

APPLICATION GUIDELINE #11

(Thermal Damage Curves)

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Motors have two distinct segments which are quite different from each other. These segments are the rotor and the stator.

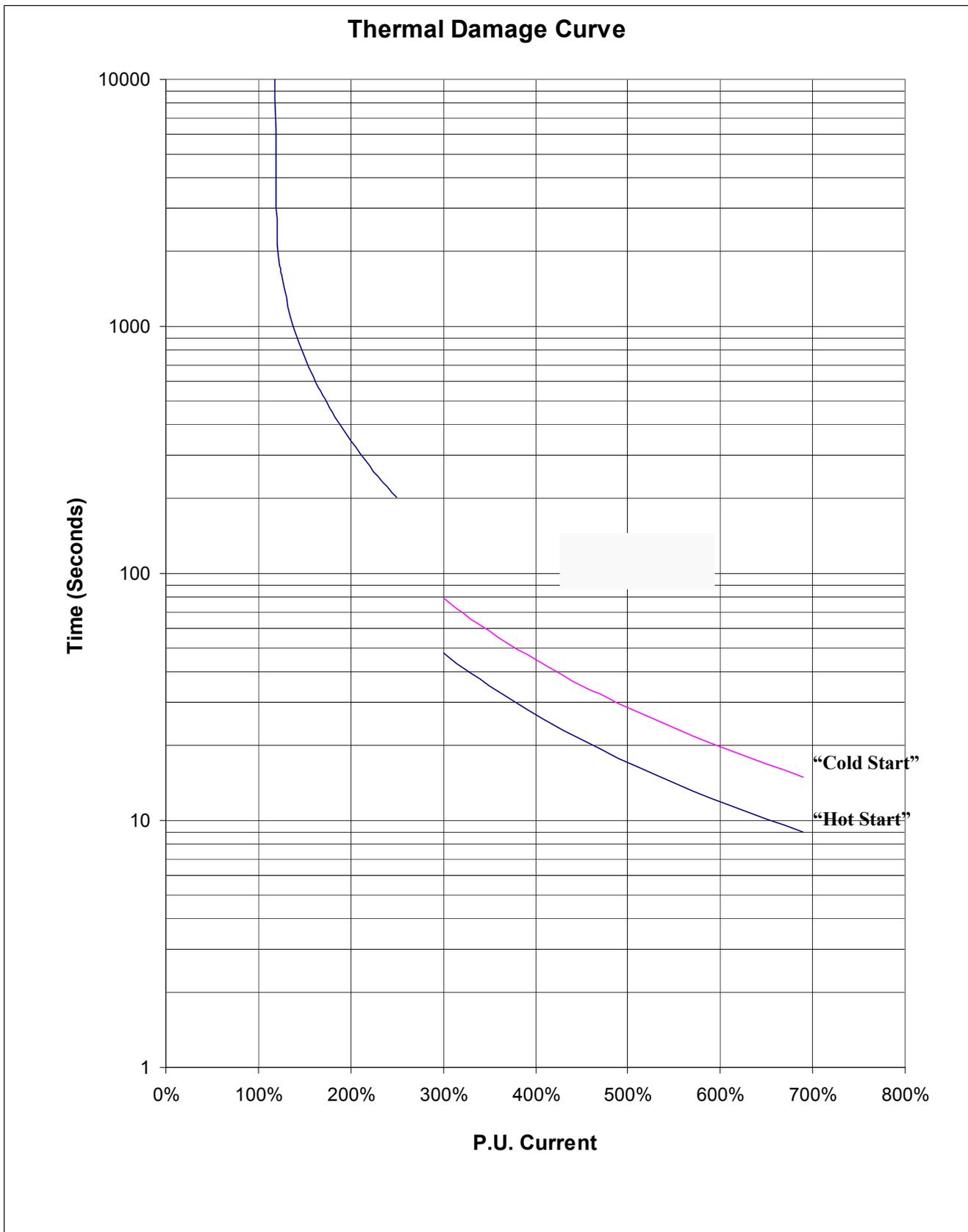
During starting (especially with high inertia load) and during a stalled or locked rotor condition, the rotor typically heats up much more quickly than the stator does. Due to skin effects, rotor current during a start (a very high slip, thus high frequency situation) flows primarily in the portion of the rotor bars closest to the surface of the rotor. The effective resistance of the rotor at start is approximately 3 times the effective full load operating condition's resistance. This means the I^2R heating is typically $6^2 \times 3 = 108$ times the normal full load heating effect. **Most motor failures are due to damaged rotors not damaged stator windings.** In fact, most motors that have damaged rotors, due to excessive starts, tend to have stator windings that are in good shape unless molten aluminum has spewed onto the end turns and damaged the windings. During an overload, the stator overheats more quickly than the rotor. Heating is caused by current flowing through the rotor and stator acting on the resistance. The long term concern with overheating in the stator is the degradation of the insulation life. Remember for every 10°C cooler, you double insulation life, and for every 10°C hotter your insulation life is halved.

Heat is power (P) which is volts times amps ($V \times I$). Volts is current times resistance ($I \times R$). It can be deduced that $P = I \times R \times I$ or I^2R . The total heating effect is power x time ($P \times t$) also expressed as $I^2R \times t$. Since every motor has different internal resistance characteristics the industry abbreviates this heating effect as I^2t . The I^2t term is used on motor thermal capability curves which describe the amount of current that a motor can sustain for how long. A Sample Thermal (I^2t) Curve for a Toshiba 400HP, 1800RPM, ODP Motor can be seen on the attached page. The "Running" portion of the curve is the overload portion which corresponds to normal operation of the motor up through approximately 250% overload. The "Cold Start" curve represents allowable current versus time when the motor is at ambient (or within 5°C of ambient). The "Hot Start" curve represents allowable current versus time based on the motor being operated at its full service factor loading (e.g. 1.15 times its HP rating).

From this curve you can extrapolate the cold stall time and hot stall time, which is approximately 15 seconds and 9 seconds respectively for this particular motor whose Locked Rotor Amps=690%. These times indicate the maximum amount of time this motor can be held in a stalled condition (locked rotor), without the motor suffering too large a degree of thermal damage. The degree of acceptable thermal damage may vary from manufacturer to manufacturer thus rendering the true thermal capability (stall time) of the motor subjective to the manufacturer. What is important to realize is that the less the amount of time a motor is kept in stall or a high current demand situation, the less the thermal exposure thus the better it is for the motor's overall life span.

NEMA MG1 states the following for stall time guidelines: "Polyphase motors having outputs not exceeding 500 horsepower and rated voltage not exceeding 1KV shall be capable of withstanding locked rotor current for not less than 12 seconds when the motor is initially at normal operating temperatures. Motors specially designed for inertia loads greater than those in Table 12-5 shall be marked on the nameplates with the permissible stall time in seconds."

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