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Miniature circuit-breaker versus electronic selectivity module

Selective monitoring of 24 V DC load circuits

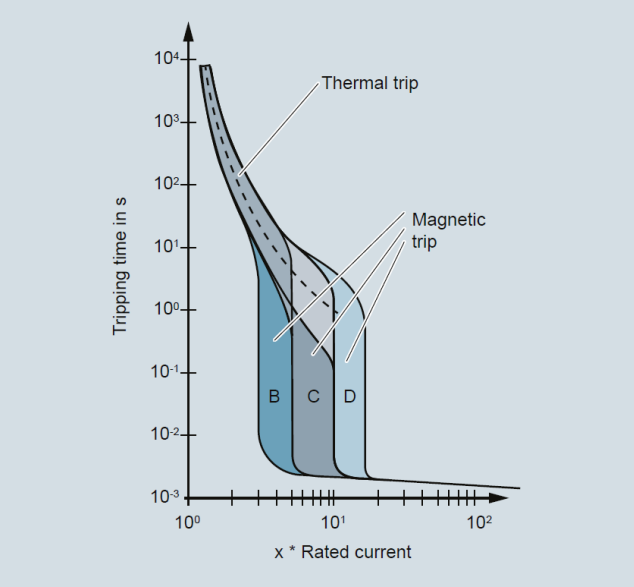
In modern plant and machine construction all 24 V DC loads – whether rugged electro-mechanical loads or highly sensitive electronics – are supplied by a single, common, stabilized switch mode power supply. To ensure that a fault in one load does not bring the complete plant to a halt, the 24 V DC power supply circuit is divided into separate branches and selectively protected. Miniature circuit-breakers (MCBs) are often used for this purpose. In many cases, however, they do not offer reliable protection. Conversely, the electronic selectivity module monitors the 24 V DC branches safely and enables reliable fault diagnosis and minimizes downtimes.

Switched-mode power supplies protect themselves with electronic output current limiting

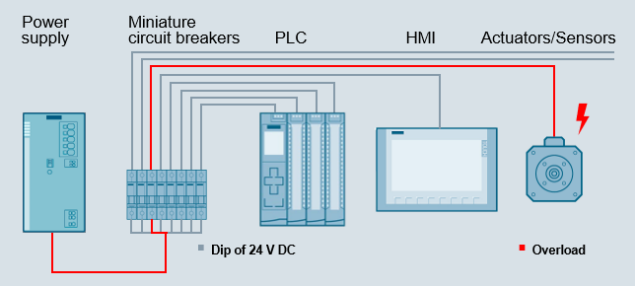
To provide power to the 24 V DC level of automated plants, primary switched mode power supplies have long ago gained widespread acceptance and replaced the unregulated transformer power supply. In most cases, however, the distribution of the 24 V feed among multiple load groups and their protection are still handled by conventional miniature circuit-breakers. The internals of switching power supplies are dimensioned for a specific nominal power output. To protect the devices against damage from overloading, the output current is electronically limited. The current limiting normally starts at 1.1 to 1.5 times the nominal value. This limited maximum current also has an effect on the tripping response of miniature circuit-breakers.

The typical behavior of miniature circuit-breakers

The function of miniature circuit-breakers is the protection of wires against thermal damage to the insulation from too high a current. The tripping characteristics are thus matched to the current voltage characteristics of the wires. Looking at the various current-time characteristics of MCBs, two general tripping ranges can be distinguished resulting from two different disconnection mechanisms. In the range of small overcurrents, a time delayed thermal tripping occurs through a bimetal. The duration until the tripping depends on the level of the overcurrent and can range from minutes to hours in the case of small overcurrent. The disconnection in the case of larger overcurrents (electrical shorts), on the other hand, is tripped electromagnetically without a delay. Here, the immediate tripping takes place within milliseconds by means of an electromagnet. So that the electromagnetic tripping of the MCB does not already respond at the normal operational starting current surges caused by the connected loads, different sensitivities exist, which are reflected in the tripping characteristics “A” to “D”. In all cases, however, a multiple of the nominal current is required for the MCB to trip rapidly. If, for instance, a miniature circuit-breaker of the commontype C is considered, the electromagnetic instant tripping occurs at 5 to 10 times the nominal current; if operated with DC voltage, the limit current values increase by a factor of 1.4. For a safe configuration, 14 times the nominal current thus has to be taken into account to achieve the instant tripping required for the selectivity.



Fast tripping is important, because when the 24 V DC supply fails the intact branches are also undersupplied. Voltage interruptions of 20ms are already critical for the PLC and will cause the process to be interrupted or even to crash.



Application example with selective protection via miniature circuit-breaker:

In the event of an overload the switched-mode power supply limits the current and the miniature circuit-breaker does not trip sufficiently quickly. The 24 V DC supplies dip, all loads are undersupplied, and the PLC switches to the „Stop“ state.

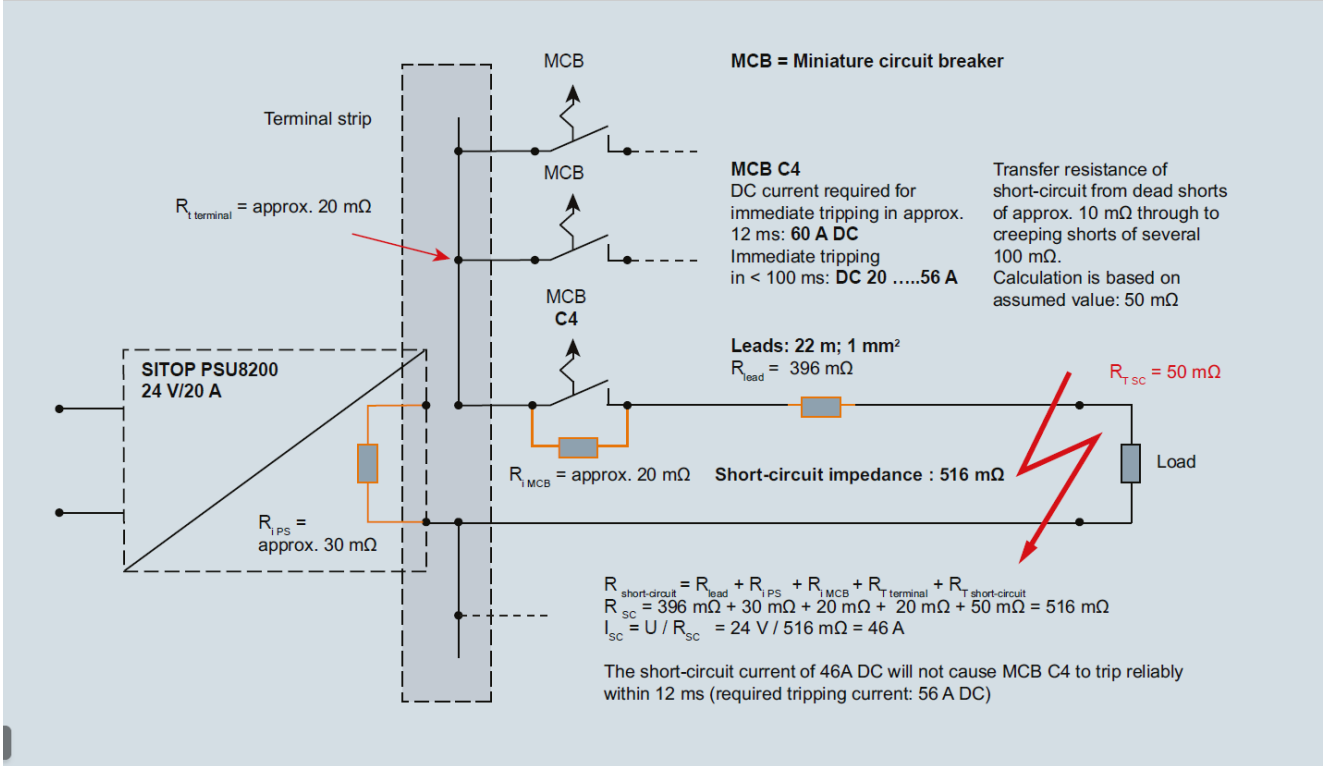
The problem with modern power supplies and conventional miniature circuit-breakers

The electronic current limiting of a power supply limits the output current during overloads to, for example, 1.5 times the nominal current. In the case of a 20 A device, this corresponds, for example, to a maximum current of 30 A. With this device, at best type C miniature circuit-breakers with a rated current up to 2 A can be safely and instantly tripped.

Oversizing is an inadequate solution approach

In the simplest case, a tripping of higher current-rated miniature circuit-breakers can be achieved by using a power supply with a higher power output. This, however, also requires more space and increases the costs. In some power supplies, a so-called “power boost” is integrated. Here, the device is capable of supplying – at least temporary – up to 6 times the nominal current.

But even this theoretically possible high output current is not the perfect solution for the problem – since in practice, ohmic resistances of the feed and return wires to and from the fault location often prevent this maximum current from flowing. Already at a loop impedance of only 0.4 Ohm (for a wire with a cross section of 1mm², this corresponds to a distance of only 11 m between power supply and load), a 20 A power supply – capable of briefly supplying 6 times the current (120 A) – can only drive 3 times the current (60 A) through the short-circuit path. With this current, a type C miniature circuit-breaker with a nominal current of up to 4 A can then be safely tripped instantly. If, in addition to the pure lead resistance, the internal resistances of the power supply and miniature circuit-breaker are taken into account as well as the transfer resistances of the terminals and the actual short circuit, even this 60 A will not be achieved and C4 will not trip immediately (see the application example on the next page).



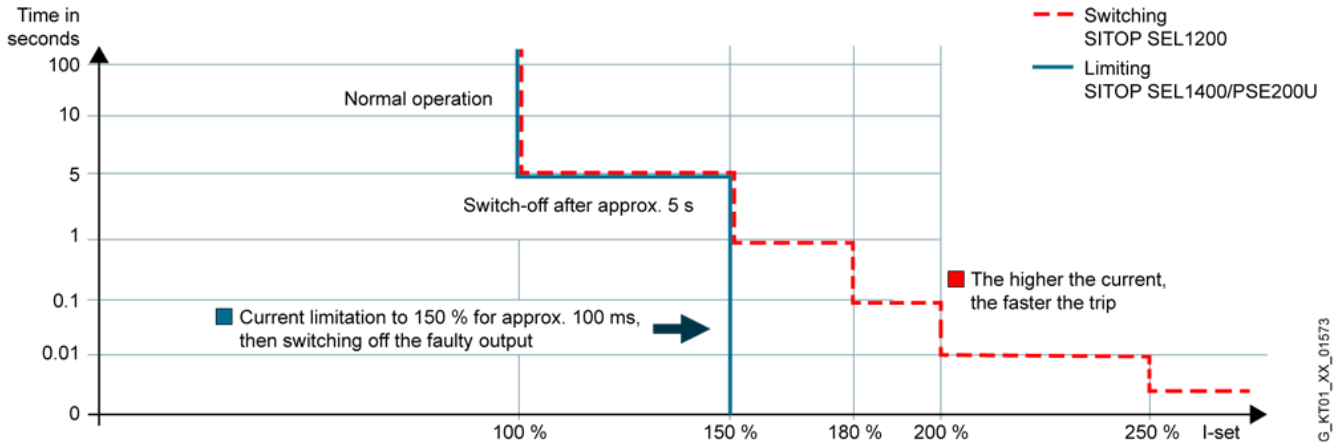
Application example with limited short circuit current
The short circuit current is reduced by various ohmic impedances which means that the current required for fast tripping of the miniature circuit-breaker cannot be achieved regardless of the output performance of the power supply.

Although a higher current is flowing in the case of lower-ohmic faults, with which larger miniature circuit-breakers can be tripped as well, the parallel load branches see a. voltage drop at least until the disconnection of the faulty path. This can disturb other electronic loads, if the disconnection does not take place within a few milliseconds. In the end, one has to realize that in the combination of switching power supply and miniature circuit-breaker, a selective disconnection of faulty load branches can only be achieved in special cases and with a lot of configuration effort.

The SITOP selectivity modules from Siemens provide this reliable protection. They cover all application requirements with the current-limiting and switching tripping characteristic.

Limiting or switching characteristic?
Which tripping characteristic is optimal for a specific application? The limiting characteristic restricts the output current to 150% of the configured value. This value corresponds to the overload behavior of SITOP power supplies of the "Advanced" and "Standard" product lines. Even in the event of a short circuit, the power supply cannot be overloaded and thus no voltage drop can occur at its output. If it drops below 20 V, there is a selective immediate switch-off of all outputs that are carrying more than 100% of the individually configured tripping current at that moment. For all non-overloaded feeders, the 24 V supply is maintained without any disturbing dip.
Even loads that do not comply with the PLC standard and are only capable of bridging a few milliseconds of undervoltage continue to run without problems. The SITOP PSE200U and SEL1400 selectivity modules have limiting characteristics and therefore offer the highest level of safety in the event of overload and short-circuit in the 24 V control circuit.
The switching characteristic is similar to that of miniature circuit breakers, but with faster tripping at lower current. It nevertheless permits higher inrush currents.
Otherwise with the switching characteristic, the higher the current, the faster the output is switched off.
It cannot be ruled out that the power supply can be loaded with a much higher current than the configured current for a few milliseconds. If the power supply unit has low overload reserves, the 24 volts may briefly drop. This is not critical for loads that comply with the PLC standard. SITOP SEL1200 selectivity modules feature switching characteristics and therefore offer very efficient protection for standard applications.
For 24 V loads with high inrush current, the switching tripping characteristic even offers advantages. After all, what applies to switching off also applies to switching on. High currents are not limited,but are allowed for a short time. In addition, two adjacent outputs of the SITOP SEL1200 or SEL1400 selectivity modules can be connected in parallel for 50% more output current, e.g. 2 outputs with 10 A for 15 A rated current.

Video SITOP SEL1200 and SEL1400 – Switching or limiting:
https://youtu.be/FNIoDqLWruY

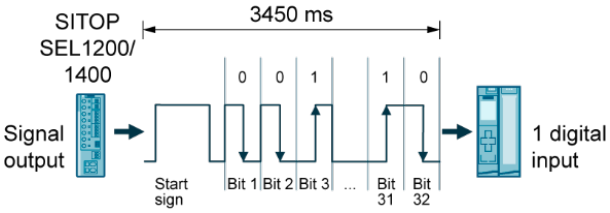


Tripping characteristics of SITOP SEL1400/PSE200U and SEL1200: Current limiting and switching

Extensive functionality assures a targeted fault localization
The tripping current of each output can be individually set with a potentiometer accessible from the front. Device versions are available with 4 or 8 outputs and, depending on the type, with adjustment ranges up to 3 A, 5 A or 10 A. The SITOP PSE200U selectivity module is also available as an NEC Class 2 version with 4 outputs 0.5-3 A and 100 VA power limitation.
The SITOP SEL1200, 1400 and PSE200U modules signal the status of the individual feeders via a multicolored LED per channel. In the event of a disconnection, the indicator changes from green to red. Depending on the device version, the fault is output by means of a common signaling contact or single-channel signaling. For single-channel signaling, the signaling output is to be connected to the PLC by only one standard digital input. The deactivated channel is signaled by a pulse pause protocol which is evaluated by a function block in the PLC (see below). Faults can be localized very quickly this way in a higher level control system or operator control and monitoring system which reduce downtimes even further.
Visualization is provided via WinCC faceplates. SITOP PSE200U reports the status of the outputs via 4 channel bits, each separated by a pause bit. Function blocks for SIMATIC S7 and SIMOTION are available for evaluation. There is also an application example for integration in LOGO! logic modules.

Application example SITOP PSE200U with SIMATIC S7:
https://support.industry.siemens.com/cs/ww/en/view/61450284
with SIMOTION:
https://support.industry.siemens.com/cs/ww/en/view/82555461
with LOGO!:
https://new.siemens.com/global/en/products/automation/systems/industrial/plc/logo/logo-application-examples.html

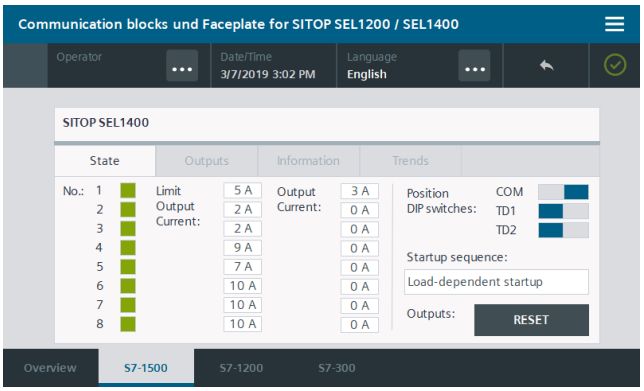
SITOP SEL1200 and 1400 selectivity modules transmit a 32-bit frame in Manchester code via their diagnostic interface:



The following device data is transmitted:

- Status information on each output and the reason for switching off, e.g:
  - ➢ Overload up to 150% for more than 5 sec.
  - ➢ Overload at and above 150%
- Current output current values at the outputs
- Current limit values of the outputs
- Device information such as manufacturing date, article number and settings

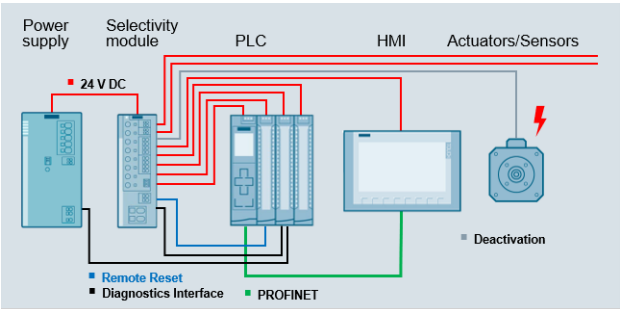
The function blocks are available e.g. for SIMATIC S7-1200, 1500, 300 and 400 CPUs. The frame is documented in the application example and can also be evaluated by other controllers.
Ready-made faceplates for WinCC facilitate the visualization of the data from SITOP SEL1200 and SEL1400.



Visualization: The states and settings of the individual outputs as well as device information of the SITOP SEL1200/1400 are clearly displayed on WinCC faceplates.

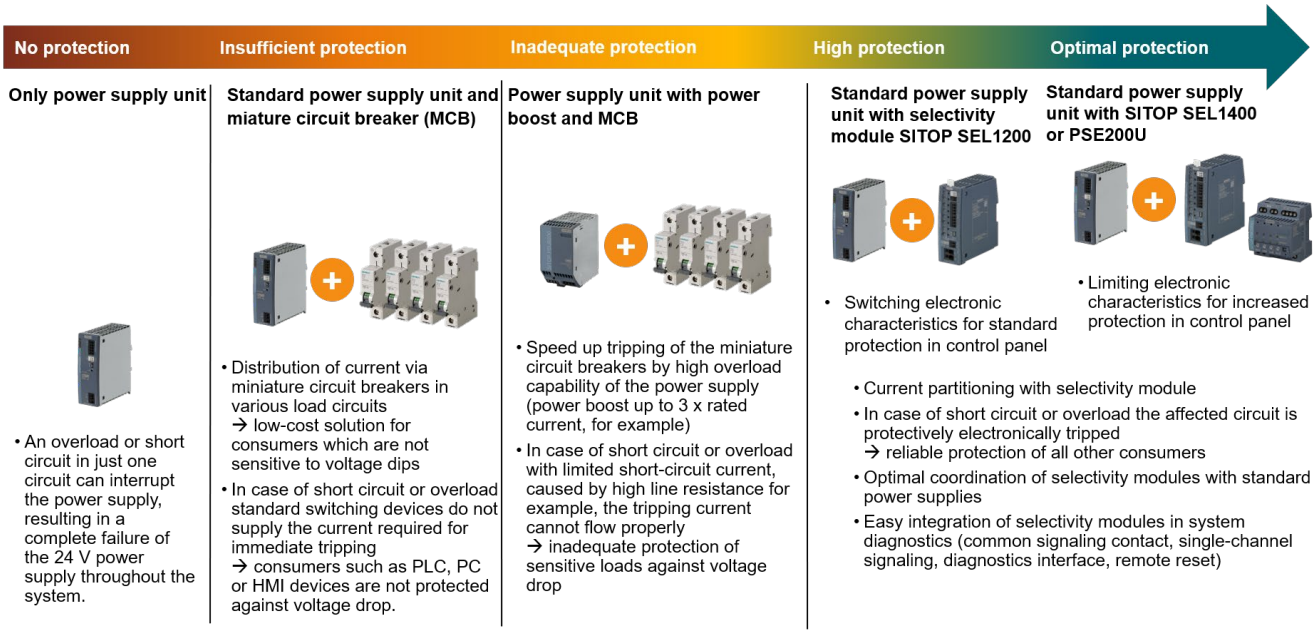
Application example for evaluation of the diagnostics interface SITOP SEL1200/1400 and visualization of the device data:
https://support.industry.siemens.com/cs/ww/en/view/109763709

Additional benefits during operation and commissioning
If a fault only occurred temporarily during operation, the affected output can be reactivated via remote reset. The function can reduce travel times and possibly downtimes especially for remote parts of the plant. Individual branches can be activated and deactivated manually by means of pushbuttons for support during commissioning and maintenance. A manually deactivated channel is indicated by a yellow LED. For safety reasons, the manual reset is not reversible via remote reset.
Another important function is the sequential switching on of the individual output channels. Fixed delay times of up to 500 ms can be selected, as well as the time for load-optimized switch-on. Load-optimized means that an output is only switched on when the previous one is again below the configured tripping current. That prevents a temporary overloading of the upstream power supply – and thus a disruption of the 24 V DC voltage – by not simultaneously switching on several connected loads. The reduced total inrush current may allow for the use of a smaller power supply.



Application example with a standard power supply (for example, from the SITOP PSU6200 product line) and selectivity module SITOP SEL1400:
The selectivity module deactivates faulty channels at once in the event of imminent danger of a 24 V DC voltage drop. Critical loads like a PLC are supplied without interruption.

Application range of miniature circuit breakers and selectivity module:
Switched mode power supplies with miniature circuit breakers offer a cost-efficient solution for loads that are not affected by voltage drops.
With a high overload capability of the power supply (Power Boost, for example, up to 6 x I rated), tripping of the miniature circuit breaker can be accelerated. However, this combination does not guarantee adequate protection for critical loads in case of low short-circuit current.
The selectivity module offers higher configuration reliability under all conditions. Plus a standard switched-mode power supply is sufficient.



Protective measures in the 24 V control circuit: Configurations with a regulated power supply and its effect in the event of a short-circuit or overload

Conclusion

Selectivity modules reliably achieve selectivity in 24 V supply circuits. With SITOP SEL1200, standard applications are reliably protected against short-circuits and overloads, and loads with high inrush current can still be switched on.

With SITOP SEL1400 and PSE200U, you achieve the highest protection against voltage dips in the power supply resulting from short-circuit or overload. This is because the SITOP SEL1400 and PSE200U selectivity modules monitor the current for each feeder and reliably prevent the supply voltage from collapsing.

The diagnostic functions themselves provide fault isolation and reaction from a central location. The channel-specific LED indicators in the control cabinet help you locate faults quickly, to prevent complete plant failures and to minimize partial failures to a very short period of time. Remote reset, manual activation and deactivation as well as sequential switching on of individual 24 V DC branches are additional benefits.

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