Motors are very important in any industrial process, since they are used as prime movers in production processes. Effectiveness, profitability, accuracy and continuity of the processes are decided by uninterrupted running motors.

Motors are to be protected from internal failures as well as external adversities. Winding burnouts, insulation failures, and short circuits are considered as internal failures. Bearing failure, coupling shaft failure, overloads due to processes, and undervoltage are all external causes.

Motor failures can cause major losses. Either such failures should be identified quickly and isolated or they should be prevented. In order to arrest the losses, timely interruption of power supply to the motor is essential. This is achieved by the protection relays.

Industry has been using fuse-backed-up starters for motor protection as well as control. This combination offers coarse but cost effective protection for small motors.

However, for larger motors, such coarse protection is not adequate.

Comprehensive motor protection relays have been in use for quite some time now. Advancement in microprocessor technology and introduction of Intelligent Electronic Devices (IEDs) for protection and control have given rise to integrated motor protection controllers. Right from simple, basic thermal overload protection, these relays offer exhaustive list of protections such as unbalance, undervoltage, undercurrent and load increase. With the extensive list, it is likely that the user's maintenance and operation engineer starts worrying about how to set such a relay precisely and how to offer the best protection to the motor.

Deciding applicable protections is not enough. The motor data is often not available. How to set the relay without such data? What to do with a rewound motor? Often, these questions are raised and do not get answered clearly. These have been the cases in the past where non-availability of motor data resulted in motor protection relay not being available for years after the motor was commissioned. Operation and maintenance engineers used to provide make shift protection to run the processes.

New generation of relays do not require such elaborate motor data. It is possible to set a motor protection relay with more precision even with minimum data. In this issue of L & T Current Trends, we bring information on comprehensive motor protection and an example on how to set motor protection relay with minimum available data. In fact, with Motorvision relays, it is possible to generate motor data even for a rewound motor.

Certain features of the relays are to be used for protective checks so that failures can be prevented. How can it be achieved? The lead article describes this aspect too.

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Motor protection has always been a challenging as well as interesting subject. Motors are the prime movers of any industry. Failure of a motor can have a severe impact on the process and overall cost effectiveness of the plant. Hence, irrespective of the motor size, careful attention must be paid to its protection, specifically if it is a part of an important process.

Statistical data of motor failures/faults over past 5 years indicate:
- about 60% failures/faults are electrical (in motor)
- about 15% failures/faults are related to starters
- about 25% failures/faults are mechanical

Out of the 60% electrical faults, most (85%) are related to stator. The analysis shows:
- about 65% failures are due to stator winding burnout
- about 15% failures are due to stator winding short circuits.
- About 5% failures are due to stator winding open circuit.

Balance 15% failures are of motor winding or insulation deterioration. This analysis clearly indicates that while considering the topic of motor protection, maximum precaution must be taken against stator winding failures.

**Motor protection in stator using bimetal relays:**

Normally, in a starter circuit, switch, fuse, contactor and bimetallic overload relay are provided. The overload relay offers protection against stator windings getting overheated due to overload and the fuse offers protection against short circuits and earth faults. Present generation of bimetal relays offer a coarse protection against single phasing also.

Fuses isolate the fault current themselves but a contactor is activated (opened) by the overload relay for fault isolation. Hence, the current breaking capacity of the contactor has to be co-ordinated while selecting overload relay range in a starter feeder. This point is taken into account while deciding the starter components, if the selection confirms to type 2 co-ordination as per IS 13947.

When the motor starting time is higher, the overload relay characteristic is cut by the motor starting curve. This means, the motor will trip during starting. In such a case, a flatter overload relay characteristic is chosen by using saturable CT operated overload relay. In some extreme cases, the overload relay circuit is even bypassed during starting.

Care must be taken in all cases to ensure that the cold withstand time and the hot withstand time of the motor fall above the respective overload relay curves, as indicated in Fig.1.

**Static overload relays:**

Electronics found its way in switchgear through static protection relays and timers. Static relays offer precise setting as against the bimetal relays. However, the protection offered by bimetal relays is against the winding burnout in motor and also burnout of the cables. Such burnouts are due to the heat generated, and the protection needs to take residual heat into account. Also, for proper protection against heating, RMS value of the current needs to be sensed and not the instantaneous value. Both these requirements are not met by static relays and hence, static overload relays have not found to get good acceptance in the industry.
Comprehensive Motor Protection Relays:
About 80-85% of the motor population is less than 37 kW (50 HP) motors. These motors are generally protected by a bimetal overload relays and fuse combination, for cost effectiveness. However, the balance 15-20% higher rated motors are expensive and they are normally protected by comprehensive motor protection relays. In this article, we shall cover different aspects of motor protection and how they can be taken care of in a comprehensive motor protection relay. Comprehensive motor protection should cover at least the following protections:
- Thermal overload
- Short circuit (not to be provided on contactor controlled starters)
- Earth fault/Earth leakage
- Unbalance
- Locked rotor (stalling)
- Single phasing

In addition to these, for large motors, especially for ACB controlled motors, time delayed undervoltage protection is essential. For ACBs, normally the control supply is DC and hence it is essential to open the ACBs controlling large motors on undervoltage. Whereas, for contactor controlled starters, it is assumed that the control supply for a contactor coil is derived from power supply and hence loss of voltage on power bus will automatically result in dropping out of contactor coil.

L&T offers supervision series Motorvision relays for comprehensive motor protection. In our April-June 1999 issue of L&T Current Trends, we have covered various protections offered by Motorvision relay. To recap, the protections available are:

Pre-start condition:
- Undervoltage Lockout
- Process Inhibit (by digital inputs)
- Adequate thermal capacity to permit successful start of the motor

Starting condition:
- Maximum Start Time (for stalling during starting or inability to reach synchronous speed due to excess load)
- Thermal Overload
- Short Circuit
- Earth Fault
- Single Phasing

Running condition:
With the current sampling at 0.7 msec, the Motorvision relay distinguishes "start" condition from "run" condition. Thereby, a separate set of protections is available in running condition of the motor. They are:
- Thermal overload
- Short circuit
- Earth fault
- Locked rotor (low set overcurrent/stalling)
- Unbalance
- Single phasing
- Undercurrent
- Undervoltage with time delay
- Load increase
- Thermistor / RTD protection

Protections such as unbalance and undervoltage cause nuisance tripping during starting and hence are made applicable during "run" condition only. A low set overcurrent protection in "run" condition facilitates setting of locked rotor protection at very low values (say 150% for 2 sec. or so) thereby preventing mechanical damage/breakdown.

Relay settings:
Availability of a comprehensive relay demands proper selection of the settings so that all protections offered are fully exploited. Let us look at how to choose the relay settings.

One of the highlights of Motorvision relay is that it simulates the thermal capacity of the motor by means of a thermal register. The heating effect inside of the motor is related to the largest of the three line currents. 100% thermal capacity means the motor temperature has reached the maximum allowed and is the level at which an overload trip will occur.
When a motor is stopped for a long time, the thermal capacity used is zero. This is known as "cold condition" and the motor has 100% of its thermal capacity available for heating before a trip will occur.

When a motor starts, it draws higher current (approx. 6 * FLC) and hence consumes higher thermal capacity during starting (till it reaches rated speed). It has to be ensured that adequate thermal capacity is available on the motor for a successful start. Starting thermal capacity is measured and recorded by the Motorvision relay and it monitors whether adequate thermal capacity is available on the motor at the time of the next start. If not, on start command, the relay gives "thermal lockout" alarm.

When running at normal FLC for some period, the motor reaches hot condition and a lower value of thermal capacity is available on such motor. Hot/cold ratio determines the amount of thermal capacity available on a motor in hot condition. Please refer to Table 1.

A motor with lower hot/cold ratio will have lesser thermal capacity available in running condition. For example, in a motor with hot/cold ratio of 70%, at steady state, in hot condition, the motor has 74% thermal capacity availability for overloads.

If the motor running current exceeds overload setting, the thermal capacity will eventually reach 100% and trip the motor. Time taken to trip depends on the present value of thermal capacity used and the t6x time setting (the time set to trip a motor in cold condition when current is 6*FLC).

<table>
<thead>
<tr>
<th>% Hot/Cold Ratio</th>
<th>80</th>
<th>70</th>
<th>60</th>
<th>50</th>
<th>40</th>
<th>30</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steady state % thermal capacity used at 100% FLC</td>
<td>17</td>
<td>26</td>
<td>35</td>
<td>44</td>
<td>52</td>
<td>61</td>
<td>69</td>
</tr>
<tr>
<td>Available % thermal capacity for overloads</td>
<td>83</td>
<td>74</td>
<td>65</td>
<td>56</td>
<td>48</td>
<td>39</td>
<td>31</td>
</tr>
</tbody>
</table>
To trip a motor faster, sometimes speed switch input is given to the Motorvision relay. It decreases the thermal trip time to 50% of the set hot and cold operating times, when the motor is stalled.

Flexibility to choose hot/cold ratio, t6x time and max. start time independently provide complete protection for motors which have not withstand time lesser than the starting time.

When a motor is overload for more than 20%, in place of standard overload characteristics, faster trippings can be achieved by using "load increase" protection. In this case, the tripping are with a definite time delay of few seconds. This protection saves the motor from carrying overloads for longer durations. Settings for t6x, Hot/Cold ratio or max. start time are based on the data normally supplied by the motor manufacturer. In case such data is not available (which can be a case of rewound motor), typical settings are to be used. Alternatively, the time-current graph recorded by the Motorvision relay can be used for working out these settings.

For the clarity on this aspect, let us take a sample data and work on the settings of Motorvision relay for such a motor.

**SAMPLE MOTOR DATA SHEET**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Manufacturer</td>
<td>: M/s. B.H.E.L., Bhopal</td>
</tr>
<tr>
<td>2. Type and frame size</td>
<td>: Sq. Cage, 1LA7 634-4</td>
</tr>
<tr>
<td>3. Application</td>
<td>: PA FAN</td>
</tr>
<tr>
<td>4. Rated output (kW)</td>
<td>: 650</td>
</tr>
<tr>
<td>5. Rated voltage (Volts)</td>
<td>: 6600</td>
</tr>
<tr>
<td>6. No. of phases and frequency</td>
<td>: 3 Ph. 50 Hz.</td>
</tr>
<tr>
<td>7. CTR</td>
<td>: 100 A / 1 A</td>
</tr>
<tr>
<td>8. Starting current in % of FLC</td>
<td>: 600 %</td>
</tr>
<tr>
<td>10. Locked rotor withstand time (Hot condition)</td>
<td>: 33 sec.</td>
</tr>
<tr>
<td>11. Locked rotor withstand time (Cold condition)</td>
<td>: 39 sec.</td>
</tr>
<tr>
<td>13. No load current</td>
<td>: 30 A</td>
</tr>
<tr>
<td>14. Minimum voltage for starting in % of rated voltage</td>
<td>: 85 %</td>
</tr>
<tr>
<td>15. Starting time at minimum starting voltage</td>
<td>: 33 sec.</td>
</tr>
<tr>
<td>16. Locked rotor withstand time at min. starting voltage</td>
<td>: 32 sec. (Hot) 45 sec (Cold)</td>
</tr>
<tr>
<td>17. Max. permissible running time at F.L. at 75% rated voltage</td>
<td>: 5 min.</td>
</tr>
</tbody>
</table>

**Inputs from process**

- Normal load : 500 kW

**MOTORVISION RELAY SETTINGS**

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Maximum start time</td>
<td>: 24 sec.</td>
</tr>
<tr>
<td>2. Hot / cold ratio</td>
<td>: 70%</td>
</tr>
<tr>
<td>3. T6x</td>
<td>: 26 sec.</td>
</tr>
</tbody>
</table>
| 4. Under current | : 50% of ARC  (ARC=52 A based on normal load)  
| Time delay | : 10 sec. |
| 5. Load Increase | : 130%  
| Time delay | : 10 sec. |
| 6. Overcurrent(Trip) | : 300% (During running)  
| Time delay | : 5 sec. |
| 7. Single phase | : Enabled |
| 8. Unbalance current | : 15%  
| Time delay | : 30 sec. |
| 9. Under voltage | : 80 %  
| Time delay | : 3 sec. |
| 10. Under voltage lockout | : 85% (Refer 14 in data) |
| 11. Earth fault | : 15%  
| Time delay | : 1 sec. |
| 12. Number of starts / hour | : 10  
| start inhibit time | : 15 min |
| 13. Overvoltage | : 110%  
| Time delay | : 10 sec. |
| 14. Short circuit | : 10 In |

**CALCULATION**

\[
\text{FLC} = \frac{650}{\sqrt{3}} \times 6.6 (V) \times 0.85 (PF) = 67 A
\]

\[
\text{Hot / cold ratio} = \frac{\text{Hot withstand}}{\text{Cold withstand}} = \frac{100}{69.699} \approx 70\%
\]

\[
\text{t6x} = \text{Time set to trip the relay at } 6 \times \text{FLC} \text{ (Normally 80% of cold withstand time)} \approx 26.4 \text{ sec.}
\]

\[
\text{Cold withstand time} \geq \text{t6x} > \text{Max. start time} > \text{Starting time}
\]

Hence, Max. start time = 24 sec.