

## Motor Protection

### Voltage Unbalance & Single-Phasing

**For Summary of Suggestions to Protect Three-Phase Motors Against Single-Phasing see the end of this section, page 137.**

Historically, the causes of motor failure can be attributed to:

Overloads	30%
Contaminants	19%
Single-phasing	14%
Bearing failure	13%
Old age	10%
Rotor failure	5%
Miscellaneous	9%
	100%

From the above data, it can be seen that 44% of motor failure problems are related to HEAT.

Allowing a motor to reach and operate at a temperature 10°C above its maximum temperature rating will reduce the motor's expected life by 50%. Operating at 10°C above this, the motor's life will be reduced again by 50%. This reduction of the expected life of the motor repeats itself for every 10°C. This is sometimes referred to as the "half life" rule.

Although there is no industry standard that defines the life of an electric motor, it is generally considered to be 20 years.

The term, temperature "rise", means that the heat produced in the motor windings (copper losses), friction of the bearings, rotor and stator losses (core losses), will continue to increase until the heat dissipation equals the heat being generated. For example, a continuous duty, 40°C rise motor will stabilize its temperature at 40°C above ambient (surrounding) temperature.

Standard motors are designed so the temperature rise produced within the motor, when delivering its rated horsepower, and added to the industry standard 40°C ambient temperature rating, will not exceed the safe winding insulation temperature limit.

The term, "Service Factor" for an electric motor, is defined as: "a multiplier which, when applied to the rated horsepower, indicates a permissible horsepower loading which may be carried under the conditions specified for the Service Factor of the motor."

"Conditions" include such things as operating the motor at rated voltage and rated frequency.

Example: A 10Hp motor with a 1.0 SF can produce 10Hp of work without exceeding its temperature rise requirements. A 10Hp motor with a 1.15 SF can produce 11.5Hp of work without exceeding its temperature rise requirements.

Overloads, with the resulting overcurrents, if allowed to continue, will cause heat build-up within the motor. The outcome will be the eventual early failure of the motor's insulation. As stated previously for all practical purposes, insulation life is cut in half for every 10°C increase over the motor's rated temperature.

#### Voltage Unbalance

When the voltage between all three phases is equal (balanced), current values will be the same in each phase winding.

The NEMA standard for electric motors and generators recommends that the maximum voltage unbalance be limited to 1%.

When the voltages between the three phases (AB, BC, CA) are not equal (unbalanced), the current increases dramatically in the motor windings, and if allowed to continue, the motor will be damaged.

It is possible, to a limited extent, to operate a motor when the voltage between phases is unbalanced. To do this, the load must be reduced.

Voltage Unbalance in Percent	Derate Motor to These Percentages of the Motor's Rating*
1%	98%
2%	95%
3%	88%
4%	82%
5%	75%

\*This is a general "rule of thumb", for specific motors consult the motor manufacturer.

#### Some Causes of Unbalanced Voltage Conditions

- Unequal single-phase loads. This is why many consulting engineers specify that loading of panelboards be balanced to  $\pm 10\%$  between all three phases.
- Open delta connections.
- Transformer connections open - causing a single-phase condition.
- Tap settings on transformer(s) not proper.
- Transformer impedances (Z) of single-phase transformers connected into a "bank" not the same.
- Power factor correction capacitors not the same, or off the line.

#### Insulation Life

The effect of voltage unbalance on the insulation life of a typical T-frame motor having Class B insulation, running in a 40°C ambient, loaded to 100%, is as follows:

Voltage Unbalance	Insulation Life	
	Service Factor	Service Factor
0%	1.00	2.27
1%	0.90	2.10
2%	0.64	1.58
3%	—	0.98
4%	—	0.51

Note that motors with a service factor of 1.0 do not have as much heat withstand capability as do motors having a service factor of 1.15.

Older, larger U-frame motors, because of their ability to dissipate heat, could withstand overload conditions for longer periods of time than the newer, smaller T-frame motors.

#### Insulation Classes

The following shows the maximum operating temperatures for different classes of insulation.

Class A Insulation	105°C
Class B Insulation	130°C
Class F Insulation	155°C
Class H Insulation	180°C