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# Simulation of Ac Electric Motor Control Learning Through The Modelling of Starting Current of Three Phase Induction Motors Using The Star to Delta Connection Method

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## *Abstract*

The purpose of this study is to produce a semi-automatic control model when 3-phase a-synchronous starting motor using magnetic contactors, push buttons and timers apply the star connection method to the delta connection. The approach used in this study is a quantitative descriptive approach. Where the research is conducted at the Laboratory of Department of Electrical Engineering Education, University of Nusa Cendana, Kupang. The study population was all 3-phase synchronous motor controller using the star to delta method. The sample is a number of measurements of both voltage, current, and power in the control of a 3 phase induction motor using the star to delta method. The research instrument used a picture guide of the 3 phase induction motor control system and a picture of the main series of 3 phase synchronous motor control. The results of this study are: (1) Semi-automatic control model when 3-phase synchronous starting motor using 3 phase magnetic contactors, push button and timer by applying the star connection method to delta connection; (2) The average voltage of the 3 phase induction motor control applying the star-connection is 170 [V]; (3) The average phase current for controlling the 3 phase synchronous motor applying the star-connection without C is 112.5 [mA] for $I_R$, 111.25 [mA] for $I_S$ and 118.75 [mA] for $I_T$. (4) The average phase current of controlling the 3 phase synchronous motor applying the delta-connection of 600 [mA] for $I_R$, amounting to 552.5 [mA] for $I_S$ and equal to 557.5 [mA] for $I_T$; (5) The average phase current for controlling the 3 phase synchronous motor applying the delta-connection with C 15.18 [μF] of 62.5 [mA] for $I_R$, amounting to 55,625 [mA] for $I_S$ and 63,125 [mA] for $I_T$. (6) The mean value of the apparent power of star connection without a capacitor is 14 [Watt] and the reactive power of star connection without a capacitor is 49.5 [VAR]; (7) The mean value of the apparent power of the delta connection without capacitor is 27.25 [Watt] and the reactive power of the delta connection without capacitor is 165 [VAR]; (8) The mean value of the apparent power of the delta connection with capacitors is 15.18 [μF] of 18.75 [Watt] and the reactive power of the delta connection with capacitors is 15.18 [μF] of 24.375 [VAR]; (9) The capacitor value of 15.18 [μF] is the best value for the reactive power savings in a three-phase synchronous motor rotor coil type.

**Keywords***: Induction motor, starting current, star and delta connection.*

**Introduction**

An induction motor is the most widely used alternating current (ac) motor. The name comes from the fact that this motor rotor current is not obtained from a particular source, but is an induced current as a result of the relative difference between the rotor rotation and the rotating magnetic field produced by the stator current [1]; [6] [7].

The stator winding connected to a three-phase voltage source will produce a magnetic field that rotates with synchronous speed (ns = 120f / 2p). The rotating field at the stator will cut the conductors in the rotor, so that they are induced by the current; and in accordance with Lentz's Law, the rotors will also rotate to follow the rotating magnetic field. The relative spin difference between the stator and rotor is called slip. Increasing the load will enlarge motor torque, which therefore will also increase the induction current on the rotor, so that the slip between the rotating magnetic field and rotor rotation will increase. So, if the motor load increases, the rotor rotation tends to decrease. Two types of induction motors are known, namely induction motors with winding rotor and squirrel cage rotor [2]; [6]; [7].

AC electric motors that have a large power capacity usually have quite complex problems in determining the appropriate starting method for the motor. The choice of starting motor for these motors is usually much influenced by factors such as power capacity, type of motor such as squirrel cage rotor or coil rotor, type of motor design (motor basic, high torque, low torque) also the types of loads that are moved.

There are two starting methods used to run AC electric motors [2], namely: (1) Starting by using the full voltage of the network. Starting with this method uses a full mesh voltage connected directly to the motor terminal. This starting method is often called "Direct on Line Starting (DOL Starting). (2) Starting with a decrease in voltage [8].

To run an electric motor, a large amount of power is required by the source voltage. The amount of power needed is quite large compared to the motor after operating fully (running). The amount of power required by the motor to start the same as the amount of current drawn by the motor itself. This current ranges from 4 to 8 times the full load current of the motor. Although the magnitude of the flowing current is only in a short time, but for large motor capacities will take large power, will be able to disrupt the existing network system and damage the motor system itself. Therefore to overcome the danger that might arise due to the amount of current flowing at the start, several starting methods are used by reducing the voltage [2], which are: (1) Starting using the Star/Delta connection system. (2) Starting using the Primary Resistance Starting. (3) Starting by using Autotransformer Starting [9]; [10]; [11].

The star-delta starting system is widely used to run a squirrel cage rotor at  induction motor that has power above 5 [kW] or about 7 HP.  How to operate this motor usually depends on the type of starter chosen. Many types of starters in the market we find include the Three Phase Starting Motor, or can also use a number of contactors specifically designed to make a motor connection in a star or triangle connection [9]; [10]; [11].

If a motor is specifically designed at a voltage of 220/380 volts, while the grid voltage of the 3 phase source is 380 volts, then the motor can only be run in a star connection. This means that if this motor will be restarted it should not use a starting star or triangle system. But if this motor is served by a voltage source of 3 phase 220 volts, the starting star or triangle system can be used [2]; [8]; [9]; [10].

## Materials and Method

### *Component of 3 Phase AC Motor Control*

The semi-automatic electric motor control system that uses magnetic contactor control equipment requires other tools so that the control function runs properly such as: pushbutton, thermal overload relay, and other assistive devices. Magnetic contactors are widely used to control 1 phase and 3 phase electric motors, for example, to control two-way rotating motors, starting star-triangles, several motor units working and stopping sequentially, [9]; [10]; [14].

### *Magnet Contactor*

Magnetic contactors or magnetic switches are switches that work based on magnetism. This means that this switch works if there is a magnetic force. Magnet functions as a puller and releases contact. A contactor must be able to drain the current and disconnect the current under normal working conditions. The normal workflow is the current flowing during disconnection does not occur. A magnetic coil contactor (coil) can be designed for direct current (DC) or alternating current (AC). Contactor of this AC current in the magnetic core is a short circuit, the point is to keep the magnetic current continuous so that the contactor can work normally. Whereas in magnetic coils designed for DC currents, a short circuit is not installed [4], [5]; [6].

### *Alternating Current Magnetic Contactor (AC)*

Magnetic contactor alternating current construction is basically the same as direct current magnetic contactor. However, due to the nature of the alternating current of sinusoidal waveforms, in one period there are two times the voltage equal to zero. If the AC 50 Herz current frequency means that in 1 second there will be 50 waves. And 1 period will take 1/50 = 0.02 seconds which takes twice the zero point. Thus in 1 second there is 100 times the zero point or in 1 second the magnetic coil loses its magnet 100 times [3].

Therefore, to fill the loss of magnetism on the magnetic coil due to loss of current, a short circuit winding which functions as a magnetic induction generator when the magnetic current in the magnetic coil is lost. Thus the magnetic current in the contactor will be maintained continuously.

If a contactor designed for AC current is used in a DC current, the electrical induction does not arise so that the coil becomes hot. On the other hand, if a magnetic contactor for a DC current that does not have a short circuit winding is given an AC current then the contactor will vibrate due to the magnetism of the magnetic coil arising and disappearing every 100 times.

The contactor will work normally if the voltage reaches 85% of the working voltage, if the voltage drops, the contactor will vibrate. The size of the contactor is determined by the limit of current capacity. Usually in the contactor there are several contacts, that i.e. normal contacts open (Normally Open = NO) and normal contacts close (Normally Close = NC). No contact means when magnetic contactors don't work. The position opens and if the contactor works the contact closes/connects. Whereas NC contact means when the contactor has not worked the contact position closes and if the contactor works the contact opens. So the work function contacts NO and NC opposite. NO and NC contacts work to open a moment faster before NO contact closes [3].

***Timer***

In Put timer must always be electrified because it is used to run the timer. To SETTING the timer at ON-OFF, the small contacts next to the timer must be lowered & raised according to the time requirement ON-OFF (depending on needs). If the timer input is disconnected or there is no incoming current (power outage), then the timer must be set according to the time when setting it again (the clock must be adjusted at that time). To set the time/hour, it must be rotated clockwise [3]; [12].

### *Timer Working Principle*

The inflow in the input magnetic contactor and also on the input timer that will run the timer, after the time is spinning and has reached the time connected (time-ON) then the contact in the timer will be connected to the timer output and the current will flow towards the magnetic contactor (contact a & b) that will draw contacts on the magnetic contactor so that the input contacts on the magnetic contactor are connected to the output contacts on the magnetic contactor, so that the input current can pass through the magnetic contactor output which will run the load on that output. After the time/clock continues to rotate, it is time for the timer to disconnect (time is OFF) then the current is cut off that passes through the magnetic contactor so that the load on the magnetic contactor output does not work, the process occurs continuously, if there is no power outage on the PLN network. If the ON-OFF time setting is for 18-6 o'clock then at 18 o'clock the timer is connected to the timer output until 6 o'clock, because 6 o'clock here is used to disconnect the timer so that the timer output is not connected [3]; [12]; [13].

### *Overload Motor Protection*

Overload Motor Protection, what is meant by this motor is an electric motor that common people calls a dynamo And here is specifically what happens in 3 phase AC motors. The function of this motor is as a driver or to convert electrical energy into mechanics/motion such as; lifts, conveyors, blowers, crushers, etc. In the industrial world at this time the role of the motor is very vital. For this reason, protection is needed to maintain the smooth running of a process. This motor protection system has long been known and developed as technology advances. Starting from the use of eutic relays, from thermal types to electronics. In general, the work system of the tool can be divided into two that are thermal and electronic[2]; [14].

### *Thermal Overload*

As the name implies this motor protection uses heat as a current limiter on the motor. This tool is very much used today. Usually called TOR, thermic or overload relay. The way this tool works is by converting currents that flow into heat to influence the bimetal. Well, it is this bimetal that moves the lever to stop the current of electricity to the motor through a motor starter control. The limitation is done by adjusting the amount of current on the dial in the device. So the tool has a range adjustment such as the TOR with a range of 1 ~ 3.2 Ampere in the 2.5 Ampere setting. That is, we limit the current to the TOR at 2.5 Ampere level[ 2]; [3].

What if there is an excess current/overload on the starter motor. Like the example above, TOR is set at 2.5 Amp and for example, the current has reached 3 amperes, what we expect, Starter shut down / Trip, Correct, only when it will trip, as soon as possible or vice versa. This is very unlikely if we use Thermal Overload / TOR. Well, then how fast will the TOR trip. Using a bimetal as a barrier certainly cannot react quickly to rising currents. Please note, TOR on the market has several types called Class. So by choosing a different class, the TOR trip speed will be different. Currently, there are TORs with Class 10, Class 15, Class 20, etc. This class shows the trip speed when the TOR has a current of 6X settings. For example, TOR class 20 is used with a 10 Amp setting, when the current reaches 60 Amp this tool will trip after reaching 20 seconds. What if the excess current is only 13 Amp. We can wait for hours to trip. For more details, ask for the trip curve as shown in the picture when buying a TOR and calculate the trip speed. Please note that the TOR curve is logarithmic rather than linear. So there is no need to blame the accuracy of the TOR that has been used so far[2]; [3]; [12]; [13].

## Method

This research method with a quantitative description approach by applying measurement methods in the University of Nusa Cendana Electrical Engineering Education laboratory. The place or location of the study was conducted at the University of Nusa Cendana Electrical Engineering Education Laboratory in Kupang. The study population is all control of the 3 phase induction motor using the star delta method. The sample are a number of measurements of both voltage, current, and power in the control of a 3 phase induction motor using the star delta method.

The research instrument used the drawing guide of the 3 phase induction motor control system and the picture of the main series of 3 phase induction motor control as follows.

**Result**

***Description of Research Results***

Graphs 4-1, 4-2 and 4-3, respectively showing the variation in the source voltage and the load voltage in star connection. The load voltage in the star connection is represented by phase to phase voltage represented by RS, RT and ST voltage. Whereas the current at the load is represented by phase currents namely IR, IS and IT currents. The measured power shows apparent power in watts and reactive power in VAR units.

Graphs 4-4, 4-5 and 4-6, each shows variations in the source and load voltage in the delta connection. The load voltage in the star connection is represented by phase to phase voltage represented by RS, RT and ST voltage. Whereas the current at the load is represented by phase currents namely IR, IS and IT currents. The measured power shows apparent power in watts and reactive power in VAR units.

Graph 4-7, shows variations of load in star relationships. The current at the load is represented by phase currents namely IR, IS and IT currents. The measured power shows apparent power in watts and reactive power in VAR units.

Graph 4-8, shows variations in load in the delta connection. The current at the load is represented by phase currents namely IR, IS and IT currents. The measured power shows apparent power in watts and reactive power in VAR units.

Graph 4-9, shows the load variation in the delta connection with C capacitor compensation. The current in the load is represented by phase currents namely IR, IS and IT currents. The measured power shows apparent power in watts and reactive power in VAR units.

**Discussion**

*Star Connection Load*

On the graph; 4-1, 4-2 and 4-3, each of which is a graph for the load in a star connection. It can be seen that in graph 4-1, the supply voltage varies from 200 [V] to 360 [V], this is done in accordance with the ability of the power supply and measuring instruments available which specifically for the maximum voltage of 360 due to limited measuring capability of amperemeters. It appears that there is no difference between the voltage supply and the voltage at the load or appears to be hindered, this is because the load which is fixed in a fixed state in the sense that it is not given a varying load.

Graph 4-2 shows, the magnitude of phase currents, especially the IR, IS and IT phases. The magnitude of the phase current starts from 130 [mA] to 230 [mA], where it also appears that there is also no significant difference between the phase currents at the 3 phase induction motor load. This also happens because it does not apply variations in load or load is in a stable state.

Graphs 4-3 show, the magnitude of apparent power and reactive power. True power in the range of 12 [Watts] up to 28 [Watts] and reactive power in the range of 40 [VAR] up to 145 [VAR]. If we use the power triangle equation obtained $\tan \Theta = 3.33$. If interpreted in an angle to form an angle of 73.3 degrees. The magnitude of this angle is expressed in losses. Furthermore, when seen at the end of the measurement of apparent power, the value is 28 [Watt] while the reactive power is 145 [VAR]. Obtained $\tan \Theta = 5.17$. If interpreted in an angle it forms an angle of 79.1 degrees.

*Delta Connection Load*

On the graph; 4-4, 4-5 and 4-6, each of which is a graph for the load in the delta relationship. It can be seen that on chart 4-4, the supply voltage varies from 195 [V] to 280 [V], this is done according to the power supply capability and available measuring instances where the maximum voltage is 280 due to the limited measuring capability of amperemeters. It appears that there is no difference between the voltage supply and the voltage at the load or appears to be hindered, this is because the load which is fixed in a fixed state in the sense that it is not given a varying load.

Graph 4-5 shows, the magnitude of phase currents, especially the IR, IS and IT phases. The magnitude of the phase current starts from 300 [mA] to 650 [mA], where it appears that there is also no significant difference between the phase current at the 3 phase induction motor load. It's just that it can be seen that only the IS current is different with the same IR and IT current. This also happens because it does not apply variations in load or load is in a stable state.

Graph 4-6 shows, the magnitude of apparent power and reactive power. True power in the range of 21 [Watts] up to 120 [Watts] and reactive power in the range of 45 [VAR] up to 290 [VAR]. If we use the power triangle equation obtained tan $\Theta = 5.74$. If interpreted in an angle form an angle of 80.07 degrees. The magnitude of this angle is expressed in losses. Furthermore, when viewed at the end of the measurement of apparent power, the value is 28 [Watt] while the reactive power is 145 [VAR]. Obtained tan $\Theta = 6.44$. If interpreted in an angle form an angle of 81.18 degrees.

Especially for apparent power and reactive power analysis, it seems clear that there is an increase in current from the star connection to the delta connection. This is what requires the application of the starting current to be started through the star connection then transferred to the delta connection because in essence it is in the delta connection using a current that is greater than the starting current in the star connection.

### *Star and Delta Connection Load*

Look at graphs 4-7, 4-8 and 4-9, in this section shows that there is a reduction in losses that is displayed at reactive power. Especially for loads in star connection compared to loads in delta connection. Look at the graph 4-7. It appears that if the supply voltage is 200 [V], apparent power of 10 [Watt] is obtained and the reactive power is 40 [VAR], while on graph 4-8, it appears that apparent power of data obtained by 20 [Watt] and reactive power obtained by 125 [VAR].

Specifically by applying a capacitor when the load is connected to the delta. If in figure 4-8, it appears that using a supply voltage of 285 [V], the value of reactive power is so large that it reaches 300 [VAR] while if seen in graph 4-9, only applies reactive power of 230 [VAR], so there are savings reactive power of 300-230 which is equal to 70 [VAR] for the same load. In the same case, if use a 200 [V] supply voltage, the reactive power value reaches 125 [VAR] while if seen in graph 4-9, only applies a reactive power of 95 [VAR], so there is a reactive power savings of 125-95 which is equal to 30 [VAR] for the same load.

Based on the repetition of ten times in the measurement of voltage obtained the average voltage for the load of the star connection is 274 [V]. While the average voltage for the load in the delta connection with repetition is six times, the voltage is 235, 83 [V].

Based on ten times repetition of current measurements, the average current for the star connection load is 180 [mA] for IR, 181 [mA] for IS and 181.5 [mA] for IT. While the average current for loads in the delta connection with repetition is six times, the current for IR is 495 [mA], for IS is 521.67 [mA] and for IT is 495 [mA].

**Conclusion**

The conclusions from this study presented as follows.

1) The control model automatically when starting a 3 phase induction motor uses magnetic contactors, the push button and timer apply the star connection method to the delta connection. The three phase induction motor ignition system can apply the star connection load system to the delta as illustrated in appendix 1.
2) The average voltage of the 3 phase induction motor control applying a star connection is 274 [V].

3) The average voltage control of a 3 phase induction motor applying a delta connection is 235, 83 [V].

4) The average current of 3 phase induction motor control applying a star connection of 180 [mA] for IR, 181 [mA] for IS and 181.5 [mA] for IT.

5) The average current control of a 3 phase induction motor applying a delta connection of IR of 495 [mA], for IS of 521.67 [mA] and for IT of 495 [mA].

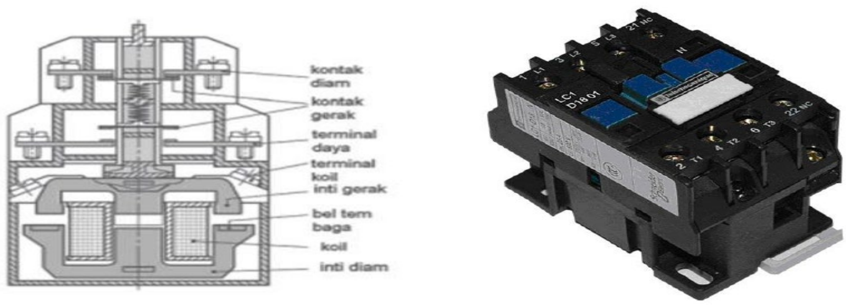



**Figure 1.** Magnet Contactor

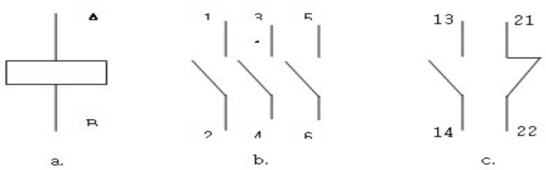



**Figure 2.** Symbol of Magnet Contactor

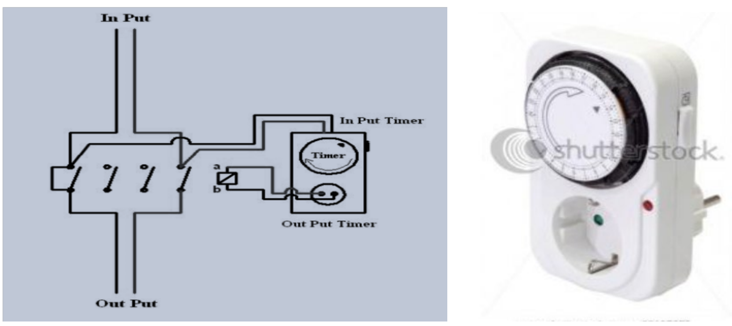



**Figure 3.**Timer Connection

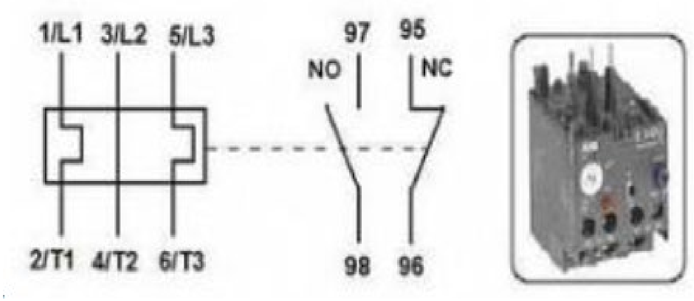



**Figure 4.** Overload symbol

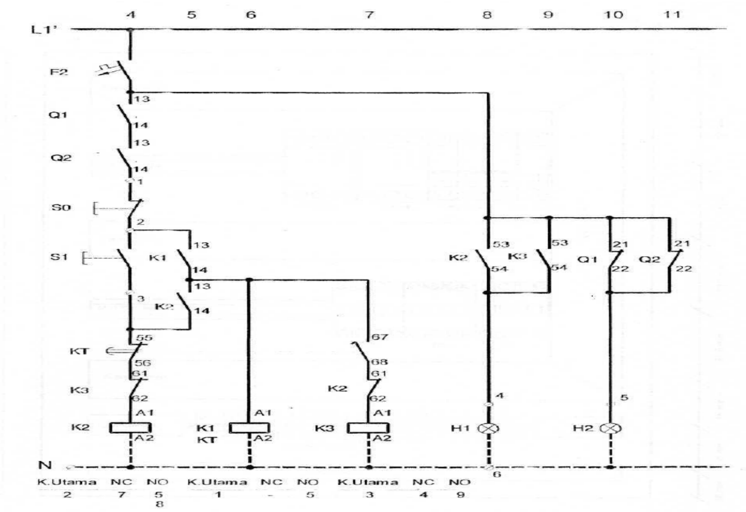



**Figure 5.**Star to Delta Connection Control Circuit

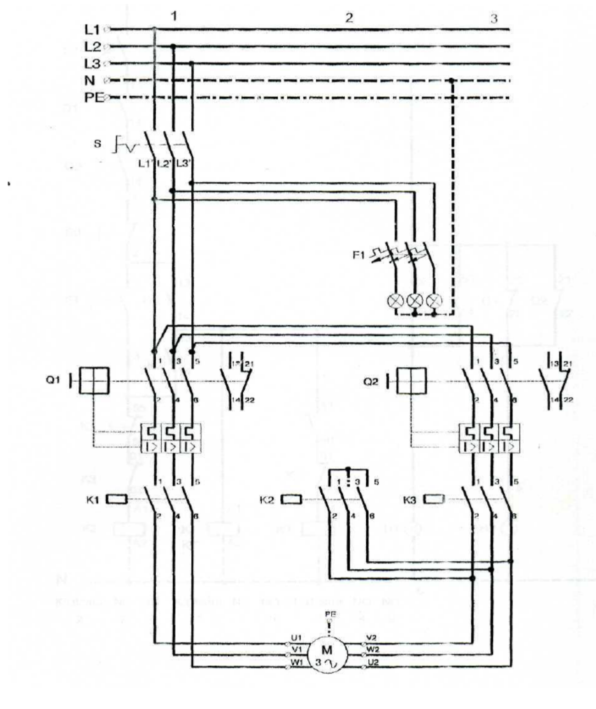
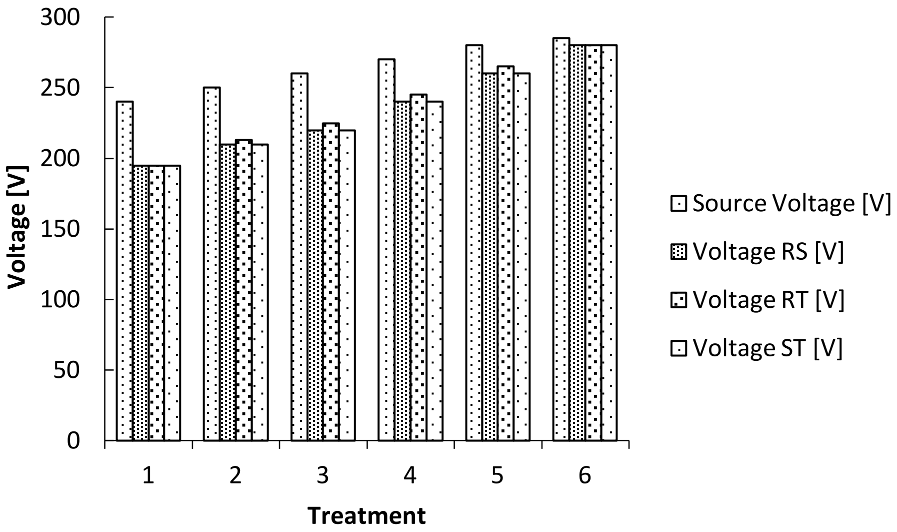
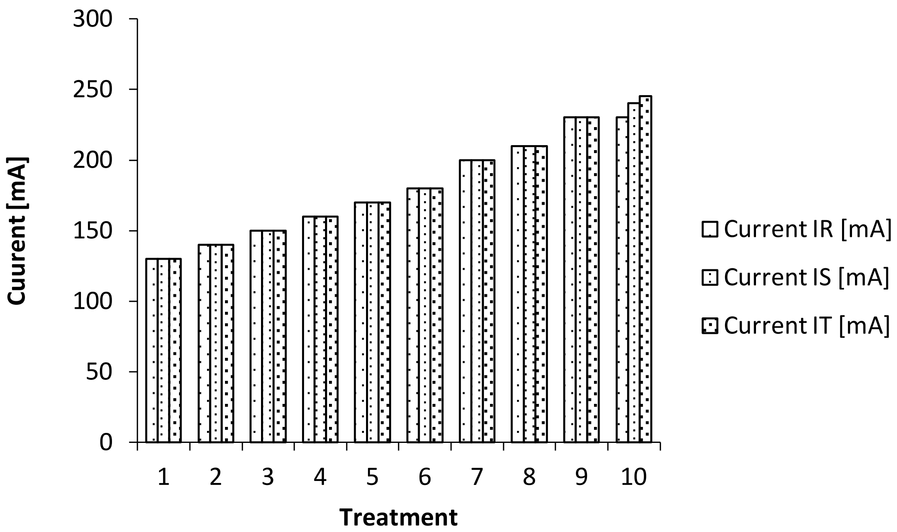


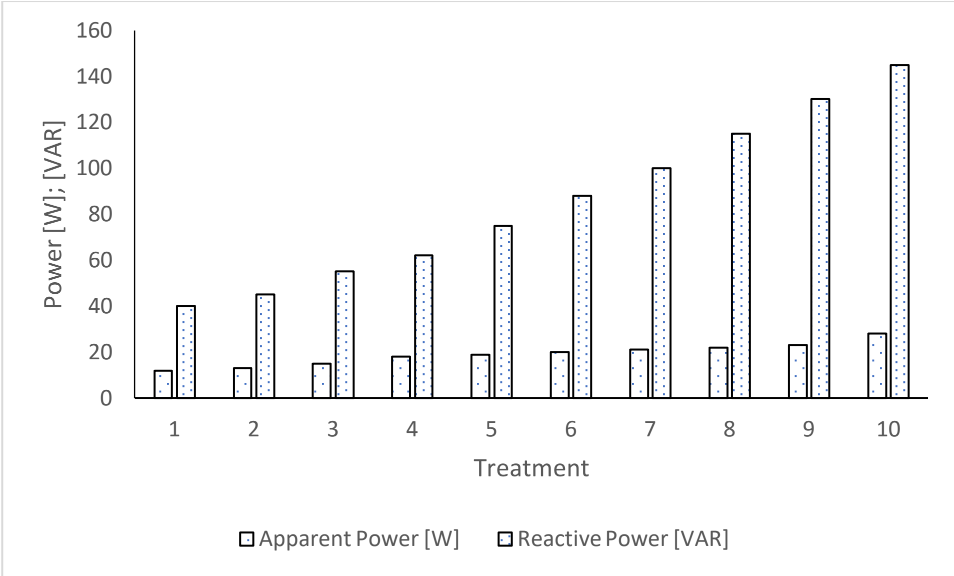

**Figure 6.** Star to Delta Connection Main Circuit



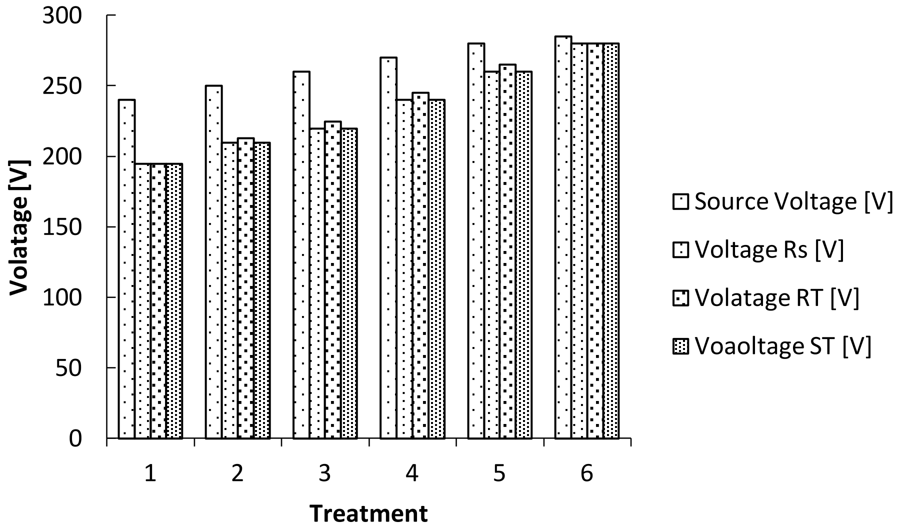

Graph 4-1 Source Voltage and Load Voltage in Star Connection



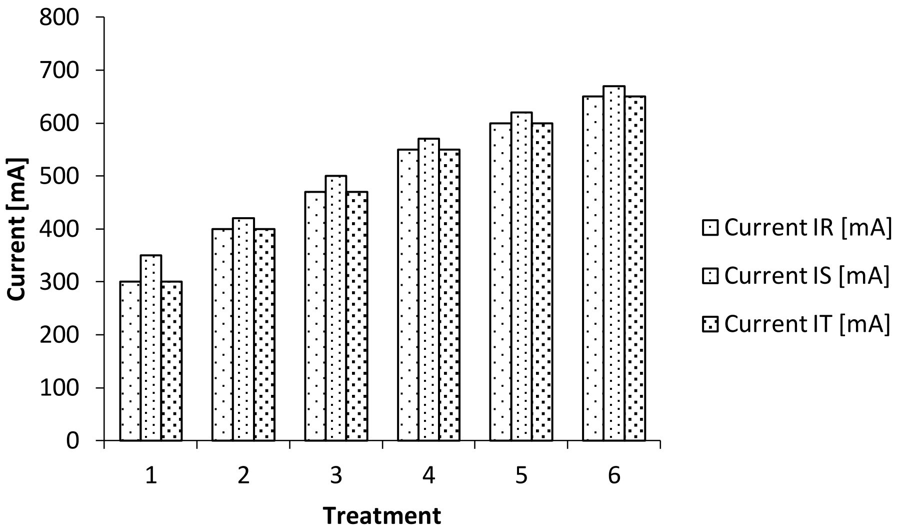

Graph 4-2 Load Current in Star Connection



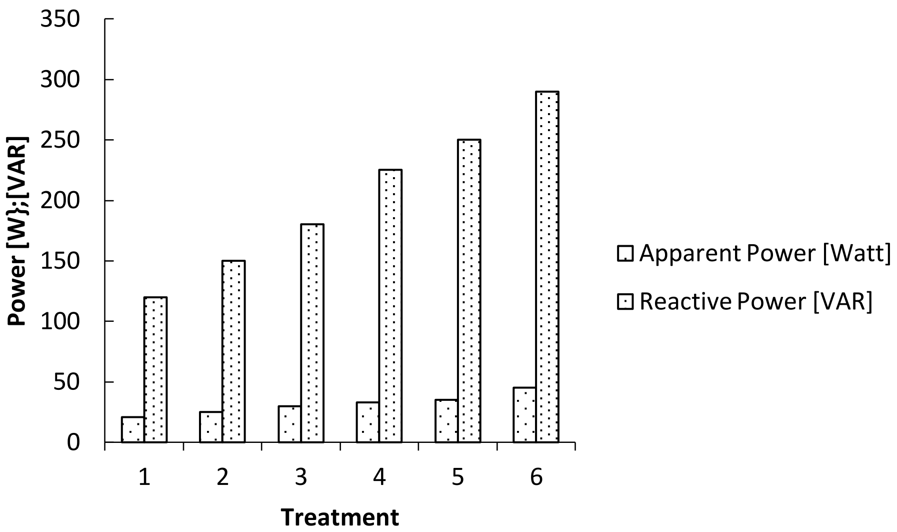

Graph 4-3 Apparent Power and Reactive Power with Star Connection Load



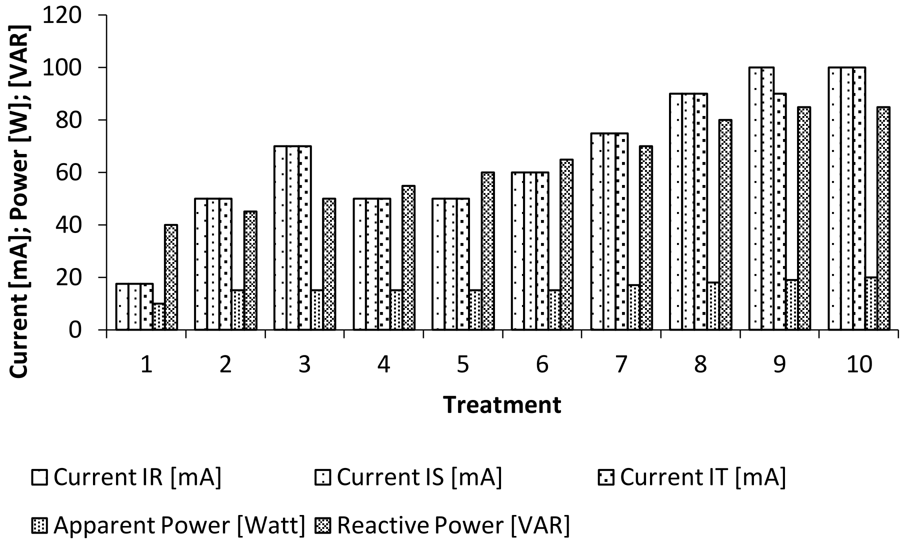

Graph 4-4 Source Voltage and Load Voltage in Delta Connection



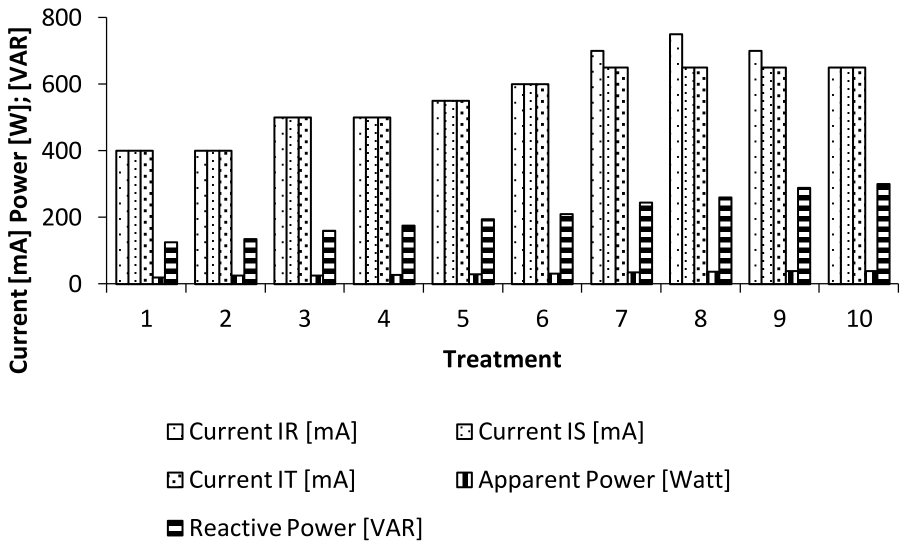

Graph 4-5 Load Current in Delta Connection



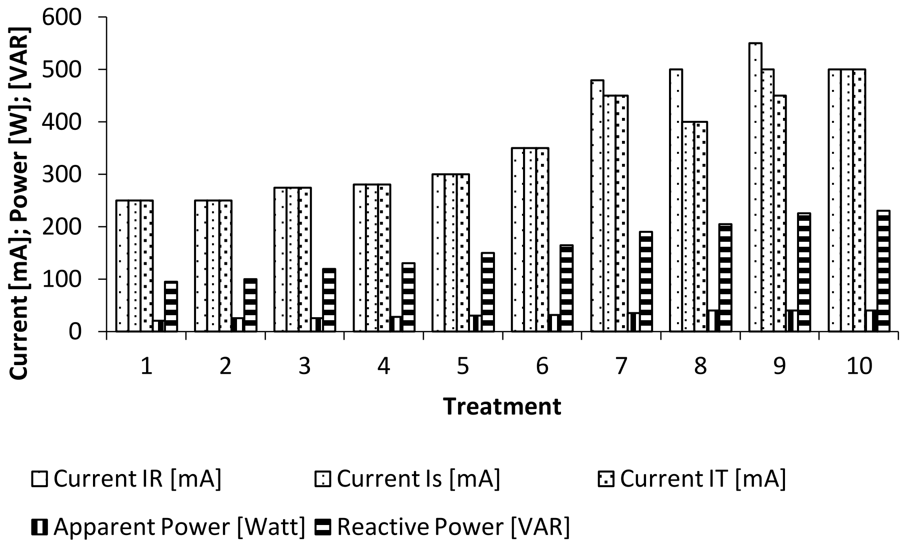

Grafik 4-6 Apparent Power and Reactive Power with Delta Connection Load




Graph 4-7 Load in Star Connection




Graph 4-8 Load in Delta Connection




Graph 4-9 Load in Delta Connection with C Capacitor Compensation

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