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Optimization 5 × 195 KW chiller compressor motor with ETAP

Novi Azman[1], Fathan Soleman[1], Idris Kusuma[1]
[1]Electrical Engineering, Faculty Engineering and Science, Universitas Nasional, Indonesia, novi.azman@civitas.unas.ac.id
[1]Electrical Engineering, Faculty Engineering and Science, Universitas Nasional, Indonesia, fathansoleman@outlook.com
[1]Electrical Engineering, Faculty Engineering and Science, Universitas Nasional, Indonesia, fathansoleman@outlook.com

ABSTRACT

One of the office buildings in Jakarta, Indonesia uses 5 units of Air Conditioning with a 195 KW Motor Compressor Chiller Design using a Central cooling system driven by a 3-phase induction Direct-On-Line (DOL) motor. The problem is that the motor compressor which is selected to start with Direct-On-Line (DOL) can only operate 3 chiller units. If the entire chiller is operating there is a large voltage drop on the BUS motor in the system. Then it takes a special TAP calculation for the motor Power Transformer and makes the motor start a Delta Start. These changes were tested in a simulation using ETAP software to get the initial solution with the Direct-On-Line (DOL) starting method. Changes to the TAP Transformer specifically to improve the network system. Considerations in the experiment of a 3-phase induction motor about its starting current which has a value of 5–7 times greater than its nominal current and a starting torque of 2 times its nominal value. A nurturing method that works to reduce starting voltages and currents. The simulation results show that the motor power is 195 KW which has the greater voltage at the start of the DOL and for the recommended starting method is the wye-delta method, using the motor does not work all the time, and also the investment cost of star-delta starting is not that large using other methods.

Key words: 3-phase induction motor, Direct-On-Line, Wye-Delta.

1. INTRODUCTION

Office Tower 1, Jakarta, Indonesia has 5 195 KW chiller units for the Air Conditioning system in the building. The system uses a central cooling system driven by a 3-phase induction Direct-On-Line (DOL) motor. From the entire chiller unit, only 3 units can be operated alternately, because if the entire unit is run, there will be a large voltage drop on the BUS motor in the system.

Induction motors are the most widely used alternating current (or alternating current) motors. The name comes from the fact that the motor rotor current is not obtained from a specific source, but is the current that is induced as a result of the relative difference between the rotor rotation and the rotating field (rotating magnetic field) generated by the stator current. The stator winding is connected to one voltage source. phase will produce a magnetic field that rotates at synchronous speed. The rotating field on the stator will cut the conductors on the rotor, so that a current is induced, and according to Lenz's law, the rotor will also rotate according to the stator rotating field. The difference in relative rotation between the stator and rotor is called slip. The increase in load will enlarge the motor coupling, which therefore will also increase the induced current in the rotor, so that the slip between the stator rotating field and the rotor rotation will increase. So, when the motor load increases, the rotor rotation tends to decrease [1]. If the rotor accelerates, the rotor frequency decreases due to the reduced slip value, this means that the rotor reactance value decreases, causing the torque value to increase to its maximum value. If the motor accelerates further, the torque will decrease according to the value needed to rotate the load at constant speed [2]. The characteristic of an induction motor starting current is that when the starting condition of an electric motor requires a large current, this lasts for some time. Then the required current will decrease under a locked rotor condition. The required current value will remain under normal load conditions. From the starting current characteristics, it is used to determine the characteristics and protection relay settings needed to protect the equipment [3]. An induction motor when turned on directly will draw 4 to 8 times the full load current and only produces a torque of 1.5 to 2.5 times the full load torque. This large initial current can cause a voltage drop on the line which will interfere with other equipment connected to the same line. For high-power motors, of course the starting current will also be greater, so that for motors with large power it is not recommended to start the motor directly. To avoid this, an induction motor is often started with a voltage level lower than the nominal voltage. Starting a 3-phase induction motor can be done in various ways, including direct DOL (Direct-On-Line) starting and star-delta start [4-6].

Direct on line method is often used for AC motors that have a small power capacity. When a motor with a very large capacity is started direct-on-line, the system voltage will be disturbed (a voltage dip occurs in the supply network) due to the large starting current. This voltage noise can cause damage to other electronic equipment connected to the source. The definition of direct start is the motor that will be run directly on the switch to the grid voltage source in accordance with the nominal voltage of the motor. This means that there is no need to adjust or reduce the voltage at the time of starting [7].

The working principle of direct DOL (Direct-On-Line) starting in general, namely, if the start button is pressed, the current will flow from the red phase through the control circuit and the contactor coil to the blue phase. This current will activate the contactor coil so that the contactor will close to connect the 3-phase supply to the motor. If the start button is released the control circuit will be retained by means of a contact holder. If then the stop button is pressed or if the load coils are working more, the control circuit will be disconnected, and the contactor will open to disconnect the 3-phase electricity supply to the motor. Reconnecting the supply to the motor can only be done by pressing the start button again, so this circuit can also provide some protection against loss of supply voltage [8].

The star-delta start method takes advantage of the drop in voltage supplied to the motor when the stator is connected in a star circuit. In brief, the working principle of this method is that when starting, first the main K_1 contactor and the K_Y star contactor are activated. The switch from star to delta circuit occurs at n_D speed, that is, when the motor speed has reached about 80% of the nominal speed. You do this by activating the K_D contactor and at the same time making the K_Y contactor inactive. However, while the motor has been separated from the star circuit but is still not connected to the delta circuit, the rotor is still rotating, as well as the rotor current still flowing in the rotor coil. There is a residual magnetic flux in the rotor that cuts the stator coil. So that there is an induced voltage to the stator whose frequency depends on the current rotor speed. The rotor speed currently depends on the load. When the motor is connected to the delta circuit, there is a very large inrush current, which can reach up to 2000% in a very short duration of around 200 ms. This is because a very large phase difference has occurred when the stator is reconnected to the power grid in a delta circuit with the flux from the rotor. This high current results in shock torque and can have a negative impact on the transmission and circuit breaker components of the drive system [9, 10].

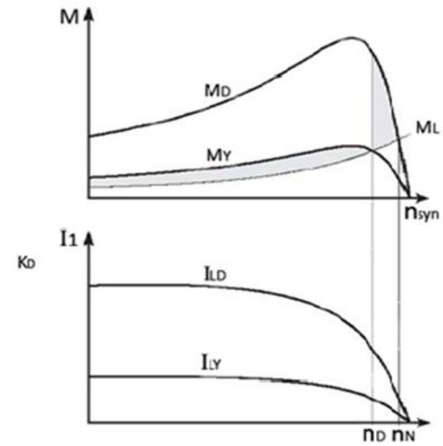

Figure 1: Characteristics of the Starting Wye-Delta Current

In Figure 1, the part of the Torque to Speed curve that is shaded is the acceleration torque needed for the load acceleration. Note that the starting torque in the star circuit must always be greater than the starting torque of the load so that the motor can lift the load and accelerate towards nominal speed [11,12].

This star delta or star-delta or wye-delta relationship is indeed quite popular as a choice of applications that require a small current consumption when the motor is started [13-16].

2. SIMULATING SYSTEM

The research that was carried out was started by studying the situation in the building which was then carried out by simulations using the ETAP Power Station software to create a One-Line Diagram simulation. Then enter the data from the motor name plate in the ETAP program. Next select the motor starting equipment that will be used to analyze the system. Set the start time and simulation total. The entire system can be seen in Figure 2.

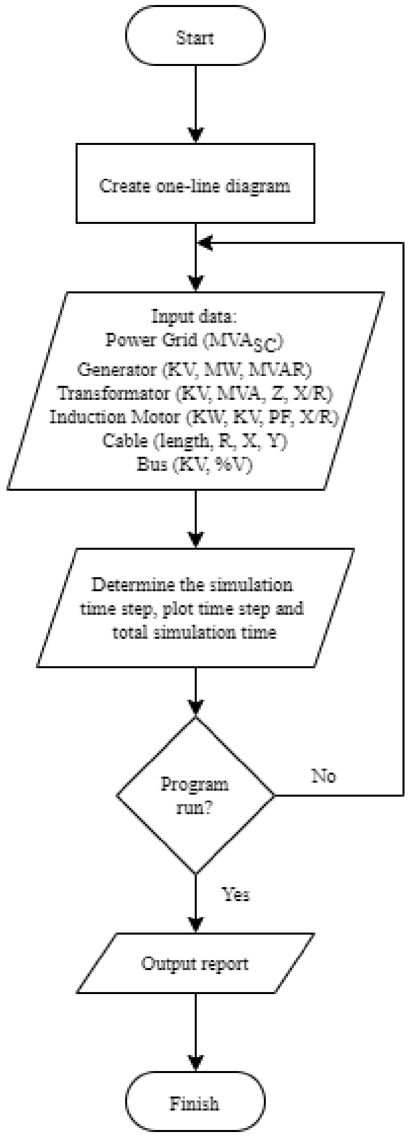

Figure 2: Research flow in simulating the system

In general, Figure 3 is a wiring diagram which is a wiring diagram for motor starting analysis so that the motor starting analysis method can be explained in the electrical system of the Office Tower Building using the ETAP Power Station program as follows:

1. Creating a one-line diagram of the system to be discussed in this paper is the electrical system for the Office Tower Building
2. PLN (national electric company) data, transformers, cables, induction motors, and buses can be entered into the program after the one-line diagram is created.
3. Determine the simulation time step, plot time step and total simulation time.
4. Run the ETAP Power Station program by selecting the motor starting analysis icon on the toolbar then selecting the run dynamic motor starting icon. The program does not run (error) if there is an error in the one line diagram or missing data, so the data must be checked and re-entered.
5. The motor starting analysis report and plot can be obtained once the program is run. To get the calculation results in the toolbar on the right of the program.
6. Optimization of the TAP power transformer (increasing voltage) to reduce the voltage drop during motor starting in order to optimize the power network.

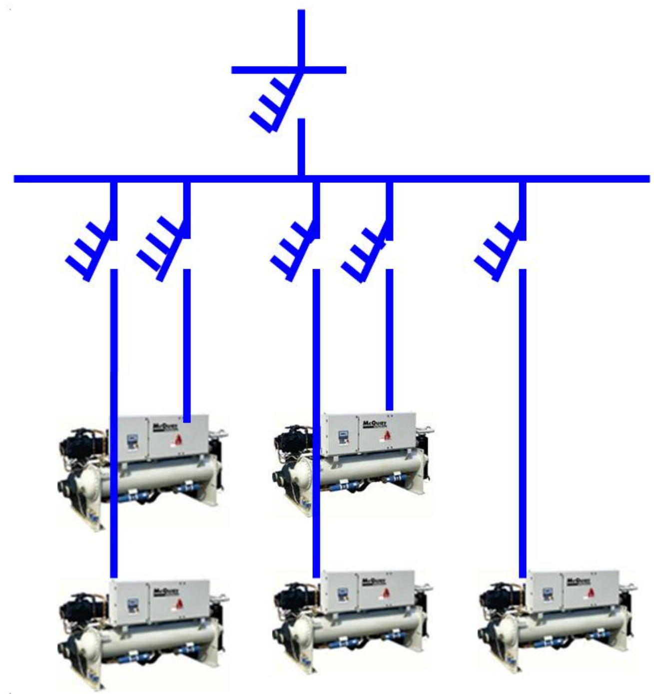

Figure 3: Wiring Motor Chiller 195 KW × 5 Units

The data collected in this study came from two sources. Primary data is data that is obtained directly in the field in the form of information from related parties. In this case the authors collect data concerning the Motor - Motor Compressor screw in the office tower building. Secondary data is data obtained from literature studies in the form of manual books, research results in the form of reports and so on to help provide complete information on the Motor Starting Analysis. The specifications of the induction motor used in the system are 195 kW = 261 HP, Motor Design D, PF = 0.9.

Figure 4 is the result of a system design with ETAP software from data obtained from fields ranging from resources, namely PLN to the building.

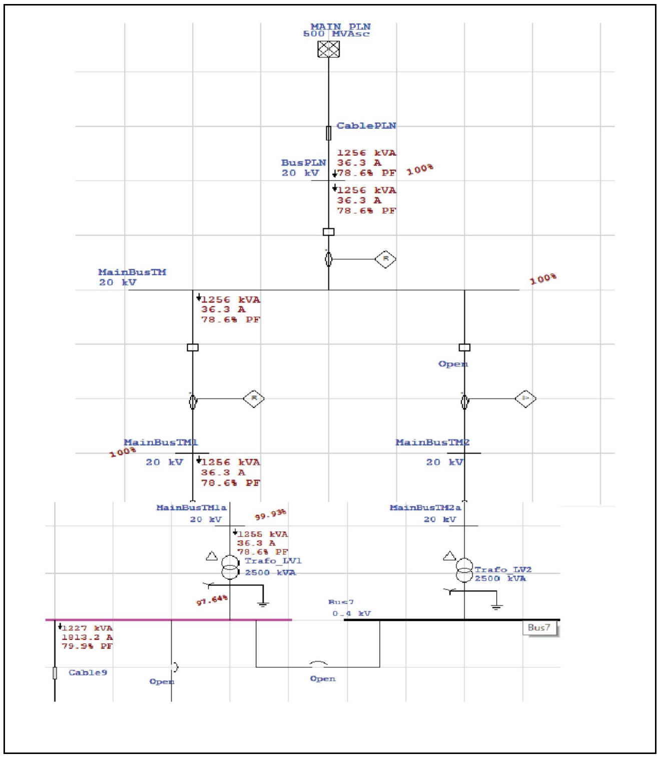

Figure 4: Block diagram of the PLN distribution network to the building

Furthermore, in Figure 5 is the simulation result of the existing system in the building studied in this study with the direct-on-line (DOL) system.

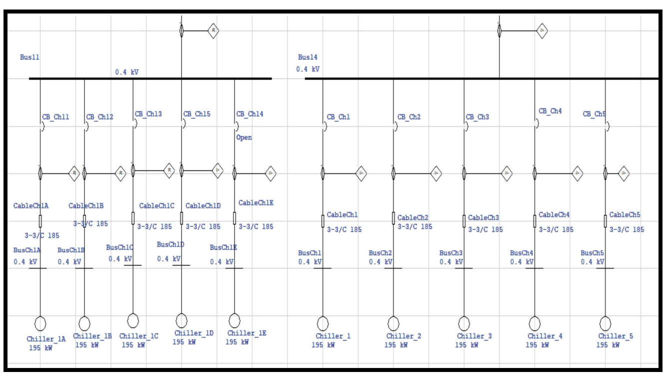

Figure 5: DOL System Block Diagram

3. RESULT AND ANALYSIS

Based on the results of the offset motor starting analysis described in the previous sections, that to produce sufficient starting torque, an induction motor requires a starting current of 5 to 7 times the nominal current. The following is the calculation of the starting current on the chiller compressor motor in the research conducted. Also, in Figure 6 is the standard code letter for the NEMA induction motor.

Nominal Code Letter	Locked Rotor (kVA/HP)	Nominal Code Letter	Locked Rotor (kVA/HP)
A	0-3.15	L	9.00-10.00
B	3.15-3.55	M	10.00-11.20
C	3.55-4.00	N	11.20-12.50
D	4.00-4.50	P	12.50-14.00
E	4.50-5.00	R	14.00-16.00
F	5.00-5.60	S	16.00-18.00
G	5.60-6.30	T	18.00-20.00
H	6.30-7.10	U	20.00-22.40
J	7.10-8.00	V	Over 22.40
K	8.00-9.00		

Figure 6: NEMA Standard Code Letter Induction Motor

The motor starting current can be obtained using the equation

$$S_{start} = S_{rate}\ x\ Letter\ Code\ Factor$$

S_{start} = 261 HP × 4.5 = 1,174 KVA

$$I_{Start} = \frac{S_{Start}}{\sqrt{3}V_{nominal}}$$

$I_{start} = S_{start}$ / (1.73 × 0.4) = 1,174 / (1.73 × 0.4) = 1,174 / 0.692 = 1,697.25 A

While the nominal power and nominal current of the motor are:

$$S_{nominal} = \frac{Motor\ Power}{PF\ x\ Eff}$$

$S_{nominal}$ = 195 KW / (0.9 × 0.9) = 240.74 KVA

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

$I_{nominal}$ = 240.74 / (1.73 × 0.4) = 347.89 A

Then the large ratio of the motor starting current to the nominal motor current is:
Ratio = 1,697.25 A / 347.89 = 4.8×

Then we calculate the results of the direct-on-line motor starting analysis prior to the TAP. One line diagram of the system can be seen in Figure 7. Based on the results of the ETAP analysis, it is found that the current at the DOL starting motor has a maximum current of 1,721 A. Furthermore, the calculation of the starting current on the chiller compressor motor.

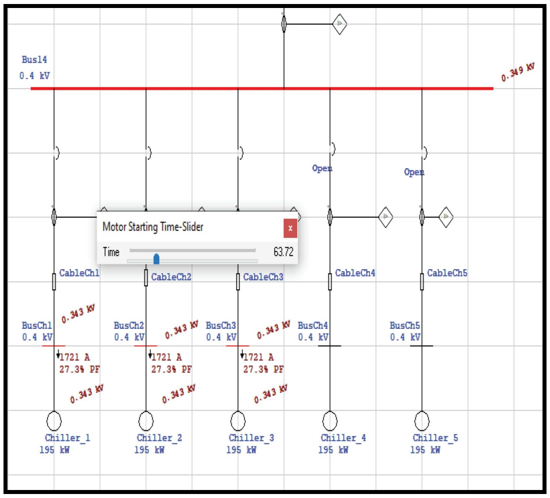

Figure 7: DOL simulation results before TAP

S_{start} = 261 HP × 4.5 = 1,174.5 KVA
I_{start} = S_{start} / (1.73 × 0.4) = 1,174 / (1.73 × 0.4) = 1,174.5 / 0.692 = 1,697 A

While the nominal power and nominal current of the motor are:

$S_{nominal}$ = 195 KW / (0.9 × 0.9) = 240.7 KVA

$I_{nominal}$ = 240.7 / (1.73 × 0.4) = 347.83 A

Then the large ratio of the motor starting current to the nominal motor current is:
Ratio = 1,697 A /347.83 = 4.87× (Actual)
Ratio = 1,721 A /347.83 = 4.94× (ETAP)

Table 1 describes the analysis of 3 units chiller alerts when running.

Table 1: Chiller Analysis Alert of 3 units Running

DeviceID	Type	Alert	Condition	Rating/Limit	Unit	Operating	% Operating	
Bus14	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.349	87.2	0.550
BusCh1	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.358	89.6	0.500
BusCh2	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.358	89.6	0.500
BusCh3	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.343	85.7	0.550

After knowing the deficiencies that occurred in the existing situation, then further improving the direct-on-line method with TAP. However for the electricity system network in the building under study, there is a voltage drop so that 1 unit of chiller cannot be added before TAP is applied to the power transformer. This proves the existence of a chiller compressor motor running 3 systems and 2 units of chiller compressor motor only for backup. able to add capacity. With the addition of TAP to the power transformer, it is hoped that it can improve the grid system in the electricity and can increase the capacity of the chiller. The results of the changes by running 4 units with the DOL method can be seen in Figure 8.

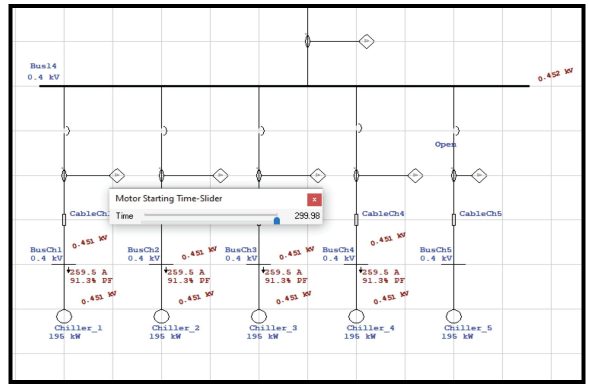

Figure 8: Results of the DOL Method of 4 units Running Method

Calculation of the starting current on the chiller compressor motor whose voltage has been TAP is 460 volts. Where the motor starting current obtained by the analysis of the ETAP is 1,809 A.

S_{start} = 261 HP × 4.5 = 1,174.5 KVA
I_{start} = S_{start} / (1.73 × 0.46) = 1.174 / (1.73 × 0.46) = 1,174.5 / 0.795 = 1,477.35A

While the nominal power and nominal current of the motor are:

$S_{nominal}$ = 195 KW / (0.9 × 0.9) = 240.7 KVA
$I_{nominal}$ = 240.7 / (1.73 × 0.46) = 302.76 A

Then the large ratio of the motor starting current to the nominal motor current is:
Ratio = 1,477.35 A /302.76 = 4.87× (Actual)
Ratio = 1,872 A /302.76 = 6.1× (ETAP)

Table 2 describes the alert analysis on 4 running chiller units.

Table 1: Chiller Analysis Alert of 4 units Running

DeviceID	Type	Alert	Condition	Rating/Limit	Unit	Operating	% Operating	
Bus14	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.377	94.3	0.600
BusCh1	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.371	92.7	0.600
BusCh2	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.371	92.7	0.600
BusCh3	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.371	92.7	0.600
BusCh4	LV Bus	Bus Voltage	Under Voltage	0.400	kV	0.371	92.7	0.600

Based on existing data that there is a busbar weighing on the busbar 14 load of the chiller compressor motor in the direct-on-line starting model which can be analyzed when running full load there is a voltage drop due to the inrush current of six times that seen in the analysis of the chiller running 4 units . So the first solution is to simulate with a wye-delta staring motor on the load of the chiller compressor motor after TAP on the Tap Changer power transformer to get a better operating voltage, but not more than what is expected in the form of a voltage drop to the lowest to 0.371 volts.

The results of the analysis of the motor starting with the direct-on-line method where when the Power Transformer Tap Changer is changed, the voltage on Bus 14 is at 460 Volts, which before changing the voltage is 400 Volts which does not run the motor optimally, from the simulation it results in BUS14 maximum function and there can be no additional load on BUS 14 because the voltage is too high to use. So that the use of the Power Transformer Tap Changer with the direct on line (DOL) starting method is not effective or not optimal so it is necessary to try another method, namely the wye delta starting method, Then with the Direct On Line (DOL) motor starting method as for the results of the Tap Changer Transformer Power will be simulated in more detail with dynamic motor starting analysis.

Figure 9 is a dynamic analysis of the motor staring pool where the DOL method voltage is before starting. The one-line diagram explains after previously changing the Power Transformer on the Tap Changer in order to get better voltage quality and to be able to improve the BUS 14 load on the Motor Compressor Chiller 4 unit running in this condition the voltage is still stable, At the time of the new start the DOL method is interesting. flow ± 6 times, which is the result of ETAP analysis.

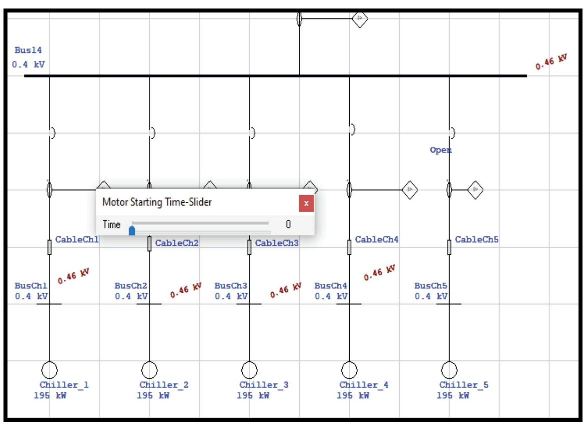

Figure 9: DOL Method Voltage before Start

Figure 10 is a Percentage Graph for 4 running motor Chiller units, on Chiller1 the blue color shows when the motor current at terminal 0 directly rises to 600 percent after running Chiller1 then on motor chiller2 (green color) then Chiller3 (red color) and Chiller4 (green color) according to the calculation in 4.3 according to the graph.

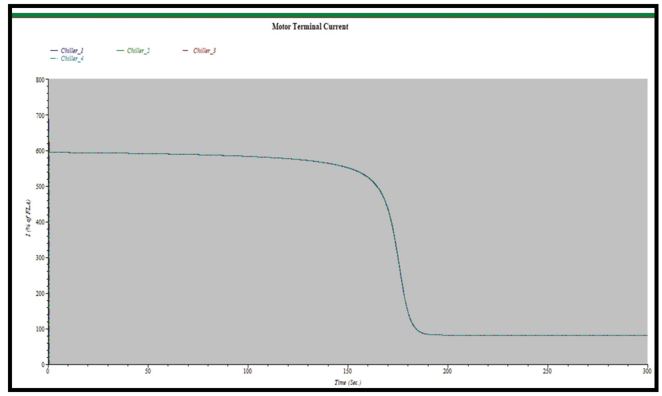

Figure 10: Graph of Motor terminal Current on 4 Chiller

In Figure 11, the Motor Terminal Voltage Graph on 4 Chiller units running for Chiller 1A to Chiller 1D (4) is the same as the simultaneous under voltage at the motor terminal shown in the graph when Load running there is a direct voltage drop of 10 percent and up to 120 percent of unload on the chiller motor and the maximum voltage to reach the normal.

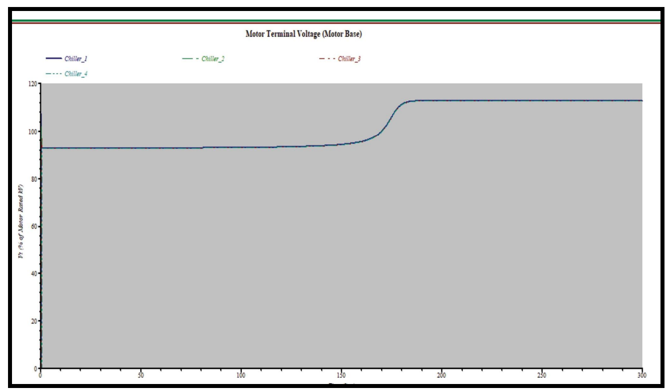

Figure 11: Graph of Motor terminal Voltage (Motor Base)

In Figure 12 is a graph of the Motor Terminal, the initial voltage of 120 percent (460Volt) drops to 90 percent from the ETAP can record on this DOL motor starting method Running Voltage Drop occurs due to the motor rush, after 19 seconds of running the motor returns to normal rose to 110 percent.

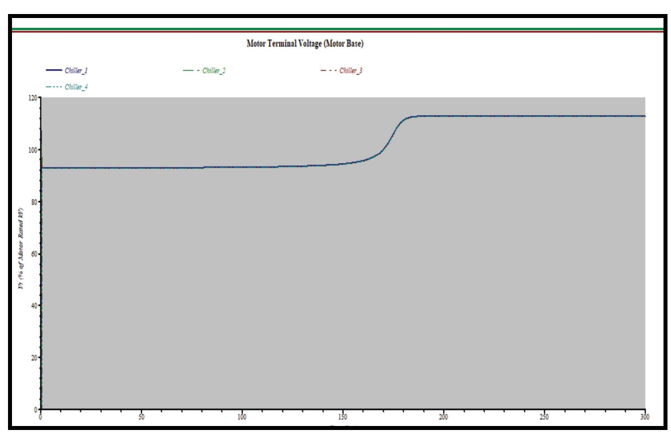

Figure 12: Motor Terminal Voltage (Motor Base)

Next is to perform the analysis with a different method, namely the start wye-delta method. Figure 13 is a one-line diagram of a chiller system that has been changed to a starting wye-delta. Analysis in Figure 13 Dynamic Wey-Delta on 5 Chiller units uses the Wey-Delta motor starting method, where each motor has a timer or a switch time of 7 seconds from Wey-Delta. So that in Figure 13 the Wey-Delta on 5 Chiller Unit Wiring can be fulfilled which before the direct On Line motor starting method only a maximum of 4 units on the chiller motor can run, so the author wants to go deeper into analyzing the Wey-delta motor starting.

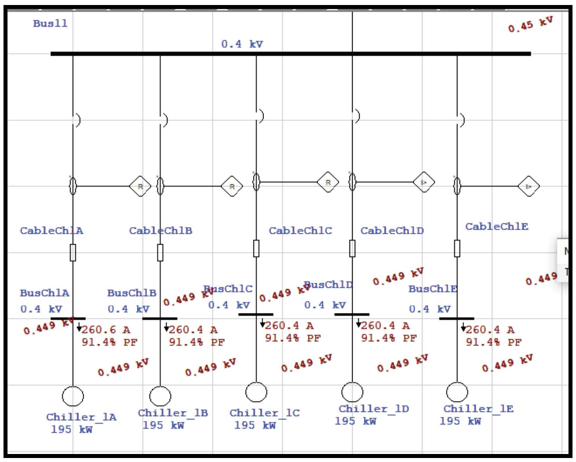

Figure 13: Dynamic Wye-Delta on 5 Chiller

In Figure 14 is a graph of the Motor Terminal Current on Chiller 1A running with the wye-delta motor starting method at 400 percent initial start and the time shift when to the delta position rises back to about 600 percent of the Full load A and a few seconds later the Full Load A changes to The initial position is in accordance with the nominal running motor. Thus, at the initial start of this method it will jump up to 400 percent only so that the current drop becomes small and causes it to run the chiller compressor motor 5 units.

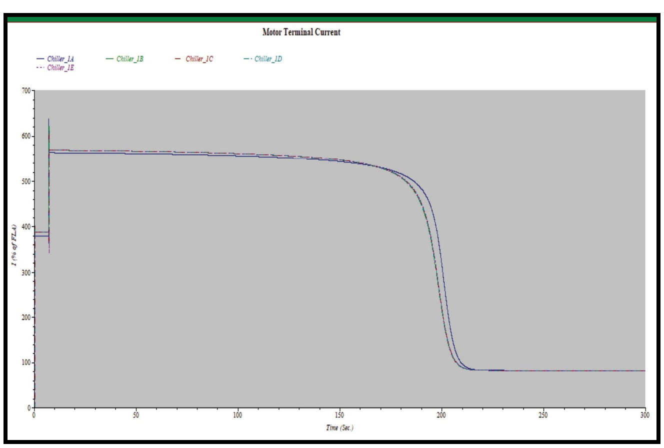

Figure 14: Wye-Delta Method Motor Current Terminal

With the wye-delta motor starting method, we will see in Figure 15 that the Bus Motor Voltage Terminal will rise first at start 60 percent of course with a small motor torque, over time it has been determined on the wye-delta principle, and the voltage will return to rise according to Tap Changer Power Transformer requires a special voltage at the motor terminal of 120 percent to reduce the inrush on another chiller motor. The current at the same time has been determined by the wye-delta method, so that chiller 1 when running is affected by chiller 2 so that there is a decrease in the quality of the voltage and chiller no.2 runs a surge of current above chiller 1 and so is chiller 3 and 4 as well 5, the voltage drop voltage is greatest because the motor starts at the end.

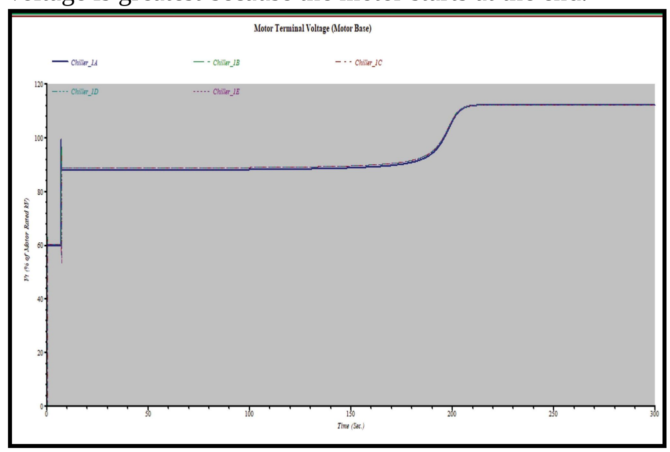

Figure 15: BUS Motor Voltage Terminal Motor

4. CONCLUSION

Tap changer is a transform ratio changer tool to get a better (cool) secondary operating voltage from the varying primary / network voltage. To reduce the added power due to the design on the 195KW chiller motor that is not optimal, it is necessary to have a Special Tap on the Power transformer so that the voltage on the Bus Motor is stable and the chiller unit.

The results of Starting Direct On Line show that the current ratio will pull as hard as possible on the network bus of the electrical system, which occurs in each motor starting method that is most preferred and commonly used is DOL (Direct On Line) because it is simpler in terms of design, installation, or operation and maintenance. In addition, the starting torque obtained is also large because at the time of starting the starting current is very large (approximately 650% lock rotor current), so it is very easy to bring the motor to its nominal rotation.

In the wye-delta starting method, the motor gets twice the supply shock voltage with a large first shock voltage (460V) so that the current is small so that the motor rotates slowly. After that in a certain delay the motor will get a second shock supply voltage that is smaller than the first supply voltage, which is 660v to get a current that is greater than the first supply voltage, the motor will rotate faster so that it has maximum speed. This method is more durable in use in industry because the motor will be better and will not be damaged quickly.

This study concluded that the motor requires a large current when starting, causing the current in the network to increase then gradually (time) the current goes down and returns to normal. Also occurs in voltage, where there is a voltage drop on the network then gradually (time) the voltage rises and returns to normal.

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(Periodical style)

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