# WHY CAN'T I START MY MOTOR?

## DEMYSTIFYING MOTOR RELAY LOCKOUTS

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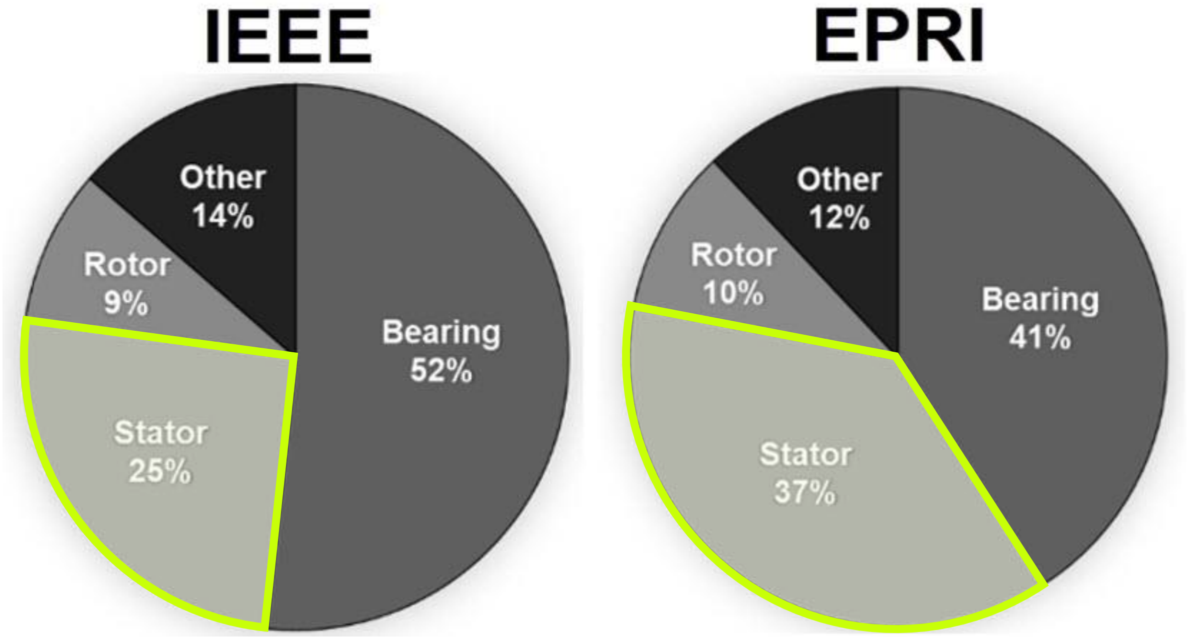
# Agenda

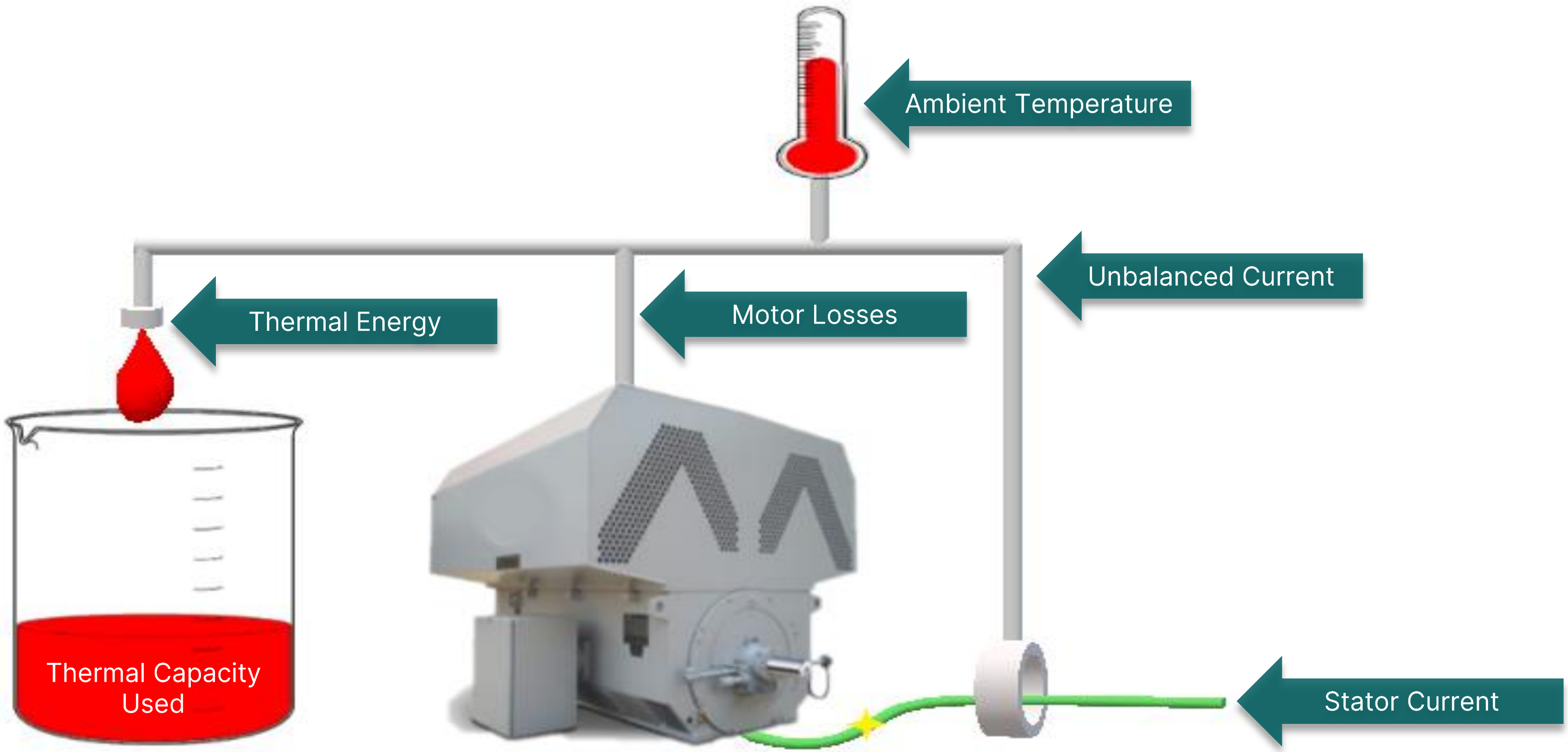
# Introduction

- Electric motors are the most abundant and critical machinery in plant operations
- Proper motor management is key to maximizing life expectancy and process uptime
- The second most common failure mode among medium-voltage motors is stator failure



# Motor Thermal Protection and Modeling

- What is Thermal Capacity Used (TCU)?

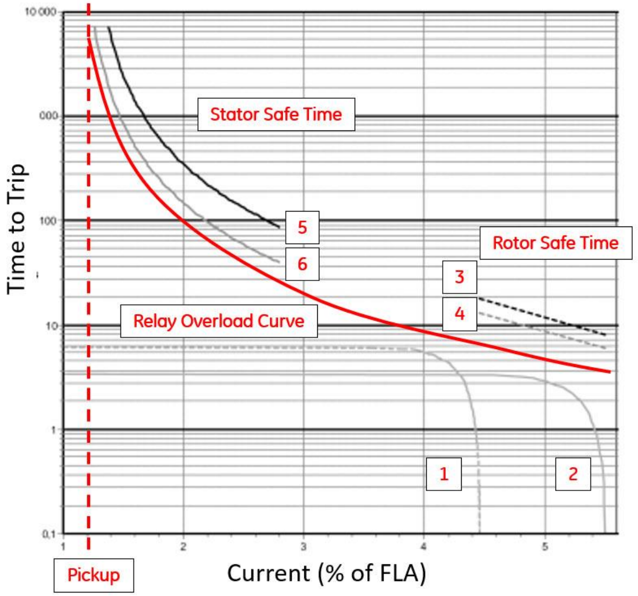


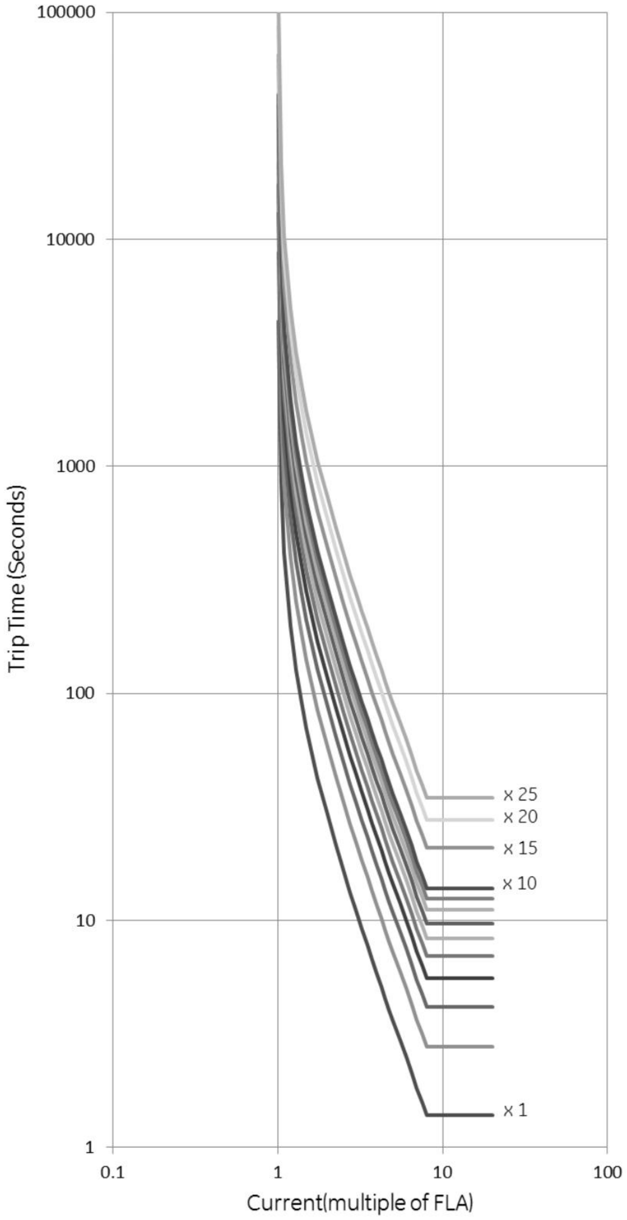

A trip occurs when the Thermal Capacity Used reaches 100%

# Motor Thermal Protection Parameters

- Overload Curve and Pickup
  - Also known as “curve number” or “time-dial multiplier” (TDM)
  - Typically set according to motor’s thermal limit curves
  - Relay will issue a trip when TCU reaches 100%
  - Pickup typically is set 10-15% above motor’s service factor

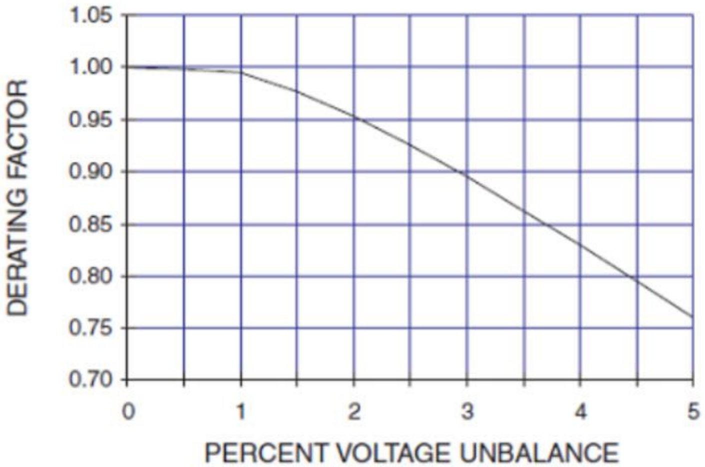
| SETTING [GROUP 1] | PARAMETER |
|---|---|
| Trip Function | Disabled |
| Overload Curve | Motor |
| Curve Effect | Cutoff |
| TD Multiplier | 1.00 |
| Unbalance Bias K Factor | 0 |
| Cool Time Constant Running | 15 min |
| Cool Time Constant Stopped | 30 min |
| Hot/Cold Safe Stall Ratio | 1.00 |
| RTD Bias | Disabled |
| RTD Bias Minimum | 40 °C |
| RTD Bias Center | 130 °C |
| RTD Bias Maximum | 155 °C |
| RTD Bias Pickup Delay | 2 s |
| RTD Bias Voting | Disabled |



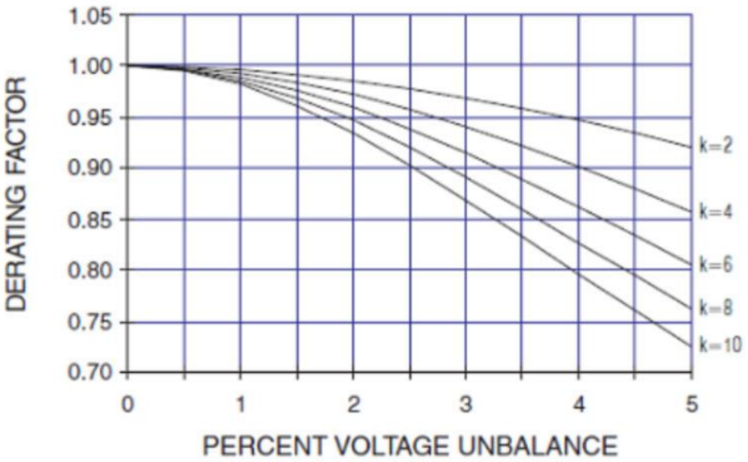



# Motor Thermal Protection and Modeling

- Unbalance Bias K Factor
  - Optional parameter to account for heating effect of unbalanced current
  - Otherwise, this is not considered in current-based thermal model
  - NEMA has provided recommended motor derating as a function of voltage unbalance
  - Calculated based on locked rotor current
    - $K = \frac{175}{I_{LR}^2}$ (1) $K = \frac{230}{I_{LR}^2}$ (2)
    - When locked rotor current is unknown, this setting should be disabled



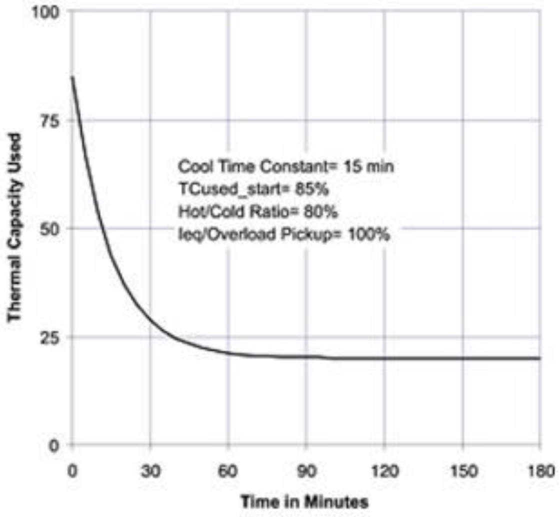
NEMA



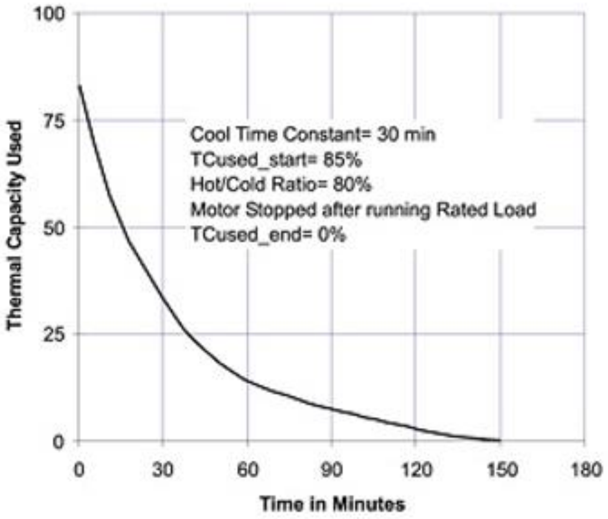
RELAY

# Motor Thermal Protection and Modeling

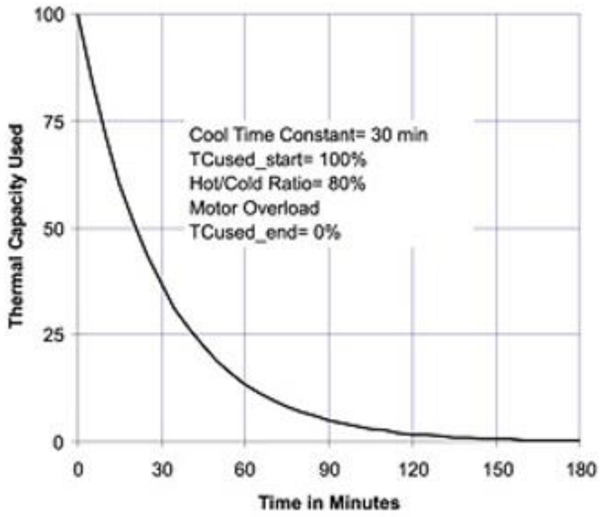
- Stopped and Running Cooling Time Constants
  - Emulate characteristics of motor cooling
  - In a running condition, cooling systems assist with motor cooling
  - In a stopped condition, the motor is at a standstill with less ventilation and slower cooling
  - Care should be taken when reviewing motor data sheet to see if *total cooling time* or *cooling time constant* is required by relay
    - Time constant is 1/5$^{th}$ of the total cooling time value




100% LOAD




MOTOR STOPPED

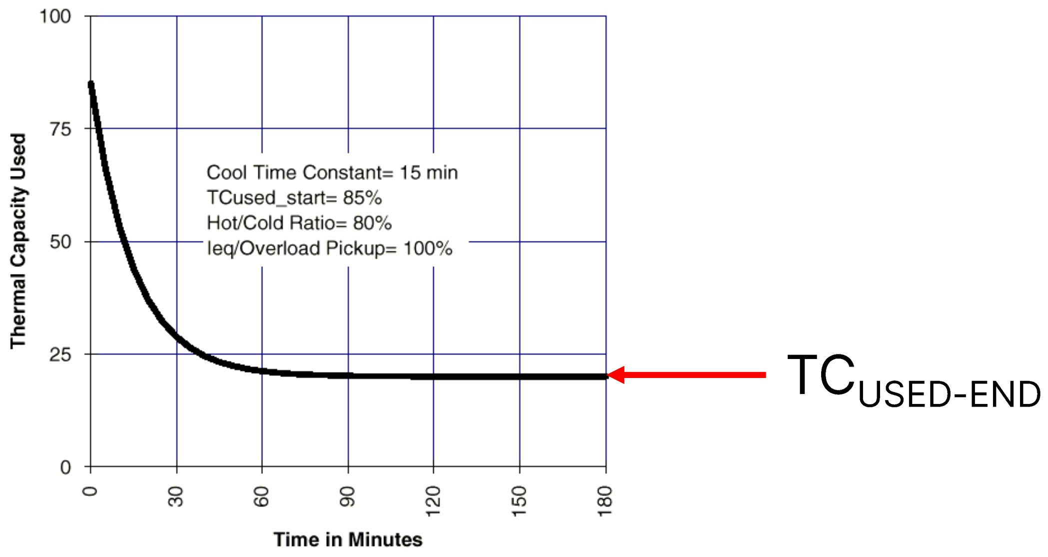



MOTOR TRIPPED

# Motor Thermal Protection and Modeling

- Hot/Cold Safe Stall Ratio
  - Distinguishes between a cold (ambient temperature) or hot (ambient + rated temperature rise) motor
  - This setting, in conjunction with load current vs. the pickup setting, will dictate the TCU motor will settle to during steady state operation
  - Determined by ratio of hot locked rotor time and cold locked rotor time
    - If no locked rotor times are provided, the feature should be disabled

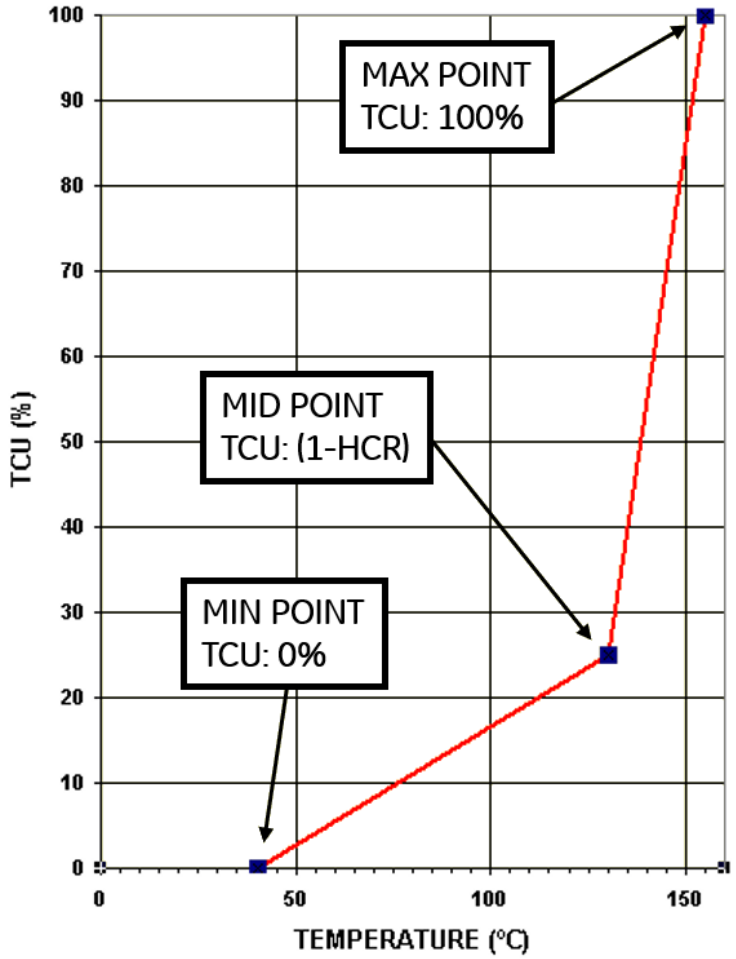
$$TCU_{end} = \left(\frac{I_{eq}}{OL \times FLA}\right)\left(1-\frac{hot}{cold}\right) \times 100\%$$



# Motor Thermal Protection and Modeling

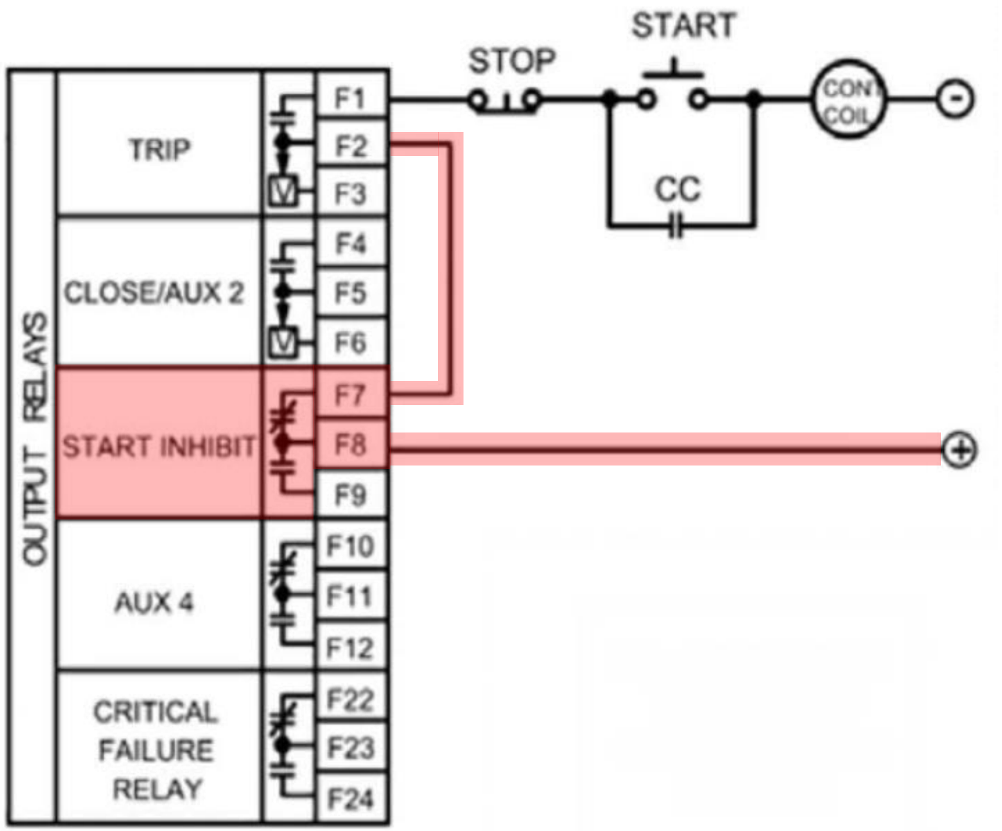
- RTD Biasing
  - Includes RTD measurements into thermal
  - When enabled, the relay registers a second TCU based on RTD measurements
  - If overload pickup is exceeded, the relay considers both the current-based TCU and RTD-based TCU
    - If RTD TCU is higher, the relay may issue a thermal trip quicker than if just the current-based TCU is used

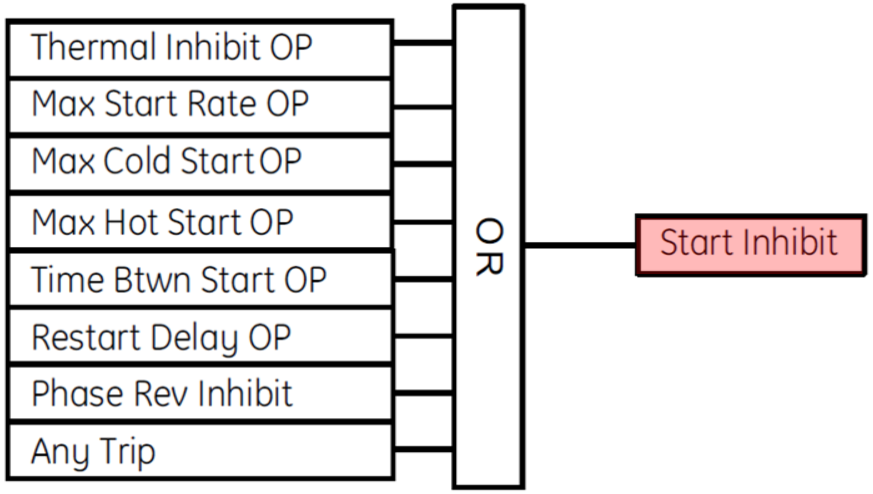
  - RTD Bias Minimum: Set to rated ambient temperature, or 40°C, if unspecified.
  - RTD Bias Center: Ambient temperature + rated temperature rise of stator + 10°C safety margin.
  - RTD Bias Maximum: Set at or slightly below stator insulation rating. E.g., Rating - 10°C.



# Motor Start Supervision

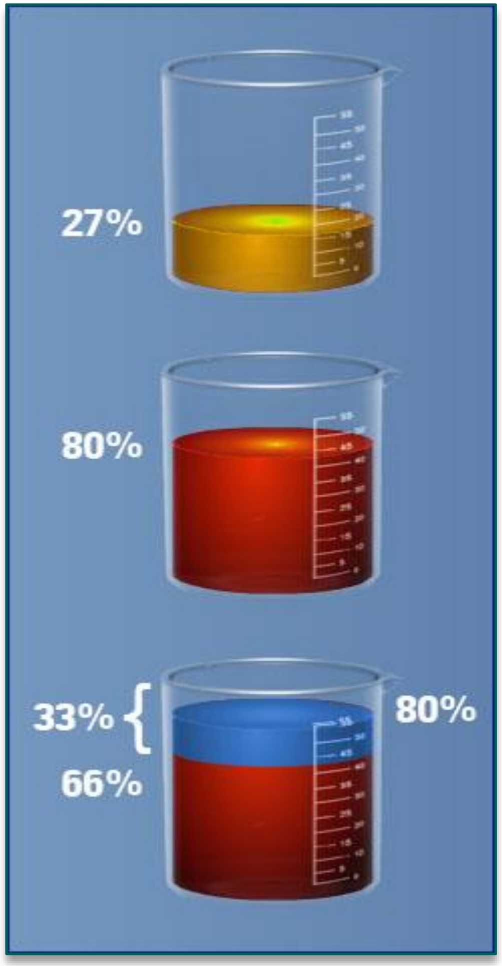
- Start Supervision
  - A Start Inhibit will open the "start" circuit to block a restart



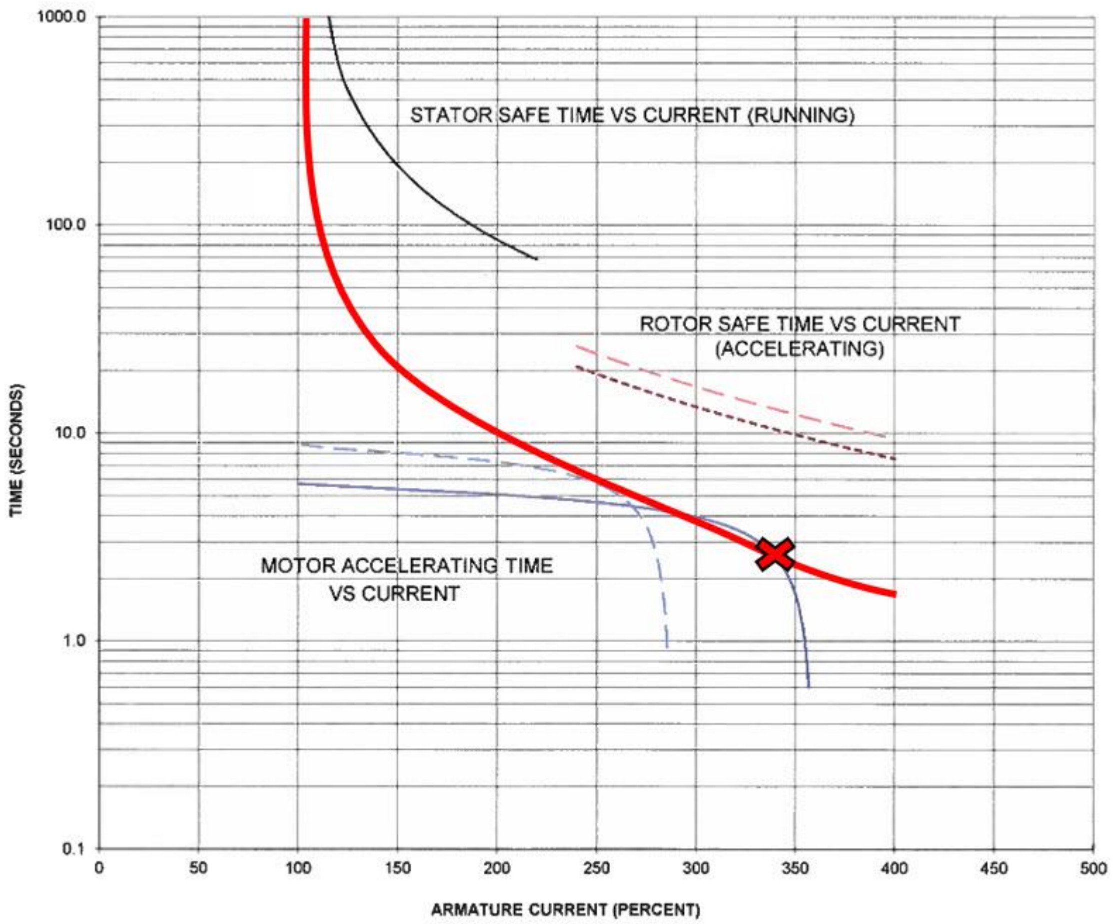
# Motor Start Supervision

- Ensures the motor cannot be restarted if it is already too hot
- Thermal Inhibit is the primary supervisory element of the relay’s TCU
  - Ensures enough thermal capacity is available to permit a motor restart
- Other Start Inhibits:
  - Maximum starting rate
  - Time between starts
  - Restart Delay



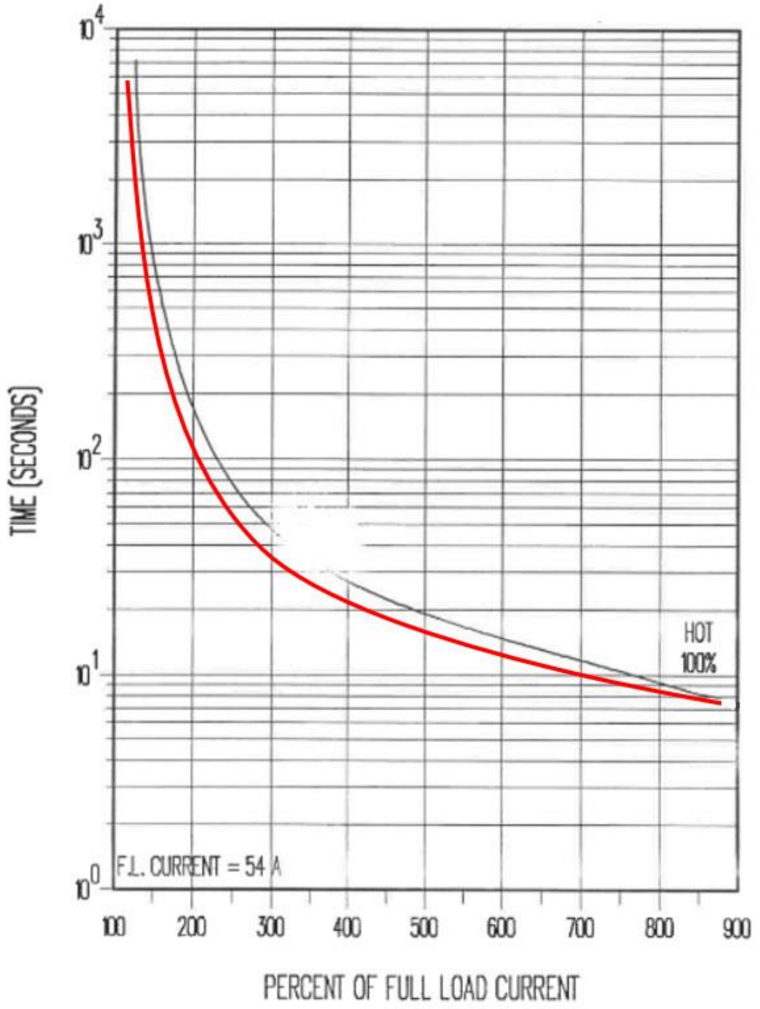
# Troubleshooting – Overload Curve Too Low

- Proper overload curve selection is vital
- Many cases where the overload curve is arbitrarily set to most conservative option, curve 1
- In the example, the relay overload curve (in red) intersects the motor acceleration curve
  - Total acceleration time is around 6s, but relay would trip in 2.5 sec
  - A higher overload curve is needed to allow operation
- Caution should be taken when troubleshooting relay settings



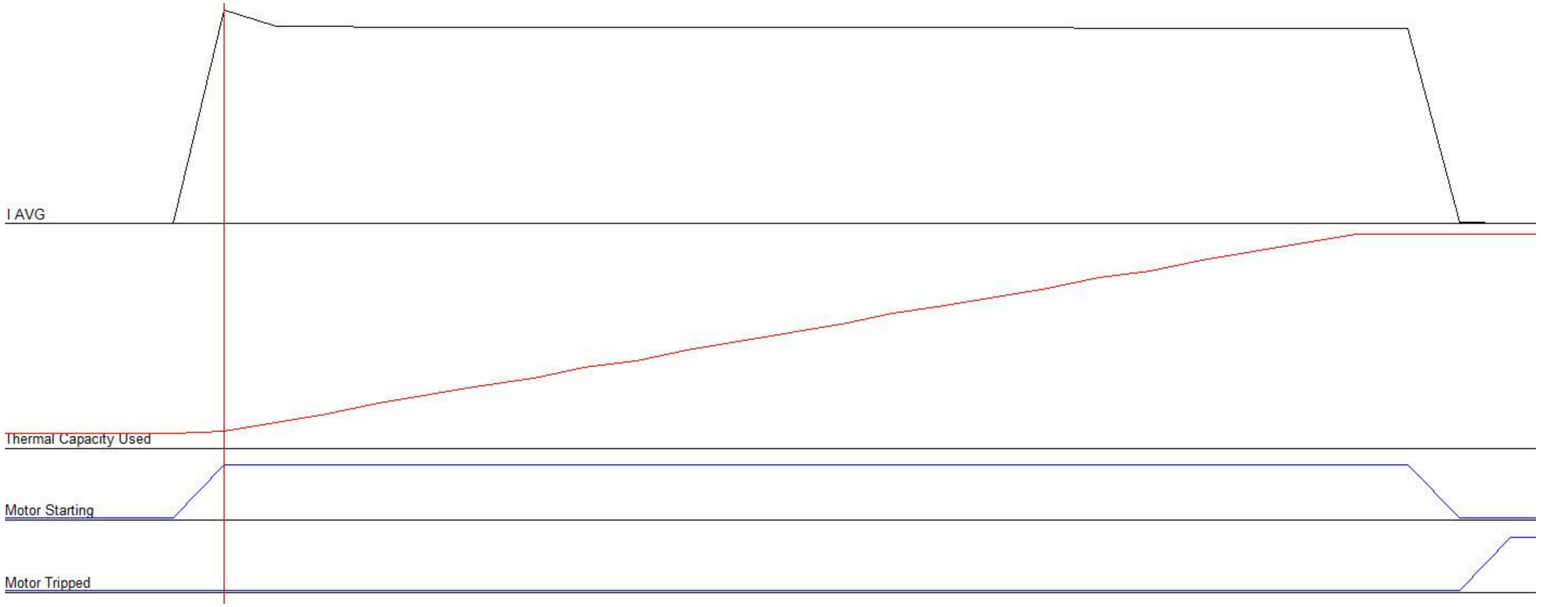
# Troubleshooting – Overload Curve Too Low

- Example of caution, where a facility could not start a motor
- The relay overload curve was set to 1
- After review of motor data, curve 4 was selected
  – Acceleration characteristics of the motor are not known, so the highest possible curve was selected, 4
- After the motor cooled, another start was attempted, and the relay tripped
- Relay diagnostic data was reviewed



# Troubleshooting – Overload Curve Too Low

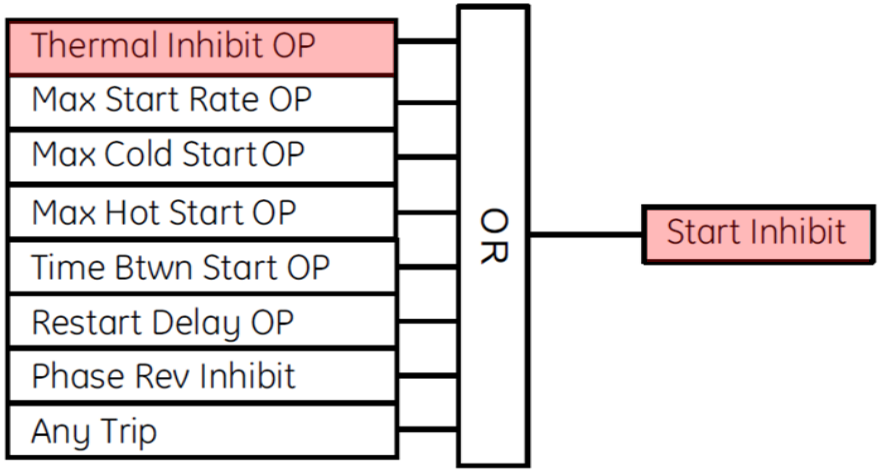
- Motor start data was captured by relay
- Log is approximately 9s
- Inrush current is seen but does not decrease during log
- Personnel noted the plant had 4 additional, identical motors, driving identical loads
  - All are protected by identical relays and relay configurations
  - All other motors start in 2.3s
- Recent major maintenance was performed on "suspect" motor
- Further examination revealed a mechanical problem of the motor




Ultimately, the relay was fulfilling its intended purpose, to protect the motor

# Troubleshooting – Total Cooling Time vs. Cooling Time Constant

- Example, a relay's running and stopped cooling time *constants* were set as 100 and 200 minutes, respectively
- A thermal trip occurred, and the relay indicated a thermal lockout
- Personnel let the motor cool overnight
- Upon return the next morning, the relay still indicated a thermal lockout
- After reviewing relay settings and the motor datasheets, it was determined the listed specifications were for *total cooling times*
  – Time constants are less by a factor of 5
- With total cooling time entered into relay's settings, this resulted in a total lockout time of 200 x 5 = 1000 minutes ( approximately 16.6 hours! )
- After the setting was corrected, no additional excessive lockouts occurred



# Troubleshooting – Incorrect Hot/Cold Safe Stall Ratio

- A possible oversight is to calculate ratio of *cold/hot* stall times instead of *hot/cold*
- This could cause the TCU to settle at an inversely high value
- For example, if the ratio was supposed to yield 0.87 but was incorrectly calculated to be 0.13
  - Steady state TCU would settle at 87% (calculated as 1-hot/cold ratio)
  - If a motor start only consumed 20% TCU, the TCU would then slowly rise to 87%
  - This would reduce the time to trip if an overload condition occurred and produce a potential undesired operation

# Troubleshooting – RTD Biasing and Failed RTDs

- RTD voting and time delay can be implemented to prevent misoperation
- On a motor relay with RTD biasing enabled, personnel noted a consistent thermal lockout
- The TCU registered the by relay was abnormally high with no apparent cause
  - Relay event logs showed TCU randomly spiking to 100%
  - However, no trip was issued as load current was well below pickup
- RTD records were reviewed, but no high RTD readings were found
- By chance, the RTD metering screens were displayed, and it was noticed one RTD reading was spiking to 400°C and then returning to normal
- Investigation revealed intermittent failure of the RTD
  - Repeatedly biased the relay’s TCU to 100%
  - The brief nature of the failure caused the relay diagnostics to not capture the events
  - However, the relay’s faster core processing were still affected
- Issue could be mitigated by RTD voting and/or a RTD biasing delay

# Conclusions

- It is crucial to understand the motor relay’s method of thermal modeling
- Familiarity of common errors and their effect will greatly help in troubleshooting
- Motor protective relaying is an art as much as it is a science

# THANK YOU

# QUESTIONS?