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Optimizing Preventive Maintenance for DC Battery Back-Up Systems in Gas Turbine Compressors

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ABSTRACT

Objectives: In general, the objective of this Capstone Project is to formulate an optimal preventive maintenance strategy for the DC Battery Backup Control System to support the operational sustainability of Gas Turbine Compressors in the oil and gas sector.

Findings: Unit shutdown on July 21, 2024, triggered by a main power supply failure (220 VAC). The battery VRLA (Valve Regulated Lead Acid) type, with a constant load of 10A, the battery should be able to support the load without a 220 Vac power supply for 8 to 10 hours. However, in practice, it can only sustain the load for less than 5 minutes.

Methodology: This study employs a mixed-methods approach, integrating both qualitative and quantitative data. Qualitative data were collected through interviews involving managers, supervisors, and technicians, as well as direct field observations. Quantitative data were obtained from daily operational reports and historical analyzer records. The problem analysis strategy was conducted using a Fishbone Diagram and the 5-Why analysis tool to systematically identify root causes.

Conclusion: Based on field observations and technical analysis, battery capacity degradation from its original specification was identified, resulting in the failure of the DC backup battery to sustain the load during the loss of the 220 VAC main power supply. The Fishbone Analysis and 5-Why approach further revealed that human factors played a significant role in contributing to the failure. Based on these findings, corrective actions were implemented, including battery replacement and improvement of the maintenance strategy. Final testing demonstrated a significant improvement in system reliability, with the batteries capable of supporting the control load stably in accordance with operational requirements.

Keywords: DC Battery Back-Up; Gas Turbine Compressor; Battery Capacity Degradation; Preventive Maintenance; Reliability Analysis.

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INTRODUCTION

Electrical system reliability is a crucial factor in maintaining the continuity of operations in oil and gas facilities, particularly in Gas Turbine Compressor units which serve as the primary movers for gas transmission and distribution systems. One vital supporting component is the 24 VDC Battery Back-Up system, designed to ensure the continuous supply

of power to control, protection, and instrumentation systems when primary power interruptions or failures occur.

Without a reliable 24Vdc supply, control systems fail to function optimally, posing a significant risk of operational disruptions or even total gas turbine shutdowns. The battery is a device that uses an electrochemical process to convert electrical energy into chemical energy when it is charged and then converts chemical energy back into electrical energy when the battery is discharged (Zahra et al., 2023). Faults in the battery system are particularly critical during abnormal conditions. Since the battery is the ultimate backup source, any failure at this stage results in fatal system breakdowns and significant operational risks (Kostenko, 2025)

Consequently, the 24Vdc power supply is reinforced by backup batteries and chargers to ensure continuous availability despite external power failures. In this context, 24Vdc serves as the 'lifeblood' of the control system, ensuring that the Gas Turbine Compressor operates safely, efficiently, and sustainably." Failure of the battery back-up system can lead directly to unplanned shutdowns, production losses, as well as increased safety risks and financial losses. The problem serving as the focus of this research is the failure of the DC Battery Back-Up system to sustain control loads during a blackout, even though initial voltage measurements were within the normal range.

PT Indoturbine is a national private company specializing in the procurement, maintenance, and operation of Gas Turbine Compressors and Generators. A key strategic business line is the operation of five (5) Gas Turbine Compressor units in East Kalimantan. To meet these requirements, two units are operated continuously while the remaining three are kept on standby. This research is motivated by a unit shutdown incident on July 21, 2024, triggered by a main power supply failure (220 VAC). Based on data from the Historical Analyzer, the shutdown lasted for 11 minutes until full system recovery. Upon the loss of primary power, the DC voltage dropped drastically alongside the load current, falling below the permissive shutdown threshold of 21.0 VDC. This event led to a cascading shutdown of the consumer's plants 1, 2, 4, and 5. From a business perspective, the Gas Turbine Compressor shutdown resulted in losses of approximately IDR 170 billion, comprising IDR 122.5 billion in production loss and IDR 47.6 billion in post-shutdown recovery costs. In the PLC system, voltage logic is governed by three primary thresholds: 21 VDC as the Low-Low limit (shutdown), 21.5 VDC as the Low limit (alarm), and 32 VDC as the High-High limit (overvoltage shutdown).

Based on the research background, the problem formulations of this study are as follows:

1. What are the root causes of the 24 VDC battery backup system failure in supporting the performance of the Gas Turbine Compressor during a main power supply disturbance?
2. Are the specifications and capacity of the installed DC battery backup system adequate to support operation and maintain the performance of the Gas Turbine Compressor during main power supply disturbances?
3. How effective is the implementation of preventive maintenance in maintaining the battery backup system, including inspection and maintenance procedures?

LITERATURE REVIEW

The literature review in this Capstone Project is structured to provide a solid theoretical and empirical foundation for analyzing the failure of the 24 VDC Battery Back-Up

system in Gas Turbine Compressors. When the main power supply system fails, the battery bank, acting as an auxiliary power system, provides emergency power to various critical loads (Li et al., 2022). The battery functions as a DC power source to operate relays within the protection and control systems, therefore, its reliability and stability must remain optimal (Humainah et al., 2023). As the backup power supply of power plants and substations, valve-regulated lead-acid (VRLA) batteries are the last safety guarantee for the safe and reliable operation of power systems, and the batteries' status of health (SOH) directly affects the stability and safety of power system equipment (Yu et al., 2023). Basic battery theory, specifically regarding VRLA (Valve Regulated Lead Acid) batteries, explains that battery performance is determined not only by voltage values but also by actual capacity, discharge characteristics, Depth of Discharge (DoD), State of Charge (SoC), efficiency, service life, and operational environmental conditions such as temperature and charging methods. SOC (State of Charge) represents the capacity of the battery used by the system. The optimal SOC for Storage falls in a range between 40% and 60%. This range is crucial for maintaining battery health during storage. Moreover, it is important to maintain certain environmental conditions, for instance, Storage should be in a clean, dry, and well-ventilated area, with temperatures between 10°C and 30°C, and relative humidity not exceeding 65% (Samuele, 2024).

It can also be defined as the remaining battery capacity, whereas DOD (Depth of Discharge) is the percentage of the VRLA battery capacity that has been discharged (Iskandar et al., 2021). Therefore, analyzing the causes of battery failure and estimating as well as predicting the State of Health (SOH) are highly beneficial in identifying malfunctioning batteries in a timely manner and in developing maintenance plans.

A maintenance approach based solely on voltage inspection is considered insufficient to represent the comprehensive health condition of the battery. Preventive maintenance is a proactive maintenance strategy that involves regularly scheduled inspections, tests, and servicing of equipment to prevent potential failures before they occur (Ulansky & Raza, 2024). Backup battery failures typically do not show voltage anomalies during normal operation. They are only detected when the battery is required to sustain the load autonomously during an AC power outage.

To determine whether the battery is fully charged, battery condition measurements must be performed by conducting an adjustable load simulation test so that the current can be maintained at a constant rate, causing the battery voltage to drop from its nominal value (Ihsan et al., 2022). When the battery level reaches 80%, it signifies that the battery has reached the end of its lifespan and necessitates replacement (Vaghela et al., 2024). According to IEEE 1188-2005, it is recommended that a cell/unit or battery be replaced when its capacity falls below 80% of the manufacturer's rated capacity. As the VRLA battery life is generally 5–7 years, the internal resistance of the battery generally rises slowly with the increase of battery usage time (Li et al., 2022).

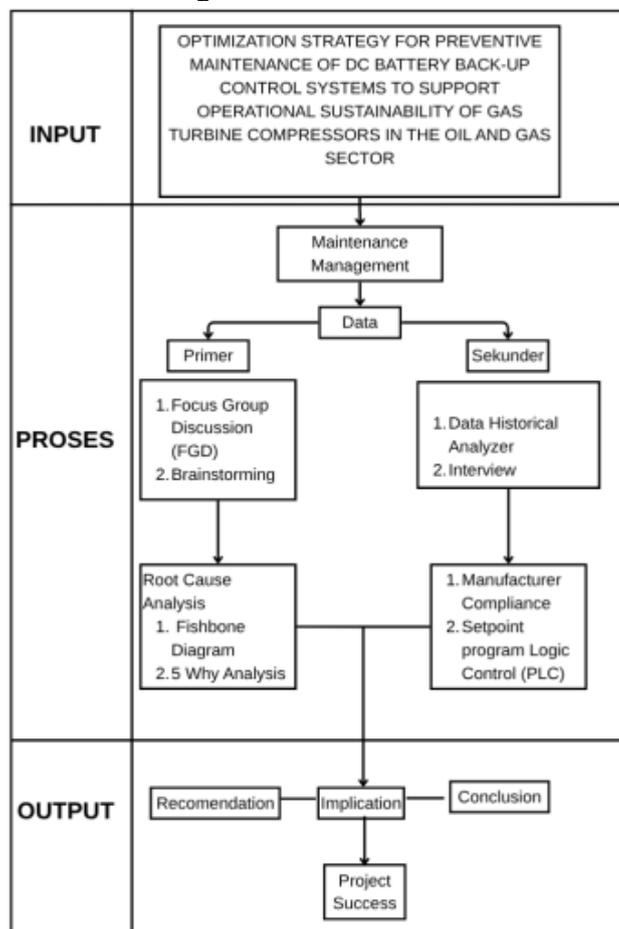
This condition creates a gap between manufacturer specifications and actual field performance, which has the potential to cause sudden system failures. The state-of-the-art research in this field points toward the application of periodic capacity testing, DoD and SoC evaluation, and the integration of technical analysis with preventive maintenance practices based on actual data.

Furthermore, Root Cause Analysis (RCA) theories, including Fishbone Diagrams and the 5-Why method, are used as a qualitative analysis framework to trace the fundamental

causes of system failure from the aspects of manpower, work methods, equipment, materials, measurement, and environment. Fishbone Diagram (also known as Ishikawa Diagram or Cause-and-Effect Diagram) is a graphic technique to show the causes of some events or phenomena (Nugroho & Khoirudin, 2020). Fishbone analysis is typically used in the context of quality improvement, where quality improvement teams utilize this tool to help them understand and identify the root causes of problems occurring within a process or system (Hardiansyah et al., 2024).

As illustrated in Figure 1, the research framework follows a structured progression from Input to Output. The process begins with the identification of an optimization strategy for DC battery backup maintenance to support gas turbine sustainability. This is followed by a comprehensive Process phase involving maintenance management through two data streams: primary data, which utilizes Focus Group Discussions and brainstorming for Root Cause Analysis (Fishbone and 5-Why), and secondary data, which incorporates historical analysis and interviews to ensure Manufacturer Compliance and PLC setpoint accuracy. The workflow culminates in the Output phase, where findings are translated into practical recommendations and implications, ensuring conclusive results and overall project success."

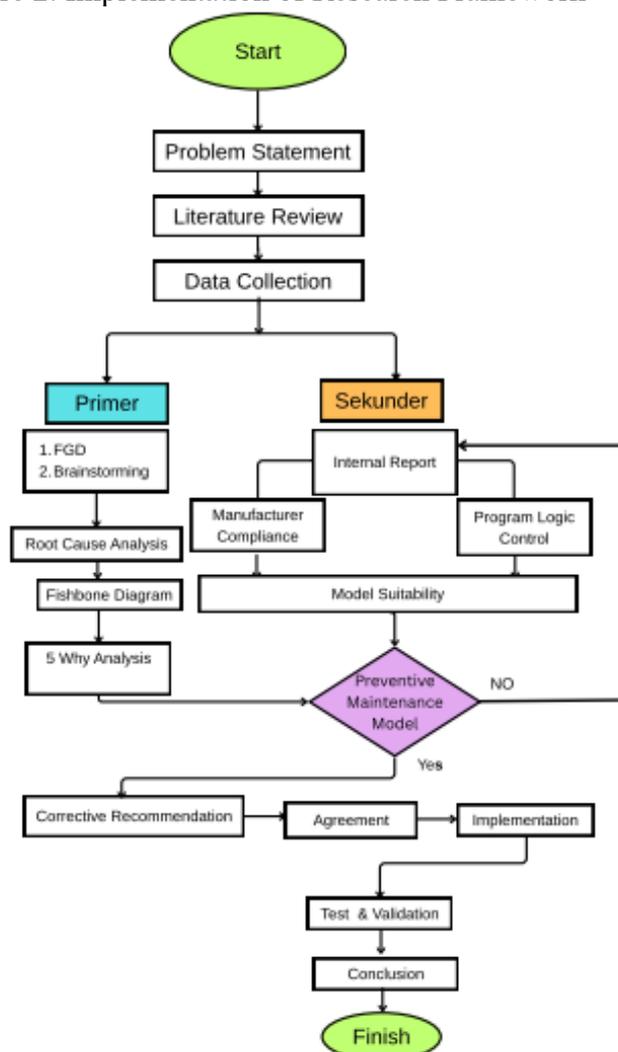
Figure 1. Research Framework



The implementation of the research framework, as depicted in Figure 2, follows a comprehensive operational workflow beginning with the problem statement, followed by an

extensive literature review and systematic data collection. The process bifurcates into two main streams: primary data collection through Focus Group Discussions (FGD) and brainstorming, which feeds into a Root Cause Analysis using Fishbone diagrams and 5-Why/5W+1H techniques; and secondary data derived from internal reports to ensure manufacturer compliance and Program Logic Control (PLC) alignment. These streams converge to evaluate model suitability, which determines the validity of the proposed Preventive Maintenance Model. If the model is deemed unsuitable, the process reverts to internal reporting for refinement; otherwise, it proceeds to corrective recommendations and formal agreement. The final stages involve the implementation of the strategy, followed by rigorous testing and validation to derive the final conclusions, effectively concluding the research cycle.

Figure 2. Implementation of Research Framework



METHOD

In this research, the author employs a mixed-methods approach implemented within a multiple case study design framework. This approach was selected as it is most suitable for exploring system failure phenomena across the five engine gas turbine compressor units in-

depth within their specific operational contexts. Specially, the study utilizes a convergent design, where qualitative data (obtained through interviews and observations) are collected simultaneously with secondary quantitative data (Historical Analyzer, Daily Reports) to provide mutual reinforcement and validation.

The period for data collection, analysis, and initial implementation spanned seven months, from July 2024 to January 2025. The data collection process for this study employs a mixed approach, incorporating both primary and secondary data collection methods.

Testing was conducted through a real load test by simulating a main power supply failure through the deactivation of the battery charger. The battery was subjected to a direct operational load current ($\pm 9.8-10$ A) to measure its discharge capacity, the duration it maintains voltage at the permissive level, and the real-time voltage drop patterns. Non-participatory observations were conducted to record the in-situ conditions of the five battery units, each consisting of two batteries. The battery used is a VRLA (Valve Regulated Lead Acid) type, 12 VDC 100 AH (24 VDC series two batteries). Furthermore, these observations are crucial for identifying discrepancies between written Standard Operating Procedures (SOPs) and actual field maintenance practices, which are frequently identified as failure modes in the Root Cause Analysis (RCA).

The battery testing process is conducted through the following steps:

1. Battery Voltage Measurement
2. Load Current Measurement
3. Voltage Drop Measurement during Discharge
4. Ambient Temperature Measurement
5. Battery Capacity Data Processing

In this study, the author will perform battery testing without 220 Vac power to analyze Effective Battery Capacity, Depth of Discharge (DoD), State of Charge (SoC) and efficiency. The formula used to calculate the State of Health (SoH) of the battery is as follows:

Effective Battery Capacity

Effective Battery Capacity is the usable capacity of a battery during operation. The battery capacity is calculated using the following formula:

$$C_{\text{efektif}} = I \times t \dots \dots \dots (1)$$

Where:

- I = Actual load current (A)
- t = Duration the battery is capable of supporting the load until reaching the shutdown voltage limit (hours).

Analysis Depth of Discharge (DoD)

The percentage of a battery's capacity that has been used during operation. Depth of Discharge (DoD) is calculated using the following formula:

$$DoD = \frac{I \times t}{C_{\text{nominal}}} \times 100\% \dots \dots \dots (2)$$

Where :

- I = Load current (A),
- t = Discharge time (hours),
- C_{Nominal} = Nominal battery capacity (Ah)

Analysis State of Charge (SoC)

State of Charge (SoC) analysis is used to describe the proportion of the remaining battery capacity during the discharge process .The calculation is performed using the following formula:

$$\text{SoC}(\%)=100\%-\text{DoD}(\%).....(3)$$

Analysis Efficiency (η)

Battery efficiency analysis is conducted to evaluate how much of the actual capacity can still be utilized compared to the battery's nominal capacity. The calculation is performed using the following formula:

$$\eta = \frac{C_{\text{efektif}}}{C_{\text{nominal}}} \times 100\%.....($$

Technical Analysis Initial Findings During Field Observation

Preliminary observations were conducted by performing load testing without a 220 Vac power supply on five battery units. The load testing was carried out with a constant load of 9.8–10A. The test results are presented below.

Battery unit #1, recorded during a real load test on August 13, 2024. It displays the 24Vdc control voltage drop profile under a constant current of around 9.8 A. The initial voltage was 25.2 Vdc, which then dropped gradually to 21.5–21.6 Vdc in less than 30 seconds.

Battery unit #2, recorded during a real load test on August 15, 2024. The battery was able to support a constant load of about 9.6 A for approximately 5 minutes.

Battery unit #3, recorded during a real load test on August 15, 2024. The test results indicate that the battery is in very poor condition and is unable to support the 9.8 A control load. When the 220 Vac power was turned off, the voltage immediately dropped to 0.00 V.

Battery unit #4, recorded during a real load test on August 8, 2024. Under a full load of 9.8 A, the voltage gradually decreased until it reached a low point of approximately 21.7 V within ±5 minutes, before the AC supply was finally restored.

Battery unit #5, recorded during a real load test on August 15, 2024. After the VAC supply was disconnected, with a constant load current of around 9 A the battery voltage began to drop gradually from 24.4 Vdc to about 21.7 Vdc within approximately 2 minutes.

Table 1. Battery Voltage and Current Measurements over Time Before Battery Replacement

Unit	Load (A)	Start Voltage (Vdc)	End Voltage (Vdc)	Duration	Date
Unit #1	9.8	25.5	21.6	30 seconds	13-08-2024
Unit #2	9.6	25.5	23.6	5 menit	15-08-2024
Unit #3	9.8	25.2	0	10 seconds	15-08-2024
Unit #4	9.8	25.2	21.7	5 seconds	08-08-2024
Unit #5	9.0	24.4	9.0	2 seconds	15-08-2024

Source: Author 2025

Table 1 presents the results of the overall battery health test conducted under load conditions without a 220 VAC power supply. The field test data indicate that the battery with a nominal specification of 24 VDC 100 Ah was only able to sustain the load for less than five minutes, far below its designed capacity.

Table 2. Results calculation of Efectif Battery Capacity Before Battery Replacement

Unit	Load (I)	Time (t)	Efektif Battery Capacity (AH)	Nominal Capacity (AH)
Unit #1	9,8	30 seconds	0,081	100
Unit #2	9,6	5 seconds	0,80	100
Unit #3	9,8	10 seconds	0,027	100
Unit #4	9,8	5 minutes	0,81	100
Unit #5	9,0	2 minutes	0,30	100

Source: Author 2025

Table 2 presents the results of the effective capacity calculations, showing that the five battery units are only capable of providing an actual capacity ranging from 0.027 Ah to 0.81 Ah, which is less than 1% of the manufacturer's nominal capacity of 100 Ah.

Table 3. Results calculation Depth of Discharge (DoD) Before Battery Replacement

Unit	Efektif Capacity (AH)	Nominal Capacity (AH)	Depth of Discharge (DoD) (100%)
Unit #1	0,081	100	0,081
Unit #2	0,80	100	0,80
Unit #3	0,027	100	0,027
Unit #4	0,81	100	0,81
Unit #5	0,30	100	0,30

Source: Author 2025

Table 3 shows presents the Depth of Discharge (DoD) calculations, showing that the battery capacity discharge across all units remains far below the manufacturer's nominal capacity, with DoD values of less than 1%.

Table 4. Results calculation State of Charge (SoC) Before Battery Replacement

Unit	DoD (%)	SoC (%)
Unit #1	0,081	99,919
Unit #2	0,80	99,20
Unit #3	0,027	99,973
Unit #4	0,81	99,19
Unit #5	0,30	99,70

Source: Author 2025

Table 4 presents the State of Charge (SoC) calculation results, showing very high values across all units, exceeding 99%. These high SoC values do not reflect a healthy battery condition; instead, they indicate that the batteries are unable to discharge energy effectively when subjected to a load.

Table 5. Results calculation Battery Efficiency Before Battery Replacement

Unit	Efektif Capacity (AH)	Nominal Capacity (AH)	Efisiensi(η) (%)
Unit #1	0,081	100	0,081
Unit #2	0,80	100	0,80
Unit #3	0,027	100	0,027
Unit #4	0,81	100	0,81
Unit #5	0,30	100	0,30

Source: Author 2025

Table 5 presents the efficiency calculation results, showing that all battery units have a capacity utilization efficiency of less than 1% of the manufacturer's nominal capacity. According to IEEE-1188-2005, it is recommended to replace the battery if the capacity value is <80%.

Table 6. Result Measurement Effective Battery Capacity, DoD, SoC and efficiency Before Battery Replacement

Unit	Efektif Capacity (AH)	Nominal Capacity (AH)	Efisiensi(η) (%)
Unit #1	0,081	100	0,081
Unit #2	0,80	100	0,80
Unit #3	0,027	100	0,027
Unit #4	0,81	100	0,81
Unit #5	0,30	100	0,30

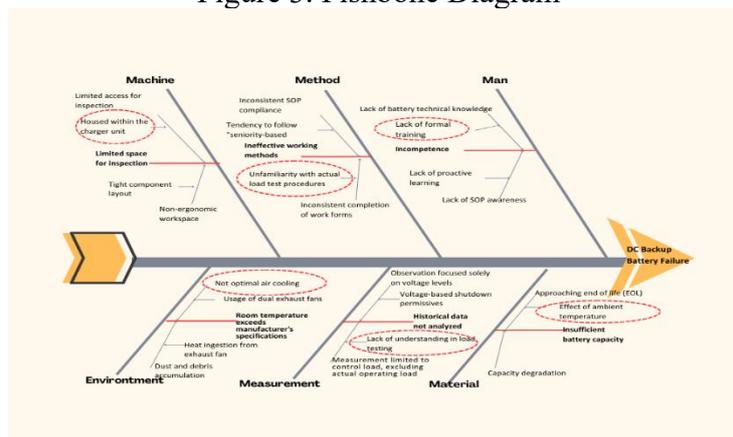
Source: Author 2025

Table 6 presents the condition of the five battery units in terms of Effective Battery Capacity, Depth of Discharge (DoD), State of Charge (SoC), and efficiency before battery replacement.

Route Cause Analysis (RCA) Fishbone Diagram

The Fishbone Diagram, also known as the Ishikawa model. In this diagram, various causes are categorized into specific groups such as Manpower, Material, Method, Measurement, and Environment. The arrows in the diagram illustrate how each cause is interrelated and flows toward the occurrence of the non-conformity.

Figure 3. Fishbone Diagram



Source: Author 2025

Figure 3 illustrates the results of the Fishbone analysis the failure of the battery back-up system was not caused by a single isolated factor, but rather by the cumulative impact of manpower, methods, machines, materials, measurements, and environmental factors. The detailed results of the analysis are presented below.

Table 7. Primary Root Causes Derived from the Fishbone Analysis

No	Factor	Main Causes
1	Man	Lack of adequate training
2	Method	Inappropriate battery testing procedures
3	Machine	Limited accessibility for battery maintenance
4	Material	Influence of room temperature
5	Measurement	Lack of understanding of testing methodologies
6	Environment	Suboptimal cooling system

Source: Author 2025

Table 8. 5-Why Fishbone Analysis

Factor	Why 1	Why 2	Why 3	Why 4
Man	Technicians failed to detect battery degradation	Technicians only checked battery voltage levels.	Lack of understanding of capacity testing methods using actual loads.	Personnel have not received specialized battery training
Method	Battery failure went undetected	Testing was conducted without actual operational loads.	Testing methodology was solely based on voltage values.	Voltage is used as the permissive shutdown logic in the PLC

Factor	Why 1	Why 2	Why 3	Why 4
Machine	Batteries are rarely inspected thoroughly.	Restricted access for physical inspection.	Batteries are installed inside the battery charger cabinet.	Initial design prioritized space efficiency.
Material	Battery unable to support the load.	Significant decline in battery capacity	Room temperature exceeded manufacturer's specifications.	
Measurement	Load test forms were not completed	Technicians did not understand actual load testing procedures	Lack of established practice/precedent from senior technicians	

Source: Author 2025

Technical Analysis Initial Implementation

Technical analysis of the 24 VDC Battery Back-Up system's performance, focusing on key parameters such as battery capacity, Depth of Discharge (DoD), State of Charge (SoC), and energy utilization efficiency. The analysis was conducted to evaluate the actual capability of the batteries in supporting the control load during a primary power supply failure, as well as to assess the level of capacity degradation compared to the manufacturer's specifications.

Research Gap

Based on these studies, there is a research gap between battery maintenance theory and field operational practices, specifically in the application of technical analysis methods integrated with decision-making processes and the implementation of real corrective actions. The battery used is a VRLA (Valve Regulated Lead Acid) type, specifically the LEADLINE EVR 12100 model. Theoretically, with a constant load of 10A, the battery should be able to support the load without a 220 Vac power supply for 8 to 10 hours. However, in practice, it can only sustain the load for less than 5 minute. This gap becomes increasingly relevant when the battery back-up system serves as a critical power source for control systems that operate continuously.

Therefore, this research was developed as a Capstone Project oriented toward solving real-world problems in the field. The main variables analyzed include technical battery performance (effective capacity, DoD, SoC, and efficiency), operational environmental factors, and the effectiveness of the applied preventive maintenance practices. Through a technical analysis approach, Root Cause Analysis (RCA), implementation of corrective actions, and final testing, this research is expected to provide practical and applicable contributions in improving the reliability of DC Battery Back-Up systems and supporting the operational sustainability of Gas Turbine Compressors.

Work Plan and Project Execution

Work Plan

In line with the objectives of this Capstone Project, the direct observations conducted were not merely for analysis but were immediately translated into actionable solutions, leading to the successful resolution of the problem. Following the identification of on-site issues, a comprehensive work plan was prepared, which includes cost estimation, work schedule, testing and commissioning procedures, and the handover of completed work.

Project Execution

Based on the testing results and field observations, it was determined that the batteries were unfit for service and required immediate replacement. The rectification work was carried out from December 2024 to January 2025.

RESULTS AND DISCUSSION

Results

Quantitative results were obtained from actual load testing on the DC Battery Back-Up system before and after corrective actions. The primary parameters analyzed include voltage, current, discharge duration, effective battery capacity, Depth of Discharge (DoD), State of Charge (SoC), and battery capacity efficiency. Initial testing showed that all battery units were only able to sustain the control load for a very short duration (less than five minutes), despite initial voltages measuring as normal. Calculations for effective capacity and DoD indicated that the batteries had undergone significant capacity degradation and no longer met manufacturer specifications. This condition explains the automatic shutdowns of the Gas Turbine Compressors when the primary power supply was interrupted. After implementing corrective actions consisting of battery replacement and adjustments to maintenance practices re-testing showed a significant performance improvement. All units were able to support the control load for test durations ranging from 40 to 54 minutes without exceeding permissive shutdown limits. Post-implementation DoD values remained low while SoC remained high, indicating that the batteries maintain adequate capacity reserves to support reliable system operations.

Qualitative results were derived through field observations, documentation studies, and root cause analysis using Fishbone Diagrams and the 5-Why method. This analysis identified that the battery back-up system failure was not only caused by technical battery factors but was also influenced by manpower, work methods, measurement, and environmental conditions. Findings revealed that previous preventive maintenance practices focused more on voltage measurements without actual load-based capacity testing. Additionally, relatively high battery room temperatures and limited inspection access contributed to accelerated battery degradation. These factors collectively explain why the batteries appeared normal in terms of voltage yet failed under load.

Table 9. Battery Voltage and Current Measurements over Time Before Battery Replacement

Unit	Load (A)	Start Voltage (Vdc)	End Voltage (Vdc)	Duration	Date
Unit #1	9.8	25.5	21.6	30 seconds	13-08-2024
Unit #2	9.6	25.5	23.6	5 seconds	15-08-2024
Unit #3	9.8	25.2	0	10 seconds	15-08-2024
Unit #4	9.8	25.2	21.7	5 minutes	08-08-2024
Unit #5	9.0	24.4	9.0	2 minutes	15-08-2024

Source: Author 2025

Table 10. Battery Voltage and Current Measurements over Time After Battery Replacement

Unit	Load (A)	Start Voltage (Vdc)	End Voltage (Vdc)	Duration	Date
Unit #1	9.8	25.4	23,4	40 menit	12-01-2025
Unit #2	9.6	26.0	23.9	54 menit	12-01-2025
Unit #3	9.8	25.9	23,3	54 menit	14-01-2025
Unit #4	9.8	25.4	22,9	53 menit	12-01-2025
Unit #5	9	25,3	22,6	54 menit	12-01-2025

Source: Author 2025

Table 11. Measurement Effective Battery Capacity, DoD, SoC efficiency and Remark Before Battery Replacement

Unit	Efektif Battery (Ah)	DoD (%)	SoC (%)	Efisiensies (%)	Remark
Unit #1	0,08	0,08	99,92	0,08	Drop < 1 minutes
Unit #2	0,80	0,80	99,20	0,80	Drop ±5 minutes
Unit #3	0,03	0,03	99,97	0,03	Dropout
Unit #4	0,80	0,80	99,20	0,80	Fluktuating
Unit #5	0,30	0,30	99,70	0,30	Low Capacity
Avarage	<1 Ah	<1%	>99%	<1%	Unfit for Services

Source: Author 2025

Table 12. Result Measurement Effective Battery Capacity, DoD, SoC efficiency and Remark After Battery Replacement

Unit	Efektif Battery (Ah)	DoD (%)	SoC (%)	Efisiensies (%)	Remark
Unit #1	6,53	6,53	93,47	6,53	Stabil
Unit #2	8,64	8,64	91,36	8,64	Stabil
Unit #3	8,82	8,82	91,18	8,82	Stabil
Unit #4	8,65	8,65	91,35	8,65	Stabil
Unit #5	8,10	8,10	91,90	8,10	Stabil
Avarage	8,15 Ah	8,15	91,85	8,15	Fit and Reliable

Source: Author 2025

Discussion

The discussion of the research results shows that the DC Battery Back-Up system failure resulted from a gap between the applied maintenance approach and actual operational conditions. These results reinforce findings in the literature review that voltage parameters alone are insufficient to assess battery health, and actual capacity testing is a critical element in maintaining the reliability of operation-support systems. The successful implementation of corrective actions and the subsequent performance improvement prove that an approach based on technical analysis and RCA is effective in resolving the problems encountered. Consequently, this Capstone Project not only generates academic findings but also provides a practical contribution to enhancing operational reliability, reducing the risk of unplanned shutdowns, and supporting the operational sustainability of Gas Turbine Compressors in the oil and gas sector.

CONCLUSION

This research identifies that battery capacity degradation, primarily driven by human factors as revealed through Fishbone and 5-Why analyses, led to the failure of the DC backup system during AC power loss. By implementing a refined maintenance strategy and battery replacement, final testing validated a significant recovery in system reliability. The study concludes that synchronizing maintenance intervals with actual State of Health (SOH) data effectively ensures the operational stability of gas turbine control loads.

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