

Medium-Voltage Motor Starters and Protection

What would industry do without motors? Can you imagine the processes and products that would not be available to us today if we did not utilize motors of all sizes and types? Of course there must be some safe way of controlling and protecting the large investments and maintaining a safe environment. Medium-voltage (2.3 kV to 15 kV) starters have been around for many years and we have very complex ways of controlling and protecting the circuits and the motors. The higher voltage presents higher levels of safety concern and manufacturers have incorporated interlocks designed to protect us. Those methods include both electrical and mechanical interlocks, all of which an electrician or technician must have a full understanding of how they work and how to work safely. Medium-voltage motor starters have interlocks and protection not usually found in low-voltage equipment. This article will concentrate on mechanical and electrical interlocks that all ANSI compliant medium-voltage motor starting equipment must have as well as motor protection that includes thermal algorithms, number-of-starts limitation, negative sequence protection, resistance temperature detectors (RTDs), and more.

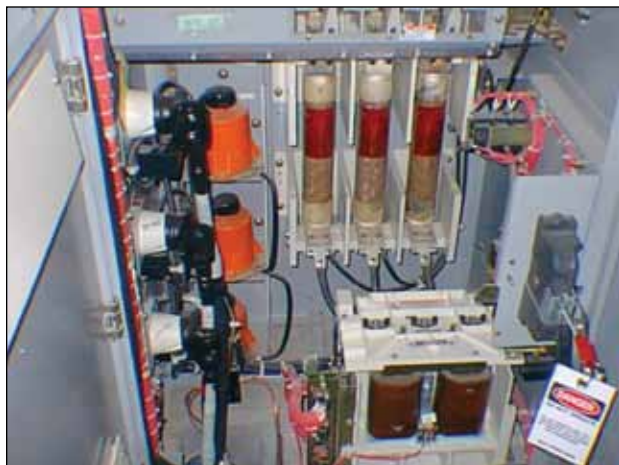


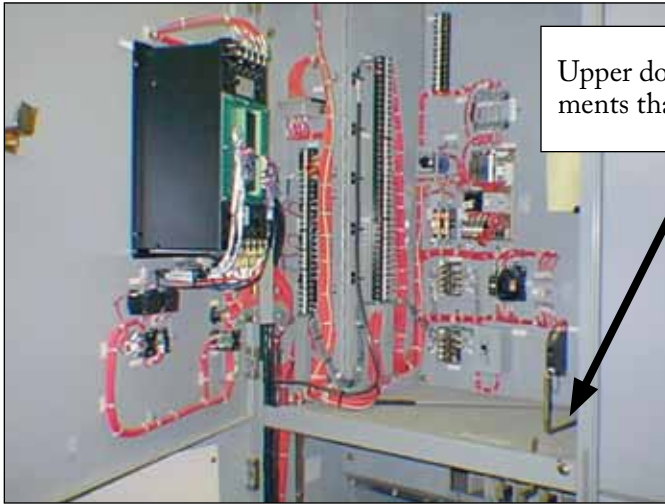
Figure 1

Medium-voltage starters usually have current limiting fuses for motor protection which respond extremely fast to protect the equipment from large current levels during faults on the system. The fuses are large in comparison to low-voltage fuses, and they must be installed in such a manner as to keep the technician from obtaining access when they are

energized. Door interlocks are used to insure that the starter is shutdown and racked out from a live bus before one can gain access to them.

A modern day 5 kV medium-voltage starter as seen in Figure 1 shows the current limiting fuses which are bolted into place, the isolation switch, the operation handle, and the vacuum contactor. When the operation handle is placed in the off position, the incoming source supply is isolated from the starter by the isolation switch and the components in the cubicle are grounded for safety. The door interlock releases the door to the power components allowing access to the fuses, current transformers, contactor, and motor cable connections. The motor control circuits and protection are installed in a separate low-voltage compartment above medium-voltage compartment. The control compartment allows safe troubleshooting of the circuits without exposing the technician to the higher voltages.

From a safety aspect, working around medium-voltage equipment requires a greater knowledge base of the switchgear and equipment and heightened awareness for safety. NFPA 70E places the typical job tasks for medium-voltage motor switchgear to be levels 3 to 4 which require FR rated clothing and arc-flash suits to be worn during testing, racking, and troubleshooting. Door interlocks, keyed interlocks, electrical interlocks, and more must be fully understood and



Upper door interlocks prevent access to compartments that are energized with higher voltages.

Figure 2

never bypassed without the required skills and knowledge of their function and purpose and then only performed by qualified personnel.

The use of appropriate test instruments designed for this application cannot be overstressed. Shock hazards must be observed and proper voltage-rated PPE must be used.



Figure 4



Figure 3

Medium-Voltage Starter Protection

Many different types of relays for motor and motor circuit protection are installed on medium-voltage starters such as shown below. Microprocessor relays have provided protection for motors at new levels that offer some 75 protection function including motor starting limitation and temperature monitoring to name a few. Microprocessor based relays can learn the normal starting parameters and cooling times of the motor. All modern relays have computer interface such as RS-232 and RS-485 communications that allow users to set parameters, look at real time running data, observe vectors of current and voltages, diagnose complex problems by observing event records and sequence of events.

Additional protection features include:
 Start inhibit for number of starts
 Start inhibit for available thermal capacity
 RTD temperature protection

- 50 - Instantaneous overcurrent
- 51 - Time delayed overcurrent
- 27 - Undervoltage
- 59 - Overvoltage
- 67 - Directional overcurrent
- 46 - Negative sequence overcurrent

- 32 - Reverse Power
- 40 - Loss of Field
- 49 - Thermal Capacity
- 60 - Voltage Balance

- 81 - Frequency
- 87 - Differential
- 86 - Lockout Relay

The NEMA device function numbers listed above are only a few of the protection functions that can be used to protect a motor.

When applying protective relays to motors or any other equipment, a question to be answered is “How much protection is enough”? The answer may depend on rewind cost, loss of production, effect on downtime, the consequences of a motor failure on the electrical system and process and other considerations.

Differential protection is used on motors where the available short-circuit current is close to the value of locked-rotor current. It is also frequently used because of the ability to provide extremely sensitive settings as compared to phase overcurrent settings. Differential protection is always a preferred protection. However, it costs more than instantaneous overcurrent relaying because all six leads must be brought out of the motor to the terminal box and additional current transformers are required. The selection of the protective relays must include differential protection, which may add to the cost.

When a motor stator winding is energized with the rotor stationary, stator winding currents may range from three to seven times rated full-load value depending on motor design and supply system impedance. Actual values of locked-rotor current are part of the motor data supplied by the motor manufacturer. Heating in the stator winding, proportional to I^2t , is 10 to 50 times rated conditions and the winding is without benefit of the ventilation normally produced by rotation of the rotor.



Figure 5

Depending on the design, a motor may be thermally limited by the stator or the rotor during locked-rotor conditions. The motor manufacturer can furnish the allowable locked-rotor time only after the motor design is completed. This is given as time at rated locked-rotor current starting from either rated ambient temperature or rated operating temperature also referred to as cold stall time or hot stall time. It also is given as part of the motor time-current curve defined by IEEE Standard 620-1996.

Starting times depend on motor design and load torque characteristics and must be determined for each application. Although starting times of 2 to 20 seconds are common, high inertia loads may take several minutes to bring to full speed. Starting time is increased if bus voltage is less than nominal.

The life of the motor is reduced if the winding temperatures are allowed to exceed their insulation class levels for a significant time. It is usually assumed that for every 10 degrees C above the design temperature limit, the life of the motor is reduced by a factor of 2.6

When normal cooling conditions and ambient temperatures exist, the temperature of the stator winding is directly related to the stator current, and the running thermal overload limit can be shown on a time-current plot as recommended in IEEE STD 620. Running thermal overload can thus be provided by an overcurrent relay which has a time-current characteristic similar to the thermal overload limit.

The protection provided for any motor may be determined by a mixture of things such as the motor cost, the motor application, the criticality of the load, repair costs, the process down time to repair or replace the motor, and many more!



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