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IEEE Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines

Sponsor

Electric Machinery Committee
of the
IEEE Power Engineering Society

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Abstract: Thermal limit curves for induction machines are defined. A procedure is established for the presentation of these curves, and guidance for the interpretation and use of these curves for machine thermal protection is provided.
Keywords: machine thermal protection, rotor cage windings, stator cage windings, thermal limit curves, three-phase squirrel cage induction machines

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Introduction

(This introduction is not part of IEEE Std 620-1996, IEEE Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines.)

This revision of IEEE Std 620-1987 was initiated by the Induction Machinery Subcommittee of the Electric Machinery Committee of Power Engineering Society. The standard was originally issued in 1981 for trial-use only and had expired. Further, it was felt that the revised standard of 1987 needed to be issued as a guide.

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Contents

IEEE Guide for the Presentation of Thermal Limit Curves for Squirrel Cage Induction Machines

1. Overview

1.1 Purpose

This guide defines thermal limit curves for induction machines, establishes a standard procedure for the presentation of these curves, and provides guidance for the interpretation and use of these curves for machine thermal protection.

1.2 Scope

This guide applies to three-phase squirrel cage induction machines, 250 hp (200 kW) and above. It is intended to be used for machines designed for specified load and application conditions. However, it may also be used for smaller, general purpose machines if application and load conditions are specified.

CAUTION
The portion of the thermal limit curves dealing with locked rotor and running overload conditions applies to all applications for a given machine. The acceleration portion of the curves when requested can be provided only if the user supplies load inertia (Wk^2), the load speed-torque curve, and the starting voltage.

2. Thermal overloads

2.1 Causes

The stator and rotor cage windings of a squirrel cage induction machine may exceed design temperatures due to a number of reasons, some of which are as follows:

a) The machine may lock up, i.e., remain at zero speed with voltage applied to the stator winding, as might happen in the case of low starting voltage and/or mechanical malfunction.
b) The machine may start but fail to accelerate to its running speed, due to inadequate accelerating torque at some speed lower than the breakdown torque point, causing it to run at that subsynchronous speed.
c) The machine may be overloaded continuously at close to its operating speed.

Under the locked-rotor condition, there is normally no ventilation, and the heat loss from the windings is by conduction and radiation. During acceleration, depending on the speed, the heat loss is both by conduction and by the ventilating effect of air movement. During running overloads, the normal ventilation of the machine is the primary mode of cooling.

2.2 Effects

Under locked rotor conditions, the current in the windings is 4 to 8 times the rated full-load current, and the stator winding losses are approximately 16 to 64 times the rated losses. The rotor losses are higher still at high slip values because of the increase in rotor resistance due to skin effect. Up to the breakdown torque point during acceleration, the current reduces somewhat in magnitude from the locked rotor value as the machine accelerates, but it is still many times the rated value. The stator and rotor losses are therefore high during the acceleration period. The temperatures of the stator and rotor cage windings therefore rise rapidly during the locked-rotor and acceleration conditions. The current can be maintained at any of these high values for brief periods until the winding temperatures reach values beyond which insulation, and/or winding damage, could occur. At running conditions, the overloads can be maintained for relatively longer periods of time depending on individual designs, since the currents are not as high as during starting and acceleration. Some motor loss of life is, however, experienced with each overload exceeding the thermal limit.

A knowledge of the length of safe operating time for each one of these overcurrent conditions is necessary if protection against damage due to over-temperatures is to be provided. Thermal limit curves are the vehicle for providing such information.

2.3 Thermal limit curve

A thermal limit curve is a plot of the maximum permissible safe time versus line current in the windings of the machine under conditions other than normal operation. It represents the following three situations:

a) Locked rotor
b) Starting and acceleration
c) Running overload

The complete curve, representative of these three conditions for the winding (stator or rotor) with the shortest safe time, may be discontinuous and may consist of up to three segments (see figure 1).

The thermal limit curve is intended to be used in conjunction with the machine time-current curve for a normal start to set the machine protective devices for the thermal protection of the machine during starting and running conditions. The machine time-current curves, when available, are presented on the same plot as the thermal limit curves.

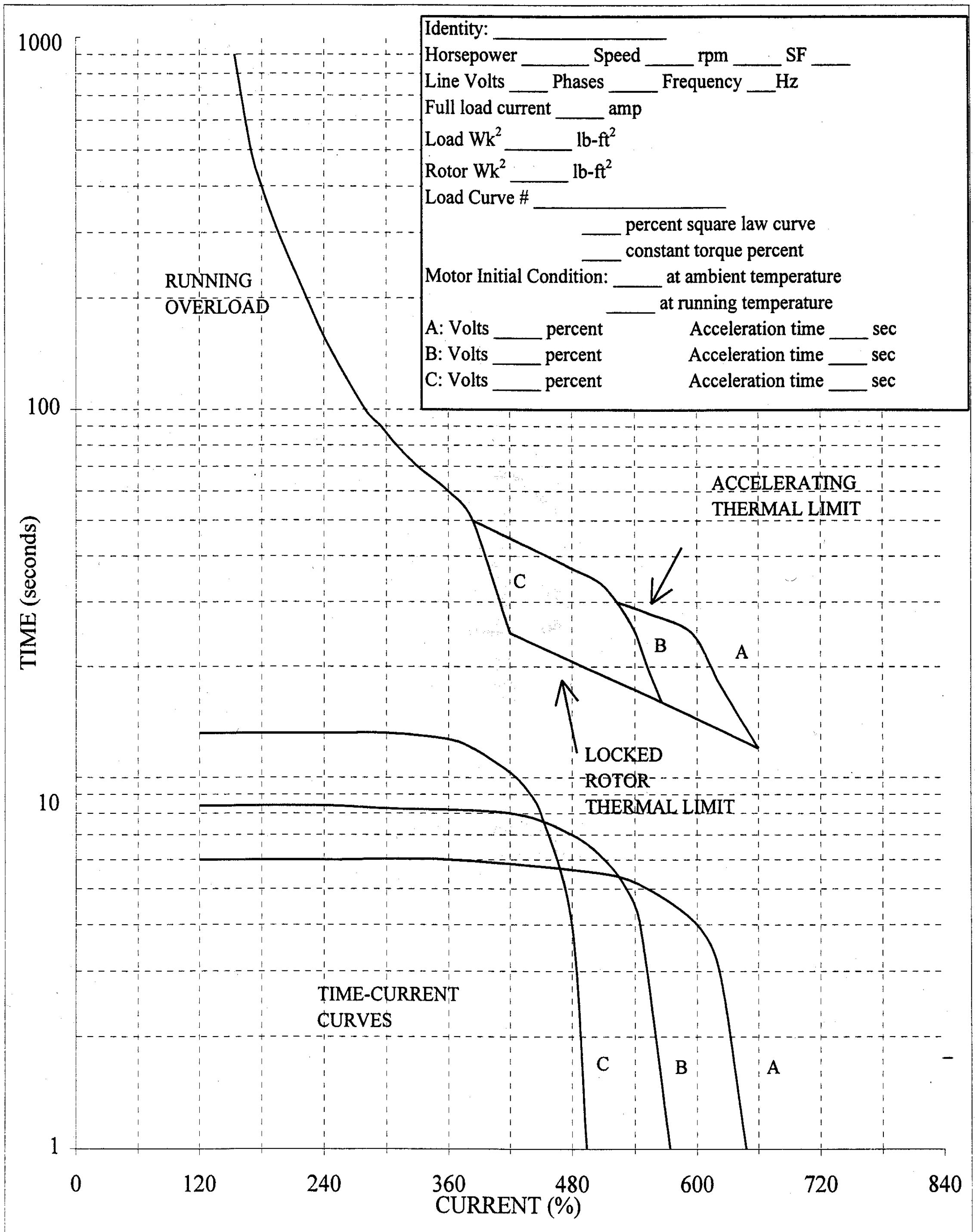

Figure 1—Typical thermal limit curves per IEEE 620-1996

3. Presentation

3.1 Dependent variables

The thermal limit curve shall be drawn with current as a percentage of the machine rated full-load current against the safe time in seconds.

3.2 Current scale

The current shall be plotted as the abscissa on a linear scale.

3.3 Time scale

Time shall be plotted as the ordinate on a multicycle logarithmic scale.

3.4 Conditions represented

The curve shall represent the following three conditions:

a) From approximately 60% of the locked rotor current to the rated locked rotor current, a safe locked rotor thermal capability curve shall be drawn that indicates the maximum length of time which the machine can stay locked without damage.

b) From the current at locked rotor to approximately the current at the breakdown torque point, a curve representing the thermal capability during acceleration shall be drawn.

c) From approximately the rated full-load current (or current at service factor load for motors with service factors) to current at approximately the breakdown torque, a motor running overload thermal capability curve shall be drawn.

The thermal limit curve may be continuous when a single curve adequately represents the data, or may be discontinuous with one or two breaks if necessary.

The thermal limit curves shall represent two initial conditions: the machine initially at ambient temperature, and the machine initially at the rated load operating temperature.

3.5 Acceleration curve

The motor acceleration time-current curve shall be plotted on the same graph as the thermal limit curve.

3.6 Curves at multiple voltages

When the motor is designed for starting at a voltage or voltages lower than the rated voltage, the thermal limit and the acceleration time-current curves shall be drawn for the rated voltage and for each of the lower voltages. These curves may be drawn on a single graph or on a series of graphs, one for each voltage. Curves for no more than three voltages may be represented on a single graph.

3.7 Additional information

The following information shall appear on the same figure as the thermal limit curves (see figure1) preceded by the legend “Thermal Limit Curves Per IEEE Std 620-1996”:

a) Machine identity
b) Horsepower
c) Service factor
d) Speed
e) Line voltage
f) Number of phases
g) Frequency
h) Rated full-load current
i) Load and motor rotor inertias (Wk^2)
j) Load speed torque curve—reference number or description such as one of the following:
    1) National Electrical Manufacturers Association (NEMA) standard
    2) xx percent square law curve
    3) yy percent constant torque curve
k) Motor initial thermal condition
    1) Cold
    2) Running temperature

4. Application

4.1 Caution

The thermal limit curves are not an indication of the overload capacity of the motor, and shall not be used as a basis for planned running overload operations. Repeated operation up to the thermal limit will reduce motor life. In some cases, this reduction may be significant. Continuous operation of the stator winding above the insulation limiting temperature can reduce the life by one-half for each 10 °C that the winding temperature exceeds this limiting temperature.

If it is intended to frequently run the motor at overloads, a motor with a larger rating should be considered.

4.2 Starting from reverse rotation

Starting from reverse rotation is not addressed by this guide. Such conditions shall be a matter of agreement between the user and the manufacturer.

4.3 Margins

A margin between the locked rotor thermal limit curve and the current time curve for acceleration is desirable but may not be achievable in all applications. In such cases as large motors starting at low voltages and/or accelerating high inertia loads, a margin between the acceleration thermal limit curve and the time current curve should be the norm. If these conditions cannot be met, consultation between the manufacturer and the user is recommended.

5. Bibliography

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