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ANALYSIS OF THE WORKING OF VARIABLE FREQUENCY DRIVE (VFD) ON THE MOTOR HOIST CRANE IN AN ELECTRIC SYSTEM TO DAMPEN SWING

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Abstract

This study aims to analyze the performance of Variable Frequency Drive (VFD) on three-phase crane hoist motors in reducing load swings and improving energy efficiency. The method used was a laboratory experiment with a quantitative approach, using frequency variations of 30 Hz, 40 Hz, and 50 Hz. Data was obtained through a digital gyroscope sensor and recording of current and voltage in real time. The test results show that the 40 Hz frequency provides optimal performance with good swing damping and the highest energy efficiency. VFD has been proven to be able to reduce impulsive forces during starting and stopping, shorten damping time, and reduce electrical power consumption. In addition, the use of VFD also reduces the Total Harmonic Distortion (THD) value to below 5%, according to the IEEE-519 standard. These findings confirm that the integration of VFD in the hoist crane system not only improves operational stability, but also supports energy efficiency and work safety.

Keywords: Variable Frequency Drive , Induction Motor, Crane Pulley / Lift Crane, Swing Damping, Energy Efficiency

INTRODUCTION

In the modern industrial world, a hoist crane is an important tool used to move heavy loads vertically and horizontally. This system is widely found in factories, warehouses, ports, and large construction projects. However, one of the main problems that often arise in the operation of a hoist crane is the occurrence of load swings when the lifting or lowering process takes place. The swing occurs due to a sudden change in acceleration in the drive motor which causes an inertial force in the load. This condition not only reduces work efficiency, but also poses a high safety risk to the operator and the environment around the appliance. Therefore, a control system is needed that is able to finely regulate the movement of the motor so that swings can be minimized without reducing the working speed of the tool.

One of the technologies that is widely used to solve this problem is Variable Frequency Drive (VFD). VFD is an electronic device that can regulate the frequency and voltage of the induction motor resource so that the rotational speed of the motor can be adjusted according to the load needs. With this setting, the starting and stopping process becomes smoother, the initial current is lower, and the torque can be controlled gradually. This is especially useful for lifting applications such as hoist cranes, as it is able to reduce initial impact and smooth the movement

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of loads. VFD-based multispeed systems are also proven to maintain the stability of motor speed when loads change, so that lifting performance becomes more stable and safe for long-term use. In addition to the advantages in terms of speed control, the use of VFDs also has a positive impact on energy efficiency and electrical power quality.

Research states that the application of VFD can save industrial motor power consumption by up to 20% under partial load conditions. This efficiency is generated because the VFD is able to adjust the power needs of the motor to the actual load, so that there is no waste of electrical energy. However, on the other hand, the use of VFDs also has the potential to cause harmonic distortion that can disrupt the electrical power system as a whole. In addition, a thorough analysis of VFD performance is required to obtain an optimal configuration between energy efficiency and system stability.

Based on the research, it is explained that with the application of an active harmonic filter, the Total Harmonic Distortion (THD) value can be suppressed below 5%, which means it is safe according to the IEEE-519 standard. In an international study, Omar et al. (2022) showed that the application of VFD in overhead crane systems was able to reduce the swing amplitude by up to 37% and significantly improve the accuracy of load positioning. Similar results were also examined that the swing control model in the crane system used a zero-vibration antisway strategy to suppress load oscillations. Meanwhile, there are also those who develop a PID control system based on the PSO SA optimization algorithm to improve position accuracy and speed up swing damping time. The results of these studies prove that the application of VFD-based control systems and combinations with intelligent control can improve the stability, efficiency, and safety of crane operations.

Based on the descriptions of several journals that have been reviewed, it can be concluded that swing control on hoist cranes is important to support safety and work effectiveness in the industry. However, further research is still needed on how VFD frequency regulation affects swing damping and energy efficiency in motor drive systems. Therefore, this study aims to analyze the performance of VFD in three-phase crane hoist motors with a focus on the ability to dampen swings and optimize electrical power consumption. It is hoped that the results of this research can contribute to the development of a more stable, efficient, and industrial hoist system in Indonesia

LITERATURE REVIEW

1. Variable Frequency Drive (VFD)

Variable Frequency Drive (VFD) is a power electronics device that functions to regulate

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the rotational speed of an induction motor by changing the frequency and voltage given to the motor. The working principle of VFD is based on the setting of a Pulse Width Modulation (PWM) signal that produces synthetic sinusoidal waves with variable frequencies. With this method, the motor can rotate as needed without having to undergo mechanical changes. In addition, the VFD is also able to reduce the initial current of the motor so as to extend the life of the components and reduce power losses due to current surges during starting. The use of VFDs is now increasingly widespread in the industry because it is able to increase energy efficiency while maintaining torque stability, especially in heavy load drive systems such as hoist cranes.

2. Induction Motor and Hoist Crane System

Three-phase induction motors are the most widely used type of motor in industrial systems because they have a simple construction, high durability, and good efficiency. In a hoist crane system, the induction motor functions to drive the drum that winds the rope or load lifting chain. However, the large initial torque of the motor often causes sudden movements in the load, resulting in swings that can disrupt the stability of the operation. To overcome this, a speed control system is needed that is able to finely regulate the acceleration and deceleration of the motor. One effective solution is the use of VFDs that can adjust the working frequency of the motor lift so that the process and take place are more stable. Load Reduction

Figure 1. Induction motors and variable frequency drives

3. Research Related to the Use of VFDs

On Lifting Systems Various studies have proven that the application of VFD provides significant results in reducing swing in the hoist crane system. The use of VFD on overhead cranes is able to reduce the amplitude of swing by up to 37% and improve the accuracy of load positioning. Other research shows that the application of PID control based on the PSO-SA optimization algorithm on bridge cranes can speed up damping time as well as reduce load positioning errors. According to research, it has also developed a negative zero vibration control method that is effective in suppressing oscillations by taking into account the elasticity of the

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lifting rope. From these results, it can be concluded that VFD-based control systems and intelligent algorithmic approaches make a major contribution to improving the stability and efficiency of load lifting in the industry.

4. Energy Efficiency and Power Quality in VFD Systems

In addition to its role in speed control, the use of VFDs also affects energy efficiency and electrical power quality. The application of VFD in industrial motors is able to save energy up to 20% in partial load conditions without degrading the mechanical performance of the system. However, the use of VFD can cause harmonic distortion that has the potential to disrupt the stability of the power grid. To overcome this, VFD systems are generally equipped with active harmonic filters so that the Total Harmonic Distortion (THD) value remains below 5% according to the IEEE-519 standard. Thus, it reduces the load swing on the hoist crane, but also helps to improve energy efficiency and maintain the quality of electrical power in industrial power systems.

In addition to improving energy efficiency, VFDs can also extend the operational life of the motor and reduce maintenance costs. This is because the motor works at the optimal speed according to the actual load, so the heat generated is lower and the mechanical components do not wear out quickly. In addition, the frequency-based control system makes the starting and stopping process smoother, reducing mechanical stress on the shaft and gearbox of the motor. In the long run, the use of VFDs not only provides direct energy savings, but also overall operational cost efficiency. Therefore, the application of VFD in hoist crane systems can be categorized as a technological investment that supports the concept of energy-efficient and sustainable industry.

Table 1. Research Summary Related to the Use of VFD in Cran Hoist Systems

Yes	Researcher (Year)	Research focus	Main results
1.	Omar et al. (2022)	Application of VFD to overhead cranes	Reduces swing by up to 37% and improves stability.
2.	Li et al. (2022)	PSO-SA algorithm-based PID control	Faster damping time and load position more accurate.
3.	Cao et al. (2021)	Negative zero vibration method Control	Suppresses load oscillations due to rope elasticity.

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4.	Turinno et al. (2023)	Motor energy efficiency analysis with VFD	Power consumption drops Up to 20% without lowering performance.
5.	Maulana et al. (2024)	Harmonic analysis of the system VFD	THD value < 5% with use active filter.

METHODS

Research Design

This study was conducted to analyze the performance of Variable Frequency Drive (VFD) on three-phase hoist crane motors in reducing load swings and improving the efficiency of the electrical system. The method used is a laboratory experiment with a quantitative approach, where direct testing is carried out on the hoist crane system controlled using VFD. The induction motor used has a power of 1.5 kW with a working voltage of 380 V and a nominal frequency of 50 Hz. The VFD system used is a Sinusoidal PWM Inverter type with a maximum current capacity of 5 A. This research was conducted in the Electric Drive System Laboratory to ensure that the test conditions are controlled and the results obtained can be measured objectively (Nugrahanto, 2022).

Tools and Materials

The main tools used in this study consist of a VFD, a three-phase induction motor, a hoist control circuit, and a digital gyroscope-based swing measuring sensor. In addition, a data logger is also used to record current, voltage, and swing damping time in real time. The test load is in the form of a fixed load with a mass of 10 kg suspended using a steel rope on the hoist crane system. To ensure accuracy, the test is performed three times on each frequency variation. The use of digital sensors and automatic recording aims to make the data obtained more accurate and easy to analyze.

Figure 2. Motor use of hoist crane

In addition to the main tool, the MATLAB/Simulink software is used as a simulation

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support to compare the results of the experiment with the mathematical model of the system. This simulation refers to a dynamic model of induction motors and swing damping equations developed by Cao et al. (2021). With a combined approach between direct testing and simulation, this study is expected to be able to provide more comprehensive results related to the effect of frequency variation on the stability and efficiency of the hoist crane system.

Figure 3. Use of matlab sortware.

Research Procedure

The first step in this study is to calibrate the VFD system and sensors so that the data obtained is accurate. After that, the motor working frequency is set at 30 Hz, 40 Hz, and 50 Hz values to determine its effect on the speed and swing of the load. Each variation was tested with a load lifting duration of 20 seconds, then the maximum swing angle values, damping time, current, and voltage that occurred during the process were recorded. The measurement results are then compared to determine the most optimal working frequency in dampening the swing. The test results data were then processed using quantitative analysis by calculating the percentage of swing angle reduction, electrical power efficiency, and Total Harmonic Distortion (THD) value. The efficiency value is calculated based on the comparison between the input power and output of the motor, while the THD value is obtained through harmonic spectrum analysis from the VFD output voltage data. The results were then compared with previous standards and results to assess how effective the VFD system used in this study was in controlling swings and improving energy efficiency.

RESULTS AND DISCUSSION

The test results show that the frequency variation (VFD on Variable Frequency Drive) has a great influence on the rotational speed of the motor and the load stability of the hoist crane system. At low frequencies (30 Hz), the movement of the load is noticeably smoother and the swing that occurs is relatively small, but the lifting speed is slow. On the other hand, at high frequencies (50 Hz), the motor rotates faster, but the resulting inertial force is greater so that it causes the load oscillation to increase. The most stable condition is found at the mid-range,

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which is 40 Hz, where the system is able to achieve a balance between lift speed and swing damping. These results show that the regulation of the working frequency through VFD is very important in maintaining the stability of the movement and operational comfort of the crane.

In addition to affecting stability, frequency regulation through VFD also has a direct impact on electrical power consumption and energy efficiency. When the motor is operated at low frequencies, the electric current flowing to the motor becomes smaller so that power usage decreases.

However, system efficiency tends to be optimal when the frequency is adjusted to the actual load being lifted. Tests show that at a frequency of 40 Hz, the motor works at the most efficient conditions because the current and torque of the motor are in good balance. This proves that the use of VFD can help reduce the waste of electrical energy and extend the operational life of the motorcycle.

These results are in line with previous research that emphasizes the importance of frequency and voltage regulation so that the power efficiency of induction motors increases significantly. From the results of observations of the angle of load swing, it can be seen that the VFD system is able to shorten the damping time compared to conventional systems. When the motor stops, the VFD regulates the process of deceleration of torque gradually so that the impulsive force that causes the swing becomes smaller. Thus, the load reaches the stationary position faster without the need for additional damper mechanisms. In general, the application of VFD not only makes the operation of the hoist crane smoother and more stable, but also provides advantages in terms of energy efficiency, load control, and work safety. These findings reinforce that VFDs are an effective and economical solution for industrial drive systems that require speed control and high stability in the lifting process. So it's economical to use.

CONCLUSIONS AND SUGGESTIONS

Conclusion

Based on the results of research and analysis that has been conducted, it can be concluded that the use of Variable Frequency Drive (VFD) on the hoist crane motor is proven to be able to improve the stability of the lifting system and significantly reduce load swing. The regulation of the working frequency of the motor has a direct influence on the rotational speed, torque, and inertial force that occurs during the starting and topping process. From the test results, it was obtained that the 40 Hz frequency is the most optimal point, as it produces a balanced lift speed with a good level of swing damping. In addition, the application of VFD has also been proven

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to increase efficiency by reducing electrical power consumption and extending the operational life of the motorcycle. Overall, the VFD system can be said to be effective and feasible to apply to industrial crane hoist systems as an effort to create a safe, energy-efficient, and more reliable operation.

Suggestion

For further research, it is recommended that tests be carried out using more diverse load variations in order to obtain results that are more representative of field conditions. In addition, it is necessary to develop additional control systems such as fuzzy logic or adaptive PID so that the motor response to load changes becomes faster and more stable. Advanced research can also add real-time power quality measurements to find out the impact of harmonization in more detail. From a practical perspective, the implementation of VFD should be accompanied by a harmonic filter and a more current protection system to maintain the stability and reliability of the system as a whole. With this step, it is hoped that the development of VFD-based hoist crane systems in the future can be more efficient, safe, and support the concept of energy-saving industries.

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