Application handbook

Manual motor starters
North American applications

Power and productivity
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Forward

Although manual motor starters have been a staple in European electrical applications for several decades, their popularity within North America is relatively new. This can be attributed, in part, to questions regarding how best to classify, test, and use these devices within this region.

Is it a circuit breaker? A starter? A disconnect switch? The answer, to each, is yes.

When properly applied, these compact devices can offer a very cost-effective alternative to conventional motor starting solutions. Reviewing these applications is the main purpose of this handbook.

Although we will not cover, in detail, all of the technical aspects or considerations for each application, we intend to create a general overview of the product to assist our customers in making an informed purchasing decision. The ABB team is ready and willing to address any additional questions that you may have.

Helping you to save time, save space, and save money – with ABB manual motor starters.

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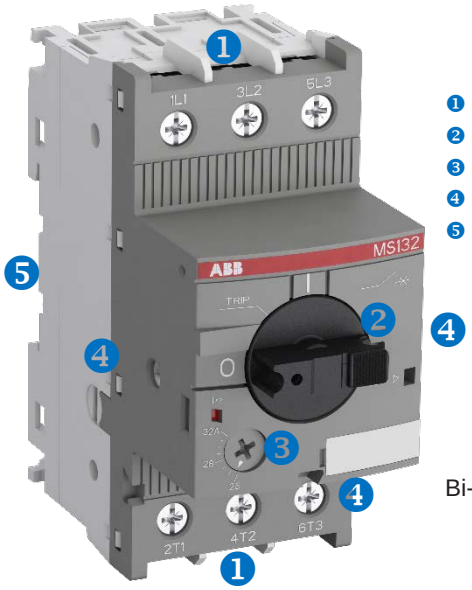
Contents

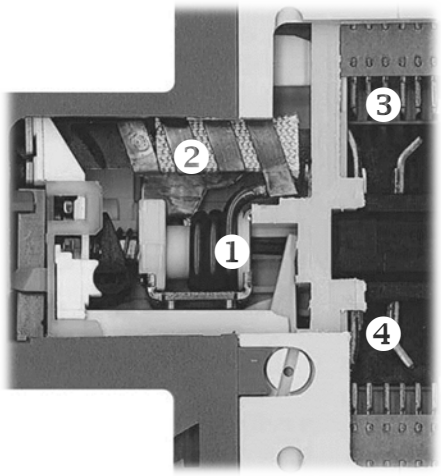
Product overview

Basic function

Manual motor starters are manually operated devices incorporating control, disconnect, overload and short-circuit protection into one, compact product.



❶ Power terminals
❷ ON/OFF handle (operator)
❸ Thermal adjustment dial
❹ Accessory mounts
❺ DIN clip



Magnetic trip coil ①
Bi-metallic elements (thermal) ②
Arc chutes ③
Main contacts ④

Control and disconnect functionality is realized through the rotary-style knob on the device face. Protective functionality is realized through the internal releases (tripping elements), which provide:

— Overload protection
— Short-circuit protection
— Phase loss sensitivity

Upon detection of a fault, the manual motor starter disconnects all phases from the supply, directly isolating the protected load. In addition, manual motor starters increase reliability by reacting quickly, protecting against load-side circuit and motor damage by operating within milliseconds following a short-circuit fault.

For North America, manual motor starters are tested in accordance with the harmonized Standards for Safety for Electromechanical Contactors and Motor-Starters, UL 60947-4-1 (formerly UL 508) and CSA C22.2 No.60947-4-1 (formerly CSA C22.2 No.14).

The term “manual motor starter” is not directly stated in either standard, with the terms “Manual Motor Controller” or “Combination Motor Controller” used as it pertains to these devices. Internationally, these devices are referred to as “motor-protective circuit breakers” or simply “circuit breakers”.

Other common aliases for a manual motor starter include:

— Manual motor protector (MMP)
— Manual starter protector (MSP)
— Motor circuit protector (MCP)
— Motor protection circuit breaker

Product overview

Release (tripping element)

Similar to molded case circuit breakers, standard (MS) manual motor starters are equipped with two releases:

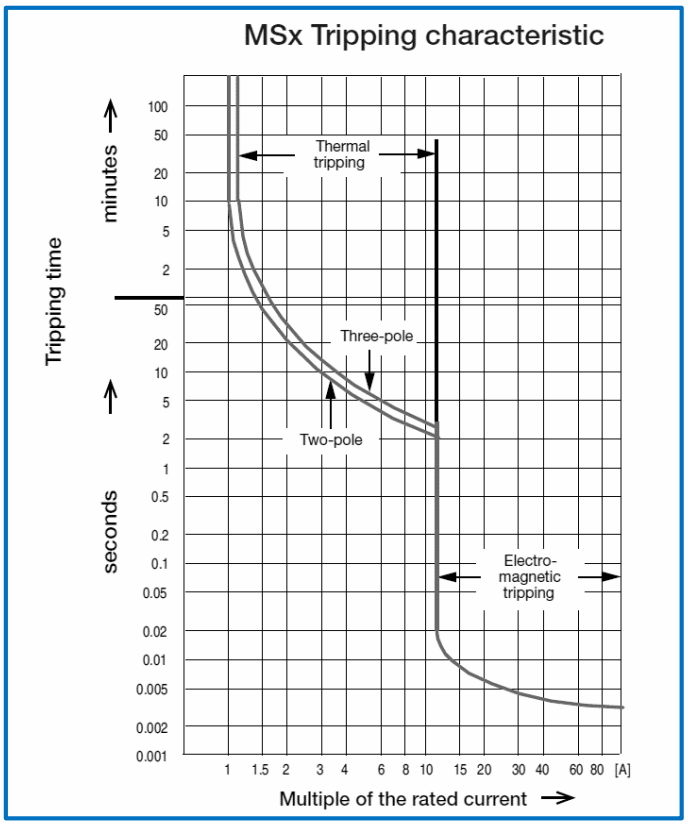
— An adjustable, inverse time-delay overcurrent release for overload protection

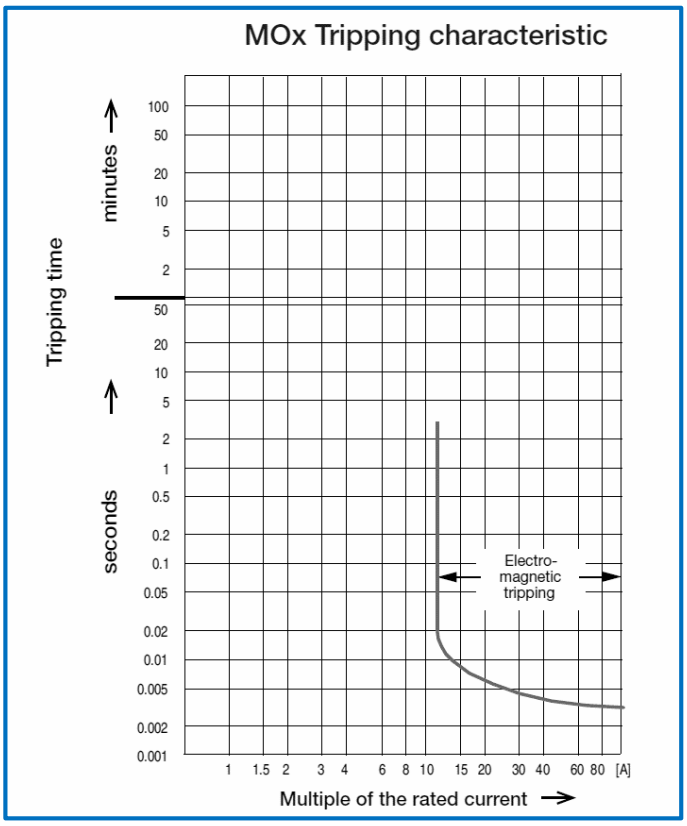
— A fixed, instantaneous release for short-circuit protection

Magnetic only (MO) manual motor starters are equipped with only the instantaneous short-circuit release. When combined with an external overload relay and controller, this wiring schematic closely resembles that of conventional combination starters (e.g. circuit breaker, contactor, and overload relay).

Time-current characteristic (tripping characteristic)

Tripping times in accordance with the harmonized UL 60947-4-1 and CSA C22.2 No. 60947-4-1 standards can be seen in the figures below. For three-pole loads and currents of between 3 - 8 times the set current, the tolerance of the tripping time is ±20 %.





The tripping characteristics for manual motor starters can be accessed in the Download Center (http://www.abb.com/abblibrary/downloadcenter).

Product overview

Overload protection

An overload is defined as an operating condition in an electrically undamaged circuit which causes an overcurrent. This release should be adjusted to the actual full-load current shown on the motor nameplate. A radial dial on the front of the manual motor starter provides the interface for selection. In compliance with international and national standards, manual motor starters are designed to trip at 125% of the dial setting, eliminating the need for additional calculation.

Overload trip classes

Manual motor starters fulfill different trip classes in accordance with the harmonized UL 60947-4-1 and CSA C22.2 No. 60947-4-1 standards. The trip class of a manual motor starter indicates the maximum tripping time from a cold state. This tripping time refers to a steady symmetrical three-pole load with 7.2 x the current setting.

Class	Tripping time T_p [s] at 7.2 x I_e
10A	$2 < T_p \leq 10$
10	$4 < T_p \leq 10$
20	$6 < T_p \leq 20$
30	$9 < T_p \leq 30$

The information above is based on UL 60947-4-1 Table 2 and is intended for reference only.

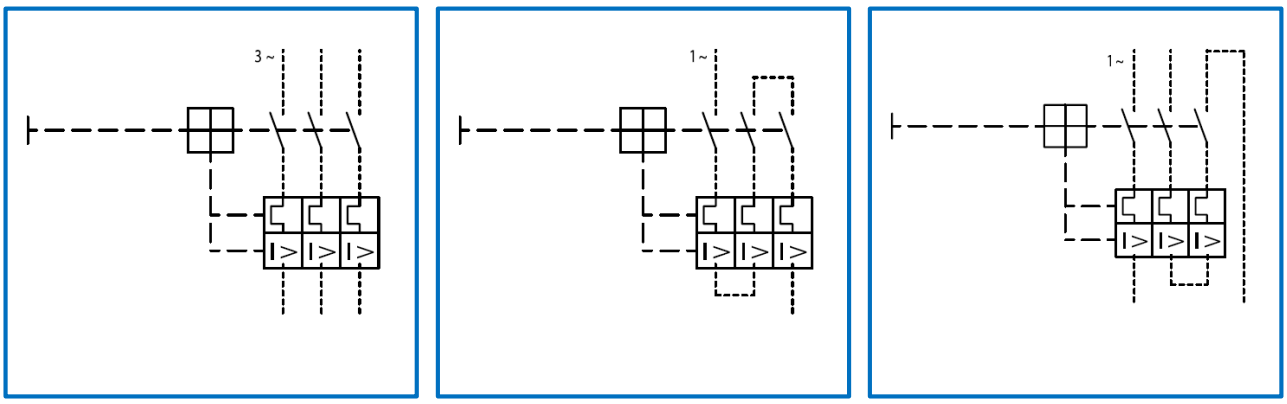
Short-circuit protection

A short circuit is defined as an accidental or intentional conductive path between two or more conductive parts forcing the electrical potential between these conductive parts to be equal to, or close to, zero. The short-circuit release is a fixed multiple value (non-adjustable) of the manual motor starter's rated operational current I_e.

Phase loss sensitivity

Phase loss sensitivity is a characteristic of inverse time-delay, thermal over-current releases. Strong imbalance between phases can damage motors and other loads. Manual motor starters are designed to detect these conditions and trip to prevent load-side circuit and motor damage.

In order for manual motor starters to protect single-phase loads, all three main poles must be connected in series (see figures below).



Product overview

Product offering

ABB provides a comprehensive manual motor starter offering for North American applications. The MMS device types are divided into three ranges to simplify selection, coordination, and installation:

— MS116 standard range up to 32 A
— MS132 / MO132 high performance ranges up to 32 A
— MS165 / MO165 high performance ranges up to 65 A

MS116
0.10 … 32 Amps
Overload Class 10A

MS132 / MO132
0.10 … 32 Amps
Overload Class 10 (MS only)

MS165 / MO165
10 … 65 Amps
Overload Class 10 (MS only)

The chart below shows an overview of North American ratings for manual motor starters by product type.

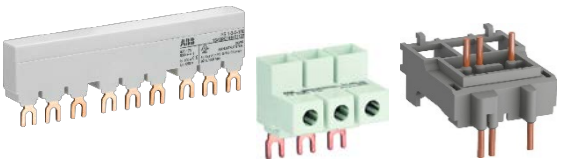
Rating	Manual motor starter type				
	MS116	MS132	MS165	MO132	MO165
Manual Motor Controller	■	■	■	■	■
Manual Motor Controller, Suitable as Motor Disconnect	■	■	■	■	■
Manual Motor Controller, Suitable for use in Group Installations	■	■	■	■	■
Manual Motor Controller, Suitable for Tap Conductor Protection in Group Installations		■	■	■	■
Manual self-protected Combination Motor Controller (Type E)		■	■		
Combination Motor Controller (Type F)		■	■	■	■
Protection of ABB Micro drives		■		Contact ABB	

For additional information regarding product selection, please see our Main Catalog for Motor Control and Protection 1SBC100192C0201, which can be accessed in the Download Center (http://www.abb.com/abblibrary/downloadcenter).

Product overview

Accessories and enclosures

Since manual motor starters combine the functions of multiple components, such as circuit breakers, disconnect switches, and overload relays, they are offered with many of the same types of accessories.

Signaling and status indication	— Auxiliary contacts *HK1, HKF1* — Trip (bell) alarms *SK1* — Short-circuit indicators *CK1*	
Increasing functionality	— Undervoltage releases *UA1* — Shunt trips *AA1* — Current limiters *S803W*	
Reducing installation time and saving space	— Three-phase busbar *PS1* — Feeder (in-feed) terminal blocks *S1* — Close couplers *BEA*	
External operation and enclosures	— Handles and shafts, UL/CSA Types 1, 3R, 12 — Shaft alignment accessories — Door-mount kits, UL/CSA Type 12 *DMS132* — Enclosures, UL/CSA Type 12 *IB132*	
Marking	— Printers, plotters, and engravers — Marking accessories	

Compact IB132 accessory enclosures are designed specifically for manual motor starters. These UL/CSA Type 12 enclosures are available for applications up to 10 Amps.

Auxiliary and signaling contacts can be combined to provide external status indication for a variety of conditions and states. The table below shows an overview of the functionality of these contact types.

Contact type		Condition / state of manual motor starter					
		OFF	ON	Overload trip	Short-circuit trip	Undervoltage trip	Shunt trip
Auxiliary contacts	Normally-open	O	X	O	O	O	O
	Normally-closed	X	O	X	X	X	X
Trip (bell) alarms	Normally-open	O	O	X	X	X	X
	Normally-closed	X	X	O	O	O	O
Short-circuit indicators	Normally-open	O	O	O	X	O	O
	Normally-closed	X	X	X	O	X	X

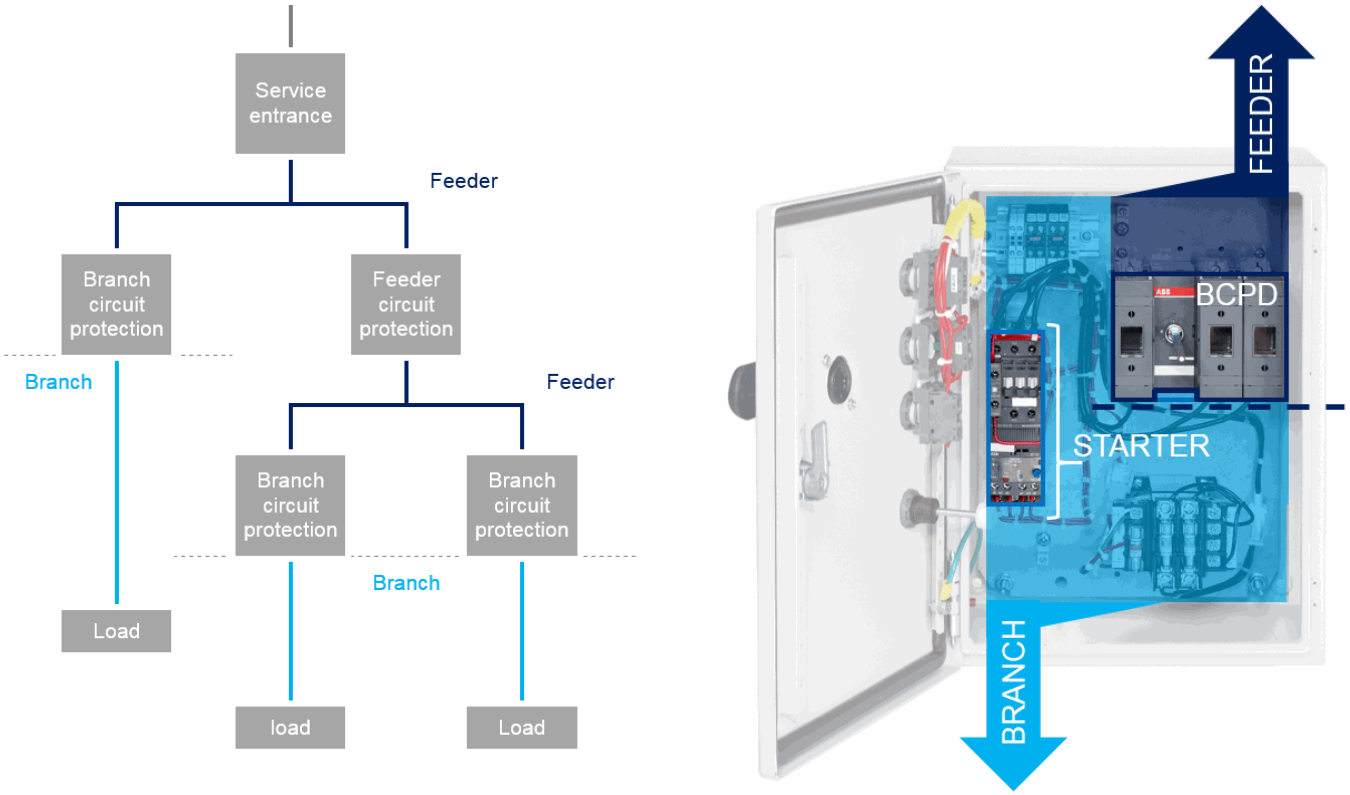
O = Open; X = Closed

Requirements for North American motor branch circuits

Defining branch circuits

Electrical distribution within a facility requires the coordination of many circuits to loads. Beyond the point of the service entrance, all circuits leading away are considered feeders or feeder taps, until just ahead of a load. The circuit between the load-side terminals of the final overcurrent protective device and the load itself is called the branch circuit. This also means that the branch circuit protective device is actually part of the feeder circuit, not the branch. The figure below shows an example of this.

Feeder vs. branch circuits



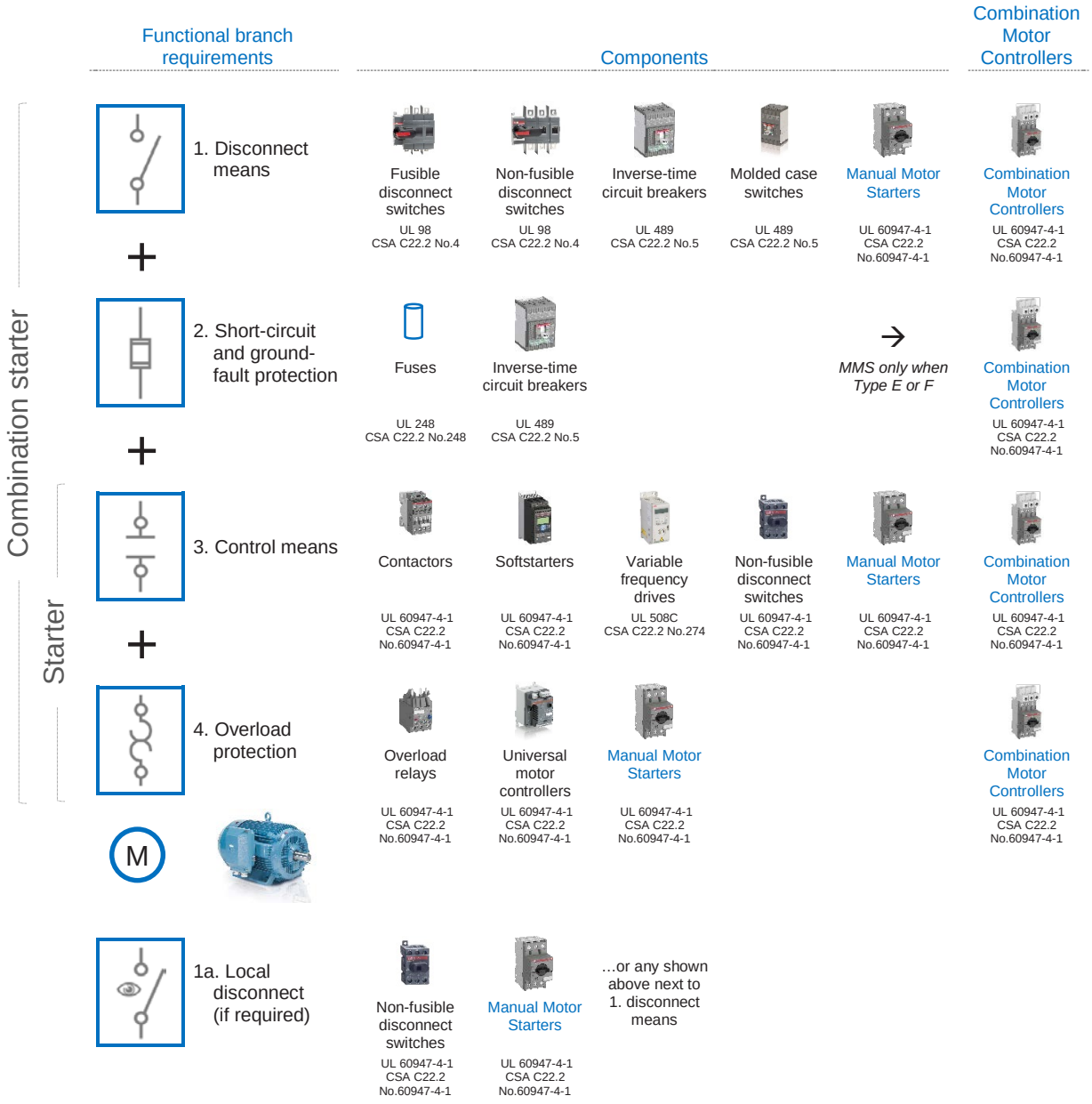
Manual motor starters, when tested as Combination Motor Controllers Types E or F, are suitable for branch circuit protection. However, these devices cannot be used for providing protection of feeder circuits. Feeder circuit protection is typically provided using either fuses, UL 489 / CSA C22.2 No.5 molded case or UL 1066 / CSA C22.2 No.31 power circuit breakers.

The term “branch circuit’ applies regardless of the type of load. Common load types for industrial and commercial applications include motors, heaters, and lamps. The requirements for motor branch circuits are more intensive than other load types, so the following section reviews these requirements in detail.

Requirements for North American motor branch circuits

Functional requirements for all motor branch circuits

The installation standards of North America require that each motor branch circuit contain electrical components capable of meeting four functional requirements: a disconnect means, short-circuit and ground-fault protection, a control means, and overload protection. This can be achieved using either multiple components or a single device.



The chart above shows a graphical representation of the functional requirements for all motor branch circuits. Manual motor starters are capable of meeting all of the requirements listed above. However, in order for manual motor starters to be used for short-circuit and ground-fault protection, they must be additionally certified as Combination Motor Controllers Types E or F.

Requirements for North American motor branch circuits

1. Disconnect means for the motor and branch circuit acc. to NEC Article 430.101 / CEC Section 28-600

The branch disconnect serves as the primary means for isolating the motor and the electrical equipment from the power source, often for maintenance purposes. The disconnect means is provided with accessories to allow its function from outside the enclosure. To meet safety requirements, the disconnect means must be lockable in the off position, and must be visible from the motor location. Manual motor starters can be used as the main branch disconnect means when marked “Suitable as Motor Disconnect”, and installed on the load side of the branch short-circuit and ground-fault protective device.

2. Short-circuit and ground-fault protection for the motor and branch circuit

acc. to NEC Article 430.51 / CEC Section 28-200

Each motor branch circuit requires a device that can protect the motor, the electrical components, and the conductors in the event of a short circuit or ground fault. Conventionally, this can only be achieved using either fuses or an inverse-time (e.g. thermal-magnetic) circuit breaker. However, through Combination Motor Controller testing, the available options are expanded to also include Recognized instantaneous-trip (magnetic only) circuit breakers and manual motor starters, which can offer cost-effective alternatives for customers.

3. Motor control means acc. to NEC Article 430.81 / CEC Section 28-500

The controller provides the means for the routine starting and stopping of the motor. Controllers range in complexity from the very basic manual switches to continuous speed control using variable frequency drives. Depending on the size of the motor and the type of application, customers can select from a wide variety of motor control options available from ABB. One critical aspect for selection is to ensure that the control means is properly rated for the type of load to be controlled, in this case “AC Motor” or “DC Motor” ratings. Not all controllers are suitable for use in motor applications. Additionally, it is important to consider the electrical durability of the control device, as some devices suitable for motor control are not designed with this intention (e.g. molded case circuit breakers).

4. Overload protection for the motor and branch circuit acc. to NEC Article 430.31 / CEC Section 28-300

Each motor branch circuit requires a device that can protect the motor, the electrical components, and the conductors from excessive heating due to motor overloads or failures to start. Although most devices used for short-circuit and ground-fault protection also offer thermal protection against overheating, very few motor applications allow for the use of inverse-time circuit breakers alone to protect the installation against overload conditions (exc. 1 hp or less, non-automatically started).

1a. Local motor disconnect acc. to NEC Article 430.102 / CEC Section 28-604

An additional disconnect means is required if the main disconnect means is not within sight of the motor installation or exceeds a distance of 15 m (50 ft.) in the U.S. and 9 m (29.5 ft.) in Canada. Typically, customers will use enclosed UL 60947-4-1 / CSA C22.2 No. 60947-4-1 manual motor starters or non-fusible disconnects when marked “Suitable as Motor Disconnect”, since the local disconnect is already positioned downstream from the short-circuit and ground-fault protective device. However, all devices suitable for the main disconnect means can also be selected for this purpose.

See page 41 for a list of suitable products for each functional requirement by Category Code (CCN).

North American standards and certifications

To assist in understanding how to properly apply manual motor starters within North America, the following section provides a review of electrical product certification within this region.

North American standards

Below is an overview of the North American standards referenced within this document.

Installation standards

- Govern the installation of electrical components and conductors in each country
- Scopes include all electrical installations beyond the point of the utility service drop
- Applicable for residential, commercial, and industrial structures
- Often adopted into law by local governments

NFPA® 70 National Electrical Code® (NEC)
United States

CSA C22.1 Canadian Electrical Code (CEC)
Canada

NOM-001-SEDE-2012 Instalaciones Eléctricas (utilización)
Mexico

Application-specific standards

- Govern specific applications (e.g. industrial control panels)
- Can allow for greater flexibility when designing and building electrical equipment

NFPA® 79 – Industrial Machinery
UL 508A – Industrial Control Panels
CSA C22.2 No.14 – Industrial Control Equipment

Product standards

- Govern the products themselves
- Quantify the necessary product construction, marking and tests required for certification

UL 60947-4-1 – Electromechanical Contactors and Motor-Starters
UL 508 – Industrial Control Equipment
UL 508A – Industrial Control Panels
UL 508C – Power Conversion Equipment
UL 489 – Molded-Case Circuit Breakers, Molded-Case Switches, and C.B. Enclosures
UL 98 – Enclosed and Dead-Front Switches
UL 1077 – Supplementary Protectors for Use in Electrical Equipment
UL 248-1 – Low-Voltage Fuses

CSA C22.2 No.60947-4-1 – Electromechanical Contactors and Motor-Starters
CSA C22.2 No.14 – Industrial Control Equipment
CSA C22.2 No.274 – Adjustable Speed Drives
CSA C22.2 No.5 – Overcurrent Protection
CSA C22.2 No.4 – Enclosed and Dead-Front Switches
CSA C22.2 No.235 – Supplementary Protectors
CSA C22.2 No.248 – Low-Voltage Fuses

Global harmonization efforts

As globalization continues to impact consumers more and more each year, it is becoming increasingly important for customers to understand the rules and regulations of multiple world regions. In an effort to limit the scope of knowledge required to achieve this without sacrificing safety, Standards Development Organizations, including Underwriters Laboratories (UL), the Canadian Standards Association (CSA), and the International Electrotechnical Commission (IEC) are working together. Taking their like-standards, they are combining best practices, eliminating antiquated verbiage, and producing harmonized global standards.

Most notably for the purpose of this document, these organizations have adopted the IEC 60947-4-1 standard to harmonize the UL 60947-4-1 and CSA C22.2 No. 60947-4-1 standards for Electromechanical Contactors and Motor-Starters, which now govern the certification of manual motor starters, replacing UL 508 and CSA C22.2 No.14.

North American standards and certifications

Certifications in North America

For electrical products to be legally installed in the United States, the Occupational Safety and Health Administration (OSHA) lawfully requires these devices to be certified through a Nationally Recognized Test Laboratory (NRTL). An NRTL holds the responsibility to properly certify manufactures' products to the appropriate product safety standards. OSHA currently recognizes 15 organizations as NRTLs, most notably including:

— Underwriters Laboratories, Inc.
— Canadian Standards Association
— Intertek Testing Services NA, Inc.

Each product certified through an NRTL is given a unique certification mark to indicate conformity, which becomes a clear sign to inspectors, those Authorities Having Jurisdiction (AHJ) over an installation, that the product can be legally and safely accepted.

Accreditation within Canada is performed by the Standards Council of Canada (SCC).

Product certification marks

Each Nationally Recognized Test Laboratory's product mark is unique, and also differs depending on whether the product has been certified for use in the United States, Canada, or both. This is typically indicated by the inclusion of the letters "C" or "US" in the mark. Below are several examples.

Nationally Recognized Test Laboratory	Certified for use in the United States		Certified for use in Canada		Certified for use in both the U.S. and Canada	
	Listed	Recognized	Listed	Recognized	Listed	Recognized
Underwriters Laboratories, Inc.						
Canadian Standards Association						

Products are marked to differentiate between whether they are "Listed" devices, indicating that they meet all of the requirements outlined in the respective product standards, or "Recognized" devices, which meet only some of the requirements of their standard. Recognized components are subject to additional "Conditions of Acceptability" and can be somewhat limiting in regards to their use in electrical installations.

ABB manual motor starters are Listed products bearing a cULus mark.

North American standards and certifications

Acceptability of joint U.S.-Canadian approvals

The Memorandum of Understanding (MOU), signed between UL and CSA in 2003, affords manufacturers the ability to certify products for both the U.S. and Canada through a single organization. This reduces the time to bring products to market, and allows for the most state-of-the-art products to start benefiting customers more quickly. The MOU covers the mutual acceptance of components certified by either organization for use in electrical end-product equipment (e.g. Industrial Control Panels).

For more information regarding the MOU, please follow the links shown below.
(http://ul.com/newsroom/pressreleases/expansion-of-ul-csa/).
(http://www.csagroup.org/ca/en/services/testing-and-certification/agreement-on-acceptance-of-components).

Categorizing manual motor starters – where do they fit?

Products certified through UL are categorized according to their intended use. This categorization is part of a hierarchical structure of 4-digit codes, referred to as Category Codes (CCN). In addition to providing a means for categorization, CCNs also provide installers with clear direction regarding how to properly apply the devices. This is important to consider, as although two products may appear physically similar, their suitable uses may differ drastically. To help avoid issues in regards to proper application, the Online Certification Directory available on UL's website provides customers with a means of searching for certified components (http://ul.com/database).

Manual motor starters belong to two separate CCNs:

Manual Motor Controllers NLRV		← Dual categories →		Combination Motor Controllers NKJH
NLRV	Listed Manual Motor Controllers certified according to UL 60947-4-1 (UL 508) for use in the United States		Listed Combination Motor Controllers certified according to UL 60947-4-1 (UL 508) for use in the United States	NKJH
NLRV7	Listed Manual Motor Controllers certified according to CSA C22.2 No. 60947-4-1 (CSA 22.2 No.14) for use in Canada		Listed Combination Motor Controllers certified according to CSA C22.2 No. 60947-4-1 (CSA 22.2 No.14) for use in Canada	NKJH7

Naturally, any attempt to categorize the vast array of products and technologies available for electrical applications can create drawbacks. Most notably, CCNs are intentionally broad, often unable to differentiate between like-products technically. For this reason, manual motor starters tested and classified under CCN Manual Motor Controllers (NLRV) occupy the same category as other manual controllers, such as non-fusible disconnect switches, meaning that the inclusion of protective releases, such as thermal and magnetic trip mechanisms, is often understated our completely overlooked.

In an effort to credit their ability to protect circuits in addition to loads, manual motor starters can be tested and classified under an additional product CCN – Combination Motor Controllers (NKJH). This also means that the suitable applications for manual motor starters are split between the two categories. The simplest explanation of the division of applications can be viewed as:

Applications requiring an upstream branch circuit protective device (fuses or 489/No.5 circuit breaker)	Applications requiring no additional branch circuit protection
Manual Motor Controllers (NLRV)	Combination Motor Controllers (NKJH)
— Single motor / motor disconnect — Group installations — Tap conductor protection in group installations	— Manual self-protected Type E — Type F — Protection of ABB Micro drives

North American voltage supply networks and load types

Electrical networks within North America supply power to residential, commercial, and industrial structures. Depending on the amount of power required for a given installation, various voltage configurations can be utilized.

North American voltages

North American commercial installations are typically supplied using either 120/240 V AC split (dual) or 208Y/120 V AC, 3-phase wye networks. Industrial installations within the U.S. commonly use 480Y/277 V AC, 3-phase wye networks. For Canada, the network voltages are increased to 600Y/347 V AC. 3-phase delta networks, which do not offer a line-to-neutral voltage, are also common, most often supplying either 240, 480 or 600 V AC.

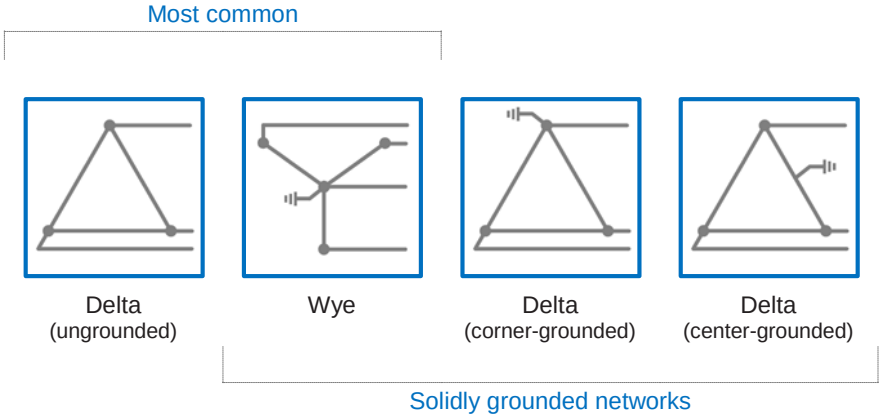
Application	Network configuration (excluding ground wire)	Nominal supply voltage (line-to-line)	Nominal supply voltage (line-to-neutral)
Commercial	2-phase, 3-wire	240 V AC 2-phase (split/dual)	120 V AC 1-phase
	3-phase, 4-wire (wye)	208 V AC 3-phase	120 V AC 1-phase
Industrial and large commercial in the United States	3-phase, 3-wire (delta)	240 V AC 3-phase	--
	3-phase, 4-wire (wye)	480 V AC 3-phase	277 V AC 1-phase
	3-phase, 3-wire (delta)	480 V AC 3-phase	--
Industrial and large commercial in Canada	3-phase, 4-wire (wye)	600 V AC 3-phase	347 V AC 1-phase
	3-phase, 3-wire (delta)	600 V AC 3-phase	--

Manual motor starters are commonly applied in both industrial and commercial applications. To meet the requirements for North America, they are suitable for use on 1- and 3-phase networks with line-to-line voltages up to 600 V AC.

Three-phase network configurations

North American 3-phase supply networks differ based on the secondary winding of the upstream transformer. The two most common secondary winding styles are wye, which includes three power legs and a neutral, and delta, which includes only three power legs without a neutral connection. These networks can be either grounded or ungrounded.

Solidly grounded wye and ungrounded delta networks are most common in North America.



North American voltage supply networks and load types

Straight vs. slash voltage ratings

Short-circuit protective devices with straight voltage ratings (e.g. 480 V AC) can be applied in any circuit, grounded or ungrounded, where the line-to-line voltage does not exceed the maximum rating specified.

Short-circuit protective devices with slash voltage ratings (e.g. 480Y/277 V AC) can be applied only in solidly grounded networks where the voltage from line-to-ground does not exceed the lower of the two ratings (e.g. 277 V AC), and the voltage from line-to-line does not exceed the higher of the two ratings (e.g. 480 V AC). The lower rating represents the device's interrupting capability per pole.

Depending on the how they are applied, manual motor starters carry either straight (Δ) or slash (/) voltage ratings.

Rating type	Maximum voltage
Manual Motor Controller	600 Δ
Manual Motor Controller, Suitable as Motor Disconnect	600 Δ
Manual Motor Controller, Suitable for use in Group Installations	600 Δ
Manual Motor Controller, Suitable for Tap Conductor Protection in Group Installations[1)]	600 Δ
Manual self-protected Combination Motor Controller (Type E)	600Y/347V
Combination Motor Controller (Type F)	600Y/347V
Protection of ABB Micro drives	480Y/277V

[1)] MS132/MO132 and MS165/MO165 only

North American load types

Although the name suggests that their suitable application is limited only to motors, manual motor starters can additionally be used for controlling and protecting other types of loads, such as heaters. When combined with an additional controller, the applications for manual motor starters are even broader. The table below shows the tested controller ratings for ABB manual motor starters and AF contactors.

Tested controller ratings for manual motor starters	Tested controller ratings for AF contactors < 100 Amps
— AC-1: General use — AC Motor	— AC-1: General use — AC Resistance Air Heating (100,000 electrical cycles) — AC Motor — Elevator control, AC Motor (500,000 electrical cycles) — AC-5a: Electric discharge lamps (ballast) — AC-5b: Incandescent lamps (tungsten) — AC-8a: Hermetic refrigerant compressors — DC-1: General use — DC Motor

General use and heaters

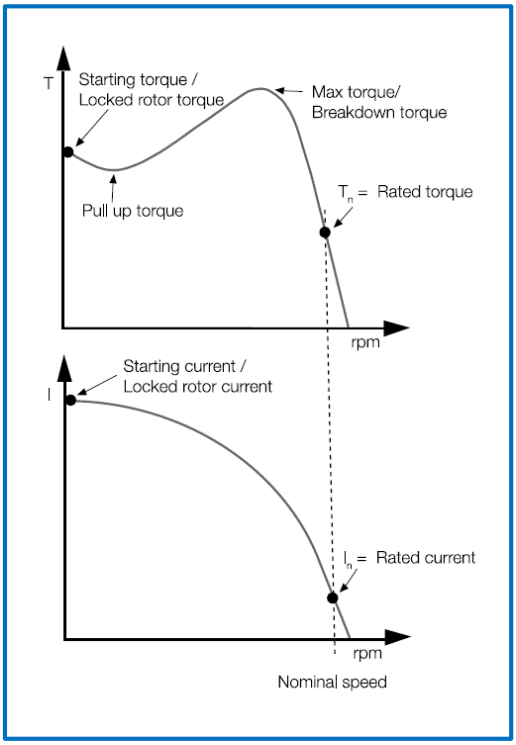
The newly harmonized utilization category AC-1 covers general and resistive type loads within North America. This includes non-inductive or slightly inductive loads, as well as resistance furnaces and heaters. Additional ratings, such as "Resistance Air Heating" and "CSA Electrical Heating Control", which require additional electrical cycling, can be performed to further validate control devices for use in heating applications. However, the general use AC-1 rating is sufficient for most heating applications.

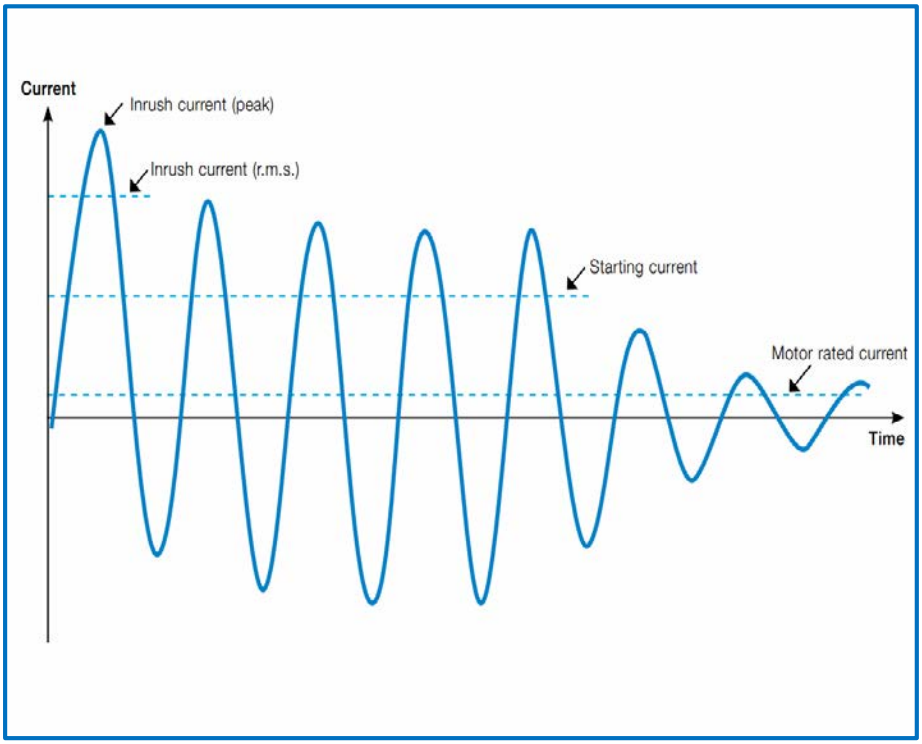
ABB manual motor starters are suitable for manual control of heating loads. Magnetic only (MO) types can be selected when additional overload protection is not required.

North American voltage supply networks and load types

Motors

Due to their high inrush peaks, locked rotor currents, and high potential for overheating, motor loads represent one of the most demanding load types for North America. The figures below show an overview of an across-the-line motor start. Starting current is a characteristic of the motor. Starting time is a function of load torque, inertia and motor torque and is influenced by the motor technology. As the starting current ratio (6-10 x I_e) is higher than the rated operational current I_e, an excessively long starting or braking period can cause an overload (temperature rise) in the motor. This can create electromechanical stresses or damage the motor's insolation if not properly protected.





Manual motor starters are well suited for both the control and protection of motors, including high-efficiency types. Since the tests for IEC utilization category AC-3 and UL/CSA "AC Motor" have yet to be fully harmonized, manual motor starters and AF contactors carry both ratings to ensure international acceptability. For North American elevator applications, AF contactors should be used in combination with manual motor starters to serve as the control means.

For additional information regarding IE3 high-efficiency motors for Europe, please click the "Info on IE3 Motors" link in the SOC selection tool (http://applications.it.abb.com/SOC/page/selection.aspx).

Hermetic refrigerant compressor motors

A hermetic refrigerant compressor motor is a combination of a compressor and a motor, both of which are enclosed in the same housing, with no external shaft or shaft seals, with the motor operating in refrigerant. These motors are commonly used in air-conditioning and refrigeration equipment. Two harmonized utilization categories exist for these types of loads: AC-8a and AC-8b. AC-8b is an additional test accompanying AC-8a and is referred to as a "recycle rating", which covers applications where overload releases are automatically reset. Manual motor starters can be used for the protection of these motors. For control, use AF contactors.

North American voltage supply networks and load types

Lamps and lighting loads

Two lamp-specific utilization categories exist: AC-5a for electric discharge (florescent) lamps, and AC-5b for incandescent lamps, both of which have been fully harmonized. Manual motor starters are suitable for the manual control of lamp loads, but only when applied according to UL 508A.

The table below shows a correlation between these ratings and a variety of commercially available lamps.

Lamp type	Ballast AC-5a	Tungsten AC-5b
Compact fluorescent lamps	■	
Florescent lamps with electronic ballast[1)]	■	
Halogen electric light bulbs		■
Halogen metal vapor lamps	■	
High-pressure discharge lamps	■	
Incandescent (filament) light bulbs		■
LEDs	■	
Mercury vapor high-pressure lamps	■	
Mixed lamps		■
Sodium vapor high-pressure lamps	■	

[1)] The AC Motor ratings of manual motor starters allow for the control of AC fluorescent ballast loads when applied acc. to UL 508A.

Transformers and capacitors

A transformer is a passive electrical device designed to change one voltage to another by magnetic induction. The inrush current for transformers can be 10 – 20 times the nominal current, and typically lasts for a period of up to 40 ms. Manual motor starters are suitable for control and protection of control transformers when marked “Suitable for Tap Conductor Protection in Group Installations”. See pg. 28.

Capacitors are mainly used for reactive energy correction (raising the power factor). When capacitors are energized, overcurrents of high amplitude and high frequencies (3 to 15 kHz) occur during the transient period (1 to 2 ms). For more information regarding the control and protection of capacitors, please contact ABB.

Mechanical and electrical durability

Due to product design characteristics, controllers vary in regards to the amount of electrical and mechanical operations which can be sustained over the product life. Below is a comparison between ABB manual motor starters, AF contactors, and Tmax XT circuit breakers.

Rating	Manual motor starters	AF contactors < 100 Amps	Tmax XT circuit breakers XT2
Mechanical durability	Up to 100,000	10,000,000	25,000
Electrical durability	Up to 100,000	1,000,000	8,000

Since molded case circuit breakers are designed to protect circuits and loads rather than control them, the mechanical and electrical durability of these devices is quite low. Contactors, which are designed specifically for load control, have very high mechanical and electrical durability. Manual motor starters, which are designed to provide both control and protection, are rated higher than other circuit breaker types.

Short-circuit current ratings

Short-circuit current ratings (SCCR) are tested values for motor control and protection devices to ensure safe reaction during short circuits and ground faults. Since even low-level faults are capable of producing incredible amounts of energy, unprotected equipment can easily cause damage to the installation and endanger personnel within close proximity. Short-circuit current ratings have been mandatory for Industrial Control Panels since 2006.

A complete list of ABB's tested SCCR can be accessed online through our SOC selection tool (http://applications.it.abb.com/SOC/page/selection.aspx).

Components requiring short-circuit current ratings

All power circuit components for Industrial Control Panels are required to have marked short-circuit current ratings expressed in kiloamperes (kA) and voltage. This includes devices such as:

- Disconnect switches
- Branch circuit protective devices
- Branch circuit fuseholders
- Load controllers
- Motor overload relays
- Terminal blocks
- Busbar

ABB manual motor starters are tested for short-circuit current ratings in a wide variety of applications. SCCR values for manual motor starters may differ depending on how they are applied. See page 34 for more guidance regarding selection.

Standard (low) fault ratings - Mandatory

In order for electrical products to be certified as suitable for use in motor applications, they must be tested to a minimum standard value based on the size and type of the device. These are referred to as standard fault or low fault ratings. The table below shows the standard values for motor controllers according to UL 60947-4-1 and CSA C22.2 60947-4-1.

Standard fault test current, rms symmetrical	Maximum hp 600 V or less	Maximum kW	Maximum Amps 600 V – 1500 V
1 kA	0 – 1 hp	0 – 0.746 kW	--
5 kA	Over 1 – 50 hp	Over 0.746 – 38 kW	0 – 50 A
10 kA	Over 50 – 200 hp	Over 38 – 149 kW	Over 50 – 200 A
18 kA	Over 200 – 400 hp	Over 149 – 298 kW	Over 200 – 400 A
30 kA	Over 400 – 600 hp	Over 298 – 441 kW	Over 400 – 600 A
42 kA	Over 600 – 900 hp	Over 441 – 671 kW	Over 600 – 850 A
85 kA	Over 900 – 1600 hp	Over 671 – 1193 kW	Over 850 – 1500 A
100 kA	Over 1600 hp	Over 1193 kW	Over 1500 A

Note: For a manual motor controller intended for use as a disconnecting means, the minimum short-circuit current rating is 5kA. The information above is based on UL 60947-4-1 Table 9.3.4.2.1DV.1.1.1 and is intended for reference only.

The standard fault value is also the assumed rating for unmarked components.

IEC refers to standard fault current as prospective current "*r*".

Short-circuit current ratings

High fault ratings - Optional

The standard fault values shown on the previous page are the minimum requirement for all motor control components. Since the available fault current for a given installation can vary drastically, standard fault ratings alone are often too low for many applications. For this reason, manufactures, including ABB, often choose to test their devices beyond the minimum requirements. Any short-circuit testing above the minimum standard fault level and up to a maximum of 200 kA is referred to as a high fault rating.

There are two methods for testing high fault SCCR. The first method, referred to as component-level testing, is performed in an enclosure, but with the upstream short-circuit protective device mounted separately in open air. This is common for devices intended to be supplied separately from the short-circuit protection. The second method, which applies to combination starters, involves testing with all components in a single enclosure. This is referred to as Combination Motor Controller (CMC) testing. CMC testing is common for devices supplied as a complete assembly (e.g. enclosed starters).

IEC refers to high fault current as rated conditional current I_q.

Defined acceptance criteria

Failure of components under fault conditions can create safety concerns for personnel working in close proximity to electrical equipment. To outline what constitutes a pass, the harmonized UL 60947-4-1 and CSA C22.2 No.60947-4-1 standards define acceptance criteria for these components. Several criteria exist for all devices:

— The short-circuit protective device successfully interrupts the fault
— The enclosure door has not blown open, and it remains possible to open it manually
— No damage to, or separation between, the conductors and the terminals
— No damage to the insulating bases of live parts, and no access to current carrying parts

For Combination Motor Controllers, the included circuit breaker, switch, or manual motor starter should be capable of being manually operated, and should not be damaged, exposing conductive parts.

In addition to the above criteria, a distinction is made between two types of coordination: Type 1 and Type 2. This pertains to the suitability of components for continued service following a fault.

Type 1 coordination

Type 1 coordination allows some components, such as the controller and overload protection device, to sustain damage such that they become inoperable following a short-circuit fault. This coordination type requires that these components be replaced before re-commissioning.

Type 2 coordination

Type 2 coordination requires that no damage to overload protection and other components occurs, with the exception that the contacts of the contactor or starter are allowed to weld. This welding must be easily separated by manual effort (e.g. with a screwdriver). Both the overload tripping performance and controller switching capabilities are verified following the short-circuit test.

Short-circuit current ratings

What rating do I need? Calculating available fault current for a facility

The necessary short-circuit current rating for any device is determined based on the available fault current at its point of installation.

Most industrial and commercial buildings are supplied by one or more transformers proving incoming power to the facility. Using rated information from these transformers, it is possible calculate the available fault current for any installation within the building. UL 508A Ed.2, Supplement SB4.3 provides the following formulas for determining available fault current in circuits containing transformers with isolated secondary windings.

Available fault current beyond single-phase transformers

$$I_{sc} = \frac{\left(\frac{kVA \times 1000}{V_{secondary}}\right)}{Z\%}$$

Available fault current beyond 3-phase transformers

$$I_{sc} = \frac{\left(\frac{kVA \times 1000}{V_{secondary} \times \sqrt{3}}\right)}{Z\%}$$

$\sqrt{3} \approx 1.732$

The available fault current directly at a transformer's secondary terminals I_{sc} can be calculated from the transformer full-load current kVA, the secondary voltage line-to-line $V_{secondary}$ and the transformer impedance $Z\%$. For transformers with an unmarked impedance, this can be assumed to be 2.1% (0.021 Ω).

Let's consider a facility supplied by a 3-phase, 3,000 kVA transformer with an isolated secondary winding producing 480 V AC line-to-line, and with a marked impedance of 5.75%. Using the formula above, we can calculate the maximum available fault current for this facility to be just under 63 kA (62,755 A).

Since this calculation does not account for any additional impedance from the wires, and also assumes infinite utility source power, the calculated value can be assumed to be "worst-case" for any installation supplied from this power source.

Additional current limiting devices

In addition to transformers, other devices, such as some types of fuses and circuit breakers, also serve to limit the available fault current within a facility. The published let-through energy I^2t and peak let-through I_p can be used to determine the load-side available fault current. The higher of these two ratings is the available fault current beyond the device.

Using our example above, we know that our facility has a maximum available fault current of 63 kA. Let's assume that for a 63 kA fault at 480 V AC, a current-limiting circuit breaker as has an I^2t of 30 kA, and an I_p of 27 kA. The available fault current downstream from this circuit breaker is 30 kA.

In this example, the required SCCR for all components installed beyond this circuit breaker must be equal to, or greater than, 30 kA at 480 V AC.

Suitable applications for manual motor starters

For North America, the suitable applications for manual motor starters can be divided into two categories: those which require the use of upstream branch circuit protection (e.g. circuit breakers or fuses), and those which require no additional upstream branch protection.

Recall from earlier discussion that manual motor starters are classified by UL under two categories:
— Manual Motor Controllers (NLRV)
— Combination Motor Controllers (NLDX)

These categories follow the same division in regards to the need for upstream coordination.

First, we will review those applications specific for Manual Motor Controllers (NLRV), which require upstream branch circuit protection.

Defining Manual Motor Controllers (NLRV)

ABB manual motor starters are initially tested as Manual Motor Controllers (NLRV). A manual controller is defined as a hand-operated switching device whose contacts are controlled by the position of a mechanical actuator. These controllers can optionally be provided with the following functions:
— An instantaneous trip element for short-circuit protection (not suitable for branch circuit protection without further testing)
— Motor overload protection
— Suitability for motor disconnecting means, on the load-side of the branch circuit protective device
— Suitability for tap conductor protection in group installations

These additional functions are considered “optional” for devices within this category. To understand this, consider non-fusible disconnect switches tested according to UL 60947-4-1 / CSA C22.2 No. 60947-4-1. These devices feature no internal releases, and are therefore not suitable for load protection. Even so, both manual motor starters and non-fusible disconnect switches are classified within the same category NLRV.

Manual motor starters, tested as Manual Motor Controllers (NLRV)

Tested according to UL 60947-4-1 and CSA C22.2 No. 60947-4-1
as Manual Motor Controllers (NLRV)
- Load control (AC-1, AC Motor)
- Motor overload protection
- Component-level short-circuit current ratings with fuses and circuit breakers

Optional additional testing within this category includes
- Suitable as motor disconnect
- Suitable for use in group installations
- Suitable for tap conductor protection in group installations

Suitable applications for manual motor starters

Manual starters (non-combination)

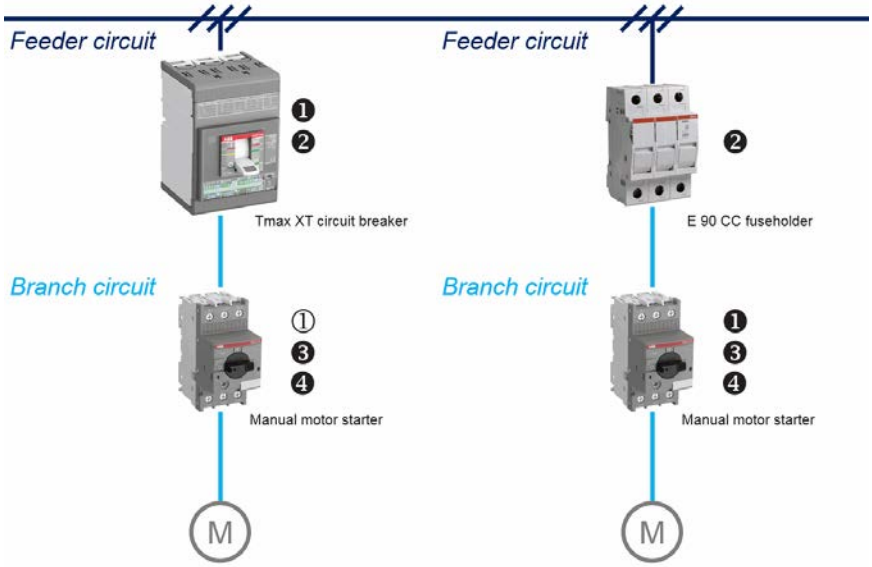
Manual starting methods offer a cost-effective alternative to remotely controlled starters. Manual starters feature a front-facing switching mechanism, typically in the form of a rotary knob, toggle switch, or pushbutton. This mechanism is the interface for direct ON/OFF control of the load. What sets manual motor starters apart from simple motor switches (e.g. non-fusible disconnect switches) is the inclusion of protective releases. If a fault occurs, the switching mechanism will trip the device handle to either an OFF or designated TRIP position.

As these manual starters still require that additional branch protection be provided separately upstream, they are commonly identified using the terms “non-combination” or “non-combo”.

Manual starters are often used on smaller 1- or 3-phase motors, typically 10 hp or less, and are popular in HVAC applications. They can be either enclosed or provided with accessories for flush mounting directly to a wall or panel door.

The examples in the figure below show manual motor starters applied as non-combination, single-motor starters. In addition to providing the means for motor control and overload protection, they can be used as the main branch disconnect when marked “Suitable as Motor Disconnect” and installed on the load side of the branch circuit protective device.

Manual motor starters as non-combination manual starters



Branch functional requirements, pg. 10

- ❶ Disconnect means
- ① Disconnect means (alternate)
- ❷ Short-circuit and ground-fault protection
- ❸ Control means
- ❹ Overload protection

Application information

Starting method: Manual
SCCR reference for MMS: “Motor Disconnect”
Maximim voltage: 600 Δ
Upstream branch protection: Required

For information regarding the use of manual motor starters as manual self-protected Combination Motor Controllers (Type E), without the need for upstream branch circuit protection, see page 31.

Suitable applications for manual motor starters

As part of a magnetic or solid-state starter (non-combination)

Although manual motor starters are suitable for manually controlling motors by themselves, they can be combined with another controller, like a contactor, to allow for remote control. This also increases the electrical durability of the starter. In these applications, the manual motor starters serves the primary function for motor and branch overload protection.

Manual motor starters can offer advantages versus conventional overload relays, including:

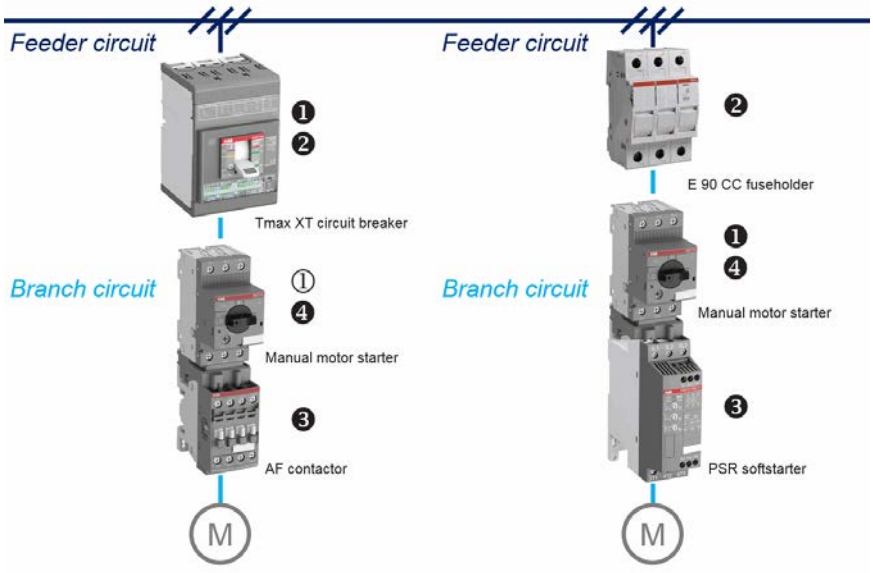
- ✓ Up to six direct-mount auxiliary and signaling contacts
- ✓ Undervoltage and remote (shunt) tripping accessories
- ✓ Visible trip indication
- ✓ Direct-opening overload protection to ensure functionality even if contactor welds

Coupling adaptors are available for directly mounting to AF contactors and PSR softstarters to reduce installation time and panel space.

Applications include anywhere thermal (bi-metallic) overload relays are used today.

The examples in the figure below show manual motor starters applied in non-combination, single-motor applications. The use of the additional controller (e.g. contactor) allows these starters to be remotely controlled. In addition to providing overload protection, the manual motor starter can also be used as the main branch disconnect when marked “Suitable as Motor Disconnect” and installed on the load-side of the branch circuit protective device.

Manual motor starters as non-combination starters



Branch functional requirements, pg. 10

- ❶ Disconnect means
- ① Disconnect means (alternate)
- ❷ Short-circuit and ground-fault protection
- ❸ Control means
- ❹ Overload protection

Application information

Starting method: Remote
SCCR reference for MMS: “Motor Disconnect”
SCCR reference for controller: Component-level
Maximim voltage: 600 Δ
Upstream branch protection: Required

For information regarding the use of manual motor starters with AF contactors as Combination Motor Controllers (Type F), without the need for upstream branch circuit protection, see page 32.

Suitable applications for manual motor starters

Local motor disconnect acc. to NEC Article 430.102 / CEC Section 28-604

The installation standards of North American require that each motor circuit include a means of safely disconnecting the motor from its supply power. This is typically utilized for maintenance purposes. With very few exceptions, this disconnect means must not exceed a distance of 15 m (50 ft.) in the U.S. and 9 m (29.5 ft.) in Canada from the motor itself, and must be within sight of the installation. If the primary disconnect means does not meet these criteria, a secondary, local disconnect must be installed, often in the form of an enclosed switch.

Manual motor starters, when additionally marked “Suitable as Motor Disconnect”, are suitable for providing a means for local motor disconnect. The inclusion of at-motor overload trip indication and reset can allow for quick and simple diagnostic troubleshooting and maintenance, reducing downtime. At-motor short-circuit protection also helps to mitigate fault detection issues caused by the increased wire impedance of long motor cables.

ABB manual motor starter handles feature a trip-free mechanism, meaning the device will trip even if the handle is locked in the ON position or held by hand. They are capable of being locked in the OFF position directly, and accessory enclosures and through-door handles are available that meet the requirements for lock-out / tag-out and are 3x padlockable.

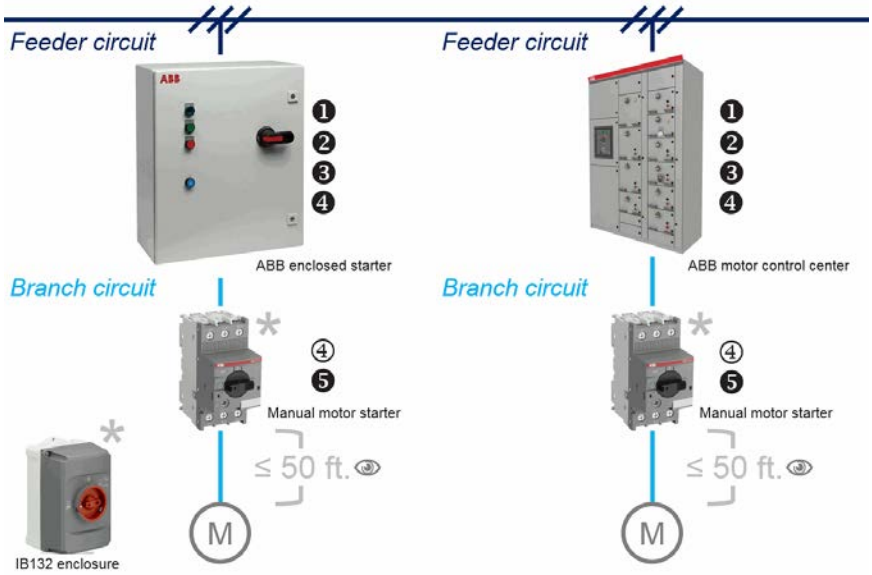
Manual motor starters provide advantages versus conventional non-fusible disconnect switches, including:

- ✓ Local at-motor overload, short-circuit, and phase loss protection
- ✓ Undervoltage and remote (shunt) tripping accessories
- ✓ Lockable device handles without accessory (excludes Type MS116)
- ✓ Reduced downtime by providing greater diagnostic capabilities on location

Local motor disconnects are common in material handling applications, such as conveyors, but can also be found in industrial applications employing centralized motor control centers.

This application is not recommended for motors controlled by drives. For more information, see page 39.

Manual motor starters as local motor disconnects



Branch functional requirements, pg. 10

- ❶ Disconnect means
- ❷ Short-circuit and ground-fault protection
- ❸ Control means
- ❹ Overload protection
- ④ Overload protection (alternate)
- ❺ Local motor disconnect

Application information

SCCR reference for MMS: “Motor Disconnect”
Maximim voltage: 600 Δ
Upstream branch protection: Required

Suitable applications for manual motor starters

Group installations

A group installation is defined as two or more motors, or one or more motors and other loads, protected by a single branch circuit protective device (BCPD). Group installations help to reduce both panel space and cost.

Group installations are permissible under NEC Article 430.53 in three instances, when either:

1. Each motor does not exceed 1 hp (6 A), and the upstream BCPD is not larger than 15 A.
2. Each motor circuit is individually protected against overload, with the BCPD sized for the smallest motor in accordance with individual branch requirements. The BCPD should not open under normal operating conditions for any load.
3. Each load is controlled, and each motor protected against overload conditions, by devices listed for use in group installations. The BCPD must additionally be sized properly to protect the group. As an exception, the controllers and overload protection do not need to be listed for use in group installations if the upstream BCPD does not exceed the maximum size allowed for the individual motor circuit.

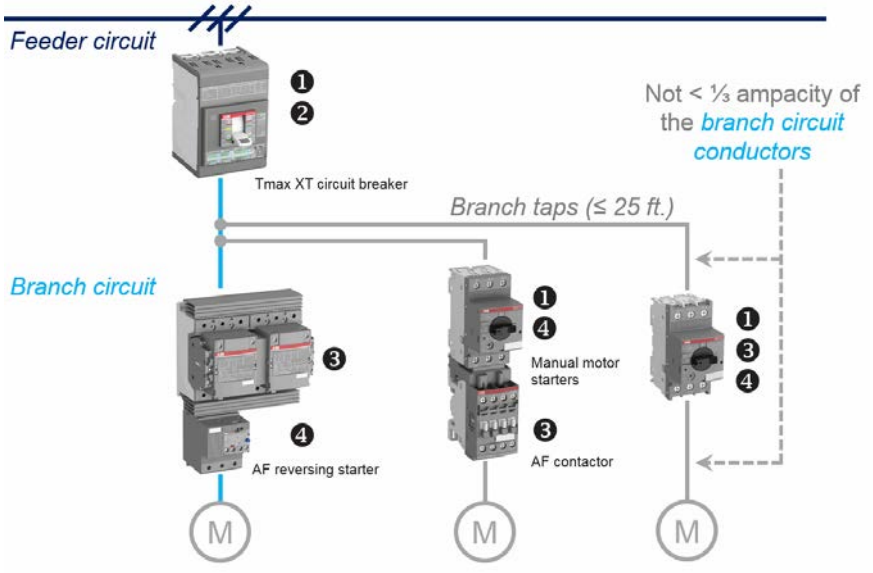
In all instances, the individual load tap conductors must have an ampacity of at least 125% of the motor full-load current. If the distance from the BCPD to the individual motor overload protection is not greater than 7.5 meters (25 feet), the tap conductors can be reduced to ⅓ the ampacity of the branch conductors. For longer distances, the ampacity of the individual load tap conductors must be equal to the branch circuit conductors. When the individual load tap conductors are sized less than the branch circuit conductors, they must be protected from physical damage by being enclosed in a raceway or another approved method.

Group installations are typically employed in Industrial Control Panels designed to control multiple motors and other loads. Examples include a set of similarly sized loads (e.g. a fan bank), or a combination of a large main load and smaller support loads (e.g. lubrication pumps or cooling fans).

ABB manual motor starters are suitable for use in group installations, and provide:

- ✓ An individual, lockable disconnect means for each load circuit
- ✓ Quick and compact group wiring using three-phase accessory busbar and coupling adaptors

Manual motor starters in a group installation



Branch functional requirements, pg. 10

❶ Disconnect means
❷ Short-circuit and ground-fault protection
❸ Control means
❹ Overload protection

Application information

SCCR reference for MMS: "Group Installation"
SCCR ref. for controllers: Component-level
Maximim voltage: 600 Δ
Upstream branch protection: Required

Suitable applications for manual motor starters

Tap conductor protection in group installations

Please note: as of the date of this publication, the following application is not applicable in Canada under CSA C22.1 *The Canadian Electrical Code* (CEC), Section 28.

When manual motor starters are employed in standard group installations, their ability to protect against short circuits is not taken into consideration. In an effort to credit these devices for protection against short circuits, the National Electrical Code® (NEC) allows manual motor starters marked "Suitable for Tap Conductor Protection in Group Installations" to protect the individual group taps, instead of the upstream group BCPD. This allows the size of the individual tap conductors to be smaller and more cost-effective than in standard group installations, as well as the potential for larger groups and for greater disparity between individual load sizes.

When the individual load tap conductors do not exceed a distance of 3 meters (10 feet) from the BCPD before terminating to a manual motor starter marked "Suitable for Tap Conductor Protection in Group Installations", they are allowed to be sized with and ampacity as low as $^{1}/_{10}$ the rating of the upstream group BCPD.

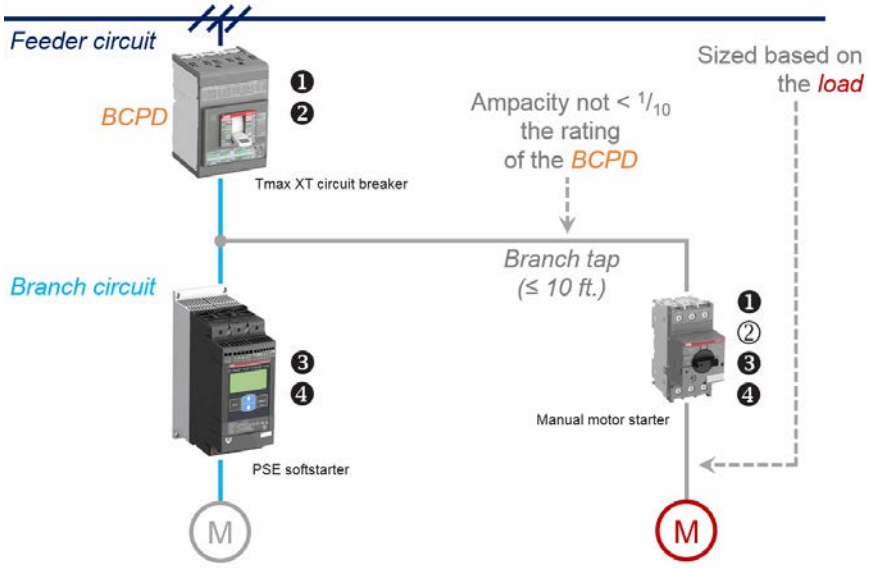
The conductors between the manual motor starter and the load are sized based on the NEC rules for the load itself, and are no longer a factor of the branch circuit conductor ampacity as they are in standard group installations.

Manual motor starters marked "Suitable for Tap Conductor Protection in Group Installations" can additional be used for the overcurrent protection of control transformers, eliminating the need for fuses or a UL 489 / CSA C22.2 No.5 circuit breaker.

Tap conductor protection offers advantages versus conventional group installations, including:

- ✓ Smaller and more cost-effective wire sizes between the BCPD and each individual load
- ✓ Larger groups with greater disparity between load sizes
- ✓ Protection of control transformers

Manual motor starters for tap conductor protection in group installations



Branch functional requirements, pg. 10

❶ Disconnect means
❷ Short-circuit and ground-fault protection
② Tap conductor protection
❸ Control means
❹ Overload protection

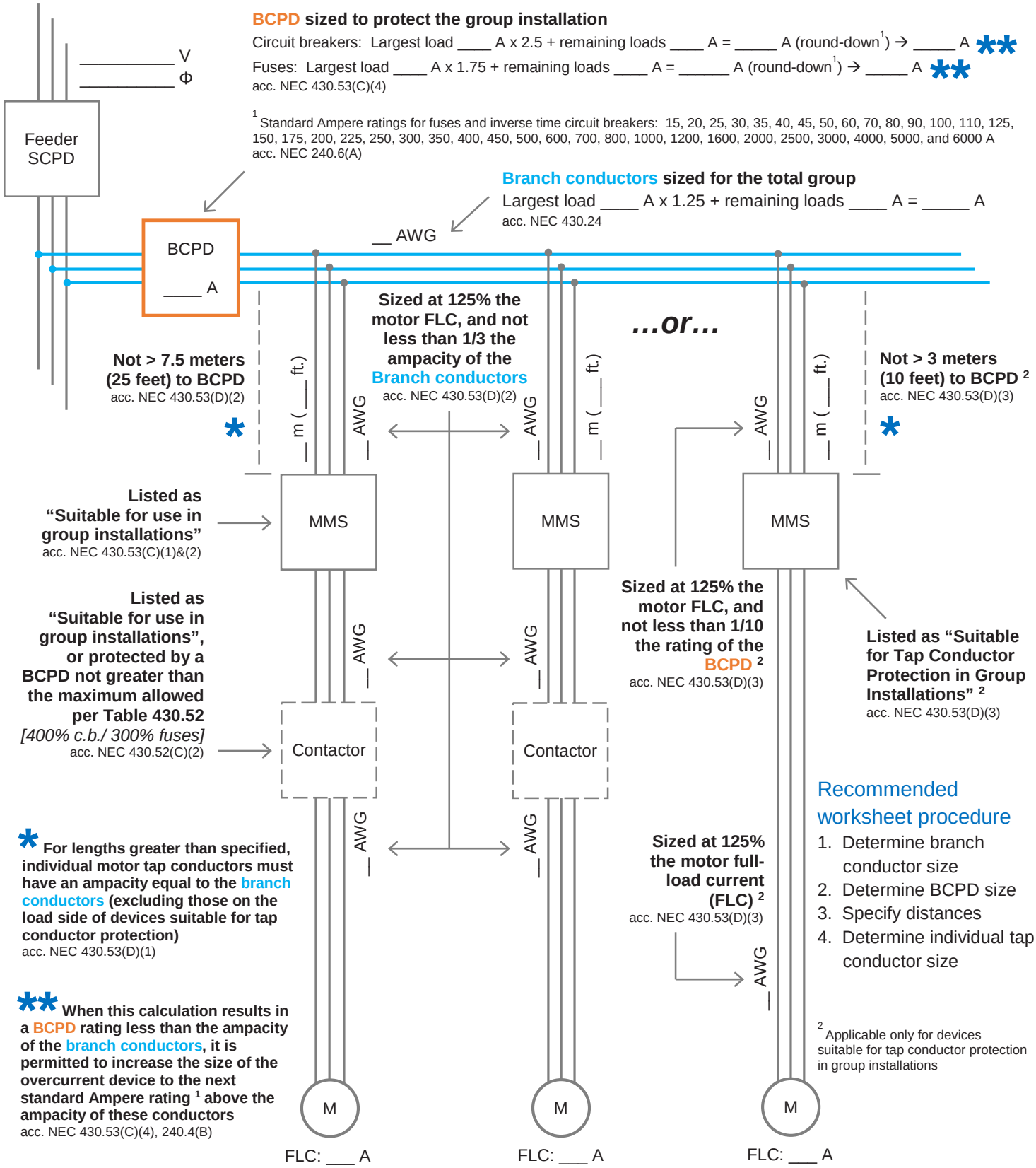
Application information

SCCR reference for MMS: "Tap Conductor Protection"
Maximim voltage: 600 Δ
Upstream branch protection: Required

Suitable applications for manual motor starters

Group installation worksheet

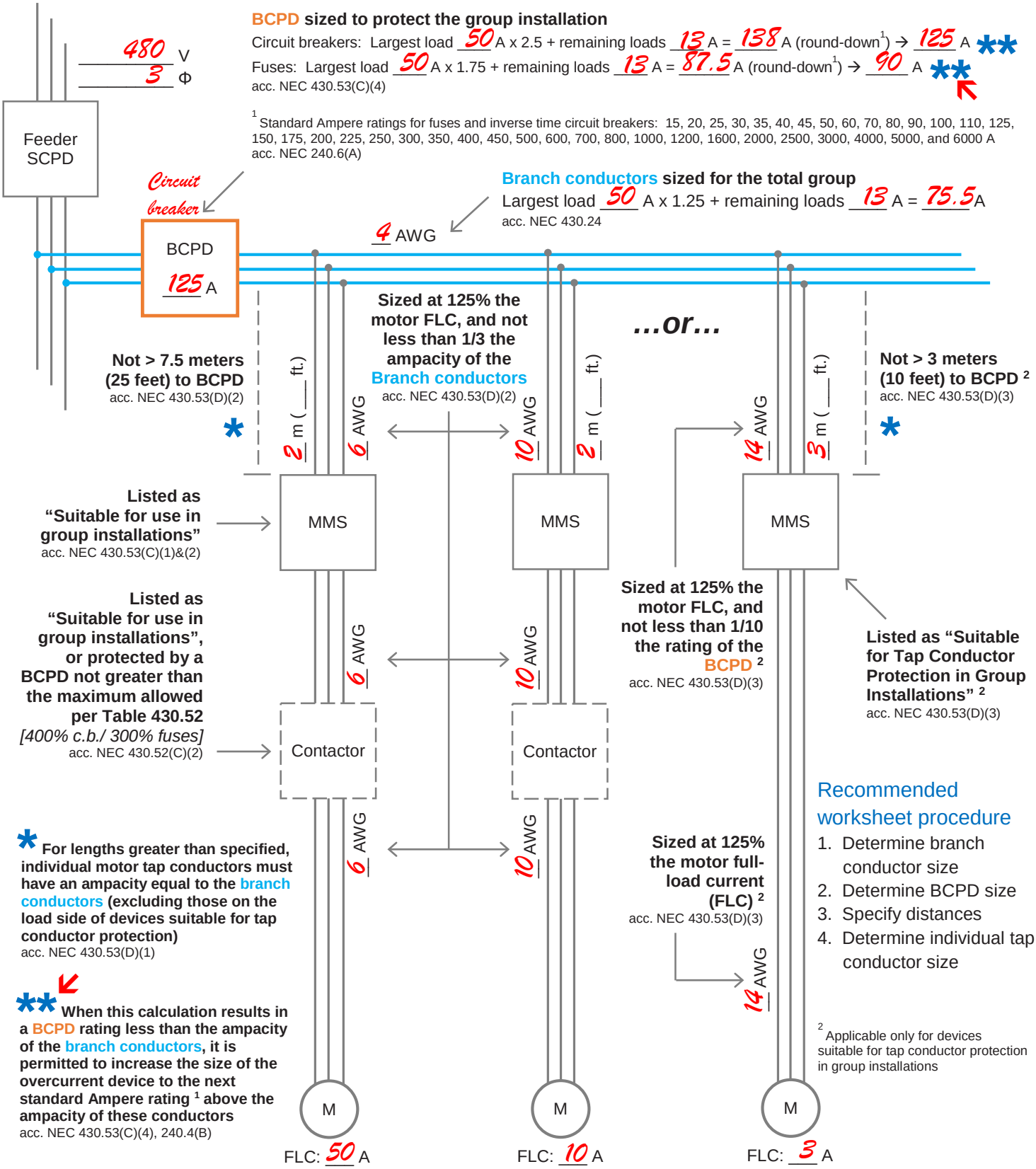
The worksheet below can be used for sizing devices for group installation. The rules shown to the far right are applicable only for devices suitable for tap conductor protection in group installations. Wire Ampacities: pg. 43.



Suitable applications for manual motor starters

Group installation worksheet example

Below is an example of a calculation for a group installation.

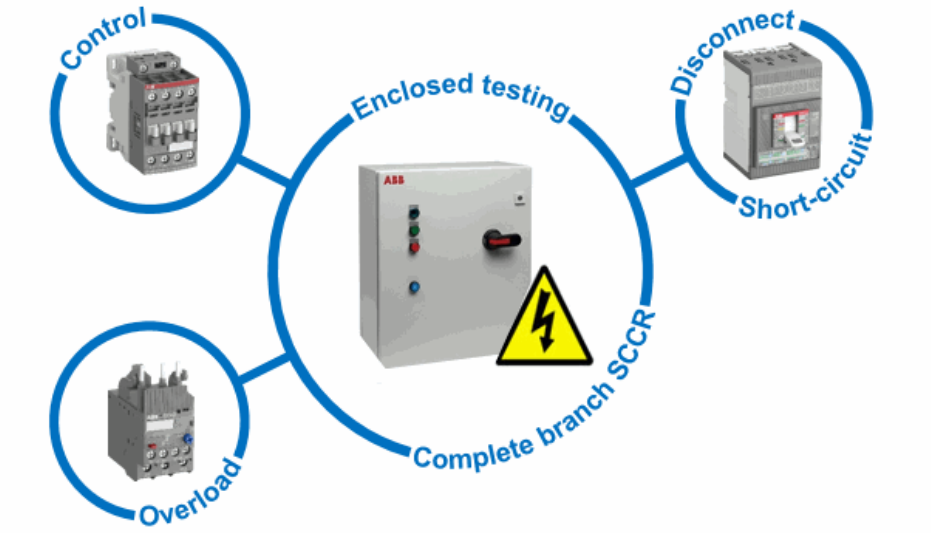


Suitable applications for manual motor starters

Defining Combination Motor Controllers (NKJH)

A Combination Motor Controller (CMC) is a single device, or assembly of devices, which provides the combined functions of branch circuit disconnect means, short-circuit protection, control means, and overload protection. These are:

— Listed combinations tested according to UL 60947-4-1 and CSA C22.2 No.60947-4-1
— Tested in a single enclosure
— Tested for a complete branch short-circuit current rating; Type 1 or Type 2 coordination



The figure below shows the currently six construction types for Combination Motor Controllers. Manual motor starters are used for Types E and F.

Tested in an enclosure	Type A	Type B	Type C	Type D	Type E	Type F (two-component)	Type F (three-component)
Disconnect means	Motor disconnect UL 98 or UL 489	Motor disconnect UL 98 or UL 489	Inverse-time circuit breaker UL 489	Instantaneous-trip circuit breaker UL 489	Self-protected control device UL 60947-4-1	Manual self-protected combination controller UL 60947-4-1	Manual self-protected combination controller UL 60947-4-1
Short-circuit and ground-fault protection	Fuses UL 248	Motor short-circuit protector UL 60947-4-1					
Control means	Magnetic or solid-state motor controller UL 60947-4-1	Magnetic or solid-state motor controller UL 60947-4-1	Magnetic or solid-state motor controller UL 60947-4-1	Magnetic or solid-state motor controller UL 60947-4-1		Magnetic or solid-state motor controller UL 60947-4-1	Magnetic or solid-state motor controller UL 60947-4-1
Overload protection	Overload relay UL 60947-4-1	Overload relay UL 60947-4-1	Overload relay UL 60947-4-1	Overload relay UL 60947-4-1		Manual self-protected combination controller UL 60947-4-1	Overload relay UL 60947-4-1
Tested combination SCCR	Straight voltage rated (e.g. 480 Δ)	Straight voltage rated (e.g. 480 Δ)	Straight voltage rated (e.g. 480 Δ)	Straight voltage rated (e.g. 480 Δ)	Slash voltage rated (e.g. 480Y/277V)	Slash voltage rated (e.g. 480Y/277V)	Slash voltage rated (e.g. 480Y/277V)

Note: The information above is derived from UL 60947-4-1 and is intended for reference purposes only.

A complete listing of ABB's tested Combination Motor Controllers can be accessed online through UL's website, keyword "ABB" (http://ul.com/search/?q=ABB).

Suitable applications for manual motor starters

Manual self-protected Combination Motor Controllers, Type E

Type E represents the only CMC construction type to allow use of a single component. Manual motor starters are the most common example. The term “self-protected” refers to the level of coordinated protection provided, as these combinations are subject to an intense validation process following short circuit, including thousands of electrical and mechanical operations. For this reason, Type E Combination Motor Controllers ensure proven continuity of service following a fault, and provide a level of coordinated protection that exceeds even Type 2.

Due to the compact nature of manual motor starters, Type E Combination Motor Controllers are slash voltage rated (e.g. 600Y/347). This limits their use to solidly grounded networks for the higher voltages (e.g. above 347V).

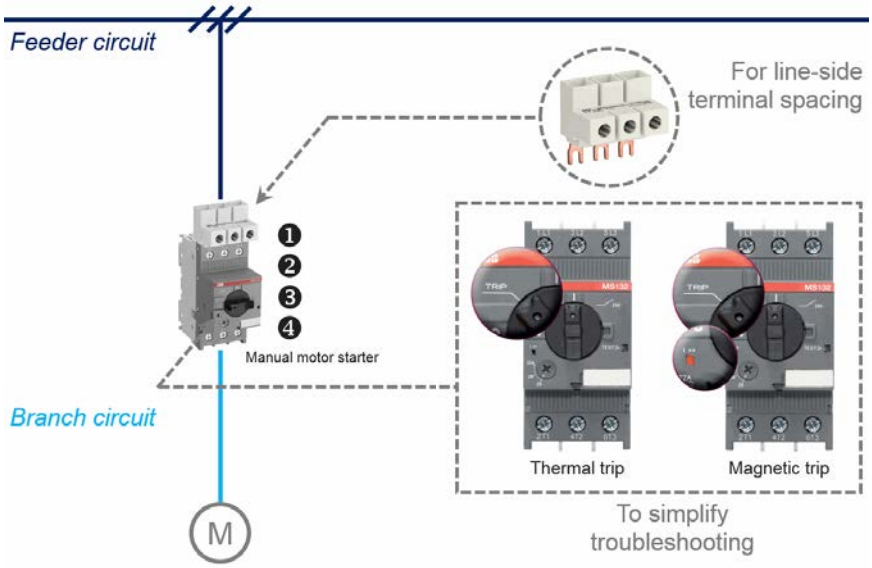
Two additional criteria exist for manual motor starters certified as Combination Motor Controllers:

— Line-side terminal spacing of 2 inches over-surface (creepage) and 1 inch through-air (clearance) similar to the requirements common for UL 489 / CSA C22.2 No.5 circuit breakers
— A means of visibly differentiating between thermal (overload) and magnetic (short-circuit) trip, so as not to inhibit troubleshooting

These requirements can be met using either accessories (e.g. terminal feeder blocks and side-mount trip indicators) or inherent design features. MS165 requires no additional accessories to meet the above criteria; MS132 requires only the line-side terminal feeder block (S1-M3-..). Both types feature an integral trip indicator window, which turns red upon tripping of the instantaneous release, indicating a short circuit.

✓ Type E manual self-protected Combination Motor Controllers provide significant advantages for customers by incorporating control, disconnect, overload and short-circuit protection into one, compact and cost-efficient product.

Manual self-protected Combination Motor Controller (Type E)



Branch functional requirements, pg. 10

❶ Disconnect means
❷ Short-circuit and ground-fault protection
❸ Control means
❹ Overload protection

Application information

Starting method: Manual
SCCR reference: “Type E”
Maximim voltage: 600Y/347V
Upstream branch protection: Not required

For information regarding manual starter applications in ungrounded (delta) networks above 347 V, see page 23.

Suitable applications for manual motor starters

Combination Motor Controllers, Type F

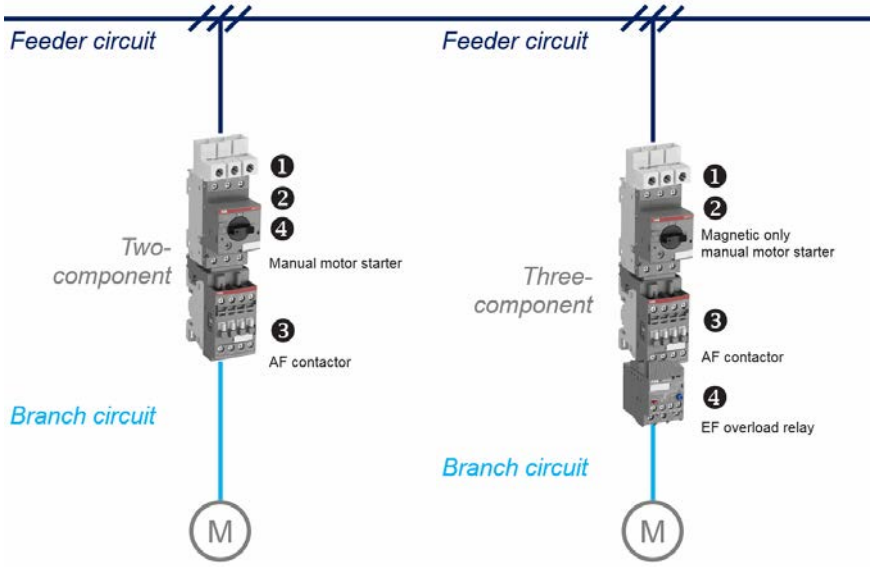
Type F constructions are divided into two styles: two-component and three-component assemblies. Two-component Type F assemblies utilize a manual, self-protected device for both short circuit and overload protection. Three-component Type F assemblies utilize a separate overload relay, and short circuit protection is provided by a magnetic only (MO) manual motor starter.

The additional criteria for line-side terminal spacing and visible trip indication described on page 31 are also applicable for Type F Combination Motor Controllers.

Type F Combination Motor Controllers can be tested for either Type 1 or Type 2 coordination.

- ✓ With the inclusion of a contactor for remote control, Type F Combination Motor Controllers increase functionality while still offering customers the benefit of using compact and cost-efficient manual motor starters for branch short circuit protection.
- ✓ Three-component assemblies provide additional benefits, including selectable Class 10, 20, 30 overload protection (electronic), along with a wiring schematic identical to that of a conventional combination starter (e.g. molded case circuit breaker, contactor, and overload relay).

Combination Motor Controllers (Type F)



Branch functional requirements, pg. 10

❶ Disconnect means
❷ Short-circuit and ground-fault protection
❸ Control means
❹ Overload protection

Application information

Starting method: Remote
SCCR reference: "Type F"
Maximim voltage: 600Y/347V
Upstream branch protection: Not required

For information regarding remote starter applications in ungrounded (delta) networks above 347 V, see page 24.

Suitable applications for manual motor starters

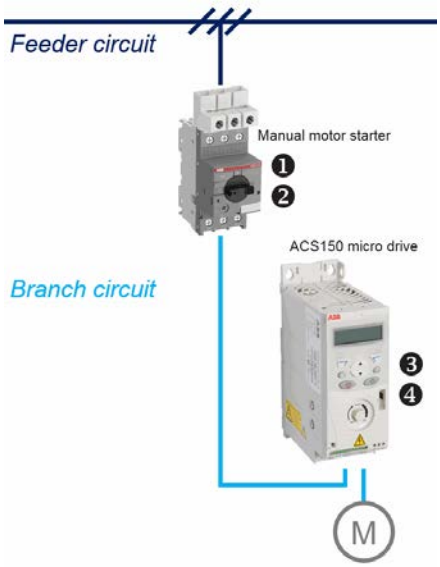
Protection of ABB Micro drives

Type E manual self-protected Combination Motor Controllers can be used for the protection of frequency converters (e.g. variable frequency drives). This requires further component-level short circuit testing to be performed according to UL 508C. ABB has performed testing to allow the use of manual motor starters for the protection of ACS150 and ACS3xx Micro drives.

The additional criteria for line-side terminal spacing and visible trip indication described on page 31 are also required for Type E manual self-protected Combination Motor Controllers used in this application.

✓ Use of manual motor starters for drive protection provides customers with a compact and cost-efficient alternative to non-resettable semiconductor fuses.

Protection of ABB Micro drives



Branch functional requirements, pg. 10

1. Disconnect means
2. Short-circuit and ground-fault protection
3. Control means
4. Overload protection

Application information

Starting method: Variable frequency drive
SCCR reference: Component-level (see below)
Maximim voltage: 480Y/277V
Upstream branch protection: Not required

For more information regarding ABB's tested combinations with Type E manual self-protected Combination Motor Controllers and ACS150 / ACS3xx Micro drives, please consult Document No. 3AUA0000173741, which can be accessed in the Download Center (http://www.abb.com/abblibrary/DownloadCenter).

Selection criteria

Sizing manual motor starters for motor applications

Manual motor starters should be sized based on the nameplate full-load current (FLC) of the motor. The rated operational current I_e of the manual motor starter represents the maximum full-load current rating of the device. Similar to thermal overload relays, these devices are provided with a thermal setting range. Manual motor starters should be selected so that the motor current rating falls between these ranges. If the thermal setting ranges of two devices overlap for the intended motor current, select the device with a range that will allow greater flexibility for adjustment. For magnetic only (MO) manual motor starters, select the device with a rated operational current I_e equal to, or the next size above, the FLC of the motor.

Selecting the right SCCR for your application

With so many different applications and ratings available for manual motor starters, it can sometimes be difficult to know which SCCR to select. Below are some general tips to assist in selection. Additionally, an "SCCR reference" is shown next to each application diagram in the previous section. This reference correlates to a UL/CSA maximum short-circuit current rating table column header. These tables can be found in our Main Catalog for Motor Control and Protection 1SBC100192C0201, which can be accessed in the Download Center.

UL/CSA Maximum short-circuit current ratings – MS132

Type	Manual Motor Controllers								Manual self-protected Combination Motor Controllers (Type E)[2]	
	Branch circuit protection, max. size per NEC / CEC[1]		for motor disconnect		for group installations		for tap conductor protection in group installations			
	Fuses	Circuit breaker	480 V	600 V	480 V	600 V	480 V	600 V	480Y / 277 V	600Y / 374 V
	A	A	kA	kA	kA	kA	kA	kA	kA	kA

If the secondary winding style of the upstream facility transformer is known to be wye, or for delta networks 347V and below, consider first the application of manual motor starters as Combination Motor Controllers. For manual control, select from the "Type E" SCCR. For remote control, select from "Type F", and ensure that any minimum component size requirements are respected.

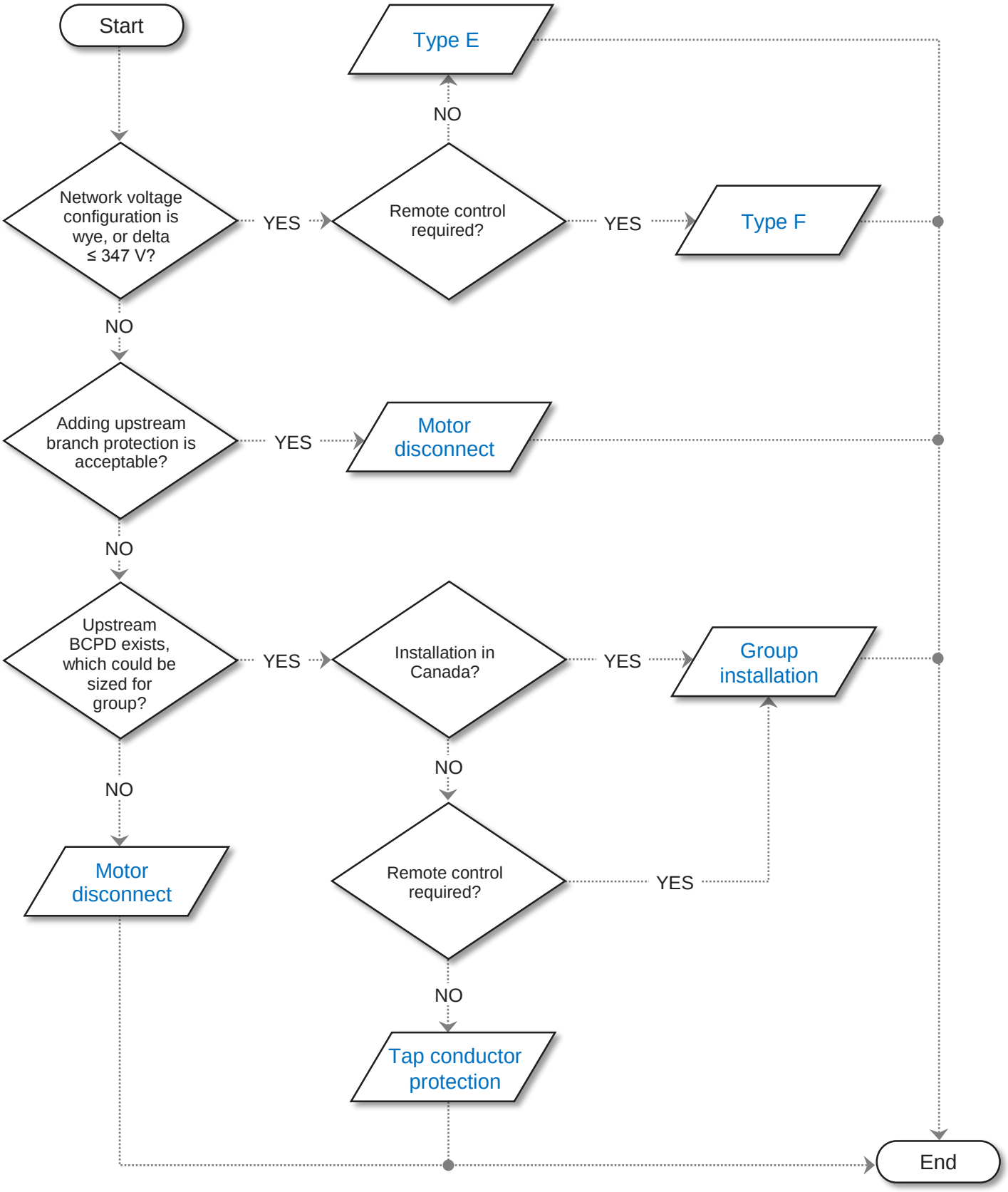
For delta networks above 347 V, consider the addition of an upstream fuse block and fuses. The manual motor starter can serve as the main branch disconnect when marked "Suitable as Motor Disconnect" and positioned on the load-side of the branch circuit protective device. The "Motor disconnect" SCCR should referenced. These ratings apply whether the upstream BCPD is fuses or a circuit breaker unless otherwise noted.

For panels designed to control multiple branch circuits, consider the possibility of a group installation. Most industrial control panels are supplied by a circuit breaker or set of fuses that could be sized based on the requirements for group installation. In the U.S., when using manual motor starters in group installations for manual control, the "Tap Conductor Protection" SCCR should be referenced. For Canada, or for the U.S. when also combining AF contactors for remote control, select from the "Group installation" SCCR. 3-phase accessory busbar is available to provide a compact solution for group installation.

If the upstream protective device is too large to protect the group, or if any of the other requirements for group installation cannot be met, manual motor starters should be employed as non-combination starters. They can provide manual control themselves, or provide overload protection as part of a magnetic or solid-state starter assembly. Close coupling adaptors are available for AF contactors and PSR softstarters to reduce installation time and panel space. In these applications, the "Motor disconnect" SCCR is referenced. If an additional controller is used (e.g. contactor), use the component-level short-circuit current ratings for these devices.

Selection criteria

The flowchart below reflects the information provided on the previous page.



Selection criteria

Frequently asked questions (FAQ)

Q: Why do Type E and Type F assemblies require larger terminal spacings (e.g. line-side terminal feeder block)?

A: When manual motor starters are certified as Combination Motor Controllers, they replace standard molded case circuit breakers for branch short-circuit protection. UL 489 / CSA C22.2 No.5 circuit breakers are required to have greater creepage and clearance distances between terminals, a requirement which is then extended to the manual motor starters for Type E and Type F assemblies.

Q: Why not simply use Type E or Type F ratings for all applications?

A: These ratings are limited to applications in solidly grounded networks with line-to-ground voltages not exceeding 347 V AC. The addition of an upstream branch circuit protective device increases the voltage rating of manual motor starters to 600 V AC in either grounded or ungrounded networks.

Q: Why are manual motor starters not just tested as circuit breakers acc. to UL 489 / CSA C22.2 No.5?

A: UL 489 / CSA C22.2 No.5 circuit breakers are only suitable for providing overload protection for motors less than 1 hp (2.1 Amps at 480 V AC). This would significantly limit the advantages of manual motor starters in motor applications.

Q: Can manual motor starters be used in lighting applications?

A: According to UL 508A Ed.2, Table 33.1, controllers carrying “AC Motor” ratings (e.g. manual motor starters) can be used for the control of AC fluorescent ballast loads. When applied using this standard, manual motor starters are suitable for the control of lamp loads only.

Q: Do I need to use a separate S803W current limiter for each individual manual motor starter?

A: One S803W can be used to increase SCCR for multiple MMS, as long as the sum of the load currents do not exceed the rated current of the S803W. Three variants are available for 32, 63, and 100 Amps.

Q: Can manual motor starters be used in heating applications?

A: Manual motor starters carry AC-1 General use ratings, which apply when controlling heaters. Magnetic only (MO) manual motor starters can be used if additional overload protection is not required.

Q: Can I use accessories like busbar and feeder terminals without effecting the SCCR?

A: ABB accessory three-phase busbar and feeder blocks have been validated to correspond to the maximum SCCR for the manual motor starters; there is no derating for use of these accessories.

Q: Are there any mitigation techniques for issues with shaft alignment?

A: Compact MMS may require the use of longer shafts to reach the panel door. For issues with shaft alignment, use of the MSHA1 shaft supporter and MSH-AR shaft alignment ring is recommended.

Q: Can I substitute between upstream protective devices without effecting the SCCR?

A: For component-level SCCR, upstream protection can be substituted with any like device, assuming the I^2t and I_p values of the substitute are equal to or lower than the original component (e.g. substituting Class J fuses for Class RK5). For Combination Motor Controllers, substitutions are not allowed.

Q: Does the upstream protection for a group installation need to be included in the same enclosure?

A: No – but any tap leaving an enclosure must be suitably protected (e.g. in conduit).

Installation and commissioning

Installation instructions

Installation instructions for manual motor starters can be accessed through the ABB Download Center (http://www.abb.com/abblibrary/DownloadCenter).

2D and 3D drawings

2D and 3D drawings for manual motor starters and accessories can be accessed through the CADENAS portal (http://abb-control-products.partcommunity.com/portal/portal/abb-control-products).

Mounting

— Tool-less mounting and dismounting on a 35 mm DIN rail according to DIN EN 60715
— Screw mounting directly to the panel back-plate. MS116 / MS132 manual motor starters require accessory.

Motor current setting procedure

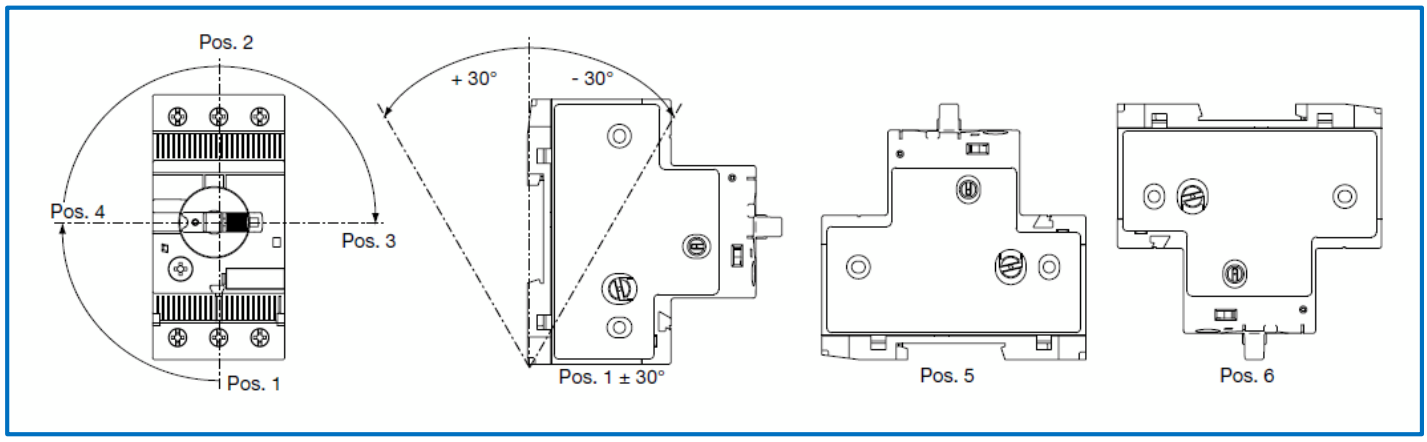
Set the motor current using the radial dial on the front of the manual motor starter to the appropriate current level using a screwdriver. To avoid issues with nuisance tripping, the dial should be set to the actual current value stated on the motor nameplate.

Test function

It is possible to check the proper mechanical function of an installed manual motor starter using the TEST function. Actuation of the TEST release using a screwdriver simulates device tripping. This function is useful during commissioning to verify the wiring of the circuit and the function of accessories (e.g. signaling contacts).

Mounting positions

Mounting positions 1…6 are permitted for manual motor starters.



Environmental and application-specific factors

Ambient air temperature compensation and derating

Temperature compensation applies to bi-metallic devices which employ a secondary bi-metal to counteract the bi-metals of the inverse time-delay overcurrent release. The secondary bi-metal is not heated by motor current, instead reacting only under the influence of ambient air temperature. As a result, the effects of ambient temperature in regards to manual motor starter tripping characteristics is automatically compensated.

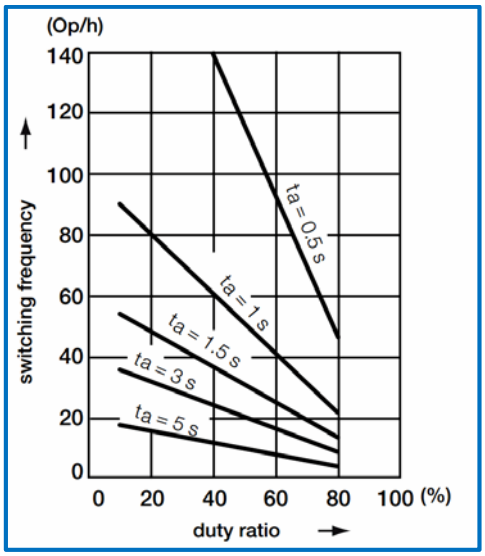
ABB manual motor starters have an allowable ambient temperature range for single mounting between -25°C to 60°C. Correction factors for ambient temperatures up to 70°C and for group mounting are shown below.

Device	Current correction factors for single mounting, or group mounting with spacing ≥ 9 mm[1)]			Current correction factors for group mounting without spacing		
	40°C	60°C	70°C	40°C	60°C	70°C
MS132-0.16 … 4.0	1.00	1.00	1.00	1.00	1.00	1.00
MS132-6.3	1.00	1.00	1.00	1.00	1.00	0.79
MS132-10	1.00	1.00	0.80	0.91	0.80	0.70
MS132-12	1.00	1.00	0.91	1.00	0.91	0.83
MS132-16	1.00	1.00	0.81	0.93	0.87	0.81
MS132-20	1.00	1.00	0.90	1.00	0.95	0.85
MS132-25	1.00	1.00	0.92	1.00	0.92	0.80
MS132-32	1.00	1.00	0.90	1.00	0.93	0.78

Note: Temperature values between those shown can be linearly interpolated. [1)] Use of PS1-..-**1**-.. one-slot busbar for group mounting provides spacing between MMS = 9 mm.

Duty cycles and restarting

To avoid issues with nuisance tripping, manual motor starters should not be operated at an arbitrary operating frequency. Applications involving up to 15 starts per hour are acceptable. Higher starting frequencies are acceptable if the duty ratio is lower and the motor's making current does not appreciably exceed six times the full-load current. The diagram below provides guideline values for starts-per-hour as a factor of the duty ratio (on vs. off time) and the time required to start the motor t_a.



Example: For a motor with a duty ratio of 60 percent and a start duration of 1 second, 40 starts per hour is acceptable.

After tripping, the bi-metals need to cool down before the manual motor starter can be reset. The device handle will not be capable of being switched to the ON position until this is achieved.

Environmental and application-specific factors

Frequencies and direct current (DC)

The magnetic trip values for manual motor starters are valid for frequencies from 50 – 60 Hz. Frequencies other than 50/60 Hz will have an impact on the instantaneous short-circuit release. In the range from 45 ... 66 Hz, the operating values of the instantaneous short-circuit release are within tolerance. For frequencies above 60 Hz, or for direct current (DC), the operating value of the instantaneous short-circuit release is increased; for frequencies below 50 Hz, the operating value of this magnetic release is decreased. Correction factors for these applications are shown below.

	DC	10 Hz	45 … 66 Hz	100 Hz
Current correction factors	1.1	0.9	1	1.1

Thermal tripping characteristics for manual motor starters are valid for DC and AC with frequencies from 0 Hz to 400 Hz. For three-pole loads and currents of between 3 - 8 times the set current, the tolerance of the tripping time is ±20 %. See page 5.

Effects of variable frequency drives

The presence of Pulse Width Modulated (PWM) adjustable frequency drives in a motor circuit can create complications for components positioned between the motor and drive. The voltage reflection phenomenon, which amplifies the voltage transmitted between the drive and the motor, can create dielectric stresses that damage the magnetic trip coil of manual motor starters if not properly mitigated. This phenomenon is directly influenced by the rise time (dV/dt) of the IGBT's and the motor cable length, and is most severe at the motor. Drives with slow rise times help to reduce the intensity of this phenomenon.

Several mitigation techniques are recommended if using manual motor starters on the load-side of PWM drives:

— Recommended chopping frequency of 8 kHz or less
— The manual motor starters should be installed within close proximity to the drive itself, preferably directly below the drive output terminals. Due to the nature of the voltage reflection phenomenon, manual motor starters are not recommended to for use as local, at-motor disconnects in drive applications; see page 25
— The ambient temperature limits of the manual motor starter should not be exceeded
— The drive should provide a level of harmonic filtration in conformity with the EMC Directive, EMC 2004/108/EC as tested acc. to IEC/EN 61800-3 (e.g. ABB ACS550/ACH550 drives)
— For any drives not conforming to this Directive, the installation of an additional load reactor, dV/dt filter, or sine filter between the drive and the manual motor starter is recommended

For more information regarding the effects of AC drives and recommend installation techniques, please consult Document No. 3AUA489002B2141, which can be accessed in the Download Center (http://www.abb.com/abblibrary/DownloadCenter).

Additional reference information

Definitions acc. to UL 60947-4-1, UL 50

STARTER Combination of all the switching means necessary to start and stop a motor in combination with suitable overload protection

COMBINATION STARTER Equipment consisting of a protected starter incorporating an isolating function. Also called “Combination Motor Controller”.

MANUAL CONTROLLER A hand-operated switching device whose contacts are controlled by the position of a mechanical actuator, optionally provided with additional functions.

COMBINATION MOTOR CONTROLLER Single device or a single of assembly of devices that provides the combined functions of branch circuit disconnect means, short circuit protection, motor overload protection, and control for one motor branch circuit.

SELF-PROTECTED COMBINATION MOTOR CONTROLLER Combination motor controller with coordinated protection, so as to permit continuity of service up to its rated short-circuit current. A self-protected combination motor controller is evaluated as a complete unit whether comprised of a single or multiple components. The coordinated protection may be inherent or obtained by correct selection of components or accessory parts in accordance with the manufacturer’s instructions.

MANUAL SELF-PROTECTED COMBINATION MOTOR CONTROLLER Self-protected combination motor controller without magnetic controller function.

TYPE 1 Enclosures constructed for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection against falling dirt.

TYPE 3R Enclosures constructed for either indoor or outdoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt, rain, sleet, and snow; and that will be undamaged by the external formation of ice on the enclosure.

TYPE 12 Enclosures constructed (without knockouts) for indoor use to provide a degree of protection to personnel against incidental contact with the enclosed equipment; to provide a degree of protection against falling dirt; against circulating dust, lint, fibers, and flyings; against dripping and light splashing of non-corrosive liquids; and against light splashing and consequent seepage of oil and non-corrosive coolants.

Additional reference information

Bibliography

Various tests have been referenced within this handbook. They are recommended further reading to assist in achieving compliant installations:

CSA C22.1 Canadian Electrical Code, Part I (23rd Ed.). (2015). Toronto, Ontario, Canada: Canadian Standards Association (CSA Group).

CSA C22.2 No. 60947-4-1 Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters (2nd Ed.). (2014). Toronto, Ontario, Canada: Canadian Standards Association (CSA Group).

Guide Information for Electrical Equipment, the White Book 2014. (2014). Northbrook, IL, USA: Underwriters Laboratories Inc.

IEC 60947-4-1 Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters (3rd Ed.). (2009). Geneva, Switzerland: International Electrotechnical Commission.

NFPA®70 National Electrical Code® (2014 Ed.). (2013). Quincy, MA, USA: National Fire Protection Association®

UL 50 Standard for Safety, Enclosures for Electrical Equipment, Non-Environmental Considerations (12th Ed.). (2007). Northbrook, IL, USA: Underwriters Laboratories Inc.

UL 508A Standard for Safety, Industrial Control Panels (2nd Ed.). (2013). Northbrook, IL, USA: Underwriters Laboratories Inc.

UL 60947-4-1 Standard for Safety, Low-Voltage Switchgear and Controlgear – Part 4-1: Contactors and Motor-Starters – Electromechanical Contactors and Motor-Starters (3rd Ed.). (2014). Northbrook, IL, USA: Underwriters Laboratories Inc.

Acronyms and abbreviations

BCPD	Branch circuit protective device
CEC	Canadian Electrical Code
CMC	Combination Motor Controller
CSA	Canadian Standards Association
IEC	International Electrotechnical Commission
MMC	Manual Motor Controller
MMS	Manual motor starter
NEC	National Electrical Code®
NFPA®	National Fire Protection Association®
NRTL	Nationally Recognized Test Laboratory
OSHA	Occupational Safety and Health Administration
SCC	Standards Council of Canada
SCCR	Short-circuit current ratings
UL	Underwriters Laboratories

Additional reference information

Products suitable for motor branch circuits by Category Code (CCN) acc. to 2014 UL White Book

The information below is an extension of the information provided on pages 10 – 11.

1. Disconnect means for the motor and branch circuit acc. to NEC Article 430.101

Any motor branch	When tested and installed as, or part of, a Combination Motor Controller	When marked "suitable as motor disconnect" and installed downstream from the branch short-circuit and ground-fault protective device
— Fusible disconnect switches (UL 98 only) — Non-fusible disconnect switches (UL 98 only) — UL 489 Inverse-time circuit breakers (e.g. thermal-magnetic) — Molded case switches — Horsepower-rated cord-and-plug receptacles and connectors	— **Self-protected Combination Motor Controllers (manual motor starters)** ★ — UL 489 Instantaneous-trip circuit breakers (magnetic only)	— **Manual motor starters** ★ — Non-fusible disconnect switches (UL 60947-4-1)
— CCN: DIVQ, WHTY, WHXS, WIAX, WJAZ, AXUT, QLGD, QLHN, QLIW, QLKH, RTRT	— CCN: **NKJH** (Comp. DIVQ2, NLRV)	— CCN: **NLRV**

Note: For motors less than ⅛ hp, the overcurrent protective device can serve as the disconnect means (e.g. panelboards).

2. Short-circuit and ground-fault protection for the motor and branch circuit acc. to NEC Article 430.51

Any motor branch	When tested and installed as, or part of, a Combination Motor Controller	Not acceptable
— UL 489 Inverse-time circuit breakers (e.g. thermal-magnetic) — Cartridge fuses	— **Self-protected Combination Motor Controllers (manual motor starters)** ★ — UL 489 Instantaneous-trip circuit breakers (magnetic only)	— UL 1077 supplementary circuit breakers — Miscellaneous or miniature fuses
— CCN: DIVQ, JDDZ	— CCN: **NKJH** (Comp. DIVQ2, NLRV)	— CCN: JDYX, QVNU2

3. Motor control means acc. to NEC Article 430.81

Any motor branch – manual control	Any motor branch – remote control	Not acceptable
— **Manual motor starters** ★ — Non-fusible disconnects (UL 60947-4-1) — UL 489 Inverse-time circuit breakers (e.g. thermal-magnetic) — Molded case switches — **Combination Motor Controllers (Type E)**★	— Contactors — Softstarters — Variable frequency drives — **Combination Motor Controllers (Types** A–D,**F)** ★	— Industrial control switches — Contactors not rated for motor loads
— CCN: DIVQ, **NKJH**, NKPZ, **NLRV**, WJAZ	— CCN: NKJH, **NLDX**, NMFT, NMMS	— CCN: NRNT

Note: Fusible and non-fusible disconnect switches (98/No.4 only) can be used as a motor controller only for motors ⅛ hp or smaller.

4. Overload protection for the motor and branch circuit acc. to NEC Article 430.31

Any motor branch	Motors 1 hp or less, non-automatically started
— **Manual motor starters** ★ — Overload relays — Universal motor controllers — **Combination Motor Controllers** ★ — Any softstarter, variable frequency drive, or other controller with integral overload protection — A protective device integral to the motor itself	— UL 489 Inverse-time circuit breakers (e.g. thermal-magnetic) — Cartridge fuses
— CCN: NKCR, **NKJH**, NKPZ, NLDX, **NLRV**, NMFT, NMMS	— CCN: DIVQ, JDDZ

The 2014 UL White Book helps customers match the requirements of the 2014 National Electrical Code® to UL certified products using Category Codes (CCN) and is available for download on UL's website (http://ul.com/wp-content/uploads/2014/09/UL-White-Book.pdf).

Additional reference information

Horsepower to full-load Amperes acc. to UL 60947-4-1, Tables G.1 and G.2DV.1.1

Motor operational current: single- and three-phase

Motor power hp	120 V 1-ph A	200 V 1-ph A	200 V 3-ph A	208 V 1-ph A	208 V 3-ph A	220-240 V 1-ph A	220-240 V 3-ph A	380-415 V 3-ph A	440-480 V 3-ph A	550-600 V 3-ph A
1/10	3	—	—	—	—	1.5	—	—	—	—
1/8	3.8	—	—	—	—	1.9	—	—	—	—
1/6	4.4	2.5	—	2.4	—	2.2	—	—	—	—
1/4	5.8	3.3	—	3.2	—	2.9	—	—	—	—
1/3	7.2	4.1	—	4	—	3.6	—	—	—	—
1/2	9.8	5.6	2.5	5.4	2.4	4.9	2.2	1.3	1.1	0.9
3/4	13.8	7.9	3.7	7.6	3.5	6.9	3.2	1.8	1.6	1.3
1	16	9.2	4.8	8.8	4.6	8	4.2	2.3	2.1	1.7
1-1/2	20	11.5	6.9	11	6.6	10	6	3.3	3	2.4
2	24	13.8	7.8	13.2	7.5	12	6.8	4.3	3.4	2.7
3	34	19.6	11	18.7	10.6	17	9.6	6.1	4.8	3.9
5	56	32.2	17.5	30.8	16.7	28	15.2	9.7	7.6	6.1
7-1/2	80	46	25.3	44	24.2	40	22	14	11	9
10	100	57.5	32.2	55	30.8	50	28	18	14	11
15	135	—	48.3	—	46.2	68	42	27	21	17
20	—	—	62.1	—	59.4	88	54	34	27	22
25	—	—	78.2	—	74.8	110	68	44	34	27
30	—	—	92	—	88	136	80	51	40	32
40	—	—	120	—	114	176	104	66	52	41
50	—	—	150	—	143	216	130	83	65	52
60	—	—	177	—	169	—	154	103	77	62
75	—	—	221	—	211	—	192	128	96	77
100	—	—	285	—	273	—	248	165	124	99
125	—	—	359	—	343	—	312	208	156	125
150	—	—	414	—	396	—	360	240	180	144
200	—	—	552	—	528	—	480	320	240	192
250	—	—	—	—	—	—	604	403	302	242
300	—	—	—	—	—	—	722	482	361	289
350	—	—	—	—	—	—	828	560	414	336
400	—	—	—	—	—	—	954	636	477	382
450	—	—	—	—	—	—	1030	—	515	412
500	—	—	—	—	—	—	1180	786	590	472

Ampacities of insulated conductors acc. UL 508A, Table 28.1

Wire size		75°C (167°C)	
AWG	mm^2	Copper	Aluminum
14	2.1	15	—
12	3.3	20	15
10	5.3	30	25
8	8.4	50	40
6	13.3	65	50
4	21.2	85	65
3	26.7	100	75
2	33.6	115	90
1	42.4	130	100
1/0	53.5	150	120
2/0	67.4	175	135
3/0	85.0	200	155
4/0	107.2	230	180

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