Topics in Circuit Protection for Power Supplies

Bulletin1694 Electronic Circuit Protection

This document discusses a new method of providing protection on the secondary of these switched mode power supplies

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The circuit protection market demand is changing based on the growth of 24V DC control voltage. In the US and Canada we've seen a shift from120V AC to 24V DC as the voltage of choice for control circuits. Generally, this change is driven by a trend to use this lower voltage as a safety precaution and to reduce personnel protection requirements. This trend began in Europe, as they transition from higher voltage control level schemes to the lower 24V DC. The adoption of 24V DC has led to the creation of new lines of Power Supplies to provide the 24V DC. Primarily those power supplies use a switched mode technique for creating the 24V DC (versus older linear or diode/transformer schemes).

The switch mode power supply, such as the Allen-Bradley Bulletin 1606 line and some other power supplies, incorporate a self-protection feature to prevent overcurrents and subsequent over heating leading to self-destruction. This is an excellent feature for the power supply but leads to some issues when attempting to provide protection on the load side of power supply.

A new method of providing protection on the secondary of these switched mode power supplies is required. This is further discussed in the following.

Separately, but related, reduced voltage levels and current demands lead to the use of smaller wire. That smaller wire can affect the application of protective devices.

What about the other circuit breakers that Rockwell Automation offers?

The protection on the secondary of the switch mode power supply is best when using the Bulletin1694 Electronic Circuit Protector. Given "ideal conditions" (more on this later) an Electro-Mechanical circuit protection device (a fuse or Miniature Circuit Breaker (MCB) such as a Bulletin 1492-SP or a Bulletin 1489) provides some degree of protection during an "ideal" short circuit. But the Bulletin 1694 offers a significantly better level of protection. It is designed to work in the specific environment associated with a 24V DC power supply.

The primary of the power supply will continue to require some form of fuse or MCB protection. The secondary should be protected with the Bulletin 1694.

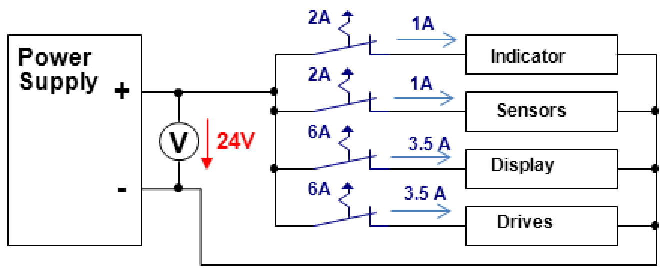
Isn't a fault, a fault, and any circuit protection device will "see" the fault and act to protect?

Designing for Electro-Mechanical Circuit Protection

Not exactly. Consider the design of a fuse or a miniature circuit breaker. Under a short circuit they are designed to operate when a significant amount of current is present, essentially from an "infinitely large" source with wire that is capable of carrying all the available current to the ground plane or opposite polarity. And, the protection device requires some amount of time to sense the high current levels.

With a DC Power Supply, there is a limit to the available current. Circuit designers may oversize their power requirements - to attempt to account for the need to supply sufficient current to trip electromechanical devices.

Consider a simple circuit of 2 —1 A and 2 — 3.5 A Loads

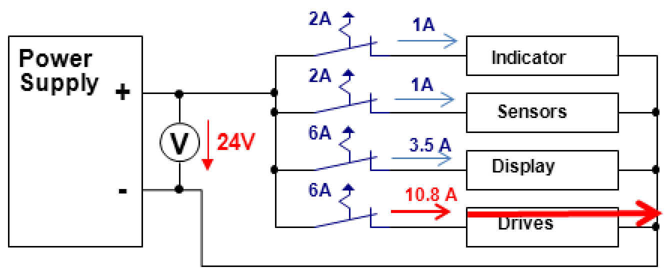


The 1 A loads typically are fused at 2 A and the 3.5 A loads are fused at 6 A. The tripping current for a fuse is about 1.8 times the fuse value so the current required to trip the fuse is shown in the table below:

	Typical Current	**Fuse Value**	**Fuse tripping** Value (*1.8)
Indicators	1A	2A	3.6A
Sensors	1A	2A	3.6A
Display	3.5A	6A	10.8A
Drive	3.5A	6A	10.8A
Total	**9A**		

Note: Based only on the typical current of 9 A, a 10 A power supply might be considered.

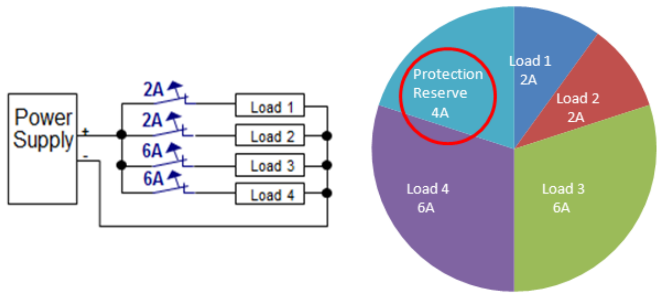
However, if there is a fault in the current to the drive, the current flow would look like:



	Typical Current	**Fuse Value**	**Fuse tripping** Value (*1.8)	**Application Current**
Indicators	1A	2A	3.6A	1 A
Sensors	1A	2A	3.6A	1 A
Display	3.5A	6A	10.8A	3.6 A
Drive	3.5A	6A	10.8A	10.8 A
Total	**9A**			**16.4 A**

Note: Based upon worst case fault potential ---Choose a 20 A supply.

With an Electro-Mechanical circuit protection device (a fuse or MCB) the circuit designer must account for additional current that may be required to trip the fuse or circuit breaker (Reserve for Protection).



Designing for Electronic Circuit Protection

When using Bulletin 1694 Electronic Circuit Protection (ECP), planning for the extra "tripping" is not required. Protection is based upon load conditions, current and voltage, and the product design does not require the "Reserve Current" to operate.

This may permit the use of smaller power supplies, cooler running equipment and the possibility of smaller enclosures.

Effect of Operating Conditions

There is an additional point to consider. The control system power consumption differs when a system is operational and stable versus "starting up." Many control system designers oversize power supplies to account for start-up requirements.

A point not often considered is the action of the fuses or MCB can be different during normal operational conditions versus those start-up conditions.

When in normal operation a fault (short circuit) is more easily detected by a fuse or MCB because the Power Supply has sufficient over capacity to provide enough current ("infinite" current) for enough time so the fuse or MCB trips.

When the system is "starting up" there are extra power demands placed on the Power Supply. The Power Supply may not be able to supply sufficient current for the fuse or MCB to provide magnetic protection (fast protection).

Even if there is a short circuit, the power supply may not be able to provide the "infinite" current associated with a short circuit. While a fault may actually be present the amount of current to flow through the fuse or MCB is less than "infinite" and the fault level current is sensed as an overcurrent by the fuse or MCB. The response of the (fuse or MCB) is more delayed under the lower current (yet overcurrent) for this condition. The fuse or MCB senses this current as an "overcurrent" versus "short circuit current." It is possible that the "fault" current is not detected for several seconds during a "starting up" of a machine or process. During that "non-trip time" there may be significant damage to components.

When using Bulletin 1694 ECP these "start-up" conditions can be sensed, often there is a lower voltage associated with the start-up demand placed upon the power supply. The Bulletin 1694 ECP senses the overcurrent.

The Bulletin 1694 ECP senses Over Current.

Effect of Wire Size and Length

Fault circuit impedance (resistivity)

The resistivity (e.g. DC discussion) of a faulty circuit is very important and is often critical. The best current reserve in the power supply unit does not help if Ohm's law does not permit current flow. Wire resistance has a great influence and is often underestimated, it is best described in this typical example:

A display panel with a power consumption of 5.5 A is located 30 m (total wire length of 60 m) from the control cabinet. The designer uses a 10A power supply, a wire with a cross section of 1mm^2 and a 6 A MCB with a C characteristic to protect the wire and the display.

Calculation of the fault circuit resistivity:

- Power supply unit (internal R)	30 mΩ
- Connectors etc.	20 mΩ
- MCB's	20 mΩ
- Short circuit (in the device)	45 mΩ
- Line 60 m 1mm^2 (18 mΩ /m)	1080 mΩ
	Total =1195 mΩ

The resistance limits the current flow. Not more than the following current can flow:

In the event of a fault: $I = V/R$

$= 24V / 1.195\Omega$

$= 20A$

No more than 20 A can flow through this circuit - (Under a FAULT CONDITION!)

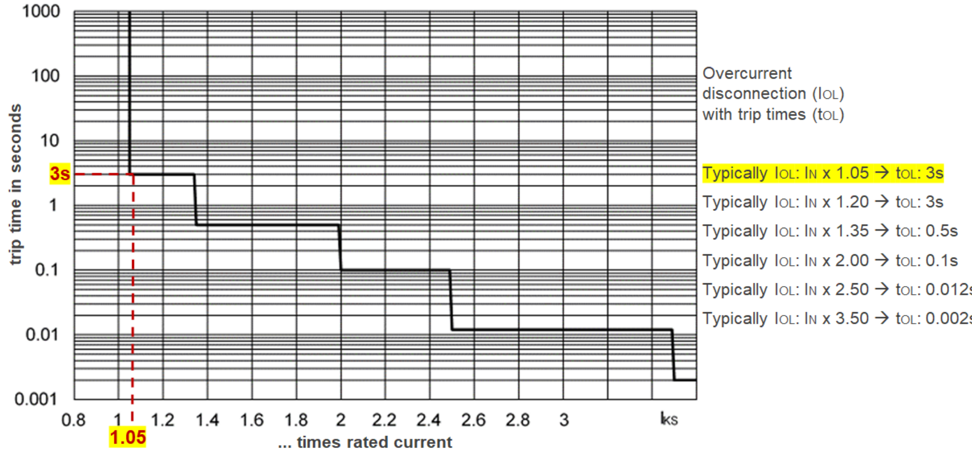
20 A on a 6 A MCB is an I/In ratio of 3.33.

The MCB does not react as if this is a fault. This is "sensed" as an overcurrent. Typically the MCB would trip in 3 to 10 seconds at this current level.

This is not the response normally desired for a fault condition.

Using Bulletin 1694 ECP, this fault current on a 6 A circuit would be sensed about 3s.

Figure 5: Trip characteristic of Bulletin 1694



The Bulletin 1694 ECP provides appropriate protection response when using smaller cross sectional wire size and longer wire lengths.

What about Class 2 (or NEC Class 2) Power Supply requirements? What does that have to do with circuit protection?

Certain connected equipment require a "Class 2" (max 100 VA) power source. This can be provided by a certified Class 2 Power Supply (the Allen-Bradley Bulletin 1606 line offers several Class 2 Power Supplies) or a larger power supply used with a protection device, such as Bulletin 1694 ECP, that provides a certified Class 2 Power Supply level. Fusing (or MCB) to a low current level from a larger power supply is not an acceptable method to provide a Class 2 Power circuit.

For additional information, see Instruction Manual of Bulletin 1694.

What about "power boost", doesn't that provide all the extra current that is needed to trip a regular MCB, like a 1492-SP?

The Power Boost feature is an excellent tool to provide that extra momentary current that may be needed for an inrush condition or a very brief overcurrent. It is not in place to provide the extra current needed to trip the MCB. One of the conditions of a tripping a MCB (or even a fast fuse) is that there is time **and** current. The momentary overcurrent or the inrush that may occur during start-up is an undesirable time for tripping. The MCB and Fuse are designed to not trip for that period. To protect the power supply before it goes into self-protect, the MCB (fuse) needs the extra current and time, but trip before the power supply stops providing the current. This may be a mutually conflicted goal. Especially if there are any inductive or capacitance factors that affect the circuit. The inductive and capacitance loads require time to "stabilize" and during that time are drawing extra current. However the power supply protective circuits may not want to provide the extra current to self-protect.

To provide fast tripping before the self-protect occurs, may require a B or Z curve MCB. However to permit the capacitance or inductive load to stabilize and not false trip may require a D type MCB trip curve.

Enter the Electronic Circuit Protector. The tripping characteristic is shaped to permit most capacitance/inductive loads to energize, yet the protector is designed to trip prior to the self-protection of the power supply.

What about providing the protection using a PLC/PAC DC output card with an electronic fuse?

Note: PLC cards with built-in E-fuse protection are not intended to replace fuses, circuit breakers, or other code required wiring protection devices. The E-fuse protection of the PLC module usually is designed to provide protection for the module from short circuit conditions, which is usually based on a thermal cut-out principle. In the event of a short circuit condition on an output channel, that channel will limit the current within milliseconds after its thermal cut-out temperature has been reached. PLC cards with E-fuse protection are generally not recommended for over-current protection.

However, the protection of the electronic fuse of these devices, while primary designed to protect the output card, does provide fast protection and most probably would act faster than the sell-protection circuit of the Power Supply, thus providing the necessary trouble-shooting information:

- 1756-OB16E
- 1756-OB8EI
- 1756-OV16E
- 1756-OV32E

When using other DC output cards, the use of a Bulletin 1694 ECP assists in trouble-shooting overcurrent conditions.

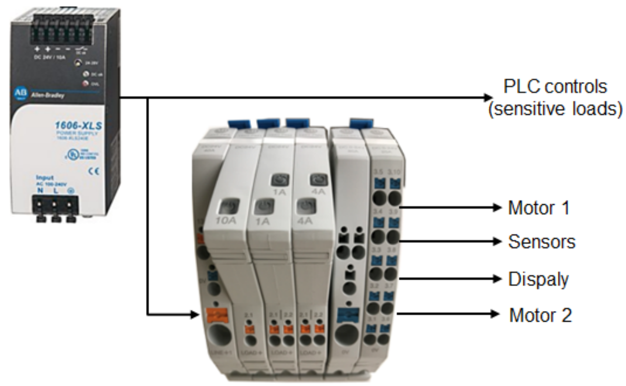
PLCs manufacturers often recommend using fuses with the output modules, which are sized to provide short circuit protection for wiring only to external loads. In the event of a short circuit on an output channel, the transistor or relay associated with that channel will likely be damaged. The module should be replaced or a spare output channel used for the load. The external fuses do not always provide overload protection. In the event of an overload on an output channel, it is likely that the fuse will not blow and the transistor or relay associated with that channel will be damaged. To provide overload protection for your application, user supplied circuit protection like the Bulletin1694 protector should be installed externally and properly sized to match the individual load characteristics.

Oversize Bulletin1694 protectors according to 100% of the nominal current ratings of the individual loads. The Bul. 1694 ECP operation allows for inrush requirements of the loads to certain limits, allowing up to 2x current for 1 second at minimum. Please note a Bul. 1694 protector sized at higher amp rating than the current carrying capacity of the PLC card may damage the transistor or the relay associated with that I/O channel in the PLC card.

What about protecting through PLC/PAC DC input cards with the Bulletin 1694?

Generally, the input card is not concerned with the fault status of the connected input. For example, if there is a shorted, faulty sensor, the input card reports on the status of the input (on/off) but not on the condition of the sensor. If the sensor draws excessive current, it may be sufficient to send the power supply into self-protection. When using the Bulletin 1694 ECP to protect the sensors, the overcurrent condition would be noted and the circuit(s) turned off with the notification of the problem circuit. The power supply would remain energized for other loads or for assisting during the maintenance activity.

How should the Bulletin 1694 be used with 24V DC (powered) PLCs, like the Micro800?



When using a device like the Bulletin 1694 that monitors the output current from a 24V DC power supply, initially a designer may consider applying the current monitor to every 24V DC load. Our recommendation is to **not** apply the 1694 protection to the PLC 24V DC system power for the overcurrent protection.

Why does the Bulletin 1694 provide better for protection of the Power Supply secondary than a miniature circuit breaker or fuse?

Simply stated, a fuse or MCB is not designed for the specialty conditions associated with the 24V DC systems used today. Fuses and MCBs were designed for the higher voltage AC world. The self-protection of the Bulletin 1694 ECP operates very quickly. Many of you may recall a statement that has been used; "It is very difficult to protect a solid state circuit with a mechanical device."

With the 1694 the electronic circuits are being protected by electronic components. The 1694 is designed to operate in the 24V DC environment.

Many of the connections to a 24V DC power supply are solid state circuits (sensors, PLC/PAC I/O cards, transducers, etc.) Damage to those devices can be minimized with fast acting protection. (Note this does not eliminate damage within a sensor or solid state device. but can minimize that damage.)

Modern switch mode power supplies (such as the Allen-Bradley Bulletin1606 product line) incorporate a self-protection circuit. That internal circuit prevents the power supply from providing excessive current. While that protection is a good thing for protecting the power supply, if the device that required the excessive current cannot be determined, there is the potential of unnecessary trouble shooting time required to isolate the faulty device. An MCB may not be able to isolate the faulty device, because the MCB requires both an overcurrent and time with the overcurrent to activate. The power supply shuts off before the MCB can trip!

The Bulletin 1694 Electronic Circuit Protector is intended to discover the overcurrent and isolate that circuit so the offending device does not contribute to additional problems.

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