GE Multilin

Motor Protection Seminar - 2005
Motor History & Facts

➢ The first U.S. patent for a motor was issued to Thomas Davenport in 1837.

➢ In 1888, Nikola Tesla patented the first AC poly-phase motor.

➢ Today in U.S. more than 1 billion motors are in service.

➢ Motors consume 23% of electricity in North America.

➢ Electricity consumption by motors in manufacturing sector is 70%. In oil, gas and mining industries around 90%.

➢ Three phase squirrel-cage induction motors account for over 90% of the installed motor capacity.
Motor Downtime

- Motor initial cost could be as low as 2% of the lifetime operational cost.
- The driven process downtime in some cases is more expensive than motor.
- Motor downtime contributors are:
  - Power system failures.
  - Inadvertent shutdown because of human mistake or motor protection maloperation
  - Motor failure
  - Load failure
Motor Failure Rates and Cost

- Motor failure rate is conservatively estimated as 3-5% per year.
- In Mining, Pulp and Paper industry motor failure rate is up to 12%.
- Motor failure cost contributors:
  - Repair or Replacement.
  - Removal and Installation.
  - Loss of Production.

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IEEE STUDY

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IEEE STUDY
Thermal Stress Causes Motor Failure

- Many of the motor failure contributors (IEEE Survey) and failed motor components (EPRI Survey) are related to motor overheating.
- Thermal stress potentially can cause the failure of all the major motor parts: Stator, Rotor, Bearings, Shaft and Frame.
• Setting of the motor protection relay is based on the motor datasheets information and system configuration.

• Datasheets are normally provided by motor manufacturer.

• System configuration data can be obtained from single line diagram.
Motor Specifications

Starting Current:

- When rated voltage and frequency is applied to NEMA B motor, it will typically draw 600% of full-load current and decrease to rated value as rotor comes up to speed.
Thermal Modeling: Motor Thermal Limits Curves

The motor thermal limits curves consist of three distinct segments which are based on the three running conditions of the motor:

- The locked rotor or stall condition.
- Motor acceleration.
- Motor running overload.

Ideally, curves have been provided for both a hot and cold motor. A hot motor is defined as one that has been running for a period of time at full load such that the stator and rotor temperatures have settled at their rated temperature. Conversely, a cold motor is defined as a motor that has been stopped for a period of time such that the rotor and stator temperatures have settled at ambient temperature. For most motors, the motor thermal limits are formed into one smooth homogeneous curve.
Thermal Modeling: Motor Thermal Limits Curves

The acceleration curves are an indication of the amount of current and associated time for the motor to accelerate from a stop condition to a normal running condition. In this particular example, there are two acceleration curves:

The first is the acceleration curve at rated stator voltage while the second is the acceleration at 80% of rated stator voltage; a soft starter is commonly used to reduce the amount of inrush voltage and current during starting. As can be seen on the curve shown, since the voltage and current are lower, it takes longer for the motor to start. Therefore starting the motor on a weak system can result in voltage depression, providing the same effect as a soft-start.
Motor Data Sheets

Motor Performance Data

- **Rated output**: 3hp
- **Voltage**: 400V
- **Frequency**: 60 Hz
- **Locked rotor Amps**: 413 Amps
- **Locked rotor torque**: 250\%
- **Breakdown torque**: 250\%
- **Current**: 413 Amps
- **Power Factor**: 0.82

Thermal Limit Curves

This performance data is final and the motor will be manufactured accordingly.
Motor Thermal Limit Curves

Thermal Limit Curves:

A. Cold Running Overload
B. Hot Running Overload
C. Cold Locked Rotor Curve
D. Hot Locked Rotor Curve
E. Acceleration curve @ 80% rated voltage
F. Acceleration curve @ 100% voltage
# Motor Thermal Parameters

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## Motor Data Sheet Parameters

- **G. Temperature Rise, Insulation Class**
- **H. Full Load Current**
- **I. Locked Rotor Current**
- **J. Locked Rotor Time; Cold/Hot**
- **K. Number of Starts; Cold/Hot**

## Calculated Performance

- NEMA STARTING CODE: F
- LOCKED ROTOR CURRENT: 540 %
- LOCKED ROTOR TORQUE: 77 %
- PULL UP TORQUE: 77 %
- BREAKDOWN TORQUE: 245 %
- COUPLING TYPE: DIRECT
- ARRANGEMENT: F1
- ROTATION: DUAL
- MAX. BRG. VIBR. (PK-PK): 0.0016 in
- BEARING TYPE: SEAT SLEEVES
- BEARING LUBRICATION: OIL
- END PLAY: 0.50 in

- LOCKED ROTOR TIME
  - COLD: 35 Sec
  - HOT: 30 Sec

- NUMBER OF STARTS (NEMA MG1-20.43)
  - COLD: 2
  - OR HOT: 1
Motor Specifications

Horsepower:
- Engineering unit of power 33,000 lb 1ft in 1 min.
- $HP = 1.341 \times KW$
- $KW = 0.746 \times HP$

Motor rating (per NEMA MG-1)
- Large Motors: > 500HP (1800 & 3600 rpm)
- Medium Motors: 1-500HP (1800 & 3600 rpm)
Motor Specifications

**Efficiency:**

An indication of how much electrical energy is converted to output shaft mechanical energy expressed as a percentage.

Electrical Energy in = Mechanical Energy out + Losses (mostly heat)

- **Losses**
  - Core loss
  - Stator loss
  - Rotor Loss
  - Friction and Windage
  - Stray loss
## Motor Specifications

### Motor Data Sheet

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### Overload Curve

The overload curve shows the performance of the motor under varied conditions. The motor's capacity to handle overload is calculated as follows:

\[ HCR = \frac{LRT_{HOT}}{LRT_{COLD}} \]
**Thermal Model. Hot/Cold Stall Time Ratio (HCR)**

- Typically motor manufacturer provides the values of the locked rotor thermal limits for 2 motor conditions:
  - **COLD**: motor @ ambient temperature
  - **HOT**: motor @ rated temperature for specific class and service factor.

- NEMA standard temperature rises for motors up to 1500HP and Service Factors 1 and 1.15 respectively.

- HCR defines the proportional increase of Thermal Capacity Used (TCU) of the motor running fully loaded at settled temperature in comparison to the motor resting at ambient temperature.
Motor Specifications

Service Factor:

When the voltage and frequency are maintained at the values specified on the nameplate, the motor may be overloaded up to the horsepower obtained by multiplying the nameplate horsepower by the service factor.

At the service factor load greater than 1.0 the motor’s efficiency, power factor and speed will differ from nameplate. But the locked rotor current and breakdown torque will remain the same.

For a given insulation, motors with a 1.15 service factor have a lower rise then those with a service factor of 1.0. This allows the motor to operate close to the service factor without exceeding rated temperature limits of the insulation. If the motor is operated at the service factor, the motor will have a temperature rise in excess of the 100% rated rise for motors with a 1.0 service factor. This will shorten the life expectancy considerably.
Motor Specifications

Information required to set Thermal Model:

- Motor FLA
- Locked Rotor Current
- Locked Rotor Time Hot
- Locked Rotor Time Cold
- Service Factor
- Motor Damage Curves
Motor Management Relays have three basic categories of protection elements:

- TRIPS
- ALARMS
- BLOCKS
Thermal Protection Algorithm Requirements

- **ACCURACY** Precise estimate of the motor thermal image
- **SIMPLICITY** Easy to understand and calculate thermal estimate
- **DEPENDABILITY** Capability of constant thermal image monitoring
- **COMPLIANCE TO INDUSTRY STANDARDS**
- **EASY SETUP** Use of standard readily available motor parameters
- **RELIABILITY** Alternative backup method of the thermal estimate
- **FLEXIBILITY** Compatibility with different motor applications
Thermal Model Enhancements and Additions

- Motor Start Inhibit
- Standard, Custom and Voltage Dependant Overload Curves
- Thermal Model Biasing by Current Unbalance
- Thermal Model Biasing by RTD Inputs
- Separate Thermal Time Constants for Running and Stopped Motor Conditions
- Independent Current Unbalance Detector
- Acceleration Limit Timer
- Mechanical Jam Detector
- Start and Restart Supervision
Important Motor Protection Device Functions and Features

- Phase Short Circuit, Differential Protection (large motors), Ground Fault Protection
- Voltage and Frequency Elements, Phase Reversal Detection
- Reactive and Active Power, Power Factor
- Protection Device Failure Detector
- Event Recorder, Data Logger, Oscilography
- Communication Capability, Integration into DCS/SCADA
- User Friendly Software Interface
- Rugged Construction, Easy Installation
Two Main Risks for an Overheated Motor

- **Stator Windings Insulation Degradation**

  ![Graph showing insulation lifetime at different temperatures]

  Insulation lifetime decreases by half if motor operating temperature exceeds thermal limit by 10°C. For F class insulation, stator temperature of 165°C causes motor lifetime to decrease to 50%.

- **Rotor Conductors Deforming or Melting**

  In most cases, rotor thermal limit is defined by the allowed motor stall time. These motors are classified as rotor limited. Stator limited motors - if voltage rating is 10 times greater than HP rating: For example: 500HP, 6900V.
Thermal Model - Motor States

- **Motor Stopped:** Current < “0” threshold & contactor/breaker is open.

- **Motor Starting:** Previous state is “Stopped” & Current > “0” threshold. Motor current must increase to the level higher than overload pickup within 1 second otherwise motor algorithm will declare the “Running” state.

- **Motor Running:** Previous state is “Starting” or “Overloading” & Current drops below overload pickup level.

- **Motor Overloading:** Previous state is “Running” & Current raises above overload pickup level. Thermal Capacity Used (TCU) begins to accumulate
The primary motor protective element of the motor protection relay is the thermal overload element and this is accomplished through motor thermal image modeling. This model must account for thermal process in the motor while motor is starting, running at normal load, running overloaded and stopped. Algorithm of the thermal model integrates both stator and rotor heating into a single model.

- Thermal Overload Curves
- Overload Pickup Level
- Motor Current Unbalance Biasing
- Main Factors and Elements Comprising the Thermal Model are:
  - Overload Pickup Level and Overload Curve
  - Running and Stopped Cooling Time Constants
  - Hot/Cold Stall Time Ratio
  - RTD & Unbalance Biasing
  - Motor State Machine
  - Start Inhibit
Thermal Modeling

If the motor has been designed conservatively, the portion of the acceleration curve under the motor thermal limits curve is less than a third to a half in terms of trip time, and the motor has been applied conservatively (during acceleration or running the acceleration and thermal limits curve do not cross) then thermal model settings can be set easily.

If the acceleration curves and the thermal overload curves are very close, accuracy in the settings becomes very important in order to ensure reliable motor protection without nuisance tripping.
Thermal Model - Thermal Capacity Used

- Thermal Capacity Used (TCU) is a criterion selected in thermal model to evaluate thermal condition of the motor.
- TCU is defined as percentage of motor thermal limit utilized during motor operation.
- Thermal Limit of the model is dictated by overload curve constructed in the motor protection device in the reference to thermal damage curves normally supplied by motor manufacturer.
- IEEE Std 620-1996 provides the guidelines for the presentation of motor thermal limit curves.
- Motor protection device is equipped with set of standard curves and capable to construct customized curves for any motor application.
Thermal Model - Thermal Capacity Used

We will use the following model to aid in a better understanding of motor thermal modeling concepts. The motor’s thermal capacity, that is to say, the amount of heat energy the motor can hold, will be represented by the glass vessel. The lava like fluid filling the vessel will represent thermal energy or heat energy that has been absorbed by the motor.
Thermal Model - Thermal Capacity Used

The sources of thermal energy that will fill the vessel or heating the motor are:

- Ambient temperature
- Motor losses due to current unbalances and I squared T
- Motor heating due to a start
Motor cooling will be represented by:

- The vapour evaporating from the surface of the liquid when the motor is running or stopped will represent the motor's ability to dissipate heat.
- The fan is representative of the additional cooling effect of the motor's cooling system which is commonly a fan mounted on the motor shaft.
Now that we understand what the thermal model is trying to do let’s see how it accomplishes this task with the following hypothetical situation.

For a given motor, the thermal damage and acceleration curves are shown in this diagram. From a quick look at the motor curves we can see that the acceleration curve barely fits under the stall limits portion of the thermal limits curve. The protection relay tripped 10 second into the start. The customer notes from the relay data that during the start, the motor drew 600% rated current for for 4 seconds and then the current dropped to 300% for only 6 seconds before the relay tripped.

Given that the thermal damage curve was selected correctly the customer wants to know why the relay tripped the motor even though the current draw did not exceed the thermal damage curve limits?
**TCU Calculation for the Hot Motor**

- Example: Cold and Hot Safe Stall Times are 10 and 8 seconds.
- HCR is calculated as 8 sec / 10 sec = 0.8
- TCU of the Hot Motor running at allowed overload (SF • FLA) for a long time is calculated as (1-0.8) • 100% = 20%
- Thermal algorithm effectively shifts an overload curve down, decreasing time before trip by 20%
- In the hot motor TCU calculation, thermal algorithm accounts for loads lower than the allowed overload.

\[
\text{TCU}_{\text{END}} = \frac{I_{eq}}{SF \times FLA} \times (1 - HCR) \times 100\%
\]

- \(I_{eq}\) – equivalent heating motor current; \(FLA\) – full load motor current; \(SF\) – motor service factor.
TCU Example

The area under the thermal damage curve represents the thermal capacity of the motor and the area under the acceleration curve represents the thermal capacity used to start the motor. During the first 4 seconds of the start, the motor draws 600% current. This current level is greater than the motor's full load current rating and therefore the percentage of thermal capacity used will increase, (the vessel will fill).

From the graph we can see that if the motor drew 600% for 5 seconds 100% of the motor's thermal capacity would have been used.

The motor draws 600% for 4 seconds, so four fifth's or 80% of the motor's thermal capacity was used during this portion of the motor's acceleration. This can be imagined as 80% of the vessel being filled with thermal energy.
TCU Example

To determine how long the motor can run when the motor’s current draw drops to 300%, the thermal capacity already used at 600% must be taken into account. From the graph we can see that motor can draw 300% of its rated current for 30 seconds if no thermal capacity had been used. Since 80% of the motors thermal capacity has already been used which represents 24 of the 30 seconds available at 300% the motor can only draw 300% current for an additional 6 seconds. This can be represented visually by moving the area of 4 seconds at 600% current into the area of 30 seconds by 300% current.

When the motor’s current draw dropped to 300%, the relay could allow the motor to continue to run for an additional 6 seconds before the motor’s Thermal Capacity Used reached 100% at which time the relay had to trip the motor.
**Start Inhibit**

Upon a start, the inrush current is above the motor’s full load current causing the thermal capacity used within the motor to rise rapidly. GE Multilin Motor Management Relays “learn” the amount of thermal capacity required to start the motor and if the start inhibit function is enabled, use this information in addition to the thermal capacity used data to ensure that there is enough thermal capacity within the motor for a successful start before a start is attempted.
Start Inhibit Example

Under such a condition, if the relay had the Start Inhibit feature enabled, the relay would lock-out the motor start until the thermal capacity of the motor had dropped to 60% such that a successful motor start could be achieved without the thermal capacity used exceeding the volume of the vessel.
Thermal Model

- Select O/L Curve
- Determine Overload Pickup
- Hot/Cold Safe Stall Ratio
- Unbalanced Bias
- Cooling Times and Start Inhibit
- RTD Biasing
Typical Motor Thermal limits Curves

- Thermal limit curve when motor is cold
- Thermal limit curve when motor is hot
- Acceleration curve @ 80% rated voltage
- Acceleration curve @ 100% voltage

Time in seconds
Phase current in multiples of FLC
Thermal Model - Thermal Limit Curves

- Thermal limit plot includes hot and cold running overload limit curves (5 & 6) and hot and cold locked rotor limit curves (3 & 4) as a standard.

- In special cases plot can be furnished with acceleration curves for the range of operational voltages.

- MPD (motor protection device) Overload curve (2) should be selected to fit in between cold and hot motor thermal limit curves.
Thermal Model - Thermal Limit Curves
Standard Overload Curves Equation

\[ T = \frac{87.4 \times TDM}{I^2 - 1} \]

**Where:**
TDM is relay setpoint “TD Multiplier”

I - current in multiples of FLA
Overload Curve Selection

The overload element uses a Thermal Capacity algorithm to determine when to activate an overload trip. The volume of this vessel is representative of the thermal capacity of the motor. A running motor will have some level thermal capacity used due to the losses which will be represented by a certain level of thermal capacity in our vessel.
**Overload Curve Selection**

Whenever the current exceeds the Overload Pickup, the vessel begins to fill with heat energy. The valve that controls how fast the vessel is filled is proportional to the amount of overload current. For example if the current is just over the overload pick up level, the imaginary valve is partially open and the vessel is being filled slowly, versus the situation where the current far exceeds the pickup level, in which case one could imagine the valve as fully open and the vessel being quickly filled with thermal energy. When the vessel is full, the vessel starts to overflow and a trip is issued.

If there is some thermal energy in the vessel from a previous overload condition, the remaining volume of vessel will be first filled before a trip command is issued by the relay. The overload trip will only occur at the time specified on the curve and the overload current is being drawn at stable rate (no ramping of current).
If the motor starting current begins to infringe on the thermal damage curves or if the motor is called upon to drive a high inertia load such that the acceleration time exceeds the safe stall time, custom or voltage dependent overload curve may be required.
**Thermal Model Behavior - Long Starts**

- The main issue is that the duration of the high inertia load starts is longer than the allowed motor safe stall time. That is why the standard thermal algorithm method can not be applied.
- For these starts, thermal model must account for the current change during acceleration and also use the acceleration thermal limits for TCU calculations.
- Motor thermal limit is growing along with motor rotation speed during acceleration.
- Starting current is proportional to system voltage during motor acceleration, thus voltage could be a good indication of the current level corresponding to the locked rotor conditions.
- Voltage dependant dynamic thermal limit curve is employed to enhance the thermal model algorithm.
The two graphs illustrate the resultant overload protection curves for 80% and 100% line voltage, respectively. For voltages in between, the motor relay will shift the acceleration thermal limit curve linearly and constantly based on measured line voltage during a motor start.
Let us assume that in the high inertia start application, the motor data is the same except the safe stall times, i.e. cold SST @ 100% is 8 seconds.

Application of the standard thermal model curve causes the trip in about 10 seconds in the middle of the acceleration.
Thermal Model Behavior - Long Starts (cont.)

- For high inertia starts, one should apply the acceleration thermal limit curves instead of locked rotor thermal limit curves and motor can start successfully without tripping.

- This method is relevant for the situation with the constant terminal voltage of 100%.
- What happens if voltage deviates from 100% ?
Thermal Model Behavior - Why motor is in danger?

Thermal Limit is a function of the motor speed.

Starting current is proportional to the terminal voltage.

Let us assume that the motor current is the only parameter to be sensed by motor relay and the acceleration thermal limit curve from the previous slide is applied to protect the motor.

This situation implies the danger to burn the stalled motor.

@ 80% voltage start motor trip time is 40 seconds instead of required 12.5 seconds.
Thermal Model Behavior - Voltage Dependant Curves

- Voltage dependant overload curve in 469 motor relay is provided to handle the situation described in the previous slide.
- The acceleration section of the overload curve dynamically shifts in response to motor voltage deviations.

- Thermal model accumulates almost the same TCU during 100% and 80% voltage motor starts.
Thermal Model

- Select O/L Curve
- Determine Overload Pickup
- Hot/Cold Safe Stall Ratio
- Unbalanced Bias
- Cooling Times and Start Inhibit
- RTD Biasing
Determining The Overload Pickup:

• The protection engineer will typically set the overload pickup to 100% of the motors capability. For motors with a 1.15 service factor, a maximum pickup of 125% of the full load current can be selected while the maximum pickup for 1.0 service factor motors is 115% of full load current. Having said this, it is common practice to set the pick up to no more than the rated motor full load current plus no more than 10% of the service factor unless there is another independent measure of motor temperature such as stator RTD's.

• If the motor’s winding temperature is also being directly monitored by an RTD biasing function to the thermal model, the overload pickup can be safely increased to the maximum allowable value for that motor.

• Note that the motor feeder cables are normally sized at 1.25 times the motor’s full load current rating which would limit the motor overload pickup setting to a maximum of 125%.
Thermal Model

- Select O/L Curve
- Determine Overload Pickup
- Hot/Cold Safe Stall Ratio (2 methods)
- Unbalanced Bias
- Cooling Times and Start Inhibit
- RTD Biasing
If the thermal limits curves are being used to determine the HOT/COLD ratio proceed as follows:

- From the thermal limits curves run a line perpendicular to the current axis that intersects the hot and cold curves at the stall point.
- Draw a line from each point of intersection to the time axis.
• Record the corresponding times. In this case 10 and 15 seconds respectively.

• The Hot/cold ratio can now be calculated as follows: The HOT/COLD ratio = 10/15 = 0.67

NOTE:
If hot and cold times are not provided and only one curve is given verify with the manufacturer that it is the hot curve (which is the worst case). If the supplied curve is the hot curve then the Hot/ Cold ratio can be set to 1.0
**Motor Data Sheet**

**Method**

**Thermal Model**

**Hot/Cold Safe Stall Time Ratio**

\[ HCR = \frac{LRT_{\text{HOT}}}{LRT_{\text{COLD}}} \]

**Calculations**

\[ HCR = \frac{30s}{35s} = 0.86 \]
**Thermal Model**

If you have an ideal motor on a perfectly balanced system, that is a system that is supplying power with no negative sequence components, using the hot/cold stall ratio you could calculate the thermal capacity that the motor would have used once the motor has been running at rated current for an extended period of time.

For example, the motor would have used 33.3% of its total thermal capacity under the following conditions:

- Hot/cold ratio was 10/15.
- Motor had run for at least 5 times its running cooling time constant.
- Motor was drawing 100% rated current.
- Zero current unbalance

With no negative sequence or motor unbalance currents:

\[
TC_{\text{end}} = I_{\text{pu}}(1-\text{hot/cold}) \times 100\%
\]

If we assume 1pu TC = 1 (1-10/15) 100%  
\[
= (1-0.667)100\%
\]
\[
= 33.3\% \text{ (After 5 time constants)}
\]

Unfortunately, there are no ideal motors or power systems that provide purely positive sequence power and so we need to deal with this next.
Thermal Model

- Select O/L Curve
- Determine Overload Pickup
- Hot/Cold Safe Stall Ratio
- Unbalanced Bias
- Cooling Times and Start Inhibit
- RTD Biasing
A positive sequence set of vectors consists of three equal vectors that are displaced by 120 degrees and have a rotational phase sequence of ABC.

A negative sequence set of vectors consist of three equal vectors that are displaced by 120 degrees, but have a rotational phase sequence of ACB.

In the real world, the power system is never perfectly balanced therefore negative sequence currents will always exist.
Negative sequence currents (or unbalanced phase currents) will cause additional rotor heating that will not be accounted for by electromechanical relays and may not be accounted for in some electronic protective relays.
**Thermal Model - Current Unbalance**

- Current Unbalance causes extra heating not accounted by the regular thermal model.

- Main causes of current unbalance
  - Blown fuses
  - Loose connections
  - Stator turn-to-turn faults
  - System voltage distortion and unbalance
  - Faults
**Thermal Model - Current Unbalance**

- Equivalent heating motor current is employed to bias thermal model in response to current unbalance.

\[
I_{EQ} = \sqrt{I_M^2 \times (1 + K \times \left(\frac{I_2}{I_1}\right)^2)}
\]

- \(I_M\) - real motor current; \(K\) - unbalance bias factor; \(I_1\) & \(I_2\) - positive and negative sequence components of motor current.

- \(K\) factor reflects the degree of extra heating caused by the negative sequence component of the motor current. Enter \(K\) value into motor relay settings.

- IEEE guidelines for typical and conservative estimates of \(K\).

\[
K = \frac{175}{I_{LRC}^2} \quad \text{TYPICAL} \\
K = \frac{230}{I_{LRC}^2} \quad \text{CONSERVATIVE}
\]

- \(I_{LRC}\) - Motor Locked Rotor Current @ 100% voltage (in pu)
**Thermal Model - Current Unbalance**

The graph shows recommended motor derating as a function of voltage unbalance that is recommended by NEMA. Assuming a typical induction motor with an inrush of 6 x the motors Full Load Current rating and a negative sequence impedance of 0.167, voltage unbalances of 1, 2, 3, 4, 5% are equivalent to a current unbalances of 6, 12, 18, 24, 30% respectively.

Based on this assumption, the graph illustrates the amount of motor derating for different values of k entered for the setpoint Unbalance Bias k Factor. Note that the curve created when k=8 is almost identical to the NEMA derating curve.

If a k value of 0 is entered, the unbalance biasing is defeated and the overload curve will time out against the measured per unit motor current.
Thermal Model

- Select O/L Curve
- Determine Overload Pickup
- Hot/Cold Safe Stall Ratio
- Unbalanced Bias
- Cooling Times and Start Inhibit
- RTD Biasing
Thermal Model - Motor Cooling Curves

- TCU decay of the motor running @ full load.

- TCU decay of the stopped motor.
Motor cooling is characterized by separate cooling time constants (CTC) for running and stopped motor states. Typical ratio of the stopped to running CTC is 2/1.

CTC defines the rate of the TCU exponential decay, when motor current doesn’t exceed the overload level.

Thermal Model - Motor Cooling

Thermal Model Cooling Motor Tripped

- Cool Time Constant: 30 min
- TCused_start: 100%
- Hot/Cold Ratio: 80%
- Motor Stopped after Overload Trip
- TCused_end: 0%
Thermal Model - Motor Cooling

Thermal Model Cooling 100% load

\[ TC_{\text{USED\_END}} = \frac{I_{\text{eq}}}{\text{overload\_pickup}} \left(1 - \frac{\text{hot}}{\text{cold}}\right) \times 100\% \]

\[ TC_{\text{USED\_END}} = \frac{1}{1}(1-0.8/1) \times 100\% \]

\[ TC_{\text{USED\_END}} = 20\% \]
Thermal Model - Motor Cooling

Thermal Model Cooling 80% load

\[ TC_{\text{used\_end}} = \left( \frac{I_{eq}}{\text{overload\_pickup}} \right) \left( 1 - \frac{\text{hot}}{\text{cold}} \right) \times 100\% \]

\[ TC_{\text{USED\_END}} = (0.8/1)(1-0.8/1)\times100\% \]

\[ TC_{\text{USED\_END}} = 16\% \]
**Thermal Model - Motor Cooling**

- Enter the Running & Cooling Time Constants into the motor relay settings
- Do not enter the actual cooling time in the motor relay settings
- It takes the motor typically 5 time constants to cool.
  - If the motor data sheet says it takes 150 mins to cool, enter a time constant of 30 minutes.
  - If the motor data sheet says it takes 75 mins to cool, enter a time constant of 15 minutes.

---

**Thermal Model Cooling Motor Tripped**

<table>
<thead>
<tr>
<th>Time in Minutes</th>
<th>Thermal Capacity Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>120</td>
<td>0</td>
</tr>
</tbody>
</table>

- Cool Time Constant = 30 min
- TCused_start = 100%
- Hot/Cold Ratio = 80%
- Motor Stopped after Overload Trip
- TCused_end = 0%

**Thermal Model Cooling 100% load - Running**

<table>
<thead>
<tr>
<th>Time in Minutes</th>
<th>Thermal Capacity Used</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100</td>
</tr>
<tr>
<td>30</td>
<td>75</td>
</tr>
<tr>
<td>60</td>
<td>50</td>
</tr>
<tr>
<td>90</td>
<td>25</td>
</tr>
<tr>
<td>120</td>
<td>0</td>
</tr>
</tbody>
</table>

- Cool Time Constant = 15 min
- TCused_start = 85%
- Hot/Cold Ratio = 80%
- Ieq/Overload Pickup = 100%
When the motor is stopped, its thermal capacity used value will decay according to the same formula shown previously. If the thermal capacity used were at 100% before stopping the motor, the thermal capacity used will take 5 time constants or 2.5 hours to decay. Note that after only three time constants, the motor would be within 5% of its final value of zero from its initial value. If the same motor were stopped with 85% of its thermal capacity used, it would decay according to the same formula taking 5 time constants to decay to zero completely and would be within 5% of zero form its initial value after 3 time constants.
Thermal Model

- Select O/L Curve
- Determine Overload Pickup
- Hot/Cold Safe Stall Ratio
- Unbalanced Bias
- Cooling Times and Start Inhibit
- RTD Biasing
Thermal Model - RTD Biasing

- TCU calculation at center point of RTD bias curve:

\[ TCU_{CENTER} = (1 - HCR) \times 100\% \]

- TCU Calculation at lower section of RTD bias curve:

\[ TCU_{RTD} = \left( \frac{T_{ACTUAL} - T_{MIN}}{T_{CENTER} - T_{MIN}} \right) \times TCU_{CENTER} \]

- TCU Calculation at higher section of RTD bias curve:

\[ TCU_{RTD} = \left( \frac{T_{ACTUAL} - T_{CENTER}}{T_{MAX} - T_{CENTER}} \right) \times (100 - TCU_{CENTER}) + TCU_{CENTER} \]
Thermal Model - RTD Biasing

RTD Bias Curve Example

- RTD input is a indicator of the thermal capacity used dependent on stator temperature (very slow).
- The relay will use the calculated thermal capacity unless the RTD thermal capacity is higher.

Factory preset curve:

( Min. = 40° C, Center = 110° C & Max. = 155° C )

Center thermal capacity = 15%.
Additional Protection Elements

Additional Common Induction and Synchronous Motor Protective elements:

- Short circuit
- Ground Fault
- Differential Trip
- Current Unbalance
- Single Phasing
- Undervoltage & Overvoltage Protection
- Mechanical Jam Detection
- Undercurrent
- Underpower
- Acceleration Timer
The short circuit element provides protection for excessively high overcurrent faults.

Phase-to-phase and phase-to-ground faults are common types of short circuits.

The Short Circuit trip element is coordinated with external up stream fuses such that the element will operate first.
Short Circuit Trip

- When a motor starts, the starting current (which is typically 6 times the Full Load Current (FLC) rating of the motor) has asymmetrical components. These asymmetrical currents may cause one phase to see as much as 1.7 times the normal RMS starting current. As a result, the pickup of the short circuit element must be set higher than the maximum asymmetrical starting currents seen by the phase CTs to avoid nuisance tripping. The rule of thumb is to set the short circuit protection pickup to a value which is at least 1.7 times the maximum expected symmetrical starting current of the motor. This allows the motor to start without nuisance tripping.

- It is important to note that the device that the relay is to control under such conditions must have an interrupting capacity equal to or greater than the maximum available fault current.
Short Circuit Protection

- Acceleration curve (motor current during starting)
- Locked Rotor current
- Motor Thermal Limit
- Instantaneous Overcurrent Protection
Ground Fault

Resistive Grounded System and a Inductive Grounded System
Ground Fault

- A ground fault is a fault that creates a path for current to flow from one of the phases directly to the neutral through the earth bypassing the load.
- This current is sometimes referred to as zero sequence current.
- Damage to a phase conductors insulation and internal shorts due to moisture within the motor are common causes of ground faults.
- A strategy that is typically used to limit the level of the ground fault current is to connect an impedance between the supplies neutral and ground. This impedance can be in the form of a resistor or grounding transformer sized to ensure that the maximum ground fault current is limit to no more then 10 amps to reduce the chances of metal damage to the motor.
Ground Fault

Best

Zero Sequence CT
Ground Fault
Zero Sequence CT Connection

There are several ways by which a ground fault can be detected. The most desirable method is to use the Zero Sequence CT approach, which is considered the best method of ground fault detection methods due to its sensitivity and inherent noise immunity.

All phase conductors are passed through the window of the same CT referred to as the zero sequence CT. Under normal circumstances, the three phase currents will sum to zero resulting in an output of zero from the Zero Sequence CT’s secondary. If one of the motors phases were to short to ground, the sum of the phase currents would no longer equal zero causing a current to flow in the secondary of the zero sequence. This current would be detected by the motor relay as a ground fault.
Ground Fault

Residual Ground Fault Connection
**Ground Fault**

Residual Ground Fault Connection

If the cables are too large to fit through the Zero sequence CT’s window or the trench is too narrow to fit the Zero Sequence CT, the residual ground fault configuration can be used.

This configuration is inherently less sensitive than that of the zero sequence configuration owing to the fact that the CTs are not perfectly matched. During the motor start, the motor’s phase currents typically rise to magnitudes in excess of 6 times the motor’s full load current. The slight mismatch of the CTs combined with the relatively large phase current magnitudes produce a false residual current which will be seen by the relay. This current will be misinterpreted by the motor relay as a ground fault unless the ground fault element’s pickup is set high enough to disregard this error.
This diagram shows the Asymmetrical Starting Currents. When a motor first starts using a residual ground fault connection, the three phases do not sum to zero because of the DC offset in each of the three phase CTs. This difference appears as a ground fault current and will cause a ground fault trip if the trip level and time delay are programmed correctly. If the residual ground fault connection is to be used, the Ground Fault trip delay must be set to a delay other than instantaneous to avoid a nuisance ground fault trip, in addition to allowing enough time for the asymmetrical starting current offsets to even out.
This slide shows the noise generated during a start and a run when residual ground scheme is used.

None of this noise would be seen by the motor relay using a zero sequence CT scheme.
Phase Differential

- Consists of three instantaneous overcurrent elements for phase differential protection.

- Differential protection may be considered the first line of protection for internal phase to phase or phase to ground faults. In the event of such faults, the quick response of the differential element may limit the damage that may have otherwise occurred to the motor.
The Differential Trip element function can only be used if both sides of each stator phase are brought out of the motor for external connection such that the phase current going into and out of each phase can be measured.

The differential element subtracts the current coming out of each phase from the current going into each phase and compares the result or difference with the differential Pickup Level. If this difference is equal to or greater than the pickup level for a period of time greater than a user specified delay, a trip will occur.

Separate pickup levels and delay times are provided for the motor starting and running conditions.

GE Multilin motor protective relays support both 3 and 6 CT configurations. In this example both sides of each of the motors stator phases are being past through a single CT. This is called core balance method and is the most desirable owing to its sensitivity and noise immunity.

The level may be set more sensitive if the Differential CTs are connected in core balance configuration (3 CTs).
If 6 CTs are used in a summing configuration, during motor starting, the values from the two CTs on each phase may not be equal as the CTs are not perfectly identical.

Asymmetrical currents may cause the CTs on each phase to have different outputs. To prevent nuisance tripping in this configuration, the starting differential level may have to be set less sensitive, or the starting differential time delay may have to be extended to ride through the problem period during start. The running differential delay can then be fine tuned to an application such that it responds very fast and is sensitive to low differential current levels.
This method allows different CT ratios for system/line and neutral.

This method has a dual slope characteristic. The main purpose of the percent-slope characteristic is to prevent a maloperation caused by unbalances between CTs during external faults. CT unbalances arise as a result CT accuracy errors or CT saturation.

This method has a built-in CT Saturation Detector. External faults near generators typically result in very large time constants of DC components in the fault currents. Also, when energizing a step-up transformer, the inrush current being limited only by the machine impedance may be significant and may last for a very long time. When saturation is detected the element will make an additional check on the angle between the neutral and output current. If this angle indicates an internal fault, then tripping is permitted.
Current Unbalance and Single Phasing Protection

Current Unbalance Detection (Alarm)

- System voltage unbalance
  1% voltage imbalance translates into a 6% current unbalance
- Stator turn-to-turn faults
- If voltage unbalance is typically 2%, then set alarm to 15% (> 2 x 6%)

Motor Single Phasing (Trip)

- Blown Fuses
- Bad Connections
- 20% Trip Level is recommended

Single Phasing is declared when:

- 2 seconds after 40% current unbalance has been detected.
- Average current is above 25% of FLA and the current in one of the phases is less then 2% of FLA.

Current Unbalance (%)

\[ I_{UN} = K \times \frac{I_1}{I_2} \times 100\% \]

Where, K – adjustment factor
- \( I_1 \) – positive sequence current
- \( I_2 \) – negative sequence current

K Adjustment Factor

\[
\begin{align*}
\text{if } I_{AVG} & \geq I_{FLA} \text{ then } K = 1 \\
\text{if } I_{AVG} & \leq I_{FLA} \text{ then } K = \frac{I_{AVG}}{I_{FLA}}
\end{align*}
\]
Under Voltage

If an induction motor operating at full load is subjected to an under voltage condition, the following effects will occur (Moisey, 1997):

• Full load speed will decrease
• Efficiency will decrease
• Power factor will increase
• Full load current will increase
• Temperature will increase
Over Voltage

When the motor is running in an overvoltage condition, the following affects will occur (Moisey, 1997):

- Slip will decrease because slip is inversely proportional to the square of the voltage
- Efficiency will increase slightly and power factor will decrease because the current being drawn by the motor will decrease
- Temperature rise will decrease because the current has decreased (based on the formula I^2t)
- Most motors are designed close to the saturation point........increasing the V/HZ ratio could cause saturation of air gap flux causing heating
Under & Over Voltage Protection

- The overall result of an under or overvoltage condition is an increase in current and motor heating and a reduction in overall motor performance.

- The undervoltage trip should be set to 90% of nameplate unless otherwise stated on the data sheets. Motors that are connected to the same source may experience a temporary undervoltage when one of motors starts. To override these temporary sags, a time delay setpoint has been incorporated into undervoltage element.

- The over voltage element should be set to 110% of the motors nameplate unless otherwise started in the data sheets.

- The undervoltage element can be considered as backup protection for the thermal overload element. If the voltage decreases, the current will increase, causing an overload trip. In some cases, if an undervoltage condition exists it may be desirable to trip the motor faster than the overload element.
Possible causes of motor mechanical jam:

- Worn motor bearings
- Load mechanical breakage
- Driven load process failure

Element is used to disconnect the motor on abnormal overload conditions before motor stalls.

The Mechanical Jam element is designed to operate for running load jams.

In terms of relay operation, element prevents motor from reaching 100% of thermal capacity while Mechanical Jam is detected. It helps to avoid mechanical breakage of the driven load and reduce start inhibit waiting time.
Undercurrent

The Undercurrent element is active only when the motor is running. It is blocked upon the initiation of a motor start for the time defined by the U/C BLOCK FROM START setpoint.

A trip or alarm will occur once the magnitude Ia, Ib, or Ic falls below the pickup level for the time specified by the UNDERCURRENT ALARM DELAY.

This is useful for indicating the loss of suction in a pump application, or a broken belt in a conveyor application.
Underpower

The second method of load loss detection is to use the underpower element.

- A value other than zero must be entered to ensure the underpower element is blocked when the motor is stopped. The Underpower element is active only when the motor is running, and will be blocked upon the initiation of a motor start for a period of time defined by the BLOCK ELEMENT FROM START setpoint. This time delay may be useful in applications which require the motor to be running for a period of time before full power is required as is the case in centrifugal pump or fan applications.

- When enabled, if the magnitude of the three phase total power falls below the pickup Level for a period of time specified by the delay, a trip or alarm will be generated.
Acceleration Timer

- The motor relay’s Thermal Model is designed to protect the motor under both starting and overload conditions.
- The Acceleration Timer may enhance the motor protection scheme.

- For example, a given motor should always complete a start within 2 seconds. If the safe stall time is 8 seconds and a failure occurred such that the motor was held in a stall condition, the motor would normally remain at stall for a total of 8 seconds before the thermal model would generate a trip. The accelerator timer could be configured to generate a trip if the motor remained at stall for more then 3 seconds thereby reducing the stress on both the motor and driven equipment.

- Note that some soft starts limit the motors starting current to less then the motors rated full load current. Therefore if the relay does not see the motor’s current rise to a value greater than the motors rated full load current within 1 second after a start, the acceleration timer will be ignored.
Additional Protection Elements

Additional Protective Elements for Synchronous Machines:

• Field application
• Field temp. monitoring

Monitoring/Control Elements for Synchronous Machines:

• Power Factor Correction
Additional Special Features Available In Motor Management Relays

- Starts per hour
- Time between starts
- RTD alarm and trip settings (stator, bearing, etc.)
- Two speed motor protection
- Load averaging filter for cyclic load applications
- Reduced voltage starting supervision
- Variable frequency filter allowing accurate sensing and calculation of the analog values in VFD applications
- Analog input differential calculation for dual drives applications
- Speed counter trip and alarm
- Universal digital counter trip and alarm
- Pulsing KWh and Kvarh output
- Trip coil supervision
- Emergency Restart Input
- Undervoltage auto restart (additional element per special order).
- Experimental broken rotor bar detection system
Setting Example

- CT Rating, Voltage Sensing
- FLA & Ground CT
- Thermal Model Settings
  - Overload Pickup, Overload Curve, Unbalance Bias K Factor, Hot/Cold Safe Stall Ratio, Running & Stopped Cooling Time Constants, RTD Bias
- Short Circuit Trip
- Current Unbalance Alarm & Trip
- Ground Fault
- Acceleration Trip
- Start Inhibit
- Starts per hour, Time Between Starts
- RTD Alarm & Trip
- Phase Differential Trip
- Undervoltage, Overvoltage Trip

The following is example of how to determine the relay setpoints for a specific motor that has been applied conservatively. This is only an example for teaching purposes and may not address all issues relating to your specific application. It is recommended that the setpoints for your motor protective relaying application be determined by your local protection engineer.
Setting Example
Select CT Rating, Voltage Sensing

Phase CT
The phase CT should be chosen such that the FLA is 50% to 100% of CT primary. Since the FLA is 297 a 300:5 CT may be chosen.

CT: 50% <FLA <100%
300/5

Voltage Sensing
Enter the connection type and ratio. Enter motor nameplate voltage. In this case, a 14400/120 PT will be used, so 120:1 ratio.

Current Sensing

<table>
<thead>
<tr>
<th>SETTING</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase CT Primary</td>
<td>300 A</td>
</tr>
<tr>
<td>Motor Full Load Amps</td>
<td>297 A</td>
</tr>
<tr>
<td>Ground CT Type</td>
<td>5 A Secondary</td>
</tr>
<tr>
<td>Ground CT Primary</td>
<td>50 A</td>
</tr>
<tr>
<td>Phase Differential CT Type</td>
<td>None</td>
</tr>
<tr>
<td>Enable Two Speed Motor Option</td>
<td>Off/No</td>
</tr>
</tbody>
</table>

Voltage Sensing

<table>
<thead>
<tr>
<th>SETTING</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage Transformer Connection Type</td>
<td>Open Delta</td>
</tr>
<tr>
<td>Enable Single VT Connection</td>
<td>Off</td>
</tr>
<tr>
<td>Voltage Transformer Ratio</td>
<td>120.00 :1</td>
</tr>
<tr>
<td>Motor Nameplate Voltage</td>
<td>13200 V</td>
</tr>
</tbody>
</table>
Setting Example

Select FLA, Ground CT

Set:

FLA = 297 A

GF <=> System ?

Motor FLC
Set the Motor Full Load Amps to 297A, as specified by the data sheets.

Ground CT
For high resistive grounded systems, sensitive ground detection is possible with the 50:0.025 CT. On solidly grounded or low resistive grounded systems where the fault current is much higher, a 1A or 5A secondary CT should be used. If residual ground fault connection is to be used, the ground fault CT ratio most equal the phase CT ratio. If residual connection is used, pickup levels and timers must be set with respect to the acceleration time. The zero sequence CT chosen needs to be able to handle all potential fault levels without saturating.
Setting Example
Thermal Overload Pickup

The overload pickup is set to the maximum allowed by the service factor of the motor.

For motors with a 1.15 service factor, a maximum pickup of 125% of the full load current can be selected.

While the maximum pickup for 1.0 service factor motors is 115% of full load current.

Having said this, it is common practice to set the pickup to no more than the rated motor full load current plus no more than 10% of the service factor unless there is another independent measure of motor temperature such as stator RTD's.

If the motor's winding temperature is also being directly monitored by an RTD biasing function to the thermal model the overload pickup can be safely increased to the maximum allowable value for that motor.

Note that the motor feeder cables are normally sized at 1.25 times the motor's full load current rating which would limit the motor overload pickup setting to a maximum of 125%.

If service factor is unknown, we must assume 1.0

<table>
<thead>
<tr>
<th>SETTING</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Curve Style</td>
<td>Standard</td>
</tr>
<tr>
<td>Overload Pickup Level</td>
<td>1.15 FLA</td>
</tr>
<tr>
<td>Unbalance k Factor</td>
<td>8</td>
</tr>
<tr>
<td>Cool Time Constant Running</td>
<td>15 min</td>
</tr>
<tr>
<td>Cool Time Constant Stopped</td>
<td>30 min</td>
</tr>
</tbody>
</table>
**Setting Example**

Select Overload Curve for Thermal Model

**Overload Curve**

The standard overload curve to be just below the cold thermal limit and above the hot thermal limit to give maximum process uptime, without compromising protection.

The best fitting curve is curve 3
Setting Example

Determine Unbalance Bias K Factor for Thermal Model

Unbalance Bias Of Thermal Capacity
Enable the Unbalance Bias of Thermal Capacity so that the heating effect of unbalance currents is added to the Thermal Capacity Used.

K=175/LRA^2 = 175/5.4^2 = 6
(Typical)

K=230/LRA^2 = 230/5.4^2 = 8
(Conservative)
Setting Example

Determine Hot/Cold Safe Stall Ratio for Thermal Model (method 1)

**Hot/Cold Ratio**

The hot/cold curve ratio is calculated by simply dividing the hot safe stall time by the cold safe stall time or use the motor thermal limits curve. For this example, both are available. Using the data sheets the Hot/Cold Curve Ratio equals 30 / 35 = 0.86

\[
HCR = \frac{LRT_{\text{hot}}}{LRT_{\text{cold}}}
\]

**Hot/Cold Ratio**

= 30/35

=> 0.86
Determining Hot/Cold Curve Ratio

Determine Hot/Cold Safe Stall Ratio for Thermal Model (method 2)

Overload Curve Method

Hot/Cold Curve Ratio

If the thermal limits curves are being used to determine the HOT/COLD ratio proceed as follows:

- From the thermal limits curves run a line perpendicular to the current axis that intersects the hot and cold curves at the stall point.
- Draw lines from each points of intersection to the time axis.
- Record the corresponding times. In this case, 6 and 8 seconds respectively.
- The Hot/cold ratio can now be calculated as follows:

\[
\frac{6 \text{ s}}{8 \text{ s}} = 0.75
\]

NOTE:

- If hot and cold times are not provided and only one curve is given verify with the manufacturer that it is the hot curve (which is the worst case), then the Hot/ Cold ratio should be set to 1.0.
**Thermal Model - Motor Cooling**

- Enter the Running & Cooling Time Constants into the motor relay settings
- Do not enter the actual cooling time in the motor relay settings
- It takes the motor typically 5 time constants to cool.
  - If the motor data sheet says it takes 150 mins to cool, enter a time constant of 30 minutes.
  - If the motor data sheet says it takes 75 mins to cool, enter a time constant of 15 minutes.
Setting Example

Stopped & Running Cool Time Constants

This information is usually supplied by the motor manufacturer but is not part of the data that was given with this motor. If RTD’s are present and will be wired to the relay biasing of the thermal model will be used so it is not critical to have these cooling times from the manufacturer: the default values of 15 and 30 minutes can be used for the running and stopped cool times respectively.
Setting Example

Determine RTD Bias Setpoints for Thermal Model

Enable RTD Biasing

This will enable the temperature from the Stator RTD sensors, to be included in the calculations of Thermal Capacity. RTD bias model determines the Thermal Capacity Used based on the temperature of the Stator and is separate from the overload model for calculating Thermal Capacity Used. RTD biasing is a back up protection element which accounts for such things as loss of cooling or unusually high ambient temperature. This measured temperature is used to bias or modify the thermal capacity value stored in the motor relay.
**Setting Example**

Determine RTD Bias Setpoints for Thermal Model

- RTD input is an indicator of the thermal capacity used dependent on stator temperature (very slow).

- Motor relay will use the calculated thermal capacity unless the RTD thermal capacity is higher.

### RTD Bias Function
- **Set to Enabled/YES**

### RTD Bias Minimum
- **Set to 40 °C** which is the ambient temperature obtained from the data sheets.

### RTD Bias Center Point
- The center point temperature is set to the motor's hot running temperature and is calculated as follows:
  - Temperature Rise of Stator + Ambient Temperature.
  - The temperature rise of the stator is 80 °C + 10% hot spot allowance, obtained from the data sheets.
  - Therefore, the RTD Center point temperature is set to 90°C + 40°C or 130 °C.

### RTD Bias Maximum
- This setpoint is set to the rating of the insulation or slightly less. A class F insulation is used in this motor which is rated at 155 °C, so setting should be 155 °C.
When a motor starts, the starting current (which is typically 6 times the Full Load Current (FLC) rating of the motor) has asymmetrical components. These asymmetrical currents may cause one phase to see as much as 1.7 times the normal RMS starting current. As a result the pickup of the short circuit element must be set higher than the maximum asymmetrical starting currents seen by the phase CTs to avoid nuisance tripping. The rule of thumb is to set the short circuit protection pickup to a value which is at least 1.7 times the maximum expected symmetrical starting current of the motor. This allows the motor to start without nuisance tripping.

It is important to note that the device that the relay is to control under such conditions must have an interrupting capacity equal to or greater than the maximum available fault current.
**Setting Example**

Determine Short Circuit Trip Settings

**Short Circuit Trip**

The short circuit trip should be set above the maximum locked rotor current but below the short circuit current of the fuses. The data sheets indicate a maximum locked rotor current of 540% FLC or 5.4 x FLC. A setting of 6 x FLC with an instantaneous time delay will be ideal but nuisance tripping may result due to the asymmetrical starting currents and DC offset. If asymmetrical starting currents limits the starting capability, set the S/C level higher to a maximum of 9.2 x FLC to override this condition (1.7 x 5.4 = 9.2 where 1.7 is the maximum DC offset for an asymmetrical current). With 300:5 CT, 9.2 x FLC = 9.2 x 297/300 = 9.10 CT

<table>
<thead>
<tr>
<th>Short Circuit Trip</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Short Circuit Trip</td>
<td>Latched</td>
</tr>
<tr>
<td>Overreach Filter</td>
<td>Off/No</td>
</tr>
<tr>
<td>Short Circuit Trip Relays</td>
<td>Trip</td>
</tr>
<tr>
<td>Short Circuit Trip Pickup</td>
<td>9.1 CT</td>
</tr>
<tr>
<td>Intentional Short Circuit Trip Delay</td>
<td>0 ms</td>
</tr>
<tr>
<td>Short Circuit Trip Backup</td>
<td>Off/No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Current Sensing</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase CT Primary</td>
<td>300 A</td>
</tr>
<tr>
<td>Motor Full Load Amps</td>
<td>297 A</td>
</tr>
<tr>
<td>Ground CT Type</td>
<td>5 A Secondary</td>
</tr>
<tr>
<td>Ground CT Primary</td>
<td>50 A</td>
</tr>
<tr>
<td>Phase Differential CT Type</td>
<td>None</td>
</tr>
<tr>
<td>Enable Two Speed Motor Option</td>
<td>Off/No</td>
</tr>
</tbody>
</table>
Setting Example
Determine Current Unbalance Alarm/Trip Settings

Unbalance Alarm and Trip
The unbalance settings are determined by examining the motor application and motor design. The heating effect of unbalance will be protected by enabling unbalance input to thermal memory; described previously.

A setting of 10% x FLA for the Unbalance Alarm with a delay of 10 seconds would be appropriate

Trip can be set to 25% x FLA with a delay of 5 seconds.

<table>
<thead>
<tr>
<th>Current Unbalance</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Setting</td>
<td>Parameter</td>
</tr>
<tr>
<td>Current Unbalance Alarm</td>
<td>Unlatched</td>
</tr>
<tr>
<td>Current Unbalance Alarm Relays</td>
<td>Alarm</td>
</tr>
<tr>
<td>Current Unbalance Alarm Pickup</td>
<td>10 %</td>
</tr>
<tr>
<td>Current Unbalance Alarm Delay</td>
<td>10 s</td>
</tr>
<tr>
<td>Current Unbalance Alarm Events</td>
<td>On/Yes</td>
</tr>
<tr>
<td>Current Unbalance Trip</td>
<td>Latched</td>
</tr>
<tr>
<td>Current Unbalance Trip Relays</td>
<td>Trip</td>
</tr>
<tr>
<td>Current Unbalance Trip Pickup</td>
<td>25 %</td>
</tr>
<tr>
<td>Current Unbalance Trip Delay</td>
<td>5 s</td>
</tr>
</tbody>
</table>
Setting Example
Ground Fault & Acceleration Trip Settings

Ground Fault
Limit the ground fault current to less than 10amps.
In this example, use $0.16 \times CT$ or $0.16 \times 50 = 8A$

Acceleration Trip
This setpoint should be set higher than the maximum starting time to avoid nuisance tripping when the voltage is lower or for varying loads during acceleration. A value greater than 15 seconds should be entered (based on motor data sheet).

<table>
<thead>
<tr>
<th>Setting</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Fault Alarm</td>
<td>Unlatched</td>
</tr>
<tr>
<td>Ground Fault Alarm Relays</td>
<td>Alarm</td>
</tr>
<tr>
<td>Ground Fault Alarm Pickup</td>
<td>0.10 CT</td>
</tr>
<tr>
<td>Intentional GF Alarm Delay</td>
<td>500 ms</td>
</tr>
<tr>
<td>Ground Fault Alarm Events</td>
<td>On/Yes</td>
</tr>
<tr>
<td>Ground Fault Trip</td>
<td>Latched</td>
</tr>
<tr>
<td>Ground Fault Trip Relays</td>
<td>Trip</td>
</tr>
<tr>
<td>Ground Fault Trip Pickup</td>
<td>0.15 CT</td>
</tr>
<tr>
<td>Intentional GF Trip Delay</td>
<td>500 ms</td>
</tr>
<tr>
<td>Ground Fault Trip Backup</td>
<td>Off/No</td>
</tr>
<tr>
<td>Ground Fault Overreach Filter</td>
<td>Off/No</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Setting</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acceleration Timer Trip</td>
<td>Latched</td>
</tr>
<tr>
<td>Acceleration Timer Trip Relays</td>
<td>Trip</td>
</tr>
<tr>
<td>Acceleration Timer from Start</td>
<td>20.0 s</td>
</tr>
</tbody>
</table>
Enable Start Inhibit

This function will limit starts when the motor is already hot. The motor relay learns the amount of thermal capacity used at start. If the motor is hot, thus having some thermal capacity used, the relay will not allow a start if the available thermal capacity is less than the required thermal capacity for a start.

For example, if the THERMAL CAPACITY USED for the last 5 starts is 24, 23, 27, 25, and 21% respectively, the LEARNED STARTING CAPACITY is 27% × 1.25 = 33.75% used. If the motor stops with 90% thermal capacity used, a start block will be issued. When the motor has cooled and the level of thermal capacity used has fallen to 66%, a start will be permitted. If the COOL TIME CONSTANT STOPPED setpoint is programmed for 30 minutes, the lockout time will be equal to:

<table>
<thead>
<tr>
<th>Setting</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>Start Inhibit Block</td>
<td>On/Yes</td>
</tr>
<tr>
<td>Thermal Capacity Used Margin</td>
<td>25 %</td>
</tr>
</tbody>
</table>
**Start Inhibit**

Upon a start, the inrush current is above the motor’s full load current causing the thermal capacity used within the motor to rise rapidly. GE Multilin Motor Management Relays “learn” the amount of thermal capacity required to start the motor and if the start inhibit function is enabled, use this information in addition to the thermal capacity used data to ensure that there is enough thermal capacity within the motor for a successful start before a start is attempted.
TCU / Start Inhibit Example

Thermal Capacity required to start

For example, if the THERMAL CAPACITY USED for the last 5 starts is 24, 23, 27, 25, and 21% respectively, the LEARNED STARTING CAPACITY is $27\% \times 1.25 = 33.75\%$ used.

Thermal Capacity used due to Overload

If the motor had been running in an overload condition prior to stopping, the thermal capacity would be some value; say 80%.

If Motor is Stopped:

When the motor has cooled and the level of thermal capacity used has fallen to 66%, a start will be permitted.
Setting Example
Starts/Hr, Time Between Starts

**Starts/Hour**
Starts/Hour can be set to the # of cold starts as per the data sheet. For this example, it is 2

**Time Between Starts**
In some cases, the motor manufacturer will specify the time between motor starts. In this example, this information is not given so this feature can be disabled. However, if the information is given, the time provided on the motor data sheets should be programmed.
### Setting Example

RTD Alarm & Tripping

#### Stator RTDs

RTD trip level should be set at or below the maximum temperature rating of the insulation. This example has a class F insulation which has a temperature rating of 155°C, therefore the Stator RTD Trip level should be set to between 140°C to 150°C, with 150°C being maximum. The RTD alarm level should be set to a level to provide a warning that the motor temperature is rising.

#### Bearing RTDs

The Bearing RTD alarm and trip settings will be determined by evaluating the temperature specification from the bearing manufacturer.

<table>
<thead>
<tr>
<th>RTD #1</th>
<th>Parameter</th>
</tr>
</thead>
<tbody>
<tr>
<td>RTD #1 Application</td>
<td>Stator</td>
</tr>
<tr>
<td>RTD #1 Name</td>
<td>St Ph A1</td>
</tr>
<tr>
<td>RTD #1 Alarm</td>
<td>Unlatched</td>
</tr>
<tr>
<td>RTD #1 Alarm Relays</td>
<td>Alarm</td>
</tr>
<tr>
<td>RTD #1 Alarm Temperature</td>
<td>135°C</td>
</tr>
<tr>
<td>RTD #1 Alarm Events</td>
<td>On/Yes</td>
</tr>
<tr>
<td>RTD #1 Trip</td>
<td>Latched</td>
</tr>
<tr>
<td>RTD #1 Trip Voting</td>
<td>RTD #4</td>
</tr>
<tr>
<td>RTD #1 Trip Relays</td>
<td>Trip</td>
</tr>
<tr>
<td>RTD #1 Trip Temperature</td>
<td>155°C</td>
</tr>
<tr>
<td>RTD #1 Hi Alarm</td>
<td>Off</td>
</tr>
</tbody>
</table>
The Differential Trip element function can only be used if both sides of each stator phase are brought out of the motor for external connection such that the phase current going into and out of each phase can be measured.

The differential element subtracts the current coming out of each phase from the current going into each phase and compares the result or difference with the differential Pickup Level. If this difference is equal to or greater then the pickup level for a period of time greater a user specified delay, a trip will occur.

Separate pickup levels and delay times are provided for the motor starting and running conditions.

Motor protective relays support both 3 and 6 CT configurations. In this example both sides of each of the motors stator phases are being past through a single CT. This is called core balance method and is the most desirable owing to it’s sensitivity and noise immunity.

The level may be set more sensitive if the Differential CTs are connected in core balance configuration (3 CTs).
Phase Differential

If 6 CTs are used in a summing configuration, during motor starting, the values from the two CTs on each phase may not be equal as the CTs are not perfectly identical.

Asymmetrical currents may cause the CTs on each phase to have different outputs. To prevent nuisance tripping in this configuration, the starting differential level may have to be set less sensitive, and the starting differential time delay may have to be extended to ride through the problem period during start. The running differential delay can then be fine tuned to an application such that it responds very fast and is sensitive to low differential current levels.

**Summation Method**

<table>
<thead>
<tr>
<th>SETTING</th>
<th>PARAMETER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Phase Differential Trip</td>
<td>Latched</td>
</tr>
<tr>
<td>Phase Differential Trip Relays</td>
<td>Trip</td>
</tr>
<tr>
<td>Differential Trip Pickup While Starting</td>
<td>0.30 CT</td>
</tr>
<tr>
<td>Differential Trip Delay While Starting</td>
<td>20 ms</td>
</tr>
<tr>
<td>Differential Trip Pickup While Running</td>
<td>0.30 CT</td>
</tr>
<tr>
<td>Differential Trip Delay While Running</td>
<td>0 ms</td>
</tr>
</tbody>
</table>
The overall result of an under or overvoltage condition is an increase in current and motor heating and a reduction in overall motor performance.

The undervoltage trip should be set to 90% of nameplate unless otherwise stated on the data sheets. Motors that are connected to the same source, may experience a temporary undervoltage when one of motors starts. To override these temporary sags, a time delay setpoint should be set.

The overvoltage element should be set to 110% of the motors nameplate unless otherwise started in the data sheets.
Motor Protection

- 239
- 369
- 469
- M60
- SPM
- MM2
- LM10
239 Motor Protection

- Small to medium sized motors
- Pumps, conveyors, compressors, fans, sawmills, mines
- Thermal overload (15 selectable curves)
- Phase short circuit
- Locked rotor / mechanical jam
- Thermal memory lockout
- Single phase/unbalance
- Ground fault O/C
- Overtemperature via stator thermistor and optional 3 RTDs (RTD)
- Undercurrent
- Trip/alarm/auxiliary/service outputs
- Setpoint Access, Emergency Restart, External Reset, Option 1, Option 2 digital inputs
- Two speed motor protection
- Current, unbalance, motor load, thermal capacity, temperature metering
- Optional analog output (AN)
- Fault diagnosis – last 5 trip records
- AC/DC control power & flash memory
- RS485 ModBus™ communications
- 40 character illuminated display
- 6 LED indicators
239 Motor Protection

Functional Block Diagram

DEVICE PROTECTION

- 37 Undercurrent/minimum load
- 38 Motor/load bearing overtemperature
- 39 Mechanical jam
- 46 Current unbalance
- 49 Stator winding overtemperature
- 50 Phase short circuit
- 51 Timed overload
- 50G/50N Ground fault instantaneous or definite time
- 74 Alarm relay
- 86/94 Lockout and trip relay
369 Motor Protection

- Thermal model biased with Unbalance
- Thermal Overload Curves (15 + 1 custom)
- Phase short circuit, locked rotor / mechanical jam, variable lockout time
- Single phase/unbalance, ground fault O/C
- Overtemperature 12 RTDs and RTD Thermal Compensation (R)
- Starts/hour, time between starts
- Undercurrent
- Phase Reversal (M)
- Back-Spin Detection (B)
- Ability to "learn" individual motor parameters motor inrush current, cooling rates, and acceleration time
- Starter Failure Feature, Motor Load Averaging Interval
- AC/DC control power & flash memory
- 5 pre-defined digital inputs
- Trip/Alarm/Aux1/Aux2 Relay Outputs
- Load, current, unbalance metering
- Voltage/frequency/power metering (M)
- Event recorder (last 40), waveform capture
- 4 analog outputs (M)
- Front RS232 port & 3 rear RS485 ports
- Modbus Protocol
- Fiber optic link (F)
- Ethernet Port (E)
- 40 character display, 10 LEDs and keypad
369 Motor Protection

**DEVICE** | **PROTECTION**
---|---
14 | Speed switch
27/59 | Undervoltage/Overvoltage
37 | Undercurrent/Underpower
38 | Bearing RTD
46 | Current Unbalance
47 | Phase Reversal
49 | Stator RTD
50 | Short circuit & short circuit backup
50G/51G | Ground o/c & ground o/c backup
51 | Overload
55 | Power factor
66 | Starts/hour & time between starts
81 | Frequency
86 | Overload lockout
87 | Differential
369 Motor Protection
369-RRTD Application

Switchgear Location | Motor Location

---|---

369

Power, AC Sensing, Control Circuits

RS-485 or Fiberoptic

RRTD Module

Power

Up to 12 RTDs or Process Inputs
469 Motor Protection

- Medium & large motors, driven equipment
- Thermal model biased with RTD and/or Unbalance
- Voltage Dependant Curve for Large Inertia Loads
- Phase differential protection
- Mechanical jam, short circuit trip, overload alarm, undercurrent, ground fault, current unbalance
- Starting current & capacity, acceleration time, average motor load, max RTDs, min/max analog inputs
- Power setpoints (PF, W, Var, Underpower)
- Undervoltage & overvoltage
- Underfrequency & overfrequency
- Monitoring setpoints (demand, counters)
- Dual overload curves for 2 speed motors
- Reduced voltage starting control
- A, V, W, var, VA, Hz, Wh, varh, demand, torque, temperature
- Event recorder & waveform capture
- 12 programmable RTDs
- 5 pre-defined & 4 assignable digital inputs, 6 outputs
- 4 analog inputs & 4 programmable analog outputs
- RS232 & RS485 ports
- Modbus protocol
- Complete drawout construction
- New enhanced display (E)
- Available with 10BaseT Ethernet (T)
469 Motor Protection

DEVICE | PROTECTION
--- | ---
14 | Speed switch
19/48 | Reduced voltage start and incomplete sequence
27/59 | Undervoltage/Overvoltage
32 | Reverse power
32 | Mechanical Jam
32 | Acceleration time
32 | Over Torque
37 | Undercurrent/Underpower
38 | Bearing RTD
46 | Current Unbalance
47 | Phase Reversal
49 | Stator RTD
50 | Short circuit backup
50G/51G | Ground overcurrent backup
51 | Overload
55 | Power factor
66 | Starts/hour and time between starts
81 | Frequency
86 | Overload lockout
87 | Differential
469 Motor Protection
M60 Motor Protection

- Stator Differential (87) with CT Saturation Detection
- Current/Amp Unbalance
- Thermal Model (RTD/Unbalance Bias, Programmable Curves)
- Voltage Dependant Curve for Large Inertia Loads
- Phase, Ground, Neutral IOC
- Phase and Neutral Directional OC
- Ground TOC
- Starts per hour, Time between starts, Restart time delay
- Emergency Restart, Mechanical Jam
- Acceleration Time Logic
- Sensitive Directional Power (32)
- Phase Undervoltage & Overvoltage (27/59P)
- Auxiliary Undervoltage & Overvoltage (27/59X)
- Neutral Overvoltage
- VT Fuse Failure for Supervision of Voltage Dependant Functions
- Breaker Failure (50BF)
- Negative Sequence Overvoltage
- FlexLogic with gates and timers
- Transducer I/O
- Contact Inputs/Outputs
- Virtual Inputs/Outputs
- Remote Inputs/Outputs
- FlexElements (16)
- Programmable LED Panels & Optional Pushbuttons
- Metering, Event Recorder & Oscillography
- DNP, Modbus RTU & UCA Protocols
- 6 Setting Groups
- Ethernet Port and RS485 port

M60-G00-HPH-F8F-H6P-M8H-P5C-U5D-WXX
M60 Motor Protection

<table>
<thead>
<tr>
<th>DEVICE NUMBER</th>
<th>FUNCTION</th>
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<tbody>
<tr>
<td>27P</td>
<td>Phase Undervoltage</td>
</tr>
<tr>
<td>27X</td>
<td>Auxiliary Undervoltage</td>
</tr>
<tr>
<td>32</td>
<td>Sensitive Directional Power</td>
</tr>
<tr>
<td>46</td>
<td>Current Unbalance</td>
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<tr>
<td>47</td>
<td>Phase Sequence Voltage</td>
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<tr>
<td>49</td>
<td>Thermal Overload</td>
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<tr>
<td>50BF</td>
<td>Breaker Failure</td>
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<tr>
<td>50G</td>
<td>Ground Instantaneous Overcurrent</td>
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<tr>
<td>50N</td>
<td>Neutral Instantaneous Overcurrent</td>
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<tr>
<td>50P</td>
<td>Phase Instantaneous Overcurrent</td>
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<table>
<thead>
<tr>
<th>DEVICE NUMBER</th>
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</thead>
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<tr>
<td>51G</td>
<td>Ground Time Overcurrent</td>
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<tr>
<td>50N</td>
<td>Neutral Overvoltage</td>
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<tr>
<td>50P</td>
<td>Phase Overvoltage</td>
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<tr>
<td>50X</td>
<td>Auxiliary Overvoltage</td>
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<tr>
<td>50_2</td>
<td>Negative Sequence Overvoltage</td>
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<tr>
<td>66</td>
<td>Starts Per Hour, Time Between Starts</td>
</tr>
<tr>
<td>67N</td>
<td>Neutral Directional Overcurrent</td>
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<tr>
<td>67P</td>
<td>Phase Directional Overcurrent</td>
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<tr>
<td>67S</td>
<td>Stator Differential</td>
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<tr>
<td>...</td>
<td>Mechanical Jam</td>
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</tbody>
</table>
SPM Synchronous Motor Protection & Control

- Field application
- Reluctance torque synchronizing (collector ring)
- Cage winding & stall protection during start
- Restart lockout for hot rotor
- Reduced voltage starting
- Power factor (pull-out) trip with auto resynchronizing
- Incomplete sequence trip
- Loss of DC field current trip
- Loss of DC field voltage trip
- Field winding overtemperature trip
- PF regulation maximizes efficiency (optional)
- Field voltage, field current, motor amp calibration
- Contactor status input, reduced voltage status input
- Trip/FAR/FCX outputs
- Metering
  - AC stator current
  - Power factor
  - DC field current
  - DC field voltage
  - DC field resistance (Exc field)
  - Motor running time
  - Type of trips (counters)
- Rear RS485 Modbus port
- Windows based SPMPC software
  - Trending capability
- Drawout construction
SPM Synchronous Motor Protection & Control

ANSI DEVICE NUMBERS

- 26F Field overtemperature
- 27 Undervoltage
- 37 Undercurrent or underpower
- 48 Incomplete sequence
- 50 Instantaneous overcurrent
- 55 Power factor
- 56 Field application
- 86 Lock out
- 94 Tripping
- 95 Reluctance torque sync./resync.
- 96 Autoloading relay
MM2 Motor Protection

- Motor protection & management system for low voltage, low horsepower motors
- Specifically designed for Motor Control Center applications
- Front panel control buttons (start A, start B, stop, manual, auto)
- Protection & Control
  - Thermal Overload (12 different overload curves)
  - Single phase / Current unbalance
  - Locked/stalled rotor
  - Ground fault
  - Undervoltage, overvoltage, overtemperature
  - Undercurrent and underpower
  - Configurable motor start controller
  - Contactor failure, undervoltage auto restart
- Monitoring & Metering
  - Motor operational parameters and historical data
  - Process data
  - Display phase current, ground current, thermal capacity, analog input, power, energy, etc.
  - Status of relay inputs
  - Trip record and pre-trip values
  - Maintenance information
- Remote monitoring - via serial communications
  - RS485 ModBus™, 1200 - 19,200 bps
- Outputs: 2 contactor, 2 programmable
- Inputs: 6 fixed, 10 programmable
- Front Panel
  - 11 LEDs, key pad, and 2x20 LCD display
- Includes EnerVista setup software
- MM2 unit with remote display (optional)
MM2 Motor Protection

Functional Block Diagram

DEVICE PROTECTION

- Standard Protection
  - 49/51 overload
  - 46 phase unbalance (single-phase)
    - welded/open contactor
- Option 2 Enhancement
  - 50G/51G ground fault
  - 48 locked rotor/stalled rotor
  - 49 hot winding (thermistor)
  - 37 undercurrent/underpower
  - 27 undervoltage/overvoltage
  - 59 overvoltage

*refer to the ANSI standard Device Designation Numbers in the catalog for a complete list of ANSI numbers.
MM2 Motor Protection
LM10 Low Voltage Motor Relay

- Low voltage motors up to 500HP
- Designed for GE Evolution MCC ... but applicable to any LV MCC
- Motor Types
  > Full Voltage non-reversing, Full Voltage reversing, Reduced Voltage, Two Speed- one winding, Two Speed-two winding, Custom Motor Type
- Selection of NEMA overload trip classes (Class 10, 15, 20 or 30)
- Protection
  > Overcurrent Trip, Cool Down Time, Current Unbalance Trip, Ground Fault Trip, Over/Undervoltage Trip, Jam Protection, Stall Protection, Load Loss Trip, Auxiliary Sense Failure, Power Loss Autorestart Feature
- 7 Digital Inputs and 4 Relay Outputs
- Power Supply Input (96 to 140VAC range)
- DeviceNet protocol (control, status, metering, settings)
  > Standard Harris 5Pin Micro connector (allows daisy chain from one unit to another)
  > Hardware Selectable MAC ID & Baud Rate (Up to 63 address & 500kbps)
- Status LEDs
  > Module Status, Network Status, Overcurrent Trip, Gnd Fault Trip, O/C Unbalance
- RJ11: 6C Telephone Jack
  > Used to connect to either PDU or PC; PC cable included, connect via Com1 and use enerVista LM10 setup software
- Real-Time Metering
  > Ia, Ib, Ic, Ig, Vab, 3ph-kW, 3ph-PF, Iavg, Current Unbalance, Elapsed Motor Hours (user can reset)
- Trip History (Last 10 faults)
  > Maintained in non-volatile memory
  > Ia, Ib, Ic, Ig, Vab, 3ph-kW, 3ph-PF, Iavg, Current Unbalance
LM10 Low Voltage Motor Relay
Avoid the Effects of Hydrogen Sulfide on Your Relays:

“Silver Whiskers is the name given to long filaments of silver sulfide formed on the surface of silver electrical contacts or surfaces operating in an atmosphere rich in hydrogen sulfide and high humidity. Such atmospheres can exist in sewage treatment and paper mills. If left too long, the silver whiskers form a potentially devastating short circuit”

Conformal Coating/Harsh Environment Option Available for:

- 369
- 469
- 489
- SPM
- 750/760
- 745
- F35
- F60
- T60
- T35
- M60
- G30
- C30
- C60
- B30
- B90
- L60
- L90

Coming Soon: PQMII, 239, MMII
Monitoring, Control & Communications Solutions

- MultiNet Converter
- Protocol Converter
- MultiLink Ethernet Switches
- enerVista Viewpoint Monitoring Software
- enerVista Integrator
- Automation Projects
Communication Solutions...

**MultiNet – RS485 to Ethernet Converter**

- Converts Modbus RTU over RS485 into Modbus TCP/IP over Ethernet
- Supports both 10BaseT and 10BaseF fiber connections
- Industrially hardened product
- Connect up to 32 RS485 serial devices to an Ethernet network
- Modbus TCP/IP provides multiple SCADA masters allowing simultaneous communications to the same IED
- Easy to use set up software

Serial IEDs are connected to an Ethernet network via the MultiNet unit.

**Coming Soon:**
4 RS485 port MultiNet
(any protocol translated)

---

One simple communications solution for all your GE Multilin IEDs
Communication Solutions...

MultiNet Connections

SCADA

HMI

Viewpoint

Modbus TCP/IP

LAN/WAN

Modbus TCP/IP

Modbus TCP/IP

Terminating Network (120Ω Resistor and 100pF Capacitor)

Terminating Network (120Ω Resistor and 100pF Capacitor)

+ - Shield
RS485 COM PORT
IED #1

+ - Shield
RS485 COM PORT
IED #2

+ - Shield
RS485 COM PORT
IED #32

GE Consumer & Industrial
Multilin
Communication Solutions...

MultiNet Set-up
Communication Solutions...

Protocol Converters

Modbus to Devicenet Converter (D485)
Modbus to Profibus Converter (P485)

- Connect any Modbus RTU device to a Profibus or Devicenet network
- Communicate with up to 5 Modbus devices per converter
- Software contains the memory maps for all GE Multilin devices
- Industrially hardened product
The GE-Multilin Solution for communicating to all relays, meters and other power system devices

Meets all Industrial standards and requirements for Substation hardened equipment

Modular Construction supports many different communication types for easy interoperability with any networking devices

Enhanced security providing reliable communications and protection against tampering or message forgery

IEC61850-3 Compliant and optimized to give priority to GOOSE Peer-to-Peer messages

Factory Certified to work optimally with all GE Multilin products
Communication Solutions...

MultiLink – Ethernet Switches

Key Features

- High-Speed recovery of redundant LANs using open standard solutions
- Link Loss Alert feature allowing detecting and re-routing of broken Fiber connections
- Ethernet Ports available on the Front or Rear of the ML2400
- Giga-bit Uplink ports available for connecting multiple switches
- Redundant Power Supply options available

Modular Construction supports any device

Each switch has a modular construction that allows support for mixed types of communication ports on one switch. This modularity allows for connecting to any Ethernet device in your facility in a cost-effective solution. Media formats available include:

- 10/100Mb RJ/45 Copper Ethernet
- 10Mb Multimode Fiber Optics – ST Connectors
- 100Mb Multimode Fiber Optics – SC Connectors
- 100Mb Singlemode Fiber Optics – SC Connectors
- 100Mb Multimode Fiber Optics – MTRJ Connectors
- 100Mb Multimode Fiber Optics – LC Connectors
- 100Mb Singlemode Fiber Optics – LC Connectors

Ideal for Harsh Industrial Environments

GE Multilin’s MultiLink line of switches have been tested and certified to meet the same rigorous environmental standards as all of our protection relays and meters.

- Operating Temperature -40° to +85°
- Type tested to all IEC, IEEE and NEBS level 3 substation requirements
- IP 60 Rated
- CSA, UL and CE approved
- Zero moving parts
- Metal casing construction

GE Consumer & Industrial
Multilin
Communication Solutions...

MultiLink – Ethernet Switches

3 Models Available to fit any Application

ML2400 - 19" Rack Mounted Managed Switch

ML1600 - 9" Panel Mounted Managed Switch

ML600 - Compact Unmanaged Switch
Communication Solutions...

Ethernet Communications?

• 369 Relay
  > Use MultiNet with existing relays
  > Purchase “E” option (10BaseT)

• 469 Relay
  > Use MultiNet with existing relays
  > Purchase “T” option (10BaseT)

• 239, 269Plus, MMII & SPM Relays
  > Use MultiNet with existing relays

• M60 Relay
  > Purchase Ethernet option (10BaseT/F)
  > Connect rear RS485 port to MultiNet

• Use MultiLink Ethernet Switches to connect relays directly or via MultiNet converters
Monitoring/Control Software Solutions...

**EnerVista**
A suite of software tools that manage every aspect of working with GE Multilin IEDs
Monitoring/Control Software Solutions...

**EnerVista VIEWPOINT**
Premium Workflow Toolset Simplifying monitoring, Troubleshooting, Settings Mgmt, & Reporting

Enervista™ Viewpoint Streamlines your job function

- **Protection Engineer**
  - Streamline the process of creating control logic

- **Electrical Personnel**
  - Perform Detailed analysis of trip data

- **Electrical Engineer**
  - Receive Reports indicating Plant efficiency

- **Maintenance Personnel**
  - Simplify the process of reading power levels

- **Commissioning Engineer**
  - Verify correct operation of protection elements
Viewpoint Monitoring is a cost effective and simple software package for Utilities to control and monitor intelligent electrical devices (IEDs) using a PC.

- Windows-based software
- Connect to IEDs via modem, serial or Ethernet via Plug-n-Play screens
- Pre-built drivers for GE Multilin digital relays, such as UR, 750, 760, 469, 745, PQM, F60, F35, PQMII, etc.
- Easy set-up screens & interactive help files
- Build single-line drawings, metering, annunciator, and status screens easily
- Generic Modbus driver for other manufacturer’s IED implementation (Control & Monitoring)
- Automatic Oscillography Retrieval & SOE Capture

Alternative Energy
Remotely monitor and manage devices without incurring significant capital costs

Distributed Generation
Utilities can connect easily with independent generators via LAN/Internet

Utility
Control & monitor non-SCADA sites with minimal capital investment
Monitoring/Control Software Solutions ...

Viewpoint Monitoring

Plug and Play Monitoring
Pre-Configured Modules for Analyzing the Health and Status of your Power System Equipment
**Monitoring/Control Software Solutions**... 

**Viewpoint Monitoring**

**Single-Line Monitoring and Control**

**Monitor and Control all devices in your Power System**

- Identify the status of all the devices in your power system on one customized single line monitoring screen
- Monitor the magnitude of any power quantity measured by your metering and protection devices
- Navigate through multiple monitoring screens to view the status of different parts of your network

**Create single-line monitoring screens in minutes**

- Construct system diagrams with drag and drop ease
- Contains all necessary symbols and tools required for replicating your power system
- Includes a library of meters and Dials to graphically represent any metered quantity
Monitoring/Control Software Solutions ...

Viewpoint Monitoring

Trending Reports
Historical Record of monitored data
• Trend up to 500 data points
• Records data with 1 minute resolution indefinitely
• View data in time based graphical or tabular format

Annunciator Alarming
Instant Alarm Notification
• Create alarms on any monitored analog or digital data point
• Receive alarm warnings through Audio, Visual or Email notification

Global Comtrade Viewer
View waveforms recorded from any device
• Convert waveforms that were stored in CSV format to COMTRADE compatible files
• Merge and Overlay waveforms that were recorded in multiple devices
• Identify the harmonics content in all monitored parameters
Monitoring/Control Software Solutions ...

Viewpoint Monitoring

Automatic Event and Waveform Retrieval

**Effortless Data Archiving**

- Instantly detects and retrieves any new waveform from all GE Multilin devices, EMP Meters and MicroVersa Trip Units, and saves these files on a Network location.

- Automatically acquires any new events recorded in all devices and stores them in system wide Sequence of Event Record.

- Sort and Query through system event record to view events categorized by date, device type, timestamp, or customized criteria.

- No configuration required.
Monitoring/Control Software Solutions ...

Viewpoint Monitoring

Plug-and-Play Monitoring for the 469 - Trip Data -

On-screen View of Diagnostic Data Makes It Easy to Identify Cause of Motor Trip
Monitoring/Control Software Solutions ...

Viewpoint Monitoring

Plug-and-Play Monitoring for the 469
- Overview -

View Motor Status Using Digital Inputs, Analog Inputs and RTD Inputs
Monitoring/Control Software Solutions ...

Viewpoint Monitoring

Plug-and-Play Monitoring for the 469 - RTDs -

Monitor Temperature at Any Motor Location in One View
Monitoring/Control Software Solutions ...

Demonstration

Viewpoint Monitoring Software
EnerVista INTEGRATOR
Integrate Previously Unavailable Data into your Existing System

Easily Enhance Current Systems to Display Data from GE Multilin Devices

- **Motors**: Motor status, Motor load, Thermal capacity, RTD Temperature
- **Transformers**: Power, Total Harmonic Distortion, Phase current, current demand, Percent differential
- **Meters**: Phase voltage and current, Power, Power factor, Demand, Total Harmonic Distortion
- **Feeders**: System frequency, Bus and Line voltage, Phase current, current demand
- **Generator**: Generator Status, Generator Load, power demand, Differential current
- **BUS**: Differential current, Restraining current, Feeder voltage, Feeder Current, Breaker status, switch status
- **Line**: Power flow, Megawatts, MegaVars, Demand
- **Trip Units**: Breaker status, Phase currents, phase voltage, demand, Power factor
Monitoring/Control Software Solutions ...

EnerVista INTEGRATOR
Integrate Previously Unavailable Data into your Existing System

Makes it easy to integrate Multilin Devices into existing Systems
Monitoring/Control Software Solutions ...

**EnerVista INTEGRATOR**
Integrate Previously Unavailable Data into your Existing System

<table>
<thead>
<tr>
<th>Customer Types</th>
<th>LAUNCHPAD</th>
<th>VIEWPOINT</th>
<th>ENERGY AGGREGATOR</th>
<th>INTEGRATOR</th>
<th>PMCS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maintenance Personnel</td>
<td>- Document Library</td>
<td>- Monitoring Volts, Current, PF</td>
<td>- Energy usage reports</td>
<td>- Integrate Multilin Devices to HMI</td>
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<tr>
<td></td>
<td>- Waveform download</td>
<td></td>
<td>- Indicates plant inefficiencies</td>
<td>- Creating Monitoring screens</td>
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<td></td>
<td>- Event Record Viewing</td>
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<td>- Load shedding Reports</td>
<td>- Confiuguring Automatic Waveform and Event Retrieval</td>
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<td></td>
<td>- Setup Software subscriptions</td>
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<tr>
<td>Electrical Engineer</td>
<td>- Document Library</td>
<td>- Trending of Relay Data</td>
<td>- Monitoring quality of power</td>
<td>- Integrate the following data into current reporting tools: Watts, VAR’s, Demand</td>
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<tr>
<td></td>
<td>- Config Recording of Waveforms</td>
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<tr>
<td>Protection Engineer</td>
<td>- Element Configuration</td>
<td>- Graphical setting &amp; logic Editor</td>
<td>- Load shedding Reports</td>
<td>- Automatically receive energy usage reportsMonitor relay and system data</td>
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<td></td>
<td>- Settings File Creation</td>
<td>- Relay Connectivity report</td>
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<tr>
<td></td>
<td>- Document Library</td>
<td>- Prot Element, Debugging Reports</td>
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<td>Commissioning Engineer</td>
<td>- Uploading of Settings</td>
<td>- Monitor phasor quantities</td>
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<td></td>
<td>- Testing Relay elements</td>
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<tr>
<td></td>
<td>- Storing relay Manuals</td>
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<tr>
<td>Integrator</td>
<td>- Document Library (Storing memory maps)</td>
<td>- Setting up Power usage reports</td>
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<tr>
<td>Operator Personnel</td>
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Automation Projects Available:

- **PMCS - Power Management Control System**
  Monitoring, Control and Complete Automation of Power Systems

- **Compact Monitoring System**
  Customized Monitoring, Control, Alarming and Data Archiving

- **Energy Cost Allocation / Billing System**
  Energy Usage Monitoring and Billing
Compact Monitoring System
Customized Monitoring, Control, Alarming and Data Archiving

Ideal for:
- Local monitoring and control of substations
- Total control and remote monitoring of small Industrial and commercial facilities

Key Benefits:
- Entire site monitoring through customized one-Line diagrams
- Access to remotely monitor status of power system
- Alarm operations personnel of critical power level changes
- Historical trending of any power system quantity
- Archiving and viewing of all fault data (system wide sequence of events, waveform files)
PMCS – Power Management Control System
Monitoring, Control and Complete Automation of Power Systems

Ideal for:
• Management of power in a facility of any size
• Automated control of all power system equipment

Key Benefits:
• Improve visibility of entire power system network
• Drill into operating conditions of specific power system equipment
• Reduce root cause analysis time
• Receive warnings of impending power system issues before problems occur
• Automate power system functions such as: load shedding, transfer schemes, and initiating backup generators
Monitoring/Control Software Solutions …

Project Deliveries may include:

Installation and Configuration of Meters, Relays and Other Devices
- Installation and wiring at customer site
- Engineering of panels
- Construction and wiring of panels
- Programming all devices

Setting up of Communications Networks
- Connecting device communications
- Installing and configuring Ethernet switches
- Connection to corporate network for remote monitoring

Integration of Monitoring and Control System
- Configuration of system workstation
- Installing of software components
- Creating customized power system monitoring diagrams
- Configuring automatic fault data collection and historical trending functions
- Program system automation functionality
  - Load shedding schemes
  - Auto-Transfer schemes
- Enabling remote monitoring of system

Customer Training
- Teach operators, engineers and technicians how to navigate and control equipment through monitoring system
- Training on system troubleshooting and fault diagnostic methods
- Instruct service personnel on how to maintain devices and system
Q & A
Thanks for the time