Dynamic Braking Application on Three Phase Induction Motor using PLC

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Abstract
The use of an induction motor requires the process of stopping the motor speed quickly, using mechanically and electrically generated braking torque. Dynamic braking, which is done by making a magnetic field stationary motor. This condition is carried out by injecting a DC current into the three phase induction motor stator coil after the connection of the stator coil is released from the AC supply voltage source. The advantages of dynamic braking include ease of speed regulation of three-phase induction motors and mechanical losses can be reduced. A system for reversing the direction of star-delta three phase induction motor rotation with Programmable Logic Control (PLC) as a controller. requires an exchange of rotating directions from the direction of turning right to turn left. The process of changing the direction of rotation of the motor requires dynamic braking, the braking process is carried out by injecting a DC current into the stator coil of an induction motor, which is related to PLC. By applying dynamic braking on a three phase induction motor it is obtained faster than without dynamic braking. The injection current is given to a 3-phase induction motor of 1 KW for dynamic braking of 2.2 A. The timing of the motor stops for a minimum load of 100 Watt without braking at 6.2 seconds and with braking of 4.4 seconds, for a maximum load of 600 W, without braking.

Keywords: Dynamic braking, induction motor, injection current, PLC

1. Introduction

1.1. Background
The advantages that can be obtained in controlling three phase induction motors are, the structure of the three-phase induction motor is lighter (20% to 40%) compared to direct current (DC) motor for the same, sturdy, and more efficient three phase induction motor treatment. In its use, the induction motor is often needed to stop the motorcycle quickly. This situation is carried out by injecting direct current into the three-phase induction motor stator coil after the connection of the stator coil is released from the source of the alternating current supply voltage. This method is known as dynamic braking. By applying dynamic braking on a three-phase induction motor, the results of the process of stopping the rotation of the induction motor are faster than without dynamic braking. But in reality, most induction motors cause a large shock (flicker) and a large starting current (5-7 times I nominal). This will cause a large voltage drop in the supply voltage of the PLN. For a motor with small power, the starting current
is not too influential on the voltage drop, while for motors with greater power will cause a large voltage drop as well as reduce the quality of electricity that affects the flashing light and the beat of the motor which causes the motor to break quickly.

Along with the development of technology, many industries are demanding cheap and easy motor operating systems, especially for induction motors. Easy and inexpensive operation using computers, especially PCs.

1.2. Problem Formulation
The simulation stops motor rotation quickly with a dynamic braking process. Moreover, Braking is done by making a magnetic field stationary. by injecting DC current into the three-phase induction motor coil stator.

2. Research methods

2.1. Preliminary
The virtue of this research lies in the ability to optimize braking efficiency that minimizes losses that can occur for applications in the industry. Become a dynamic braking model for three phase induction motors in Nanggroe Aceh Darussalam.

The induction motor when turned on directly will draw a current of 5 to 7 times from the full load current and only produces the torque of 1.5 to 2.5 times the full load torque. This large initial current can cause a voltage drop on the channel so that it will interfere with other equipment connected to the same channel. For large-powered motors, the starting current will also be greater, so that for large motors it is not recommended to turn on the motor directly, an induction motor is often started with a voltage level lower than its nominal voltage. Standing induction motors can be done by: [1] Directing on Line (DOL), Sequencing of triangles, Sequencing with an autotransformer, Fostering with multilevel prisoners, Sedition with Primary Prisoners, Soft starters and Sequencing with an electronic switch.

The use of dynamic breaking use of dynamic braking method as one method to stop the rotation of the three-phase induction motor. A Simulation model to control the dynamic braking method process on an induction motor for conveyor applications.

In the use of an Induction motor, it is often necessary to process the motor quickly, especially on conveyor applications. To stop the braking rotation, it is needed which can be produced mechanically or electrically. This braking is done by injecting DC current and voltage in the stator winding of the induction motor after being released from the source of the phase supply voltage. The direct current injected on the stator coil will develop the stationary field to reduce the voltage on the rotor and produce a magnetic field. The magnet will rotate at the same speed as the rotor but in the opposite direction to make it stationary to the stator. Terrestrial interaction and the magnetic force of the rotor will develop the torque opposite the motor torque.

2.2. Induction Motor Braking
The braking method uses depending on the desired condition to occur, for example, to stop the engine rotation or just to slow down the rotation. This is also closely related to torque and slip that occurs on the engine. Regenerative braking method occurs when the rotor of an induction motor rotates faster than the stator rotating field so that a negative slip occurs and the engine supplies power. Therefore, whenever the motor has a tendency to spin faster than the rotary field, regenerative braking occurs [2]. Reduced motor speed and braking torque make the motor work at constant speed and does not cover the possibility of working faster. Judging from the effect of stator resistance, the maximum torque that occurs during the regeneration process is greater than the maximum torque during the motoring process. However, during the regenerative braking process, there is a possibility of dangerous
speed if the load torque is greater than the breakdown torque of the motor because the torque that arises cannot slow down the motor and vice versa occurs acceleration [3]. Whereas for plugging braking or also called counter current braking it works by exchanging the phase sequence input of an induction motor so that the direction of the stator swivel field can be reversed. In practice, this method is carried out by interchanging the supply of voltage to two motor terminals, thus braking torque can occur and the motor can stop quickly. However, the motor must not be connected to a voltage source when zero speed occurs.

![Figure 1. Dynamic braking circuit with direct current injection](image1)

The induction motor braking method which is then a dynamic braking method is used to stop the rotation of the induction motor rotor. The voltage at the stator is changed from an alternating voltage (AC) source to a direct voltage (DC) in a very short time. The torque generated from braking depends on the amount of DC current injected into the stator winding. Figure 2.5 shows the shape of the braking circuit with direct current. Injection on a three-phase induction motor. The direct current injected into the stator coil will develop a stationary magnetic field to reduce the voltage in the rotor. Because the rotor coil is connected briefly, the flowing current produces a magnetic field.

Replace circuit and phasor diagram of induction motor during the dynamic braking process. When the stator is dc flowed, a stationary magnetic field is formed in the stator. The magnetic field formed depends on the connection of the stator winding, the number of turns, and the amount of current [3].

![Figure 2. Torque-speed curve during dynamic braking](image2)

The stator current has an effect on the magnetization formed, while the motor current influences the torque. So that the equation can be written [3]

\[ T = \frac{3}{2nN_s} I_2^2 R_2 \]  

\[ ..................................................(1) \]

That from the entire method of induction motor speed rotation mentioned above, it is considered the most effective and safest method to be used to stop the rotation of the induction motor because it is very unlikely to occur losses that are wasted during the braking process is the braking method and motor stop with dynamic braking method that is by injecting direct current to the stator from a three-phase induction motor.
Induction motors in general, are three-phase motors, whereas the models developed to date are dual motor models because the calculations and analyzes made are easier [3]. Therefore, a transformation from three phases into two phases is needed to model an induction motor. Figure 2.9 shows the axes for three phases and two phases [2]. The induction motor used in the simulation is modeled using the reference rotor flux (reference frame flux rotor).

![Figure 3. Flux reference frame rotors](image)

The transformation from the stator reference frame to the rotor reference frame is represented in the following equation:

\[
\begin{bmatrix}
I_d \\
I_q
\end{bmatrix} =
\begin{bmatrix}
\cos \theta_e & \sin \theta_e \\
-\sin \theta_e & \cos \theta_e
\end{bmatrix}
\begin{bmatrix}
I_d \\
I_q
\end{bmatrix}
\]

\[\text{(2)}\]

The controlling circuit diagram is shown in figure 4.

![Figure 4. Start diagram star – delta](image)
2.3. **Software Design**

To be able to work as desired, the PLC must be programmed. Programming and sending programs to the PLC. Power supply wiring is testing, the data processing and analysis is collecting and concluding the results of data analysis.

3. **Results and Discussion**

3.1. **Test Results**

In the testing implementation, a three-phase induction motor is used to simulate load and not load with the following specifications: Three Phase Induction Motor Specifications for simulation

| Specification   | Value           |
|-----------------|-----------------|
| Voltage         | 380/220 V       |
| Motor Relations | Y / Δ           |
| Flow            | 4.7 A / 2.70 A  |
| Power           | 1 KW            |
| Rpm             | 2830            |
| Frequency       | 50 Hz CONT.     |

Generator specifications as motor load:

| Specification   | Value           |
|-----------------|-----------------|
| Voltage         | 220/380 V       |
| Generator relation | Y / Δ       |
| Flow            | 8.8 A           |
| Power           | 0.8 KW          |
| Rpm             | 1500 Rpm        |
| Frequency       | 50 Hz CONT.     |
| Cos phi         | 1               |

To get the DC injection current value, the calculation is carried out as follows (nominal motor rotation rotor 2380 RPM)). The given injection current is attempted to be smaller than the normal injection current, this is so that braking does not damage the motor because the current is too large .. The selection of DC injection current is 45% (2.2 A) nominal current because it has the greatest braking
torque and energy and requires the smallest braking time. In the implementation of the test PLC is used to simulate the operational conditions of induction and braking motors.

![Image](image_url)

**Figure 6. The whole system**

Measurements and tests carried out, can be compared and analyzed between without and with dynamic braking. A Comparison is shown in table 1.

**Table 1. Data without load and braking (5 repetitions).**

| No | Stop time (seconds) | Motor Speed (Rpm) |
|----|---------------------|-------------------|
| 1  | 10.2                | 2820              |
| 2  | 10.3                | 2830              |
| 3  | 10.0                | 2820              |
| 4  | 10.5                | 2825              |
| 5  | 10.7                | 2828              |
| Average | 10.3            | 2824.6            |
Table 2. Data on excitation current value 1 A

| No | Load is connected to the generator (Watt) | Time stops (seconds) | Repair (%) |
|----|-----------------------------------------|----------------------|------------|
|    |                                         | Without braking      | Braking    |            |
| 1  | 0                                       | 6.6                  | 5.9        | 10.6       |
| 2  | 100                                     | 6.2                  | 4.9        | 21.0       |
| 3  | 200                                     | 5.8                  | 4.6        | 20.7       |
| 5  | 300                                     | 5.5                  | 3.9        | 29.1       |
| 6  | 400                                     | 5.3                  | 3.8        | 28.3       |
| 7  | 500                                     | 5.0                  | 3.4        | 32.0       |
| 8  | 600                                     | 4.8                  | 3.1        | 35.4       |

Figure 7. Graph at the value of excitation current 1 A

From table, a comparison chart can be made without and with dynamic braking on excited. The comparison graph is shown in figure 7.

Table 3. Data on excitation current value 1.5 A

| No | The Load is connected to the generator (Watt) | Time stops (seconds) | Repair (%) |
|----|----------------------------------------------|----------------------|------------|
|    |                                              | Without breaking     | Braking    |            |
| 1  | 0                                            | 6.6                  | 5.7        | 13.6       |
| 2  | 100                                          | 6.2                  | 4.6        | 25.8       |
| 3  | 200                                          | 5.8                  | 4.3        | 25.9       |
| 5  | 300                                          | 5.5                  | 3.9        | 29.1       |
| 6  | 400                                          | 5.3                  | 3.8        | 28.3       |
| 7  | 500                                          | 5.0                  | 3.1        | 38.0       |
| 8  | 600                                          | 4.8                  | 2.9        | 39.6       |
Figure 8. The graph at the value of excitation current 1.5 A

From table 3. A comparison chart can be made without and with dynamic braking on the 1.5 excitability. The comparison graph is shown in figure 8.

| No | The Load is connected to the generator (Watt) | Time stops (seconds) | Repair (%) |
|----|---------------------------------------------|----------------------|------------|
|    |                                             | Without breaking     | Braking    |
| 1  | 0                                           | 6.6                  | 5.6        | 15.2       |
| 2  | 100                                         | 6.2                  | 4.4        | 29.0       |
| 3  | 200                                         | 5.8                  | 3.9        | 32.8       |
| 5  | 300                                         | 5.5                  | 3.5        | 36.4       |
| 6  | 400                                         | 5.3                  | 3.2        | 39.6       |
| 7  | 500                                         | 5.1                  | 3.0        | 41.2       |
| 8  | 600                                         | 4.8                  | 2.4        | 50.0       |

Figure 9. The graph at the value of excitation current 2.2 A
From table 4. A comparison chart can be made without and with dynamic braking on the 1.5 excitability. The comparison graph is shown in figure 9.

Comparison of the percentage of braking improvements, the comparison graph is shown in figure 10. Dynamic braking is faster by using a higher excitation current. This is because the dynamic braking system makes the stationary magnetic field. This condition is carried out by injecting a DC current into the three-phase induction motor stator coil after the connection of the stator coil is released from the AC supply voltage source. The dynamic braking method has the advantage of being able to adjust braking speed for a three-phase induction motor. Likewise, with the greater load, the motor stop time is faster. Induction motor without generator load and braking have a stopping time of 10.51 seconds.

4. Conclusion
The conclusion of the testing and analysis that has been done are the induction motor starting system using PLC makes it easy to operate. Then the injection current given to the three-phase induction motor is 1 KW for dynamic braking of 2.2 A. Lastly, Time stops the motor for a minimum load of 100 Watt without braking at 6.2 seconds and with braking of 4.4 seconds, for maximum loads of 600 W, without braking at 4.8 seconds and with braking of 2.4 seconds.

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