

Low-voltage power distribution and control systems > Switchgear >

Front access Magnum PXR low-voltage switchgear

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Product Description

Front Access Switchgear



**Magnum PXR Front-Accessible Switchgear
40.20-Inch (1021.0 mm) Deep Enclosure**

The front-accessible switchgear offering allows mounting against a wall, or in other tight locations, where a standard rear-accessible switchgear lineup would not normally fit.

Eaton’s Magnum PXR front-accessible switchgear combines the robustness of UL® 1558 low-voltage switchgear with the flexibility of UL 891 switchboard design. The three divisions of rear-accessible switchgear are redistributed into two vertical sections, with the breaker and the bus in one half and cable and bus in the other half on the right-hand side. Both sections can be easily accessed by operators and maintenance personnel from the front of the switchgear.

Product Offering

- UL 1558
- UL 891
- 2000–6000 A bus
- 800–6000 A breakers
- 100 and 150 kA bus bracing
- 600 Vac class
- NEMA® 1 indoor (corner section available for layout flexibility)
- NEMA 3R outdoor, both aisle and aisleless enclosures

Application Description

- Commercial—Office buildings, high rise and convention centers
- Industrial—Automotive, petro-chemical, pharmaceutical, pulp and paper, utility and data centers
- Institutional—Universities and hospitals
- Government—Water treatment, federal buildings and municipalities
- Critical Power OEMs—Generator and UPS manufacturers

Features

- Standard 40.20-inch (1021.0 mm) switchgear depth
- Up to 4-high Magnum circuit breaker with Power Xpert Release trip units arrangement
- Breaker sections are 18.00 (457.2), 22.00 (558.8), 24.00 (609.6), 30.00 (762.0) or 44.00 (1117.6) inches (mm) wide depending on breaker type and frame sizes
- Cable compartments are 18.00 (457.2), 22.00 (558.8), 24.00 (609.6), 30.00 (762.0) or 44.00 (1117.6) inches (mm) wide depending on cable or conduit sizes
- Substation arrangement, with close coupling to dry-type or liquid-filled transformers, where required
- Can be close-coupled to traditional rear-access switchgear

Ratings

Table 20.6-1. Voltage Ratings (AC)

System Voltage	Maximum Voltage
208/240	254
480	508
600	635

Table 20.6-2. Available Bus Ratings

Cross Bus Ampacity	Bus Bracing kA
2000 3200 4000	100, 150
5000 6000 8000 10,000	100, 150

Overview

Eaton's Magnum PXR switchgear is backed by 70 years of power circuit breaker and switchgear development that have set the industry standards for quality, reliability, maintain-ability and extended operating life, when it comes to protecting and monitoring low-voltage electrical distribution systems. Magnum PXR switchgear is designed to meet the changing needs of our customers by providing:

- Lower installation and maintenance costs
- Higher interrupting ratings and withstand ratings
- Better coordination capability
- Increased tripping sensitivity
- Enhanced safety measures
- Higher quality, reliability and maintainability
- Communications and power quality monitoring and measuring capabilities
- Flexible layouts that maximize use of capital by minimizing equipment footprint

Magnum PXR switchgear can meet the needs of general applications, service entrances, harsh environments, multiple source transfers, special grounding systems and many others.

With a modern design, Magnum PXR metal-enclosed low-voltage switchgear and power circuit breakers provide:

- 100% rated, fully selective protection
- Power Xpert Release (PXR) digital trip units
- Two-step stored-energy breaker closing
- Standard 100 kA short-circuit bus bracing
- Optional 150 kA short-circuit bus bracing
- Optional metal barriers to isolate the cable compartment from the bus compartment
- Both indoor and outdoor aisle and aisleless enclosures
- Full range of safety solutions dealing with arc flash hazard and operator error
- Using a PC or laptop with the Power Xpert Protection Manager (PXPM) software, allows operators to do secondary injection testing without a bulky external test kit

Many other features for coordinated, safe, convenient, trouble-free, and economical control and protection of low-voltage distribution systems are also provided.

Magnum PXR breakers are designed to:

- ANSI Standards C37.13, C37.16, C37.17, C37.50
- UL 1066

Magnum PXR switchgear conforms to the following standards:

- CSA® C22.2, No. 31-10
- ANSI C37.20.1
- ANSI C37.51
- UL Standard 1558 and UL Standard 891
- American Bureau of Shipping (ABS)
- Built in an ISO® certified facility

Maximum ratings for Magnum PXR switchgear are 600 Vac, 10,000 A continuous cross bus and 100 kA short-circuit capacity.

Seismic Qualification



Refer to www.eaton.com/seismic for information on seismic qualification for this and other Eaton products.

Structure Features

Standard finish: Gray paint finish (ANSI 61) using a modern, completely automated and continuously monitored electrostatic powder coating. This continually monitored system includes spray de-grease and clean, spray rinse, iron phosphate spray coating spray rinse, non-chemical seal, oven drying, electrostatic powder spray paint coating and oven curing.

Integral base: The ruggedly formed base greatly increases the rigidity of the structure, reduces the possibility of damage during the installation of the equipment, and is suitable for rolling, jacking and handling. A lifting angle is permanently welded into the bus compartment structure for increased strength. The bottom frame structure members are indented to allow the insertion of a pry bar.

Heavy-duty door hinges: Each breaker door is mounted with hinge pins. Removal of the door is easily accomplished by just lifting the hinge pin. This allows easy access to the breaker internal compartment for inspection and maintenance.

Through-the-door design: The following functions may be performed without the need to open the circuit breaker door—lever the breaker between positions, operate manual charging system and view the spring charge status flag, close and open breaker, view and adjust trip unit and read the breaker rating nameplate.



Through-the-Door Design

Cassette design: The breaker cassette supports the breaker in the cell, as well as on the movable extension rails when the breaker is placed into or removed from the cell. The extension rails allow the breaker to be drawn out without having to de-energize the entire switchgear lineup.

Accessibility: When the door is open or removed, each breaker compartment provides front access to isolated, vertical wireways, primary disconnects, cell current transformers and other breaker compartment accessories for ease of field wiring and troubleshooting field connections.

Four-position drawout: Breakers can be in connected, test, disconnected or removed position. The breaker can be moved between the connected, test and disconnected positions while the compartment door is closed.

Closing spring automatic discharge: Mechanical interlocking automatically discharges the closing springs when the breaker is removed from its compartment.

Optional safety shutters: Positive acting safety shutters that isolate the breaker connections to the main bus when the breaker is withdrawn from the cell is an option offered for additional safety beyond our standard design. They reduce the potential of accidental contact with live bus. Insulating covers (“boots”) are furnished on live main stationary disconnecting contacts in compartments equipped for future breakers.

Breaker inspection: When withdrawn on the rails, breaker is completely accessible for visual inspection; tilting is not necessary. The rails are permanent parts of every breaker compartment.

Interference interlocks: Supplied on breakers and in compartments where the compartments are of the same physical size. Interference interlocks ensure an incorrect breaker cannot be inserted.

Optional key interlock (switchgear mounted): This mechanism holds the breaker cell mechanically trip-free to prevent electrical or manual closing. Breaker can be stored in compartment, and completely removed for maintenance or for use as a spare without disturbing the interlock. Modification of the breaker is not required.

Breaker door interlocking: Added safety feature to prevent unintentional access to behind the circuit breaker door while the switchgear is in the CONNECTED position. The area behind the breaker door is still accessible when in the TEST position.

Bus Features

Buses and connections: Vertical and cross bus ratings in Magnum PXR switchgear are based on a UL and ANSI standard temperature rise of 65 °C above a maximum ambient air temperature of 40 °C.

Bus ampacities: Vertical and main bus ratings in Magnum PXR switchgear are 2000, 3200, 4000 and 5000 A. In addition, a 6000 main bus rating is available for both indoor and outdoor, while 8000 and 10,000 A main bus rating is available for indoor only. Vertical section bus is sized per main cross bus maximum rating or by ANSI C37.20.1 to a maximum of 5000 A.

Bus bracing: Standard bracing is 100 kA. The “U” shaped bar is the heart of the Magnum PXR switchgear vertical bus. This configuration provides a much higher mechanical strength. To further demonstrate the strength and rigidity of this bus system, it has been verified through testing to withstand 85 kA short-circuit for a full 60 cycles.

Silver and tin plating: Bolted, silver-plated copper bus is standard. The plating is over the entire length of the bar, not just at the joints. Optional tin-plated copper bus is available.

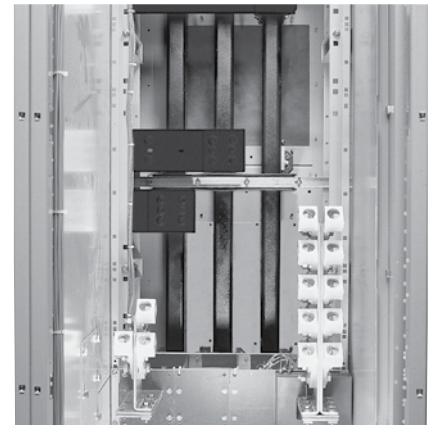
Bus joints: All joints are bolted and secured with Belleville-type spring washers for maximum joint integrity. These washers reduce the potential of joint hardware loosening during the change of joint temperature associated with variations of the loads. Maintenance-free hardware is also provided.

Full neutral: For four-wire applications, the neutral bus is rated 100% of main bus rating as standard.

Ground: A ground bus is furnished the full length of the switchgear assembly and is fitted with terminals for purchaser’s connections.

Glass reinforced polyester and standoff insulation system: Glass reinforced polyester has been used on both low and medium voltage switchgear for decades. By combining this industry-proven material with insulation, a total system providing exceptional mechanical and dielectric withstand strength, as well as high resistance to heat, flame and moisture, is produced. Substantial testing to demonstrate accelerated effects of heating and cooling on the mechanical and dielectric properties of this system prove it to provide superior performance for decades of trouble-free operation.

Optional epoxy bus coating: For applications requiring additional bus protection in harsh environments, Magnum PXR switchgear is designed for the addition of optional conductor insulation covering, in addition to providing full UL air clearance without insulation. This material is applied during the assembly of the bus, and covers all vertical and horizontal phase bus bars. Removable boots provide access to section-to-section bus joints for inspection and maintenance purposes.



Optional Insulated Bus

Barriers: Optional grounded metal barriers isolate the main bus and connections from the cable compartment providing added safety to the workers while reducing the potential of objects falling into the bus compartment. In addition, vertical barriers between cable sections can be added to reduce potential hazards. Barriers are removable to give access to the bus compartment for inspection and maintenance. Barriers can be either solid metal or vented for ease of infrared scanning.



Optional Bus Compartment and Vertical Section Barriers

Wiring Features

Cable compartment: The cable compartment gives ample room for terminating the power cables. Removable top roof sheets allow for easy conduit hub installation. The floor of the cable compartment is open to allow cable entry from underground duct banks. Optional floor plates are available.

In addition to cable, Pow-R-Way® busway and nonsegregated bus duct can be terminated in the compartment.

Lug pad: The lugs are located on the breaker run-backs to accommodate lug orientations at a 45° angle to reduce the bending radius of the cable needed for making the connections, thus reducing installation and maintenance time. Mechanical setscrew type lugs are standard. Optional NEMA two-hole compression lugs are available as an option.

Control wireway: An isolated vertical wireway is provided for routing of factory and field wiring in each switchgear section. Breaker secondary terminal blocks are mounted as standard above each circuit breaker. The terminal blocks are rated 30 A, and will accept bare wire, ring or spade terminals for wire size ranges of #22–#10. Extruded loops are punched in side sheets of the vertical wireway to allow securing of customer control wiring without the use of adhesive wire anchors.

Control circuits may be wired in all cells without removing the circuit breaker. In addition, power circuits may be connected in the rear of the switchgear at the same time control circuits are being wired in the front of the switchgear.

Control wire: Standard wire is Type SIS insulated stranded copper, extra flexible No. 14 AWG minimum. Type VW-1 wire is available.

Control wire marking: Each wire is imprinted with ink cured under ultraviolet light for durability and for easy identification by the user. The enhanced solvent resistance and durability of the aerospace grade UV cure ink has been tested for severe environments. The imprinting is made every 3.00 inches (76.2 mm) along the length of the wire to make field troubleshooting easier. The point of origin, wire designation and point of destination are imprinted in the following format: <origin zone/wire name/destination zone>. Each device has a uniquely designated zone. “<” indicates the direction of the wire origination and “>” indicates the direction of the wire destination.

As an option, wire name marking can be made using sleeve type or heat shrink sleeve type.



Control Wire Marking

Uni-connector secondary terminal block: Adds connections and serves as rejection feature for Magnum DS breakers to prevent incorrect installations with 84 connections in total on a standard and double-wide frame, and 72 connections on a narrow frame. The customer's secondary terminal connections are located at the front of the structure behind a separate door providing access to these connections without the need to open the breaker compartment door.

Short-circuiting terminal blocks: One provided for each set of instrumentation or relaying application current transformers.

Shipping split connection: At each shipping split, the control connections are made with plug-in terminal blocks rated 600 V, 30 A. The terminal blocks mechanically interlock without removing the line or load connections. This method of making the shipping split control connections increases the speed of installation and reduces the potential of incorrect connections.

Instrumentation/Metering Features

Flexibility: Magnum PXR switchgear allows for a variety of metering options.

See <https://www.eaton.com/content/dam/eaton/products/low-voltage-power-distribution-controls-systems/power-energy-meters/metering-devices-protective-relays-software-and-connectivity-v3-t9-ca08100004e.pdf> for Metering and Power Management products.

- Analog switchboard type meters such as ammeters and voltmeters
- Electronic power metering such as the Power Xpert Meter 4000/6000/8000 series and Power Xpert Meter 1000/3000 series
- Instrument compartments—white interior panels for ease of visibility

Voltage transformers: Voltage transformers are rated 10 kV BIL, and are protected by both primary and secondary fuses. The primary fuses are of the current limiting type.

Current transformers: Current transformers for metering and instrumentation are mounted in the breaker compartments and are front accessible. Secondary wiring between the current transformer and the standard shorting terminal block is color-coded for ease of identification. Bus mounted CTs are available for metering and relaying.

Control power transformers: Control transformers are provided when required for AC control of circuit breakers, space heaters and/or transformer fans. Like voltage transformers, they are protected by current limiting primary fuses. Non-current limiting fuses are used on the secondary side to protect branch circuits.

Instrumentation—secondary terminal compartment door: Devices, such as control pushbuttons, indicating lights, switches and analog meters can be mounted on these panels, within space limitations.



Devices Mounted on Secondary Terminal Compartment Door

Instrument compartment door: Devices, such as electronic power metering and analog switchboard type meters that do not fit on the secondary terminal compartment door, are mounted on the instrument compartment door or on a panel of a blank cell.

General Description

Accessories and Options

Switchgear accessories: Standard accessories furnished with each Magnum PXR switchgear assembly include:

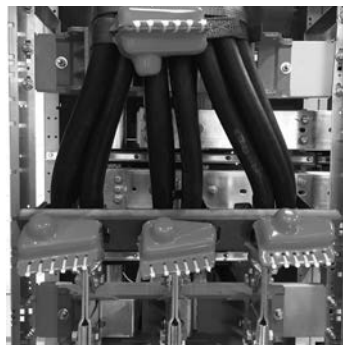
- One breaker racking tool
- Insulating covers or “boots” furnished on live main stationary disconnecting contacts in compartments equipped for future breakers
- Removable cover to block opening in the door when the breaker is temporarily removed from its compartment

Optional Accessories

- Traveling type circuit breaker lifter, rail-mounted on top of switchgear
- Floor-running portable circuit breaker lifter and transfer truck with manual lifting mechanism. This requires approximately 84.00 inches (2133.6 mm) deep front aisle space
- Test cabinet for electrically operated breakers, with pushbuttons, control cable and receptacle, for separate mounting
- Optional space heaters to be placed in the bottom of the breaker, cable and bus compartments. Space heaters are provided as standard in outdoor gear to reduce condensation
- Remote racking device (MRR1000) for both breaker racking and operation (open/close) from a safe distance. Mounts to any existing Magnum PXR breaker. Uses standard 120 V, 15 A, single-phase, 60 Hz supply, available from any outlet



Magnum Shutter Module



Cable Lashing Device



Optional Switchgear Mounted Lifter



MRR1000 Remote Racking Device

Enhanced Switchgear Options

- Infrared scanning windows for bus thermal scans
- Maintenance-free (Torque-&-Forget) bus hardware
- Lug booting that provides additional protection against accidental contact to live parts in the cable compartment
- Grounding balls and covers for protecting maintenance personnel downstream of switchgear feeder breakers
- Pendant for remote open and close of electrically operated breakers
- Thermal monitoring as 24/7 solution over the traditional IR window



Grounding Balls and Covers



Remote Control Pendant

Circuit Breakers

Eaton's type MPS and MPN power circuit breakers constitute a complete, modern and rugged line of low-voltage power circuit breakers using Eaton's DE-ION® principle of arc extinction. The breaker family is distinguished by its similarity of appearance and operation frame to frame. All frame sizes are either manually or electrically operated. Refer to www.eaton.com/CAG for detailed information on Magnum circuit breakers with Power Xpert Release trip units.

Breaker Features

Four Physical Frame Sizes

Narrow, standard, double narrow and double to promote breaker application in compact modular enclosures and to improve enclosure density.

Contacts

Magnum circuit breakers with PXR trip units have silver tungsten moving contacts and silver graphite stationary contacts. The contacts provide a long-wearing, low-resistance joint. The contacts are protected from arcing damage even after repeated interruptions by the "heel-toe" action, which causes the integral arcing contacts to mate before the main contacts part. The arcing contacts then part last, striking the arc away from the main contacts.

The main contacts are of the butt type and are composed of multiple fingers to give many points of contact without alignment being critical.



*Magnum circuit breaker with PXR contacts
(arc chutes removed)*

Stored-Energy Mechanism

A cam-type closing mechanism closes the breaker. It receives its energy from a spring that can be charged by a manual handle on the front of the breaker or by a universal electric motor.

Release of the stored energy is accomplished by manually depressing a button on the front of the breaker or electrically energizing a releasing solenoid.

Arc Chute

There are three basic means of extinguishing an arc: lengthening the arc path; cooling by gas blast or contraction; deionizing or physically removing the conduction particles from the arc path.

The DE-ION principle is incorporated in all Magnum circuit breakers with PXR. This makes faster arc extinguishing possible for a given contact travel and ensures positive interruption and minimum contact burning.

Levering Mechanism

The worm gear levering mechanism is self-contained on the breaker drawout element and engages slots in the breaker compartment. A standard 3/8-inch (10 mm) drive set is used to lever the breaker between the connected, test and disconnected positions.

Mechanical interlocking is arranged so that levering cannot be accomplished unless the breaker is in the opened position.

Protection During Levering Operation

When levering the breaker between the connected, test and disconnected positions, the operator is protected from contact with live parts by the breaker door.

True two-step stored energy closing:

Refers to the sequence required to charge and close the breaker.

1. The breaker closing springs are charged either through the manual-charging handle or by the optional charging motor. The breaker is mechanically interlocked to prevent closing of the breaker until the closing springs are fully charged.
2. With the closing springs fully charged, the breaker can then be closed by pressing the manual close pushbutton on the breaker, or by the optional spring release coil through a remote electrical signal.

This means that the energy required to open the breaker is always restored following a closing operation.

“Stored energy” is energy held in waiting, ready to open or close the breaker within five cycles or less. The unique cam and spring design provides necessary energy for a single close-open sequence as well as the energy for multiple charge-close operations such as this possible sequence: charge-close-recharge-open-close-open.

The closing springs are interlocked with the breaker racking mechanism to ensure the closing springs are discharged before the breaker can be removed from the compartment.

Provisions for padlocking: All breakers include provision for padlocking open to prevent electrical or manual closing. This padlocking can secure the breaker in the connected, test or disconnected position by preventing levering of the breaker.

Ease of inspection and maintenance:

Magnum circuit breakers with PXR are designed for maximum accessibility and the utmost ease of inspection and maintenance.

Manually operated breakers: Manually operated breakers are equipped with a manual charging handle to charge the closing springs. Manual closing and tripping pushbuttons are used to operate the breaker. Remote closing and tripping can be accomplished by installing optional electric spring release and shunt trip coils. The breaker closing springs must be charged manually, then remote closing and tripping signals can be sent to the breaker.

Electrically operated breakers: Electrically operated breakers are equipped with a spring charging motor and electrically operated spring release and shunt trip coils. The breaker manual charging handle can be used to charge the closing springs when power is not available to the charging motor.

Optional Breaker Accessories

- **Shunt trip device (ST):** Provides for remote electrically controlled breaker opening when energized by a rated voltage input
- **Spring charge motor (MOT):** Charges the breaker closing springs automatically, facilitating remote or local closing. The motor assembly includes its own cut-off switch that changes state at the end of the charging cycle. This contact can be wired out for external indication
- **Spring release device (SR):** Provides for remote electrically controlled breaker closing when its coils are energized by a rated voltage input
- **Undervoltage release (UVR):** Trips the breaker when an existing voltage signal is lost or falls below an established threshold

- **Auxiliary switch:** Up to 6a/6b auxiliary individual dedicated Form C contacts are available for customer use to indicate if the breaker is in the OPEN or CLOSE position
- **Mechanical trip indicator flag:** The red trip indicator flag pops out to provide local visual indication when the Power Xpert Release trip unit acts to trip the breaker on an overcurrent condition. Available in two options: an interlocked version that mechanically locks out the breaker until the indicator is manually reset and a non-interlocked version for indication only
- **Overcurrent trip switch (OTS/bell alarm):** Provides two Form C contacts that change state when the PXR trip unit acts to trip the breaker. The contacts are available for external indication or customer use and are manually reset by the mechanical trip indicator
- **Padlockable pushbutton cover:** Permits padlocking hinged cover plates to block access to the PUSH ON and PUSH OFF buttons on the breaker faceplate
- **Mechanical operations counter:** Records mechanical operations of the breaker over its installed life
- **Latch check switch:** Provides one Form C contact that changes state when the breaker is ready to close. Can be wired to the spring release device for fast transfer applications or wired for external ready-to-close indication

Magnum PXR Switchgear— Trip Unit Details

Power Xpert Release trip unit. Eaton's PXR trip units feature a dependent curve that is depicted in the nameplate by a blue shaded area of the trip curve. The dependent curve affords better protection flexibility. Additionally, all of the trip units have, as standard, thermal memory, 50/60 Hz operation and thermal self-protection at 90 °C.

PXR integral microprocessor-based breaker overcurrent trip systems:

Provide maximum reliability with true rms sensing as standard, gives excellent repeatability and requires minimum maintenance. No external control source is required for its protective functions.



PXR 20

Trip functions: PXR trip units provide the maximum flexibility and are available in the following configurations dependent on the PXR module chosen. For PXR 20, LSI and LSI_G, and for PXR 25, LSI and LSI_G. Please note that with the flexibility of the PXR trip units, the A letter is no longer needed as the ground fault functionality is completely programmable. In each case, either the short delay or instantaneous (not both) functions may be defeated. This reduces the need for spare breaker inventories and provides maximum usage of interchangeable breakers.

PXR 20: Enables the user as many as nine phase and ground current protection settings for maximum flexibility in trip-curve shaping and multi-unit coordination, and adds zone selective interlocking. Unit is programmable via dials on the front of the unit, an LCD display with navigation buttons, and via micro-B USB and PXP software. Provides 0.5% accuracy current metering, ability to enable/disable ground fault, along with the Arcflash Reduction Maintenance System™.

PXR 25: Provides programmability for more sophisticated distribution systems. Adds 0.5% accuracy voltage metering along with the 0.5% current metering.

- Increased protection and coordination capabilities
- Systems monitoring information including power factor, voltage current, harmonic distortion values, and waveform capture with an LCD display as well as downloadable with a micro-B USB connection and Power Xpert Protection Manager installed on a laptop
- Multiple programmable contacts for customer use (quantity changes based on double/standard versus narrow frames)
- Time stamping of trip events for improved troubleshooting and diagnostics
- Accuracy of 0.5% on metered values and 1% on energy and power
- Systems diagnostic information
- Breaker health menu
- Additional protection functions:
 - Undervoltage/overvoltage
 - Underfrequency/overfrequency
 - Voltage unbalance
 - Reverse power
- Added communications capabilities for the breaker including native Modbus RTU, PROFIBUS and others through CAMS. Please note these options are not currently available in low-voltage switchgear

Zone selective interlocking: The PXR zone selective interlocking (ZSI) capability provides positive system coordination without time delays. ZSI allows the breaker closest to the fault to trip without any preset time delay. The breaker closest to the fault trips first, while the remainder of the distribution system remains online, thus avoiding unnecessary and costly downtime.

Devices

Arcflash Reduction Maintenance System

The Arcflash Reduction Maintenance System Maintenance Mode function of the PXR trip units can reduce arc flash incident energy that is generated on a fault condition. This is accomplished by a separate trip circuit that, when armed, provides a fast-acting response to the fault. This is separate from the normal system protection setting of instantaneous. The PXR Arcflash Reduction Maintenance System Maintenance Mode operates at the same time as the normal LSIG protection. For most fault conditions as shown in the **Figure 20.6-1** time-current curve, the Arcflash Reduction Maintenance System protection will override the LSI protection and the normal LSIG protection provides an added backup function. Eaton's Arcflash Reduction Maintenance System employs a separate, dedicated trip circuit that eliminates trip unit's microprocessor latencies, resulting in clearing times that are faster than standard instantaneous tripping. This provides superior arc flash reduction compared to competitors' systems that simply lower the standard instantaneous pickup set point or employ ZSI tripping.

There are three ways to arm the Maintenance Mode setting. One method is locally at the trip unit front panel. Both the PXR 20 and the PXR 25 have a two-position switch on the front of the trip unit for the Maintenance Mode. Turning the switch to the ON position will locally arm the function. The setting for the level of reduction is in the SYSTEM submenu of programmable settings (PGM SET).

For the second method, a remote switch or external relay contact wired through the breaker secondary terminals can remotely arm the Maintenance Mode protection function. A high-quality gold-plated or palladium contact is required in this application.

The third method is via a communication device. The trip unit display will show a confirmation screen that verifies the Maintenance Mode function has been set. A Dashboard or Dashboard Lite display interface module can be used as one of the communication methods to arm the protection function remotely from a safe distance.

The Arcflash Reduction Maintenance System setting has five unique settings (1.5, 2.5, 4.0, 6.0, 10.0 x I_n) for the pickup of the reduction setting. This setting level can be used to prevent inrush currents or load surges from triggering the Maintenance Mode function. The PXR trip units are now able to go to a new lower setting of 1.5 X the frame rating I_n for the maximum reduction of arc flash energy. For all three arming methods, the PXR trip units provide a local indication as a blue LED ring around the ON/OFF switch to confirm the Maintenance Mode function is on or off. In addition, one of the three programmable relays in the frame module of the breaker can be set to indicate the status of the Maintenance Mode protection. This normally open relay contact allows the user to wire in an external stack light or annunciator for remote indication.

The Maintenance Mode function will provide fast tripping even when the regular Instantaneous is set to OFF. The instantaneous LED position is also used to indicate a trip initiated by the Maintenance Mode setting. The LCD display, if powered, will indicate the message Maintenance Mode Trip.



Maintenance Mode Setting

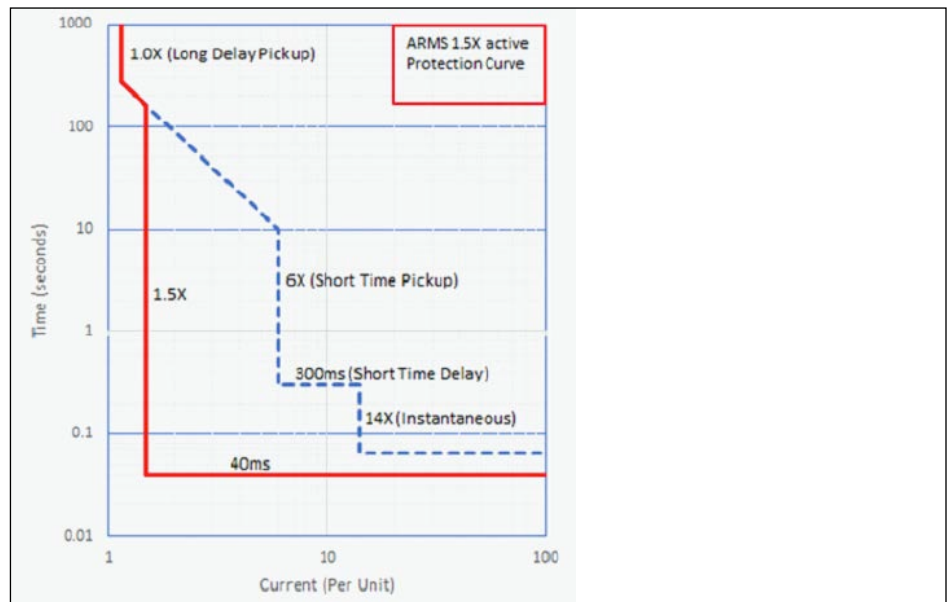


Figure 20.6-1. Arcflash Reduction Maintenance System Time-Current Curve

Table 20.6-3. Magnum PXR Switchgear Class UL 1066 Low-Voltage Power Circuit Breakers

Frame Amperes	Breaker Type	Frame Type	rms Symmetrical Current Ratings kA 50/60 Hz ①			Short-Time Withstand Rating	Fixed Internal Instantaneous Trip	Available Programmed I _n Rating for PXR Trip Units (Can be Field Adjusted for a Fee)
			Interrupting at 254 Vac	Interrupting at 508 Vac	Interrupting at 635 Vac			
800	MPN-408	Narrow	42	42	42	42	—	100, 200, 250, 300, 400, 600, 800
	MPN-608	Narrow	65	65	65	65	—	
	MPN-C08	Narrow	100	100	65	20	18 x I _n	
	MPS-408	Standard	42	42	42	42	—	
	MPS-608	Standard	65	65	65	65	—	
	MPS-C08	Standard	85	85	100	85	85	
1600	MPN-416	Narrow	42	42	42	42	—	100, 200, 250, 300, 400, 600, 800, 1000, 1200, 1600
	MPN-616	Narrow	65	65	65	65	—	
	MPN-C16	Narrow	100	100	65	65	18 x I _n	
	MPS-616	Standard	65	65	65	65	—	
	MPS-816	Standard	85	85	85	85	—	
	MPS-C16	Standard	100	100	100	85	85	
2000	MPN-620	Narrow	65	65	65	65	—	100, 200, 250, 300, 400, 600, 800, 1000, 1200, 1600, 2000
	MPS-620	Standard	65	65	65	65	—	
	MPS-820	Standard	85	85	85	85	—	
	MPS-C20	Standard	100	100	100	85	85	
3200	MPS-632	Standard	65	65	65	65	—	100, 200, 250, 300, 400, 600, 800, 1000, 1200, 1600, 2000, 2500, 3000, 3200
	MPS-832	Standard	85	85	85	85	—	
	MPS-C32	Standard	100	100	100	85	85	
4000	MPN-640	Double Narrow	65	65	65	65	—	2000, 2500, 3200, 4000
	MPN-840	Double Narrow	85	85	65	85	—	
	MPN-C40	Double Narrow	100	100	65	100	—	
	MPS-840	Double	85	85	85	85	—	
5000	MPS-C40	Double	100	100	100	100	—	2500, 3200, 4000, 5000
	MPS-850	Double	85	85	85	85	—	
6000	MPS-C60 ②	Double	100	100	100	100	—	3200, 4000, 5000, 6000

① Interrupting ratings shown based on breaker equipped with integral PXR trip unit. Interruption ratings for non-automatic breakers are equal to the published short-time withstand rating. These interruption ratings are based on the standard duty cycle consisting of an open operation, a 15-second interval and a close-open operation, in succession, with delayed tripping in case of short-delay devices. The standard duty cycle for short-time ratings consists of maintaining the rated current for two periods of 0.5 second each, with a 15-second interval of zero current between the two periods.

② Breaker applied in a tested fan cooled enclosure.

Metering Devices



Power Xpert Meter 1000



Power Xpert Meter 3000



Power Xpert Meter 4000/6000/8000

The Power Xpert 1000 Meters

The Power Xpert Meter 1000 series power and energy meters monitor the most critical aspects of an electrical distribution system. This premier metering instrument uses the latest in advanced technology to make it simple to use, powerful, scalable and highly flexible.

The Power Xpert Meter 1000 (PXM1000), 1100 (PXM1100), 1200 (PXM1200) and 1300 (PXM1300) deliver a cost-effective solution for energy and sub-metering applications. These three-phase meters provide high accuracy and advanced features in the standard 4-inch form factor and can be expanded with multiple modular I/O options.

Meter series benefits include:

- Utility billing accuracy that will help meet stringent customer specifications
- Ease of use in multiple applications
- Can be field expanded with multiple modular protocols:
 - I/O options (DI/DO, RO, AI/AO)
 - Communications options (8 GB, ModbusTCP/IP, BACnet/IP, COMTRADE, Dual RJ-45, EtherNet/IP, IPV6)

The Power Xpert 3000 Meter

The Power Xpert Meter 3000 (PXM3000) provides an extensive array of data, including power quality, energy and demand readings so you can manage energy utilization to help reduce peak demand charges and power factor penalties, and to identify excessive energy consumption.

Utilizing both a premier web interface with cloud storage and onboard data storage up to 4 GB, the PXM3000 allows you to keep your data at your fingertips to help reduce your overall energy usage and better manage your energy costs.

Key features include:

- Rich web interface
- Multiple protocols including Modbus RTU/TCP and BACnet/IP
- Onboard historical data charts
- Onboard waveform display
- Optional digital/analog inputs and outputs
- Storage of up to three custom data logs

Power Xpert Meter 4000/6000/8000

The Power Xpert Meter 4000/6000/8000 series is an internet-enabled (including a built-in web server) power quality and energy meter with comprehensive power and energy measurement, and integrated quality analysis.

These meters allow you to use a standard web browser to surf the meter and visualize a waveform and analyze trends.

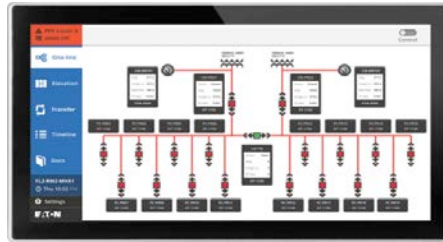
Meter series benefits include:

- Accurate detection of fast transients
- Early warning of impending problems
- At-a-glance view of power quality
- Reduces power monitoring cost
- Supports continuous, non-disruptive monitoring
- Accessible via the ethernet
- Uses industry-standard communication protocols

Communications



PXG900



Dashboard

Power Xpert Gateway 900

Ethernet communications available via Power Xpert Gateway PXG900.

- Modbus TCP connection to PXR 20 and PXR 25 trip units
- Basic web browser view
- Optional 12-inch display

Power Xpert Dashboard

- The Power Xpert Dashboard is an intelligent collection of views displayed on a single touchscreen from switchgear-mounted devices including meters, relays, trip units and transfer controls
- The Dashboard can be integral to the switchgear assembly or remotely mounted
- Detail information about each breaker is displayed
- Remote enabling of the Arcflash Reduction Maintenance System via communication as a standard
- Ability to configure/monitor alarms for various devices
- Remotely open/close circuit breakers through control mode
- Initiate a transfer scheme in a main-tie-main switchgear for uninterrupted power supply

Automatic Transfer



Programmable Logic Controller



ATC-900

Automatic transfer and intelligent control packages are as follows:

- Eaton ATC-900 controller
 - Automatic transfer for a two source lineup with no tie breaker
 - Additional option for a 7-inch screen available
- Eaton programmable logic controller (PLC) with Eaton touch screen
 - Automatic transfer for main-tie-main arrangement
 - Standard sequence provided with configurable options
 - Custom sequence of operations available
- Eaton's Power Systems Control (offered through Eaton Engineering Services & Systems)
 - Custom automatic transfers
 - On-site commissioning
 - Integration into existing networks

For information on automatic transfer and intelligent control solutions, visit:



High Resistance Grounding

General Description

Where continuity of service is a high priority, high-resistance grounding can add the safety of a grounded system while minimizing the risk of service interruptions due to grounds. The concept is a simple one: provide a path for ground current via a resistance that limits the current magnitude, and monitor to determine when an abnormal condition exists. This provides for maximum continuity of service, because no tripping occurs for the resistance limited ground fault.

The ground current path is provided at the point where the service begins, by placing resistance in the connection from system neutral to ground. Control equipment continuously measures ground current; a relay detects when the current exceeds a predetermined level. An alarm alerts building personnel that a ground exists. The system has built-in fault tracing means to assist in finding the source of the ground. An integral transformer provides control power from the primary source.



Integrated HRG

Standard Features

- Current sensing ground fault detection (1–5 A pickup/0.5–20 second delay)
- Ground current transformer (10/10 ratio)
- Control circuit disconnect switch (fused)
- Lockable door handle
- Ground current ammeter (0–10 A, 1% accuracy)
- Indicating lights:
 - Red (ground fault)
 - Green (normal)
 - White (pulse)
- Adjustable pulsing timer (0–10 seconds)
- Tapped resistors (1–5 A)
- Three-position selector switch (normal, pulse, test)
- Control switch for manual or automatic reset
- Ground fault contacts (1NO/1NC)
- Shorting terminal block for ground current transformer
- UL label
- Rated for use up to 200 kA fault current system
- Front accessible
- Nylon flag type wiremarkers
- Three “zig-zag” or “wye-broken delta” grounding transformers for systems without a neutral point

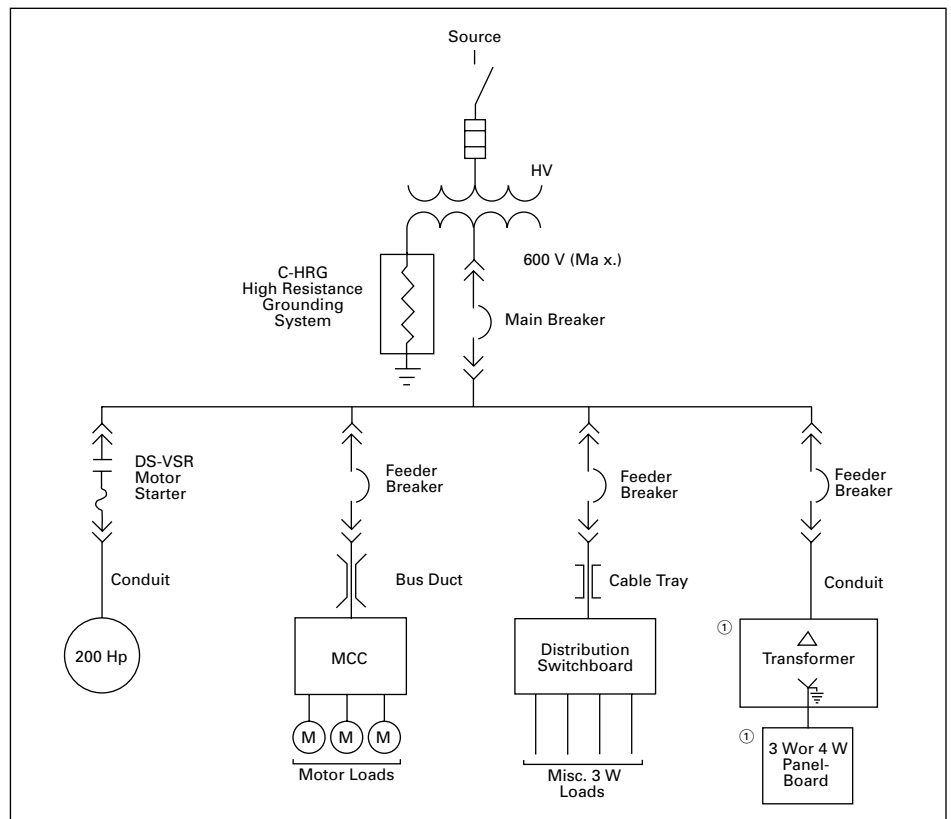


Figure 20.6-2. Typical Distribution System

① Phase-to-neutral loads require a delta-wye distribution transformer. The neutral on the secondary side of this transformer must be solidly grounded.

Surge Protection Devices



Integrated SPDs

Eaton integrates our industry-leading SPD Series surge protective devices into panelboard and switchboard assemblies. Lead length is kept to a minimum to maximize SPD performance. Integrated SPD units are UL listed and labeled to UL 1449 3rd Edition.

Key features include:

- Thermally protected metal oxide varistor (MOV) technology
- 20 kA nominal discharge current (I_n) rating (maximum rating assigned by UL)
- 50 through 400 kA surge current capacity ratings
- Three feature package options (basic, standard, and standard with surge counter)
- 200 kA short-circuit current rating (SCCR)
- 10-year warranty

The breadth of the SPD Series’ features, options and configurations ensures that the correct unit is available for all electrical applications, including service entrances, distribution switchboards, panelboards and point-of-use applications.

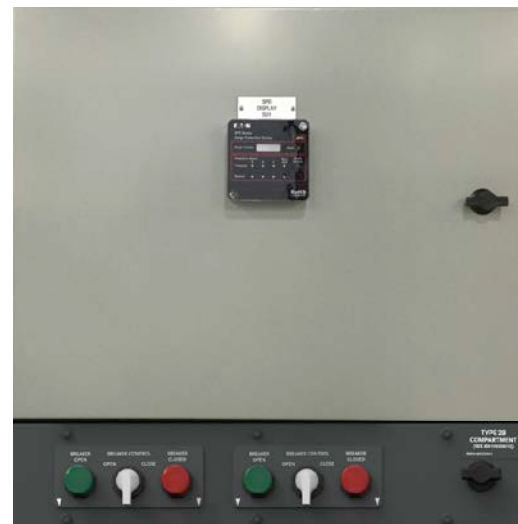
For complete SPD product description, application and ratings, visit www.eaton.com/spd.

Table 20.6-4. Side-By-Side Comparison of the SPD Series’ Available Feature Packages

Feature Package Comparison	Basic	Standard	Standard with Surge Counter
Surge protection using thermally protected MOV technology	■	■	
Dual-colored protection status indicators for each phase	■	■	
Dual-colored protection status indicators for the N-G protection mode	■	■	
Audible alarm with silence button		■	■
Form C relay contact		■	■
EMI/RFI filtering, providing up to 50 dB of noise attenuation from 10 kHz to 100 MHz		■	■
Surge counter with reset button			■

Power Xpert SPD

- The Power Xpert SPD is an advanced monitoring display to track and record surge events and remaining protection status on each phase
- Surge events are categorized as low, medium and high in accordance to the IEEE standard C62.41. These events are logged with time and date stamps
- The RJ45 ethernet port provides communication between the surge device and the LAN connection, ModbusTCP/IP or BACnet/IP protocols
- Ability to access the remote webpage through Power Xpert Gateway 900 or Power Xpert Dashboard
- Email alarm notifications are available when configured through Power Xpert Gateway 900 or Power Xpert Dashboard



Breaker Layouts

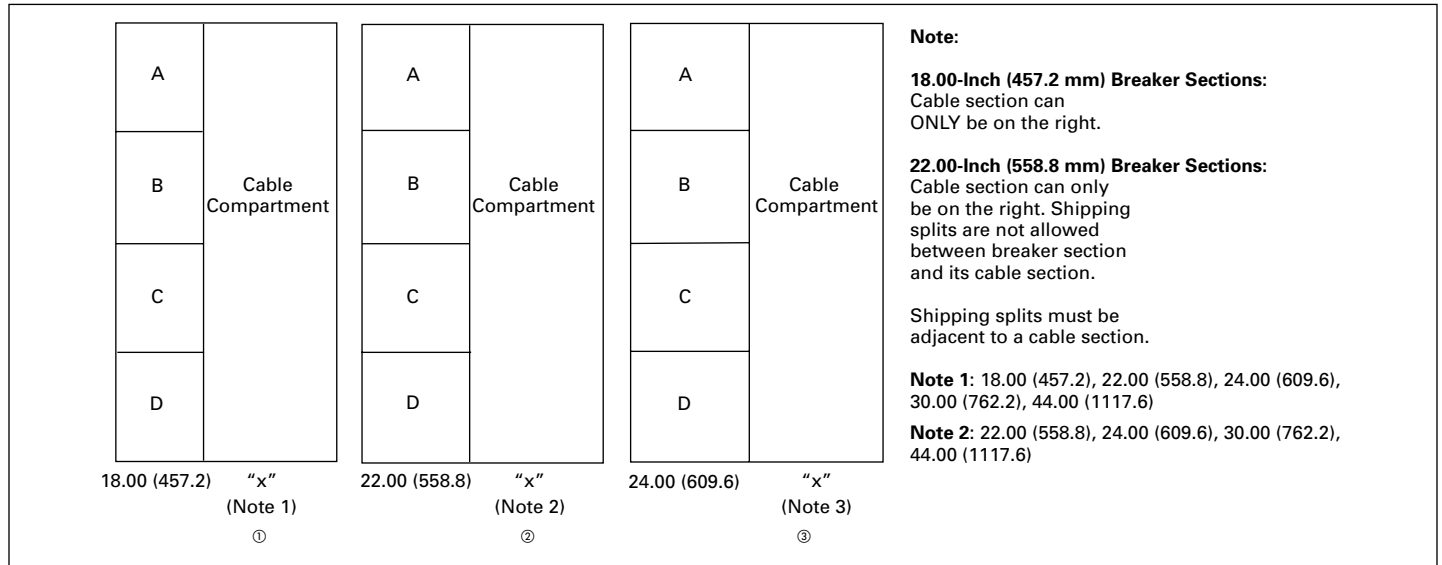


Figure 20.6-3. Front-Accessible Breaker Structures—Dimensions in Inches (mm)

① 18.00 (457.2), 22.00 (558.8), 24.00 (609.6), 30.00 (762.2), 44.00 (1117.6)

② 22.00 (558.8), 24.00 (609.6), 30.00 (762.2), 44.00 (1117.6)

③ 24.00 (609.6), 30.00 (762.2), 44.00 (1117.6)

④ See **Table 20.6-5** for information on cables and conduits.

Note: Cable section can ONLY be on the right. Shipping splits are not allowed between breaker section and its cable section. Shipping splits must be adjacent to a cable section. Section bus sized per main bus rating (maximum) or by ANSI C37.20.1.

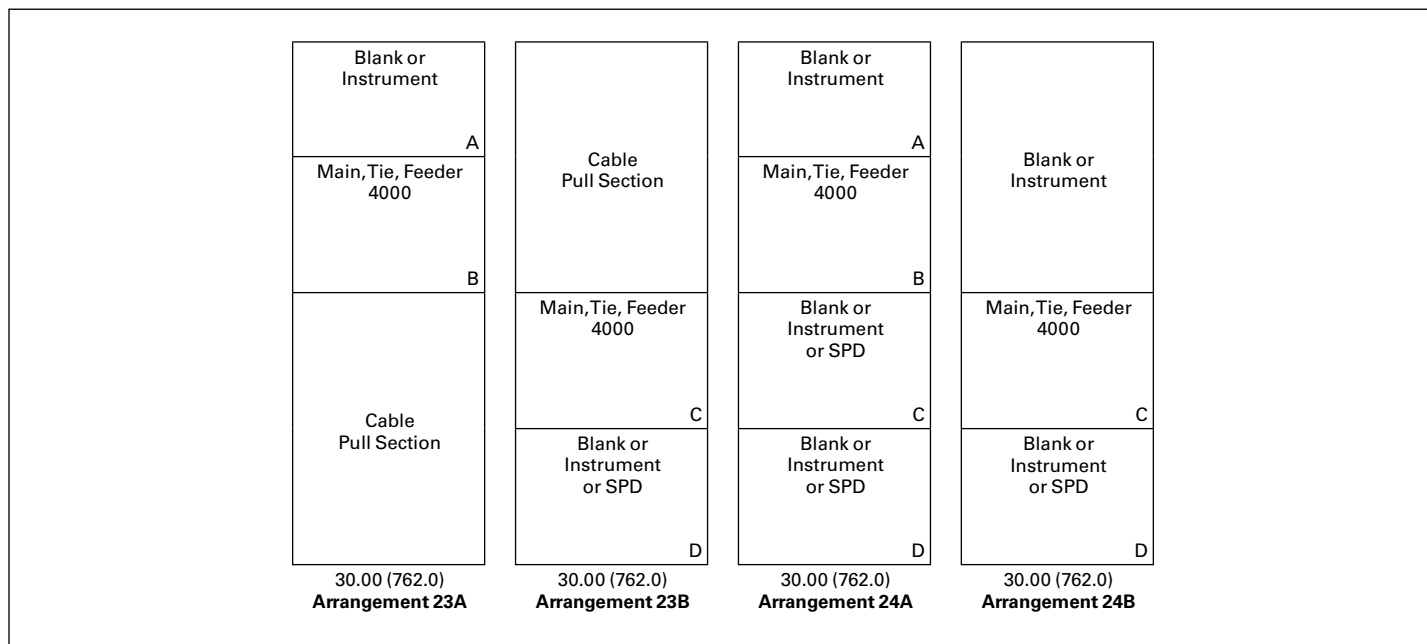


Figure 20.6-4. Typical Structure and Breaker Arrangements—4000 A, MPN Front Access Mains, Ties, Feeders and Miscellaneous—Dimensions in Inches (mm)
Note: Front access depth is 40 inches.

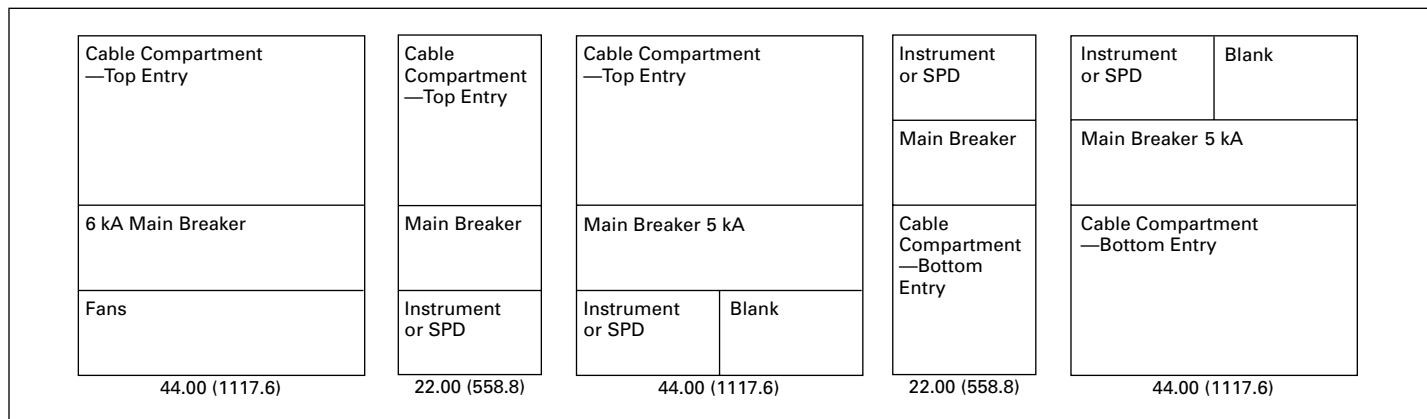


Figure 20.6-5. Combination Breaker/Cable Sections—Dimensions in Inches (mm)

Metering	Feeder MPN-608 800 A	Cable Compartment	Metering	Feeder MPN-608 800 A	Cable Compartment	Metering
Main MPS 632 3200 A	Feeder MPN-608 800 A		Tie MPS 632 3200 A	Feeder MPN-608 800 A		Main MPS 632 3200 A
Cable Compartment	Feeder MPN-608 800 A		Blank	Feeder MPN-608 800 A		Cable Compartment
	Feeder MPN-608 800 A		Blank	Feeder MPN-608 800 A		
22.00 (558.8)	18.00 (457.2)	18.00 (457.2)	22.00 (558.8)	18.00 (457.2)	22.00 (558.8)	22.00 (558.8)

Figure 20.6-6. Front-Accessible Standard and Narrow Breakers Main-Tie-Main Typical Layout—Dimensions in Inches (mm)

Structure Dimensions

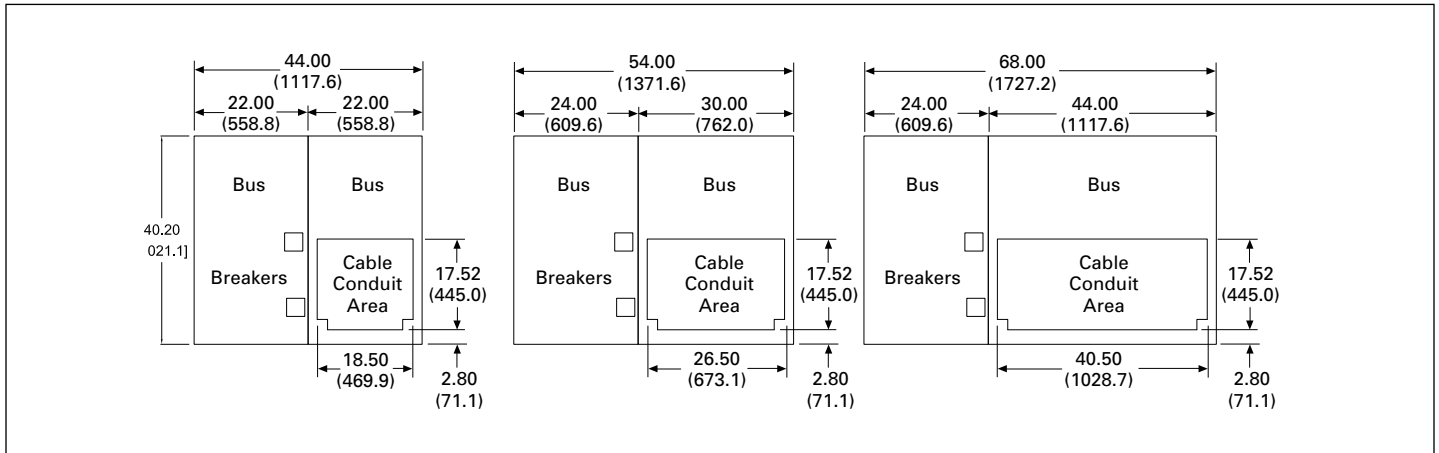


Figure 20.6-7. Floor Plans and Available Conduit Space—Front-Access Structures—Dimensions in Inches (mm)

Note: See Table 20.6-5 for further information on cable and conduit recommendations.

Table 20.6-5. Front-Access Structure Dimensions in Inches (mm)

Cable Compartment Structure Width	Recommended Number of Conduits	
	3.00 Inch (76.2 mm)	4.00 Inch (101.6 mm)
18.00 (457.2)	—	6
22.00 (558.8)	—	8
24.00 (609.6)	12	8
30.00 (762.0)	15	11
44.00 (1117.6)	22	17

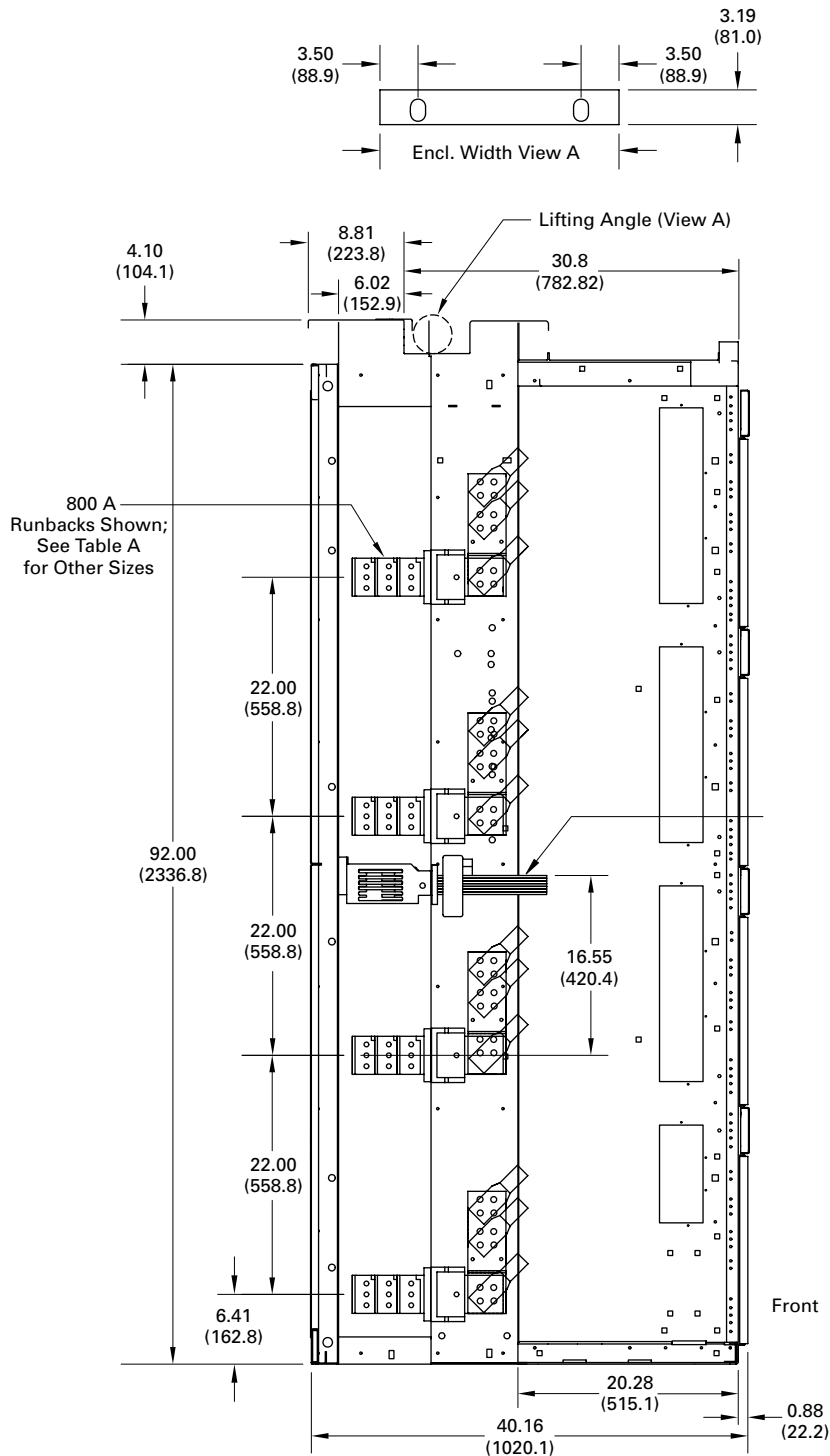


Table A. Bus Cross-Sections

Ampere Rating	800 A	1200/1600 A	2000 A
Runback Cross-Section	3.50 x 0.25	2.50 x 0.38	4.50 x 0.50

Figure 20.6-8. Front-Access Section View—Dimensions in Inches (mm)

Note: Top-mounted breaker lifting device available for bottom cable entry/exit only. For cables exiting the top of the switchgear, a floor-mounted lifter must be used.

Document References

Instruction manual IB01901001E for Eaton’s Magnum PXR front- and rear-access low-voltage switchgear, including installation, inspection, operation and testing.

Typical Breaker Schematics

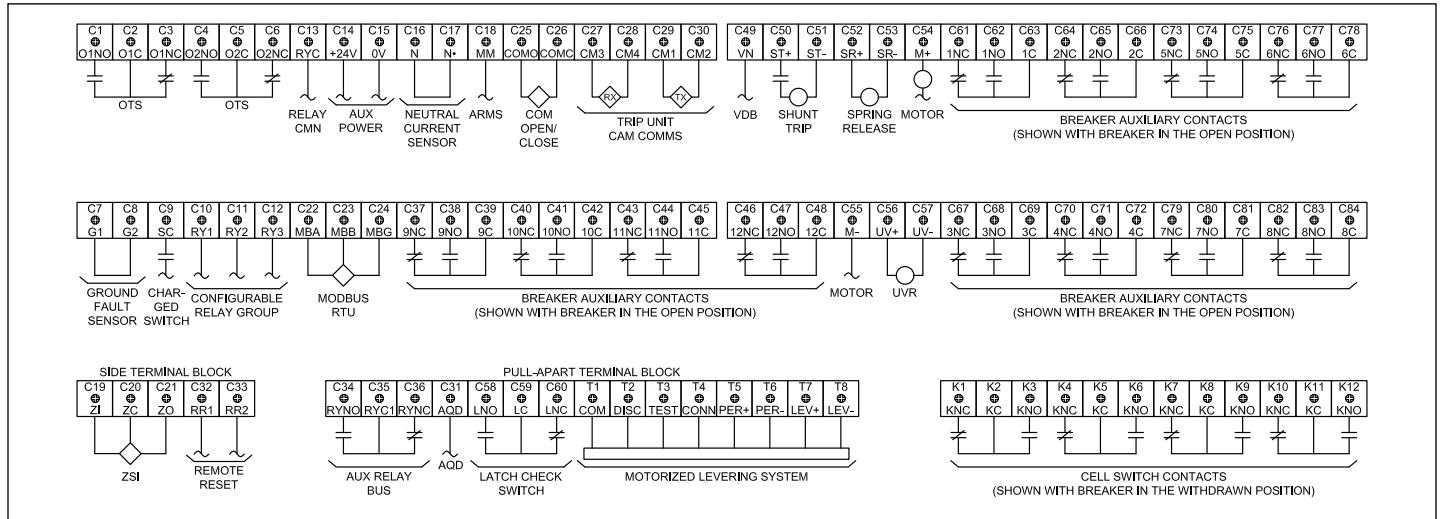


Figure 20.6-9. Typical Magnum PXR Switchgear Secondary Terminal Block Connection Diagram

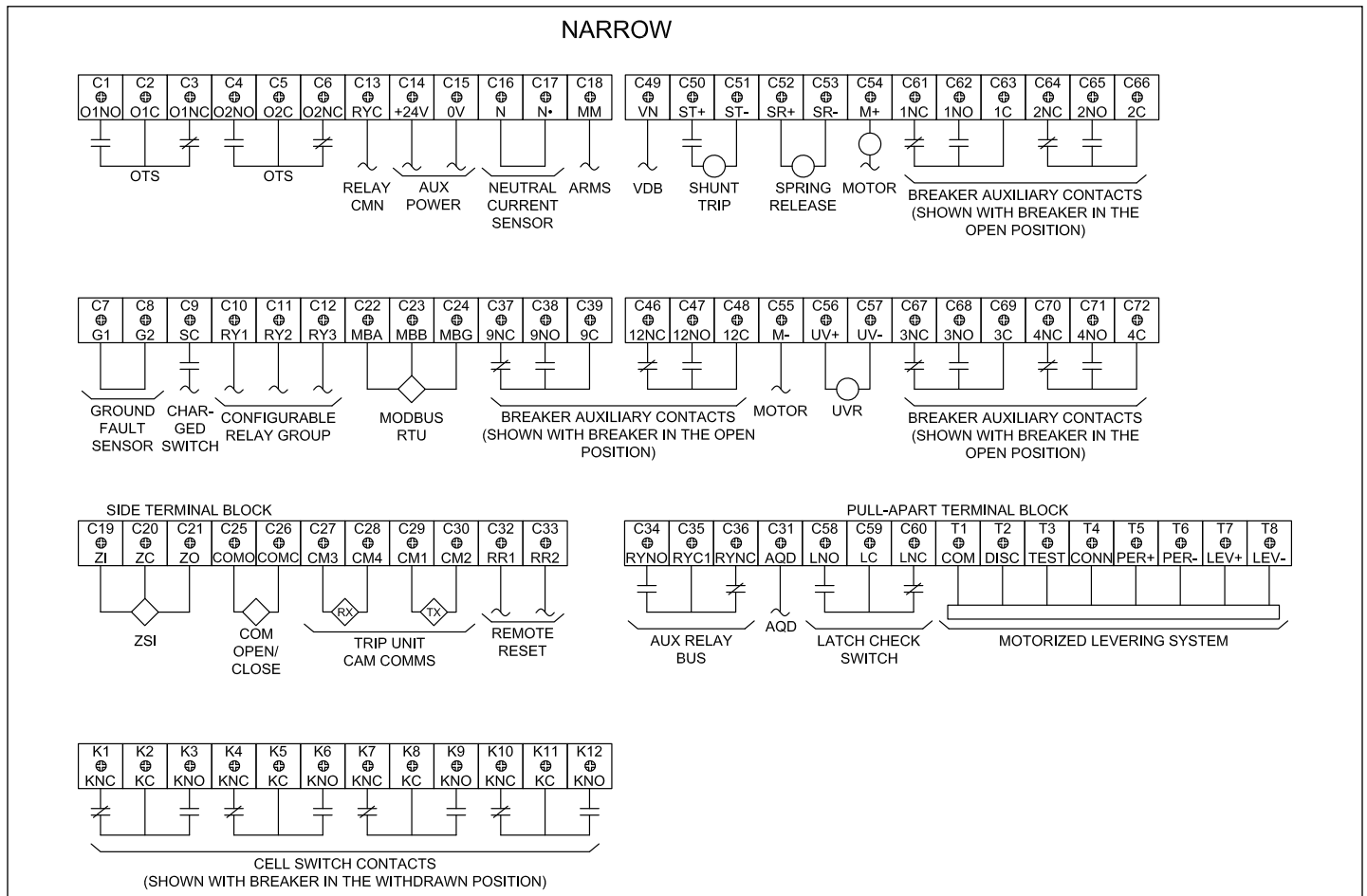


Figure 20.7-10. PXR Secondary Layout for Narrow Frame

Heat Loss

Table 20.6-6. Heat Loss Data ①

Estimated Heat Loss Per Breaker (Watts)

Breaker Frame	Drawout Mounting Only
800	150
1600	329
2000	374
3200	719
4000	749
5000	1000
6000	1440

Estimated Heat Loss Per Structure (Watts) ①

Loss is based on fully loaded vertical and cross bus rating in a structure as given below.

Rating	Vertical Bus	Cross Bus
2000	410	288
3200	1623	1163
4000	1097	1169
5000	1410	886
6000	2030	1265
8000	—	2240
10,000	—	3500

① For lower than maximum load currents, watt loss may be estimated by reducing the full load loss by the following:

$$W_L = (I_L / I_{FL})^2 W_{FL}$$

Where:

W_L = Load Watts

W_{FL} = Full Load Watts

I_L = Actual Load Current

I_{FL} = Full Load Current

Vertical section bus is sized per main cross bus maximum rating or by ANSI C37.20.1 to a maximum of 5000 A. (4000 A in 18.00-inch [457.2 mm] structure.)

Note: In addition to the available bus bracings shown in **Table 20.6-2**, the bus has been tested for short-circuit values of 85,000 A for a full 60 cycles.

Closing Times of Magnum Circuit Breakers with PXR

- 5 cycles or less

Opening Times—Dependent on Function Used

- Standard instantaneous: 60 ms+
- ARMS trip: 40 ms maximum
- Shunt trip: 50 ms maximum
- Trip signal from an Eaton Arc Flash Relay: ~67 ms

Weights

Center of Gravity

For seismic calculations, the following dimensions should be used to locate the center of gravity for indoor Magnum PXR switchgear.

Table 20.6-7. Center of Gravity Location

Dimensions in Inches (mm)		
Vertical	Left-to-Right	From the Front
60.00 (1524.0)	Center of lineup	26.00 (660.4)

Table 20.6-8. Magnum PXR Front Access Construction Switchgear Structure Approximate Weights (Less Breakers) ①

Width in Inches (mm)	Depth in Inches (mm)	Approximate Weight in Lb (kg)
Breaker Structure		
18.00, 22.00 and 24.00 (457.2, 558.8 and 609.6)	40.00 (1016.0)	1100 (500)
30.00 (762.0)	40.00 (1016.0)	1750 (795)
44.00 (1117.6)	40.00 (1016.0)	2200 (1000)

Cable Compartment

18.00, 22.00 and 24.00 (457.2, 558.8 and 609.6)	40.00 (1016.0)	800 (363)
30.00 (762.0)	40.00 (1016.0)	1550 (705)
44.00 (1117.6)	40.00 (1016.0)	1600 (727)

① See **Table 20.6-9** for breaker weights.

Table 20.6-9. Magnum PXR Circuit Breakers with PXR Weights

Breaker	Drawout in Lb (kg)
Narrow	
MPN-408	130 (59)
MPN-508	130 (59)
MPN-608	130 (59)
MPN-C08	145 (66)
MPN-416	130 (59)
MPN-516	130 (59)
MPN-616	130 (59)
MPN-C16	145 (66)
MPN-620	145 (66)
MPN-C20	145 (66)

Standard

MPS-408	130 (59)
MPS-608	130 (59)
MPS-808	145 (66)
MPS-C08	145 (66)
MPS-616	130 (59)
MPS-816	145 (66)
MPS-C16	145 (66)
MPS-620	145 (66)
MPS-820	145 (66)
MDS-C20	145 (66)
MPS-632	175 (79)
MPS-832	175 (79)
MPS-C32	175 (79)

Double Wide

MPN-640	310 (141)
MPN-840	310 (141)
MPN-C40	310 (141)
MPS-840	310 (141)
MPS-C40	310 (141)
MPS-850	310 (141)
MPS-C50	310 (141)
MPS-C60	310 (141)

Note: Impact weight equals 1.5 times breaker static weight. Three-pole frame weight given; four-pole frame weight equals 1.33 times more.

Service Conditions

Standards

Magnum circuit breakers with PXR meet or exceed all applicable requirements of ANSI Standards C37.13, C37.17, C37.50 and CSA.

System Voltage and Frequency

Magnum circuit breakers with PXR are designed for operation on AC systems only, 60 Hz or 50 Hz, 635 V maximum.

Continuous Current Ratings

Unlike transformers, generators and motors, circuit breakers are maximum-rated devices and have no built-in temporary overload current ratings. Consequently, it is vital that each application take into consideration the maximum anticipated current demand, initial and future, including temporary overloads.

The continuous rating of any Magnum circuit breakers with PXR is limited to the sensor rating, or the frame size current rating, whichever is the lesser. For instance, an MPS-616 1600 A frame breaker with 800 A sensors has a maximum continuous rating of 800 A, but the same breaker with 1600 A sensors is limited to 1600 A maximum.

All current ratings are based on a maximum ambient air temperature of 40 °C (104 °F).

Ambient Temperature

The temperature of the air surrounding the enclosure should be within the limits of: -30 °C (-22 °F) to +40 °C (+104 °F).

Altitude

The breakers are applicable at their full voltage and current ratings up to a maximum altitude of 6600 ft (2012 m) above sea level. When installed at higher altitudes, the ratings are subject to the following correction factors in accordance with ANSI C37.20.1.

Table 20.6-10. Altitude Derating Factors

Altitude		Voltage Correction	Current Correction
Feet	Meters		
6600	2012	1000	1000
7000	2134	0.989	0.998
7500	2286	0.976	0.995
8000	2438	0.963	0.993
8500	2591	0.950	0.990
9000	2743	0.933	0.987
9500	2896	0.917	0.983
10,000	3048	0.900	0.980
10,500	3200	0.883	0.977
11,000	3353	0.867	0.973
11,500	3505	0.850	0.970
12,000	3658	0.833	0.967
12,500	3810	0.817	0.963
13,000	3962	0.800	0.960

All low-voltage air power circuit breakers are tested per the ANSI Standard C37.1 for a system X/R ratio of 6.6 maximum. It is common within low-voltage systems to experience power factor and X/R values outside the range of the standard values, and thus a means to evaluate published product ratings is necessary.

For applications of power breakers within distribution systems having calculated X/R ratios higher than 6.6, the derating of the air power breakers kAIC rating is required. Per IEEE sanctioned methodology, the calculated short circuit current at the point of interest is increased by the **Table 20.6-11** multiplying factors (MF) to yield an “apparent value of short circuit current,” which is then compared to the published breaker ratings. Only breakers having published ratings higher than the “apparent fault current” can be safely applied.

For example, if unfused air power breakers rated 65 kAIC were being considered within a 480/277 Vac distribution system where the X/R at the point of breaker application is 14.25 and the calculated fault current was determined to be 60 kA, the determination of the suitability of these breakers yields:

$$\begin{aligned} \text{Apparent Fault Current} &= 60 \text{ kA} \times \text{MF} \\ &= 60 \text{ kA} \times 1.112 \\ &= 66.72 \text{ kA} \end{aligned}$$

and therefore because 66.72 kA exceeds the 65 kAIC rating, the breakers are not adequate and higher rated kAIC breakers would need to be applied.

Table 20.6-11. Air Power Breaker Derating

System X/R Ratio	System % PF	Derating and Multiplying Factors for Air Power Breakers			
		Fused		Unfused	
		Derating	MF	Derating	MF
1.73	50.0	1.000	1.000	1.000	1.000
3.18	30.0	1.000	1.000	1.000	1.000
3.87	25.0	1.000	1.000	1.000	1.000
4.90	20.0	1.000	1.000	1.000	1.000
6.59	15.0	0.939	1.065	1.000	1.000
8.27	12.0	0.898	1.114	0.962	1.000
9.95	10.0	0.870	1.149	0.937	1.067
11.72	8.5	0.849	1.178	0.918	1.089
14.25	7.0	0.827	1.209	0.899	1.112
19.97	5.0	0.797	1.255	0.874	1.144

Unusual Environmental and Operating Conditions

Special attention should be given to applications subject to the following conditions:

1. Damaging or hazardous fumes, vapors, etc.
2. Excessive or abrasive dust.

For such conditions, it is generally recommended that the switchgear be installed in a clean, dry room, with filtered and/or pressurized clean air. This method permits the use of standard indoor switchgear and avoids the derating effect of non-ventilated enclosures.

3. Salt spray, excessive moisture, dripping, etc.

Drip shields in equipment rooms and space heaters in indoor weatherproof enclosures, may be indicated, depending upon the severity of the conditions.

4. Excessively high or low ambient temperatures.

For ambient temperatures exceeding 40 °C, and based on a standard temperature rise of 65 °C, the continuous current ratings of breaker frame sizes, and also buses, current transformers, etc., will be subject to a derating factor calculated from the following formula:

$$\sqrt{\frac{105^\circ \text{ Total} - \text{Special Ambient, } ^\circ\text{C}}{105^\circ \text{ Total} - 40^\circ \text{ } ^\circ\text{C Standard Ambient}}}$$

Circuit breakers are not adversely affected by very low outdoor ambient temperatures, particularly when energized and carrying load currents. The standard space heaters in weatherproof switchgear will raise the temperature slightly and prevent condensation.

Electrical components such as relays and instruments, however, must be applied within the manufacturer's specified limits.

5. Exposure to seismic shock.

Magnum PXR switchgear and Magnum circuit breakers with PXR trip units breakers have been certified for applications through International Building Code 2018 (IBC) and California Building Code 2019 (CBC). Assembly modifications may be required, so such conditions must be specified.

6. Abnormally high frequency of operation.

In line with above, a lesser number of operations between servicing, and more frequent replacement of parts, may be indicated.

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