

Design of Battery Energy Storage System as Backup Power for Suralaya Coal-Fired Power Plant

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Abstract — Coal dominance in Indonesia's electricity generation poses serious environmental challenges due to CO₂ emissions and harmful pollutants. In support of the Net Zero Emissions (NZE) 2050 target, alternative solutions are needed to reduce reliance on fossil-based power plants during peak load conditions. Battery Energy Storage System (BESS) offers a promising solution due to its ability to store and deliver energy efficiently. This study determines the optimal and economically feasible BESS capacity at Suralaya Coal-Fired Steam Power Plant Units 5–7 (600 MW each, total 1,800 MW). Technical analysis calculates the required reserve power and storage capacity during operational disruptions, covering energy (MWh), power (MW), and battery capacity (Ah) based on load data, disruption duration, and battery efficiency. Economic analysis applies the Cost Benefit Analysis (CBA) method, incorporating Net Present Value (NPV), Payback Period (PP), and Cost Benefit Ratio (CBR) over a 15-year period. Results indicate that a Lithium-Ion BESS with 467.83 MWh energy, 200 MW power, and 311.887 Ah capacity meets backup power requirements. The project is economically feasible, with a CBR of 5.46, a PP under 3 years, and a positive NPV.

Keywords: Backup power, Battery energy storage system, Cost benefit analysis, Net zero emissions, Suralaya power plant.



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INTRODUCTION

Power plants that use fossil fuels such as coal make a significant contribution to environmental destruction. The process of burning coal also produces emissions in the form of carbon dioxide (CO₂), which is the dominant element causing greenhouse gases (GHG). The NZE program requires industrialized and developed countries to achieve net zero emissions by 2050 [1]. PLTU produces CO₂ emissions and its operation as a base load generator still dominates the electricity system in various countries, one of which is Indonesia [2]. To mitigate the global warming trend, more than 150 countries in the world have proposed a goal of zero-zero emissions of carbon neutrality to reduce their dependence on fossil energy [3].

Coal Fired Steam Power Plants are one of the main sources of energy in Indonesia, especially those with abundant coal reserves. However, it is also known to have some challenges, especially regarding efficiency and environmental impact. Along with the increasing awareness of the importance of sustainability and the need to reduce greenhouse gas emissions, there is a push to integrate technologies that can improve the performance and efficiency of Coal Fired Steam Power Plant. One technology that is emerging as a solution is the Battery Energy

Storage System (BESS). Coal-Fired Steam Power Plant usually operates continuously to provide electricity according to base load demand. However, electricity demand is not always stable and can change throughout the day, depending on community and industrial activities. This condition poses a challenge for the Coal-Fired Steam Power Plant in terms of load adjustment, which in turn can affect operating efficiency and equipment life [1]. ESS can ensure balanced supply and consumption of electricity loads, and more reliable stability of the power grid [4].

This research is motivated by the challenges in maintaining the stability of electricity supply in the Steam Power Plant system, especially Suralaya Coal-Fired Steam Power Plant, which is one of the main generators in the Java-Bali electricity system. Power disruptions or emergency conditions that cause generating units to not be able to operate optimally can have a significant impact on the continuity of electricity supply to the network. Battery Energy Storage System (BESS) emerged as a solution to maintain system stability through its function as a backup power source [5]. The BESS industry is also constantly evolving to improve the performance and operational characteristics of new battery technologies. BESS can be used for a variety of electrical purposes, including generation, transmission and distribution, and customer service [6].

This study aims to examine the role of BESS in maintaining the stability of electrical energy availability at Suralaya Coal-Fired Steam Power Plant, especially during power disturbances or emergency conditions. In addition, this study also seeks to determine the optimal capacity of the BESS system required to effectively function as backup power, taking into account power requirements, duration of disturbance, and battery efficiency. BESS can react to network requests almost instantly, but also has the capacity to function over longer periods of time and has a wide range of storage and power capacities [7].

This study analyzes the appropriate BESS investment scenario for Suralaya Coal-Fired Steam Power Plant, including technical and economic aspects, to ensure that the implementation of this energy storage system is not only operationally reliable, but also financially viable in supporting the transition to a reliable renewable energy system. This research uses lithium-ion batteries, Lithium battery energy storage systems (BESS) are widely used due to their various advantages, including energy delivery and balancing, peak shaving, frequency regulation, power quality improvement, and backup capacity compensation [8].

BESS consists of several main components that work together to ensure effective and efficient system operation [9], [10], [11]. The first is the Battery Framework, which consists of an array of battery cells organized into modules and battery packs that convert electrochemical energy into electrical energy. The second component is the Power Conversion System (PCS), which manages power conversion between the BESS and the power grid. The PCS operates in two ways, namely adjusting DC voltage levels using a DC/DC converter, and converting DC to AC or AC to DC using a bidirectional inverter. The third component is the Battery Management System (BMS), which serves as the primary security system for the battery. The BMS monitors and controls the temperature of the entire system, protects cells from internal degradation and rapid capacity reduction, and prevents abnormal heat buildup, excessive heat transfer, and poor heat dissipation in the event of a malfunction [10]. The fourth component is the Energy Management System (EMS), which is designed to manage, monitor, and optimize energy usage across all battery components. The EMS regulates the energy supplied to and absorbed by the battery, thereby improving the overall efficiency of the system.

BESS offers a range of operational benefits that make it suitable for various electricity system applications [11]. In terms of load management, BESS helps balance electricity demand during peak and non-peak periods by storing energy when demand is low and releasing it when prices rise, allowing consumers to reduce electricity costs through peak shaving. BESS also supports

energy time shifting, or arbitrage, by storing energy during off-peak hours when costs are low and supplying or reselling it during high-demand periods, thereby reducing exposure to price fluctuations regardless of seasonal patterns. As a backup power source, BESS can replace conventional generators during outages and maintain supply until the main power source is restored. When integrated with renewable energy, BESS can store energy over extended periods, and commercial systems functioning as Uninterruptible Power Supplies (UPS) can further reduce operational disruptions [12]. In addition, BESS supports black-start capability, meaning it can restart electricity generation after a complete blackout without relying on the external grid, with its fast response time helping to accelerate grid restoration. BESS also contributes to frequency control by adjusting grid frequency within permissible limits, preventing mismatches between generation and demand that could lead to disconnections or blackouts. Finally, BESS facilitates renewable energy integration by combining storage with various renewable sources for on-grid, off-grid, and hybrid systems, supporting a sustainable and cost-effective alternative to fossil fuels.

Generating units at coal-fired steam power plants go through four types of start-up procedures, namely cold start, warm start, hot start, and very hot start, depending on how long the unit has been shut down prior to restart. A cold start, which follows an extended outage period, demands the longest preparation time, requiring up to 650 minutes from ignition to full load. In contrast, a very hot start, initiated shortly after a brief shutdown, can bring the unit to full load in as little as 50 minutes. The longer the start-up process takes, the greater the volume of electricity that cannot be supplied to the grid during that window, directly translating into revenue losses. The estimated time required for each start-up category is detailed in Table 1. This start-up time gap is a key factor driving the need for BESS as a backup power source, as it can supply electricity during the recovery period and significantly reduce financial losses for PT. PLN (Persero).

Table 1. List of Estimated Time for Each Type of Start at Coal-Fired Steam Power Plant

Start Type	From Ignition to turbine start (minutes)	From turbine start to parallel (minutes)	From parallel to full (minutes)	From ignition to full load (minutes)
Cold Start	240	220	190	650
Warm Start	80	70	90	240
Hot Start	40	15	35	90
Very Hot Start	10	10	30	50

METHOD

This research method is carried out with technical and economic analysis. Technically, the calculation of reserve power requirements and storage capacity required when there is a disruption in the operation of the generating unit is carried out. The technical analysis includes the calculation of energy requirements (MWh), power (MW), and battery capacity (Ah) using load assumptions, duration of disruption, and battery efficiency. Furthermore, a financial analysis is carried out using the Cost Benefit Analysis (CBA) method, which includes the calculation of Net Present Value (NPV), Payback Period (PP), and Cost Benefit Ratio (CBR), assuming benefits for 15 years and a certain discount rate.

To calculate how much BESS capacity will be installed, the formula below can be used:

$$BESS\ Energy = \frac{Power\ Required \times Duration\ Required}{DOD \times Battery\ Efficiency} \quad (1)$$

where BESS Energy is the required BESS energy capacity (MWh), Power Required is the required backup power (MW), Duration Required is the required backup duration (hours), DoD

is the maximum allowable depth of discharge (%), and Battery Efficiency is the battery efficiency (%).

$$E_{charge} = \frac{E_{required}}{Roundtrip\ Efficiency} \quad (2)$$

where E_{charge} is the energy required from the grid for charging (MWh), and $E_{required}$ is the required usable energy (MWh).

In this study, two types of investment costs are considered for BESS installation, namely battery procurement costs (\$) and Operation & Maintenance (O&M) costs (\$/kW-year). Throughout this paper, all monetary values expressed using the symbol \$ refer to United States Dollar (USD), unless otherwise stated. Both cost components vary depending on the type of battery selected. The battery procurement cost is calculated by multiplying the required energy capacity by the unit battery price, as shown in Equation (3), while the Cost_{O&M} is determined by multiplying the rated power capacity by the annual O&M cost rate, as shown in Equation (4).

$$Cost_{battery} = E_{battery} \times Battery_{price} \quad (3)$$

$$Cost_{O\&M} = P_{battery} \times O\&M\ Cost \quad (4)$$

where Cost_{battery} is the total procurement cost of the battery (USD), $E_{battery}$ is the required BESS energy capacity (MWh), $Battery_{price}$ is the unit price of the battery (\$/kWh), Cost_{O&M} is the total annual operation and maintenance cost (\$/year), $P_{Battery}$ is the rated power capacity of the BESS (kW), and O&M Cost is the unit rate of operation and maintenance cost (\$/kW-year).

Cost Benefit Analysis (CBA) is an analytical technique used to estimate and evaluate the economic benefits and costs associated with alternative courses of action [13]. It is widely applied in project feasibility assessments to determine whether a proposed initiative can generate a net positive contribution to social or economic welfare. In the context of investment decision-making, CBA provides a structured basis for evaluating whether the benefits of implementing a project or policy outweigh its associated costs over a defined period. If the total costs exceed the total benefits, the project may be reconsidered, redesigned, or rejected in favor of a more viable alternative.

Net Present Value (NPV) is the difference between the present value of incoming cash flows and the present value of outgoing cash flows at a certain period of time [14], as expressed in Equation (5).

NPV offers several advantages in its application. It takes into account the actual interest rate and is relatively easy to apply since it does not rely on a trial-and-error approach. Furthermore, NPV considers the time value of money and accounts for cash flows over the entire project life cycle. Nevertheless, the method has limitations; the minimum desired rate of return can be difficult to determine, and it does not directly indicate the actual rate of return on an investment [14].

$$NPV = \sum_{t=1}^T \frac{C_t}{(1+r)^t} - C_0 \quad (5)$$

where NPV is the net present value (Rp), C_t is the net cash inflow during period t (Rp), r is the discount rate (%), t is the time period (years), and C_0 is the initial investment cost (Rp).

Payback period (PP) is the period or number of years required to recover the initial investment costs that have been spent. It is often used as a key criterion in making investment decisions,

as it provides a straightforward measure of how quickly an investment can be recouped. The formula used to calculate the payback period is as follows [15]:

$$PP = \frac{\text{Investment Value}}{\text{Net Cash Inflow}} \quad (6)$$

where Payback Period is the time required to recover the initial investment (years), Investment Value is the total initial investment cost (Rp), and Net Cash Inflow is the annual net cash inflow generated by the project (Rp/year).

This formula calculates the time required to recover the initial investment cost. The Payback Period is obtained by dividing the total initial investment by the annual net cash inflow. The result indicates how many years are needed for the project to return the invested capital, without considering the time value of money. The selection criteria for the payback period are straightforward. A project is considered feasible if the payback period is shorter than the targeted return on investment period.

RESULT AND DISCUSSION

A. BESS Sizing

Based on the operational data and technical parameters established in the methodology, the BESS capacity required for each generating unit was calculated using Equation (1). The backup power requirement was set at 200 MW with a 2-hour discharge duration, reflecting the estimated recovery time for the unit to resume normal operation following a disruption. A depth of discharge (DoD) of 90% and a battery efficiency of 95% were applied, consistent with typical performance specifications for utility-scale lithium-ion systems. The complete set of input parameters and the resulting BESS energy capacity are presented in Table 2. The calculation yields a required energy capacity of 467.83 MWh per unit, which represents the minimum storage needed to maintain grid supply continuity during a single generating unit outage.

Table 2. BESS System Design Parameters

Power Required (MW)	Duration (Hours)	DOD (%)	Battery Efficiency (%)	BESS Energy (MWh)
200	2	90	95	467.8362573

Based on the parameters presented in Table 2, the required BESS energy capacity is calculated as follows:

$$BESS\ Energy = \frac{\text{Power Required} \times \text{Duration Required}}{\text{DOD} \times \text{Battery Efficiency}}$$

$$BESS\ Energy = \frac{200\ MW \times 2\ h}{90\% \times 95\%} = \frac{400\ MWh}{0.855}$$

$$BESS\ Energy = 467.836\ MWh$$

The daily load profile of Unit 5 recorded on July 3, 2024 is shown in Figure 1. The curve reflects the unit's power output over a 24-hour period, illustrating how the generating load varies in response to grid demand. A notable decline in output can be observed during a specific window within the day, which corresponds to the type of operational disruption targeted by the BESS backup scenario. This data served as the primary basis for determining the required charge and discharge duration for the BESS assigned to Unit 5.

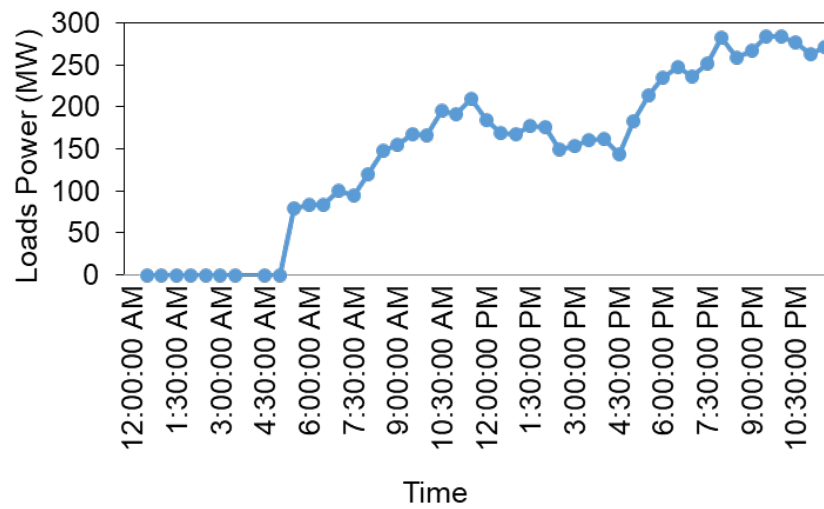


Figure 1. Unit 5 Load Profile Curve on July 3, 2024

The sizing result derived from this profile is presented in Table 3.

Table 3. BESS Capacity Result for Unit 5

Unit	Charge (Hours)	Discharge (Hours)	P_{bat} (MW)	E_{bat} (MWh)	Total MWh
5	2	2	200	467.83	467.83

Figure 2 presents the load profile of Unit 6, recorded over two consecutive days on July 6 and 7, 2024. A two-day observation window was used to capture a more complete picture of the unit's charging and discharging behavior under real operating conditions. The profile reveals a pattern similar to that observed in Unit 5, with a temporary reduction in power output during periods of grid imbalance or unit-side disturbance. The consistency of this pattern across different days strengthens the reliability of the 2-hour backup duration assumption used in the BESS sizing calculation.

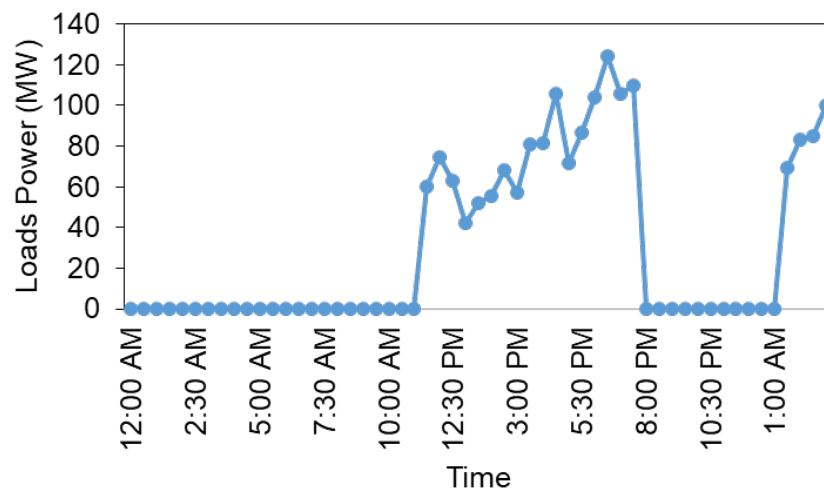


Figure 2. Unit 6 Load Profile Curve on July 6–7, 2024

The corresponding BESS capacity result for Unit 6 is shown in Table 4.

Table 4. BESS Capacity Result for Unit 6

Unit	Charge (Hours)	Discharge (Hours)	P _{bat} (MW)	E _{bat} (MWh)	Total MWh
6	2	2	200	467.83	467.83

The load profile of Unit 7 on October 9, 2024 is illustrated in Figure 3. This data was collected during a different month from Units 5 and 6, offering an additional seasonal reference point for evaluating unit behavior under varying demand conditions. The profile shows a comparable disruption pattern, indicating that the operational instability observed is not limited to a particular time period but reflects a recurring characteristic of the unit's operating environment.

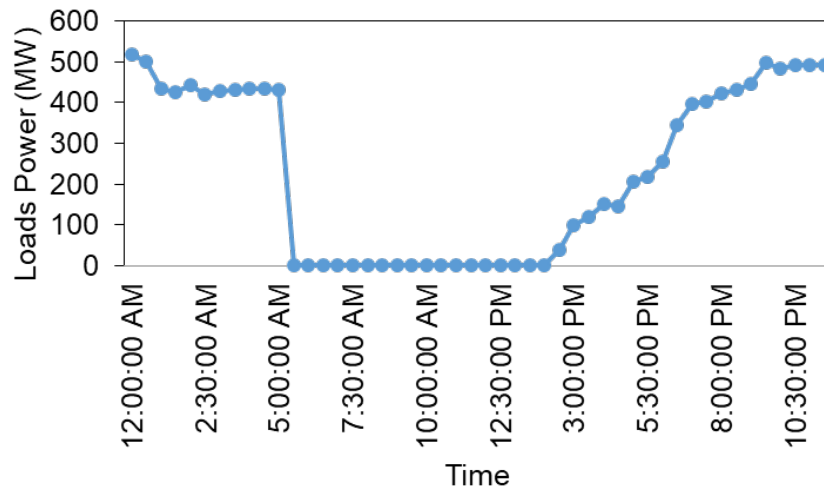


Figure 3. Unit 7 Load Profile Curve on October 9, 2024

This consistency across all three units supports the use of a uniform BESS sizing approach, as confirmed by the capacity results shown in Table 5.

Table 5. BESS Capacity Result for Unit 7

Unit	Charge (Hours)	Discharge (Hours)	P _{bat} (MW)	E _{bat} (MWh)	Total MWh
7	2	2	200	467.83	467.83

As shown in Tables 3, 4, and 5, the BESS sizing results are identical across all three generating units, each requiring a power output of 200 MW and an energy storage capacity of 467.83 MWh. This outcome is a direct consequence of the uniform operational parameters applied to each unit, that is, identical backup duration, DoD, and battery efficiency values, which reflects the standardized operating conditions at Suralaya. The consistency of these results simplifies the procurement and deployment process, as a single BESS configuration can be replicated across Units 5, 6, and 7 without requiring unit-specific design adjustments. In the event of a unit trip or forced outage, the installed BESS will discharge to maintain the supply of 200 MW to the grid for up to 2 hours, providing sufficient time for the unit to complete its start-up sequence and return to normal operation.

$$E_{bat} = 467.83 \text{ MWh} = 467,830,000 \text{ Wh}$$

$$BESS_{voltage} = 1,500 \text{ V}_{DC}$$

$$Battery_{capacity} = \frac{E_{bat}}{BESS_{voltage}} = \frac{467,830,000 \text{ Wh}}{1,500 \text{ V}_{DC}}$$

$$Battery_{capacity} = 311.887 \text{ Ah}$$

B. Economic Analysis

After the BESS capacity is determined for each unit, the next step is to conduct an economic analysis to determine the estimated investment needs, which are then used to calculate the Net Present Value (NPV), Cost Benefit Analysis (CBA), and Payback Period of each combination. Below is an example of an investment estimation calculation for units 5, 6, or 7.

The battery investment cost is calculated by multiplying the total energy capacity (in kWh) by the battery price per kWh, then converted to Rp using the current exchange rate, as follows:

$$Cost_{battery} = E_{battery} \times Battery_{price}$$

$$Cost_{battery} = 467,830 \text{ kWh} \times \$150/\text{kWh}$$

$$Cost_{battery} = \$70,174,500 \times Rp16,500/\$$$

$$Cost_{battery} = Rp1,157,879,250,000.00$$

In addition to the battery investment cost, the cost O&M is estimated based on the rated power capacity of the BESS multiplied by the O&M cost rate per kW, as follows:

$$Cost_{O\&M} = P_{battery} \times O\&M \text{ Cost}$$

$$Cost_{O\&M} = 200,000 \text{ kW} \times \$7/\text{kWh}$$

$$Cost_{O\&M} = \$1,400,000 \times Rp16,500/\$$$

$$Cost_{O\&M} = Rp23,100,000,000.00$$

Thus, the total estimated investment cost components for one BESS unit consist of the battery cost of Rp1,157,879,250,000.00 and the cost O&M of Rp23,100,000,000.00.

When a trip occurs, the Coal-Fired steam power plant stops operating temporarily, thus losing electricity production that should be supplied to the system. This calculation is done by multiplying the unit's power capacity (in MW) by the duration of the disruption (in hours), resulting in the total energy lost (in MWh). The value of energy lost is then multiplied by the selling price of electricity per MWh to determine the total financial loss. This calculation is important for evaluating the financial impact of operational disruptions, as well as a basis for investment considerations.

Unit Trip Scenario without BESS

It is assumed that the 500 MW Unit Power is according to the Daily Operation Plan data from PLN P2B.

$$Energy \text{ Loss} = Unit \text{ Power} \times Trip \text{ Duration}$$

$$Energy \text{ Loss} = 500 \text{ MW} \times 5 \text{ Hours} = 2,500 \text{ MWh} = 2,500,000 \text{ kWh}$$

$$Financial \text{ Loss} = Energy \text{ Loss} \times Price \text{ per kWh}$$

$$\text{Financial Loss} = 2,500,000 \text{ kWh} \times \text{Rp}874.94/\text{kwh} = \text{Rp}2,187,350,000.00$$

Cost Benefit Analysis

To quantify the economic impact of operating without BESS, a derating scenario was constructed to model the financial losses that would accumulate over the project's benefit period. In this scenario, one generating unit is assumed to operate below its rated capacity on a continuous basis due to unmitigated disruptions, resulting in a sustained reduction in electricity output. The key assumptions underpinning this scenario, including the number of affected units, the duration of reduced output per year, and the total benefit period considered, are outlined in Table 6. These parameters form the foundation for the Cost Benefit Analysis presented in the following subsection.

Table 6. Power Plant Derating Scenario without BESS

Number of Units Affected	Duration of Days	Duration of Hours	Duration of Years
1	365	24	15

This analysis illustrates the potential financial losses due to operational disruptions at the coal-fired steam power plant if the Battery Energy Storage System (BESS) is not procured. Without BESS, the coal-fired steam power plant becomes more vulnerable to unit trips, deratings, or forced outages, which can cause a loss of production of 100 MW for 131,400 hours (over a 15-year period), as detailed in Figure 4. Assuming a selling price of electricity (JTF) of Rp874.94/kWh and a Capacity Factor (CF) of 66.34%, the total potential loss of opportunity reaches Rp7.63 trillion.

Meanwhile, the investment cost (Cash Out) is only Rp1.18 trillion, resulting in a net benefit of Rp6.45 trillion with a Cost Benefit Ratio (CBR) of 5.46, which significantly exceeds the feasibility threshold of 1. Based on these calculations, the BESS procurement project is highly feasible to implement, as it provides significant economic benefits while reducing the risk of operational disruption at the plant.

LOSS OF OPPORTUNITY ASSUMPTION		"If Procured without BESS, the power plant system become more vulnerable to sudden load fluctuations or disturbances. The potential for unit trips, deratings, or forced outages could increase, i.e. loss of energy and revenue by 100 MW for an average of 365 days a year, for 15 years on unit 5, 6, or 7"		
NO.	ITEM	UNIT	TOTAL	DESCRIPTION
CALCULATION ASSUMPTIONS				
1	Cost of Production	Rp/kWh	874.94	
2	Capacity Factor (CF)	%	66.34	Target Beyond RKA (Unit 5-7)
CASH OUT				
1	Cash Out	Rp	1,180,979,250,000	
CASH IN / LOSS OF OPPORTUNITY				
A	Opportunity Loss Due to Derating/Outage	Rp	7,626,918,475,440	
1	Derating / Total Loss Production	kW	100,000	
2	Duration of Interruption Time	Jam	131,400	
3	Loss of Opportunity (Profit Margin = Cost of Production x Loss Power x CF x Duration of Interruption)	Rp	7,626,918,475,440	
B	Loss of Opportunity Due to Cold Start Up Unit	Rp	-	
	Start Up Cost (HSD fuel usage cost)	Rp	-	
C	Total Loss of Opportunity (A + B)	Rp	7,626,918,475,440	
D	Benefit (Total Loss of Opportunity - Cash Out)	Rp	6,445,939,225,440	
COST BENEFIT RATIO				
	Cost Benefit Ratio (Benefit / Cash Out)		5.46	
CONCLUSION				
The work/program is feasible, because the CBA value > 1				

Figure 4. Loss of Opportunity Assumption

Net Present Value (NPV)

Since the annual benefit is assumed to be uniform throughout the project's useful life, the net cash inflow during period t (C_t) is obtained by dividing the total projected benefit over 15 years by the project period, as follows:

$$C_t = \frac{Rp6,445,939,225,440}{15 \text{ Years}}$$

$$C_t = Rp429,729,281,696/\text{year}$$

$$\text{Discount rate } (r) = 10\% \text{ or } 0.1$$

$$\text{Project Period } (t) = 15 \text{ years}$$

$$\text{Cash Out } (C_0) = Rp1,180,979,250,000$$

$$NPV = \sum_{t=1}^T \frac{C_t}{(1+r)^t} - C_0$$

$$NPV = \sum_{t=1}^{15} \frac{Rp429,729,281,696}{(1+0.1)^t} - Rp1,180,979,250,000$$

$$NPV = \frac{Rp429,729,281,696}{(1.1)^1} + \frac{Rp429,729,281,696}{(1.1)^2} + \dots + \frac{Rp429,729,281,696}{(1.1)^{15}} - Rp1,180,979,250,000$$

The summation of discounted cash flows from $t = 1$ to $t = 15$ yields a total present value of Rp 3,261,958,475,000. Subtracting the initial investment cost (C_0) gives the following NPV:

$$NPV = Rp3,261,958,475,000 - Rp1,180,979,250,000 = Rp2,080,979,225,000$$

$$NPV \approx Rp2.08 \text{ trillion}$$

With a discount rate of 10%, the NPV value is Rp2.08 trillion. Since the NPV is positive, the total present value of future benefits exceeds the initial investment cost, confirming that this project is financially feasible to implement over the 15-year benefit period.

Payback Period

The payback period is calculated by dividing the total initial investment cost by the annual net cash inflow, as defined in Equation (6). Using the investment values obtained from the economic analysis, the calculation is as follows:

$$PP = \frac{\text{Investment Value}}{\text{Net Cash inflow}} = \frac{Rp1,180,979,250,000}{Rp429,729,281,696}$$

$$PP = 1,003 \text{ days}$$

The result of 1,003 days is equivalent to approximately 2.75 years, meaning the initial investment cost is fully recovered in less than 3 years from the start of operation. Given that the project has a useful life of 15 years, the remaining operational period after the investment is recovered is approximately 12 years, during which the system continues to generate net financial benefits without additional capital expenditure.

Taken together, the results of the economic analysis confirm that the BESS procurement project at Suralaya Coal-Fired Steam Power Plant is highly feasible from a financial standpoint. The Cost Benefit Ratio of 5.46 indicates that for every rupiah invested, the project returns 5.46 rupiah in benefits. The payback period of under 3 years is well within the 15-year benefit period,

leaving a substantial margin of profitability. Combined with a positive NPV, these three indicators collectively demonstrate that the investment is not only financially sound but also capable of delivering long-term economic value to PT. PLN (Persero).

CONCLUSION

This study demonstrates that a Lithium-Ion BESS with an energy capacity of 467.83 MWh, a power rating of 200 MW, and a battery capacity of 311.887 Ah is technically sufficient to serve as backup power for Units 5–7 of Suralaya Coal-Fired Steam Power Plant during operational disturbances. The sizing results are consistent across all three units, reflecting the standardized operating conditions applied in the analysis. From an economic perspective, the unit trip scenario without BESS support resulted in a financial loss of Rp 2,187,350,000.00 per event, while the derating scenario over a 15-year period accumulated potential losses of up to Rp 6,445,939,225,440.00. These figures highlight the significant financial exposure associated with unmitigated operational disruptions and underscore the urgency of implementing a reliable backup power solution. The economic analysis confirms that the BESS procurement project is highly feasible, with a Cost Benefit Ratio of 5.46, a Payback Period of under 3 years within a 15-year benefit period, and a positive NPV of approximately Rp 2.08 trillion. Based on these results, the implementation of BESS at Suralaya Coal-Fired Steam Power Plant is strongly recommended for consideration by PT. PLN (Persero) as a financially sound and operationally beneficial investment.

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