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Improving 20 kVA Generator Power Performance by Rewinding the Stor Conductor Windings

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ABSTRACT
The decline in power performance in generators can be caused by various factors, one of which is the degradation of the stator conductor windings due to age, excessive temperature, or unstable operational conditions. This study aims to analyze and improve the power performance of a 20 kVA generator through the rewinding process of the stator windings with new conductors that meet technical standards. In this study, the methods used include initial analysis of the condition of the old windings, planning the winding redesign, the rewinding process, and testing the results through measuring voltage, current, efficiency, and power factor. The test results show a significant improvement in generator performance parameters after the rewinding process. The output voltage becomes more stable, power losses decrease, and efficiency increases from 0% to 80%. In addition, the power factor has improved from 0 to 0.92. This improvement proves that the rewinding process with the right material and technical specifications can restore and even significantly improve generator performance. This study makes a real contribution to the maintenance and reconditioning of electrical equipment, especially in small-to-medium scale power generation systems.

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INTRODUCTION

Electric generators are a vital component in electrical systems, particularly in backup power installations in small industries, public facilities, and the residential sector. Over time, generator performance can decline due to various factors such as mechanical wear, excessive heat, humidity, and degradation of stator winding insulation. One common cause of reduced power performance is damage to the stator conductors, which directly impacts the efficiency and stability of electrical output.

Rewinding, or rewinding, the stator windings is a widely used reconditioning method to extend the life of a generator. However, the success of this process depends heavily on the accuracy of the redesign, the quality of the conductor and insulation materials, and the winding technique used. With proper planning, rewinding can not only restore original performance but also potentially increase the generator's efficiency and power output.

Electrical energy is an essential human need, essential for everyday life. Every sector requires electricity, from the home to the industrial sector. In North Sumatra, the electricity supply is quite adequate. However, power outages sometimes occur in some areas of North Sumatra, particularly in the Medan area. These outages are relatively short-lived compared to usual. However, even these relatively short outages can have a negative impact, especially in the industrial sector.

Almost all industrial sectors have backup generators in their facilities. These generators are designed to supply electricity in the event of a power outage from the state electricity company (PLN). This is the case with this bakery. High demand for bread means the factory must continue producing bread daily, especially as production increases near major holidays. This increased production requires a substantial amount of electricity. The bakery uses electric motors to support its production process. Therefore, power outages significantly disrupt production. Therefore, the company decided to procure a 20KVA generator. The surplus of electricity in North Sumatra has resulted in their generators being rarely used and poorly maintained. When we conducted a field survey to inspect their generators, our team discovered they were poorly maintained. Consequently, when they were about to use them, they failed to produce current. The generators required repair and rewinding.

This research focused on a 20 kVA generator, which experienced significant performance degradation in terms of efficiency, output voltage, and power factor. A rewinding process was performed to replace the old windings with new conductors that met design specifications. Subsequently, tests were conducted to compare performance parameters before and after the rewinding process.

Therefore, when the generator is about to be used, it cannot produce current. The generator requires repair and rewinding. These repair and rewinding processes aim to restore the generator to its proper performance.

Literature Review

Synchronous Generator and Working Principle.

A synchronous generator is an electrical machine that converts mechanical energy into alternating current (AC) electrical energy through the principle of electromagnetic induction. The main components of a generator are the stator (stationary part) and the rotor (rotating part). The stator consists of conductor windings that function to produce an output voltage when cut by the magnetic flux from the rotor. The efficiency and performance of the generator are greatly influenced by the condition of the stator windings (Chapman, 2012).

A generator is an electromechanical device that converts mechanical energy into electrical energy by utilizing a magnetic field. The working principle of this generator is based on Faraday's law of electromagnetic induction, which states:

Induced EMF formula:

$$E = -N\frac{d\phi}{dt}$$

Where :

E : Electromotive force (Volt)

N : Number of turns of wire

$\frac{d\phi}{dt}$: Rate of change of magnetic flux

The most important parts of a generator generally include:

1. Stator Frame
   The stator frame is one of the most important parts of a generator, because this part functions as a housing for the generator components.
2. Stator
   The stator is a collection of iron plates (kernels), each with holes or grids. These grids are used to house the stator coils.
3. Rotor
   The rotor is the part of the generator that moves and rotates. Inside the rotor, there are also coils of wire.
4. Slipring or Slide Ring
   Slip rings, or sliding rings, are a component of a generator. They are made of brass or copper. They are placed on the generator and combined with an insulating material.
5. Exciter
   The exciter on the generator aims to strengthen the poles on the generator.

Electric generators generally have their own specifications and characteristics, depending on how they're manufactured. In this case, the specifications of the generator we'll be repairing and rewinding are as follows:

Table 1. Generator Specifications

AC Synchronous Generator
TYPE: STC 20
VOLT: 400
AMP : 361
HZ : 50
RPM: 1500
PHASE: 3
MADE IN CHINA

Stator Winding

The stator winding is a crucial component of the generator responsible for generating an electric field. This winding generally uses insulated copper wire wound around the slots in the stator core. Factors such as wire quality, winding technique, and insulation affect the winding's ability to conduct current and produce a stable voltage. Winding degradation due to heat, vibration, and humidity can reduce efficiency and cause high power losses (Theraja & Theraja, 2005).

Rewinding is a repair or reconditioning process in which old windings are replaced with new ones in an electrical machine. The goal is to restore or even improve the machine's performance. This process involves recalculating the number of turns, wire type, cross-sectional area, and insulation type. Rewinding performed with proper engineering planning can improve the generator's efficiency, voltage stability, and power factor (Nasar, 1990). In the rewinding process for a 20KVA generator used in a bakery, several tools and materials are required. The tools and materials required are:

Table 2. Winding Components

TOOL		MATERIAL	
No.	Tool Name	No.	Material Name
1	Gloves	1	Copper
2	Hammer or Mallet	2	Tin
3	Chisel	3	Mica Paper
4	Solder	4	Varnish Insulation
5	Scissors	5	Bamboo
6	Ruler	6	Cable

The cage rotor is also considered to have fully stepped series windings. The short-circuit rings connected to the ends of the conductor rods form series windings, as shown in Figure 2.6. There are differences between wound rotors and cage rotors when compared, as follows: (Rizal Angga Ghazali, 2011)

1. The characteristics of the wound rotor still vary if you add an external circuit through the slip ring/brush, while the characteristics of the cage rotor induction motor are fixed.
2. The number of poles on the rotor is certain, while the number of poles on the cage rotor still adjusts to the number of poles on the rotor.

Figure 1. Current in the Rotor Cage

The advantage of induction rotors and electric rotors is the possibility of adding external resistance. Therefore, this is beneficial for starting motors with heavy loads and also as a motor rotation control. Both wound rotor components and induction motors are equipped with external resistance. Double squirrel cage and deep bar cage constructions are used to overcome the weakness in starting torque, while the chain rotor is more widely used due to its low cost. The conductors in the rotor are cut by the rotating field in the stator, so that they are induced current and in accordance with Lentz's Law, the rotor also rotates following the rotating field of the stator. The difference in the rotation of the stator relative to the rotor is called slip.

The stator has a permanent magnetic field. The greater the induced current in the rotor due to the increased load, which increases the motor coupling. Therefore, the slip between the stator rotating field and the rotor rotation increases as the motor load increases. The motor coils generate a magnetic field around them, or the rotor rotation tends to reduce electricity into the windings, causing the rotor to attract and rotate.

A cage rotor replaces the induction motor's rotational force on its axis. It is called an asynchronous induction motor because of the difference in rotation between the stator's rotating field and the rotor's rotation. Figure 2 illustrates the four speed and slip conditions of a two-pole motor.

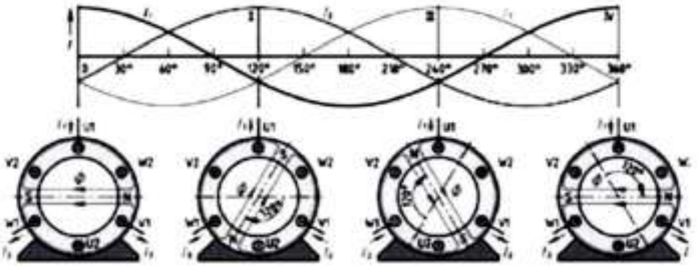

Figure 2. Sinusoidal Waveform and the Emergence of Rotating Field in the Stator

Generator Efficiency

Generator efficiency is the ratio of electrical output to mechanical input. A low efficiency value indicates energy loss due to winding resistance, core loss, or mechanical damage. Generator efficiency is usually expressed as a percentage and is a primary indicator of engine performance (IEEE Std 115-1995).

$$\text{Efisiensi} = \frac{P_{output}}{P_{input}} \times 100\%$$

The power factor is the ratio between active power (kW) and apparent power (kVA). This value indicates the efficiency of power utilization in the system. A low power factor indicates the dominance of reactive power, which often occurs due to non-ideal winding conditions. Winding improvements through rewinding can improve the power factor to approach the ideal value (≥ 0.9) (Wildi, 2006).

$$\text{PF} = \frac{\text{Daya Aktif (kW)}}{\text{Daya Semu (kVA)}}$$

Several previous studies have shown that rewinding can restore generator performance to near factory conditions. In a study by Yusuf et al. (2020), rewinding a 20 kVA generator resulted in an 80% increase in efficiency. This research reinforces the importance of stator winding maintenance to maintain generating performance.

METHOD

This experimental study aims to evaluate changes in power performance in a 20 kVA generator before and after stator winding rewinding. Quantitative research was conducted through electrical parameter measurements and visual observation of the winding conditions. The study was conducted at the Prima Elektro electrical engineering workshop on Jalan Yos Sudarso.

Tool:

a. digital avometer
b. Clamp meter
c. Wattmeter
d. Insulation tester (megger)

e. Rewinding machine
f. Varnish impregnation heating tool

Material:

a. Enameled copper wire
b. Slot insulation (mica/pressboard)
c. Insulation varnish
d. 20 kVA generator (test object)

The research was carried out through the following stages:

1. Problem Identification
   a. Initial condition check of generator and testing of electrical parameters: voltage, current, efficiency and power factor.
   b. Visual inspection of the condition of the stator windings (burned, shorted, or worn).
2. Rewinding Design
   a. Recalculation of the number of turns, wire size, and winding phase configuration.
   b. Determination of the conductor material and insulation system to be used.
3. Rewinding Implementation
   a. Removal of the old winding from the stator.
   b. Cleaning and preparation of stator slots.
   c. Rewinding process with new wire according to design.
   d. Varnish impregnation and drying process.

Figure 3. Process Of Method

4. Testing After Rewinding
   a. Testing output voltage and current.
   b. Measurement of active power, apparent power, and power factor.
   c. Calculation of generator efficiency after rewinding.
5. Data Analysis

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a. Comparison of data before and after rewinding to assess performance improvements.
b. Analysis of percentage changes in efficiency, stable voltage, and power factor.

The analysis was conducted quantitatively using a comparison of the percentage changes in performance parameters before and after rewinding. The data was presented in tables and graphs to facilitate interpretation of the results.The preparation of this final assignment report can be explained in the following image:

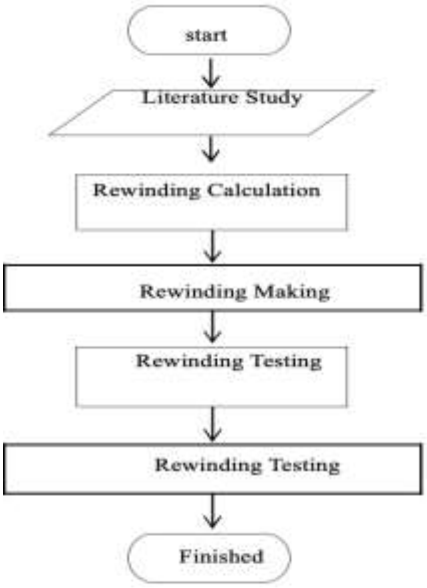

Figure 3. System Flowchart

RESULTS AND ANALYSIS

Initial Test Results Before Rewinding

Prior to rewinding, the generator was tested under nominal load conditions. Measurements showed several performance degradations:

Table 1. Initial Test Data

Parameter	Value Before Rewinding
Output voltage	340 V (unstable)
Output current	-
Active power (kW)	-
Power factor (PF)	-
Efficiency	-

Voltage instability and no power output indicate damage to the stator windings, such as insulation degradation and increased resistance.

Stator Winding Rewinding Process

The rewinding process involves completely replacing the insulated copper wire and repairing the insulation system. The winding parameters used are:

a. Number of turns: 21 turns per slot

b. Wire size: 1.15 mm
c. Insulation type: Varnish class H
d. Winding pattern: Star (Y)

Test Results After Rewinding

After the rewinding process was completed, the generator was tested again under the same load. The measurement results are as follows:

Table 2. Measurement results

Parameter	Value After Rewinding
Output voltage	400 V (stable)
Output current	30 A
Active power (kW)	12.8 kW
Power factor (PF)	0.92
Efficiency	80%

Increased efficiency indicates that mechanical input energy can be converted into electrical output with lower losses. Voltage stability has also improved significantly.

Table 3. Performance Comparison Analysis

Parameter	Before Rewinding	After Rewinding	Change (%)
Active Power (kW)	0 kW	12.8 kW	+80%
Efficiency	0%	80%	+80%
Power Factor	0	0.92	+92%

The analysis results show that the rewinding process successfully improved generator performance in terms of energy efficiency, active power, and voltage stability. This performance improvement demonstrates that rewinding with the appropriate technical specifications can be an effective solution for generator repair. In addition to increased efficiency, the winding operating temperature was also lower, indicating improved heat dissipation and reduced internal resistance.

Figure 4. The Effect of Changes in the Number of Turns on the Current Value

Based on the simulation, Figure 4 shows that the more rewinding, the greater the resulting current. Furthermore, the greater the number of turns, the greater the resulting

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current. This is in accordance with Faraday's law of induction, where increasing the number of turns will increase the induced voltage. Increasing the induced voltage will also increase the current after loading the generator. The thicker the permanent magnet, the more it will affect the magnetic density and flux density, thus affecting the current output.

Figure 5. Effect of Changes on Voltage Value

As can be seen in Figure 5, the generated voltage increases as the magnet thickness increases. Similarly, with the number of turns, each additional turn produces a higher voltage. This increase in voltage is consistent with Faraday's law of induction, which states that increasing the number of turns increases the induced voltage. The thickness of the permanent magnet also affects the magnetic density and flux density, thus affecting the generated voltage.

CONCLUSION

Based on the results of the testing and analysis conducted, it can be concluded that the stator conductor winding rewinding process on a 20 kVA generator has a significant impact on improving the generator's power performance. The main conclusions of this study are as follows: Rewinding processBy re-specifying the number of turns, type of conductor wire, and insulation method, it is possible to restore generator performance that previously decreased due to damage and degradation of the stator windings. After rewinding, there was an increase in active power (output) from 0 kW to 12.8 kW, indicating an increase of ±80%. Generator efficiencyincreased from the previous 0% to 80%, indicating that input energy can be converted into output with much smaller power losses. Power factorimproved from 0 to 0.92, which means the electrical load is becoming more effective and approaching ideal conditions. Thus, rewinding is not only a repair method, but can also be a performance improvement solution for medium capacity generators such as 20 kVA, if done with proper technical planning.

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