Analysis of Electric Motor Failure in Crane Drive Container Transport Equipment Loading and Unloading

Fachrul Reza, Pristisal Wibowo, Haris Gunawan

Abstract
The crane drive system, which is in charge of lifting and moving heavy loads during the loading and unloading of containers in ports, relies heavily on electric motors. Decreased productivity, operational disruptions, and even financial losses can result from motor failure. Two important factors overheating and overloading are the subject of this study's analysis of the reasons behind the failure of the crane drive motor. The winding temperature of the motor, the load current, and the phase interface voltage were measured to collect data. According to investigations, the tow motor is overloaded when the lifting load is above 125% of its rated capacity and is overheated at 135–145°C due to clogged cooling systems and high duty cycles. This condition increases the damage to the winding insulation and results in an increase in current of up to 30% above the rated current. The thermal protection system should be improved, the motor coolant should be maintained periodically, and load limiters should be used to determine the maximum lifting load limit.

Keywords: Electric Motor, Crane, Overheating, Overloading, Motor Failure

Fachrul Reza[1]
[1]Bachelor of Electrical Engineering, Universitas Pembangunan Panca Budi, Indonesia
e-mail: Fachrulreza77@gmail.com[1]

Pristisal Wibowo[2], Haris Gunawan[3]
[2,3]Master of Electrical Engineering, Universitas Pembangunan Panca Budi, Indonesia
e-mail: pristisalwibowo@dosen.pancabudi.ac.id[2], harisgunawan@dosen.pancabudi.ac.id[3]

Introduction

The electric motor drives the crane, which is an important part of the machine in the operation of container loading and unloading in the port. The reliability of the motor is essential for operational effectiveness and safety. However, in reality, heavy workloads and harsh environmental conditions are the main causes of crane drive motor failures [1].

Overload and overheating are the two main causes of crane electric motor failure. Overload occurs when the mechanical load exceeds the motor's rated capacity, while overheating occurs when the winding temperature exceeds the limit of the insulation class. Insulation damage, decreased performance, and even total motor failure can occur as a result of both conditions [2].

To suggest precautions to improve system reliability, this study attempts to examine the causes and consequences of overload and overheating in crane drive motors.

Literature Review

Electric Motor on Crane Drive

Electric motors are the main components that function to convert electrical energy into mechanical energy through the interaction of magnetic fields between stators and rotors. In cranes, electric motors are used to drive hoist, trolley, and gantry systems, each of which plays a role in the process of lifting and moving containers [3]

The most widely used type of motor is the three-phase induction motor because it has a simple construction, low maintenance costs, and the ability to generate high initial torque. This motor works on the principle of electromagnetic induction, where the current flowing on the stator generates a rotating magnetic field that induces a current on the rotor so that a rotating force arises [4].

The performance of an induction motor is determined by several parameters, including: power (P), nominal current (In), torque (T), efficiency (η), and slip (s). The basic relationship of motor power can be expressed by: [5]

$$P=3\times V\times I\times \cos\phi$$

Where:
P = power (W)
V = phase-phase voltage (V)
I = current (A)
cos φ = power factor

Crane motors are generally designed with an intermittent working rating (S3 or S4) according to the IEC 60034-1 standard, meaning that the motor works repeatedly with a breakage period to prevent overheating [6].

Overheating on Electric Motors

Overheating is a condition in which the temperature of the motor exceeds the maximum limit specified by the insulation class. This excess temperature leads to degradation of the insulation material, a decrease in dielectric strength, and the potential for permanent damage to the winding of the motor [7].

Table 1. Cable Temperature Limit

Insulation Class	Maximum Temperature Limit (°C)	Allowable Temperature Rise (°C)
Class A	105	60
Class B	130	80
Class F	155	105
Class H	180	125

The crane motor generally uses class F insulation, with a normal operating temperature below 120°C, and the protection trip is set at 130–135°C.
Factors that cause overheating include:
1. Overloading.
2. Cooling disorders (clogged fans, dirty ventilation).
3. Inter-phase voltage imbalance.
4. Too frequent duty cycles without cooling downtime.
5. Harmonic current or voltage is not sinusoidal.

The relationship between the winding temperature and the life of the motor is exponential. An increase in temperature of 10°C above the nominal limit can reduce the insulation life by up to 50% [8].

Overloading on Electric Motors

Overloading occurs when the motor is working beyond its nominal power capacity or torque. This condition causes the drawn current to increase greater than the nominal current, resulting in large copper losses (I^2R losses), and accelerating the increase in winding temperature [9].

The IEC 60034-1 standard specifies that an electric motor can withstand a load of more than 115% of nominal power for a certain period of time without damage. However, if the load exceeds 125–130%, there will be overheating which triggers overcurrent or thermal relay protection.
The relationship between increased power loss due to overload is expressed by: [10]

$$P_{loss} = I^2 R$$

This means that a 30% (1.3 × In) increase in current leads to a 69% greater increase in heat$1.3^2 = 1.69$ [11].
Factors that cause overload in motor cranes:
1. Factors that cause overload in motor cranes:
2. Mechanical malfunctions in the gearbox, brakes, or drums.
3. A voltage drop (undervoltage) that causes the current to rise.
4. High duty cycle without adequate cooling

Motor Protection Against Overheating and Overloading

To prevent failures due to these two phenomena, automatic protection systems such as:
1. Thermistor / PT100 Sensor: detects the temperature of the winding motor, provides a trip signal if the temperature exceeds the setpoint
2. Overload Relay: cuts off the power supply when the current is more than the nominal current.
3. Load Limiter (Weight Sensor): limit the weight of the crane's load so that it does not exceed the design capacity.
4. VFD (Variable Frequency Drive): controls the speed and current start of the motor to reduce current surges.

Good performance of the protection system must be able to detect temperature rises early and provide an alarm before the temperature reaches the maximum isolation limit [7].

Research Methodology

Research Location

Research was conducted on the container crane drive system at Belawan port. The drive motor analyzed is a three-phase induction motor with a nominal power of 45 kW, a voltage of 380 V, and an insulation class of F.

Analysis Parameters

In this study, there are two main parameters analyzed to determine the cause and impact of electric motor failure on the crane drive system of loading and unloading container transport equipment, namely overheating and overloading:

1. Parameter Overheating

   The overheating parameter is used to analyze the extent to which the increase in motor temperature affects the performance and reliability of the crane drive system.

   Aspects observed include:
   - The winding temperature of the motor during normal operation, medium load, and full load.
   - Temperature rise to the working time (thermal rise) to find out how quickly the motor reaches critical heat conditions.
   - The surface temperature of the motor housing as an indicator of the efficiency of the cooling system.
   - Comparison of actual temperature with maximum temperature limit based on insulation class (Class F or H) as per NEMA MG1 and IEC 60034-1 standards.
   - The effect of temperature on load current and motor efficiency, where an increase in temperature can cause the winding resistance to increase so that the input power increases.

The analysis was carried out using a temperature sensor (PT100 or thermocouple) attached to the motor body and the stator winding. Temperature data is recorded during the crane's work cycle starting from the time the motor starts, lifts, holds, to lowering the load.

The observation results are compared with the manufacturer's nominal data to determine whether there is thermal stress or overheating conditions that can accelerate the degradation of the motorcycle's insulation.

2. Parameter Overloading

   The overloading parameter is used to assess how much load the motor receives compared to its nominal capacity, as well as its impact on the current and power of the motor.

   The aspects analyzed include:
   - Load current in each crane operating condition (no load, nominal load, and excess load).
   - Comparison of the actual current to the nominal current (I/In) to determine the level of the loading factor of the motor.
   - The relationship between increased current and increase in circumferential temperature, which is an indication of excess power loss (I^2R losses).
   - Input power ($P = \sqrt{3} \times V \times I \times \cos \varphi$) and motor efficiency ($\eta$) which decrease as more load occurs.
   - The crane's mechanical load (load weight) is measured or estimated to determine the point of overload trip.

This analysis is carried out by recording three-phase flow data using a clamp meter or power analyzer during the operation of the motor. The data is compared to the crane drive motor specifications (rated current and rated power) to determine the overload level (e.g. 110%, 125%, or 150% of the nominal). In addition, the response time of the overload relay protection to the increase in current is also observed to determine whether the protection system is working effectively before the motor reaches an overheating condition.

Research Flowchart

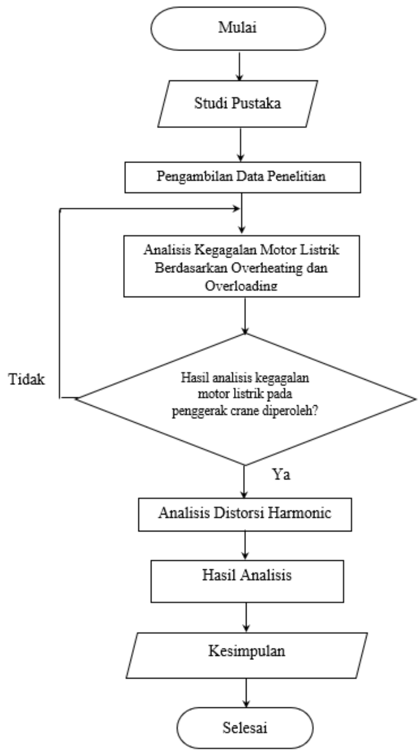

Figure 1. Research Flowchart

The flowchart in Figure 1 shows the stages of research conducted in the analysis of electric motor failures in crane drives for loading and unloading container transport equipment. The research process began from the literature study stage, which aimed to collect theories, concepts, and references related to electric motors, protection systems, and the phenomenon of failure due to overheating and overloading. This stage is important to provide a strong theoretical foundation and become a reference in the implementation of data collection and analysis in the field.

The next stage is the collection of research data, where the collection of operational data of the crane motor such as lifting load, current, voltage, winding temperature, and the activation conditions of the protection system is carried out. The data obtained was used to analyze the failure of the electric motor based on overheating and overloading parameters, with the aim of identifying the extent to which the two factors affected the performance of the motor. If the results of the analysis do not show a clear conclusion about the cause of the motor failure, the data collection process is repeated until the results obtained are considered representative and valid.

After the failure analysis data is obtained, the research is continued with harmonic distortion analysis to determine the effect of electrical power quality on motor performance. Harmonic distortion can be an additional factor that aggravates overcurrent and overheating conditions in motors. The final stage of this study includes the preparation of analysis results and drawing conclusions, where all findings are integrated to explain the main causes of crane drive motor failures and provide recommendations for improvement of the protection and maintenance system so that similar incidents do not happen again in the future.

Result

Crane Drive Motor Measurement Results Data

To determine the performance condition of the electric motor driving crane on container transport equipment, measurements were made of several main operational parameters. The parameters measured include lifting load (tons), load current (A), nominal current (A), motor winding temperature (°C), and active protection status during the test. Tests were carried out on a variety of operating conditions, ranging from normal to overloading conditions, to analyze the motor's response to increased load and temperature. The measurement data is presented in Table 5.1 as follows:

Table 2. Crane Drive Motor Measurement Results Data

No	Operating Conditions	Lifting Load (tons)	Load Current (A)	Arus Nominal (A)	Circumference Temperature (°C)	Protection Status	Information
1	Normal	35	76	82	92	-	Normal operation, stable temperature
2	Beban nominal	40	82	82	101	-	Nominal condition, safe
3	Load110 %	44	90	82	118	Active temperature alarm	Initial light overheating
4	Load120 %	48	98	82	132	Active temperature + overcurrent alarm	Overloading starts to occur
5	Load 130%	52	107	82	142	Trip thermistor	Heavy overheating, motor stop
6	After cooling	-	-	-	89	Reset normal	The motor is back in operation

Based on the measurement results in Table 2, it can be seen that the increase in lifting load has a direct effect on the increase in load current and winding temperature of the motor. Under normal conditions with a load of 35 tons, the winding temperature is still stable at around 92°C and the system works without the activation of protection. When the load is raised to a nominal load of 40 tonnes, the temperature rises to 101°C but is still within safe operating limits.

A load increase of up to 110% (44 tons) caused the current to rise to 90 A and the winding temperature to reach 118°C, triggering an active temperature alarm as an early sign of mild overheating. At 120% (48 tons) load, dual protection in the form of temperature and overcurrent alarms starts to activate as the temperature reaches 132°C. This condition indicates that the motor system is starting to experience thermal pressure and overcurrent.

When the load is increased to 130% (52 tons), the winding temperature increases sharply to 142°C and the current reaches 107 A. At this point, the thermistor protection system works by cutting off the current to the motor to prevent further damage from heavy overheating. After cooling, the winding temperature drops to 89°C and the motor returns to normal operation.

From these results, it can be concluded that the increase in load significantly affects the increase in winding temperature and electric current. The activation of the protection system at temperatures above 130°C shows that the crane motor protection system is functioning well in preventing damage due to overloading and overheating conditions.

If illustrated, the trend data shows a nonlinear relationship between load and temperature.

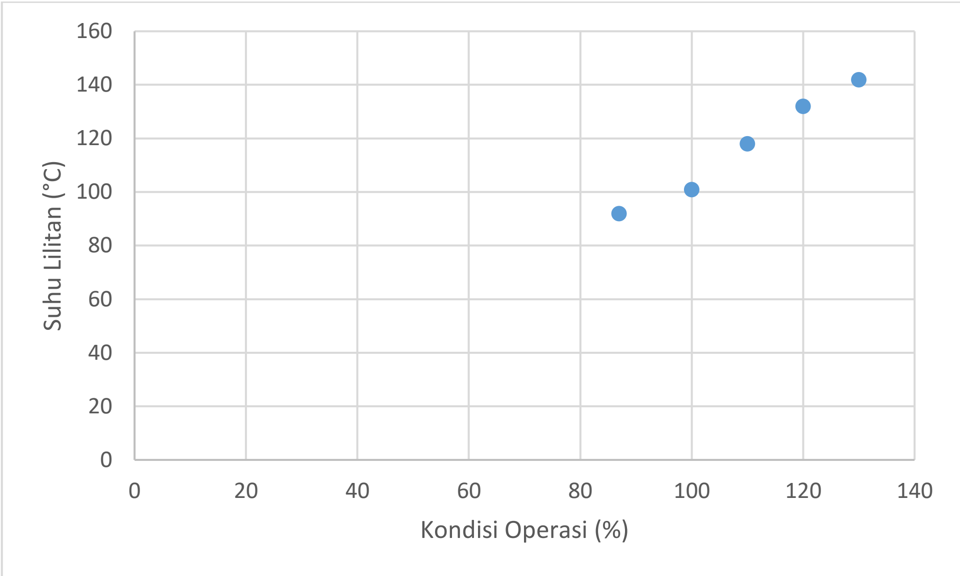

Figure 2. Graph of the trend of load conditions against the winding temperature

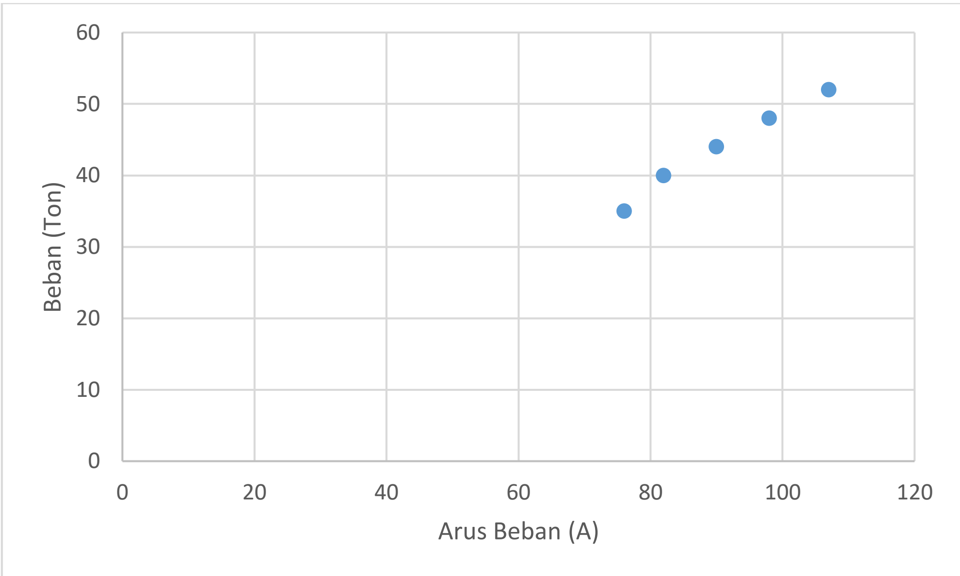

Figure 3. Trend chart of current conditions to load

The trend of 1 load on temperature where the increase in load from 100% to 130% causes a temperature spike from 101°C → 142°C. An average temperature rise of 13°C for every 10% increase in load. The increase is **exponential**, showing that the cooling of the motor is not able to compensate for the heat due to I^2R losses. Trend 2 load to current Current increases proportionally to load (82 A to 107 A). However, the increase in temperature is much more pronounced than the increase in current an indication of the occurrence of thermal inefficiency.

Overheating Data Analysis

From the results of the measurement of the temperature of the winding of the motor in the table above, it can be seen that the temperature increases as the lifting load increases. At nominal load conditions (40 tonnes), the temperature is still within the safe limit of 101°C, below the maximum limit of insulation class F (155°C). However, when the load reaches 120% (48 tons), the winding temperature increases sharply to 132°C, and when it reaches 130% of the load (52 tons), the temperature breaks through 142°C, triggering automatic trip thermistor protection.

This rise in temperature indicates that the cooling system is no longer able to compensate for heat due to increased load current. This phenomenon indicates that overheating occurs due to a combination of overload and suboptimal cooling.

Data Overloading Analysis

Based on the load flow data:

1. Arus nominal motor = 82 A
2. Current at load 120% = 98 A (up +19%)
3. Current at load 130% = 107 A (up +30%)

The increase in current that is disproportionate to the increase in load indicates that the motor is overloaded current. This excess current causes copper losses (I^2R losses) that are squared to the current, so that a 30% increase in current causes a heat increase of around 69% ($1.3^2 = 1.69$). This explains why the temperature of the motor jumped from 101°C to 142°C with only a 30% increase in load. This condition proves that overloading is the main cause of overheating and thermal protection trips.

Evaluation of Protection Performance

In addition to measuring operational parameters, an evaluation was also carried out on the protection system installed on the electric motor driving the crane. The purpose of this evaluation is to ensure that each protection component works in accordance with the set point that has been set and is able to respond to abnormal conditions such as overheating and overcurrent in a timely manner. The test is carried out by monitoring the protection response when the motorcycle operates at various load levels to trip conditions. The results of the evaluation of the performance of the protection system are shown in Table 3 below.

Table 3. Crane Drive Motor Measurement Results Data

Types of Protection	Setpoint	Trip Conditions	Status
Thermistor (PT100)	135°C	Trip at 142°C	Active, a little late
Overcurrent relay	125% In	Active at 130% load	Work well
Overload alarm	110% In	Active at 120% load	Function Compliant

Based on the results of the evaluation in Table 5.2, it can be seen that the crane motor protection system is generally working well, although there is a slight delay in one of the protection components. The thermistor protection (PT100) has a temperature setpoint of 135°C and is recorded to trip at a temperature of 142°C. This indicates an activation delay of about 7°C, which can be caused by the thermal inertia factor of the sensor or a delay in heat transfer from the winding to the sensor element. Although it was a little late, the system still worked well because it managed to cut off the current before damage to the motor due to heavy overheating.

The relay overcurrent protection has a setpoint of 125% of the nominal current (In) and is active when the motor is running at a 130% load. This shows that the current protection works more with good and accurate response, according to the actual conditions of the load that have indeed passed the safe threshold of operation. This proper response plays an important role in preventing winding damage due to overcurrent that can trigger an increase in copper losses.

Meanwhile, the overload alarm set at 110% In works at 120% load conditions, indicating that the alarm system is functioning with appropriate sensitivity to provide early warning of potential overloading. Alarm activation at this stage provides an opportunity for the operator to take precautions before the temperature and current reach the trip limits of the main protection system.

Overall, the test results show that the crane motor protection system has worked according to its function in protecting the motor from the risk of overheating and overloading. Despite the slight delay in the temperature sensor, the overall performance of the system can still be categorized as reliable and effective in maintaining the safe operation of the equipment.

Motor Harmonic Distortion Analysis

From the data taken on the crane drive motor at the research site, the table of measurement data is as follows:

Table 4. Crane Drive Motor Data

Pseudo-Power (kVa)	Active Power (Kw)	Tegangan(V)	Reactive Power (kVAR)	Current (A)	Freq (Hz)	Power Factor (%)	THD (%)
47,42	43	400	20	68,45	50	90,67	5,58%

From table 4, it can be seen that the THD value is relatively high, which is the maximum limit of the THD value, which is 5%. Where the THD measurement results obtained were 5.58%. The results show that the use of a drive motor has a significant impact on power quality, especially in creating current harmonic distortion. This is because CT-Scan equipment contains many non-linear loads such as inverters, switching power supplies, and electronic converters that produce high-order harmonic currents. This current distortion not only causes an increase in power loss, but also puts a significant strain on the neutral conductor, as can be seen from the THD value of I4 (5.58%). In addition, the voltage THD value in neutral (U4) is also well above reasonable limits, which can cause disruption of the control and protection system.

Based on the simulation results in the ETAP software, the harmoisa distortion waves created are as follows:

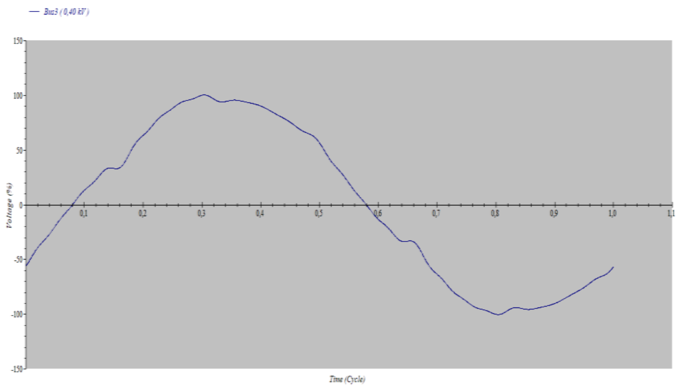

Figure 4. Harmonic Wave THD 5.58%

So based on the load data, it can be determined that the resistance value in the harmonic filter that can be used to reduce the percentage of THD in the electrical circuit due to the motor is as follows:

$$Qvar = \sqrt{\left[\frac{P_1}{PF}\right]^2 - P_1^2} - \sqrt{\left[\frac{P_1}{PF0}\right]^2 - P_1^2}$$

= = 11,347 kVAR $\sqrt{\left[\frac{43}{0,98}\right]^2 - 43^2} - \sqrt{\left[\frac{43}{0,906}\right]^2 - 43^2}$

XC ====1.3 Ohms $\frac{KV^2_{rated}}{M_{var}} \frac{0,4^2}{0,12}$

C = = = 0.0025 F or 2.500 μF $\frac{1}{2\pi f Xc} \frac{1}{2 \text{ x } 3,14 \text{ x } 50 \text{ x } 1,3}$

XL ===0.7 Ohms $\frac{XC}{n^2} \frac{1,3}{4,05^2}$

L = = = 0.002 H or 2225 Mh $\frac{XL}{2\pi f} \frac{0,7}{314,5}$

Xn = = 0.89 Mh $\sqrt{\frac{L}{C}} = \sqrt{\frac{2225}{2500}}$

R =Xn/Q=0.89 / 11.347 = 0.0784 Ohms

So that after the installation of harmonic filters in the ETAP software simulation, there was a decrease in THD to 2.99%, thus affecting a slight harmonic wave on the crane drive motor.

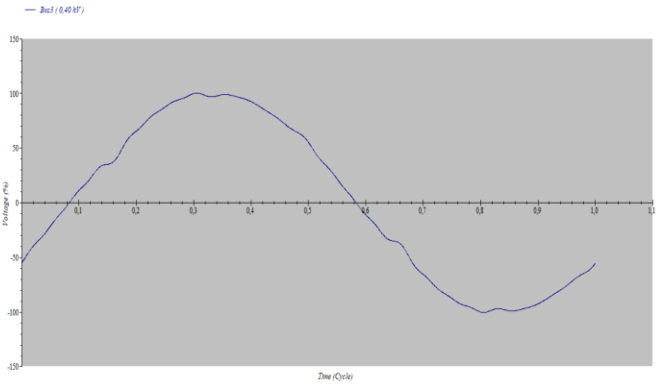

Figure 5. Harmonic Wave THD 2.99%%

Discussion

From the results of measurement and analysis:

1. There is a linear relationship between the increase in load and the increase in current, but the increase in temperature is exponential.
2. At loads above 125% of nominal capacity, the motor operates under heavy overload conditions that trigger thermal runaway.
3. The motor cooling system proved to be inadequate for long-term operation above 120% load.
4. Thermistor and overcurrent relay protection work, but the response needs to be adjusted so that the motor does not reach temperatures above 135°C.
5. The combination of overheating and overloading is the dominant cause of motor failure in the crane drive in the container loading and unloading area.

As for the technical recommendations:

1. Limit maximum operating load to 110% of nominal capacity.
2. Reset the trip temperature protection to 130°C for insulation class F.
3. Check the motor's cooling system and clean the vents every 250 hours of operation.
4. Add a digital sensor-based temperature & current monitoring system so operators can anticipate load increases in real-time.

Perform annual calibration of temperature sensors and protection relays.

Conclusion

Based on the results of tests and analysis of the performance of the crane drive electric motor, it is known that the motor experiences significant overheating in the temperature range of 132–142°C when operating with loads exceeding the nominal capacity. This sharp rise in temperature is caused by an increase in current due to overload, where copper losses (I^2R losses) increase drastically and produce heat that is difficult to release through the motor's cooling system. This condition shows that the existing cooling system is not able to compensate for the heat surge caused by high loads, so the temperature of the winding of the motor rises to near the critical limit of insulation.

From the observation results, it is also known that the safe operation limit of the motor is at a maximum load of 120% of the nominal capacity, which is around 48 tons for a 45 kW motor. Above these values, the motor begins to show symptoms of overloading which is characterized by an increase in current, temperature, and activation of the protection system. At 130% load, the thermal protection system (thermistor) and overcurrent relay are activated simultaneously, cutting off the power to prevent further damage. This proves that the protection system works well, but the trip temperature threshold is still too high so that the motorcycle had experienced severe overheating before the disconnection occurred.

To increase the reliability and service life of the motorcycle, adjustments are needed to the temperature protection setpoint, namely by lowering the trip limit from 135°C to around 130°C. This adjustment aims to protect the motor faster before it reaches a critical point of thermal insulation that can lead to degradation of the winding material. In addition, improvements to the cooling system and regular monitoring of the motor's performance are also recommended to prevent the recurrence of overheating conditions in the future, especially when the crane is operating with a load close to its maximum limit.

The THD value in the circuit after using the harmonic filter dropped to 2.99% which was previously without the harmonic filter the THD value in the circuit was 5.58%. This shows that the results of the calculation of the harmonic filter parameters have been successful so that the THD value in the series decreases by 2.21%. Comparison of harmonic distortion waveforms in the circuit before and after the installation of the harmonic filter. The difference in the wave was not so significant because the decrease in THD was relatively not so large, which was 2.21%. However, the harmonic distortion waveform after harmonic filter installation looks better and stable compared to before harmonic distortion installation.

Reference

[1] M. R. Javed et al., “An Efficient Fault Detection Method for Induction Motors Using Thermal Imaging and Machine Vision,” Sustainability, vol. 14, no. 15, p. 9060, Jul. 2022, doi: 10.3390/su14159060.

[2] J. Vanga et al., “Fault classification of three phase induction motors using Bi-LSTM networks,” Journal of Electrical Systems and Information Technology, vol. 10, no. 1, p. 28, May 2023, doi: 10.1186/s43067-023-00098-x.

[3] D. Owusu, C. Amuzuvi, and J. Attachie, “Vibration-induced Thermal Fault Analysis and Optimisation of Induction Motors Using Artificial Intelligence,” American Journal of Artificial Intelligence, vol. 9, no. 1, pp. 91–106, 2025, doi: 10.11648/j.ajai.20250901.19.

[4] A. R. Hasfi and S. Syahrorini, “Electric Motor Maintenance,” Procedia of Engineering and Life Science, vol. 7, pp. 10–14, 2024, doi: 10.21070/pels.v7i0.1596.

[5] N. Iskandar, A. Pradyta, and S. Sulardjaka, "Study and Application of Reliability Centered Maintenance on Hoist Cranes," Rotation, vol. 23, no. 4, pp. 50–57, 2021.

[6] M. Pratt, "Analysis of Electrical Power of Hoist Motors and Trolley Motors in Container Cranes in the Process of Loading and Unloading in Belawan," RELE (Electrical and Energy Engineering): Journal of Electrical Engineering, vol. 6, no. 1, 2023, doi: 10.30596/rele.v6i1.15479.

[7] R. Rasyid, M. Muhammad, and M. A. Hadi Sirad, “Overload Protection and Electricity Volume Monitoring on Internet of Things (IOT)-Based Three-Phase Induction Motors,” International Journal Of Electrical Engineering And Intelligent Computing, vol. 2, no. 1, pp. 31–42, 2025, doi: 10.33387/ijeeic.v2i1.9711.

[8] P. R. N. 24/Menkes/2022, "No TitleThe Hardest to See What Is Really in Front of Our Eyes," Haaretz, vol. 23, no. 8.5.2017, pp. 2003–2005, 2022.
[9] B. Paul and V. J. Manohar, “a Comprehensive Survey on Real Time Induction Motor Failure Diagnosis and Analysis,” ASEAN Engineering Journal, vol. 15, no. 1, pp. 199–206, 2025, doi: 10.11113/aej. V15.22096.
[10] and M. A. Jahić, A., Ž. Hederić, “Detection of failures on the high-voltage cage induction motor rotor,” International journal of electrical and computer engineering systems, vol. 6, no. 1, pp. 15–21, 2015.
[11] N. B. Malla and A. KC, “Fault Identification and Protection of Induction Motor Using PLC and SCADA,” Journal of Artificial Intelligence, Machine Learning and Neural Network, no. 41, pp. 27–38, 2023, doi: 10.55529/jaimlnn.41.27.38.
[12] S. Aryza, P. Wibowo, and D. Saputra, "Design and Construction of a Heating Process Control Tool for Biodiesel Production from Used Cooking Oil Based on Arduino Mega," in Proceedings of the National Seminar on Social, Humanities, and Technology, Jul. 2022, pp. 121–127.
[13] Rahmaniar, P. Wibowo, and P. M. Br Meliala, “Transient Stability Analysis with Critical Clearing Time Method on Transmission Line 150 kV,” Proceeding International Conference Gebyar Hari Keputeraan Prof. H. Kadirun Yahya, pp. 138–150, 2022.
[14] Anisah, S., & Tarigan, A. D. (2023). Planning On-Grid Rooftop Solar Power Plants as an Environmentally Friendly Alternative Energy Source. INTECOMS: Journal of Information Technology and Computer Science, 6(1), 503-510.
[15] Rahmaniar., B Mesra., Junaidi Agus. (2023). The Utilization of Solar Panel NRE Technology Innovation on Skewer Shaving Machine for Community Empowerment in Bandar Senembah Village. SOLMA Journal, 12(3): 1186-1194; 2023
[16] Rahmaniar., Khairul., Junaidi Agus., Sari Keumala Debby. (2023). Analysis of Shaddow Effect on Solar PV Plant Using Helioscope Simulation Technology in Palipi Village. JTEV (Journal of Electrical and Vocational Engineering). Vol. 9 No. 1 (2023)
[17] Tharo, Z., & Hamdani, H. (2020). Analysis of the Roof Cost of Household Scale Solar Power Plants. Journal of Electrical and System Control Engineering, 3(2), 65-71.