NUEVA GRANADA MILITARY UNIVERSITY

AC MOTOR START IN DELTA AND STAR CONNECTION

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1. INTRODUCTION

The three-phase alternating current motor are devices capable of transforming electrical energy into mechanical energy. They are used very frequently due to their optimal performance, low maintenance and simplicity, in their construction.

Its operation lies in the energy that originates magnetic fields in the winding of the stator which causes that the start of these motors does not need auxiliary circuit, therefore they are smaller and lighter than a single-phase induction of the same power, due to this their manufacture represents a lower cost. These engines are characterized because they have a power that does not vary in time, typical of the three phases. They also have a start with high currents and low torque; and two different configurations can be made depending on the needs of the application, which are star or triangle.

2. OBJECTIVES

GENERAL OBJECTIVE:

- Identify the parts of a three-phase alternating current motor.

SPECIFIC OBJECTIVES:

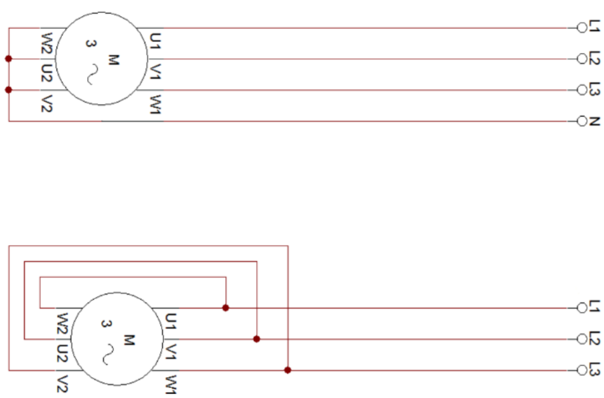
- Observe and analyze the behavior of an asynchronous motor cage squirrel connected in star and triangle.
- Determine the current consumption at startup in the two different connections.
- Relate speed and current as a function of load.

3. METHODOLOGY:

During the practice will be carried out the design of a three-phase motor with induction squirrel cage, its operation depends on a stator in which the inductor coils are located. Usually, its configuration can be of the star or triangle type, with the characteristic that the magnetic speed is not synchronized with the mechanical speed of the motor.

The engine will be configured in different types of start and in this way the respective data will be obtained to analyze their differences.

Thus, the circuit is as follows:



Graph 1: Connection of the motor in star (above) and delta (below).

Formulas

$$N_S = \frac{120 * f}{p}$$

$$N_r = N_s - N_m$$

$$s = \frac{N_r}{N_s} = \frac{N_s - N_m}{N_s}$$

Where:

N_s: *Sync speed*

N_r: *Sliding speed*

N_m: *Machine speed*

s: *Slip factor*

p: *Number of poles*

4. MATERIALS:

- Alligator clips
- Three-phase cable
- Tachometer
- Power table
- Multimeter
- Banana-banana connector
- AC Motor Squirrel cage
- Electrodynamometer
- Voltmeter AC
- Ammeter AC
- Distribution strap
- Voltage source

5. PROCESS:

1. The parts of the squirrel cage induction motor, the electro-dynamometer and the power supply are identified to have a proper connection and an accurate measure.

2. Perform a star connection, keeping in mind security rules.

3. Perform 2 different types of start up to the motor.

4. Measure starting current.

5. Registration of voltaje and current during different scenes of the practice.

6. Measure motor speed with load variation.

7. Repeat the process mentioned above for the delta connection.

8. With the results obtained, spot differences on the different connections.

9. Analyze the characteristics of current consumption according to your starting system.

10. Plot speed versus load, current versus voltage.

6. ANALYSIS AND SIMULATION:

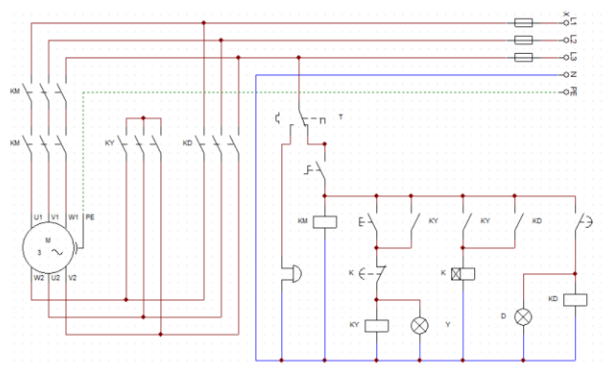
The engine has the possibility to start in different ways in order to work for different activities.

A very common start is the direct one, where the motor is directly connected to the power supply. It is used for machine motors that have constant load or constantly off and on. Grants start and the current is maximum at start-up.

Another very common start is the star-triangle start, place in the motor in star connection and then pass it to a triangle, which allows not to have the maximum current at the start and at the time of change of connection. To carry the automatic change it is necessary to have different materials that will work with a control logic. First contactors are needed, which allow the passage of current through a switch in the presence of current conduction in a coil, and there are timers that have the same function but subject to a certain time to make the change.

The star connection contactors are activated, and then after the timer change time, the star connection is opened and then placed in a triangle. Additionally, contactors are placed in the connections of the motor to the source to control them by a mechanical switch so that the user decides when to turn it off. You have a thermal relay that protects the engine when the temperature of the engine rises, disconnects all coils and activates an emergency horn. Another conversion factor is to place a rifle for each phase preventing peaks in current and voltage that the motor could not withstand.

The scheme of the control circuit together with the power circuit of the star-triangle start is as follows:



Graph 2. Power circuit (left) and control circuit (right) for the star-delta start up.

7. EXPERIMENTAL RESULTS:

El The engine depending on the connections has different characteristics. The power supply will always be the in-line voltage of the three-phase source, but in each case the source will grant different voltage therefore to compare the connections must reach the same voltage even if it is not the nominal of the motor.

In triangle connection, the line voltage is the same phase voltage (110 VAC), while the line voltage in star connection is the sum of one phase minus the other, giving a voltage of 208 VAC. Then the comparison will be made with the voltage of 110 VAC line. In addition the rated voltage of the motor is 110 VAC.

The currents and speeds of the motor at each connection were measured every 10 VAC, that is, they were calculated in a smooth start stopping every 10VAC. The data obtained are as follows:

	Delta		Star	
V( )	I( )	W(rpm)	I( )	W(rpm)
10	1.6	0	0.1	0
20	1.8	213.1	0.24	0
30	2	1708	0.29	0
40	2	1754	0.29	1544
50	2.2	1771	0.27	1686
60	2.4	1782	0.27	1730
70	2.8	1788	0.29	1754
80	3.2	1790	0.30	1765
90	3.6	1791	0.33	1771
100	4	1794	0.39	1781
110	4.4	1794	0.41	1783

Table 1: Current and speed as a function of voltage on delta and star connection.

The maximum currents consumed by the vacuum motor occur at start-up, but to find them it is necessary to start directly at the nominal voltage of the motor, 11m VAC line. In star the maximum current is 2.7 A and in triangle a maximum current of 6.9 A in direct start.

8. ANALYSIS OF RESULTS:

Due to the comparison of currents consumed by the motor in the different connections, the current value will be higher in triangle connection than in star connection. It can not only be seen reflected in the currents of the soft start which in star connection is 10% of the values of currents in star connection, but the peak current (maximum current) in direct start in triangle connection exceeds twice the current value in star connection.

The three-phase motor has a nominal current of 1.2 A, and each coil supports a maximum of 1.5 A. Under these parameters, the maximum current of each connection exceeds the value of the nominal current, which implies that at the start the maximum torque is obtained, and therefore the direct start is used for fixed load, torques that are approximately constant over time.

Current 1.2A means the maximum current that can be induced from the stator winding to the rotor or squirrel cage. The current of 1.5 A is the maximum current that each coil of the stator can support (coils that induce the magnetic field). By establishing the parameters, in star connection by consuming the in-line current equal to the phase current, the source can only grant a maximum current of 1.5 A, while in triangle connection the following calculation must be performed:

$$I_L = I_f\sqrt{3} = (1.5\ A)\sqrt{3} = 2.6\ A$$

So the maximum current that the source must supply is 2.6 A.

The data show that the source current supplied for star connection does not exceed 50% of the nominal current of the coils. But in triangle connection, the values of the currents exceed the nominal current of the coils from 70 VAC, and only indicates that the triangle connection exerts greater input power than in star connection. Check this statement, the input power of each connection is compared at 60 VAC (voltage at which the line current does not exceed the nominal current of the coils in triangle connection)

$$P_o = V_s * I_L$$

$$(60\ V)(2.4\ A):(60V)(270\ mA)$$

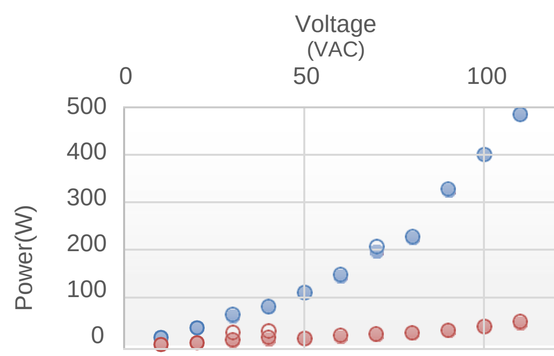
$$144W > 16.2W$$

Exactly the input power supplied in triangle connection is greater than the input power in star connection for this case. The input power values at each voltage level are as follows:

	Delta		Star	
V( )	I( )	P( )	I( )	P( )
10	1.6	16	0.1	1
20	1.8	80	0.24	4,8
30	2	60	0.29	8,7
40	2	80	0.29	11,6
50	2.2	110	0.27	13,5
60	2.4	144	0.27	16,2
70	2.8	196	0.29	20,3
80	3.2	176	0.30	24
90	3.6	324	0.33	29,7
100	4	400	0.39	39
110	4.4	484	0.41	45,1

Table 2: Power as a function of current for each type of connection.

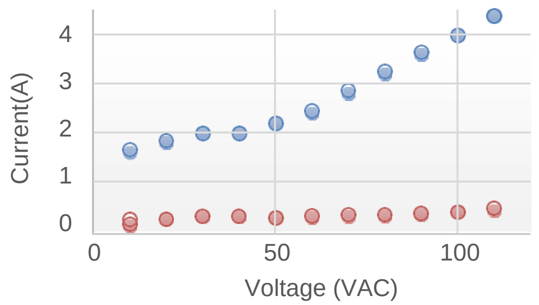
A better visualization of the behavior of the input powers supplied by the source is by graphing all the data, but in separate functions.



Graph 3: Graph of power as function of voltaje on connection star (red) and delta (blue).

It is necessary to take into account the nominal power that the motor has, which is 175W, so in triangle connection after 60 VAC it exceeds the nominal value because the current exceeds the maximum current value of the coils.

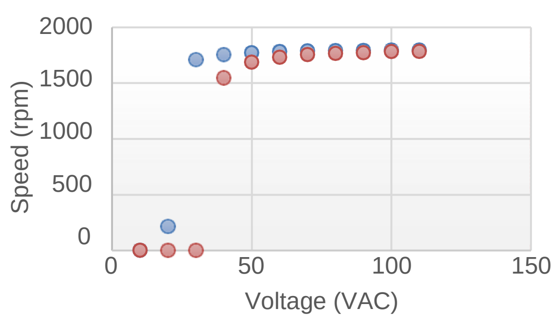
The power in triangle connection is considerably higher than the star connection since in this one it increases approximately linear with a small slope, the other graph tends to behave as an exponential function, which would imply that the current would increase in the same way. To check the above statement, the graphs of the currents as a function of the voltage are shown:



Graph 4: Graph of current as function of voltaje on star connection (red) and delta (blue).

In this way, the behavior of the current of the triangle connection tends to grow much faster than the voltage, by the ratio of $IL = \sqrt{3}If$,explaining the behavior of the power and affirming the characteristic of the current in triangle connection.

Analyzing the speed, the graphs are as follows:



Graph 5: Graph of speed as function voltaje for connection in star (red) and delta (blue).

An important fact is the nominal speed of the engine, 1670 rpm. With this data, the two connections exceed the nominal speed and also another characteristic they share is that they also tend to stay at a constant speed value. The big difference is that those properties in common occur at different voltajes.

The star-connected motor takes time to start, even if it has voltage and current supplied as shown in the graphs and tables above. This implies that the current induced from the stator to the rotor is not enough, therefore the squirrel cage structure will not receive enough force to move. After 30 VAC, the motor begins to turn and the change is large, because at 40 VAC it starts with a speed of 1544 rpm and at 50 VAC it exceeds the nominal speed.

In triangle connection, the motor also takes time to generate movement, but it does so at a lower voltage than the star connection and the change makes it of less difference, above 10 VAC and 20 VAC 213.1. But at 30 VAC it already exceeds the nominal speed and during the rest of the soft start, the speed change is minimal, tending to set the speed at a constant value. The same happens in star connection above 50 VAC, the speed tends to be set at a constant value.

9. CONCLUSIONS

The voltage measured in the motor, for the mounting in star connection was much higher than the nominal voltage applied by the three-phase source, likewise the current delivered by the source is the same that circulates through the circuit.

It is evident that the motor in triangle connection has a much higher power consumed than when it is in star connection.