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## Study of Backup Power System Analysis (Emergency Generator) for Electricity Dision at West Sumatra Shipping Polytechnic

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**Abstract:** This study aims to analyze the performance of the backup power system (emergency generator) at the West Sumatra Maritime Polytechnic. The reliability of the electricity supply is very important to support the continuity of educational activities and institutional operations. A backup power system is needed to anticipate power outages that can hamper these activities. This study was conducted using the method of literature study, field observation, interviews, documentation, and analysis of technical data obtained. That generator 1 received a load of 172.76 kVA (138.21 kW) and generator 2 of 294.62 kVA (235.70 kW), with a larger load distribution on Generator 2. The demand factor was 35.37% (generator 1) and 58.92% (generator 2), respectively, while the load factor was 0.35368 and 0.58924. These values indicate that the actual load has not reached the maximum capacity of the generator, so there is still a power reserve available. The utilization rate of generator 1 is 28.29% and generator 2 is 47.14%, which means both are still operating within safe limits, even though generator 2 is utilized more. During 5 hours of operation, fuel consumption is 225 liters and 255 liters, respectively, proportional to the size of the load carried. Voltage drops are still within the tolerance limit ( $\leq 5\%$ ), namely 2.53 Volts on generator 1 and 2.40 Volts on generator 2. Power losses in the 360 mm<sup>2</sup> NYFGbY cable are also relatively small, namely 4.164 kW and 3.76 kW, which indicates the efficiency of the electrical system installation. Thus, the existing backup power system is still reliable and efficient, although further evaluation is needed for load distribution and performance optimization.

**Keyword:** Backup Power, Emergency Generator, Demand Factor, Generator Utilization.

### INTRODUCTION

Electricity is an essential resource for various activities, particularly in educational institutions like the West Sumatra Maritime Polytechnic. A stable and reliable power supply is crucial for supporting the teaching and learning process, operating laboratory equipment, and ensuring smooth administrative functions. At the West Sumatra Maritime Polytechnic, a constant power supply is required for activities such as using computer systems, network infrastructure, laboratory equipment, and other supporting facilities. Any sudden power outage

can severely disrupt the learning process, negatively affecting the overall quality of education provided.

The reliability of the power supply system is even more critical due to the focus of the West Sumatra Maritime Polytechnic on the maritime and shipping sectors. Several practical activities involve the use of sophisticated electronic equipment and simulations that require a continuous power supply. In case of a power failure from the primary source, a backup power system is essential to quickly and efficiently take over. Additionally, a reliable backup system is necessary for ensuring that administrative and operational activities, such as data processing, communications, and critical data storage, can continue uninterrupted.

However, the backup power system currently in use at the West Sumatra Maritime Polytechnic has certain limitations that require attention. Common issues include insufficient generator capacity, slow power transfer times, and the absence of proper maintenance procedures. To address these shortcomings, it is essential to conduct in-depth research to evaluate the performance of the existing backup power system. This research aims to identify potential improvements that will enhance the reliability and efficiency of the backup system, ensuring that it can optimally support educational and operational activities.

## METHOD

This research uses a quantitative research method, which relies on numerical data collected from the existing conditions at the West Sumatra Maritime Polytechnic. The data is gathered through direct review (observation), focusing on the backup power system in place at the institution. The sample data for this study includes load measurements from official residences (flats), the main building, and dormitories, all of which are supported by the emergency generator backup power system. The research will cover various aspects, including the design of the backup power system, installation of generator sets and distribution panels, operation of generator sets in both normal and emergency conditions, as well as the routine and incidental maintenance of the generator sets.

Additionally, this study will calculate the fuel consumption of the generator sets per hour and determine the total load capacity supported by the generators across the three buildings at the West Sumatra Maritime Polytechnic. The research will take place at the dormitory building, official residences (flats), and the main building, located at Jl. Syekh Burhanuddin No.1, Korong Tiram, Ulakan Tapakis District, Padang Pariaman Regency, West Sumatra. The research will be conducted in May 2025. The required tools and materials for this research include specification data for the generator sets, load details, and a single-line diagram. Mobile phone cameras will be used for documentation purposes during the research process.

The analysis techniques used in this research include several essential calculations to assess the performance of the generator system. To determine the generator capacity, the formula  $\text{Power Capacity} = \text{Total Installed Load} \times \text{DF} \times 1.25$  is used, where the total installed load is multiplied by a diversity factor (DF) and then increased by a safety factor of 1.25. Generator utilization analysis follows to evaluate the operational efficiency of the generator sets during both normal and emergency conditions. Fuel consumption is calculated using the formula  $Q = k \times \text{kVA} \times t$ , with "k" as a constant, "kVA" representing apparent power, and "t" indicating time in hours. In addition, the voltage drop in the conductor from the generator to the load is determined using  $V_d = \sqrt{3} \times I \times L \times R \times \cos\phi$ , where "I" is current, "L" is conductor length, "R" is resistance, and " $\cos\phi$ " is the power factor. Finally, the power loss due to the resistance of cables is calculated using  $PL = 3 \times I^2 \times R \times L$ , where "I" is current, "R" is resistance, and "L" is the length of the conductor. These calculations are critical in evaluating the efficiency, reliability, and overall performance of the backup power system.

## RESULTS AND DISCUSSION

### West Sumatra Maritime Polytechnic Load Usage Data

### Installed Power in Main Building

The main building of the West Sumatra Maritime Polytechnic, consisting of three floors, houses various rooms with specific power consumption needs. Floor 1, which includes 14 rooms and 4 hallways, consumes a total of 70,260 W, primarily due to lighting, CCTV systems, air conditioning, and power outlets. Floor 2, with 8 rooms and 4 hallways, has a total power consumption of 18,396 W, while Floor 3, which includes 2 rooms and 4 hallways, totals 10,724 W. Summing up the power consumption across all floors results in a total installed power of 99,380 W. This means the generator set capacity required for this building is 99.38 kW.

### Installed Power in Dormitory A:

Dormitory A, which also consists of three floors with eight rooms per floor, has similar load usage to that of the main building. Floor 1 of Dormitory A totals 28,352 W, mainly due to lighting, electric sockets, and air conditioning in each room. Floor 2, with identical usage, also consumes 28,352 W, and the same total of 28,352 W is observed on Floor 3. The overall installed power for Dormitory A amounts to 85,056 W, indicating that the required generator set capacity for this dormitory is 85.06 kW.

### Installed Power in Dormitory B:

Dormitory B mirrors the setup of Dormitory A, comprising three floors, each with eight rooms. The total power consumption for each floor is identical to Dormitory A, with each floor using 28,352 W. Therefore, the total installed power for Dormitory B is 85,056 W, which corresponds to a required generator capacity of 85.06 kW.

### Power Consumption in Official Residences/Flats:

The official residences at the West Sumatra Maritime Polytechnic, which include three floors with 10 rooms on each floor, consume considerable power. Floor 1 has a total power usage of 46,584 W, while Floor 2 uses the same amount, 46,584 W. Floor 3, which also contains 10 rooms, has a total power consumption of 46,584 W. Summing up the power usage across all floors, the total installed power for the official residences is 139,752 W, requiring a generator set capacity of 139.75 kW.

In conclusion, each building and dormitory at the West Sumatra Maritime Polytechnic has varying power consumption, with the total power demand for each area reflecting the number of rooms and the appliances used within those spaces. For effective operation, the generator sets must meet these specific capacity requirements.

### Total Installed Power

Power installed in the main building, dormitory A, dormitory B, and flats (official residence) has a total power as shown in table 1 below:

**Table 1 Total Installed Power of Generators 1 and 2**

<b>GENERATOR 1</b>	
Unit	Power (W)
Main Building	99380
Dormitory A	85056
<b>TOTAL</b>	<b>184456 W / 184.456 kW</b>

  

<b>GENERATOR 2</b>	
Unit	Power (W)
Flat (Official Residence)	139752
Dormitory B	85056
<b>TOTAL</b>	<b>224808 W / 224,808 kW</b>

Shows the installed power data in the flat (official residence) and dormitory A whose load is backed up by generator 1 with a total power of 184.456 kW. Meanwhile, the installed power data in the main building and dormitory B whose load is backed up by generator 2 with a total power of 224.808 kW.

The West Sumatra Maritime Polytechnic has 2 emergency generator units (gensets) with a power capacity of 500 kVA each. While the total load on the Power House is 184,456 kW for generator 1 and 224,808 kW for generator 2. The Emergency Generator (Genset) has a power factor of 0.8. Determining the generator set requirements for the West Sumatra Maritime Polytechnic if all loads are operated simultaneously is based on the power triangle theory using the following equation

$$\text{Generator 1 } S = \frac{P}{\cos \phi}$$

$$\begin{aligned} & \frac{184,456 \text{ kW}}{0.8} \\ S &= 230.57 \text{ kVA} \end{aligned}$$

$$\text{Generator 2 } S = \frac{P}{\cos \phi}$$

$$\begin{aligned} & \frac{224,808 \text{ kW}}{0.8} \\ S &= 281.01 \text{ kVA} \end{aligned}$$

The actual operations at the West Sumatra Maritime Polytechnic are that generator 1 backs up the main building, Dormitory A, Laboratory, and Classrooms. A. Meanwhile, generator 2 backs up the flat (official residence), Dormitory B, Class B, Mosque, and Dining Hall. This is because the data analyzed focused on three main units: the flat (official residence), the main building, and the dormitory. The selection of these three units was based on the urgent need for a high and sustainable electricity supply.

Based on the total power calculation above, which is 230.57 kVA, generator 1 is sufficient to provide backup in the event of a power outage from PLN. Meanwhile, based on the total power calculation for generator 2, which is 281.01 kVA, generator 2 is sufficient to provide backup in the event of a power outage from PLN.

## Fuel Operations

In this study, there are 2 emergency generators used to distribute the electricity supply needs in the main building, Dormitories A and B and Flat (official residence), these emergency generators have the same type and have the same tank capacity, the capacity that can be accommodated is 2483 liters and has dimensions (P x W x H) namely (200 x 124 x 100) cm.

## Determining Generator Capacity

The highest hourly maximum load was on Friday, May 9, 2025, from 19:00 to 21:00 on generator number 1. Where the average current recorded was 262.8 A, the amount of power can be calculated using the equation:

$$\begin{aligned} P &= \sqrt{3} \cdot I \cdot V \cdot \cos \phi \\ P &= \sqrt{3} \times 262.8 \times 380 \times 0.8 \\ P &= 138.21 \text{ kW} \end{aligned}$$

Meanwhile, in generator number 2, where the recorded current is 425.73 A, the amount of power can be calculated using the formula:

$$\begin{aligned} P &= \sqrt{3} \cdot I \cdot V \cdot \cos \phi \\ P &= \sqrt{3} \times 425.73 \times 380 \times 0.8 \\ P &= 235,685 \text{ kW} \end{aligned}$$

The highest total load is between 7:00 PM and 9:00 PM, which is 138.21 kW for generator number 1 and 235.685 kW for generator number 2. To ensure the generator can be used at 100%, the demand factor (DF) must be calculated using the following equation:

$$S = \sqrt{3} \cdot V \cdot I$$

$$S = \sqrt{3} \cdot 380 \cdot 262.8$$

$$S = 172.76 \text{ kVA}$$

$$S = \sqrt{3} \cdot V \cdot I$$

$$S = \sqrt{3} \cdot 380 \cdot 425.73$$

$$S = 294.62 \text{ kVA}$$

Generator number 1

Generator number 2

Kapasitas Daya = Total bebas terpasang xDF x 1.25

Kapasitas Daya =  $500 \times 0.34552 \times 1.25$

Kapasitas Daya = 215.95 kVA

The calculation above is the result of generator number 1 which includes the distribution of the load to the main building and Dormitory A, for generator number 2 which includes the flat (official residence) and Dormitory B with the following calculation:

Kapasitas Daya = Total bebas terpasang xDF x 1.25

Kapasitas Daya =  $500 \times 0.589 \times 1.25$

Kapasitas Daya = 368.125 kVA.

### Generator Utilization Calculation

The calculation of the installed load from the calculation above shows that the total power load of the West Sumatra Maritime Polytechnic is 219.95 kW for generator number 1 and generator number 2 is 326.16 kW, and the installed power of each generator is 500 kW, then the utilization of use. From this calculation we can see that the fuel consumption of the generator is calculated as follows:

Generator 2.

### Fuel Consumption Calculation

Fuel consumption with the installed load calculation can be calculated while the generator is working with the installed power load with the following calculation:

$$Q = k \times \text{kVA} \times t$$

$$Q = 0.21 \times 500 \times 1 \text{ hour}$$

$$Q = 105 \times 5 \text{ liters/hour}$$

$$Q = 525 \text{ liters} / 5 \text{ hours}$$

From the calculation above, we can see that the fuel consumption of the generator for 3 hours with the installed power of the entire building is 1380 liters of fuel.

### Analysis

Based on the calculation results, the nominal current generated by generators 1 and 2 with a capacity of 500 kVA with a voltage of 380 Volts and a power factor of 0.8 is 760.52 A. To conduct this amount of current safely and efficiently, a cable with adequate current carrying capacity is required. Based on the current carrying capacity standard for NYY or NYFGby type copper cables, a size of 240 mm<sup>2</sup> is capable of conducting currents up to approximately 415 Amperes per core.

Therefore, a suitable and safe cable configuration to use is  $2 \times 4 \times 1 \times 240 \text{ mm}^2$ , which uses two parallel cables per phase, so that the total current carrying capacity reaches approximately 830 Amperes, which is greater than the generator current. Thus, the use of this cable is considered safe to avoid overheating, excessive voltage drops, and the risk of damage to the power distribution system. In each phase of generator 1 and generator 2, it was found that the largest current value was in generator 2 with an overall average of 425.73 A, while in generator 1 it was 262.8 A. This shows that the electrical load on Generator 2 is higher, possibly because it supplies power to units with greater operational needs.

The results of the real power and apparent power calculations also show significant differences. Generator 1 has an apparent power of 172.76 kVA and an apparent power of 138.21 kW, while Generator 2 has an apparent power of 294.62 kVA and an apparent power of 235.70 kW. This is consistent with the higher average current data for Generator 2.

The Demand Factor (DF) obtained was 34.552% for Generator 1 and 58.92% for Generator 2, respectively, indicating that only a portion of the total available power capacity is utilized during peak load. This means the system still has considerable room before reaching maximum capacity. The low load factors for both generators indicate that the load is not consistently high, but rather tends to fluctuate.

In terms of utilization, the utilization of power capacity in Generator 1 is only "27.642%", while in Generator 2 it is 47.14% of the total capacity of each. This suboptimal utilization percentage is caused by the electrical system configuration that uses different generator lines for each load, so that the load cannot be combined to one generator unit simultaneously. In addition, differences in brands and technical specifications between generators are also an obstacle in load consolidation, because it can affect the synchronization and operational safety of the system. Fuel consumption is also studied based on the generator load, with the result that Generator 1 requires approximately 525 liters/5 hours, and Generator 2 is 525 liters/5 hours. This confirms that the efficiency of fuel use is in line with the utilization level and the load carried by each generator. The voltage drop in the cable from the generator to the main load is 15.37 Volts for Generator 1 and 14.55 Volts for Generator 2, respectively.

2. This value is still within the SNI standard tolerance limit ( $\pm 5\%$  of nominal voltage), so it does not significantly affect the performance of electrical equipment.

Power loss due to cable resistance was found to be 4.164 kW for Generator 1 and 3.76 kW for Generator 2. This value is relatively small compared to the power transmitted, indicating that the cable used.

## CONCLUSION

### 1. Power Charged To The Generator

The calculation results show that generator 1 receives a power load of 172.76 kVA or 138.21 kW and generator 2 receives a power load of 294.62 kVA or 235.70 kW, this shows that the load distribution on generator 2 is higher than generator 1.

### 2. Demand Factor And Load Factor

Generator 1's demand factor was 34.552%, and generator 2's was 58.92%. Generator 1's load factor was 0.35368, and generator 2's was 0.58924. These values indicate that the load has not yet reached the generator's maximum capacity, so there is still reserve power available.

### 3. Generator Utilization

Generator 1's utilization rate is 27.642%. Generator 2's utilization rate is 47.14%. This means both generators are still operating within safe and efficient limits, but generator 2 has a higher utilization rate.

### 4. Fuel Consumption For 5 Hours Of Operation

Generator 1 consumes 525 liters of fuel. Generator 2 consumes 525 liters of fuel. Fuel consumption is proportional to the load each generator is carrying.

### 5. Voltage drop and power loss

The voltage drop is still below the tolerance threshold ( $\leq 5\%$ ), namely 15.37 Volts for generator 1 and 14.55 Volts for generator 2.

#### 6. Power Loss In The Cable

Generator 1 has a power output of 4.164 kW, and Generator 2 has a power output of 3.76 kW. This indicates that the cable installation (NYFGbY 360 mm<sup>2</sup>) is quite efficient and meets standards.

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