Replacing Control Circuit Fuses with Circuit Breakers

Note: This paper provides only a general introduction to the subject. It is recommended that any changes to an application be planned and executed by a qualified Electrical Engineer.

What is a Fuse?

A UL listed <u>fuse</u> serves as a circuit protective device. The purpose of a fuse is to make sure an electrical overload doesn't damage your equipment, wiring, or worse yet burn your building down. Fuses have been around for over a hundred years but the technology has its faults. For one thing, fuses by design sacrifice themselves to protect the electrical circuit. This requires the fuse to be replaced when it is overloaded.

A fuse works something like a light bulb. There are two posts inside with a thin piece of filament running between them. When the circuit overloads, that filament melts, breaking the circuit and stopping the electrical flow. The problem is once that filament melts, it's gone, and the fuse will need to be replaced entirely.

What is a Circuit Breaker?

A UL1077 and UL489 <u>circuit breaker</u> serves as a circuit protective device similar to a fuse. Circuit breakers have been around for over 100 years and their purpose is to make sure an electrical overload doesn't damage your equipment, wiring, or worse yet burn your building down. When an overload occurs the circuit breaker will "trip" and can be reset by toggling the switch (no replacement is required). Many of us have experienced this in our home when the load from a microwave, coffee pot, crock pot, or hot plate caused a breaker to trip.

Your circuit breaker has current sensing elements to determine when an overload condition occurs, this then opens internal contacts. When this happens, the contacts open and the electrical power is interrupted. To reset a "tripped" circuit breaker simply flip it off and then back on. This will close the internal contacts and restore power to the circuit.

Why Replace Fuses?

The primary reasons for replacing a fuse with a circuit breaker in a control panel are for convenience and operating cost. When a breaker trips, the "repair" is as simple as flipping a switch. But when a fuse is blown, the entire fuse needs to be replaced. Having a spare fuse on hand is recommended. Make certain you turn the power off to your control panel before replacing the fuse.

Additional reasons for replacing a fuse and fuse block with a circuit breaker are:

- Ease of reset
- Operating cost, this is the cost over time
- Reduced troubleshooting time
- Reduced repair cost
- Reset while unit has power applied with little risk for an arc flash event to occur

Fuses have lower up-front costs versus circuit breakers. However, if you're replacing fuses frequently circuit breakers provide a better alternative for cost savings and will more than pay for themselves in a short period of time.

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When Replacing Fuses with a Circuit Breaker

Before you begin replacing fuses with a circuit breaker it is important to check your local building codes. A permit and inspection may be required prior to replacement. The inspector is referred to as the AHJ (Authority Having Jurisdiction) in the NEC, CSA and IEC standards.

- 1. The first step is to plan the work you are attempting to perform. If a permit is required, this plan is necessary.
- 2. The second step is to perform the work.
- 3. The third step is to have the work inspected by the AHJ or plant engineer.

Safety First

When you are ready to perform the work, safely disconnect and verify the electrical power to the control panel has been disconnected. All plant and local safety requirements are to be followed, including Personal Protective Equipment (PPE) and Lock Out/Tag Out (LOTO).

Select Circuit Breakers

Selecting the proper sized circuit breaker is an important step in this process. The control wiring is dependent on the circuit protective device to protect it from overload. The supplemental breaker (UL1077 or UL489) can protect the loads similar to a UL listed fuse. Sizing the breaker is based on the circuit load and ampacity of the wire. The load is typically much less than the ampacity of the wiring. Therefore, the load will typically determine the size of the circuit protective device.

NEC Article 430 provides a one-line diagram to explain overcurrent protection. Figure 430.1 shows the components of a motor circuit.



The motor overload protection device, #5 in the diagram, protects the motor and the branch-circuit conductors. Motor overload devices do not respond immediately to the over current conditions from typical motor operation, brief overload conditions, or motor start up when inrush current can be anywhere from 6-8 times the full load current. The motor overload device protects the motor and the branch-circuit conductors. The overloads are typically sized 115% or 125% of the nameplate full-load rating of the motor and up to 130% or 140% with exceptions. See 430.32(A)(1), 430.32(C), 430.6(A)(2). (Source: Jade Learning)

NEC Figure 403.1

Motor full-load current tables and NEC Table 430.52 are used to determine the maximum for the branch short circuit and ground-fault protection devices. Nontime Delay Fuses, Dual Element (Time Delay) Fuses, Instantaneous Trip Circuit Breakers and Inverse Time Circuit Breakers are used as short-circuit and ground-fault protection devices. When migrating from Circuit Protection Fuses to Circuit Protection Breakers, you must consider the percentage of full load current of the motor. In order to properly determine this, you need to know the motor type, horsepower, and supply voltage.

Table 430.52 Maximum Rating or Setting of Motor Branch-Circuit Short-Circuit and Ground-Fault Protective Devices				
	Percentage of Full-Load Current			
Type of Motor	Nontime Delay Fuse ¹	Dual Element (Time-Delay) Fuse ¹	Instantaneous Trip Breaker	Inverse Time Breaker ²
Single-phase motors	300	175	800	250
AC polyphase motors other than wound- rotor	300	175	800	250
Squirrel cage — other than Design B energy-efficient	300	175	800	250
Design B energy- efficient	300	175	1100	250
Synchronous ³	300	175	800	250
Wound rotor	150	150	800	150
Direct current (constant voltage)	150	150	250	150

Note: For certain exceptions to the values specified, see 430.54.

¹The values in the Nontime Delay Fuse column apply to Time-Delay Class CC fuses.

²The values given in the last column also cover the ratings of nonadjustable inverse time types of circuit breakers that may be modified as in 430.52(C)(1), Exception No. 1 and No. 2.

³Synchronous motors of the low-torque, low-speed type (usually 450 rpm or lower), such as are used to drive reciprocating compressors, pumps, and so forth, that start unloaded, do not require a fuse rating or circuit-breaker setting in excess of 200 percent of full-load current.

Required Tools

Below is a list of tools that may be required:

- Personal protective equipment (used to verify the voltage has been removed)
- Proper LOTO lock and/or tag
- Digital volt meter or non-contact voltage detector
- Screw drivers, which may include philips, flat, torx, and square
- Wire stripper for the line and load wires
- Drill motor
- Drill bit sized for the DIN rail mounting screws (note, do not use thread cutting screws)



Fusebox Panel



c3controls Miniature Circuit Breakers in Control Panel

Shut Off Your Power

Start by removing all electrical power to your control panel. If the control panel is fed by a dead front disconnect switch, enable the off position and perform the proper LOTO to ensure electrical power is not inadvertently reapplied. Control power can come from an external source. If there is foreign power the wiring should be orange or yellow so always verify the power is removed with a digital volt meter or non-contact voltage detector.

Removal Fuse Block

You are now ready to start work on your control panel. It is important to keep track of each circuit, to do this mark both the line and load side of the wires by circuit. Typically this is a number or letter sequence for both line and load. The fuse size should be noted as well. Then remove the existing fuse block(s) from the back panel.

Mounting of Circuit Breaker

Circuit breakers are typically DIN rail mounted, so please ensure there is a space and a location on the sub-panel for mounting. As always follow the manufacturer's guidelines and instructions for mounting, wire stripping and proper terminal torques. The line or load cable can be cut if it is too long and if it is too short it should be replaced. Note that the wiring can be spliced if replacement is not feasible.



Supplemental Circuit Breakers

Wiring the Control Circuit Breaker

When wiring the circuit breaker in the panel use the following:

- Ensure the circuit breaker is mounted and sized properly, these can be UL1077 or UL489 breakers.
- Ensure all ground wires are connected. In the USA these can be bare copper, green or green with a yellow strip.
- Connect the incoming power to the line side of the breaker, following all manufacturer installation instructions, proper tools, and proper torque.
- Connect the load side wiring to the breaker, following all manufacturer installation instructions, proper tools, and proper torque.



Testing and Power Up

- 1. Prior to re-applying power to the control panel ensure all connections are torqued to the manufacturers' specifications, this may vary by the cable size.
- 2. It is good practice to perform a pull test on all wire connections. This ensures the wire connections are secured.
- 3. With all of the switches and push buttons in the "off" position apply power to the control panel.
- 4. Turn on the control power and verify the control circuit works properly.
- 5. Last you can start the system performing any start up testing.

Learn How to Install Circuit Breakers

If you are replacing your fuse system with a circuit breaker in your control panel contact c3controls for help in properly selecting and sizing of the circuit breaker. For additional information on circuit breakers please see <u>A Quick</u>. <u>Guide: UL489 or UL1077 in Control Panels and Equipment</u>. We can help you make sure you have everything under control with your electrical system. <u>Shop our circuit breakers</u> to get the right breaker for you today.

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