International Journal of Recent Engineering Research and Development (IJRERD)
ISSN: 2455-8761
www.ijrerd.com || Volume 04 – Issue 05 || May 2019 || PP. 30-44

Implementation of Forwarding Resistance and Dynamic Braking Methods with DC Injection in 3 Phase Induction Motor For Application of Controlled Conveyors

Denis[1], Dwi Novaldi Eko Saputro[2], Tejo Sukmadi[3], Agung Warsito[4], Susatyo Handoko[5], Yosua Alvin Adi Soetrisno[6], Nugroho Agus Darmanto[7], and Karnoto[8]

[1]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[2]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[3]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[4]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[5]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[6]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[7]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*
[8]*Diponegoro University, Department of Electrical Engineering, Jl. Prof. H. Sudarto, Semarang, Indonesia*

Abstract: Identify colors carried out an industry uses the manual way. Identification is carried out on the basis of visual sight directly on fruit that will be classified. Automation of identifying the color of the apples can be done by color sensors whicharemountedonaconveyortobemoreeffective.Theconveyorisdrivenbythe inductionmotor3phase.Theadvantages of induction motor that is the construction of a strong, relatively cheap price with high reliability, and easy to operate. In this research, used computer-based motor control mini PLC Zelio Relay type SR2 B121FU Smart. At the time of the processstartingwiththeprimaryresistorofathree-phaseinductionmotor, it absorbs less power compared to the ongoing steady – state. This is because the rotors are still not turning on the state of starting so that no power is transmitted to the rotor. The longer the time of braking, but the value of the DC current can be enlarged so as to accelerate the increase in temperature without generating the braking on the stator.

Keywords: three phase induction motors, starting primary resistor, dynamic braking

1. Introduction

In identifying colors done in an industry there are still many who use manual methods. Identification is carried out based on visual vision directly on the fruit to be classified. The weakness of manual classification is strongly influenced by the subjectivity of operators to sort and cause the classification process to be inconsistent in certain conditions so that technology is needed to identify colors automatically. In this study, we will discuss the identification of the color of apples. Automation of identifying the color of apples can be done with a color sensor mounted on a conveyor [1] [4]. The conveyor is a mechanical system that has the function of moving goods from one place to another [2]. The conveyor is driven by a 3 phase induction motor because the characteristics of an induction motor have strong construction, relatively low prices with high reliability, and easy operation [3].

In this case, we will focus on the implementation of the method of front starting and dynamic braking with DC inject in a three-phase induction motor.

2. System Design

The process of controlling and monitoring conveyors can be done automatically by utilizing the mini PLC Zelio Smart Relay so that the automation process will run more flexible because the program can be replaced flexibly. The 3 phase AC voltage source will supply a contactor circuit, while the 1 phase AC voltage source will supply auxiliary relays from the mini PLC. Then this auxiliary relay will be connected to the Zelio

Smart Relay, where Zelio Smart Relay will function to control the 3 Phase contactor openings that are connected to AC 3 Phase voltage sources. This 3 phase induction motor braking system is carried out by the DC current injection method, where the DC current injection time is controlled using Zelio Smart Relay. The entire system designed is shown in Figure 1.

2.1 Hardware Design

The three-phase induction motor control method implemented to drive conveyors in controlled conveying systems is the front resistance starting and dynamic braking method with DC inject. Media control induction motor used is the smart relay Zelio SR2B121FU type with 220 VAC voltage source as a source of input voltage and output voltage source. In this case, the Arduino Uno relay is used as a communication medium between Arduino Uno which processes color sensor data with Zelio Smart Relay. The Arduino Uno relay output will be directed to one of the zelio smart relay SR2B121FU inputs and will be processed the same as the push button by zelio smart relay. The AC 220V voltage source flows through the OMRON auxiliary relay which works as a normally close (NC) switch which will disconnect the voltage when the emergency button is pressed.1 phase voltage source 220 V as a source of output voltage zelio smart relay is used as a source of contactor circuit blocks that function as normally open (NO) switches that will connect the voltage flow according to the working sequence of contactor circuit.

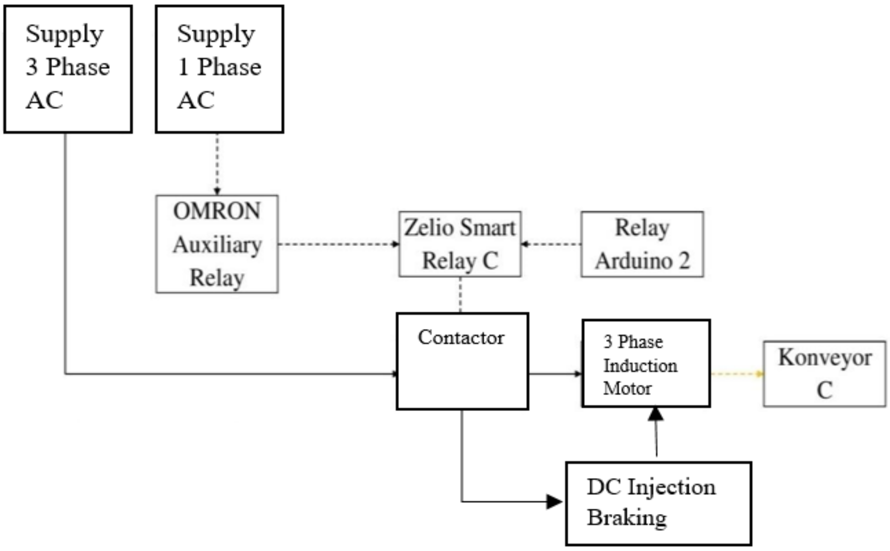


Figure 1: System Diagram Block

2.2 Power Circuit Design

In the method of starting front resistance and dynamic braking with DC inject, 4 magnetic contactors are needed to adjust the power flow to the three-phase induction motor. The three-phase power flow will enter through the 3 phase MCB (Z) and flow towards the first contactor (K9).The first contactor (K9) with normally open serves as the main contactor and shows that the B induction motor is operating. When a three phase induction motor is operated, a three-phase induction motor will enter the starting process, the first contactor operates and flows power to the second contactor (K10) and the third contactor (K11). The second contactor (K10) operates in conjunction with the first contactor and flows the voltage to the front resistor then to the three-phase induction motor. The value of the front resistance used can be changed as needed. In this research, testing variations will be carried out based on the value of the front resistance used so that it can be known the effect on the starting current produced.

After three seconds later, the second contactor stops operating and is replaced by the third contactor (K3) which functions to drain 380 V to a three-phase induction motor. The transition time between the use of front resistance and without front resistance can be changed according to the needs of the starting time. Then the three-phase induction motor will operate onward with a nominal voltage of 380 V until it is stopped.

When the three-phase induction motor operation is stopped, contactors K1, K2, and K3 stop operating and the three-phase source stops flowing to the three-phase induction motor. In a time interval of 0.4 seconds, the fourth contactor (K4) operates and provides a DC source to a three-phase induction motor to stop the rotation of the three-phase induction motor. A second later, the fourth contactor stopped operating and the three-phase induction motor was stopped completely. The power circuit scheme will be shown in Figure 2.

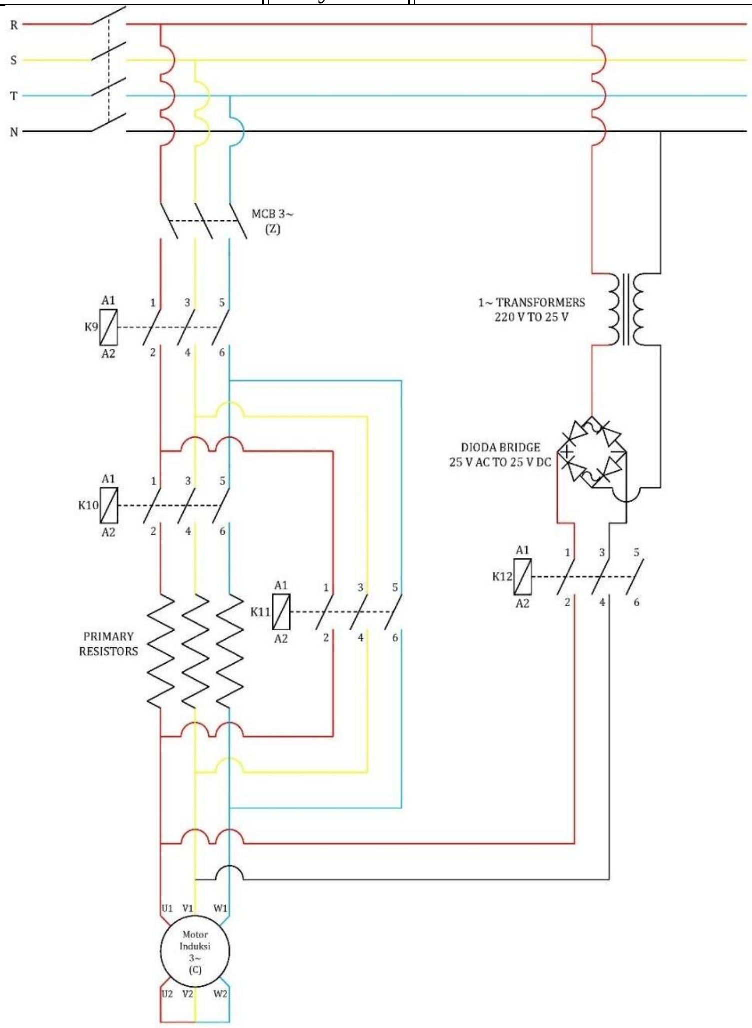


Figure 2: The front resistance starting circuit and dynamic braking with inject DC

2.3 Three-Phase Induction Motor Specification

Table 1 shows the specifications of the three-phase induction motor used.

Table 1: Three-Phase Induction Motor Specification

Parameters	Value
Manufacture	MotoriElettrici – Italy
Type	BA 7124
Power	0,37 kW
	0,5 HP
Phase	3
Voltage	Δ 220 V/Y 380 V
Current	Δ 2,02 A/Y 1,17 A
Frequency	50 Hz
Speed	1370 rpm
Pole	4
Weight	7 kg
Protection Index	IP55
Insulation Class	Class F

2.4 Software Design

In starting with front resistance, the three-phase induction motor will operate with front resistance when starting and operate without front resistance when the starting process is complete. For the operation of a three-phase induction motor with starting front resistance and dynamic braking with DC inject 4 magnetic contactors and 2 push buttons are needed to operate and stop the three-phase induction motor. Based on the ladder diagram in Figure 2, when the push button start (I1) is pressed, then the Q1 coil (main contactor) will energize together with the T1 coil (starting timer) and Q2 coil (contactor starting). When the Q1 coil is energized, the contactor Q1 becomes closed and the voltage flows when I1 is reopened so that the Q1 contactor can function as latching.

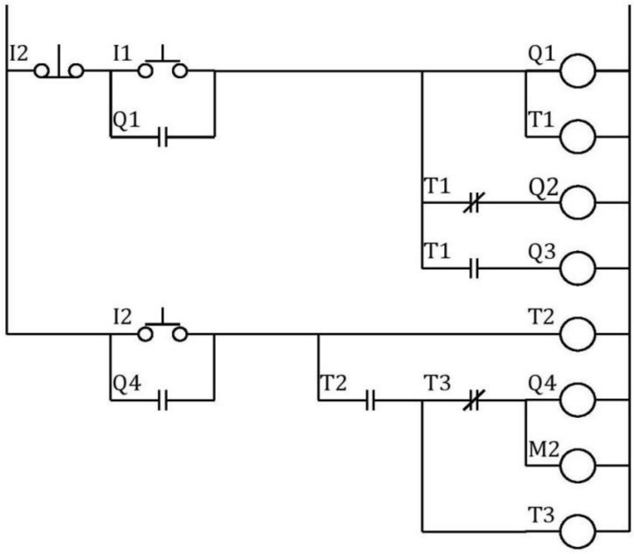


Figure 2: Basic Ladder Diagram for Front Starting Resistance and Dynamic Braking with DC Inject

In starting with front resistance, the three phase induction motor will operate with front resistance when starting and operate without front resistance when the starting process is complete. For the operation of a three-phase induction motor with a front starting resistance and dynamic braking with DC inject 4 magnetic contactors and 2 push buttons are needed to operate and stop the three-phase induction motor. Based on the ladder diagram in Figure 3, when the push button start (I1) is pressed, then the Q1 coil (main contactor) will energize together with the T1 coil (starting timer) and Q2 coil (contactor starting). When the Q1 coil is energized, the contactor Q1 becomes closed and the voltage flows when I1 is reopened so that the Q1 contactor can function as latching.

When the T1 coil is energized, then T1 will start calculating the operation time of contactor T1 based on the time given. When the time calculation is the same as the given time setting, the T1 contactor connected normally close will open and the T1 contactor connected normally open will be closed so that the contactor Q2 (contactor starting)de-energizes and the contactor Q3 (normal operation contactor) is energized. When the push button stop (I2) is pressed, the coil Q1, T1 and Q3 de-energize and the T2 (timer braking switching) coil is energized. In this ladder diagram, T2 functions as a time lag between the release of 3 phase AC voltage source and DC voltage source so that the 3 phase AC voltage source does not collide with a DC voltage source.

When the T2 coil is energized, then T2 will begin to calculate the operation time of the T2 contactor based on the time given. When the time calculation is the same as the time setting given, the T2 contactor connected normally open will be closed so that the Q4 contactor (braking contactor), and T3 (braking timer) are energized. When the T3 coil is energized, the T3 will start calculating the operation time of the T3 contactor based on the time given. When the time calculation is the same as the time setting given, then the T3 contactor connected to normally close will open so that the Q4 contactor de-energize.

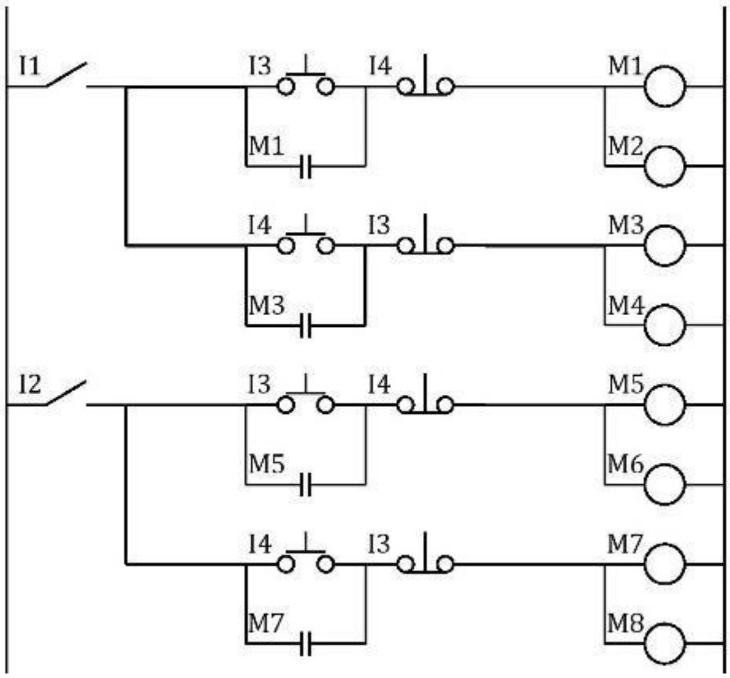


Figure 3: Ladder Diagram Circuit and the Mode Selection Process Used

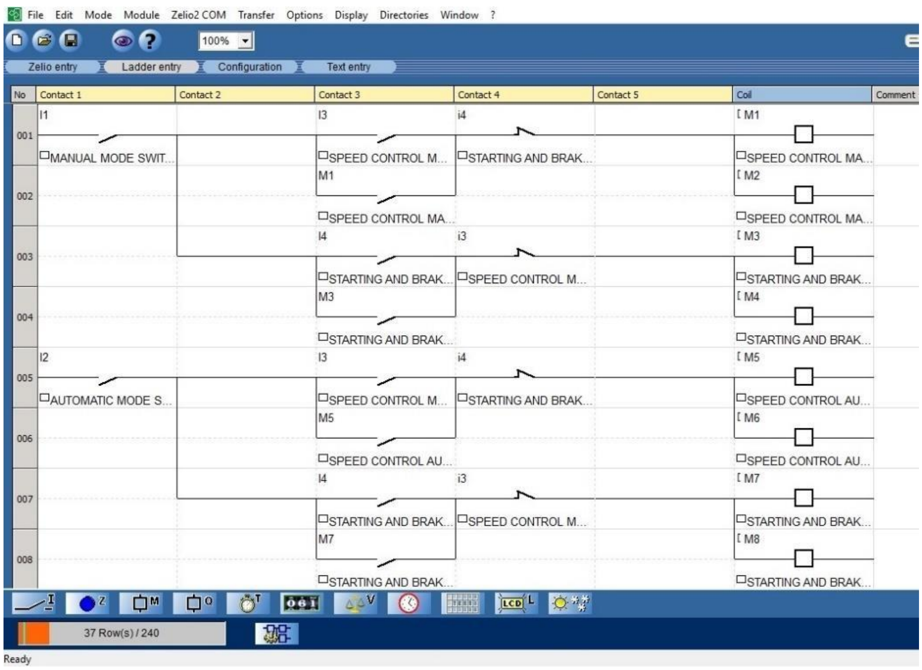


Figure 4: Realization of the Ladder Diagram Circuit and the Mode Selection Process Used

3. Result and Analysis

3.1 Parameters of Equivalent Three Phase Induction Motors

In this research, the three-phase induction motor is the main driver for controlled conveyor systems. The parameters of the three-phase induction motor that will be determined according to the equivalent circuit of the three-phase induction motor shown in Figure 5 below

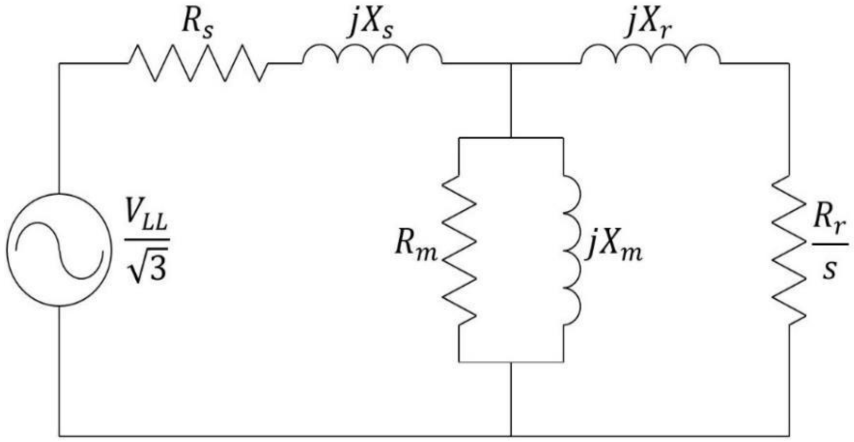


Figure 4: Equivalent Circuit per Phase of Three-Phase Induction Motor

All parameters of resistance and reactance are expressed in units of ohms to simplify the calculations and all the tests carried out in the operating voltage frequency of 50 Hz.To be able to know the equivalent circuit parameters of the three-phase induction motor used in controlled conveyor systems, it is necessary to do 4 types of tests related to the state of the 3 phase induction motor. The 4 types of testing are Testing with DC sources (DC supply test), Testing in the locked rotor test, Testing in no-load conditions (no load test) and Testing in full load conditions (full load test).

3.1.1 DC Supply Test

DC voltage testing is needed to determine the characteristics of a 3 phase induction motor. testing circuit with a DC source is shown in Figure 5

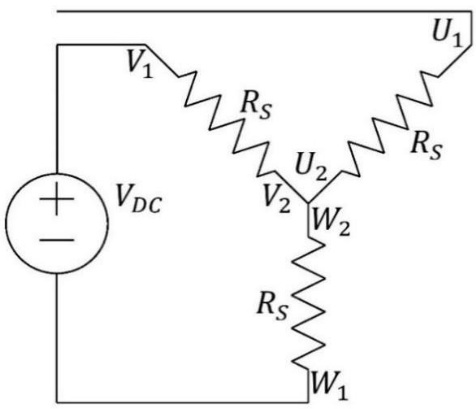


Figure 5: The Equivalent Circuit per Phase of a Three Induction Motor in a State with The DC Source

$$V_{DC} = 24{,}5 \quad V$$

$$I_{DC} = 0{,}5 \quad A$$

$$I_{DC} = \frac{V_{DC}}{2R_s}$$

$$R_s = \frac{24{,}5}{2 \times 0{,}5}$$

$$R_s = 24{,}5 \quad \Omega \qquad (1)$$

3.1.2 Locked Rotor Test

Locked Rotor testing is needed to determine the characteristics of a 3 phase induction motor. testing circuit with Locked Rotor is shown in Figure 6

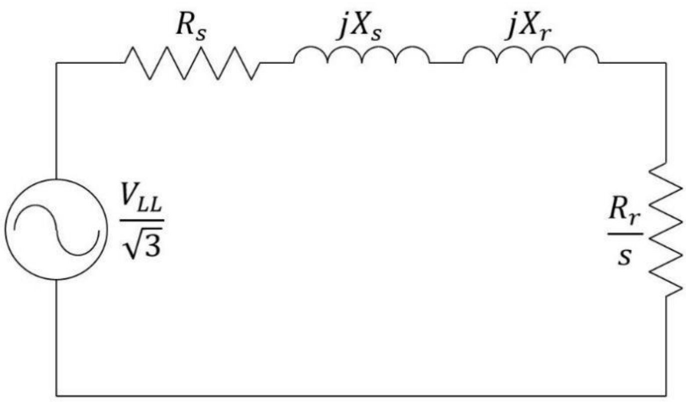


Figure 6: Substitute Equivalent Circuit per Phase Three Phase Induction Motor in a State of Short Circuit

$$V_{LR} = 399{,}5 \quad V$$
$$I_{LR} = 4{,}4 \quad A$$
$$\cos\varphi_{LR} = 0{,}93$$
$$S_{LR} = \frac{V_{LR} I_{LR}}{\sqrt{3}}$$
$$S_{LR} = \frac{399{,}5 \times 4{,}4}{\sqrt{3}}$$
$$S_{LR} = 1014{,}86 \quad VA \qquad (2)$$

$$Z_{LR} = \frac{S_{LR}}{I_{LR}^2} \angle \varphi_{LR}$$
$$Z_{LR} = \frac{1014{,}86}{(4{,}4)^2} \angle \cos^{-1} 0{,}93$$
$$Z_{LR} = 52{,}42 \angle 20{,}77^{0}\ \Omega$$
$$Z_{LR} = 49{,}01 + j18{,}59 \qquad (3)$$
$$Z_{LR} = R_{LR} + jX_{LR}$$
$$R_{LR} + jX_{LR} = 49{,}01 + j18{,}59 \qquad (4)$$

By separating real number components and imaginary number components, they are obtained:

$$R_{LR} = 49{,}01\ \Omega$$
$$X_{LR} = 18{,}59\ \Omega \qquad (5)$$

It can be seen that the total impedance for the 3 phase induction motor circuit in the short circuit conditions is as follows:

$$Z_{LR} = R_s + jX_s + jX_r + \frac{R_r}{s} \qquad (6)$$
$$Z_{LR} = R_s + jX_s + jX_r + R_r$$
$$R_{LR} + jX_{LR} = R_s + jX_s + jX_r + R_r$$
$$R_{LR} + jX_{LR} = (R_s + R_r) + j(X_s + X_r) \qquad (7)$$

The substitution of the results of the calculation of the stator resistance obtained from equation (1) and the results of the calculation of the short circuit resistance obtained from equation (5) to equation (8) is obtained:

$$R_{LR} = R_s + R_r$$
$$49{,}01 = 24{,}5 + R_r$$
$$R_r = 24{,}51\ \Omega \qquad (8)$$

3.1.3 No Load Test

No Load testing is needed to determine the characteristics of a 3 phase induction motor. testing circuit with No Load is shown in Figure 7.

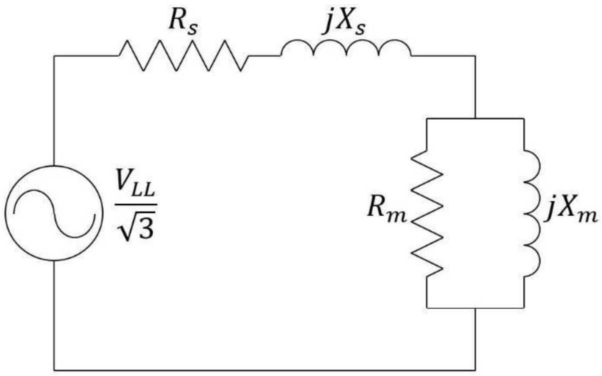


Figure 7: Substitute Equivalent Circuit per Phase Three Phase Induction Motor in a State of No Load

$$V_{NL} = 389{,}1\ V$$
$$I_{NL} = 0{,}82\ A$$
$$\cos\varphi_{NL} = 0{,}17$$
$$S_{NL} = \frac{V_{NL}I_{NL}}{\sqrt{3}}$$
$$S_{NL} = \frac{389{,}0 \times 0{,}82}{\sqrt{3}}$$
$$S_{NL} = 184{,}93\ VA \tag{9}$$
$$Z_{NL} = \frac{S_{NL}}{I_{NL}^2}\angle\varphi_{NL}$$
$$Z_{NL} = \frac{184{,}93}{(0{,}82)^2}\angle\cos^{-1} 0{,}17$$
$$Z_{NL} = 272{,}88\ \angle 80{,}21^{o}\ \Omega$$
$$Z_{NL} = 46{,}39 + j268{,}9 \tag{10}$$

By separating real number components and imaginary number components, they are obtained:

$$R_{NL} = 46{,}39\ \Omega$$
$$X_{NL} = 268{,}9\ \Omega \tag{11}$$

It can be seen that the total impedance for the 3 phase induction motor circuit in the no-load conditions is as follows:

$$Z_{NL} = R_s + jX_s + \frac{jR_mX_m}{R_m + jX_m}$$
$$Z_{NL} = R_s + jX_s + \frac{jR_mX_m}{R_m + jX_m} \times \frac{R_m - jX_m}{R_m - jX_m}$$
$$Z_{NL} = R_s + jX_s + \frac{R_mX_m^2 + jR_m^2X_m}{R_m^2 + X_m^2}$$
$$Z_{NL} = R_s + jX_s + \frac{R_mX_m^2}{R_m^2 + X_m^2} + j\frac{R_m^2X_m}{R_m^2 + X_m^2}$$
$$R_{NL} + jX_{NL} = \left(R_s + \frac{R_mX_m^2}{R_m^2 + X_m^2}\right) + j\left(X_s + \frac{R_m^2X_m}{R_m^2 + X_m^2}\right) \tag{12}$$

By separating real number components and imaginary number components, they are obtained:

$$R_{NL} = R_s + \frac{R_mX_m^2}{R_m^2 + X_m^2} \tag{13}$$
$$X_{NL} = X_s + \frac{R_m^2X_m}{R_m^2 + X_m^2} \tag{14}$$

The substitution of the results of the calculation of the stator resistance obtained from equation (1) and the results of the no-load resistance calculation obtained from equation (11) to equation (15) are obtained:

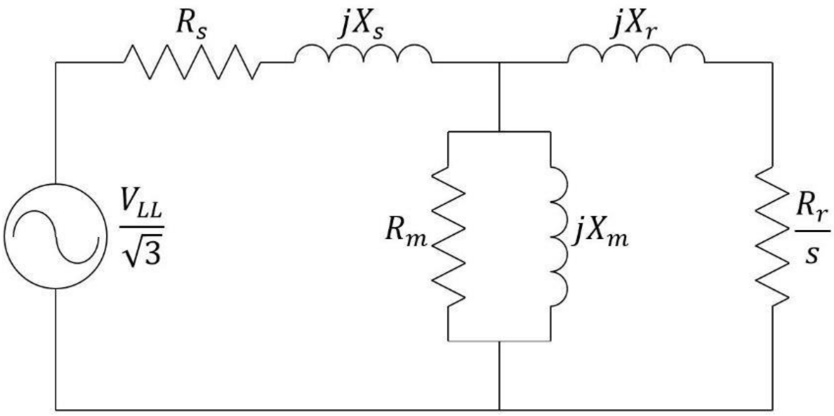
$$R_{NL} = R_s + R'_m$$

$$46{,}39 = 24{,}5 + R'_m$$

$$R'_m = 21{,}89\ \Omega \qquad (15)$$

3.1.4 Full Load Test

Full Load testing is needed to determine the characteristics of a 3 phase induction motor. Testing circuit with Full Load is shown in Figure 8.



.

Figure 8: Substitute Equivalent Circuit per Phase Three Phase Induction Motor in a State of Full Load

$$V_{FL} = 380\ V$$

$$I_{FL} = 1{,}17\ A$$

$$\cos\varphi_{FL} = 0{,}74$$

$$n_s = 1500\ rpm$$

$$n_r = 1370\ rpm$$

$$S_{FL} = \frac{V_{FL} I_{FL}}{\sqrt{3}}$$

$$S_{FL} = \frac{380 \times 1{,}17}{\sqrt{3}}$$

$$S_L = 256{,}69\ VA \qquad (16)$$

$$Z_{FL} = \frac{S_{FL}}{I_{FL}^2} \angle \varphi_{FL}$$

$$Z_{FL} = \frac{256{,}69}{(1{,}17)^2} \angle \cos^{-1} 0{,}74$$

$$Z_{FL} = 187{,}51 \angle 42{,}27^0\ \Omega$$

$$Z_{FL} = 138{,}76 + j126{,}12 \qquad (17)$$

$$Z_{FL} = R_{FL} + jX_{FL}$$

$$R_{FL} + jX_{FL} = 138{,}76 + j126{,}12 \qquad (18)$$

By separating real number components and imaginary number components, they are obtained:

$$R_{FL} = 138{,}76\ \Omega$$

$$X_{FL} = 126{,}12\ \Omega \qquad (19)$$

It can be seen that the total impedance for the 3 phase induction motor circuit in the Full load conditions is as follows:

$$Z_{FL} = R_s + jX_s + \frac{(R'_m + jX'_m) \times \left(\frac{R_r}{s} + jX_r\right)}{(R'_m + jX'_m) + \left(\frac{R_r}{s} + jX_r\right)}$$

$$Z_{FL} = R_s + jX_s + \frac{(R'_m + jX'_m)\left(\frac{R_r}{s} + jX_r\right)}{\left(R'_m + \frac{R_r}{s}\right) + j(X'_m + X_r)}$$

$$Z_{FL} = R_s + jX_s + \frac{\left\{(R'_m + jX'_m)\left(\frac{R_r}{s} + jX_r\right)\right\}\left\{\left(R'_m + \frac{R_r}{s}\right) - j(X'_m + X_r)\right\}}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2}$$

$$Z_{FL} = R_s + jX_s + \frac{\left(R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}\right) + j\left(R'^2_m X_r + X'_m \frac{R_r^2}{s^2} + X'_m X_r^2 + X'^2_m X_r\right)}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2}$$

$$R_{FL} + jX_{FL} = R_s + jX_s + \frac{\left(R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}\right) + j\left(R'^2_m X_r + X'_m \frac{R_r^2}{s^2} + X'_m X_r^2 + X'^2_m X_r\right)}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2} \tag{20}$$

By separating real number components and imaginary number components, they are obtained:

$$R_{FL} = R_s + \frac{R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2} \tag{21}$$

$$X_{FL} = X_s + \frac{R'^2_m X_r + X'_m \frac{R_r^2}{s^2} + X'_m X_r^2 + X'^2_m X_r}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2} \tag{22}$$

From equation (21) is obtained

$$R_{FL} = R_s + \frac{R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2}$$

$$(R_{FL} - R_s) = \frac{R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2}$$

$$\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2 = \frac{R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}}{(R_{FL} - R_s)} \tag{23}$$

The substitution of equation (23) to equation (22) is obtained:

$$X_{FL} = X_s + \frac{R'^2_m X_r + X'_m \frac{R_r^2}{s^2} + X'_m X_r^2 + X'^2_m X_r}{\left(R'_m + \frac{R_r}{s}\right)^2 + (X'_m + X_r)^2}$$

$$(X_{FL} - X_s) = \frac{R'^2_m X_r + X'_m \frac{R_r^2}{s^2} + X'_m X_r^2 + X'^2_m X_r}{\frac{R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}}{(R_{FL} - R_s)}}$$

$$\frac{(X_{FL} - X_s)}{(R_{FL} - R_s)} = \frac{R'^2_m X_r + X'_m \frac{R_r^2}{s^2} + X'_m X_r^2 + X'^2_m X_r}{R'^2_m \frac{R_r}{s} + R'_m \frac{R_r^2}{s^2} + R'_m X_r^2 + X'^2_m \frac{R_r}{s}} \tag{24}$$

So in the case of the three-phase induction motor used in this research, the magnetic resistance and magnetic reactance used were taken from magnetic impedance which has been simplified because it has a small magnetic resistance.

$R'_m = 21{,}89\,\Omega$

$X'_m = 259{,}61\ \Omega$

From testing on DC supply test, locked rotor test conditions, testing on no-load conditions and testing on full load conditions (full load test) the equivalent circuit is obtained per phase of three induction motors phase with the parameters known in Figure 9 below:

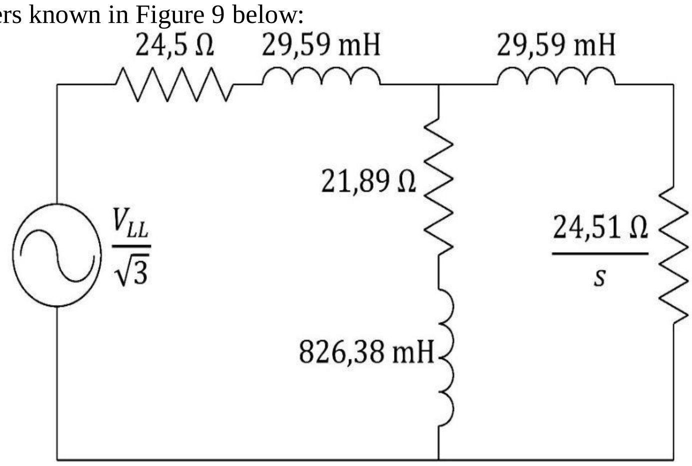


Figure 9: Equivalent Circuit Parameters per Phase Three Phase Induction Motor

Table 2: Equivelent Circuit Parameters per Phase Three Phase Induction Motor

Parameter	**Symbol**	**Value**
Stator Resistance	Rs	24,5 Ω
Stator Inductance	Ls	29,59 mH
Magnetic Resistance	R m	21,89 Ω
Magnetic Induktance	L m	826,38 mH
Rotor Resistance	Rl	24,51 Ω
Rotor Induktance	Lr	29,59 mH

3.2 Testing of Three Phase C Induction Motor in a Loaded State with a method of Starting Front Resistance 8.64 Ohm

Table 3 shows the results of the measurement of the electrical parameters of the three-phase C induction motor with the method of the front resistance starting 8.64 ohms.

Table 3: Equivalent Circuit Parameters per Phase Three Phase Induction Motor

Time	**VLL (V)**	**Current RMS (A)**	**Maximum Current (A)**	**P(W)**	**S(VA)**	**Q(VAR)**	**Power Factor**
0	0	0	0,1	0	0	0	0
1	381,8	3,3	5,69	960	1120	570	0,691
2	391,7	0,92	1,3	340	630	530	0,541
3	391,7	0,92	1,3	340	630	530	0,54

4	399,3	0,93	1,39	340	650	550	0,528
5	399,3	0,93	1,31	340	650	550	0,527
6	399,3	0,93	1,31	340	650	550	0,527
7	399,3	0,93	1,31	340	650	550	0,528

From the data in Table 3, it can be seen that the line to line three-phase voltage that enters the three-phase C induction motor is 391.7 V derived from the addition of 8.64 front resistance. This is in accordance with the working principle of the front starting resistance where the voltage entering the three-phase induction motor when starting will be shared with the front detainee. In addition, because of the front resistance, the resistive load on the three-phase induction motor will increase. In the 4th second, the line to line three-phase voltage that enters the three-phase C induction motor changes to 399.3 V due to the release of the front resistance from the three-phase C induction motor.The starting current measured is 3.3 A then changes to 0.92 A, this change is caused because the motor has entered a steady-state condition but the front resistance has not been removed from the three-phase induction motor.

In transient conditions or the transition from the front resistance to without the front resistance, the value of the current flowing to the three-phase induction motor also changes. The release of the front resistance results in a three-phase voltage flowing to the three-phase induction motor that becomes higher, from 391.7 V to 399.3 V. In addition, it also causes the current to flow to the three-phase induction motor to be higher. The RMS current measured in transient conditions is 0.93 A with a peak value of 1.39 A. The peak value is not higher than the peak current when starting. The three-phase induction motor enters the steady-state condition at the 5th second. When starting, the three-phase induction motor absorbs more power than the steady-state state. This is due to high current surges during starting. In the starting process when the front resistance has not been removed, the apparent power and reactive power of the induction motor are greater than the steady-state state because of the addition of resistive load on the three-phase induction motor while the active power absorbed by the three-phase induction motor does not change. Addition of the resistive load also causes an increase in the power factor value compared to the steady-state state.

3.3 Three Phase Induction Motor Starting in Loaded Conditions with DC Inject Braking Methods

In addition to using the starting method, the three-phase induction motor also uses a braking circuit on a three-phase induction motor so that the motor can stop immediately when a three-phase AC voltage source is disconnected from a three-phase induction motor.The braking circuit at the three-phase induction motor will be activated when the three-phase AC voltage flowed to the three-phase induction motor has been disconnected, so that there is no collision between AC voltage and DC voltage and no damage to the equipment used. The terminal used in the three-phase induction motor in the braking process is the star connection. Table 4 shows the results of measurements of voltage and current of three-phase induction motors during steady-state conditions and DC inject conditions.

Table 4: Testing of Three-Phase Induction Motor in Dynamic Braking Conditions with DC Inject

Time (S)	VLL	Current RMS (A)	Maximum Current (A)	DC Voltage(V)	DC Current(A)
5	399,3	0,93	1,31	0	0
6	399,3	0,93	1,31	0	0
7	399,3	0,93	1,31	0	0
8	0	0	0,1	24,5	0,5
9	0	0	0,1	0	0

In the DC inject process, the DC current flowing to the three-phase induction motor is 0.5 A, while the current specification allowed to flow to the three-phase induction motor on the star connection is 1.17 A. This indicates that the DC current flowing into the three-phase induction motor in the braking process is much lower than the three-phase induction motor current specification on the star connection. Table 5 shows a comparison between the timing of the three-phase induction motor stop when without a braking circuit and with a braking circuit.

Table 5: Comparison of The Time Rotation of an Induction Motor without Braking Circuit and Braking Circuit

Conditions	**Round-Off Time 3 Phase Induction Motor**
Without Braking Circuit	1,1 Second
Braking Circuit	0,5 Second

4. Conclusion

The three-phase induction motor control method for moving conveyors in a controlled conveyor system used includes the front starting resistance and dynamic braking with DC inject. The induction motor control media used is zelio smart relay type SR2B121FU with AC 220 V voltage source as an input voltage source and output voltage source. The current flowing to the three-phase induction motor is directly proportional to the voltage entering the three-phase induction motor. The value of the starting current with the primary resistor does not change during the starting process because the three-phase induction motor has not rotated and has not moved the conveyor. This is because the operating voltage of the line to line three-phase induction motor when starting very far from the specifications is 380 V so that the rotating field produced by the stator produces an electric motion that is not large enough to induce the rotor and causes the rotor to not rotate. During the starting process with front resistors, the three-phase induction motor absorbs less power than when the steady-state state. This is because the rotor is still not rotating in the starting state, so there is no power supplied to the rotor.
Starting with front resistance can reduce the starting current in a three-phase induction motor, the greater the value of the front resistance used, the smaller the starting phase of the three-phase induction motor. The magnitude of the current at the start is inversely proportional to the value of the front resistors used. In breaking the DC current injection the smaller the DC current that is used the longer the braking time, but the value of DC current can be enlarged so as to accelerate braking without producing a temperature rise at the stator.

References

[1]. A. Saputra, R. R. M., dan C. Setianingsih, "Perancangandan Implementasi Alat Untuk Penyortiran Buah Tomat (Lycopersicum Esculentum) Menggunakan Mikrokomputer Design," *e-Proceeding Eng.*, vol. 4, no. 3, hal. 4074–4082, 2017.

[2]. A. N. Cholis, "Peningkatan Efisiensipada Proses Cutting Sizer dengan Perancangan Mesin Auto Return di PT. Yamaha Indonesia," Laporan Tugas Akhir, Departemen Teknik Mesin, Universitas Islam Indonesia,2016.

[3]. D. Firmansyah, "Pengaturan Pengereman Dinamik Motor Induksi Tiga Fasa Berbasis Smartphone Android dan Simulasi Matlab," Laporan Tugas Akhir, Departemen Teknik Elektro, Universitas Lampung, 2016.

[4]. F. N. Winarto, "Perancangan Moduldan Perbandingan Metode Starting dan Pengaturan Kecepatan Motor Induksi 3 Fasa," Laporan Tugas Akhir, Departemen Teknik Elektro, Universitas Diponegoro, 2015.

[5]. T. Wildi, *Electrical Machines, Drives, and Power Systems*, Fifth. Upper Saddle River, New Jersey 07458: Pearson Education, Inc, 2002.

[6]. S. J. Chapman, *Electric Machinery Fundamentals*, Fifth. Avenue of Americas, New York: McGraw-Hill Companies, Inc, 2012.

[7]. A. K. T. B.L. Theraja, *A Textbook of Electrical Technology -Volume II - AC and DC Machines*. New Delhi, India: Nirja Construction and Development, Co., 1994.

[8]. P. L. Rongmei, S. S. L., S. Chatterji, dan V. K. Sharma, "A Novel Fast Braking System for Induction Motor," *Int. J. Eng. Innov. Technol.*, vol. 1, no. 6, hal. 65–69, 2012.

[9]. M. H. Rashid, *Power Electronics Handbook:Devices, Circuits, and Applications Handbook*. Burlington, Massachusetts: Elsevier, Inc.,2011.

[10]. Schneider Electric, *Zelio Logic Smart Relay User Manual*. Schneider Electric, 2017.

Author Profile

Denis was a lecturer from Diponegoro University. Denis was born on France, 17th April 1991. Denis got his first bachelor degree from Diponegoro University majoring Electrical Power Engineering. Denis got his master degree from GadjahMada University majoring Renewable Energy System. Denis has a brief experience to covering all energy flow through control system.

Dwi Novaldi Eko Saputrowas a student from bachelor degree in Diponegoro University which has been graduated and receive her bachelor experiencing the special Electrical Machine Drives and Power Systems

TejoSukmadiwas a senior lecturer and associate professor from Diponegoro University. Tejo was born on Solo, 17th November 1961. Tejo got his first bachelor degree from GadjahMada University majoring electrical power. Tejoalso got his master degree fromGadjahMada University majoring electrical machinery. Tejo has a brief view in electrical power and has a strong experience in electrical machinery and transformator.

AgungWarsitowas a senior lecturer and associate professor from Diponegoro University. Agung was born on Solo, 17th June 1958. Agung got his first bachelor degree from GadjahMada University majoring electrical power. Agunggot his master degree fromInstitut National Polytechnique de Toulousealso majoring power electronic. Agung has a brief view in electrical power and has a strong experience in power electronic and power quality factor analytic.

SusatyoHandokowas a senior lecturer from Diponegoro University. Susatyo was born on Semarang, 26th May 1973. Susatyogot his first bachelor degree from Institute Technology of Bandung majoring Electrical Power. Susatyogot his master degree fromInstitute Technology of Bandungmajoring Electrical Power., and Susatyo got doctor degree title from GadjahMada University with study field Power System Network. Susatyo has a brief view in electrical power and has a strong experience in Power System Programming

Yosua Alvin Adi Soetrisno was a lecturer from Diponegoro University. Yosua was born on Semarang, 13th October 1990. Yosua got his first bachelor degree from Diponegoro University majoring computer networking. Yosua got his master degree from Gadjah Mada University majoring software engineering. Yosua has a brief experience in programming of computer services especially in IoT web based environment.

Nugroho Agus Darmantowas a senior lecturer Diponegoro University. Nugroho was born on Semarang, 29th April 1958. Sudjadi got his first bachelor degree from Institute Technology of Bandung majoring Electrical Engineering. AgusDarmantogot his master degree in Institute Technology of Bandung majoring Electrical Engineering. Sudjadi has done several research based on High Voltage Measurement and Testing.

Karnotowas a senior lecturer from Diponegoro University. Karnoto was born on Semarang, 9th July 1969. Karnotoi got his first bachelor degree from Diponegoro University majoring electrical engineering. Karnotogot his master degree in GadjahMada University majoring Electrical Engineering. Karnoto has done several research based on signal processing on Electricity Distribution.