Guideline for DC 24 V Systems in Machine Construction and Process Control
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### Planning aspects

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### Flexible power distribution for centralised and decentralised control cabinet concepts

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2 Convenience of Steven Engineering, Inc - (800) 258-9200 - sales@steveneng.com - www.stevenengineering.com
Guideline DC 24 V Systems in Machine Construction and Process Control

- Planning aspects
  - Power supply, load characteristics
  - Protection, wiring
  - Requirements of the Machinery Directive and Low Voltage Directive
  - International standards and approvals
- Professional overcurrent protection and power distribution for DC 24 V systems
- Flexible power distribution for centralised and decentralised control cabinet concepts

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Requirements and planning aspects

Systematics of a DC 24 V system

Tasks and questions of electrical planning

1. Power supply
   - Type, manufacturer, current rating, output characteristics, behaviour in the overload range, price?
   - Utilisation rate of power supply in dynamic range of system?
   - Current reserve for simultaneity factors or system extensions (up to 80% utilisation)?

2. Load characteristics
   - What loads have to be protected?
   - What is the dynamic characteristic of the load current during switch-on or on duty in a group protection of several loads?

3. Overcurrent protection
   - Current rating and trip curve of circuit breaker: fast or delayed?
   - Total current consumption when protecting a group of devices?
   - Selectivity ensured in the event of short circuit/overload? Can the occurring short circuit currents be calculated?
   - Reaction of loads when the DC 24 V control voltage dips?

4. Wiring
   - What cable lengths have to be expected?
   - What are the cable cross sections in the string in questions: Sensor cables 0.25 mm², wiring 1/1.5/2.5 mm², mixed forms? $I^2t$ value, ampacity?
   - Can the breaker trip due to cable attenuation?
   - Wiring time for all load lines (plus, protected load output, minus, FE) and auxiliary contacts in the control cabinet?

DC 24 V control voltage level

Power supply

Supply voltage DC 24 V
- DC 24 V control voltage: Switch-mode power supplies (SMPS) widely replace conventional transformer power supplies (TPS). Reasons: Size, weight, efficiency.
- Output characteristics of the SMPS differ significantly from the TPS curve:
  - TPS: high overload capacity, as power $P = U \times I \sim \text{const.}$
  - SMPS: Overload behaviour depends on manufacturer, type and current rating of the SMPS (5 A / 10 A / 20 A / 40 A): often the output voltage is turned down already at 1.1 ... 1.5 times rated current $\Rightarrow$ self-protection of the SMPS (I/U curve) or switch-off (foldback curve / hiccup mode).
- What’s the use of a short-time boost function of the output current e.g. 3 times rated current for 20 ms, 6 times rated current for 12 ms?

Tasks and questions of electrical planning

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   - Type, manufacturer, current rating, output characteristics, behaviour in the overload range, price?
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DC control voltage level
Load characteristics

Load characteristics
(switch-on, dynamic processes in operation)

Electronic system components (PLC, safety technology, industrial computers, user terminals, sensors, drive controls, field bus modules, magnetic valve distributors etc.) have a high input capacity, i.e. high inrush currents. **Reason:** A great number of EMC and buffer capacitors in the DC24V input, number will continue to rise as the EMC standards for voltage dips in DC systems will be adjusted. DC24V motors (including brushless DC motors) and e.g. fans have high inrush currents.

DC control voltage level
Load characteristics / typical current-voltage curves

![Drive control](image1)
![PLC](image2)
![DC drive](image3)
![Industrial PC](image4)
![Safety technology](image5)
![DC motor](image6)
## Overcurrent protection
### Standards and Approvals

| Standard | IEC 60947-2 | EN 60947-2 | DIN EN 60947-2 | VDE 0660-101 | IEC 60934 | EN 60934 | DIN EN 60934 | VDE 0642 | IEC 60898 | EN 60898 | DIN EN 60898 | VDE 0642 | UL 489 | UL 1077 | UL 2367 | UL 508 |
|----------|-------------|-------------|----------------|---------------|-------------|-------------|----------------|-----------|-------------|-------------|----------------|---------------|---------|---------|---------|---------|---------|
| Type     | MCBs        | CBEs        | MCBs           | CBEs          | MCBs        | CBEs        | MCBs           | CBEs      | MCBs        | CBEs        | MCBs           | CBEs          | MCBs    | CBEs    | MCBs    | CBEs    | MCBs    |
| Application: | MCBs with main contact for connection to circuits up to AC 1000 V and DC 1500 V; is also used for protection of cables and devices in industrial applications | Protection of appliances (for household and similar) for the protection of circuits within electrical resources | MCBs for indoor installations and similar purposes | Protection of branch circuits | Additional protection equipment for use in electrical production means | Electronic overcurrent protection device | General; Control cabinet components |
| Low-voltage switchgear and controller - Part 2: Circuit-breakers (moulded-case circuit breakers (MCB)) | Circuit breaker for equipment (CBE) for household and similar applications | Circuit breakers for overcurrent protection for household and similar installations (miniature circuit breakers (MCB)) | Molded-case circuit breakers for branch circuit protection | Supplementary Protectors for Use in Electrical Equipment | Solid-state overcurrent protectors for supplementary overcurrent protection; for secondary circuits) | Industrial Control Equipment |
| Application area: | up to AC 1000 V; up to DC 1500 V | up to AC 440 V max. 125 A; up to DC 250 V; max. 125 A | up to AC 440 V max. 125 A; up to DC 220 V; max. 125 A | up to AC 600 V up to 220 V plus | up to AC 600 V up to DC 600 V | up to DC 60 V up to 1500 V |
| Short circuit current values which are reached, e.g. Icn = 800 A | values which are reached, e.g. Icn = 1000 A | max. 25kA (AC) | max. 10kA (DC) | 5 kA / 10kA | 300 A, 1 kA, 2 kA, 3,5 kA | min. 250 A |
| Dielectric strength | UL ≤ 300V: 1.5kV, 5 s | UL ≤ 800V: 2.0kV, 5 s | AC250V: 1.5kV / 1 min | AC440V: 2.0kV / 1 min | 1 kV + 2 Un, 1 min | 1 kV + 2 Un, 1 min |
| E-T-A devices comply with the standard | 4230-T (E); under preparation: ESS31-T, ESX20, 2216-S | 4220-T (CBEs) | 4200-T (CBEs) | NO | 4230-T (E); under preparation: ESS31-T | ESX10 / ESX10-T / REF16-S | ESX10 / ESX10-T / REF16-S |
| Comment | Selected tests in accordance with this standard can be conducted. Self-certification. | Circuit breakers for equipment protection, protection of control voltages | not applicable to CBEs | not applicable to CBEs | Circuit breakers for equipment protection, protection of control voltages | Acc. to UL same application as CBEs due to integral current limitation | Typical applications in industrial switchgear; acc. to UL same application as CBEs due to integral current limitation |

### Electro-mechanical circuit breakers
#### thermal-magnetic

**Fast DC curves (A, Z, F1 or B) in the lower tolerance band:** Magnetic short circuit trip at 3 ... 5 x In or 4.5...7.5 x In of CBE

Start-up of electronic system components often not possible as a high inrush current trips the breaker.

**Medium delayed DC curves (C, M1):** Trip at 7.5 ... 15 x In. SMPS cannot supply the current required for tripping the breaker, the output voltage is turned down (I/U curve) or disconnected (foldback, hiccup).

### MCBs to IEC / EN 60898
#### C characteristics

**Thermal-magnetic, C characteristics / AC**

- thermal: trips between 1.13 and 1.45 times rated current
- magnetic: trips between 5 and 10 times rated current

**Thermal-magnetic, C characteristics / DC**

- thermal: as with AC, trips between 1.13 and 1.45 times rated current
- magnetic: trips between 7.5 and 15 times rated current
Short circuit in SMPS output
MCBs with C characteristics

The magnetic trip range of the C breaker is no longer in the acceptable overload range of the power supply: The DC 24 V output voltage breaks down.

Graphical calculation
Trip at short circuit SMPS / MCB with C characteristics

Often the power supply cannot provide the trip current required for magnetic tripping and turns down the output voltage.
Overcurrent protection with thermal-magnetic circuit breakers

Characteristic curves

<table>
<thead>
<tr>
<th>Trip curve</th>
<th>Voltage</th>
<th>DC factor</th>
<th>Manufacturer</th>
<th>Type</th>
<th>Rated current IN</th>
<th>Thermal trip level:</th>
<th>Magnetic trip level:</th>
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<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>T-u</td>
<td>T-o</td>
<td>M-u</td>
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<tr>
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Thermal Magnetic Circuit Breakers

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<th>Manufacturer</th>
<th>Type</th>
<th>Rated current IN</th>
<th>Thermal trip level:</th>
<th>Magnetic trip level:</th>
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<td></td>
<td></td>
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<td></td>
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<td></td>
<td>T-u</td>
<td>T-o</td>
<td>M-u</td>
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<tr>
<td>Z, K</td>
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<tr>
<td>F1, F2</td>
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</table>

Ampacity of cables vs. current rating of protection

The ampacity of the cables has been added as follows:

- **rated cross section:**
  0.14 mm² to 0.5 mm² following VDE 0891 T1
  0.75 mm² to 150 mm² following VDE 0100 T1

- **Protection is provided by a blade fuse or an MCB**
- **Example:**
  at 0.34 mm² => max. I_N = 3 A at 30 °C

Caution:
This table is only an excerpt from the mentioned standards. Other vital parameters such as heat radiation on cables, laying modes and conditions, insulating materials of the cables as well as other ambient temperatures etc. have to be considered.

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<th>CBE/MCB - Current rating in A</th>
<th>Max. Load in A</th>
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<table>
<thead>
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<th>Cross section in mm², Cu wire</th>
<th>Max. Load in A</th>
<th>CBE/MCB - Current rating in A</th>
<th>Max. Load in A</th>
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<tr>
<td>150</td>
<td>335</td>
<td>350</td>
<td>274.7</td>
</tr>
</tbody>
</table>
Wiring
Length, cross section, resistance

Line impedance defines the max. trip current in DC24V applications

trip current \( I = U/R_{\text{total}} \); \( I = 24 \, \text{V}/1.19 \, \text{Ohm}; \)
\( I = 20.17 \, \text{A bei 50 m, 1.5 mm}^2 \)

E-T-A planning tool:
Easy calculation of a DC 24 V system

resistivity copper \( R_0 = 0.0178 \, \text{(Ohm x mm}^2)/\text{m} \)

cable cross section \( A \) in mm\(^2\) 0.14; 0.25; 0.34; 0.5; 0.75; 1; 1.5;
total cable resistance \( R_{\text{total}} \) in Ohm = \( \frac{R_0 \times 2xL}{A} \)
distance \( L \) in metres (one-way length) 5; 10; 15; 20; 25; 30; 35; 40; 45; 50

E-T-A planning tool:
Easy calculation of a DC 24 V system

Please observe the internationally valid standards and directives regarding ampacity.

Min. cable cross section in protected load path: 2.5 mm\(^2\)

Courtesy of Steven Engineering, Inc - (800) 258-9200 - sales@steveneng.com - www.stevenengineering.com
## Overview of electronic protection DC 24 V

### Innovative and professional

<table>
<thead>
<tr>
<th>Product</th>
<th>ESS20-00x</th>
<th>ESS31-T</th>
<th>ESX10-TB</th>
<th>ESX10-SA</th>
<th>ESX10-BA</th>
<th>ESX10-TD</th>
<th>REF16-S1xx</th>
<th>ESS22-T</th>
</tr>
</thead>
</table>

### General Data

- **Type:**
  - ESS20-00x: electronic circuit breaker
  - ESS31-T: electronic circuit breaker
  - ESX10-TB: electronic circuit protector
  - ESX10-SA: electronic circuit protector
  - ESX10-BA: electronic circuit protector
  - ESX10-TD: electronic circuit protector
  - REF16-S1xx: electronic circuit protector
  - ESS22-T: electronic circuit breaker

### Technical Data

- **rated voltage:**
  - DC 24 V
- **operating voltage:**
  - DC 18…32 V
- **current rating IN:**
  - fixed current ratings 0,5A - 12A
  - adjustable current ratings 1A/2A and 3A/6A
- **number of ways:**
  - 1-way
- **manual ON/OFF/reset:**
  - push button
- **trip (error):**
  - electronically
  - Power-MOSFET
- **overload disconnection:**
  - typ. 1.1 x IN
- **overload trip time:**
  - typ. 100 ms
- **short circuit current:**
  - typ. 1.8 x IN
- **short circuit trip time:**
  - typ. 100 ms
- **max. switch-on capacity:**
  - 75,000μF
- **signalling:**
  - make contact
  - break contact
  - change-over
- **signal Input:**
  - without
- **General Data:**
  - plug-in on terminal block
  - 17plus or S2S for rail mounting
  - spring-load terminals
  - temperature range
  - (w x h x d) without terminal block with terminal block
  - approvals

### Dimensions (w x h x d) without terminal block with terminal block

<p>| | | | | | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
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</thead>
<tbody>
<tr>
<td>Product</td>
<td>ESX10-TB</td>
<td>ESX10-SA</td>
<td>ESX10-BA</td>
<td>ESX10-TD</td>
<td>REF16-S1xx</td>
<td>ESS22-T</td>
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</tr>
<tr>
<td></td>
<td>12.5 x 105 x 60 mm</td>
<td>12.5 x 105 x 60 mm</td>
<td>12.5 x 70 x 60 mm</td>
<td>12.5 x 80 x 83 mm</td>
<td>12.5 x 92 x 60 mm</td>
<td>12.5 x 85 x 92 mm</td>
</tr>
</tbody>
</table>

### Approvals

- UL1077
- EN60934
- UL2367
- UL508
- CSA22.2 No.14
- IEC/EN 60079-0/-14/-15

### Technical Details

- **circuit breaker:**
  - electronic
- **circuit protector:**
  - electronic
- **Power-MOSFET:**
  - electronically
  - push button
  - 1-way
- **current ratings:**
  - adjustable
  - 0,5A - 10A
- **oprating voltage:**
  - DC 24 V
- **short circuit current:**
  - typ. 1.8 x IN
- **terminal block with:**
  - 17plus or SVS for block

### Temperature Range

- 0…+50 °C
- 0…+60 °C
- 0…+60 °C
- 0…+60 °C
- 25 °C…+50 °C
- 0…+50 °C

### General Data

- **plug-in on terminal block:**
  - rail mounting
- **spring-load terminals:**
  - screw terminals
  - push-in terminals
  - Sockel 80Plus
- **dimensions (w x h x d):**
  - 12.5 x 105 x 60 mm
  - 12.5 x 147.5 x 60 mm

### Accessories

- 60079-0/-14/-15
- IEC/EN
- CSA22.2 No.14 (1.2 x IN)
- UL508
- UL2367
- UL508
- UL 1604 class I, div 2
- CSA22.2 No. 14/142/213
- IEC/EN 60079-0/-14/-15
- ATEX

### Contact Information

- Courtesy of Steven Engineering, Inc - (800) 258-9200 - sales@steveneng.com - www.stevenengineering.com
Electronic circuit breaker
ESS20 (single pole), plug-in type

Product characteristics
- Rated voltage DC24V (18 ... 32 V), also battery-buffered
- Current ratings:
  - Adjustable: 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A
  - Fixed: 0.5 A, 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A
- Electronic, current limiting trip curve
- With physical isolation in accordance with UL1077 and VDE approval to IEC/EN60934
- Capacitive loads up to 75,000,000 μF and motors possible
- Aux. contact break contact or make contact
- LED status indication
- Manual ON/OFF switch
- Integral fail-safe element for power distribution systems
  - Module 17plus, SVSxx and Power-D-Box®

Features and benefits:
- Narrow width of only 12.5 mm
- Physical isolation
- Plug-in type
- A single trip curve for all types of loads
- Projectable protection through current limitation
- Approval to UL1077 and VDE (IEC/EN60934)

Electronic circuit breaker
ESS31-T (single pole) for rail mounting

Product characteristics
- Rated voltage DC24V (18 ... 30 V), also battery-buffered
- Fixed current ratings:
  - 0.5 A, 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A, 12 A
- Electronic, current limiting trip curve
- With physical isolation in accordance with UL1077 and VDE approval to IEC/EN60934
- Capacitive loads up to 40,000 μF and motors possible
- Aux. contact N/C or N/O
- LED status indication
- Manual ON/OFF switch
- Integral fail-safe element
- For rail mounting and for mounting side-by-side
- Integral power distribution system up to 40A load distribution

Features and benefits:
- Narrow width of only 12.5 mm
- Physical isolation
- A single trip curve for all types of loads
- Reliable protection through current limitation
- Approval to UL1077 and VDE (IEC/EN60934)

Electronic circuit protector
ESX10/ESX10-S (1-pole), pluggable

Product characteristics
- Rated voltage DC24V (18 ... 32 V), also battery-buffered
- Current ratings:
  - Fixed: 0.5 A, 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A, 12 A
  - Adjustable: 1 A ... 10 A (ESX10-S...)
- Electronic, current limiting trip curve
- Approval to UL 2367 as overcurrent protector, UL508 UL 1604 class I div.2, CSA 22.2, GL, ATEX, NEC class 2 (max. 3A)
- Capacitive loads up to 75,000 μF and motors possible
- Aux. contact, status output SF, remote ON/OFF, remote reset
- LED status indication
- Manual ON/OFF and reset switch
- Integral fail-safe element
- For power distribution systems
  - Module 17plus, SVSxx and Power-D-Box®

Features and benefits:
- Narrow width of only 12.5mm
- Plug-in type
- A single trip curve for all types of loads
- Projectable protection through current limitation
- Approval to UL 2367 as overcurrent protector
  - UL 508, UL 1604 class I div.2, CSA 22.2, GL, ATEX, NEC class 2 (max. 3 A)
Electronic circuit protector
ESX10-T (single pole) for rail mounting

Product characteristics
- rated voltage DC24V (18 ... 32 V), also battery-buffered
- current ratings:
  - fixed values: 0.5 A, 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A, 12 A, 16 A
  - switchable: 0.5A/1A/2A, 2A/3A/4A, 2A/4A/6A, 6A/8A/10A
- electronic, current limiting trip curve
- capacitive loads up to 75,000 μF and motors possible
- aux. contact, status output SF, remote ON/OFF, remote reset
- LED status indication
- manual ON/OFF and reset switch
- integral fail-safe element
- approval to UL 2367 as overcurrent protector
cUL 508, UL1604 class I div.2, CSA22.2, GL, ATEX, NEC class 2 (max. 3 A)
- for rail mounting and multi-way side-by-side mounting
- integral power distribution system up to 40 A load distribution

Features and benefits:
- narrow width of only 12.5 mm
- adjustable and fixed current ratings
- for rail mounting and mounting side-by-side
- a single trip curve for all types of loads
- projectable protection through current limitation
- approval to UL 2367 as overcurrent protector
  UL 508, UL 1604 class I div.2, CSA 22.2, GL, ATEX, NEC class 2 (max. 3 A)

Electronic circuit protector
REF16-S (single pole), plug-in type

Product characteristics
- rated voltage DC 24 V (18 ... 30 V)
- fixed current ratings:
  0.5 A, 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A
- electronic, current limiting trip curve
- capacitive loads up to 20,000 μF and motors possible
- auxiliary contact, status output SF
  remote ON/OFF (relay function), remote reset
- LED status indication
- manual ON/OFF and reset switch
- integral fail-safe element
- approval to UL 2367 as «Overcurrent Protector», UL 508
- for socket 80PLUS (push-in terminals) and 81PLUS (screw terminals)

Features and benefits:
- narrow width of only 12.5mm
- fixed current ratings
- for rail mounting and mounting side-by-side
- a single trip curve for all types of loads
- projectable protection through current limitation
- approval to UL 2367 as overcurrent protector
  UL 508, UL 1604 class I div.2, CSA 22.2, GL, ATEX, NEC class 2 (max. 3 A)
Electronic circuit protector
ESS22-T (double pole)

Product characteristics
● rated voltage DC24V (18 ... 32 V), also battery-buffered
● fixed current ratings:
  0.5 A, 1 A, 2 A, 3 A, 4 A, 6 A, 8 A, 10 A
● electronic, current limiting trip curve
● with physical isolation in accordance with UL1077 and VDE approval to IEC/EN60934
● capacitive loads up to 20,000 μF and motors possible
● aux. contact N/O or N/C
● remote ON/OFF, remote reset
● LED status indication
● manual ON/OFF switch
● integral fail-safe element
● for direct rail mounting

Features and benefits:
● narrow width of only 22.5mm
● 2-pole physical isolation
● for direct rail mounting
● a single trip curve for all types of loads
● projectable protection through current limitation
● approval to UL1077 and VDE (IEC/EN60934)
● meets the requirements of EN 60204-1, para 9.4.3.1
»Double pole protection of ungrounded DC 24 V systems«

Basic trip curve
Electronic overcurrent protection

Example: Electronic circuit breaker ESS20
Electronic current limitation to 1.8 x IN at short circuit or start-up
● time slot 100 ms... 3 s
  (loading time for capacitive loads, start-up of DC motors)
● electronic disconnection at overcurrent

Electronic circuit breaker ESS20
Overcurrent protection with electronic circuit breakers

Characteristic curves

### Electronic Circuit Breaker / Electronic Overcurrent Protector

<table>
<thead>
<tr>
<th>trip curve</th>
<th>trip curve comp.</th>
<th>voltage</th>
<th>manufacturer</th>
<th>type</th>
<th>rated current [IN]</th>
<th>min.</th>
<th>max.</th>
<th>ILimit *[1)]</th>
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<tbody>
<tr>
<td>EH B, C, d</td>
<td>nur DC</td>
<td>E-T-A</td>
<td>ESS20</td>
<td>0.5...10 A</td>
<td>1.05</td>
<td>1.35</td>
<td>typically 1.8/1.5 x IN</td>
<td></td>
</tr>
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<td>E B, C, d</td>
<td>nur DC</td>
<td>E-T-A</td>
<td>ESX10</td>
<td>0.5...12 A</td>
<td>1.05</td>
<td>1.35</td>
<td>typically 1.8/1.5/1.3 x IN</td>
<td></td>
</tr>
<tr>
<td>E B, C, d</td>
<td>nur DC</td>
<td>E-T-A</td>
<td>ESX10-T</td>
<td>0.5...12 A</td>
<td>1.05</td>
<td>1.35</td>
<td>typically 1.8/1.5/1.3 x IN</td>
<td></td>
</tr>
</tbody>
</table>

**Types of Circuit Breakers (electronic)**

| trip curve | standard/ | standard/ | standard/ | remark                      |
|------------| EU        | UL        | IEC        |                            |
| EH         | EN 60934  | UL 1077   | IEC 60934  | Supplementary Protector CBE (circuit breaker for equipment) |
| E          | open      | UL 2367,  | open       | Solid-State or Electronic  |
|            |           | UL 508    |            | Overcurrent Protector      |

### trip curve / Protection of small DC motors

- In a range of 1.1...1.8 x IN*[1)] the trip time is typically 3 s.
- The electronic current limitation typically begins at 1.8 x IN. **This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.8 times rated current is applied until disconnection.** The trip time varies between 100 ms and 3 s depending on the multiple of the current rating or at short circuit (Iₚ).
- Without the current limitation getting into effect at typically 1.8 x IN there would be a much higher overcurrent in the event of an overload or short circuit.

**Overload disconnection (OL) typically 1.1 x IN (1.05...1.35 x IN)**

*[1)] current limitation typically 1.8 x IN at IN = 0.5 A...6 A
- current limitation typically 1.5 x IN at IN = 8 A...10 A
- current limitation typically 1.3 x IN at IN = 12 A
- current limitation typically 1.15 x IN at IN = 16 A

*[2)] Due to the integral current limitation, the types ESX10 or ESX10-T (just like type ESS20) can be used as »Supplementary Protectors« directly at the DC 24 V output of a circuit breaker for the protection of the cables and loads in the control cabinet.
**Characteristic curves**  
**Electronic overcurrent protection**

**Electronic circuit breaker ESS20**
- In a range of 1.1...1.8 times the rated current ($I_{IN}$), the trip time is typically 5 s.
- Electronic current limitation typically starts at 1.8 times the rated current ($I_{IN}$). This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.8 times rated current is applied until disconnection*. The trip time is between 100 ms (short circuit $I_K$) up to approx. 5 s (in the event of overload with high cable attenuation).
- Without the current limitation getting into effect at typically 1.8 times the rated current ($I_{IN}$) there would be a much higher overcurrent in the event of an overload or short circuit.
- When the ESS20-0... has detected an overload or short circuit condition, the LED will change from GREEN to ORANGE. The LED goes out when the circuit breaker has tripped.
- Reset of the circuit breaker is only possible after the integral bimetal has cooled down (approx. 10 s).

*1) current limitation typically 1.8 x $I_{IN}$ at $I_{IN} = 0.5$ A...6 A  
current limitation typically 1.5 x $I_{IN}$ at $I_{IN} = 8$ A...10 A

**Electronic circuit breaker ESS31-T**
- The overload trip time is typically 500 ms (e.g. ESS31-T-...-6 A)
- The electronic current limitation typically begins in at 1.2 times the rated current ($I_{IN}$). This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.2 times rated current is applied until disconnection*. The corresponding current limitation value $I_{Limit}$ depends on the current rating of the device $I_{IN}$.
- Without the current limitation getting into effect at typically 1.2 times the rated current ($I_{IN}$) there would be a much higher overcurrent in the event of an overload or short circuit.
- Reset of the circuit breaker is only possible approximately 10 sec after tripping.

**Electronic circuit protector ESX10...**
- In a range of 1.1...1.8 times the rated current ($I_{IN}$) the trip time is typically 3 s.
- The electronic current limitation typically begins in at 1.8 times the rated current ($I_{IN}$). This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.8 times rated current is applied until disconnection*. The trip time varies between 100 ms and 3 s depending on the multiple of the current rating or at short circuit ($I_K$).
- Without the current limitation getting into effect at typically 1.8 times the rated current ($I_{IN}$) there would be a much higher overcurrent in the event of an overload or short circuit.

*1) current limitation typically 1.8 x $I_{IN}$ at $I_{IN} = 0.5$ A...6 A  
current limitation typically 1.5 x $I_{IN}$ at $I_{IN} = 8$ A...10 A  
current limitation typically 1.3 x $I_{IN}$ at $I_{IN} = 12$ A

---

**Figure:**
- Disconnection typically 1.1 x $I_{IN}$, 1.8 x $I_{IN}$
- Current limitation typically 1.8 x $I_{IN}$
- Trip time in seconds
- Times rated current

---

*Courtesy of Steven Engineering, Inc - (800) 258-9200 - sales@steveneng.com - www.stevenengineering.com*
Characteristic curves
Electronic overcurrent protection

Electronic circuit protector ESX10-S
- In a range of 1.1...1.8 x IN*1) the trip time is typically 3 s (e.g. ESX10-TB-...-6A).
- The electronic current limitation typically begins in at 1.8 x IN. This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.8 times rated current is applied until disconnection. The corresponding current limitation value \( I_{\text{limit}} \) depends on the current rating of the device IN (see table 1). The trip time varies between 100 ms and 3 s depending on the multiple of the current rating or at short circuit (\( I_{\text{k}} \)).
- Without the current limitation getting into effect at typically 1.8 x IN there would be a much higher overcurrent in the event of an overload or short circuit.

Electronic overcurrent protector REF16-S
- The trip time is typically between 80 ms to 800 ms depending on the current rating (IN).
- Electronic disconnection and/or current limitation begins at typically 1.25 times IN. This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.25 times rated current is applied.
- Without the current limitation getting into effect at typically 1.25 x IN there would be a much higher overcurrent in the event of an overload or short circuit.

Electronic circuit breaker ESS22-T
- In a range of 1.1...1.4 x IN*1) the trip time is typically 3 s.
- The electronic current limitation typically begins in at 1.4 x IN. This means: under all overload conditions (independent of power supply and load circuit resistance) typically 1.4 times rated current is applied. The trip time varies between 100 ms and 3 s depending on the multiple of the current rating or at short circuit (IN).
- Without the current limitation getting into effect at typically 1.4 x IN there would be a much higher overcurrent in the event of an overload or short circuit.
Graphical calculation
Trip at short circuit SMPS / Electronic overcurrent protection

Active current limitation ensures tripping at short circuit of the electronic overcurrent protection devices. The switch-mode power supply will not be overloaded and will reliably continue to supply the non-affected paths.

![Graphical Calculation](image)

**Reliable tripping**

of ESS20, ESX10(-T) and REF16-S

<table>
<thead>
<tr>
<th>cable cross section A in mm²</th>
<th>0.14</th>
<th>0.25</th>
<th>0.34</th>
<th>0.5</th>
<th>0.75</th>
<th>1.0</th>
<th>1.5</th>
</tr>
</thead>
<tbody>
<tr>
<td>distance L in metres (one-way length)</td>
<td>total cable resistance Ω = (R₀ x 2 x L)/A</td>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
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<td>775.92</td>
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<td>18.32</td>
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<td>1032.58</td>
<td>20.94</td>
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<td>9.49</td>
<td>7.12</td>
<td>4.75</td>
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<td>225</td>
<td>57.21</td>
<td>1160.91</td>
<td>23.56</td>
<td>16.02</td>
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<td>250</td>
<td>63.57</td>
<td>1289.24</td>
<td>26.18</td>
<td>17.80</td>
<td>11.97</td>
<td>8.90</td>
<td>5.93</td>
</tr>
</tbody>
</table>

Example 1: max. distance at 1.5 mm² and 3 A | 214 m (200 m correspond to 4.75 Ohm, 214 m correspond to 5.07 Ohm)

Example 2: max. distance at 1.5 mm² and 6 A | 106 m (100 m correspond to 2.37 Ohm, 106 m correspond to 2.37 Ohm)

Example 3: mixed wiring (control cabinet - sensor/actuator level) | R₁ = 40 m in 1.5 mm² and R₂ = 5 m in 0.25 mm²
R₁ = 0.95 Ohm \( R₂ = 0.71 \) Ohm \( R₁ + R₂ = 1.66 \) Ohm

Different supply lines and cable cross sections

rule of thumb (1): ESS20/ESX10/REF16 rated 3 A can protect cable resistances of 5 Ω

rule of thumb (2): at 1.5 mm²: 50 m distance = 100 m cable length = 1.2 Ω cable attenuation
Electronic overcurrent protection

Benefits

What are the user benefits of E-T-A's electronic overcurrent protection devices?

We meet the requirements of the updated Machinery Directive 2006/42/EC and EN60204-1 "Safety of machinery and electrical equipment", because:

● The electronic overcurrent protectors provide selective overcurrent protection: The faulty path is disconnected, the remaining components of the control technology (PLC, safety components, sensors, actuators, bus modules etc.) remain unaffected.

● The DC24V control voltage remains stable even in the event of a short circuit or overcurrent.

● Reliable trip at 1.1 x IN is ensured even with small cable cross sections and long load lines.

● Availability of the plant is increased significantly, as trouble shooting and maintenance becomes much easier.

● MCBs often cannot ensure selectivity and cable protection in DC 24 V systems. The overload or short circuit current is always determined by the total circuit resistance $R_{total}$, ($R_{total} = \text{cable resistance} + \text{internal resistance of protective element} + \text{contact resistance of terminals}$)

● Planning a DC 24 V application becomes much easier as the active current limitation to typically 1.8 times rated current provides a reliable planning factor for designing the size of the switch-mode power supply to be used and the size of the cable cross sections.

● In addition the current limitation increases typical life of relay and safety contacts in load circuits.

● The plug-in types (ESX10, REF16-S) allow quick change of the rating.

● In the event of repair works, removing the component establishes physical isolation and the current path is protected against re-connection. The types ESS20 and ESS31-T ensure physical isolation in the event of a failure (by bimetal operation).

Using electronic overcurrent protection is also a considerable contribution to cost reduction of the entire system:

● Switch-mode power supplies can now be used without problems.

● The narrow width of only 12.5 mm including auxiliary contacts allows smaller control cabinets.

● The single way design allows adjustment to the application in question or to the number of required load outputs. There are no extra costs through unused load outputs.

● E-T-A’s electronic overcurrent protection holds a single trip curve for resistive, inductive and capacitive loads. Even DC drives can easily be actuated and protected with these protection devices. The selected current rating has only to be adjusted to the load current and the cable cross sections used. This makes planning much easier and helps to reduce costs for electrical design.

● Besides fixed current ratings, we can also offer switchable devices. They help to realise the entire overcurrent protection design with only one or two types.

The advantages of E-T-A's electronic overcurrent breakers and protectors at a glance:

- small width
- adjustable and fixed current ratings
- only one trip curve required
- ease of planning
- high system and plant availability
- cost reduction
## Electronic overcurrent protection

### Overview of standards
- **UL 1077** Supplementary Protectors for Use in Electrical Equipment
- **UL 2367** Solid State Overcurrent Protectors
- **UL 508** Industrial Control Equipment
- **UL 1604** Electrical Equipment for Use in Class I and II, Division 2, and Class III Hazardous (Classified) Locations
- **UL 489** Molded-Case Circuit Breakers, Molded-Case Switches and Circuit Breaker Enclosures
- **UL 60950-1** Information Technology Equipment - Safety - Part 1 General Requirements
- **UL 508A** Industrial Control Panels (requirements for control cabinets)

### Excerpt from the UL508 approval of the ESX10-T (example):
The UL approval document of type ESX10-T (to UL508), file no. E322549 shows an information on page 2 under "General" that the ESX10-T can even be used as a "Supplementary Protector" due to its integral current limitation. = page 1)

### 1(1) UL Comment

**GENERAL:**

These devices are single pole electronic over-current switches which limit the overload current to 180 percent of rated current. They are intended to provide supplementary protection within electrical equipment.

<table>
<thead>
<tr>
<th>Approval mark</th>
<th>Type</th>
<th>Approvals / Standards as per 17 March 2014</th>
</tr>
</thead>
<tbody>
<tr>
<td>ESS20</td>
<td>Electronic Circuit Breaker</td>
<td>UL 1077: Supplementary Protectors for Use in Electrical Equipment, File E67320</td>
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<tr>
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<td>Comment: According to UL 508A, table SA 1.1, section 40.1.3 only devices approved to UL 1077 (=Supplementary Protectors-) may be used for overcurrent protection in control circuits which have been designed as &quot;Industrial Control Panel&quot; to UL 508A</td>
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<tr>
<td>ESS31-T</td>
<td>Electronic Circuit Breaker</td>
<td>UL 1077: Supplementary Protectors for Use in Electrical Equipment, File E67320</td>
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<td>Comment: According to UL 508A, table SA 1.1, section 40.1.3 only devices approved to UL 1077 (=Supplementary Protectors-) may be used for overcurrent protection in control circuits which have been designed as &quot;Industrial Control Panel&quot; to UL 508A</td>
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<tr>
<td>ESX10-T</td>
<td>Electronic Overcurrent Protector</td>
<td>UL 2367: Solid State Overcurrent Protectors File E306740</td>
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<td>UL 508: Industrial Control Equipment File E322549</td>
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<td>UL1604: Electrical Equipment for Use in Hazardous Locations Class I div 2, Groups A, B, C, D; TC T5; File E329204</td>
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<td>17plus</td>
<td>Power Distribution System (ESS20/ESX10)</td>
<td>UL 60950-1: Information Technology Equipment - Safety - Part 1 General Requirements, File E216113</td>
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<td>SVS..</td>
<td>Power Distribution System (ESS20/ESX10)</td>
<td>UL 508: Industrial Control Equipment Comment: UL approval for SVS under discussion, components (pcb, terminal blocks etc.) UL approved</td>
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<td>Here: SVS04-08</td>
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</table>

Courtesy of Steven Engineering, Inc - (800) 258-9200 - sales@steveneng.com - www.stevenengineering.com
Space-saving design, application and wiring
Electronic overcurrent protection

installation width:
18 mm + 9 mm = 27 mm

-50%!

MCB and signalling module

installation width: 12.5 mm each
Standard solutions
Modular power distribution Module 17plus

- modular power distribution system, total current max. 32A/ 50A
- two-way terminal block
- DC24V supply via busbars
- load output (protected): 1 x per way
- signal supply via left and and right terminal blocks
- signalling already pre-wired, external protection required
- for all types ESS20-..., ESX10-1.., 2210-S21.

Standard solutions
Socket 80Plus / 81Plus

- modular sockets, total current max. 32 A/41 A
- single way design
- PT terminals (80Plus)
- screw terminals (81Plus)
- retaining clips for a tight fit of the breakers
- DC 24 V+ and GND can bridged via jumpers
- load output (protected):
  - 2 x per way (80Plus), 1 x per way 81Plus
- signal supply
- signalling variants via busbars
- for all breakers type REF16-S and 2216-S
### SVS02-x

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<tr>
<th>Product</th>
<th>Number of slots</th>
<th>Dimensions: mm (without CBE, including rail)</th>
<th>Tolerance to DIN ISO 285 part 1 IT13</th>
<th>Fitted with</th>
<th>Max. Amperage</th>
<th>Operating Voltage</th>
<th>Supply Terminals</th>
<th>Load Outputs per Slot</th>
<th>Min. Outputs per Load</th>
<th>Signalling Line Entry / Outputs</th>
<th>Signalling</th>
<th>Termination Cross-Sections</th>
<th>Remote Control Input</th>
<th>Specials to Customer</th>
<th>Bus-Connection</th>
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<td>4/8/12/16</td>
<td>8 ways: 52.1 x 109.5 x 105.4</td>
<td>52.1 x 171.5 x 105.4</td>
<td>8 ways: 52.1 x 235.5 x 105.4</td>
<td>10 ways: 52.1 x 296.5 x 105.4</td>
<td>4/8/12/16 ESS20-003</td>
<td>EXXI0-103 2210-027x3500</td>
<td>24 V DC</td>
<td>5 x (L+) protected</td>
<td>2 x per way</td>
<td>Terminal X31</td>
<td>10 mm² max. (S1) plug-in type</td>
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### SVS04-x

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<th>Max. Amperage</th>
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<th>Supply Terminals</th>
<th>Load Outputs per Slot</th>
<th>Min. Outputs per Load</th>
<th>Signalling Line Entry / Outputs</th>
<th>Signalling</th>
<th>Termination Cross-Sections</th>
<th>Remote Control Input</th>
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<td>4/9/13/16</td>
<td>8 ways: 52.1 x 125.5 x 105.4</td>
<td>52.1 x 167.5 x 105.4</td>
<td>8 ways: 52.1 x 211.5 x 105.4</td>
<td>15 x terminals X22-X24</td>
<td>30 x terminals X22-X24</td>
<td>15 x terminals X22-X24</td>
<td>10 mm²</td>
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### SSV14-x

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<th>Tolerance to DIN ISO 285 part 1 IT13</th>
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<th>Min. Outputs per Load</th>
<th>Signalling Line Entry / Outputs</th>
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<th>Termination Cross-Sections</th>
<th>Remote Control Input</th>
<th>Specials to Customer</th>
<th>Bus-Connection</th>
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| SSV14-x | 4/9/13/16 | 10 ways: 64.5 x 104 x 184 | | | | | | | | | | | | | |"
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<th>Max. Amperity</th>
<th>Total Current</th>
<th>Voltage</th>
<th>Supply Terminals</th>
<th>Load Outputs</th>
<th>Minus Outputs</th>
<th>Signalling</th>
<th>Termination Cross-Sections</th>
<th>Remote (Control Input)</th>
<th>Specials</th>
<th>Bus-Capable, Connection</th>
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<td>8/12/16</td>
<td>8 ways 56.5 x 184 x 127.8 16 ways 56.5 x 284 x 127.8</td>
<td>EEX10-145 E-164B-7xx</td>
<td>Max. 40 A</td>
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<td>2 x 6 pin</td>
<td>20</td>
<td>1 x per way</td>
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<td>SVS18</td>
<td>10 ways</td>
<td>50 x 185 x 142.3</td>
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<td>Max. 6 A</td>
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<td>24 V DC</td>
<td>U+B</td>
<td>2 x 9 pin</td>
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<td>1 x per way</td>
<td>Group-signalling terminals X31</td>
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<td>56.4 x 210 x 142.3</td>
<td>ES20-003 ES20-103</td>
<td>Max. 40 A</td>
<td>Max. 8 A</td>
<td>24 V DC</td>
<td>U+B</td>
<td>2 x 9 pin</td>
<td>8</td>
<td>1 x per way</td>
<td>Group-signalling terminals X31</td>
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<td>No</td>
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</table>

Note: PROFIBUS is a bus-capable communication protocol, and PROFIBUS is a customer special.
ControlPlex® Board
Intelligent power distribution system SVS100

Intelligent DC 24 V Power Distribution System

- Fieldbus versions
  - PROFIBUS-DP
  - Modbus-RTU
  - DeviceNet
  - CC-Link
  - CANopen
  - Interbus
  - ...

- Ethernet versions
  - Profinet
  - EtherNet/IP
  - EtherCAT
  - Modbus-TCP
  - ...

ControlPlex®
Intelligent power distribution system SVS100

ControlPlex® consists of SVS100-PWR and SVS100-COM
- Power distribution backplane for 16 ways (or 8 ways)
- Supply +24 V, 0 V, PE 2 x 10 mm² each, max. 40 A
- All terminals: spring-loaded terminals or push-in
- To be used in decentralised IP67 systems and at the same time as IP20 solution
- Voltage supply for all ways F1 to F16 and of the loads is effected directly from the DC24V supply. The supply for the electronic control unit (COM module) can also be fed separately
- Protection for SVS100-COM is already integrated
- Additional integral total current measurement on the SVS100 (max. 50A)
- Complete wiring of US1, US2, 0 V, 0 V, PE per slot
- Joint US1 supply (SVS100-16-PWR)
  A) 1 x US1 via F1 (7 x US2 output to F2, F3, ..., F8)
  B) 1 x US1 via F9 (7 x US2 output to F10, F11, ..., F16)
- Extendable to 64 ways by way of cascading of the power distribution systems
**ControlPlex® Board**

Intelligent power distribution system SVS100

**ControlPlex®** for electronic circuit protectors type **ESX50D-S**, plug-in types for F1 to F16, parameterisable current rating 1…10 A, per software with internal communication interface (right unit)

**ESX50D** version: “OFFLINE” rating adjustment directly on the unit via selector switch 1 A … 10 A (left unit)

**Features of type ESX50D-S**
- A single trip curve for all types of loads (capacitive load up to 40,000μF, DC motors etc.)
- Adjustable alarm values for the load current, e.g. 90% (50% ... 100%)
- Indication of input voltage, load current, load voltage, limit values, unit temperature
- Status indication system voltage (“DC24V OK”)
- Status indication per way (overload/short circuit)
- Adjustment of switch-on delay/disconnection sequences per software (e.g. for PROFlenergy)
- QUIT/RESET and ON and OFF operation per way possible (e.g. for PROFlenergy)
- Additional manual reset on the device possible
- Multicoloured LED, to be switched off ONLINE & OFFLINE, “Sleep Mode” (e.g. PROFlenergy)
- History memory (“HISTOMEMO”), event-triggered recording of measuring values

**ControlPlex® Software and user dialogue platform**
- Clear lay-out “At a glance: Everything hunky-dory”.
- Parameterisable via USB or directly via communication interface e.g. current rating 1 A to 10 A in 1A steps, limit values, switch-on sequences ...

**Optional**: current rating adjustable directly on the unit
- All adjustments can be saved (internally or externally), documentation serves as a test record of machine/system. All future changes or replacements will be recorded.
- Ease of start-off without manual, only “Windows” and “Mouse” knowledge required.
- Start-up configuration is saved for machine approval, system documentation etc.
- Overcurrent parameters are not accessible to the user. The only electronic trip curve for all DC 24 V load types makes electrical planning easy!
Customer-specific solutions from Power-D-Box® to control cabinet

Standard 19" box
PDB-P-L-ESS20-30A0-B1
● for the electronic circuit breaker ESS20

Special version 19" box S438 with de-coupling diodes
19BGT-3-ESS20-30R2RB-B1GR-LS438
● for the electronic circuit breaker ESS20
Customer-specific solutions
from **Power-D-Box®** to control cabinet

**Control cabinet SBG T018**
- economic and space-saving control cabinet design
- saves up to 50% of costs through use of cascadable power distribution systems for DC24V with slots for electronic circuit breakers

New possibilities provided by additional electronic sub-assemblies:
- intelligent alarm processing
- remote control
- bus connection
- emergency functions
- redundancy
Customer-specific solutions from Power-D-Box® to control cabinet

Demo control cabinet T029

Redundant power supply with diode de-coupling

Power Distribution Module (PDM) for ESX20, 2216 and REF16

Power distribution systems SVS for ESX10-S and ESS20

High current distribution by means of XB345-D01 and hydraulic-magnetic Circuit Breaker Type 8345
Customer-specific solutions from Power-D-Box® to control cabinet

AC power distribution system SBG-V0071 for 10 load circuits protected with thermal-magnetic Circuit breaker 2216 and main switch (back-up fuse) through 2-pole, hydraulic-magnetic circuit breaker 8340-F.
Customer-specific solutions from **Power-D-Box®** to control cabinet

Power supply and protection module **SBG-V0057** with SMPS 20A and for eight load circuits, protected by electronic circuit protector type **REF16** for installation in control cabinets, compatible with servo outputs for motor drives.
Customer-specific solutions
from Power-D-Box® to control cabinet

Power Distribution Module (PDM) and Power Distribution Box (PDB) for thermal-magnetic circuit breaker type 2216 and electronic circuit protector type REF16-S

- Redundant (2 x 15 ways) or non-redundant (1 x 30 ways)
- Mounting on rear wall in control cabinet (PDM) or in 19" rack (PDB)
- Spring-loaded terminals on the rear or front
- Line entry up to 2 x 80A
- Group signalling
- Voltage monitoring optional
E-T-A
A globe-spanning network

Europe
- Belgium
- Bosnia/Herzegovina
- Bulgaria
- Denmark
- Germany
- Finland
- France
- Ireland
- Italy
- Croatia
- Luxemburg
- Macedonia
- Montenegro
- Netherlands
- Norway
- Austria
- Poland
- Portugal
- Russia
- Sweden
- Switzerland
- Serbia
- Slovakia
- Slovenia
- Spain
- Czech Republic
- Turkey
- Hungary
- United Kingdom

America
- Argentina
- Brazil
- Chile
- Canada
- Mexico
- USA

Asia
- Brunei
- China
- Hong Kong
- India
- Indonesia
- Japan
- Korea
- Malaysia
- Philippines
- Singapore
- Taiwan
- Thailand

Africa
- South Africa
- Tunisia

Oceania
- Australia
- New Zealand