and privatization of the electricity system, increasing penetration of renewable energy (RE), as well as the emergence of smart grid technologies, which overall have led to high dynamics and uncertainty in power grid operations (Torto et al., 2024). Montero et al., (2022) state that the Unit Commitment (UC) problem is a traditional form of optimization used to develop the most efficient operating schedule for a group of thermal generation units. In providing electricity there are three major processes which are power generation, transmission and distribution (Setiawan et al., 2021). Adjustments to unit commitment in the second stage can be made to flexible generation resources to accommodate the intermittent nature of renewable energy (Wang et al., 2023).

Unit commitment is an important schedule procedure in power system daily operations, and an ideal version is to combine the unit commitment with the optimal power flow, thereby, it achieves an AC-power-flow-constrained unit commitment problem, which is referred to as the AC unit commitment (Shao et al., 2023). Sakhavand et al., (2024) explained two separate variables to represent the amount of generation in the Unit Commitment (UC) problem, so that all the necessary information can be accommodated more precisely. (Raghunathan et al., 2022) explained power system operations, optimization problems such as economic dispatch and unit commitment are considered very crucial. The purpose of this method is to regulate when a generator must be operated (on) or stopped (off) within a certain period, in order to reduce operational costs as low as possible while still meeting load demands and system constraints. Unit commitment study has to determine the most optimal on / off schedule of the generating unit (Aryani et al., 2025). The Bengkulu region is one of the areas that continues to show growth in electricity demand from year to year, this is reflected in the peak load data that continues to rise. The increasing integration of renewable energy sources in today's power systems requires that unit commitment problems be solved repeatedly within a short time span, so that operational decisions can be adjusted quickly to changing system conditions (Jiménez-Cordero et al., 2022). Zhang et al., (2023) explained Frequency stability constraints in the unit commitment process need to be considered to obtain a safer operation plan due to renewable energy sources. Increasing the proportion of electricity from variable renewable energy sources (VRE) increases the power storage (PS) benefits, with the magnitude of the increase depending on the composition of the electricity generation used (Chyong & Newbery, 2022).

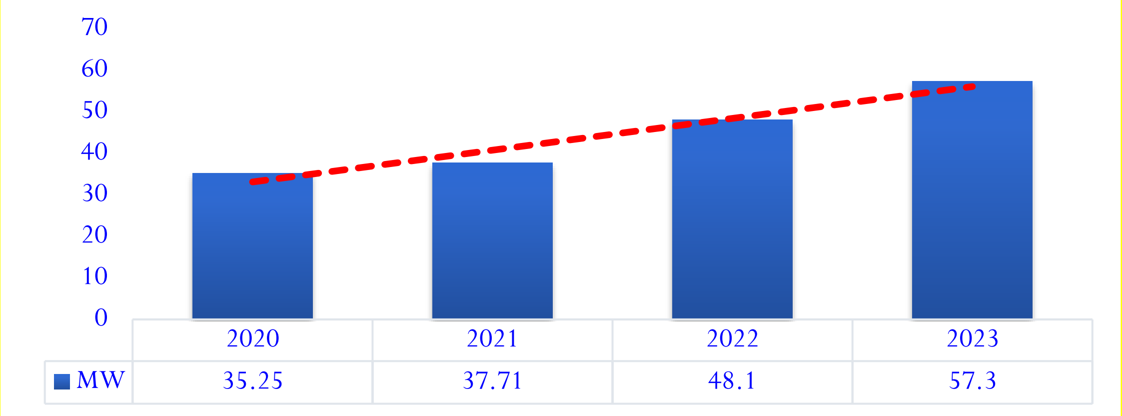

Figure 1. Bengkulu electricity load growth (PLN, 2023)Figure 1.1 Bengkulu electricity load growth (PT PLN (Persero), 2023)

This increase in load indicates an increase in economic activity and an increase in the number of customers in Bengkulu, therefore the electricity system needs to be designed more efficiently. The electricity system in this region is supported by Diesel Power Plants (PLTD), Minihydro Power Plants (PLTM), Micro Hydro Power Plants (PLTMH) and also plants from the private sector or Independent Power Producer (IPP) (PT PLN (Persero), 2023). The increasing deployment of wind and solar power plants is gradually displacing conventional synchronous generators in the power system, leading to a significant reduction in system inertia (Tuo & Xingpeng, 2023). Diesel Power Plant (PLTD) is a type of power plant that is characterized by considerable operational costs, due to its dependence on fossil fuels. Therefore, managing the plant's operating schedule is very important so that its production costs do not swell. Valdmanis & Bazbauers, (2020) explained that Given that wind and solar power plants do not rely on fuel, emit no greenhouse gases during operation, and continue to improve in terms of technological efficiency, many policymakers consider them among the most promising sources of future energy.

However, access to up-to-date plant technical data is often limited. This makes it difficult to directly analyse the current system. As a follow-up, this research is designed in the form of a simulation of a power generation system based on Diesel Power Plants (PLTD), Micro Hydro Power Plants (PLTM), Micro Hydro Power Plants (PLTMH) and Steam Power Plants (PLTU) which are under private ownership or Independent Power Producer (IPP), and are considered to represent the general situation in Bengkulu. The Unit Commitment Method with a Priority List approach will be used in this simulation, and the results compared at three time periods in a day, namely during low load, increasing load towards peak, and high load, based on total operating costs. With this approach, it is expected to see the lowest cost based on the load of the time period. With the reforms in the energy structure, the high proportion of volatile new energy means that the conventional Unit Commitment (UC) theory is no longer able to meet the needs of day-ahead market decision-making in the new power system (Huang et al., 2023). Production costs generally include start-up costs, no-load costs, and additional energy costs that are typically modeled using a multilevel linear function (Yang et al., 2022). Ponciroli et al., (2020) examined the complexity of solving Unit Commitment and Economic Dispatch problems is increasing due to the deployment of new technologies, the need for more accurate dynamic modeling of generating units, and the emergence of new policies. Lumbreras et al., (2024) concluded that the Unit Commitment (UC) problem involves many linear relationships, both full and incremental, which cannot be effectively represented using conventional decision trees, as each node in such trees is only associated with a particular value of a variable. In contrast, linear regression trees are able to represent linear relationships in the context of specific variables. This approach allows the extraction of richer information compared to standard decision trees, without having to sacrifice the interpretability of the model. Power system operation strategies have shifted from a focus on cost minimization to considering emission minimization, as concerns about global warming and the environmental impacts of burning fossil fuels grow (Singh et al., 2024).

2. Methods

2.1 Place and time of research

This research is conducted in simulation and does not involve direct data collection from the field. The reference location of the system is the Bengkulu region, which generally uses Diesel Power Plant (PLTD), Minihydro Power Plant (PLTM), Micro Hydro Power Plant (PLTMH) and also plants from the private sector or Independent Power Producer (IPP).

2.2 Research design

This research is descriptive quantitative research conducted through a numerical simulation approach. The goal is to compare the total operational cost of the power plant system at three extreme time periods in one day, namely the time period at low load, the load starts to rise towards the peak, and at high load based on the total operational cost, and will be simulated using the Priority List Method.The simula tion is carried out with assumption data based on the general characteristics of the Diesel Power Plant (PLTD) system, Minihydro Power Plant (PLTM), Micro Hydro Power Plant (PLTMH) and also plants from the private sector or Independent Power Producer (IPP), as well as system loads that are regulated on an hourly basis where start-up costs are not calculated or considered zero, due to data limitations.

2.3 Data collection method

The data used in this research consists of:

1. Literature study: referring to scientific journals, electric power engineering textbooks, and PLN Statistical report Year 2023 to understand the characteristics of power plants and electricity systems in Bengkulu region.
2. Secondary data: data taken from official sources such as PLN's RUPTL report, journals, reference books, and government websites related to energy.
3. Assumption data, i.e., data compiled by ourselves based on technical logic and previous references, such as the amount of electricity load per hour, generating capacity, and operating costs of each type of generator.

2.4 Data analysis method

To simplify the simulation, the generation system is simplified to consist of only 4 units, as presented in Table 1.

Table 1. Bengkulu Region Generating System (PLN, 2023)

Type of generator	Installed power (MW)	Capability (WM)
PLTD	35,97	20,77
PLTM	1,00	0,50
PLTMH	0,60	0,40
PLTU (IPP)	41,62	40,92

Each plant will have a specific capacity and operating cost per megawatt-hour (MWh). The system load is set for 24 hours with a peak load of 57.30 MW (PLN, 2023), with fluctuating variations to resemble real conditions. In this study, the electricity system was analyzed based on three categories of load conditions, namely low load, medium load, and high load. To determine the boundaries of each load category, the Equal Interval Classification approach is used.

$$\text{load range} = \text{peak load (MW)} - \text{lowest load (MW)} \tag{1}$$

$$\text{load interval} = \text{load range}/3 \tag{2}$$

Equal Interval Classification is a statistical classification method that divides a range of data into classes with the same distance or difference between classes. This approach is often used in grouping continuous numerical data, as it is considered simple and able to provide an objective division, especially when the data does not have extreme distributions. By using this classification, the Unit Commitment simulation can be performed more systematically according to realistic load conditions. Each category represents the electricity load conditions at certain times that will be further analyzed in the operational cost calculation simulation.
The following are the general steps taken in this research:

1. Determining daily load data for 24 hours.
2. Running the Unit Commitment simulation, which determines when the generator starts or stops.
3. Comparing the total cost at three extreme time periods in one day, i.e. at low load, load starting to rise towards peak, and at high load based on its total operational cost and see which one is more efficient.

Simulations were conducted using Microsoft Excel to calculate and present results in a simple manner. This research is considered successful if it is able to:

1. Develop a reasonable simulation of the generating system.
2. Display the results of the Unit Commitment simulation, which determines when the generator starts or stops.
3. Provide a simple conclusion about the total cost at the three extreme time periods in a day which is more efficient under simulated conditions.

3. Results

After simulating the load on the electricity system in the Bengkulu region, the analysis focused on the peak load of 57.30 MW recorded at 19:00 WIB. This time was chosen as it represents an extreme condition where energy demand is at its highest in a single day. The simulation was conducted using the Unit Commitment approach, where the selection of generating units to operate is determined based on the order of the lowest operational cost until the total load demand is met. In this simulation, data from various types of generators available in the region, such as PLTD, PLTM, PLTMH, and PLTU (IPP), are used, taking into account the minimum and maximum power limits of each unit. Start-up costs are assumed to be zero due to data limitations, so the focus of the calculation is only on operating costs when the unit is running. The simulation results show the combination of generating units that are active during peak load hours, as well as the total operating costs required to meet the load of 57.30 MW. This finding is the basis for comparison with simulations at other times to find the most efficient generation combination pattern.

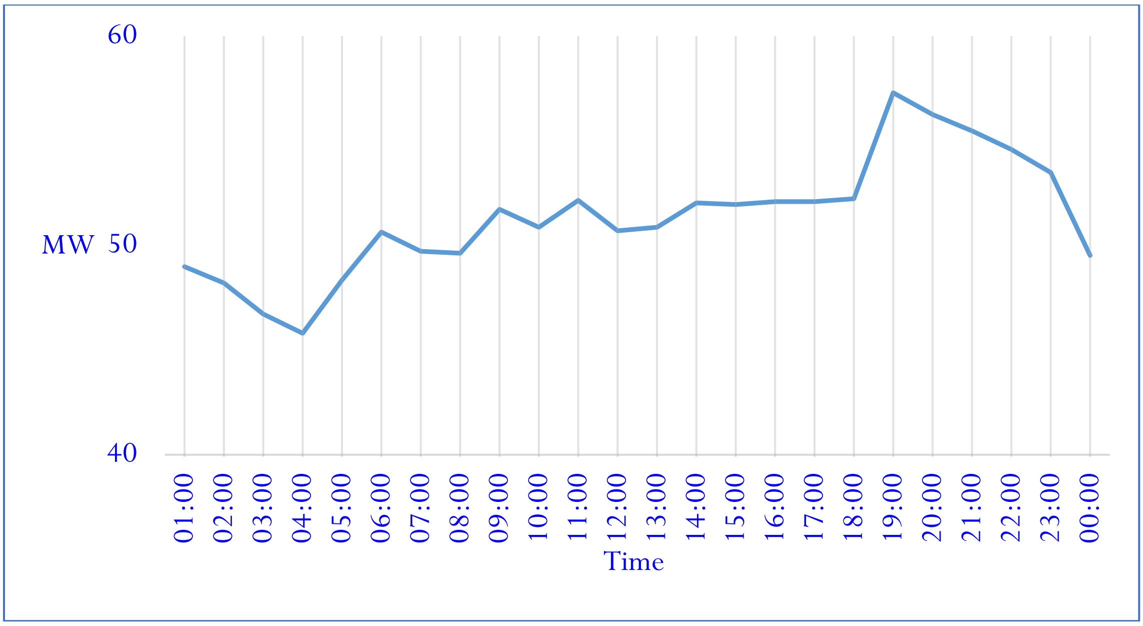

Figure 2. Simulation graph of Bengkulu region load demand

Based on observations of the daily load simulation graph in the Bengkulu region electricity system, it can be seen that the load pattern fluctuates quite clearly throughout the day. The lowest load occurs at around 04.00 in the morning, where community and industrial activities are still very minimal. Based on daily load data, the lowest load is around 45.81 MW. Since the load trend has started to decline since midnight and reaches its lowest point, this is considered as the minimum load period (off-peak load). at this time community activity is very low, both in the household and industrial sectors. the majority of the load only comes from basic needs such as lighting, electronic devices that remain on, and minimum operational loads from the public service sector (such as hospitals, communication networks, etc.).

Starting at 06.00 the load increases. At this time the community begins to carry out activities in the household sector and at 14.00 to 18.00, the electricity system load shows a trend that tends to be stable, but slowly begins to increase along with the increase in community and commercial sector activities in the afternoon to evening. During this time, the load tends to be at an intermediate level, meaning that it has not yet reached peak load, but it is already much higher than the load in the early morning or morning. This increase reflects the activities of offices, shops, public facilities, as well as air conditioners and other electronic equipment that begin to be actively used simultaneously.

The peak load occurs at 7 p.m., which is when people generally start returning home after a long day of activities. During this period, electricity consumption increases sharply as various household appliances are used simultaneously, such as lighting, televisions, air conditioners, water heaters, and other electronic devices. This reflects the surge in energy consumption in the household sector, which is the main contributor to the peak load at night. In addition, some commercial activities and public facilities are also still operating into the night, adding to the load on the electricity system. As people's activities decrease, the load decreases again and some backup generating units can be deactivated to save operational costs. To obtain the boundaries of each load category, the Equal Interval Classification method was used, which is a classification approach that divides the load range evenly into three equal intervals. This method was chosen because it is considered simple, objective, and in accordance with the characteristics of daily load data that tends to be continuous, hence obtained.

Table 2. Load period categories

Category	Load (MW)
Low load period	0-49.64
Medium load period that starts to rise gradually	49.65-53.47
High or peak load period	53.48-57.30

Based on the division of load categories and the determination of time periods for each condition (low, medium, and high load), the calculation of the average actual load in each period is carried out. This calculation aims to get a representation of the electrical power that the system really needs at each time span, so that the Unit Commitment simulation results can reflect realistic and relevant operational conditions. The average load values are calculated from the power demand data during the hours included in each category, and are presented in the following table 3.

Table 3. Loading time period

Time	Average Load (MW)	Description
00.00 – 05.00 Morning	47.94	Low load period
11.00 – 18.00 Day	51.29	Medium load period that starts to rise gradually
19.00 – 22.00 Night	55.43	High or peak load period

Each of these periods is analyzed using the Unit Commitment approach to see which combination of generating units operates and what the total costs incurred are. The ultimate goal is to find out at which time conditions the generating system works most efficiently in terms of cost and generation arrangement. The total generation cost of a power system is determined by summing the products of each unit's generation cost and its corresponding energy output (Setiawan, 2023).

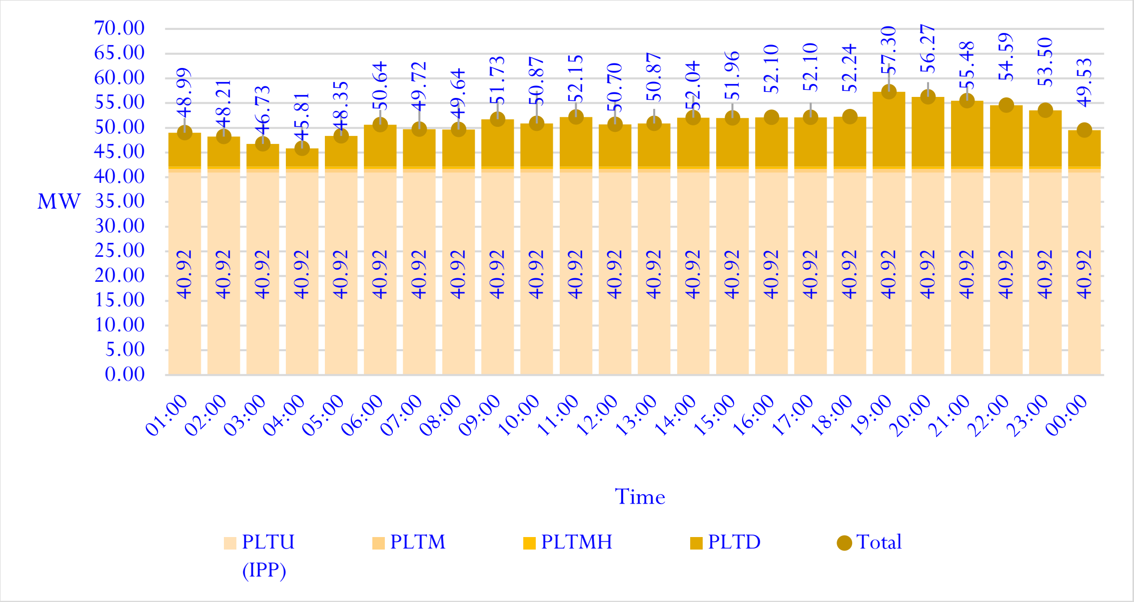

Figure 3. Scenario of unit comitment of Bengkulu region power plant

Judging from the simulation results of the Unit Commitment scenario in the low load period, namely between 00.00 to 05.00 in the morning, it can be seen that the generation system in the Bengkulu region tends to utilize the plant with the lowest operating cost. In this condition, the system load is served first by the most economical plants, namely PLTM (Pembangkit Listrik Tenaga Minihidro), PLTMH (Pembangkit Listrik Tenaga Mikrohidro), and plants from IPP (Independent Power Producer) which in this study is assumed to be PLTU. These three types of plants are able to supply a total power of 42.17 MW, or about 92.1% of the total load demand at that time. Since the total power from the MHP, MHP, and IPP is still insufficient to cover the entire load, the rest is fulfilled by several PLTD (Diesel Power Plant) units installed in the Bengkulu electricity system. The selected PLTD units are those with the lowest operating cost per kWh, so that the combination of plants remains cost-efficient. The utilization of a limited number of PLTD is done only to cover the difference between the total load and the power supplied by the main generator. This approach reflects an effort to optimize the combination of plants so that the system remains reliable and costs remain minimal. Therefore, the short-term optimization of dispatchable power plants—including fossil, hydro with reservoirs, renewables with storage, and virtual power plants—must account for both the day-ahead and grid balancing markets (Fusco,2023)

Between 6:00 a.m. and 6:00 p.m., the system load begins to increase compared to the early morning load. Based on the simulation results, it is observed that the load remains relatively stable but is higher than during the low-load period, thereby requiring additional power from more generating units. PLTM, PLTMH, and IPP (PLTU) remain the primary generating units in operation due to their lowest operational costs. The maximum power they can supply remains at approximately 42.17 MW, consistent with the previous period. However, since the total load demand during this hour exceeds 42.17 MW, the number of diesel power plant (PLTD) units in operation also increases. PLTD units are selected based on a list of the cheapest costs, ensuring operational cost efficiency. Generally, PLTD is used as additional power support to cover shortages from main power plants, but remains within the minimum and maximum capacity limits of each unit. At 7:00 p.m., Bengkulu's electricity system reached its peak load, with a maximum value of around 57.30 MW. This high power demand required the system to operate the largest number of power plants compared to other periods. PLTM, PLTMH, and IPP remained the backbone of supply due to their efficiency, but the number of PLTDs activated increased significantly to meet the additional power demand. The selection of diesel power plants (PLTD) is still based on the lowest to highest cost priority. Some PLTD units that were previously not used during low and medium load periods began to be activated. This indicates that the system relies on a combination of cost-effective power plants for base load needs and adds higher-cost power plants only when absolutely necessary, such as during peak load periods.

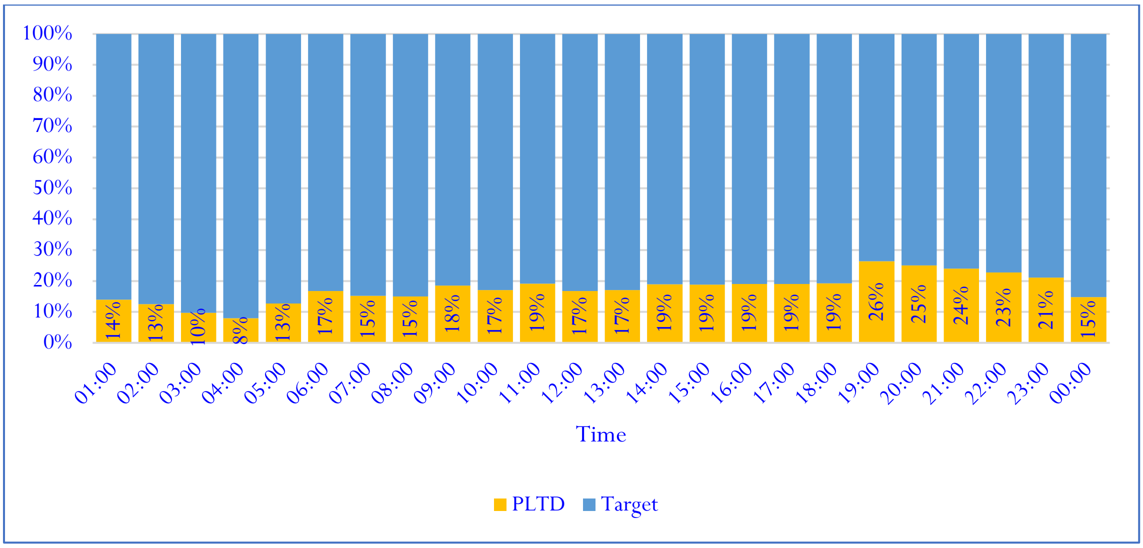

Figure 4. PLTD unit commitment scenario in Bengkulu based on total demand (%)

Based on the total load demand occurring in a single day, calculations were performed to determine the percentage contribution of the PLTD power plant to the total power supply of the electrical system in Bengkulu at each hour. The results of this analysis indicate that the PLTD only supplies approximately an average of 17% of the total average load demand per hour. This percentage indicates that PLTD is not the primary power source but is used as a backup or reserve generator, especially when load begins to increase and power from primary generators (such as PLTM, PLTMH, and IPP) is no longer sufficient. The relatively low use of PLTD aligns with its characteristic of having higher operational costs, so the system automatically prioritizes generators with lower costs. Additionally, this also indicates that the power plant operation strategy in the Bengkulu region is quite efficient, as it relies more on cheaper resources and activates PLTD only when truly necessary. The presence of PLTD in the system primarily serves as a gap-filler to maintain system reliability, not as a base load.

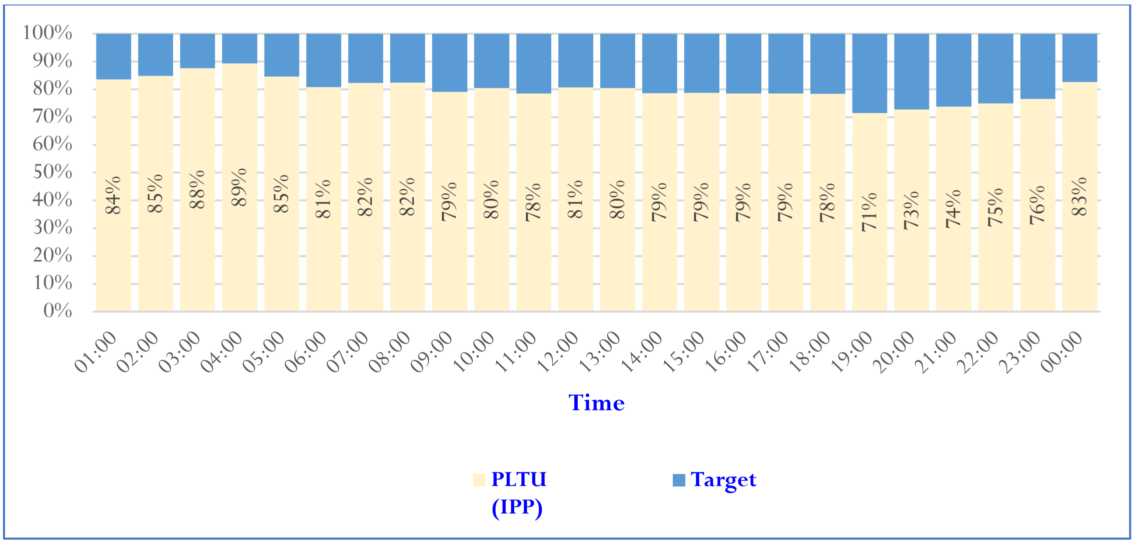

Figure 5. PLTU (IPP) unit commitment scenario in Bengkulu based on total demand (%)

Based on the recorded total daily load demand, an analysis was conducted to determine the contribution of power supplied by PLTU (IPP) to the overall load of the electricity system in Bengkulu every hour. The calculation results show that on average, the PLTU (IPP) supplies around 80% of the total hourly load demand. This indicates that the PLTU (IPP) plays a very dominant role in the system, functioning as the main power supplier (base load) that is relied upon throughout the day. Security-Constrained Unit Commitment (SCUC) has been widely studied as a key decision-making tool in determining the optimal generation schedule in electricity market operations (Yang et al,2022).

This high contribution is due to the PLTU's large and stable power capacity, as well as its relatively low operational costs compared to PLTD. Additionally, PLTU (IPP) has technical characteristics suitable for continuous operation over the long term, making it highly ideal for supplying the system's base load. With the consistent power provided by PLTU (IPP), other power plants such as PLTM, PLTMH, and PLTD only need to be activated as supplements or reserves when the load exceeds what PLTU can handle. This situation also reflects an efficient operational strategy, where the system relies more on low-cost power plants to supply the main load and reduces dependence on high-cost power plants. This is crucial in efforts to reduce the total operational costs of the system and maintain the stability of electricity supply in the Bengkulu region.

Table 4. Average power supply by power plant type

Type of plant	Average (MW)	Average (IDR)	(IDR/MW)
PLTU (IPP)	40.92	24,161	590,43
PLTM	0.75	671	895,21
PLTMH	0.50	595	1.190,19
PLTD	9.14	26,127	2.857,52

Based on the analyzed table data, the average power supply values for each type of power plant operating in the Bengkulu electricity system were obtained. The PLTU (IPP) contributes the most with an average power of 40.92 MW, indicating its role as the backbone of the system or the main base load supplier. On the other hand, hydroelectric power plants (PLTM) and micro-hydroelectric power plants (PLTMH) contribute relatively small but stable amounts, at 0.75 MW and 0.50 MW, respectively. Despite their small capacity, these power plants are still utilized due to their low operating costs and reliance on renewable energy, making them ideal for use under low to medium load conditions. Adi, T. W(2023) found that fuel prices have a significant positive effect on electricity prices and operating costs, while their effect on production and net profit is different. Meanwhile, diesel-based power plants (PLTD) only supply an average of 9.14 MW per hour, or approximately 22% of the power supplied by coal-fired power plants (IPP).

The use of PLTD is supplementary, serving to cover power shortages when demand exceeds the capacity of the main power plants. This strategy is highly rational because the operational costs of PLTD are significantly higher, at around Rp 2,857.52 per MW, compared to PLTU (Rp 590.43/MW), PLTM (Rp 895.21/MW), and PLTMH (Rp 1,190.19/MW). This means that diesel power plants are nearly five times more expensive than coal-fired power plants, so their use is minimized to avoid cost escalation. However, Adi, T. W (2024) concluded Fossil electricity consumption has a negative effect on GDP, while renewable electricity consumption has a positive effect on GDP. In addition, renewable electricity consumption has an insignificant impact on inflation and greenflation. This comparison clearly shows that Bengkulu's electricity system has been directed toward maximizing low-cost power plants such as coal-fired power plants and renewable energy, while reducing dependence on expensive diesel power plants. This composition also reflects the implementation of an efficient Unit Commitment strategy, where the combination of power plants is arranged based on the order of lowest operational costs, while still considering the minimum and maximum capacity limits of the units.

4. Discussion

In the early hours of the morning, the system load was at its lowest point, averaging 47.94 MW. This load was mostly met by low-cost power plants, namely the IPP coal-fired power plant supplying an average of 40.92 MW, the hydroelectric power plant supplying 0.75 MW, and the micro-hydro power plant supplying 0.5 MW. The remaining power requirement of 5.77 MW is met by diesel power plants (PLTD), selected from the cheapest units. Since the share of PLTD is relatively small during this period, the total operational cost is the lowest among the three periods, at Rp 40,936,446 per hour. This strategy demonstrates high efficiency, as the system only activates PLTD when absolutely necessary.

From morning to afternoon, the load increases to an average of 51.29 MW. The coal-fired power plant (PLTU), hydroelectric power plant (PLTM), and hydroelectric power plant with pumped storage (PLTMH) continue to operate at full capacity, but an additional 9.12 MW must be supplied by diesel power plants (PLTD). Since more PLTD units are activated compared to the morning period, operational costs increase to Rp 51,267,121 per hour. Nevertheless, the system prioritizes efficiency by first utilizing PLTDs with lower operational costs. This increase in costs is a logical consequence of the rising load, even though the main power plants remain at maximum capacity. At night, the system faced a peak load of 55.43 MW on average, the highest in a single day. The coal-fired power plant, hydroelectric power plant, and micro-hydro power plant were still operating at maximum capacity, but the additional power demand from the diesel power plant increased significantly to 13.26 MW. The increased use of diesel power plants directly impacts operational costs, rising to Rp 65,040,329 per hour, the highest value among the three periods. This indicates that during peak load periods, high-cost power plants like diesel power plants begin to dominate the system, resulting in reduced cost efficiency compared to other times.

Table 5. Comparison of total power plant operating costs over three time periods

Time	Average total active (MW)				Load Average (MW)	Average cost (IDR/h)
	PLTU	PLTM	PLTMH	PLTD		
00.00 – 05.00 morning	40.92	0.75	0.5	5.77	47.94	40.936.446
06.00 – 18.00 day	40.92	0.75	0.5	9.12	51.29	51.267.121
19.00 – 23.00 night	40.92	0.75	0.5	13.26	55.43	65.040.329

From the graph (Firgure 6), it can be seen that coal-fired power plants (IPP) consistently serve as the base load in the electricity system in Bengkulu. This role is quite reasonable considering that coal-fired power plants have large capacity, the lowest operating costs among other power plants (around Rp 590.43/MW), and operational characteristics that are designed to work stably for long periods of time. The same applies to hydroelectric power plants (PLTM) and micro-hydroelectric power plants (PLTMH), although their capacity is much smaller. However, both are always active in supplying power during every time period because their operational costs are still relatively low and they utilize renewable resources, making them highly suitable as part of the base load generation. Prayoga (2024) found that the higher the load (from 125 MW to 190 MW), the higher the performance and efficiency of the gas turbine. At a load of 190 MW, the best performance is obtained with a thermal efficiency of about 47.88%, while at lower loads the efficiency is also lower.

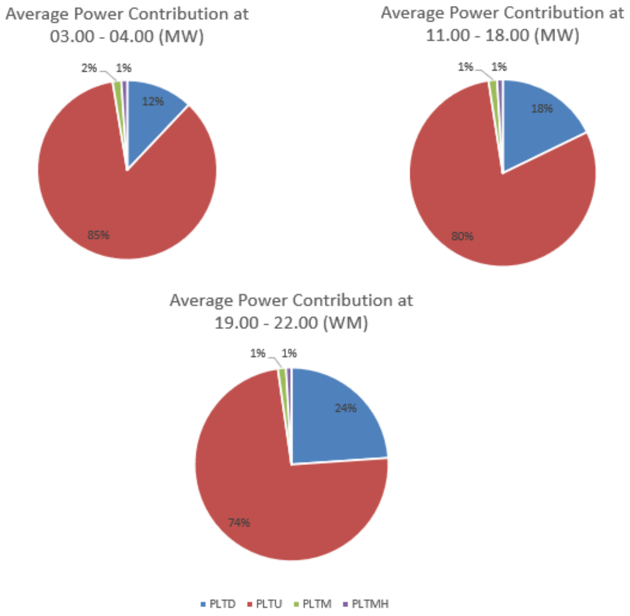

Figure 6. The most efficient power plant combination

Conversely, diesel power plants (PLTD) primarily function as peak-load units, activated only when demand exceeds the supply capacity of base-load plants. PLTDs have significantly higher operational costs (averaging Rp 2,857.52/MW), so the system will only activate them when absolutely necessary to cover power shortages. The use of PLTD is adjusted according to the lowest operational cost of each unit, ensuring that the power plant configuration remains efficient and cost-effective. With the optimal Unit Commitment principle, power generation is utilized based on cost efficiency without compromising the reliability of electricity supply.

5. Conclusion

Based on the results of the UC simulation across three extreme time periods—night to morning (low load), morning to afternoon (moderate/increasing load), and night (high/peak load)—it is evident that as the load increases, more power plants must be activated, particularly those of the PLTD type, which have high operating costs. PLTD increases total operational costs, so it is necessary to minimize the use of PLTD as much as possible and only select those with the lowest operational costs.

a. Between 00:00–05:00 (low load), the system only requires a few PLTD because most of the load is already covered by PLTU (IPP), PLTM, and PLTMH. The total operational cost during this period is Rp 40,936,446 per hour.
b. From 06:00–18:00 (moderate load), the need for PLTD increases to cover the power shortage, causing costs to rise to Rp 51,267,121 per hour.
c. From 7:00 PM to 10:00 PM (high/peak load), the use of diesel power plants increases further, resulting in the highest total cost of Rp 65,040,329 per hour.

Based on the simulation results, the most efficient power plant combination always starts with the coal-fired power plant (IPP) as the main power plant due to its high capacity and lowest operating costs. This is followed by hydroelectric power plants (PLTM) and micro-hydroelectric power plants (PLTMH), which, although smaller in capacity, are stable and economical. PLTD is only used as a supplement if the power from the three main power plants is insufficient. The activation sequence of PLTD is also adjusted to the lowest operating cost to remain cost-effective. This combination has proven capable of minimizing total operational costs in each period and demonstrates that the Unit Commitment approach with priority list techniques is sufficiently effective in supporting power plant operation decision-making.

Author's declaration

Author contribution

Rahmat Fadillah Yunus : Methodology, Writing -Original Draft, Data Curation, Visualization, Validation. **Tri Wahyu Adi :** Conceptualizatio, Writing -Review & Editing.

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Conflict of interest

The authors declare no conflict of interest.

Ethical clearance

This research does not involve humans as research subjects so it does not require ethical clearance.

AI statement

This article is the original work of the author without using AI tools for writing sentences and/or creating/editing tables and figures in this manuscript.

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