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AIRPORT EMERGENCY DIESEL PREVENTIVE MAINTENANCE MANAGEMENT USING BATTERY INTERNAL RESISTANCE MONITORING ANALYSIS

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Abstrak — *Emergency diesel generator is a very important system in every industry including the airport industry because this system supports the electricity of important equipment when a blackout occurs. in the emergency diesel generator system, there is a battery as a starter for the diesel engine. if the battery capacity decreases, the diesel generator will not be able to start the engine, therefore in the emergency diesel generator system, regular battery maintenance is needed to maintain system reliability. in this journal, preventive maintenance on the battery will be explained, especially on the emergency diesel generator system battery. one indicator of decreased capacity in the battery is an increase in its internal resistance value. in preventive battery maintenance, analyzing the increase in internal resistance can be a reference for replacing a new battery.*

Keywords: *Battery, Internal, Resistance, Preventive, Maintenance.*

1. *INTRODUCTION*

Emergency diesel generator is a very important system in every industry including the airport industry because this system supports the electricity of important equipment when a blackout occurs. in the emergency diesel generator system, there is a battery as a starter for the diesel engine. if the battery capacity decreases, the diesel generator will not be able to start the engine, therefore in the emergency diesel generator system, regular battery maintenance is needed to maintain system reliability. in this journal, preventive maintenance on the battery will be explained, especially on the emergency diesel generator system battery. one indicator of decreased capacity in the battery is an increase in its internal resistance value. in preventive battery maintenance, analyzing the increase in internal resistance can be a reference for replacing a new battery (Jhon Hericson Purba et al, 2023). In the airport industry, which demands reliable equipment, every effort is made to prevent equipment from suddenly breaking down. In-depth preven tive and predictive maintenance is needed, and proactive maintenance measures are even required (Yang S K, 2004). One of the preventive maintenance measures for batteries is to equalizing charge and record battery parameters regularly, one of which is recording the internal resistance of the battery as an early indicator of the condition of the battery capacity (Belmokhtar K et al, 2016).

1.1 *Battery Internal Resistance*

Basically, internal resistance in a battery is formed by the resistance between the battery electrodes, which is generally the resistance value of the electrolyte and the electrode itself. This internal resistance value will increase with age due to aging of the electrodes that experience redox reactions many times during the charge & discharge process which causes some ions to be intercalated and cannot be returned perfectly (Wei X et al, 2009).

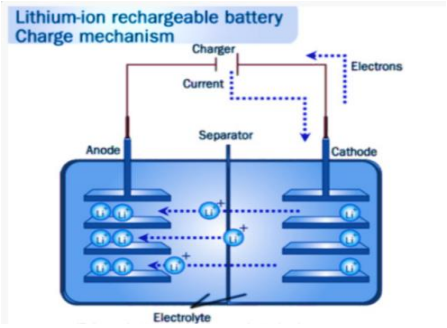


Figure 1. intercalation reaction during charge process

In its actual position, the internal resistance of the battery should be inside the battery, namely in the middle between the positive and negative poles of the battery, but in the depiction of the electrical circuit if it is depicted like that, it will show a short circuit between the positive and negative poles, and also experimentally, the increase in internal resistance of the battery has a direct effect on the voltage drop in the battery, so the most ideal depiction for internal resistance of the battery is in series with the battery (Ashok K Signal, 2013).

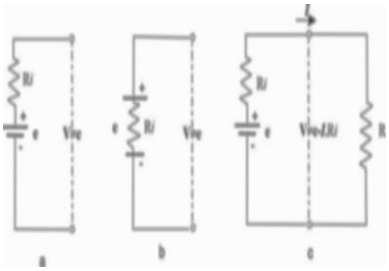


Figure 2. a) an open circuit with internal resistance Ri in series with the battery b) Ri "inside" the battery and c) a closed circuit with Ri in series with external resistance

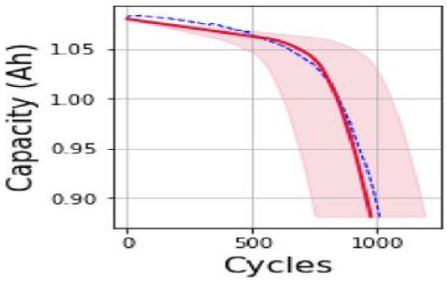
We can find the internal resistance of the battery from the difference in voltage when the battery is open circuit and when the battery is closed loop connected to the external resistance divided by the current when the battery is closed loop connected to the external resistance.

$$Ri = \frac{(e-V)}{I} \ldots\ldots\ldots\ldots\ldots\ldots (1)$$

with Ri being battery internal resistance (Ω), e is the battery voltage when open loop (V), and V being the voltage when close loop (V), I is the current when battery close loop. Basically, the increase in the internal resistance value of the battery can be known through the battery voltage drop when the loop is closed to the load, but in the emergency diesel system in the airport, the battery is always connected to the rectifier module as a float charge scheme, one of the preventive main tenance. Therefore, the decrease in voltage value cannot be seen because the voltage detected is the voltage from the float charge module rectifier.

1.2 *Battery Internal Resistance and Battery Capacity Correlation*

There have been many studies that have tested the relationship between internal battery resistance and its capacity, and under normal room temperature condi tions, 90% CI of the relationships are where the internal resistance value will increase as its capacity decreases. such as the research results of Mr. Rasheed Ibrahim in his diagram (Rasheed Ibrahim et al, 2022).



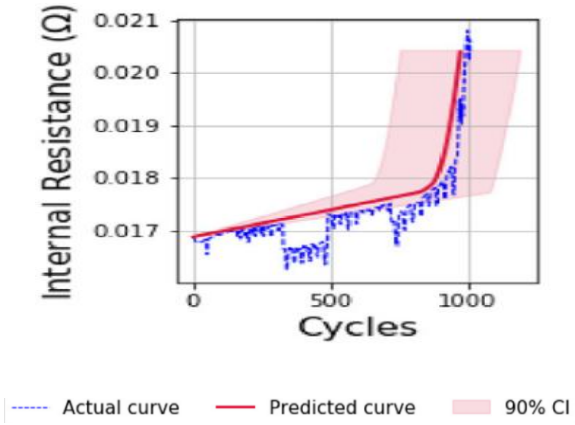


Figure 3. decreasing battery capacity and increasing battery internal resistance curve against the number of cycles

In his research, he put forward a prediction of the curve of battery capacity decline and increase in internal resistance based on battery discharge test data for the first 50 cycles and the rest were calculated using statistical methods (mean, variance, kurtosis, skewness, min and max) and gradient based approaches (area under curve and slope).

2. *METHODOLOGY*

The methodology used in this study begins with a literature study related to the relationship between internal resistance and capacity in batteries and the collection of primary data related to internal resistance standards that can be used in emergency diesel systems. After obtaining the internal resistance standards, preventive mainte nance and periodic internal battery resis tance checks are carried out, and based on the analysis of internal resistance data, we can determine whether the battery in the emergency diesel starter system can still be used or must be replaced.

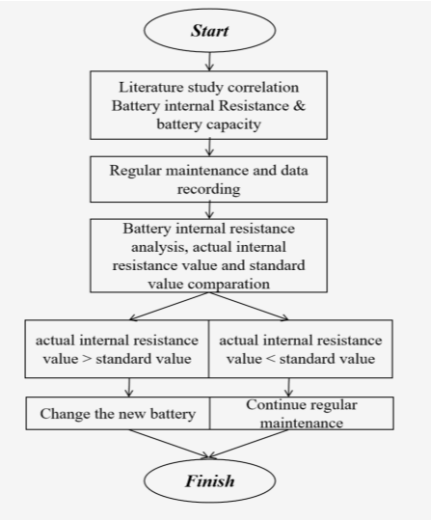


Figure 4. Flow Chart of the Research

3. *RESEARCH RESULTS AND DISCUSSION*

In general, the standard internal resistance value of the battery varies depending on the specifications & type of battery, especially even though the specifications are the same if the brand is different, the standard internal resistance value of the battery is also different. In fact, the internal resistance value of the battery that has exceeded the manufacturer's standard does not neces sarily mean it cannot be used anymore, depending on the load system that uses the battery, can it still operate normally if the internal resistance value of the battery has exceeded the manufacturer's standard? If it can still support the system load and can operate normally, there is no need for replacement. Some airport has been operating for 3 years or more, of course, there are several spare parts that have been replaced, one of which is the battery in the emergency starter system of the diesel generator, therefore we have known the maximum limit of the internal resistance value of the battery to support the emer gency system of the diesel generator, which is 3mΩ, if the resistance value is more than 3mΩ then the emergency system of the diesel cannot be turned on. Preventive maintenance carried out to extend battery life is to equalize the charge every month, so that the ions in the electrolyte are perfectly

separated and reduce the breakdown rate of the electrodes and battery cells. In addition, to maintain the reliability of the emergency diesel system, internal battery resistance measurements are also carried out once a week as an indication that the battery needs to be replaced.

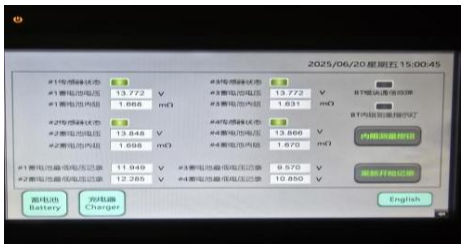


Figure 5. Display of Battery Online Monitoring Device

The data of the diesel emergency system battery January-February when the battery was replaced is as follows:

Date	Battery Number	Internal Resistance (mΩ)
27/01/2025	1	2,967
	2	2,942
	3	3,368
	4	2,98
03/02/2025	1	3,037
	2	2,979
	3	3,429
	4	2,957
10/02/2025	1	3,044
	2	2,992
	3	3,456
	4	2,965
17/02/2025	1	3,074
	2	3,016
	3	3,506
	4	3,006
New Battery Replacement		
24/02/2025	1	1,681
	2	1,715
	3	1,662
	4	1,718

Table 1. EDG Battery Regular Inspection Sheet

From the data table, we can create a curve showing the increase in the internal resistance of the battery and we can enter the internal resistance variable as the y-axis and the data collection period variable (weekly) as the x-axis by ignoring the fifth week's data because in the fifth week the new battery was replaced:

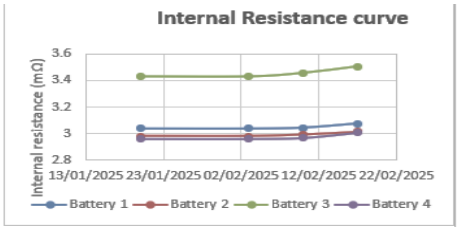


Figure 6. Battery Internal Resistance Curve

From the data obtained, we can also create a linear equation for the increase in internal resistance to forecast battery replacement as a Predictive maintenance. We can use the least squares method:

$$y = a + bx \qquad \text{.....(2)}$$

Where:

$$b = [n(\Sigma xy) - (\Sigma x)(\Sigma y)]/[n(\Sigma x^2) - (\Sigma x)^2] \text{ ..... (3)}$$

And

$$a = (\Sigma y - b(\Sigma x))/n \qquad \text{.....(4)}$$

Where:

n: number of data pairs (x, y)

Σxy: is the sum of the products of x and y for each data pair

Σx: the sum of all x values

Σy: the sum of all y values

Σx^2: the sum of the squares of all x values

The calculation of the linear equation for internal resistance of battery 1 is: $b = [4(30{,}539) - (10)(12{,}192)]/[4(30) - (10)^2]$ *So b= 0,0118 and then for a value is:* $a = (12{,}192 - 0{,}0118(10))/4$ *So a=3,0185 then the linear equation for internal resistance battery 1 is y=3,0185+0,0118x As with the calculations carried out on the internal resistance of battery 1, the other batteries also have the following linear equations:*

Battery Number	Linear Equation
Battery 1	y=3,0185+0,0118x
Battery 2	y=2,9605+0,0124x
Battery 3	y=3,390+0,02588x
Battery 4	y=2,9325+0,0155x

Table 2. Increment of Internal Resistance Battery Linear Equation

We add up the four linear equations obtained to get the average value. We assume the value of a to be 0 because we only want to find the gradient of the increase by ignoring

the initial value.
(y=0,0118x)+(y=0,0124x)+(y=0,02588x)+(y=0,0155x) => 4y=0,06558x =>
y=0,016395x. It is found that the gradient value of increasing internal resistance is y=0,016395x, then we enter the value a with the initial internal resistance from the table with the average internal resistance value after the battery is replaced.
a=(1,681+1,715+1,662+1,718)/4=1,694.
So we get a linear equation for predicting the next battery replacement after replacing the new battery, namely:
y=1,694+0,016395x. to predict in which week we should replace the battery and because the standard internal resistance should not be more than 3 milliohms, so we enter the value of y as 3, 3=1,694+0,016395x => 0,016395x=3-1,694 => x=1,306/0,016395 => x=79,658, From this value, the battery replacement is carried out after the 79th week, rounded down for preventive reasons so that the system runs reliably.

4. *CONCLUSION AND RECOMMENDATIONS*

From this research, there are several conclusions and suggestions that can be provided by the writing team as follows:

- *In the Indonesian airport industry, unit reliability is highly emphasized because the assessment of whether a unit is good or not is determined by its AF (availability factor), therefore, excellent preventive maintenance management is needed to reduce unit downtime. One of the good preventive maintenance is the periodic replacement of spare parts, some of which have been determined by the manufacturer for replacement, and some are unknown. One of the spare parts whose replacement period is unknown is discussed in this journal with a fore casting analysis approach using the least squares method.*

- *In the discussion, the average value of the internal resistance increment linear equation was found using the least squares method y=1,694+0,016395x. From this equation, we can estimate the EGD battery replacement time and we can manage our spare parts procurement planning regularly based on the analysis we've conducted. Ultimately, the EGD system will remain reliable and avoid failure to start in emergency situations (grid blackout).*

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