Upgrading for overhead crane anti-sway method using variable frequency drive

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Article Info

Article history:

Received Feb 28, 2022
Revised May 24, 2022
Accepted Jun 8, 2022

Keywords:

Induction motor
Motor starter
Overhead crane
Rotor resistance
Variable frequency drive

ABSTRACT

The paper discusses about upgrading the overhead crane anti-sway method base on the induction motor torque control from rotor resistance starter to variable frequency drives (VFDs). The upgrading included two phases. The phase 1 is to identify the performance of the overhead crane operation on anti-sway method base on the induction motor torque control using rotor resistance starter (old existing motor starter). The phase 2 is to identify the performance of the overhead crane operation on anti-sway method base on the induction motor torque control that use a variable of frequency drive (new upgrading motor starter). The primary equations connecting tractive force and load sway angle, which the motor torque control law is based on is designed for 0% load wobble at the end of the journey. The words accelerating and braking have been written. Outcomes of modelling the behaviour of a trolley-load of two masses for the normal overhead crane load ratios, a system is described weight to the length of the rope, which supports the hypothesis concerning the feasibility of direct load anti-sway control ON and OFF for regulation of motor for overhead cranes.

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1. INTRODUCTION

In terms of boosting the efficiency of operations and automation, overhead crane anti-sway control is a popular topic. Today, there are a variety of approaches such as mechanically reeving the lifting device's ropes and pulling up the spreader ropes to electrically setting the crane trolley speed or boom swing speed with the overhead crane load's zero vertical deviation at the end of acceleration/braking for completing this task. The electrical impact on the travel drive (swing drive) was frequently achieved by sending sign-reversing total motor torque to the travel gear, resulting in accelerated mechanical gear and motor wear.

It's worth mentioning that, instead of using a rotor resistance starter, today's variable frequency drives (VFDs) feature control modes for both speed and torque. As demonstrated in Figure 1 on the example of a modern VFD, Delta Electronics Inc.'s C2000, the torque control duty can be fed by analogue input, RS-485 (Modbus- RTU; Modbus-ASCII), CANopen, or other standards via COMM Card. Toque control can be implemented with or without the encoder in the sensorless mode. Investigates an inclinometer as a sway sensor in conjunction with the observer that is part of a mathematical model [1]. The approach used in is based on the measurement of the spreader's inclination angle and the conversion of the measured value into a sway angle [2].

Research by Kawai *et al.* [3] an image sensor was presented as a spreader speed sensor, with the measured value being used in a real-time controller. Image sensor feedback is used in the Siemens corpanti-sway. control system SIMOCRANE [4]. A high-performance optical camera and a deflector make up the system. The data from the camera is sent into a crane mathematical model, which produces a unique speed profile for a travelling mechanism. [5], [6] describe in detail the fuzzy controller for an anti-sway system. Another method for providing sway-free payload movement is to use a neural network. This method's description can be found in [7], [8].

Sway angle feedback is not required in open-loop systems that provide sway-free crane operation. Every open-loop system, however, requires extra variable feedback from a crane. ABB Company, for example, developed an open-loop anti-sway control system [9] based on the determination of free-oscillation frequency and its subsequent use in a mathematical model. The frequency of free oscillation is related to the length of a hanging freight cable [10]. It signifies that the length of a cable should be computed or measured using a different sensor.

The challenge of defining the sway angle is critical for precise positioning of hanging crane. Sensors and sensorless methods are the two most prevalent methods for determining the angle of crane swaying. A mathematical model of mechanical and electrical crane parts is used in almost every anti-sway control system [11].

2. METHOD

Consider the travel gear oscillations in the two-mass trolley-load system, which allow the load crane to move along its boom. In a gear like this, all processes are represented in a two-dimensional Cartesian coordinate system. To establish the structure's safety, the data from the sensors is combined with mathematical models [12]. There are two (2) phases involved to complete this research study:

Phase one (1): rotor resistance starter

Investigate on existing old induction motor and motor starter for crane control system for improvement motor start and stop running.

- Defined torque – speed curve for rotor resistance variation as shown Figure 1.
- Study circuit control for existing motor starter based on slip ring AC motor [13].
- Tested, run, and analyze.

Phase two (2): VFD

Design new induction motor circuit to link with VFD as motor starter for crane control system for improvement motor start running.

- Designed new starter motor based on existing slip ring AC motor.
- Build circuit diagram included power and control circuit diagram to synchronized with VFD.
- Tested, run, and analyze.

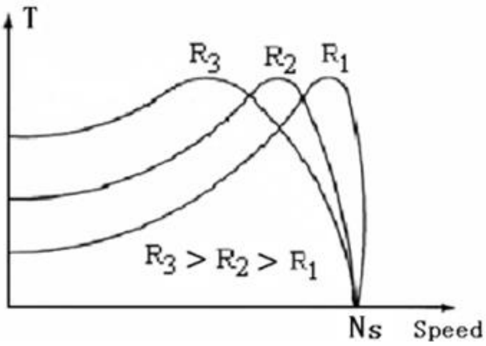


Figure 1. Torque – speed curve for rotor resistance variation

B5G and 6G mobile communication standards have been established, ushering in a new age of mobile communication [14]. It is possible to formulate the fundamental principles of the engineering approach to the sway control problem using the available technical capabilities offered by VFD, as well as develop the main VFD control algorithms for this process, by considering the onset and damping of the oscillations in one plane [15], [16]. These ideas must be supported by mathematical equations that allow swing cranes to switch from Cartesian to polar coordinate systems [17], [18].

The first stage's unique feature is VFD operation in the torque control mode (for the method IM TQC for Delta C2000 VFD, Figure 2), which is safe in terms of its operation when developing the necessary law of the overhead crane load's vertical deviation during the acceleration and braking stages of travel gear. The impact of several filtering methods on leakage current in the motor drive system has also been investigated, with the results provided in this study [19]. New issues in the correction of power quality concerns have arisen recently, necessitating the introduction of innovative power electronics-based solutions [20].

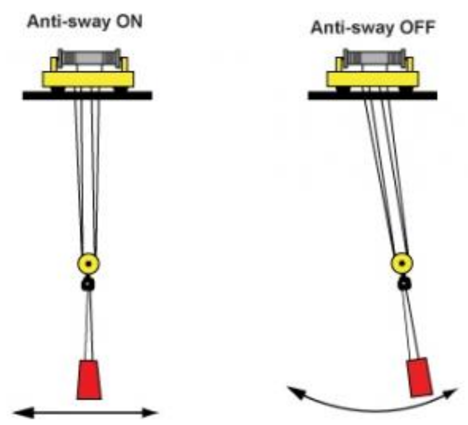


Figure 2. Overhead crane anti-sway ON and OFF

3. RESULTS AND DISCUSSION

3.1. Rotor resistance starter

It is possible to change the shape of the torque – speed curve in a wound rotor induction motor by adding more resistance to the rotor circuit. The torque – speed characteristic curves that result are presented in Figure 1. This speed control approach is fairly straightforward. With a small value of slip, it is feasible to have a big starting torque and a low starting current. The main downside of this technology is that it is inefficient due to additional losses in the rotor circuit's resistors. It is frequently used when speed needs to be reduced for a brief period of time due to its convenience and simplicity (cranes). Table 1 show the summary of rotor resistance starter for overhead cranes.

Table 1. Rotor resistance comparison on benefit and drawback

Rotor resistance starter benefits	Rotor resistance starter drawback
The following are the main advantages of the rotor resistance starter: a. The rotor resistance starter may produce a high starting torque. b. It boosts the motor's power factor. c. Harmonics in the line current are not present. d. The initial current has been reduced. e. It is possible to control the speed in a smooth and wide range.	The following are some of the rotor resistance starter's disadvantages: a. Lower efficiency because of I2R losses in the rotor circuit's external resistance. b. Only a slip ring induction motor may be started with this starter. c. The presence of slip rings and carbon brushes necessitates periodic maintenance.

3.2. Variable frequency drive

To ensure and verify the proposed solutions, a simulation of the behaviour of the two-mass trolley-overhead crane loading system was created and implemented in the Starter Software environment for the situation of direct control of the motor torque for the typical values of anti-sway ON and OFF, which corresponds to the real-world conditions of crane operation. The genuine data of the load crane was utilised to pick these parameters. Figures 3(a) to (d) shows the control system's auto tuning control reaction of anti sway OFF. While in Figures 4(a) to (c) shows how the auto tuning adjustment can track the location correctly and effectively suppress the swing angle. Figure 5 further shows that the auto tuning controller's end state is convergent to zero, demonstrating the controller's effectiveness.

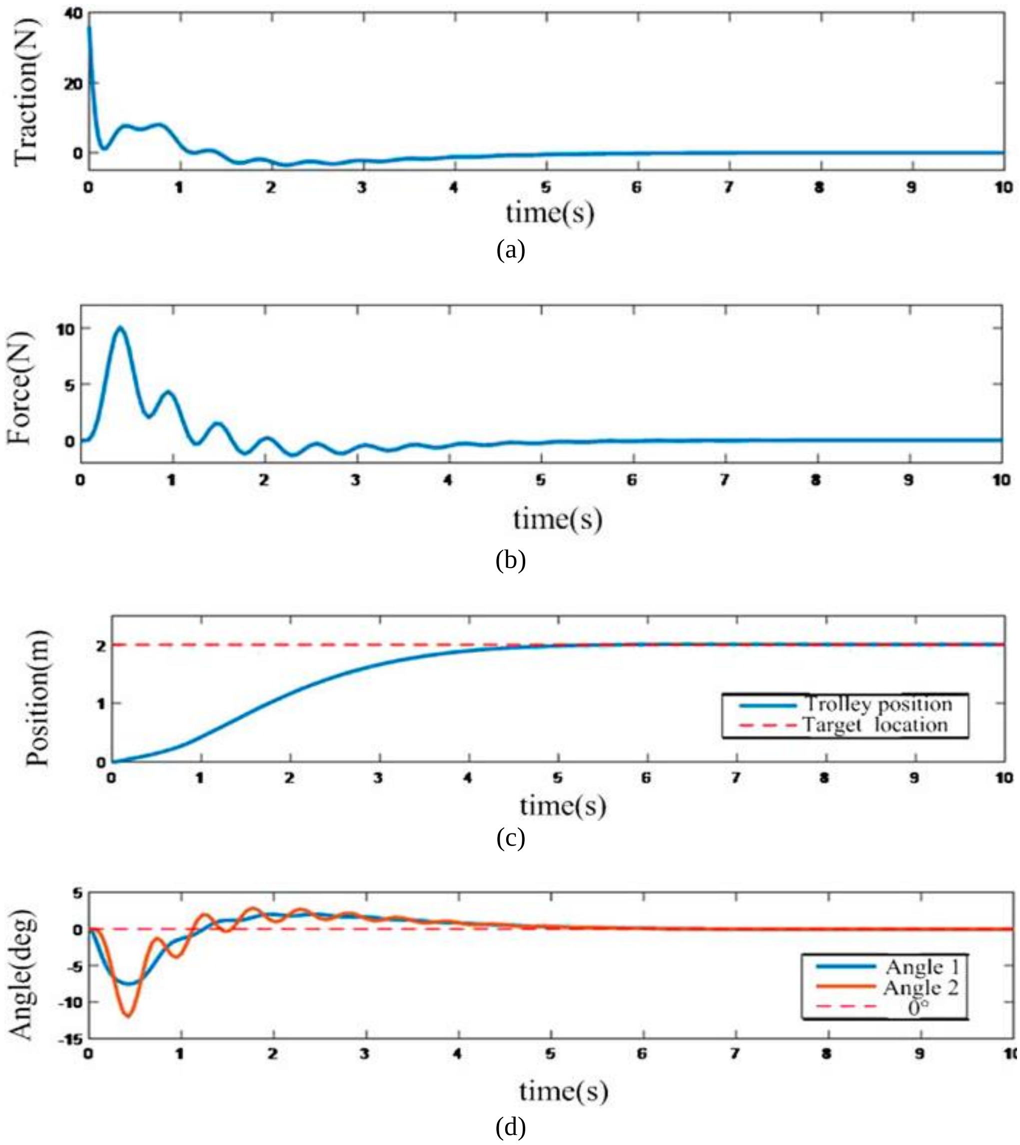
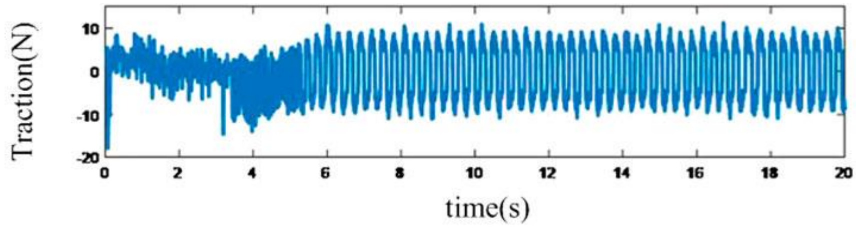


Figure 3. The control system's auto tuning control reaction (a) traction, (b) force, (c) position and (d) angle during anti-sway is OFF mode

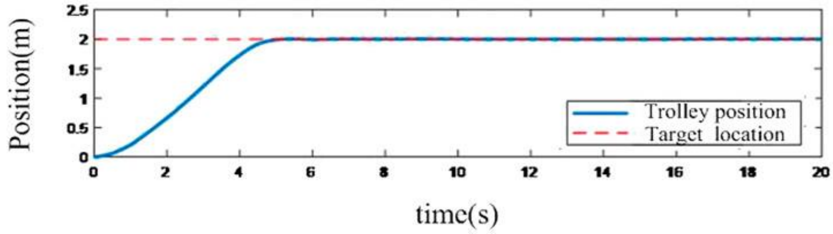
3.3. Performance of rotor resistance & motor starter for overhead crane

The Fluke Power Meter Logger can be used to show the performance of an overhead crane system before crane motor starter upgrading by using rotor resistance starter with crane operate by old design which is by using joystick in Figure 6 and Figure 7. After crane motor starter upgrading by rotor resistance starter with motor crane operate by new design which is by using VFD in Figure 8 and Figure 9. The crane system fault monitoring method based on vibration signal [21], [22].

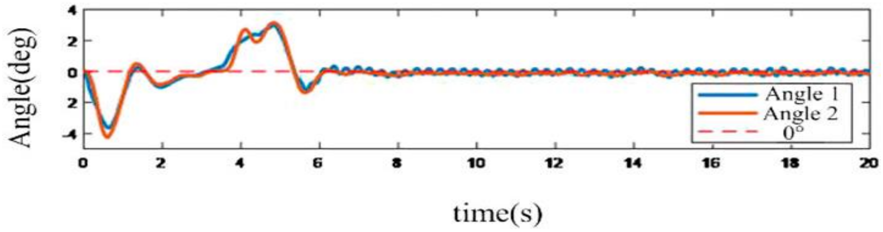
Figure 6 shown the three-phase voltage graph by rotor resistance starter with starting condition of the crane movement. While Figure 7 shown the three-phase voltage graph by rotor resistance starter with running condition of the crane movement. Each graph shows that the harmonic distortion interrupted during crane operation by the unsmoothed graph illustrated by Fluke Power meter. The control object is a big synchronous motor excitation system, which is commonly employed in large power transmission systems [23]. At production locations, wireless communications garner a lot of attention [24] once VFD are implement for crane operation such as wireless communication between transmitter & receiver, PLC & HMI and HMI & IoT which are all can link into the VFD. Thus, by the result of upgrading motor crane starter from rotor resistance starter versus to VFD improved crane hoisting [25], [26] anti sway issues.



(a)



(b)



(c)

Figure 4. The anti-swing positioning system's response is based on the sliding mode method (a) traction, (b) position and (c) angle during anti-sway is ON mode

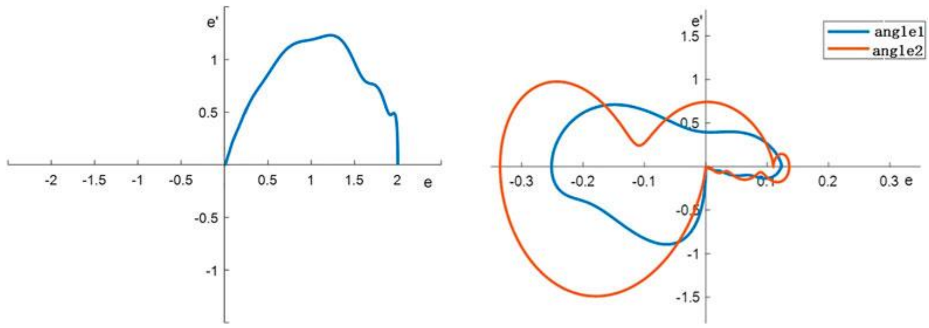


Figure 5. The response of the auto tuning compensation control system to the phase trajectory

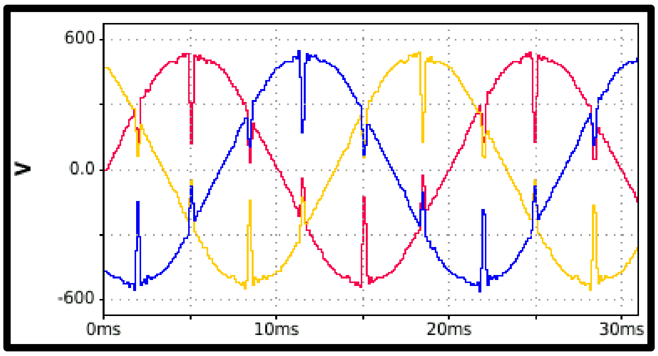


Figure 6. Three phases voltage graph with rotor resistance starter during motor starting

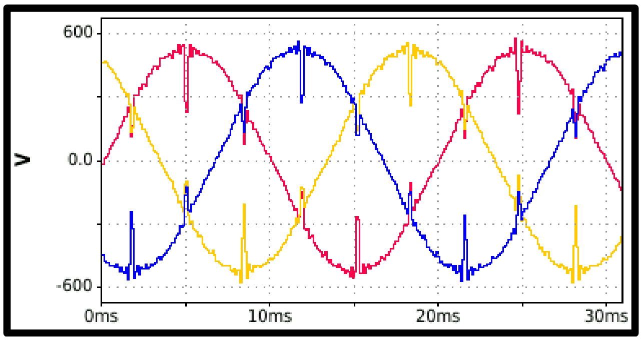


Figure 7. Three phases voltage graph with rotor resistance starter during motor continue running

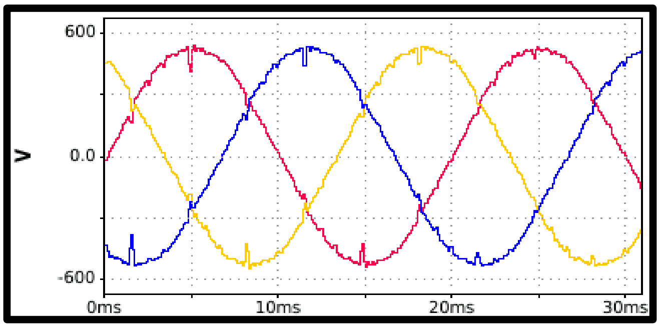


Figure 8. Three phases voltage graph with VFD starter during motor starting

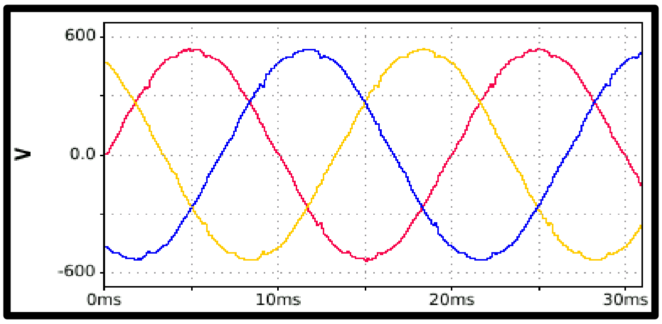


Figure 9. Three phases voltage graph with VFD starter during continue running

Figure 8 shown the three-phase voltage graph by VFD with crane motor starting condition of the crane movement. While Figure 9 shown the three-phase voltage graph by VFD with crane motor running condition of the crane movement. Figure 8 graph shows that the harmonic distortion reduced during crane operation by a bit smoothed graph illustrated before autotune. While Figure 9 shows that the harmonic distortion reduced during crane operation by the smoothed graph illustrated after VFD autotuned. Each graph is also illustrated by Fluke Power meter.

4. CONCLUSION

The lack or absence of monitored crane safety parameters crane and safety monitoring systems is the leading cause of crane accidents. Due to cost savings on upgrading and maintenance, the enhancement is a novel research for control systems in the steel sector. When human or operator safety is a problem, fewer labour is required for crane operation, which reduces time spent on the job and increases productivity. The analysis show that the acceleration operation with oscillation damping is entirely controllable, allowing the trolley speed and motor output to remain within technological and engineering constraints.

The technique is simple to implement. In the algorithms of a certain controlling VFD, the force evaluator and the cosine wave generator can be included. Once anti-sway is turned on, the Delta C2000 is comprised of a modern, sophisticated, and programmable logic controller (PLC) with the VFD mode switching algorithm from the torque control during the acceleration-braking stage at the time of moving the vehicle, automated speed stabilisation is implemented. At production locations, wireless communications garner a lot of attention once VFD are implement for crane operation such as wireless communication between transmitter & receiver, PLC & HMI and HMI & IoT which are all can link into the VFD. Thus, by the result of upgrading motor crane starter from rotor resistance starter versus to VFD improved crane hoisting anti sway issues.

ACKNOWLEDGEMENTS

Universiti Teknikal Malaysia Melaka deserves special recognition for having great research facilities. Special thanks to the Ministry of Higher Education for funding the research with grant FRGS/1/2020/ FTKEE - COSSID/ F00424. Special appreciation to Ann Joo Steel for granting me permission to continue my advanced wireless communication research and study.

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