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On-line technologies permit assessment of the entire motor system to facilitate troubleshooting.

Maintenance experts agree that excessive heat causes rapid deterioration of motor winding insulation. The common rule states that insulation life is cut in half for every 10 C of additional heat to the windings. As an example, if a motor that would normally last 20 years in regular service is running 40 C above rated temperature, the motor would have a life of about 1 year.

Leading standardization organizations have concluded that 30 percent of motor failures are attributed to insulation failure and 60 percent of these are caused by overheating. Articles have been published stating that a significant cause of bearing deterioration is overheating.

There are typically five main reasons for overheating—overload, poor power condition, high effective service factor, frequent stops and starts, and environmental reasons.

Overload conditions

Stator current is frequently used to measure load level, but load level can easily be masked by an overvoltage condition. A common mistake is made in operating at an overvoltage to reduce the stator current and to reduce the introduction of heat. It has been shown that for motors ranging from 10-200 hp, operating at a 10 percent overvoltage would typically decrease losses by only 1-3 percent.

Even though the motor current may vary when applying overvoltages, the excessive damaging heat in the motor will not improve. A load error of more than 10 percent can be introduced by relying on stator current readings to access probable load and heat levels. Under full load conditions, this is the difference between life and death to a motor.

For example at a coal-fired power plant in the United States, a 7000 hp 6.6kV motor was running with only 7 percent overcurrent, but an 8 percent overvoltage. Two identical applications had undergone unscheduled outages in the previous 12 months. A mild overload was identified by examining the stator current of this motor. However, after looking at the true load to the motor, an overload of nearly 20 percent was discovered. This explains why these motors were failing. The repair for each of these three motors ran into the hundreds of thousands of dollars.

In industrial applications, perfect voltage conditions are rare. Losses, not current levels alone, are the true source of heat. These losses are a destructive factor to windings and a significant reason for bearing damage.

This justifies the need for accurate knowledge of operating load level. Only accurate load level calculations can give reliable measurements of excessive losses and overheating in the motor.

Power condition

Electric motors in manufacturing plants generally need to be derated because of poor power conditions in order to maximize their useful life. NEMA MG-1 Sections II and IV specify what voltage quality, as a function of balance and distortion, allows what level of percentage load. Fig. 1 shows the NEMA derating curve for percentage of unbalance. According to the derating curve, the higher the level of unbalance, the lower the acceptable level of steady state load. For example, if a 100 hp motor has an unbalance factor of 3 percent, the motor should be derated to 0.88 or 88 percent of capacity, 88 hp.

The frequent use of variable frequency drives (VFDs) can result in detrimental effects to electric motors because of the condition of power in manufacturing facilities. Fig. 2 shows the voltage that a VFD, running at almost a 6-pulse mode, will send to the motor. The distorted currents are the motor's reaction to poor power condition. Severe distortions are evident. This scenario shows a NEMA derating of 0.7 which allows the motor to be operated at only 70 percent output.

Effective service factor

T he key to finding the most frequent causes of overheating is accuracy in estimating load level. This can be identified by looking at only currents and voltages. The formula for calculating effective service factor is:

$$\frac{\%\ \text{load}}{\%\ \text{NEMA derating}}$$

Effective service factor provides predictive maintenance professionals a solid conclusion of

stress on any particular motor load application.

In another example, data gathered using a dynamometer showed a 300 hp motor under test was running a nearly full load, 99.7 percent. Voltage distortion was poor due to a previously unidentified silicon controller rectifier defect in the power supply. The resulting NEMA derating factor of 0.85 results in an effective service factor of 1.17, which signaled an alarm condition.

Regardless of nameplate service factor, any motor operating above 1.0 service factor is under stress. A higher service factor signifies the motor's capability for overload for short periods of time, not higher steady state operating capabilities. Poor voltage conditions are frequent and can be caused by a variety of reasons. NEMA specifies which load level is permitted for poor voltage conditions. On-line monitoring tools capable of accurately calculating operating load ensure plant operation within appropriate limits.

Frequent starts and stops

Table 1 displays the maximum number of starts and stops for line-operated motors as a function of their rating and speed. Limiting the frequency of startup, the most stressful portion of motor operation, is highly important.

Many well-documented cases of recurring motor failure were addressed by increasing the horsepower rating of the motor which shortened the time between failures. However, the root cause of the failure was actually the frequency of starts and stops. The key is to closely monitor the number of starts—hourly for small or medium motors and daily for larger motors.

On-line testing can ensure full compliance to professional standards. It can be used in identifying reasons for failure in operations that do not comply with standards by including these standards in long-term unsupervised monitoring operations.

Environmental conditions

Thermography is frequently used to determine the conditions where electric motors are being used. Poor cooling due to high ambient temperature, clogged ducts, etc., are typical examples of nonelectrically induced temperature stress on both the motor and insulation system. Chemical abrasive substances in the air, wet operation, and high altitude operation are a few common environmental stresses.

Test to standards

Bearing and winding failures are the most common motor failures. The fundamental reason usually is excessive heat. Preventive maintenance practices frequently limit on-line electrical measurements to interpreting current levels. While important, this method is inconclusive in identifying failures caused by excessive winding heat. The best way to ensure successful preventive maintenance and monitoring is to test according to NEMA and other professional standards. Automated assessment is necessary to effectively ensure motor health. **MT**

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Fig. 1. NEMA derating curve. This figure is also defined in the formula.

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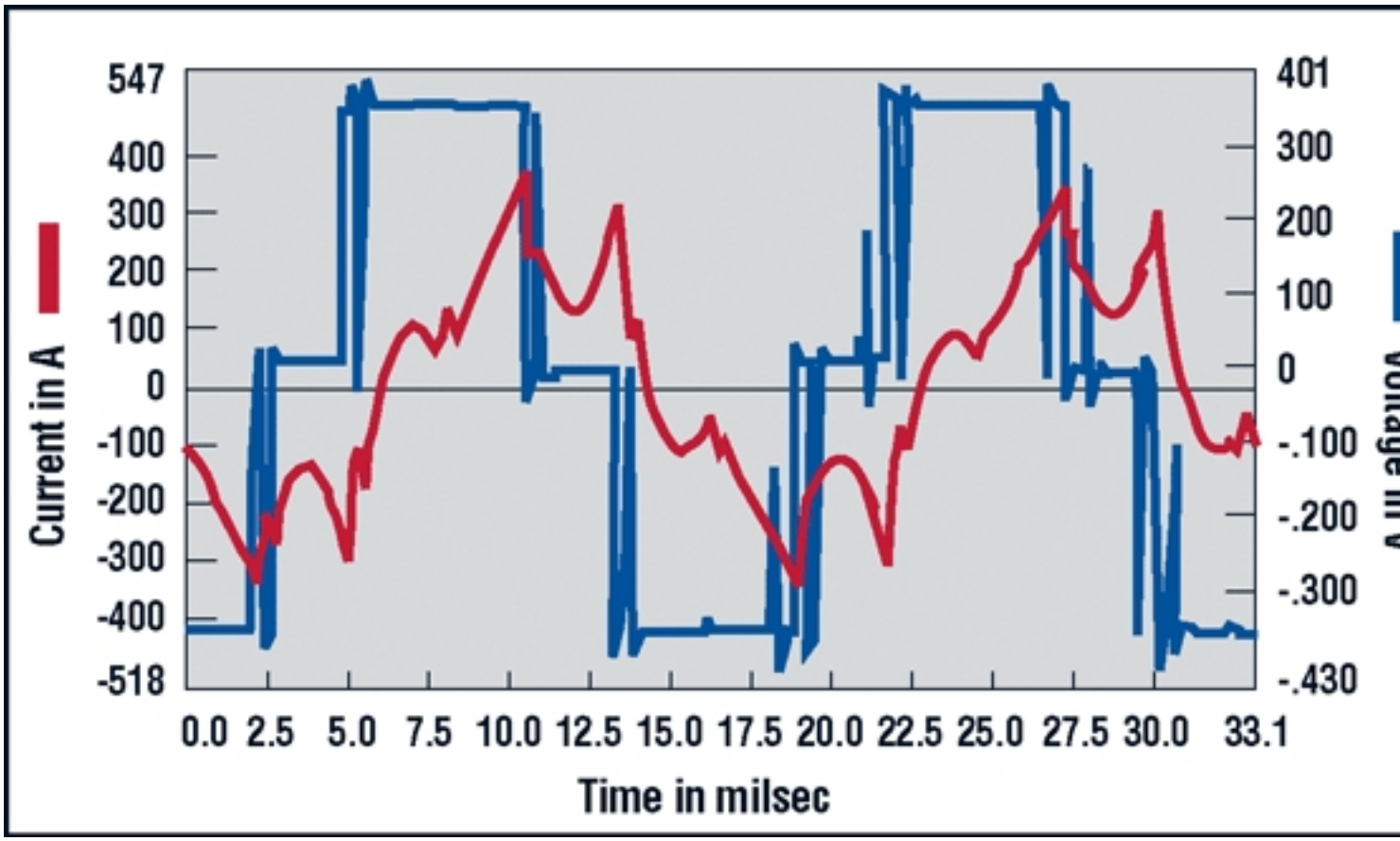

Fig. 2. Extreme distortion with a slow switching VFD (50 hp, 4-pole)

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Table 1. Maximum number of starts and stops for line-operated motors as a function of their rating and speed.

HP

2-pole

4-pole

6-pole

A

C

A

C

A

C

1

15

75

30

38

34

33

5

8.1

83

16.3

42

18.4

37

10

6.2

92

12.5

46

14.2

41

15

5.4

100

10.7

46

12.1

44

20

4.8

100

9.6

55

10.9

48

50

3.4

145

6.8

72

7.7

64

75

2.9

180

5.8

90

6.6

79

100

2.6

220

5.2

110

5.9

97

200

2

600

4

300

4.8

268

250

1.8

1000

3.7

500

4.2

440

A = Maximum number of starts/hr
C = Minimum rest or off time in seconds between starts

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