

# Analysis of Power Requirements and Backup Power Systems for 24 Hour Continuity of Flight Navigation Equipment Operation

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## Abstract

Uninterrupted operation of flight navigation equipment is paramount for aviation safety. This investigation critically assesses the power supply adequacy and optimizes the backup power system architecture at Perum LPPNPI Palembang to guarantee 24/7 operational continuity for its critical navigation infrastructure. Employing a hybrid quantitative-qualitative methodology, the research quantifies the peak and normal power demands of critical navigation systems including the Instrument Landing System (ILS), Doppler VHF Omnidirectional Range (DVOR), and Distance Measuring Equipment (DME) through technical data analysis and field verification. The reliability of the primary power grid (PLN) and the performance of the existing backup infrastructure (generator sets and UPS) are evaluated based on capacity, condition, and switchover time. The analysis reveals a primary power supply availability of 97.78%, underscoring a significant reliance on backup systems. While the existing backup capacity (872.4 kW from generators and 238.32 kW from UPS) substantially exceeds the 65.65 kW critical load, a critical gap is identified in the form of aging assets, notably a 20-year-old generator and several UPS units exceeding their technical lifespan. A strategic asset renewal plan is consequently proposed to mitigate the risk of catastrophic failure. The findings provide a tangible framework for enhancing electrical infrastructure resilience, directly contributing to the safety and efficiency of air navigation services.

**Keywords:** Power Requirements, Backup Power System, Operational Continuity, Flight Navigation Equipment, LPPNPI, OJT.

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## Introduction

The operational integrity of flight navigation equipment constitutes the backbone of aviation safety and efficiency. At LPPNPI Palembang Branch, the designated air navigation service provider, this equipment is mandated to operate ceaselessly, 24 hours a day, seven days a week. Vital infrastructure, such as the Instrument Landing System (ILS) and Doppler VHF Omnidirectional Range (DVOR), demands an unwavering supply of electricity, a principle founded on the tenet that distribution system reliability is paramount to guaranteeing stable and continuous power. Any disruption to this supply, no matter how brief, can precipitate severe consequences for flight safety. A profound analysis of power requirements and their corresponding backup systems is therefore essential to mitigate the inherent risks of power failure.

International standards, specifically ICAO Annex 10 Vol. I [1] and the Civil Aviation Safety Regulations (PKPS) Part 171-12,[2] stipulate that critical equipment including ILS, DVOR, and DME must remain operational without interruption, even during primary power source failures. This regulatory framework makes the availability of a robust backup power system obligatory for ensuring round-the-clock operations. As articulated by Tito et al.,[3] a secondary power source is indispensable for sustaining loads during the transfer from the main utility to a generator. To address this vulnerability, this research quantifies the total electrical power requirements encompassing both peak and normal loads for all operational navigation equipment. Furthermore, it evaluates the capacity and reliability of the existing backup systems, namely generator sets (gensets) and Uninterruptible Power Supplies (UPS), to identify potential discrepancies between operational necessities and system capabilities.

Building upon this analysis, technical recommendations are formulated for system optimization to guarantee operational continuity, leveraging data acquired during On-the-Job Training (OJT) at AirNav Palembang. The outcomes of this investigation are intended to serve as a scientific foundation for policy-making related to the enhancement of electrical infrastructure reliability, ultimately elevating the safety and efficiency of navigation services.

This research implements the required Power Requirement Analysis and Backup Design for aviation navigation continuity (ILS, DVOR, DME) at Sultan Mahmud Badaruddin II Airport, quantifying the critical load at 65.65 kW and primary availability at 97.78%. The central technical novelty is our analysis critically distinguishing capacity adequacy from reliability risk : despite the substantial capacity surplus (238.32 kW UPS and 872.4 kW Genset) , we identify a critical vulnerability rooted in component aging namely the 20-year-old DVOR genset and 13-year-old UPS units. This analytical framework culminates in a risk-prioritized asset renewal strategy essential for securing ICAO-mandated operational continuity.

## Literature Review

### 2.1 Aviation Safety Equipment at Sultan Mahmud Badaruddin II Airport

The Instrument Landing System (ILS) is a pivotal navigation aid designed to facilitate aircraft landings, particularly in adverse weather conditions or with limited visibility. The foundational design and operational requirements for aerodrome facilities, including the necessity for reliable ground aids, are established by international standards [4]. It provides pilots with horizontal guidance via the Localizer, vertical landing angle information via the Glide Path, and distance to the runway threshold via Marker Beacons. The Glide Path is a critical ILS component that guides the aircraft's descent angle, typically at 3°, ensuring a stable and safe approach [4]. Marker Beacon equipment, positioned along the extended runway centerline, indicates the aircraft's distance to the threshold. The ILS system incorporates three types of Marker Beacons: the Inner, Middle, and Outer Marker. The Inner Marker is installed 75 m from the runway end (450 m from the landing threshold), modulated with a 3000 Hz ID and coded with dots, signaling to the pilot that the touchdown zone has been reached. The Middle Marker, located 1050 m from the runway end, is modulated at 1300 Hz and coded with dash-dots, prompting the pilot to decide whether to continue or abort the landing. The Outer

Marker is placed approximately 7200 m from the runway end and is coded with dashes, informing the pilot that the aircraft has correctly intercepted the landing slope.

The DVOR (Doppler VHF Omnidirectional Range) is an air navigation facility that provides bearing information from an aircraft to a ground station. DVOR equipment transmits variable and reference signals on a VHF carrier frequency via its antenna array. The display on the aircraft's DVOR receiver shows the azimuth in degrees, enabling the aircraft to follow a specific route towards the airport. DVOR operates within the 108.00-118.00 MHz VHF band. The aircraft receiver has three indicators: one for azimuth, one for deviation, and one indicating whether the aircraft is flying towards or away from (To/From) the DVOR station.

Distance Measuring Equipment (DME) is a system that measures the line-of-sight distance from an aircraft to a ground station. The DME system comprises a ground-based transponder and an airborne integrator. The distance is calculated based on the time it takes for an interrogation signal from the integrator to be returned from the transponder. A Tower Set is required to support communication between Air Traffic Control (ATC) officers in the tower and pilots. Communication devices at Sultan Mahmud Badaruddin II Airport include VHF A/G PRIMARY (for controlling aircraft during takeoff and landing up to 10 NM and 1500 feet), VHF A/G SECONDARY (as a standby), and VHF A/G Emergency (for emergency or hijacking situations).

## 2.2 Primary and Backup Power Sources

The primary power source is the national utility grid (PLN), supplying electricity at a capacity of 555 kVA. PLN provides supply through multiple separate feeders to enhance reliability. The performance of an electrical system is heavily influenced by effective load management from the distribution substation, which directly affects the performance, reliability, and continuity of service to connected loads.

The backup power system consists of Generator Sets (Gensets) and Uninterruptible Power Supplies (UPS). A genset serves as a long-term backup power source during PLN outages. It is a device that generates electrical power through a combination of a prime mover (typically a diesel engine) and a generator or alternator, converting mechanical energy into electrical energy. Two 500 kVA Perkins Genset units are located in the Main Power House (MPH) building, and one 65 kVA Perkins Genset is in the DVOR building.

An Uninterruptible Power Supply (UPS) functions by converting AC power to DC to charge its batteries, and then inverting it back to AC to supply the load, thereby protecting it from power surges or sags. The critical function of a UPS is to ensure that essential systems like air traffic control, communications, radar, and security remain operational without interruption, particularly for navigation equipment like ILS, where any disruption can compromise accuracy. The UPS provides instantaneous power until the primary source is restored or the genset activates, allowing the Automatic Transfer Switch (ATS) to transfer the load. 60 kVA BORRI UPS units are utilized in the RDPS Room, Tower Room, and TX Building, while 5 kVA ICA UPS units are used in the Glide Path and Localizer SELEX RW 29 buildings to back up navigation equipment and radio links.

## 2.3 Theory of Electrical Power System Reliability

Mean Time To Failure (MTTF) is a fundamental measure of system reliability, representing the average time a system is expected to operate without failure over a given period. A higher MTTF value corresponds to higher system reliability. MTTF can be calculated by dividing the total optimal operational time by the number of failures.

$$MTTF = \sum t_{Uptime} / n \quad (1)$$

Where  $t_{Uptime}$  is the optimal time and  $n$  is the number of failures.

According to Torell & Avelar,[5] Mean Time To Repair (MTTR) is the time required to restore a system from a failure, including diagnosis time, technician acquisition time, and repair

time. A higher MTTR value indicates poorer system performance, as longer recovery times lead to lower availability. MTTR is calculated as:

$$\text{MTTR} = \text{Total Maintenance Time} \div \text{Number of Repairs} \quad (2)$$

Mean Time Between Failure (MTBF), as defined by Torell & Avelar,[5] is the average time between failures in a repairable system. It is often calculated as the sum of MTTF and MTTR, or as the total operational time divided by the number of failures. The fundamental formulas are:

$$\text{MTBF} = \text{MTTF} + \text{MTTR} \quad (3)$$

$$\text{MTBF} = \frac{\text{Total Operational Time (Uptime)}}{\text{number of failures}} \quad (4)$$

Availability (A) is the measure of a system's operational readiness, ideally approaching 100%. For critical navigation facilities, a minimum target of 99.999% is common. Availability can be calculated using the following formulas:

$$\text{Availability} = \frac{\text{Loading time} - \text{Downtime}}{\text{Loading time}} \times 100\% \quad (5)$$

$$\text{Availability} = \frac{\text{Loading time}}{\text{Operation Time}} \times 100\% \quad (6)$$

$$A = \frac{\text{MTTF}}{\text{MTTF} + \text{MTTR}} \quad (7)$$

$$A = \frac{\text{MTBF}}{\text{MTBF} - \text{MTTR}} \quad (8)$$

(Because  $\text{MTBF} = \text{MTTF} + \text{MTTR}$  )

An ideal system for navigation facilities should have an availability level approaching 100%, with a general target of at least 99.999% to avoid the risk of potentially fatal service disruptions. This reliability analysis can be used to evaluate both primary power sources (PLN) and backup systems (UPS and generators). Studies on the performance reliability of the 20 kV distribution network in specific areas of PT. PLN have highlighted challenges in maintaining optimal service indices, underscoring the necessity for local backup systems [6]

## 2.4 Power Quality Theory

Power quality is crucial for the performance of precision aviation navigation equipment like ILS, DVOR, and DME. Key power quality parameters include harmonic voltage, voltage sags, surges, and waveform disturbances. As noted by Bollen,[7] power quality disturbances can introduce errors in precision electronic systems. This inherent sensitivity of modern equipment is highlighted by findings that "Electrical devices used today are very sensitive to the quality of electrical power, where microprocessor-based devices and other power electronics require stable service voltage and the voltage level must also be maintained at the working voltage of the device.[8]

To mitigate these issues, Online Double Conversion UPS systems are frequently employed. This type of UPS provides clean and stable power by continuously supplying the load through its inverter, effectively isolating the equipment from spikes, noise, and other grid instabilities. Consequently, the power quality from PLN and the performance of the UPS in maintaining supply stability are central to this investigation.

## 2.5 Recent Studies on Airport Backup Systems

Research by Zhang et al.[9] demonstrates that a combination of UPS and diesel generators constitutes the most reliable backup system for critical airport equipment. Furthermore, a study by Rahimi & Noroozian [10] advocates for the integration of digital monitoring systems to enhance the response to power disturbances. Furthermore, the use of modeling and simulation approaches is recognized as a vital step in designing and validating reliable power system solutions for critical infrastructure [11]

## Research Methodology

### 3.1 Research Approach

This study employs an integrated quantitative and qualitative approach. The quantitative methodology is utilized to calculate power requirements, measure the performance of primary and backup power systems, and analyze reliability using metrics such as MTBF, MTTR, and availability. Concurrently, a qualitative approach is used to evaluate operational procedures, maintenance protocols, and potential risks associated with the existing system.

### 3.2 Research Stages

1. The research was conducted through the following systematic stages:
2. Literature and Regulatory Review: A comprehensive review of scientific literature, standards such as ICAO Annex 10 Vol. I and PKPS, and recent journals on power system reliability and quality in critical facilities.
3. Equipment Inventory and Identification: Cataloging all navigation equipment at LPPNPI Palembang with their technical specifications (power consumption, operating hours, backup type).
4. Power Requirement Calculation: Determining power needs based on theoretical nameplate data (summation of all equipment power) and 24-hour measurements to record daily load patterns.
5. Primary Power System (PLN) Analysis: Collecting historical outage data from PLN and calculating MTBF, MTTR, and Availability.
6. Existing Backup System Evaluation: Assessing Genset capacity, age, and start-up time; UPS capacity and runtime; and ATS switching time from PLN to Genset and vice-versa.
7. Gap Analysis and Combined System Reliability: Comparing total load against UPS and Genset capacities and simulating failure scenarios to assess system response.
8. Optimal Backup Power System Design: Formulating recommendations for a backup system based on reliability, efficiency, and scalability, with optimal criteria including Availability  $\geq 99.999\%$ , ICAO-compliant switching times, and a reserve capacity of  $\geq 125\%$  of peak demand.

### 3.3 Location and Time

This research was conducted at Perum LPPNPI Palembang Branch, the institution responsible for air navigation services in the southern Sumatra region. Data was initially collected during an OJT period from July 9, 2018, to November 30, 2018, with updated data obtained from the institution in July 2025.

### 3.4 Tools and Materials

The tools and materials used include data from the On-the-Job Training (OJT) at AirNav Palembang, a multimeter or power meter, technical specifications of navigation equipment, internal LPPNPI documents, genset catalogs, and a computer with data processing software.

## Results

### 4.1 Inventory and Power Requirements of Navigation Equipment

Based on data acquired during the OJT at AirNav Palembang, the operational navigation equipment central to this analysis is detailed below. The calculation of power requirements is predicated on the nameplate data from essential navigation, communication, and surveillance equipment. As summarized from the inventory in Table 1, the total power required for all primary operational equipment is 65,654.8 Watts, or 65.65 kW. This figure represents the minimum critical load that the backup power system must sustain to ensure the continuity of navigation services.

**Table 1.** Equipment Data

Category	Equipment Name	Brand	Type	Installation Year	Power (Watt)
Communication	VHF - ADC Secondary	Park Air	T6TR	2018	25
	Radio Link RX HF RDARA	Ubiquiti	AirFiber AF-5U	2021	40
	Radio Link TX HF RDARA	Ubiquiti	AirFiber AF-5U	2021	40
	HF-RDARA (Extended Range)	Rohde & Schwarz	4100A	2021	18
	VHF - ADC Back Up	OTE	DTR100	2005	25
	Radio Link GP Mopiens to Tower	Ubiquiti	Rocket M5	2018	0.1
	Radio Link MM Mopiens	Ubiquiti	LiteBeam M5	2018	0.32
	Radio Link GP to MM Mopiens	Ubiquiti	LiteBeam M5	2018	316
	Radio Link GP Selex to Tower	Ubiquiti	PowerBeam M5 300	2018	25
	Radio Link Localizer Selex	Ubiquiti	PowerBeam M5 300	2018	6
	Radio Link GP to MM Selex	Ubiquiti	PowerBeam M5 400	2018	12
	Radio Link BCS-BDS	Ubiquiti	Powerbeam M5-300	2019	125
	Radio Link ADS-B	Ubiquiti	Nanostation M5	2019	0.1
	Radio Link DVOR	Cambium	ePMP 1000	2018	0.63
	Radio Link Localizer Mopiens	Ubiquiti	LiteBeam M5	2018	316
	Radio Link MM Selex	Ubiquiti	Nanostation M5	2018	0.1
	Voice Recorder	Neptuno	Divos Log 2.5x	2017	1.84
	VHF - ADC Primary	OTE	DR/DT.100	2005	50
	VHF - APP Primary	OTE	DR/DT.100	2005	50
	VHF - APP Secondary	Park Air	T6T/R	2016	100
	VHF - ER Primary	OTE	DR/DT.100	2017	100
	VHF - ER Secondary	Park Air	T6T/R	2011	100

	VHF - Portable ADC	Dittel	PC 2T/FSG 2T	2011	25
	VHF - Portable	Funke	PC 2T/FSG 2T	2016	25
	ATIS	Pylot System	CR 42U-1100-3YW	2005	510
	VCSS	Garex	230 COMPACT 3	2017	
	VHF - Emergency	OTE	DR/DT.100	2005	50
	VHF - APP Back Up	OTE	DTR100	2005	50
Navigation	DME	Selex	1119A	2018	1
	ILS Rwy 29	Selex	2100	2016	121
	ILS Rwy 11	Mopiens	520	2018	123
	DVOR	Selex	1150A	2018	100
Surveillance	ADS-B	Geci	GT-280	2019	620
	MSSR Mode-S	Eldis	MSSR-1	2012	2.5
Data Processing / Automation	ATC System	Indra	AirCon 2100	2017	37.164
	AMSC (Main System)	Comsoft	CADAS PB	2013	3.22
	CBT ATC SYSTEM	OEM	LENOVO F0D100UID	2018	

The detailed calculation of the total installed load across all facilities reveals a much larger figure, representing the actual load under full operation. The breakdown is as follows: Tower Building (156,561 W), Radar and Administration Building (79,782 W), ATC System Building (38,113 W), ILS & Locator Facilities (27,771 W), and the Main Power House (MPH) Building (2,092 W). This culminates in a total installed load for the entire LPPNPI Palembang facility of 304,319 Watts, or 304.32 kW.

**Table 2.** Installed Facility Load

	Location/Building	Total Installed Load (Watt)	Total Installed Load (kW)
1	Tower Building	156.561	156,56
2	Radar & Administration Building	79.782	79,78
3	ATC System Building	38.113	38,11
4	ILS & Locator Facilities	27.771	27,77
5	Main Power House (MPH) Building	2.092	2,09
	TOTAL	304.319	304,32

#### 4.2 Primary Power System (PLN) Evaluation

The primary power supply to AirNav Palembang is from the PLN grid with an installed capacity of 555 kVA. The frequency of genset operation serves as a direct indicator of PLN's supply reliability. An analysis of the event logs for the gensets at the Main Power House (MPH) and the DVOR building during July 2025 provides empirical data on grid stability.

**Table 3.** Event log from the MPH Building Generator

Date	Time	Status / Event
July 1, 2025	5:44:14	Engine Started
	5:44:26	Gen Over Current Warning
	6:12:11	Engine Stopped
	16:07:01	Engine Started
	17:35:31	Engine Stopped
July 5, 2025	15:41:49	Engine Started
	15:47:27	Engine Stopped
July 7, 2025	8:37:19	Engine Started
	9:08:27	Engine Stopped
July 11, 2025	5:53:34	Engine Started
	5:58:23	Engine Stopped
	6:48:38	Engine Started
	7:30:42	Engine Stopped
July 13, 2025	16:31:43	Engine Started
	16:33:27	Engine Stopped
	22:42:18	Engine Started
	22:51:01	Engine Stopped
July 14, 2025	14:17:36	Engine Started
	15:17:23	Engine Stopped
July 15, 2025	2:34:00	Engine Started
	2:37:41	Engine Stopped
	2:42:54	Engine Started
	2:46:21	Engine Stopped
	2:55:27	Engine Started
	3:53:42	Engine Stopped
July 17, 2025	1:13:33	Engine Started
	1:37:09	Engine Stopped
	1:37:16	Engine Started
	1:56:59	Engine Stopped
	2:12:08	Engine Started
	4:53:51	Gen Over Current Warning
	5:03:02	Engine Stopped
July 19, 2025	17:10:45	Engine Started
	17:24:08	Engine Stopped
July 20, 2025	1:55:55	Engine Started
	5:44:47	Engine Stopped

July 21, 2025	14:15:24	Engine Started
	16:53:56	Engine Stopped
	17:20:34	Engine Started
	17:25:26	Engine Stopped

**Table 4.** Event log from the DVOR Building Generator

	Event	Date	Time	Running Duration	Notes / Remarks
1	Engine Started	30 Jun 2025	4:49:31	4 minutes 10 seconds	Genset started for testing
2	Engine Stopped	30 Jun 2025	4:53:41		Genset turned off
3	Engine Started	01 Jul 2025	16:27:52	4 minutes 9 seconds	Genset started
4	Engine Stopped	01 Jul 2025	16:32:01		Genset turned off
5	Engine Started	01 Jul 2025	18:06:39	3 minutes 11 seconds	Genset started
6	Engine Stopped	01 Jul 2025	18:10:50		Genset turned off
7	Engine Started	06 Jul 2025	16:04:16	4 minutes 10 seconds	Genset started
8	Engine Stopped	06 Jul 2025	16:08:26		Genset turned off
9	Engine Started	06 Jul 2025	20:02:29	3 minutes 9 seconds	Genset started
10	Engine Stopped	06 Jul 2025	20:05:38		Genset turned off
11	Engine Started	08 Jul 2025	22:48:36	4 minutes 16 seconds	Genset started
12	Engine Stopped	08 Jul 2025	22:52:52		Genset turned off
13	Engine Started	14 Jul 2025	8:48:24	4 minutes 9 seconds	Genset started
14	Engine Stopped	14 Jul 2025	8:52:33		Genset turned off
15	Engine Started	15 Jul 2025	18:24:29	4 minutes 6 seconds	Genset started
16	Engine Stopped	15 Jul 2025	18:28:35		Genset turned off
17	Engine Started	20 Jul 2025	20:01:02	4 minutes 5 seconds	Genset started
18	Engine Stopped	20 Jul 2025	20:05:07		Genset turned off
19	Engine Started	22 Jul 2025	5:57:47	4 minutes 8 seconds	Genset started
20	Engine Stopped	22 Jul 2025	6:01:55		Genset turned off

1. Power Supply Reliability Analysis for the Main Power House (MPH) Building

Based on the Perkins 500 kVA Genset log:

- Number of Failures ( $\lambda$ ): 19 times
  - Total Outage Time ( $T_{down}$ ): 956.64 minutes (15.94 hours)
  - MTTR:  $956.64 / 19 = 50.35$  minutes per failure
  - MTBF:  $(44,640 - 956.64) / 19 = 2,299.12$  minutes (~38.3 hours)
  - Availability (A): 97.86%
- a. Assuming the generator's running time (Start  $\rightarrow$  Stop) = the PLN outage time ( $T_{down}$ ).
  - b. Taking the total observation period = 44,640 minutes (31 days  $\times$  24 hours  $\times$  60 minutes).
  - c. Thus: PLN is “down” for the total duration of the generator set's operation; the remaining period is PLN available.
  - d. This yields MT Assuming the generator set's operating time (Start  $\rightarrow$  Stop) = PLN's outage time ( $T_{down}$ ).
  - e. Taking the total observation period = 44,640 minutes (31 days  $\times$  24 hours  $\times$  60 minutes).

- f. Thus: PLN is “down” for the total duration of the generator set's operation; the remaining period is PLN available.
- g. This results in MTTR  $\approx$  50.35 minutes (average duration of each PLN outage), MTBF  $\approx$  38.3 hours (average between outages), PLN Availability  $\approx$  97.86% (PLN provided power  $\sim$ 97.86% of the time during the observation period). TR  $\approx$  50.35 minutes (average duration of each PLN outage), MTBF  $\approx$  38.3 hours (average between outages), PLN Availability  $\approx$  97.86% (PLN provided power  $\sim$ 97.86% of the time during the observation period).

## 2. DVOR Building Power Supply Reliability Analysis

Based on the Perkins 65 kVA Genset log (test data omitted):

- Number of Failures ( $\lambda$ ): 9 times
  - Total Outage Time (T<sub>down</sub>): 35.38 minutes
  - MTTR:  $35.38 / 9 = 3.93$  minutes/failure
  - MTBF:  $(44,640 - 35.38) / 9 = 4,956.07$  minutes ( $\sim$ 82.6 hours)
  - Availability (A): 99.92%
- ## 3. Conclusion on the Overall Reliability of the PLN System

By combining data from both locations to obtain an overview:

- Total Failures ( $\lambda_{total}$ ):  $19 + 9 = 28$  times per month
- Total Outage Time (T<sub>down\_total</sub>):  $956.64 + 35.38 = 992.02$  minutes (16.53 hours)
- Average Outage Duration (MTTR<sub>overall</sub>): 35.43 minutes
- Average Time Between Outages (MTBF<sub>overall</sub>): 1,558.86 minutes ( $\sim$ 26 hours)
- Availability<sub>overall</sub>:  $A = 1558.86 + 35.43 / 1558.86 \times 100\% = 97.78\%$

Based on the event log from the 500 kVA Perkins genset at the MPH building, there were 19 failure instances, resulting in a total downtime (T<sub>down</sub>) of 956.64 minutes (15.94 hours) over a 31-day observation period (44,640 minutes). This yields an MTTR of 50.35 minutes per failure, an MTBF of approximately 2,299.12 minutes ( $\sim$ 38.3 hours), and a grid availability (A) of 97.86%. Similarly, the log for the 65 kVA Perkins genset at the DVOR building recorded 9 failure events (excluding test runs), with a total downtime of 35.38 minutes. This translates to a significantly lower MTTR of 3.93 minutes per failure, a much higher MTBF of 4,956.07 minutes ( $\sim$ 82.6 hours), and an availability of 99.92%.

By consolidating the data from both locations, a comprehensive picture of overall PLN system reliability emerges. A total of 28 failures occurred within the month, leading to a cumulative downtime of 992.02 minutes (16.53 hours). This results in an overall average outage duration (MTTR) of 35.43 minutes and an average time between outages (MTBF) of 1,558.86 minutes ( $\sim$ 26 hours). The overall availability of the primary PLN supply during the July 2025 period was calculated to be 97.78%. This figure highlights a profound dependency on the backup power systems (UPS and Genset) to maintain uninterrupted operations for the flight navigation facilities.

A noteworthy event in the MPH genset log was the "Gen Over Current Warning" on July 1 and July 17. This alert was triggered by voltage surges from the PLN source exceeding the safe limit of  $>15\%$  above 220V. The genset's automatic start-up via the ACOS (Automatic Change Over Switch) in these instances served a protective function, shielding the equipment from potentially damaging overvoltage. A permanent resolution requires reporting these events to PLN, as voltage adjustments can only be performed on their transformer.

## 4.3 Existing Backup Power System Evaluation

The backup power infrastructure at LPPNPI Palembang is comprised of Generator Sets and Uninterruptible Power Supplies. There are five operational gensets with a total installed capacity of 1,090.5 kVA and fourteen active UPS units providing a total capacity of approximately 264.8 kVA.

Batteries, as backup power, play a crucial role in maintaining the operation of electronic devices and critical systems during power outages. This technology stores electrical energy from a primary source (such as the state electricity company) and releases it when needed, ensuring a stable and uninterrupted power supply. Type and Capacity: A battery with a specification of 12V 75AH, using five 12V 75AH batteries, is equivalent to a 5 kVA UPS. Circuit Type: The batteries are connected in series or parallel, or possibly simply in series. A series circuit increases the total voltage, while a parallel circuit increases the total current capacity.

**Table 5.** Generator Set Capacity

Equipment Name	Brand	Capacity (kVA)	Installation Year	Age (as of 2025)
GENSET SILENT DVOR	Perkins	65	2005	20
GENSET OPEN MPH 1	Perkins	500	2017	8
GENSET OPEN MPH 2	Perkins	500	2017	8
GENSET SILENT RDARA	Perkins	20	2021	4
GENSET GM HOUSE	Krisbow	5.5	2019	6
TOTAL CAPACITY		1,090.5 kVA		

**Table 6.** UPS Capacity

Equipment Name	Brand	Capacity (kVA)	Installation Year	Age (as of 2025)
UPS ONLINE LOCALIZER MOPIENS	APC	5	2018	7
UPS ONLINE RADAR	Piller	20	2012	13
UPS ONLINE RDARA	APC	10	2021	4
UPS ONLINE LOCALIZER	ICA	5	2016	9
UPS ONLINE GLIDE PATH MOPIENS	APC	5	2018	7
UPS ONLINE ATC SYSTEM (2 unit)	Borri	60	2017	8
UPS ONLINE RADAR	Piller	15	2012	13
UPS ONLINE TX ROOM	Borri	60	2017	8
UPS ONLINE TOWER	Borri	60	2017	8
UPS ONLINE RDPS	Borri	60	2017	8
UPS ONLINE GLIDE PATH	ICA	5	2016	9
Various Small Offline UPS	ICA/APC	~4.8	2019-2023	2-6
Total Active Capacity		~264.8 kVA		

#### 4.4 Gap Analysis and Reliability

A comparison of the total power requirement against the backup system capacity was conducted, assuming a power factor (PF) of 0.8 for gensets and 0.9 for UPS units. The total real power capacity of the UPS system is 238.32 kW, while the genset system provides 872.4 kW.

**Table 7.** Backup System Capacity Analysis

Parameter	Calculation	Result
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Total Theoretical Peak Load	Summation of Equipment Power	65.65 kW
Total UPS Power Capacity	264.8 kVA * 0.9 PF	238.32 kW
Total Genset Power Capacity	1,090.5 kVA * 0.8 PF	872.4 kW

The analysis reveals no capacity gap; to the contrary, a significant surplus exists. The UPS capacity (238.32 kW) vastly exceeds the critical peak load (65.65 kW), confirming its ability to support all critical systems instantaneously upon a power failure. Likewise, the total genset capacity (872.4 kW) is more than sufficient to handle the entire operational load for extended durations.

Under a PLN failure scenario, the system response is designed for seamless continuity. Critical loads are instantaneously transferred to the UPS (0 ms switch time). The ATS detects the grid failure and signals the genset to start. After a brief stabilization period, the ATS transfers the load from the battery-draining UPS to the running genset. The UPS then returns to standby mode and recharges. Upon PLN restoration, the ATS transfers the load back to the grid and shuts down the genset

#### 4.5 Optimal Backup Power System Design Concept

Recommendations are structured around criteria of reliability, efficiency, and aviation safety standards. The optimal design ensures that under normal conditions, PLN supplies the main power while also charging the battery bank. In a failure event, the ATS automatically switches to the genset for backup power, while the UPS provides seamless AC power from its battery bank to bridge any momentary gap.

The optimal design criteria are an availability of  $\geq 99.999\%$ , a UPS transfer time of  $<10$  ms, an ATS-to-genset switchover time of 5-15 seconds, and a reserve capacity of at least 125% of the peak load. This requires an optimal capacity of at least 82.06 kW ( $65.65 \text{ kW} \times 125\%$ ).

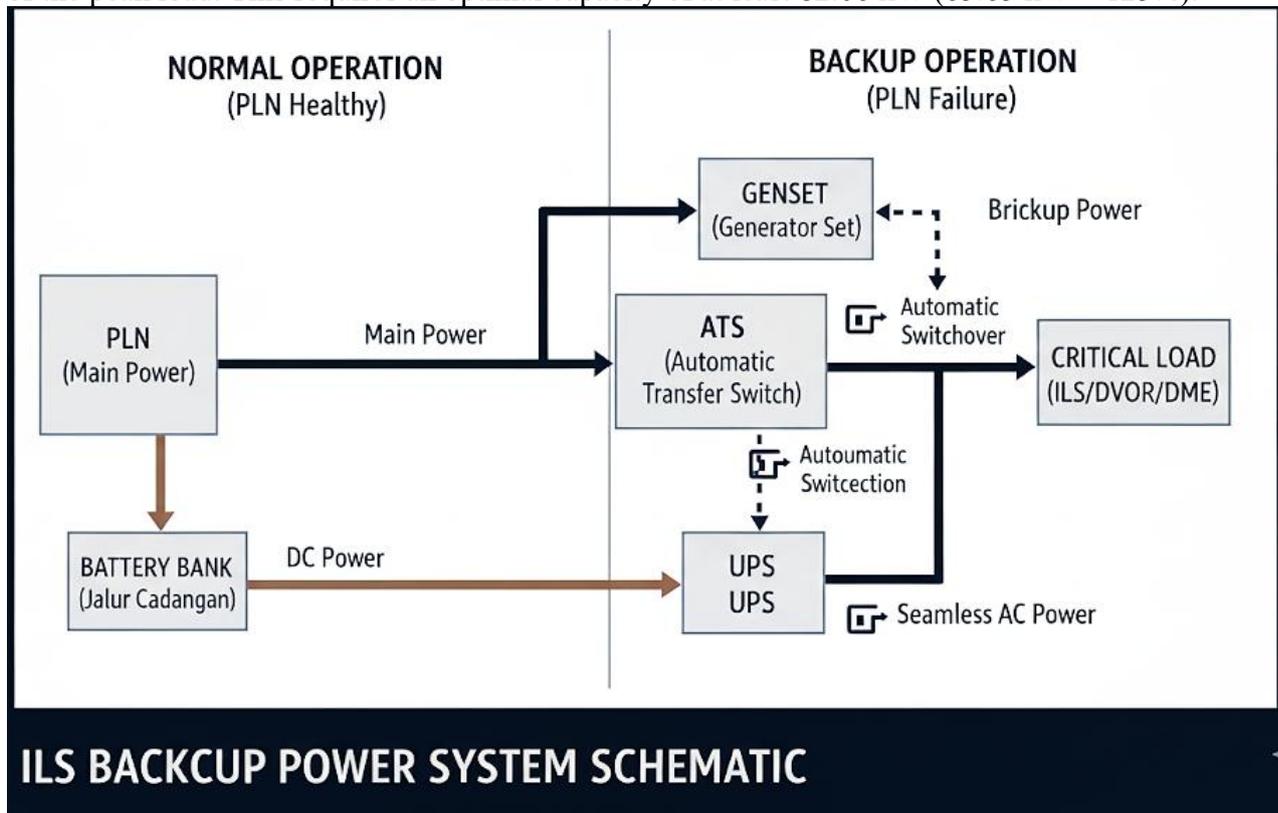


Figure 1. Backup Power System Schematic

1. Normal Conditions (PLN Healthy):
  - PLN (Main Power Source) directly supplies "Main Power" to the ATS (Automatic Transfer Switch) and then to the Critical Load (ILS/DVOR/DME).

- PLN also charges the Battery Bank.
2. Backup Conditions (PLN Failure):
    - If PLN fails, the ATS will automatically switch power to the Genset (Generator Set), which provides "Backup Power" to the Critical Load.
    - Separately, the Battery Bank provides DC power to the UPS, which then converts it to "Seamless AC Power" to the Critical Load during a brief power interruption.

**Table 8.** Evaluation Against Optimal Criteria

Backup System	Installed Capacity (kW)	Optimal Requirement (kW)	Status
UPS	238.32 kW	82.06 kW	qualify
Genset	872.4 kW	82.06 kW	qualify

As demonstrated, the installed capacity of both the UPS and Genset systems comfortably meets the optimal design requirements

#### 4.6 Recommendations

Despite sufficient capacity, the age of certain assets presents a tangible risk.

1. Asset Renewal: Two Piller UPS units (20 kVA and 15 kVA) are 13 years old, and the Silent DVOR Genset is 20 years old. Given that the typical technical lifespan for UPS components is 7-10 years, a scheduled replacement of these units is strongly recommended to prevent unexpected failures. A renewal plan for the aged genset should be prioritized within the next 3-5 years.
2. Field Measurement and Testing: A direct Power Quality Analysis should be conducted to obtain precise data on real-world load, power factor, and harmonics (THD). Routine functional tests of the ATS and gensets are essential to verify start-up and switching times meet established standards. Furthermore, battery health evaluations, such as discharge tests or State of Health (SOH) measurements, should be performed on all UPS units older than five years to ensure their runtime conforms to specifications.

#### Conclusion

The reliability of the primary power supply (PLN) is a significant concern, with a calculated availability of 97.78% during the observation period. This level of availability, indicating multiple outages per month, confirms a critical operational dependency on the backup power systems (Genset and UPS) to ensure the continuity of air navigation services. While the investigation concludes that the overall capacity of the backup power systems is more than adequate comfortably meeting the 125% reserve criterion above the theoretical peak load a latent vulnerability exists. Key assets, specifically the 20-year-old genset at the DVOR facility and two 13-year-old UPS units, have surpassed their ideal technical lifespan. This situation introduces a potential risk of functional failure that could compromise operational continuity unless it is proactively mitigated through a structured asset renewal plan.

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