DEVICE STANDARD

Purchasing and Application

1st Edition
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Advanced Motor Monitoring and Protection Relays

Low voltage, microprocessor based protective relays

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Raleigh NC

Scope:

This standard is written for microprocessor based protective relays (henceforth referred to as devices), and applies to motor control and protection for A.C. induction motors rated less than 600 volts. Scope includes monitoring and protection, and:

i. Is not inclusive of branch circuit protection or design.
ii. Specifies communications and integration requirements, but does not define control logic.

Intended Audience:

Control engineers, E&I personnel, maintenance technicians, and related professionals responsible for motor application, operation, and reliability.

References:

a) IEEE Std C37.96-2012 - Guide for AC Motor Protection
b) IEEE 1159-2009 - Recommended Practice for Monitoring Electric Power Quality
c) NEMA MG1
d) Best Practices for Motor Control Center Protection, IEEE 2013. SEL, DuPont.

Purpose:

The purpose of this standard is to aid in the purchase and application of modern motor protection relays where advanced monitoring is warranted. It is intended for use in industrial environments where motor applications are prevalent and such a standard would reduce costs.

Objectives:	Recommendations:
1) Increase reliability, improve safety, and reduce the operating costs of LV motor systems. 2) Minimize time to commission and maintain. 3) Standardize real time motor and operational data for integration into control system for process optimization. 4) Access and integrate all available operational and diagnostic data for immediate and future use.	a) Identify conditions for protection. b) Improve protection beyond factory defaults and in accordance with NEMA operating standards. c) Provide early and detailed annunciation of line, load, and operating conditions that could impair operations. d) Implement a standard communication protocol e) Provide a multi-parameter capture on fault condition for use in troubleshooting. f) Ensure that approved devices have internal testing and onboard diagnostics to immediately identify communication or functional device health.

Specification Contents

Defined conditions of protection:

Motors can be damaged or destroyed under any of the following conditions:

a) Low or high supply voltage
b) Phase unbalance
c) Continuous excessive loading
d) Single-phasing
e) Jam or stall conditions
f) Ground/earth faults
g) Mechanical failures such as seized motor bearing or binding mechanical linkages

The following industry standards must be considered when configuring motor protection set points.

1. Overload trip Classes are defined by industry standard and effect the time to trip once an overload condition is realized. NEMA trip classes 5, 10, 20 and 30 indicate the time (seconds) to effect the trip of a motor operating at 600% of rated load.
    a. Class 5 is typically used motors requiring extremely fast tripping.
    b. Class 10 is commonly used to protect artificially cooled motors such as submersible pumps of low thermal capacity.
    c. Class 20 is typically sufficient for general purpose applications.
    d. Class 30 is typically required for high inertia loads to prevent nuisance tripping.
2. NEMA MG-1, 12.44; AC motors shall operate successfully under running conditions at rated load with a variation in the voltage or the frequency up to the following.
    a. Plus or minus 10% of rated voltage with rated frequency for induction motors
    b. Plus or minus 5% of rated frequency with rated voltage.
    c. A combined variation in voltage and frequency of 10% of the rated values, provided the frequency variation does not exceed plus or minus 5% of rated frequency.
3. NEMA MG-1, 12.45; AC polyphase motors shall operate successfully under running conditions at rated load when the voltage unbalance does not exceed 1%.
4. NEMA MG-1, 14.36; When the line voltages applied to polyphase induction motor are not equal, unbalanced currents in the stator windings will result. A small percentage voltage

unbalance will result in a much larger percentage current unbalance. These unbalanced voltages will result in unbalanced currents on the order of 6 to 10 times the voltage unbalance. Consequently, the temperature rise of the motor operating at a particular load and voltage unbalance will be greater than for the motor operating under the same conditions with balanced voltages. In addition, the large unbalance of the motor currents will result in nonuniform temperatures in the motor windings.

a. Operation of a motor above 5% voltage unbalance is not recommended. Even at 5% voltage unbalance, motor current unbalance on the order of 40% can exist. Should voltages be unbalanced, the motor horsepower should be de-rated per figure 14-1.

b. Motors must be de-rated to avoid the damages caused by small amounts of phase imbalance. Phase voltage imbalance should be less than 1% for proper motor function.

c. For every 10˚ C rise in temperature, insulation life and value is roughly halved.

d. The percent temperature rise in windings can be calculated as [2 x (voltage imbalance)^2].

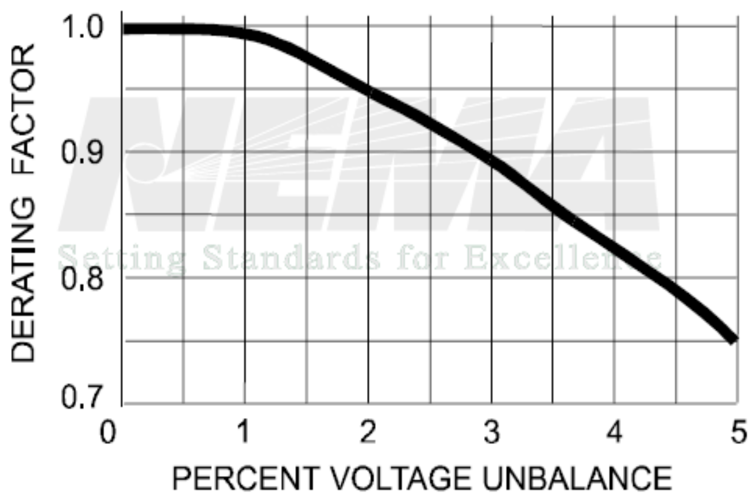

FIGURE 7 [MG1 FIGURE 14-1]

5. IEEE 1159 defines typical power disturbances in Table 2. Both short and long duration power quality issues are typically less than 1 minute in duration. Parameter setpoints, particularly fault time delays, may be reduced from factory defaults to improve protection.

The following examples denote the significance of imbalance and heat rise as it relates to motor protection:

1. Per NEMA, a voltage imbalance of 5% results in a motor output derating of 25%. For example, 100HP would be derated to a 75HP. The resulting heat rise would be 50%.

2. A voltage imbalance of as little as 3% results in a motor output derating of 10%, and a heat rise of 18%.

3. A motor with insulation rated at 155 C, having an engineered life cycle of 40,000 hours, would have a 20,000 hour life expectancy operating at 165 C.

Minimum Device Selection Criteria

The following criteria have been refined to a minimum to aid in selection. It is assumed that devices in question are to be used as part of a greater system (PLC/DCS based). For clarity, the following specified functionality should be provided within the protective device itself.

1) Pre-fault warning. A user definable threshold, separate of the actual fault threshold, to provide an earlier indication of fault. User selectable with programmable delay.
2) Fault function. User defined fault threshold with a programmable delay at parameter level. Programmable override or disable feature, independently selectable for application specific concerns.
3) Local fault capture. Upon a fault condition, the device will capture a group of diagnostic parameters (time stamped) and store them in non-volatile memory (see detail below).
4) Start Cycle and Transition Timing. Device shall recognize motor stop, motor start and motor transition modes of operation to align start and run protection/operation profiles.
5) Overload Protection. Is a function of NEMA trip class selection and designed thermal capacity of the motor. Device shall allow for programmable selection of standard trip classes and thermal modeling of motor condition protected in non-volatile memory.
6) Parameter and Fault selection. The device should provide for the specified faults and data parameters (following pages) at a minimum.
7) Setpoint security. Programmable security to limit those who can change setpoints, fully protecting setpoint standards.
8) Thermistor/RTD input. Means of monitoring winding temperature via sensing device, providing for fault and display functionality.
9) Local display. Accessory options should include an appropriate HMI display that can be installed locally to the device (panel or MCC bucket door), assisting field technicians with troubleshooting.
10) Ethernet/IP communication. Ethernet/IP options, with full ODVA compliance and interoperability with the entire data and feature set.
11) Device health. Onboard diagnostics to alert and fault if device components including power supply, microprocessor, memory, analog-to digital converters, or other related functions fail.
12) Commissioning. Pre-defined device data mapping, as well as sample configuration packages suitable for reuse. This includes tags aliasing and device register pre-mapping. A device interface, accessible through a standard web browser, will be provided to ease commissioning and create reusable templates.
13) Field servicing. May include, but is not limited to replacing a single component within a device, re-addressing communications, or replacing the entire device itself. Such servicing must be attainable through traditional maintenance personnel, enabled through the following options:
    a) A device installed, non-volatile memory module is provided for parameter back up. If a device fails, a new unit can be commissioned in the field by transferring the memory module.
    b) A factory default IP addressing scheme should be utilized to allow technicians to set IP addressing without any interface or programming requirement. One such available option allows the last octet of the IP address to be set with device DIP switches.
        i) *Option Note - If the process controller is on another subnet or multiple systems are to be controlled by a single controller, an industrial router with Network

Address Translation (NAT) capabilities must be specified. There are other benefits in retaining the default private network and using NATs, these include reducing unnecessary traffic to other devices, heighten device security, and will allow multiple duplicated systems to be set up identically without the risk of IP conflicts.

ii) If default IP Addressing scheme cannot be utilized, a less desirable option is to pre-address the first (3) parts of the IP Address of the spare communication module with a PC or workstation, thus only needing to address the last octet with the onboard DIP switches when installed.

Recommended Parameter Setpoints - Protection

Motor protective relays typically offer an extensive set of parameters, many of which should be examined to the specific nature of any application. Manufacturer defaults for protection setpoints typically provide minimal protection so as to avoid nuisance tripping.

The following setpoints should be used as a minimal and starting guideline, understanding that trip delay settings can be adjusted should nuisance tripping become a problem.

Current

Instantaneous Over Current Trip Delay	1000 ms
Instantaneous Over Current Start Delay	15 sec
Instantaneous Over Current Trip Level	400%
Undercurrent Trip Delay	10 sec
Undercurrent Trip Level	60%
Current Unbalance Trip Level	8%
Current Unbalance Trip delay	2 sec

Voltage

Under voltage Alarm Level	93%
Under voltage Start Delay	20 sec
Under voltage Trip Level	90%
Under voltage Trip Delay	2 sec
Voltage Unbalance Trip Level	2%
Voltage Unbalance Trip Delay	2 sec
Overvoltage Trip Level	110%
Overvoltage Trip Delay	2 sec

Power

High Power Trip Level	110%
High Power Trip Delay	5 sec
Low Power Trip Level	50%
Low Power Trip Delay	5 sec
Frequency Deviation	1 Hz
Residual GF Threshold	1 amp

Running condition and historical data (suggested minimum).

A minimum set of running diagnostic data should be captured for use in control and remote troubleshooting applications. System design and integration should facilitate this capture for both current and future use. Minimum parameters to monitor include:

Running condition

parameter	*note*
Motor state	running, stopped, faulted
Total Power	Watts/Kilowatts
Reactive Power	Volt amps reactive (VAR)
Thermal Capacity Utilization	% thermal capacity utilization
Time to trip	
Current % of FLA	
Current Imbalance	
Voltage Imbalance	
I phase A	
I phase B	
I phase C	
V phase A	
V phase B	
V phase C	
Active Fault	
Warning or pre-fault alert	
Last fault	Cue of 10
Time of fault Snapshot	Most recent fault/trip
Operational hours	
Starts in last hour	

Observed fault conditions (suggested minimum).

The following faults should be observed as a minimum standard. Device level faults are specified to annunciate the status and health of the device itself.

Fault conditions

Voltage	Under voltage
	Over voltage
	Voltage phase loss
	Voltage unbalance
	Phase rotation mismatch
	Under voltage restart
Current	Instantaneous over current
	Under current
	Current phase loss
	Current unbalance
Power	External Ground Fault
	Residual Ground Fault
	Power Factor Deviation
	Frequency deviation
Motor	Overload
	Starts limit exceeded
	Jam
	Stall
	Winding Temp Fault
	Thermistor/RTD open/short
Device	Contactor failure
	Device failure (relay)
	Communication fault
	Local interface fault
	Test trip fault

Fault capture

The device should provide a high speed parameter capture during a fault event, retained in local non-volatile memory and accessible by HMI or data communications. This is to capture the most accurate data as close as possible to the event. The time reference should be driven by an onboard, real time clock.

Parameter Fault

	Fault/Code
	Fault description
	Fault date and time
	I phase A
	I phase B
	I phase C
	V phase A
	V phase B
	V phase C
	Ground current
	Frequency
	Thermal Capacity

Preferred Communications

Device monitoring and control should be fully supported through multiple communications protocols, with Ethernet/IP being the recommended standard. In addition to being fully ODVA/CIP compliant, the device should have:

1) Ethernet hardware with embedded web pages to assist with configuration and monitoring with a standard web browser.
2) Hardware for dual port ethernet to facilitate ring or linear topologies (versus independent cables for each device, ex. star). This option is necessary in high density installations, such as motor control centers.
3) Led indicators should be provided on device to aid in troubleshooting.
4) Up-to-date EDS (electronic data sheet) files should be easily sourced via vendor website, without login access requirements.
5) Fully developed add on instructions (AOI) should be available for common control platforms, such as Rockwell Logix.

EtherNet/IP has become the dominant network in the U.S., and recently (Jan 2017) surpassed Profinet globally. Its inherent interoperability, together with standards, makes integration easier. EtherNet/IP is part of CIP, the Common Industrial Protocol. CIP is an object oriented protocol managed by the Open Device Vendors Association (ODVA). The ODVA manages a library of common objects, including a range of functions from network communications to behavior of I/O. This object oriented communication design provides a feasible means of implementing a motor monitoring and protection standard across low and medium voltage applications.