

Protecting Motors From Improper Voltages and Amperages.

By Norm Christopherson

It should be the responsibility of every technician making any adjustments on motors of any application to be aware of motor voltages and amperages, the problems associated with incorrect values and what to do to rectify the problems.

Most technicians are aware that the actual voltage provided to a motor should be within 10% of the data plate rated voltage. Few technicians seem to be aware of any other conditions, which affect the motor, and there are several important factors, which are addressed here.

Three phase motors have special conditions, which must be met if long motor life is to be expected. Three phase motors must have all three phases present. A three-phase motor, which only gets two of, the three phases most likely will not start. This condition is called single phasing. A three-phase motor, which had three phases when it started and lost a phase after starting, will continue to operate but will run hot and may destroy winding insulation and even fail completely burning out. If the motor is inside a fully hermetic or semihermetic compressor, the resulting burn will pump carbon, acid and smoke through the sealed system necessitating a difficult and expensive clean up.

Perhaps one of the least understood and most important conditions to be aware of is the subject of voltage and current imbalance, what they are, how to detect them, and what is the cause. A knowledge of this topic would have saved many a motor from premature failure if all technicians were aware of this possibility and were looking for it.

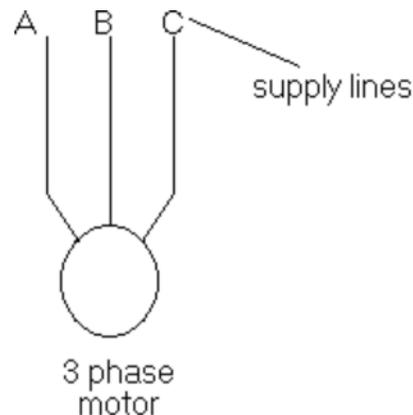


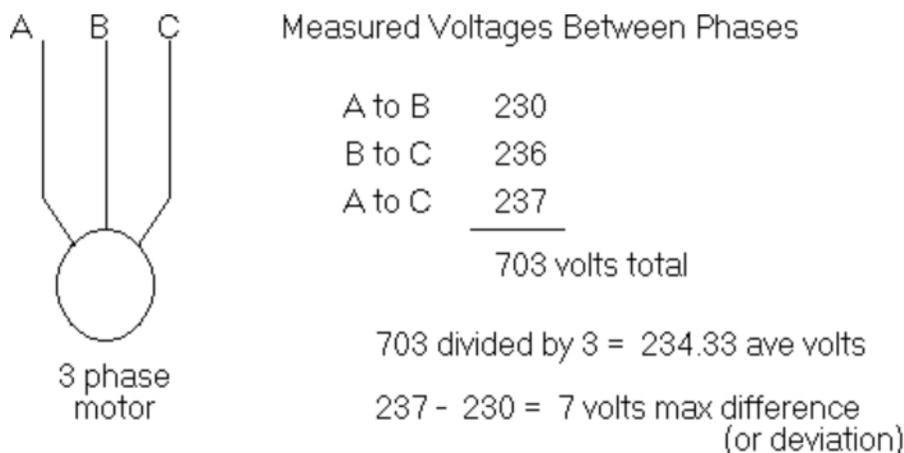
Figure 13-8

In addition to a motor getting a supply voltage within 10% of the rated voltage, the three voltages of the 3 phase must be close to the same voltage on each line. When there are unequal incoming voltages between the three supply lines the motor will run hotter and is subject to a shorter life span. This voltage difference is called voltage imbalance. Figure 13-8 illustrates a typical three-phase motor connected to a three phase electrical supply.

There are two steps involved in troubleshooting voltage imbalance problems. First, the percent of imbalance is calculated, secondly the cause must be determined and the solution applied.

The maximum allowable imbalance is 2% as measured at the motor terminals or as close to the motor as can be done safely. The following formula is used to determine the percent of voltage imbalance;

$$\% \text{Voltage imbalance} = \frac{\text{Maximum Imbalance}}{\text{Average Voltage}} \times 100$$

*Figure 13-9*

The diagram in figure 13-9 illustrates the first step in using the formula. First the three voltage differences between phases or lines are determined. In this case the three voltages are 230, 236, and 237 volts. Then the average voltage of the three is found by adding them up and dividing by three. The result in this case is 234.33 average volts. Next, the maximum difference or deviation between voltages is found, in this case 7 volts between the 230 and 237 volts.

Then these numbers are placed into the formula as follows;

$$\% \text{Voltage imbalance} = \frac{\text{Maximum Imbalance}}{\text{Average Voltage}} \times 100$$

$$\% \text{Voltage imbalance} = \frac{7}{234.33} \times 100$$

$$\% \text{Voltage imbalance} = .0298724 \times 100$$

$$\% \text{Voltage imbalance} = 2.987\%$$

The percent imbalance is more than the limit of 2% and is not acceptable. The motor windings will run too hot and the motor life will be shortened. How important is this imbalance to the life of the motor? Take a look at how much hotter the motor windings will be above normal. This can be calculated very easily and should cause a technician to stop and think every time voltage imbalance may be a problem.

As the voltage is out of balance so is the motor winding currents. A small voltage imbalance causes a larger current imbalance, which in turn causes the motor windings to run hotter. The winding with the most current is the hottest one and will be the winding, which will burn out first, a second winding may burn out soon after the first and then the motor will stop.

Motor Winding Heat Rise as a Function of Voltage and Current Imbalance.

The percent of winding heat increase due to a voltage imbalance is exponential. As an example look at the winding heat increase for the last example where the voltage imbalance is 2.987%. Calculated as follows;

$$\% \text{ Temperature rise in motor windings} = 2 \times (\% \text{ Voltage Imbalance})^2$$

$$\% \text{ Temperature rise in motor windings} = 2 \times (2.987)^2$$

$$\begin{array}{l} \text{\% Temperature rise} \\ \text{in motor windings} \end{array} = 2 \times 8.92216$$

$$\begin{array}{l} \text{\% Temperature rise} \\ \text{in motor windings} \end{array} = 17.84\%$$

The result of the voltage imbalance of 2.987% is a motor winding running 17.84% hotter than normal.

The following chart gives the percent of temperature increase over normal for several voltage imbalances in one percent increases. Notice how the temperature increase climbs exponentially as the imbalance increases.

% Voltage Imbalance	% Temperature Rise
2%	8% hotter
3%	18% hotter
4%	32% hotter
5%	50% hotter

If this problem is associated with a hermetic or semihermetic compressor the problem is still worse. The electric motor in these cases is located inside the compressor crankcase where refrigerant and oil are present. The excess heat generated by the motor operating with an imbalance may break down the chemical

stability of the refrigerant and oil causing acids to form. The two acids, which result, are Hydrochloric and Hydrofluoric. These acids become stronger with increases in temperature. For every 18 degree rise in temperature the activity of the acids double. The acids then go to work on the motor windings at an increased rate and a compressor failure is assured. Simply locating a voltage imbalance and correcting the condition early can prevent such a failure.

Troubleshooting Voltage and Current Imbalance.

There are three major items, which can cause voltage imbalance and the resulting current imbalance.

- 1) Poor wiring connections or poor contactor contacts.
- 2) Internal motor winding problems.
- 3) Power company or building electrical problems.

The first problem can be rectified by the air conditioning technician. The second problem requires the motor to be replaced and the third problem calls for the attention of the local power company or a qualified electrician. Detecting each of these problems is the job of the air conditioning technician. The technician may then repair or report the problem to the appropriate authority.

After a voltage imbalanced condition has been detected it then becomes a matter of finding the cause. Like other electrical troubleshooting techniques it is a process of elimination. Eliminate the most probable causes first.

- 1) Poor wiring connections or poor contactor contacts.

With the circuit energized and the motor operating, measure the voltage across the motor contactor or starter contacts as is illustrated in figure 13-10. This measurement is made on each of the three phases from the line side of each phase to the load side of the same phase as per the diagram below. This is done for all three phases in the same manner. An accurate digital voltmeter works best, as the voltage may be small. Good contacts show no voltage reading.

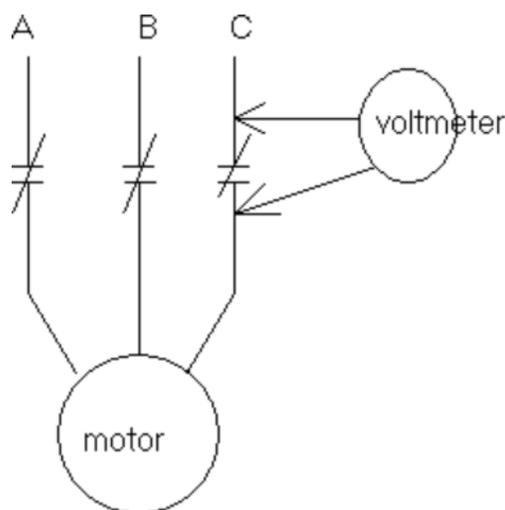


Figure 13-10

Check for voltage across each contact with the motor running. No voltage should be present. Even a small voltage indicates a poor contact.

Any poor connection, dirty or corroded contacts, or badly pitted contacts are a point of circuit resistance. Resistance drops voltage, as may be the case across starter contacts. This voltage drop can be measured by a voltmeter and may be the cause of unequal voltages to each leg or phase of the motor. It only takes one bad contact to cause the imbalance. No voltage should be noticed across any closed contact. If voltage is measured across any contact, all three should be replaced. Do not attempt to clean contacts. The starter contacts are not the only possible locations of circuit resistance. Any connection in the line from the power company to the building transformer to the circuit breaker box to the motor itself may have a poor connection resulting in a voltage drop. The voltage dropped in the line is that much less voltage on that leg at the motor.

2) Internal motor winding problems or

3) Power company or building electrical problems.

These two possibilities are detected with one test. The test results show the problem to be one or the other. For this test amperage readings are taken on each phase, then the phases are rotated and a second set of amperage readings are taken. Comparing the two sets of readings indicates if the problem is the motor or the building power system. The following example in figures 13-11 and 13-12 illustrates the procedure;

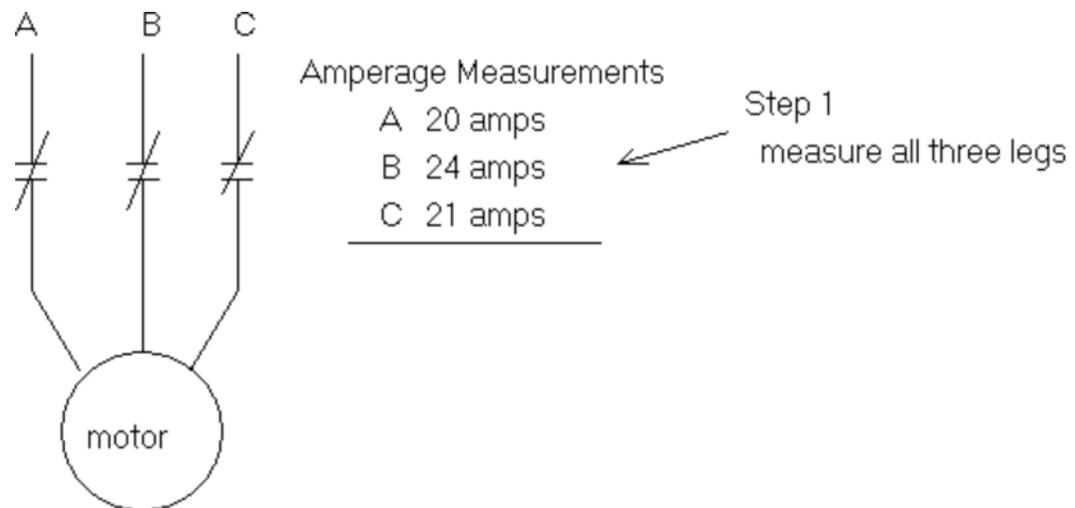


Figure 13-11

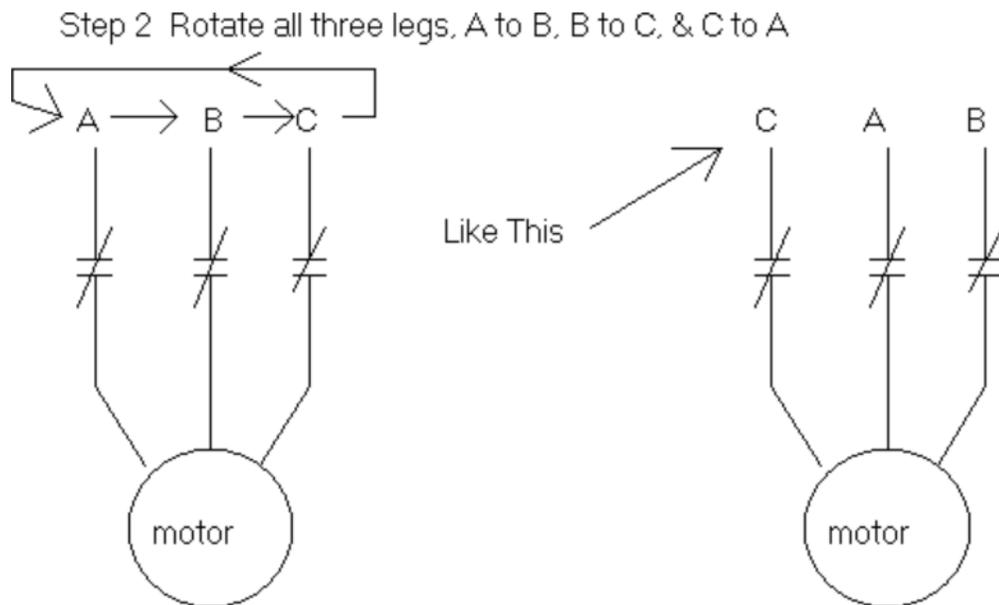


Figure 13-12

Step 3

Measure amperages again

C 21 amps
A 20 amps
B 24 amps

Notice that the amperages rotated with the wires. This means the problem is in the electrical supply, not the motor.

Had the amperages remained with the motor windings when the wires were rotated, the problem would have been in the motor.

If the imbalance is due to the supply as is in this example, a qualified electrician should be called in to rectify the problem before the motor is harmed. If the imbalance is due to the motor, the motor must be replaced. In the case of a hermetic or semihermetic compressor, it is essential that the compressor not be operated or a burnout may occur and the costs to repair will be much greater than necessary.

Anytime a motor fails the attending technician should check for voltage and current imbalance. Just replacing a failed motor may not solve the problem; a supply line problem may exist and may have caused the initial motor failure. Don't be a technician who just replaces parts, find the cause of the failure, use these methods of failure analysis. The technician who can locate these kinds of problems is a real professional and is often called upon to solve problems others are unable to work out.

Changing the motor may not solve the problem; the problem may not be the

motor but rather the three-phase supply to the motor. An analysis of the imbalance as explained here will determine if the motor or the supply line is the actual cause of the problem.

This article was extracted from a larger work by the same author.

Norm is a technical writer, seminar speaker and test proctor for EPA, 410A and ESCO & NATE certifications.

He can be contacted at nchristo@juno.com

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