Automatic Transfer Switch Option Closed Differential Undervoltage Protection Technical Bulletin

Introduction

UL 1008, the standard under which almost all automatic transfer switches in the US are manufactured, states that an Automatic Transfer Switch (ATS) shall

> "initiate transfer from the normal supply to the alternate supply upon the interruption of any or all phases of the normal supply."

Lake Shore Electric Corporation accomplishes this by providing a Closed Differential Under Voltage and Voltage Unbalance sensing relay (Model 26220), on the normal supply, as a standard feature in all automatic transfer switches.

Undervoltage Protection

a. "Why is it Necessary?"

An improper voltage condition on a single or three phase power system may have several harmful effects, particularly when motor loads are involved. This article will refer to three phase systems since motor loads are predominantly used in such systems.

b. Effects of Undervoltage

During startup, a low voltage condition will produce a lower starting current and starting torque. Although a lower starting current may be desirable, a lower starting torque may not be acceptable. The torque produced by a motor is approximately proportional to the square of the voltage applied, that is, a motor that is started at 90% of rated voltage will produce 81% of rated torque; $(.90)^2$. This may not be capable of starting the load.

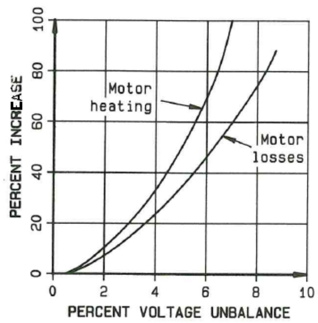
If the undervoltage condition occurs while the motor is running, the result is a lower running torque, as described above, and a higher line current. The reason for the increased line current is as follows: a lower line voltage at a given load produces an increased slip. The increased slip produces a higher line current. The reason the starting current is reduced with a lower line voltage is because the slip at starting is unity; it cannot get any worse, therefore the starting current is proportional to the starting voltage.

c. Effects of Voltage Unbalance

Another less mentioned and much more harmful condition to motors is voltage unbalance. Voltage unbalance creates a decrease in efficiency, decrease in power factor, large increase in current, large temperature increase and a decrease of insulation life.

Voltage unbalance is defined as a percentage equal to 100 times the maximum deviation from the average voltage divided by the average voltage. Therefore, a system with phase voltages of 205, 216, and 208 has an average voltage of 209.7 and a maximum deviation of 6.3 thus giving it a voltage unbalance of 3%.

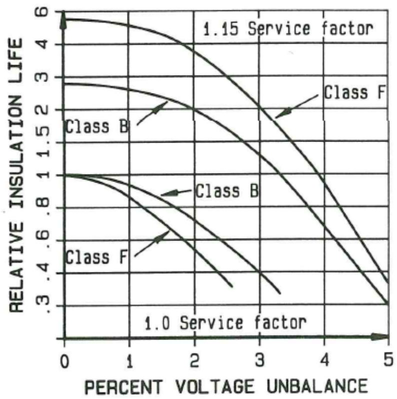
Unbalanced voltages applied to an induction motor will cause unbalanced currents to flow. The increase in temperature in the phase with the greatest current will be approximately two times the square of the percentage of voltage unbalance. The effects of voltage unbalance to increased motor temperature are shown in Figure 1.



EFFECT OF VOLTAGE UNBALANCE ON MOTOR HEATING AND LOSSES

Figure 1

This increase in temperature, created by the voltage unbalance, creates a decrease in insulation life as shown in Figure 2.



EFFECT OF VOLTAGE UNBALANCE ON MOTOR INSULATION LIFE

Figure 2

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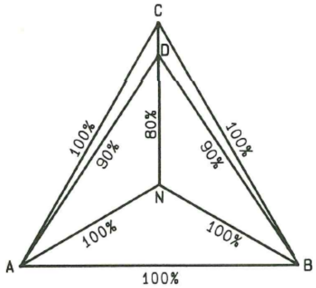
d. Protection

Undervoltage and voltage unbalance protection is necessary to prevent the harmful effects as described above.

Undervoltage relays are typically of the close-differential type, that is, all three phases of the three phase source must attain a value equal to, or greater than, the pickup setting of the undervoltage relay before it's contacts change state. This value is typically set at 90% of nominal voltage since the utility supply can stabilize at anywhere from ± 10% of nominal voltage. Once energized, the relay will not de-energize until any one of the three phases falls below the dropout setting of the undervoltage relay. This value is typically set at 80% of nominal voltage, however, this is where undervoltage relays differ. Many undervoltage relays strictly sense line to line voltage, while a Lake Shore Electric Corporation undervoltage relay generates an internal neutral, allowing it to sense a line to neutral voltage even in a three phase, three wire system.

This is important for detecting a voltage unbalance condition.



VECTOR DIAGRAM OF A
3 PHASE VOLTAGE SOURCE

Figure 3

Consider Figure 3. Triangle ABC represents a balanced voltage source. Triangle ABD represents a three phase system in which one phase has dropped to 80% of its nominal voltage, giving this system a 6.1% unbalance. A line to line sensing undervoltage relay set at 90% pickup and 80% dropout would monitor the following voltages:

AB = 100%; BD = 90%; DA = 90%

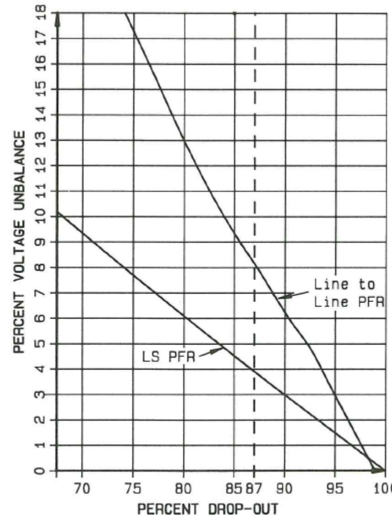
Since all three phases are equal to or greater than 90%, this relay would energize, indicating a proper voltage condition.

Now consider a Lake Shore Electric Corporation relay set at 90% pickup and 80% dropout. Since it generates its own neutral, it would monitor the following voltages:

NA = 100%; NB = 100%; ND = 80%

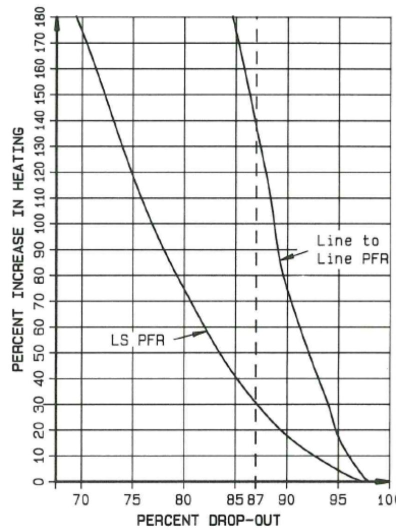
Since all three phases are not equal to or greater than 90%, this relay would not energize, indicating an improper voltage condition. If all three phases are reduced in a balanced manner, both types of relays will behave identically.

The dropout point of a Lake Shore Electric Corporation three phase voltage sensing relay can be set to protect a system for a given voltage unbalance as shown in Figure 4 and thereby protect the motors connected to this load from the severe overheating associated with this voltage unbalance as shown in Figure 5. A line to line type of voltage sensing relay (also shown in Figure 4) cannot accomplish this because the dropout point would have to be set so high it would cause nuisance undervoltage indications.



DROPOUT SETTING VERSUS PERCENT
VOLTAGE UNBALANCE

Figure 4



DROPOUT SETTING VERSUS PERCENT INCREASE
IN MOTOR HEATING

Figure 5

The vertical line in Figure 4 and Figure 5 indicates the protection undervoltage relays provide against voltage unbalance when it is calibrated for an 87% dropout. The Lake Shore Electric Corporation voltage sensing relay will dropout on a 4% voltage unbalance, thus limiting the motor overheating to 32% above normal. A line to line type voltage sensing relay with the same dropout point will not dropout until the system has an 8.5% voltage unbalance, thus allowing a 140% above normal temperature rise on any motors connected to this system.

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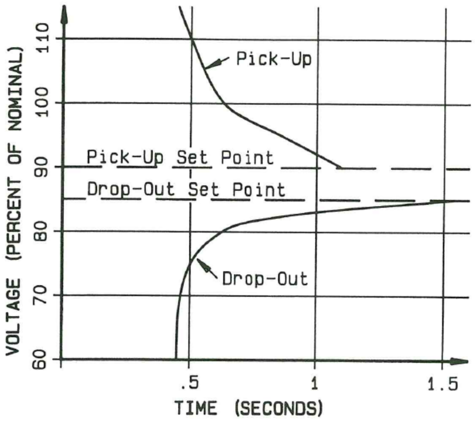
The Lake Shore Electric Corporation undervoltage relay is also equipped with an inverse time delay on both "pickup" and "dropout", as shown in Figure 6. This time delay helps avoid nuisance undervoltage indications as may occur during system transients. The inverse time characteristic allows a 1.5 second delay before the relay de-energizes when any phase falls just below the dropout setting. A .4 second delay occurs when any phase falls well below the dropout setting (20% or more).



TIME DELAY CHARACTERISTICS OF A LAKE SHORE
3 PHASE VOLTAGE SENSING RELAY

Figure 6

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