Analysis of Reduced Performance of 7.5 kW Hydraulic Pump Motor on Telescopic Spreader Quayside Container Crane (QCC)

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Keywords: Hydraulic Motor, Telescopic Spreader, Varnishing.

Abstract: Quayside Container Crane (QCC) is one of the heavy equipment used by the Nusantara Port Handal company. The Telescopic Spreader is one of the equipment found on the Quayside Container Crane (QCC). The mechanical power for the QCC work process comes from an induction motor or asynchronous motor. In operation, lifting power often weakens, causing business processes to idle. QCC mechanical resources come from induction motors or asynchronous motors, of course the work process depends on the reliability of the motor. Based on monitoring and recording, the induction motor used by QCC with a capacity of 7.5 kW often experiences a weakening of rotational power during busy work activities. After measuring the temperature when the induction motor was loaded, the temperature reached 44^0C and after measuring the motor stator resistance value, it was 1200MΩ. Based on the analysis, the increase in motor temperature caused a decrease in lifting power due to a decrease in the Insulator Resistance value which caused voltage leakage between the armature windings. Motor resistance decreases due to the reduced ability of the stator insulator due to increased heat, with a decrease in lifting capacity based on measurement results causing the vibration value to increase from the threshold, thereby disrupting the construction of the stator armature. To overcome this, re-varnishing of the insulator has been carried out which results in an increase in the resistance value of the stator insulator.

1 INTRODUCTION

Indonesia is the largest archipelagic country in the world. For this reason, Indonesia needs to manage and develop a well-managed and developed port industry (Setiono, 2010).

Handling of loading and unloading goods must be in accordance with the provisions that have been set. With these provisions, it is hoped that all stevedoring companies can implement these provisions in order to create a smooth flow of goods and harmony in work. But in practice the handling of loading and unloading is not always carried out smoothly and correctly, but few of them ignore it. Most of these stevedoring companies are only concerned with profits without paying attention and thinking about the impacts that will arise if the handling of loading and unloading is carried out unsafely and incorrectly or not in accordance with the provisions (Triatmodjo, 2006).

Quayside Container Crane (QCC) is one of the heavy equipment used by Nusantara Pelabuhan Handal. This tool stands and runs on rails on the edge of the dock with a power source from a power plant on land or with the power plant's own diesel engine. The working principle is simple, the container from the ship's hold is lifted up by a telescopic spreader using a hoist system, then with horizontal movement is carried using a trolley system towards the dock and stops between the two crane legs (*legs*) to lower the container until it is right above the truck chassis body. The next movement is to return the empty telesopic spreader from its position on the dock to the ship's hold, and land the telescopic spreader on top of the container to be unloaded next. (Lasse, 2012).

Container loading and unloading activities on ships often occur system failures in the telescopic spreader area. Especially often trips occur on spreader pumps, telescopic positions from 20 feet to 40 feet

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Suherman, E. and Rofii, A.
Analysis of Reduced Performance of 7.5 kW Hydraulic Pump Motor on Telescopic Spreader Quayside Container Crane (QCC).
DOI: 10.5220/0012584600003821

In *Proceedings of the 4th International Seminar and Call for Paper (ISCP UTA '45 JAKARTA 2023)*, pages 449-457
ISBN: 978-989-758-691-0; ISSN: 2828-853X

often cannot or jam, twistlocks that cannot rotate from the unlock position to the ***lock position*** even until the replacement of the spreader pump motor because its performance has dropped.

2 LITERATURE REVIEW

2.1 Telescopic Spreader

Telescopic Spreader is one of the equipment contained in Quayside Container Crane (*QCC).* Telescopic Spreader is made of steel structure consisting of 4 twistlocks on the head block, 4 twistlocks for locking corner containers, 4 flippers installed in each corner of the spreader connected to a gearbox and actuator that functions as a guide, telescopic device and hydraulic system, with automatic opening and locking based on several proximity sensors.

Telescopic mechanism with an expansion range of 20 feet to 45 feet, controlled by the Siemens 7 PLC system integrated with all other devices.

Figure 1: Telescopic Spreader.

2.2 Asynchronous Motor

Induction motors are the most widely used alternating current (AC) motors. Its naming comes from the fact that the rotor current of this motor is not obtained from a specific source, but is an induced current.

As a result of the relative difference between the rotation of the rotor and the rotating magnetic field generated by the stator current. Induction motors are the most commonly used motors in various industrial equipment. Its popularity is due to the design it gets, and it can be directly connected to an AC power source.

Figure 2: Three Phase Induction Motor on hydraulic pump Telescopic Spreader.

2.3 Stator

In the stator section there are several slots that are where the wire (conductor) of three coils each different phase and receive current from each phase called the stator coil. The stator consists of iron plates arranged as large as the rotor and on the inside has many grooves that are given coils of insulated copper wire.

Figure 3: Stator.

If the stator coil gets a three-phase current supply, the coil will generate a rotary magnetic flux. Due to the rotating magnetic flux in the stator coil, it causes the rotor to rotate due to magnetic induction with the rotational speed of the syncon rotor with the rotational speed of the stator.

$$n_s \frac{120}{p} f$$

Where:
ns = Synchronous speed (rpm)
f = Magnitude of frequency (Hz)
P = Number of poles

The construction of the induction motor stator itself consists of several parts:

1. Motor body (axle)
2. Magnetic polar core and magnetic amplifier circumference
3. Slip ring

2.4 Rotor

Based on Faraday's law of magnetic impact, the rotating field, which is relatively a magnetic field moving against the rotor conductor, will wave the electromotive force (ggl). The frequency of this impact emf is the same as the frequency of the mesh.

The magnitude of this impact is directly proportional to the relative speed between the rotating field and the rotor conductor. Conductor - a conductor in the rotor that forms a closed circuit, is a driving circuit for rotor current and is in line with the applicable law, particulary the law of lenz.

The direction is against the impacting fluctuation, in this case the rotor current is caused by the difference in speed between the fluctuation or rotational field of the stator and the conductor at rest. The rotor will rotate in the same direction as the direction of the stator rotation field, to reduce the speed difference above. If the rotor is loaded, then the rotation of the rotor will drop so that there is a difference in rotation speed between the rotor and stator, this difference in rotation speed is called slip.

Figure 4: Rotor.

2.5 Working Principle of Induction Motor

The induction motor works on the basis of electromagnetic induction from the stator coil to its rotor coil. When the stator coil of a 3-Phase induction motor is connected to a 3-Phase voltage source, the stator coil will produce a rotating magnetic field. Flux force lines The data induced from the stator coil will cut the rotor coil so that emf (ggl) or induced voltage arises. Because the conductor (coil) of the rotor is a closed circuit, current will flow on the rotor coil. The conductor (coil) of the rotor that is supplied by this current is in the line of flux force coming from the stator coil so that the rotor coil will experience Lorentz force which causes torque that tends to move the rotor according to the direction of movement of the stator induction field.

2.6 Calculation Procedure

In the research analysis of the performance of the 3 Phase induction motor on the loading of telescopic spreader pressure, data will be taken based on current and voltage variations, specifically minutes to 09.00, minutes to 11.00, minutes to 14.00, and minutes to 16.00, This data collection aims to obtain the value of losses on the motor based on pressure variations, determine efficiency based on pressure variations, and to obtain Power factor (PF) = 95%. So data collection is carried out including:

1. Find the input power based on the formula below. In this case, measurements are made directly on the motor. To find out the input power value, calculations are carried out with the equationv(Rofii, A. 2018):

$$\text{Pin} = \sqrt{3}\,.\,V\,.\,I\,.\,Cos\varphi \quad (2)$$

Information:
P in = Input power (Watts)
V = Voltage (Volt)
I = Current (Ampere)
cos φ = power factor

2. Determine the value of losses in a 3 Phase induction motor as a telescopic spreader drive. Calculation of losses on the motor using the equation:

$$\text{P loses} = \text{mechanical } T \times \omega r \quad (3)$$

Electricity loses (Stator winding) =

$$P_{scl} : 3\,.\,I^2\,.\,R_1 \quad (4)$$

Electrical loses (Rotor winding) =PP_{scl} : 21% × Nominal losses

3. Finding the output power of a 3 phase motor

$$\text{P Out} = \text{P in} - \text{P loses} \quad (5)$$

Information:
P in = Daya input (watt)
P Out = Daya output (watt)
P loses = total loses (watt)

4. Determine the efficiency value of motor performance degradation based on the input and output power of the motor.

To get the efficiency value of the performance of the induction motor on the telescopic spreader, calculations are carried out using the equation:

$$\text{Efficiency} = \frac{P_{out}}{P_{in}} \times 100\% \quad (6)$$

Information:
P_{out} : daya output (Watt)
P_{in} : input power (Watts)

2.7 Equivalent Circuit of Three-Phase Induction Motor

The equivalent circuit of a three-Phase induction motor is expressed in a one-Phase circuit, consisting of:

A. Stator Equivalent Circuit

If the resistance of the stator winding per phase is Rs, and the reactance is Xs, while the core losses are expressed in parallel to a resistance Rc and reactance Xc, then the equivalent circuit of the stator can be illustrated in Figure 5 below.

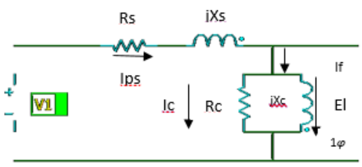


Figure 5: Stator Equivalent Circuit.

The impact voltage on the stator is:

$$E1 = 4.4fN1Kw1\varphi m \quad (7)$$

Where:
Kw1 = Stator winding factor
F = Stator Voltage Frequency
φm = Maximum Fluctuation in the Stator Gap
N1 = Number of Stator Windings

In Figure 5, V1 is the voltage source per Phase on the stator of the induction motor and E1 is the impact voltage on the stator then:

$$V = Ips\,(Rs + jXs) + E_1 \quad (8)$$

3 RESEARCH METHODS

3.1 Place and Time of Research

This research was conducted at PT. Parvi Indah Persada NPH Building Jl. Kebon Bawang 1 No.45, Kebon Bawang Tanjung Priok, North Jakarta, 14320. The time used by the researcher for this research is carried out from the date of issuance of the research permit within a period of approximately 2 (two) months.

3.2 Research Tools and Materials

Telescopic spreader hydraulic pump motor as material / object of research, Megger to measure insulation resistance (Insulation Resistance), Multitester to measure resistance value (resistance), Temperature Gun to measure motor temperature and Vibartion Meter to measure motor vibration.

3.3 Research Variables

a. Phase to phase isolation resistance
b. Isolation Resistance with phase to ground
c. Source voltage (droop or stable)
d. Motor temperature

3.4 Data Collection Techniques

In terms of collecting this data, the author plunges directly into the object of research to get valid data, then the researcher uses direct observation methods and documentation observation. The following are the steps to obtain data by taking direct prisoner measurements.

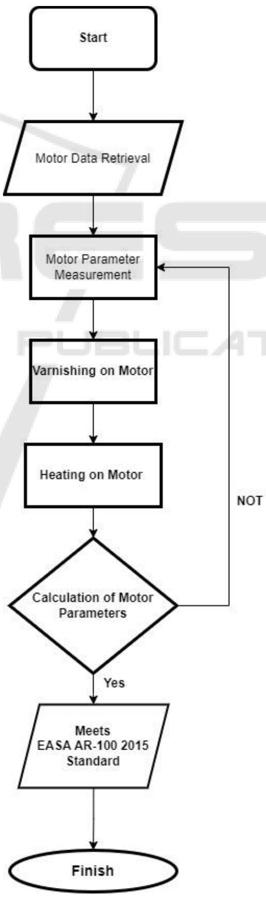


Figure 6: Research Flowchart.

3.5 Discussion Method

Based on the availability of calculated data, measuring data and standard data, discussions are carried out:

1. The effect of decreasing insulation resistance on the rotating power of the motor
2. Effects of temperature rise on insulation resistance
3. The effect of vibration on the rotating power of the motor

Then analysis can be done from these three influences, which one has the most potential to cause a decrease in the performance of the hydraulic pump motor on the telescopic spreader.

4 DISCUSSION

4.1 Data Standard Insulation Resistance

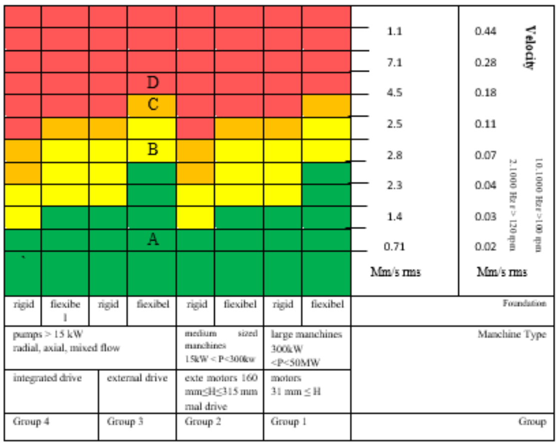
The following is a list of the use of Insulation resistance Test direct voltage against each winding rated voltage based on EASA (Electrical Apparatus Service Association) AR100-2015 Standard Insulation.

Table 1: Standard Insulation Resistance at PT. Parvi Indah.

Recommended Minimum Insulation Resistance Values at 400C	
Minimum Insulation Resistance After 1 min	Test Specimen
IR 1 min = kV + 1 Mega Ohm Unit	Most windings were made before about 1970, all terrain windings and others are not described below
IR = 100 MΩ	Most AC rolls were built after about 1970 (coil roll form)
IR = 5 MΩ	As a large machine with random winding stator coil, forming a coil roll with a voltage below 1 kV DC armature

4.2 Vibration Standards

Table 2: Vibration Standards at PT. Parvi Indah Persada.



- **A** Engine Condition
- **B** Unlimited long-term operation is permitted
- **C** Short-term surgery is allowed
- **D** Vibration Causes Damage

In the table above where the green color has good engine condition and dark yellow color has unlimited long-term operation allowed while light yellow has short-term operation allowed and pink has vibration causing damage.

A. Vibration Motor Pump Spreader Telescopic

Table 3: Vibration Tests on No-Load Telescopic Spreader Pump Motors.

Time	Drive End (DE)mm/s			Non Drive End (NDE)mm/s			Temperature $(^{0C})$	
	Horizontal	Vertical	Axial	Horizontal	Vertical	Axial	OF	ND
08.00	0.9	0.7	0.6	0.7	0.9	0.7	37	37
09.00	0.9	0.7	0.6	0.7	0.9	0.7	36	37
10.00	0.9	0.8	0.7	0.8	0.9	0.7	37	37
11.00	0.9	0.8	0.8	0.8	0.9	0.7	37	38
11.45	0.9	0.8	0.8	0.9	0.9	0.7	38	39
13.15	0.9	0.8	0.8	0.9	0.9	0.7	39	40
14.00	0.9	0.8	0.8	0.9	0.9	0.8	40	41
15.00	0.9	0.8	0.8	0.9	0.9	0.8	40	41
16.00	0.9	0.8	0.8	0.9	0.9	0.8	41	41
17.00	0.9	0.9	0.8	0.9	0.9	0.8	43	42

4.3 Motor Vibration Measurement

Measurement of the vibration of the telescopic spreader hydraulic pump motor using a vibration meter at several points on the motor body with the position of the tip of the tool placed horizontally, vertically and axial.

The increase in temperature of the telescopic spreader hydraulic pump motor when without load in the table above is caused by an increase in vibration.

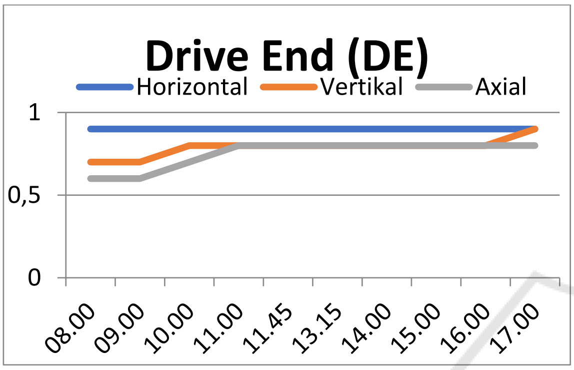


Figure 7: Telescopic Spreader Motor DE Vibration Graph.

In the chart above for the horizontal is the same amount of 0.9 while the smallest vertical is 0.7 at time 08.00 and 09.00 and the greatest is 0.9 at time 17.00 for axial is the smallest 0.6 at time 08.00 and 09.00 and the greatest is 0.8 at time 11.00 to 17.00.

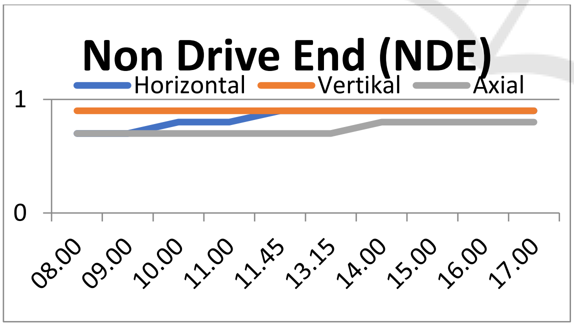


Figure 8: Telescopic Spreader Motor NDE Vibration Graph.

In the chart above for the smallest horizontal is 0.7 at time 08.00 and 09.00 and the largest is 0.9 at time 11.45 to 17.00 while the vertical is the same magnitude is 0.9 for axial, the smallest is 0.7 at time 08.00 to 13.15 and the greatest is 0.8 at time 14.00 to 17.00.

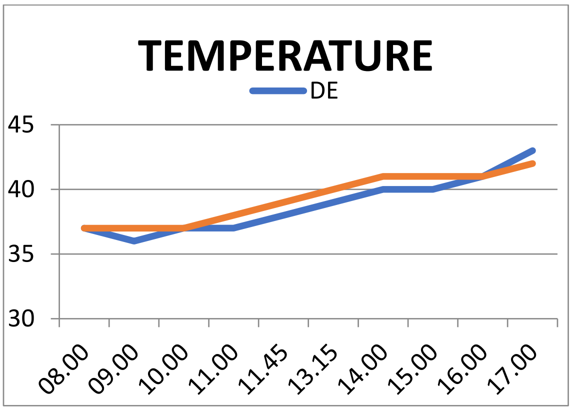


Figure 9: Telescopic Spreader Motor Temperature.

In the chart above, the smallest DE is 36 at 09.00 and the largest is 43 at 17.00, while the smallest NDE is 37 at 08.00 to 10.00 and the largest is 42 at 17.00.

4.4 Isolation Resistance

Measurement of insulation resistance of the telescopic spreader hydraulic pump motor using a device, a megger, by disconnecting all cable connections at the terminals. Select the selector on the megger according to the voltage of the motor object. Then check the connection between phase and phase of each phase, and finally check the connection between phase and ground of each phase.

Table 4: Insulation Resistance in Telescopic Spreader Motors Before and After Varnishing &; Heating.

Test Point	U-Ground	V-Ground	W-Ground	U-V	V-W	W-U	Information
Main Stator	1300 MΩ	1300 MΩ	1200 MΩ	1000 MΩ	1000 MΩ	1000 MΩ	Before
Main Stator	2000 MΩ	2000 MΩ	2000 MΩ	2000 MΩ	2000 MΩ	2000 MΩ	After

The increase in the value of insulation resistance on the telescopic spreader motor due to the varnishing process is carried out after which the heating process is carried out for 48 hours with a temperature of 110^{0}C.

4.5 No-Load Motor Current and Voltage Measurement

The second step in decreasing the performance of the telescopic spreader pump motor is to test the motor so that it can operate every hour.

Table 5: No-load Motor Voltage and Current Measurement Results.

Time	Voltase			Ampere		
	R-S	S-T	R-T	R	S	T
09.00	381 V	380 V	380 V	8,1 A	8,2 A	8,2 A
11.00	381 V	381 V	381 V	8,3 A	8,3 A	8,1 A
14.00	382 V	381 V	380 V	8,4 A	8,3 A	8,2 A
16.00	381 V	381 V	381 V	8,3 A	8,3 A	8,2 A

4.6 Hydraulic Motor Simulation Using Simulink

Changes in load that occur during the operation of Quayside Container Crane result in trips on the hydraulic pump motor of the telescopic spreader. The effect of the load change can be seen from the matlab simulation as follows:

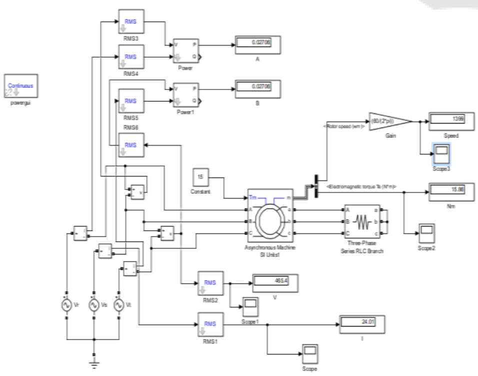


Figure 10: Hydraulic Motor Circuit.

In figure 10 the following components are used as follows:

- Power Gui
- RMS (6)
- Power (2)
- Gain
- Display (6)
- Scope (4)
- Asynchonous Manchine
- Three-Phase series RLC Branch
- Constant
- Bus selector
- Ground
- Voltase Measurement (3)
- Current Measurement (3)
- Ac Voltase Source (3)

4.7 Calculation of 3 Phase Induction Motor Efficiency

- Motor Efficiency Measurement Calculation

The calculation of the output power value is based on Table 5 as follows:

P in Calculation :

$$P = \sqrt{3}\ .\ V\ .\ I\ .\ Cos\varphi$$

$$P = \sqrt{3}\ .\ 380\ .\ 8{,}1\ .\ 0.87 \quad (9)$$

P = 4.560 Watt

- Insulation resistance calculation formula with 3 phase motor performance

Slip i Calculation:

$$S = \frac{ns-nr}{ns}\ x100\%$$

$$S = \frac{1500-1445}{1500}\ x100\% \quad (10)$$

S = 3.6%

- Mechanical Loss Calculation:

P loses = T $\times\ \omega$

$$\omega = \frac{2\pi\times nr}{60}$$

$$= \frac{2\times 3.14\times 1445}{60}$$

= 151.24 rad/s (11)

P loses = 0.12 ×151.24

= 18.14 Watt

- Winding Loses :

P_{Scl} = 3 . I^2 . R1

$= 3 \times 8.1^2 \times 65.44$ (12)

= 1.288 Watt

$$P_{Rcl} = \frac{21}{100} \times P_{Loses\ nominal}$$

$$= \frac{21}{100} \times 62.94 \quad (13)$$

= 13.217 Watt

- $P_{total\ loses} = P_m + P_{Scl} + P_{Rcl}$

= 18.14 + 1.288 + 13.217 (14)

= 44.23 Watt

- P Out Calculation:

$P_{Out} = P_{in} - P_{loses}$

= 4.650 – 44.23 (15)

= 4.605 Watt

- Efficiency Calculation:

Efficiency = $\frac{P_{out}}{P_{in}} \times 100\%$

$= \frac{4.605}{4.6} \times 100\%$ (16)

= 90%

- Formula between resistance and temperature

The calculation of resistance and temperature based on tables 3 and 4 is as follows:

Find the resistance value in DE with a temperature of 0^0C First:

$R_0 = R_t / (1 + \alpha t)$

R_0 = 6.800Ω / (1 + (0.0043 x 36)

R_0 = 6.800Ω / (1 + 0.154) (17)

R_0 = 6.800Ω / 1.154

R_0 = 5.892 Ω

Find the resistance value in DE with a temperature of 43^0C First

$R_t = R_0 (1 + \alpha t)$

R_{43} = 6.800Ω x (1 + (0.0043 x 43)

Because R_{43}= 6.800Ω x (1 + 0.184)

R_{43} = 6.800Ω x 1. 184

R_{43} = 8.051 Ω

- Find the resistance value in an NDE with a temperature of 0^0C First

$R_0 = R_t / (1 + \alpha t)$

R_0 = 6.800Ω / (1 + (0.0043 x 37)

R_0 = 6.800Ω / (1 + 0.159)

R_0 = 6.800Ω / 1, 159

R_0 = 5.867 Ω

- Find the resistance value in an NDE with a temperature of 42^0C First

$R_t = R_0 (1 + \alpha t)$

R_{42} = 6.800Ω x (1 + (0.0043 x 42)

Because R_{43}= 6.800Ω x (1 + 0.180)

R_{42} = 6.800Ω x 1,180

R_{42} = 8.024 Ω

- Insulation Resistance Formula

Calculation of Isolation Resistance based on table 5:

IR = $\frac{E_{(t)}}{I_{(t)}} = \frac{1.141_{(09.00)}}{24.5_{(09.00)}} = 46.57\ \Omega$

IR = $\frac{E_{(t)}}{I_{(t)}} = \frac{1.143_{(11.00)}}{24.7_{(11.00)}} = 46.27\ \Omega$

4.8 Research Analysis

The increase in temperature in the telescopic spreader hydraulic pump motor can be seen from table 4 so that this means that the motor insulation material will inhibit the electric current more when the higher temperature will cause the insulation of the stator winding to be damaged. Based on table 5, changes in insulation resistance have increased due to the varnishing process and heating process with a working temperature of 1100C for 48 hours. If the temperature setting is too low, then the insulation resistance can be reduced. If the temperature setting is too hot, there is a risk of insulation becoming less effective because it experiences thermal degradation or can even melt.

Based on table 4, the performance of the telescopic spreader hydraulic pump motor can be affected by vibration enhancement. Over-vibration can cause interference with the internal components of the motor and cause faster wear. This can lead to a decrease in motor efficiency and even complete failure.

So the factor that has a major influence on the decrease in the performance of the telescopic spreader hydraulic pump motor in this study is the decrease in the insulation resistance value on the stator of the spreader pump motor. The decrease in the insulation resistance value of the spreader motor is caused by the condition of the outside air which is quite dirty and due to the leakage of hose hoses in the hydraulic pump system that can penetrate the insulation of the stator winding on the telescopic spreader motor.

5 CONCLUSION

The conclusions obtained from the study on the analysis of the performance degradation of the 7.5 kW hydraulic pump motor on the Quayside Container Crane telescopic spreader are as follows:

1. The results of the efficiency calculation in chapter 4.5 of the telescopic spreader hydraulic pump motor of 90% with different outputs of 4,605 Watts,
2. For simulated performance degradation analysis of 7.5 kW hydraulic pump motor on Quayside Container Crane telescopic spreader using MATLAB R2016a,
3. The results of the data on isolation prisoners obtained at PT. Parvi Indah Persada in table 5 (Before) in phase U - ground and phase V - ground is the same at 1300 M, and W - ground is 1200 M, while between phases U-V, V-W, W-V is the same at 1000 M Ω and Based on table 6 (After) for solitary confinement in phases U, V, W-Ground the isolation resistance is the same which is 2000M there is also for isolation resistance between phaseΩ ΩU-VΩ, V-W, W-U the solitary confinement is the same i.e. 2000M.Ω The increase in insulation resistance value is quite significant in the telescopic spreader hydraulic pump motor because the Varnishing process is carried out after which the Heating process is carried out for 48 hours Advice.

5.1 Suggestion

The suggestions from this study are:

1. To make it easier to learn the analysis of electrical machines, software should be used that can present dynamic simulations.For example matlab/simulink
2. Multiply references in research and analysis, This study can be a reference to analyze the efficiency of three-phase induction motors with the *compensated ampere ratio voltage method*.

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