

Overcurrents and Short Circuits: their Effects on Energy Metering in Data Centers

Protection, coordination and measurement challenges in high short-circuit level environments



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Context

The evolution of electrical installations is accompanied by increasing demands for safety, reliability, and accuracy in energy measurement. Distribution boards, subjected to ever-increasing loads, experience a significant rise in short-circuit current levels. This situation requires careful consideration regarding the selection of appropriate metering and protection devices to guarantee the safety and longevity of the installations.

Some examples of short-circuit levels:

- Up to 50 kA in the tap-off boxes in the data centers
- Up to 19 kA for 16A circuits in distribution boards

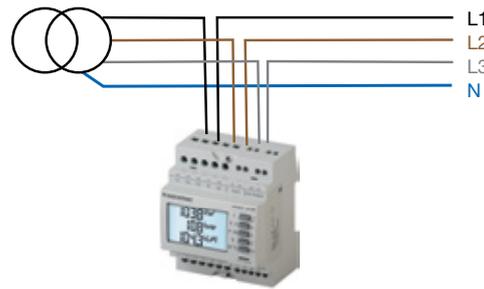
In this technical note, we analyse the behavior of direct and indirect electricity meters in the presence of short circuits and overloads, as well as the solutions and tools offered by Socomec to guarantee the safety and performance of the equipment.

Some reminders

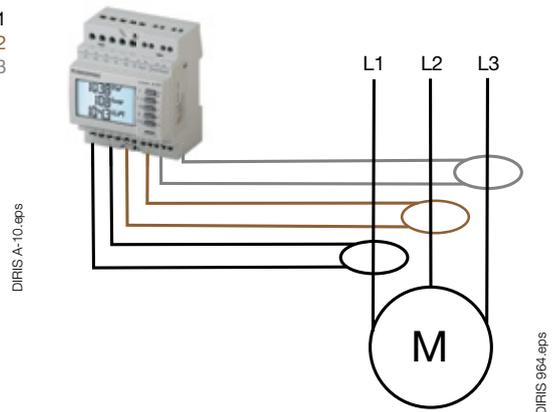
Electricity meter

An electricity meter measures the energy consumed or produced and various others electrical parameters. It can be direct connection (installed in series in the circuit) or indirect connection (measurement via current transformers).

Direct connection electric meter



Electric meter with indirect connection



Current transformer

A current transformer (CT) transforms a primary current, usually too high for electricity meters, into a secondary current or voltage signal of lower value, compatible with this latter.

Short circuit

A dangerous electrical fault caused by an unintentional connection between two active conductors, resulting in a sudden surge of current (up to $100 \times I_n$). Without adequate protection (circuit breaker or fuse), this can lead to fire and material damage.

Overload

A gradual increase in current above rated values. Like a short circuit, it can cause fires or damage if the protection is inadequate.

Some reminders (cont.)

There are two types of overloads:

- **Long overloads:** Up to $2 \times I_n$ for 2 hours. This usually occurs when the rated current value of a cable is exceeded.
- **Short-term overloads:** Up to $10 \times I_n$ for a few seconds (e.g., engine start-up)

Comparison of Different Starting Modes for Asynchronous Motors

Type	I_d / I_n	C_d / C_n	Speed Control	Torque Control	Main Advantage	Disadvantage
Direct Start	05 to 10	05 to 10	No	No	Low cost, high starting torque	High starting current
STAR - DELTA	2 to 3	1 to 2	No	No	Reduced starting current	Reduced starting torque
Auto transformer	2 to 3	1 to 2	No	No	Reduced starting current	Heavy weight
Soft Starter	3 to 5	1,5 to 2,5	No	Yes	Reduced starting current, control of start/stop	Reduced starting torque
Variable Speed Drive	1.5	1.5 to 2	Yes	Yes	Speed control, energy saving at reduced speed	High Cost

Mechanical constraint

also called electrodynamic constraint, it is expressed in kA and represents the maximum current peak that the electrical equipment will withstand.

Thermal constraint

expressed in A^2s , it is the thermal envelope of the energy that will pass through the equipment during a given time.

Behavior of direct meters in the presence of overcurrents

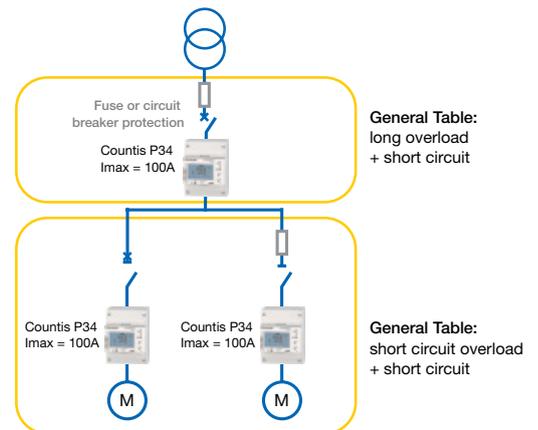
Direct meters are chosen for low current applications (< 100A) because they offer the following benefits: compactness, reduced cost, speed of implementation.

By design, direct meters are installed in series in the circuit. They therefore share the same protection than the conductor and are thus directly exposed to the same events than the load being measured:

- Long overloads
- Short-term overloads
- Short circuits

Generally, when a meter is protected by a device located on a conductor supplying multiple circuits, it is exposed to both prolonged overloads and short circuits. Conversely, if the meter is installed directly in the circuit of an individual load, it will primarily be subjected to short-circuit overloads and short circuits.

Consequently, it is necessary to verify that the protection put in place also ensures the protection of the meter.



Withstand constraint of direct meters

The standard for electricity meters, IEC 62052-11 (Electricity meters – General characteristics and testing) and EN 50470-3 (MID Directive), require a current withstand test of $30 \times I_{max}$ over 10 ms.

This implies that the electrodynamic and thermal constraint of the meter are as follows:

- **Electrodynamics constraint:** $30 \times I_{max} \times \sqrt{2}$
- **Thermal constraint:** $30 \times I_{max}^2 \times 0,01$

For example, the COUNTIS P34, rated at 0.3 – 10(100) A, has a maximum current (I_{max}) of 100 A. Its constraints are therefore as follows:

- Electrodynamic constraint = $30 \times 100 \times \sqrt{2} = 4243 \text{ \AA}$
- Thermal constraint = $30 \times 100^2 \times 0,01 = 90 \text{ kA}^2\text{s}$



It is therefore necessary to validate the coordination between the line protection and the meter, to validate that the mechanical and thermal constraints limited by the protection (fuse or circuit breaker) are supported in each of the following scenarios: overloads (long and short) and short circuit.

Behavior of direct meters in the presence of overcurrents (cont.)

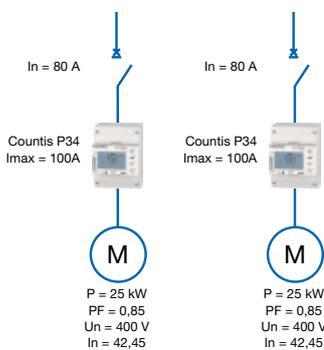
Case of long overloads

Beyond I_{max} , the meter's operation is no longer guaranteed. However, the protection is often calibrated at I_{max} , which is a problem because in the event of a long overload, the current exceeds the meter's maximum value.

By standard, the protection used must open the circuit within a conventional time (generally 1 hour) for a defined current:

- Fuse: $1.6 I_n$
- C-curve circuit breaker: $1.45 I_n$
- Industrial circuit breaker: $1.3 I_n$

A 100A fuse, for example, will guarantee a meltdown in less than 1 hour for a current greater than 160A (100×1.6).



Let's take the case of a Countis P34 measuring a 25 kW three-phase motor protected by a fuse or circuit breaker of 80A rating:

For the fuse, the melting current in case of overload is 128A ($80 \times 1.6 = 128$).

For the circuit breaker, the tripping current in case of overload is 104A: ($80 \times 1.3 = 104$).

Finally, in our example, regardless of the protection used for an 80A circuit breaker, the operating current is always higher than the meter's I_{max} value. Therefore, in the event of a long overload, the cables will be well protected by the circuit breaker, but the meter itself may be damaged.

Therefore, to ensure effective protection of the meter, the nominal current of the installation must be limited by installing a 50A fuse or a 63A circuit breaker.

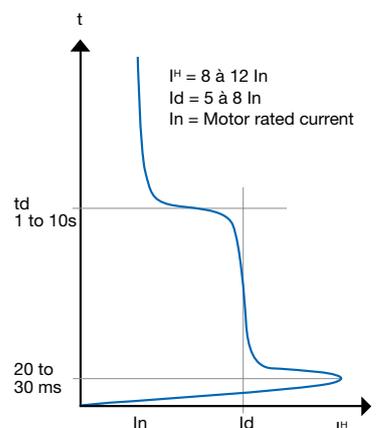
The table below summarizes the recommended protection rating based on the I_{max} value of the meter.

Recommended protection rating based on the I_{max} meter				
I_{max} of the electric meter (A)	40	45	80	100
Circuit breaker protection rating (A)	32	32	50	63
Fuse protection rating (A)	25	25	50	50



The results of the study show that the mechanical and thermal constraint withstand by the meter are greater than those induced during engine start-up, which allows us to affirm that the meter will remain undamaged during this phase.

Case of short overloads



In the event of a short-term overload, it is necessary to verify that the meter can withstand the mechanical and thermal constraint generated by the overload

Let us return to the previous case of a direct 100A meter measuring a 25 kW three-phase motor protected by an 80A circuit breaker.

During the first startup phase, which lasts approximately 20 to 30 ms, the current can reach up to $10 \times I_n$, or 425 A. During the second phase, which can last up to 10 s, the current reaches 5 to 8 I_n , resulting in a total thermal constraint of 18 kA²s.

It is therefore necessary to ensure that the mechanical and thermal constraints permissible by the meter are respectively greater than 425 A and 18 kA²s.

	100A Meter	25 kW motor start
Mechanical constraint (A)	4 200	425
Thermal constraint (A²s)	90,000	18,000

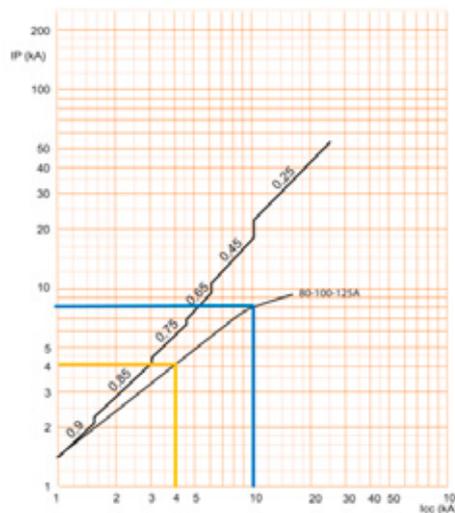
Behavior of direct meters in the presence of overcurrents (cont.)

Case of short circuits

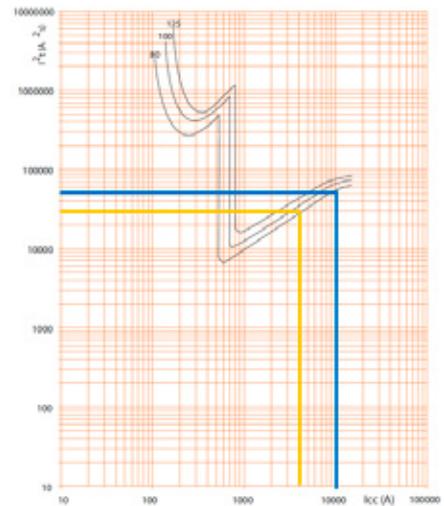
In the event of a short circuit, it is necessary to verify that the mechanical and thermal constraint limited by the protection can be supported by the meter.

Let's take the previous example where a direct 100A meter installed in a sub-panel is protected by a C-curve circuit breaker of 80 A rating with, in one case, an ICC of 10kA (in blue) and in the other case an ICC of 4kA (in orange).

Current limiting curve:



Thermal limiting curve of circuit breakers
Curve C, 1P, 3P, 4P (400 V / 60 Hz)



Whether the short-circuit current (ICC) is 10 kA or 4 kA, the thermal constraint limited by the circuit breaker is lower than the thermal constraint of the meter. However, the mechanical constraint limited by the protection device is only lower than the one of the meter when the ICC is equal to 4 kA.

Conclusion on direct meters



Installing a direct meter in a circuit makes it vulnerable to various incidents, including short and long overloads, and short circuits.

In these situations, the existing protection is often insufficient to effectively safeguard the meter, which can lead not only to its deterioration but also compromise the safety of the entire installation.

- Fire hazard
- Flash Risk
- Risk of property damage

Faced with these risks, the coordination between the meter and the protection system must be validated as follows:

- Compare the manufacturer performance of each actor
- Perform a coordination test

If the coordination is not validated, an indirect metering system will need to be implemented (**Socomec approach**).

! Installing a direct meter on an installation with a short circuit current (ICC) of 10 kA can therefore be dangerous in the event of a short circuit.

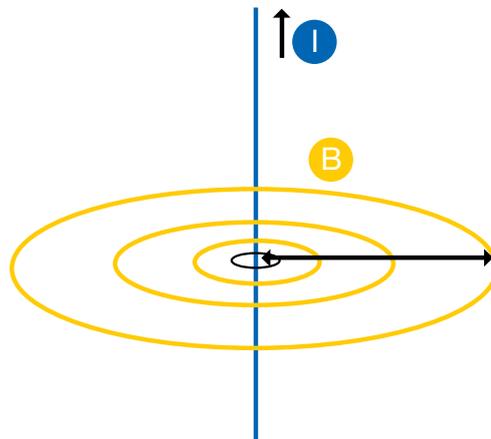
Behavior of indirect meters in the presence of overcurrents

Constraints on the performance of indirect meters

With indirect meters, the load current is measured using a current transformer. As a reminder, when an electric current flows through a conductor, a magnetic field proportional to that current is induced (Lenz-Faraday Law).

This is the principle used by current transformers to accurately measure the current value (see technical note: *Current Sensors*).

This is therefore a **non-intrusive measure**: the meter is no longer subject to the same events as the load (overloads, short circuits).



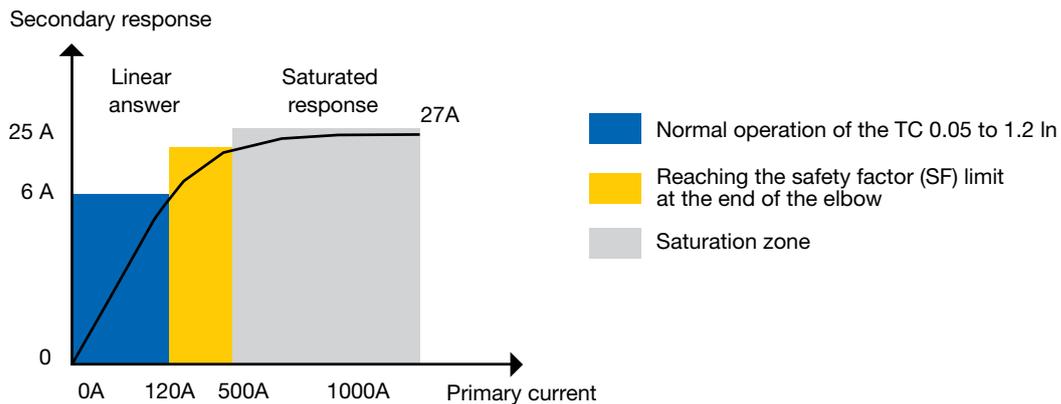
$$B = \frac{\mu_0 I}{2\pi d} \quad \longrightarrow \quad B \leftrightarrow I \text{ Proportional}$$

Behavior of indirect meters in the presence of overcurrents (cont.)

Case of standard current transformers

One of the defining characteristics of a current transformer is its safety factor (SF), which defines the transient response during which the CT's temperature rises before reaching the critical temperature defined by its class.

The curve below shows the response of a 100/5A current transformer with a safety factor of FS5.



In the saturation zone, shown in red, the TC suffers no damage for a few minutes (however, measurement performance is degraded).

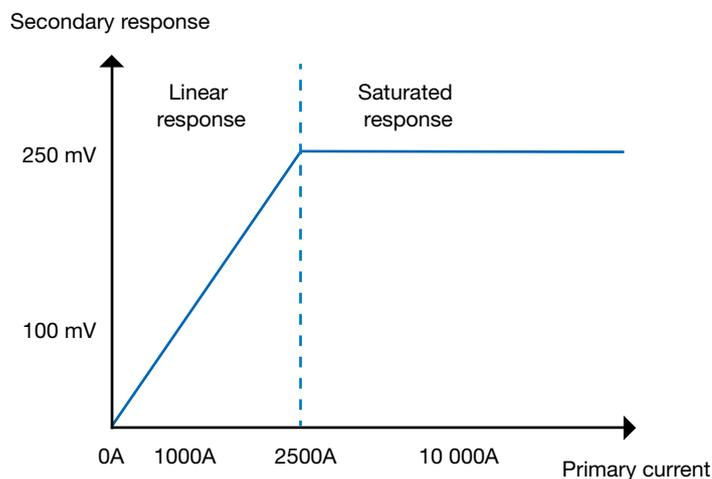
In the transition zone, shown in yellow, there is a heating constraint defined by a letter, ranging from A to H. Socomec TCs are class E, meaning they can heat up to 120°C without being degraded

	A	E	B	F	H	C
Maximum value	105°C	120°C	130°C	155°C	180°C	
Thermal margin	5°C	5°C	10°C	10°C	15°C	
Warm-up allowed	60°C	75°C	80°C	105°C	125°C	
Ambient temperature	40°C	40°C	40°C	40°C	40°C	

Whether in the presence of a long, short, or even short-circuit overload, the circuit breaker or fuse protection always trips before (a few seconds) the current transformer reaches its heating limit (several minutes).

Behavior of indirect meters in the presence of overcurrents (cont.)

Case of smart sensors (TE, TR, iTR, TF and QCT)



Réponse en tension d'un TE-55 face à un court-circuit

The output signal of the smart sensors (TE, TR/ iTR, TF, and QCT series) is a voltage that varies between 0 and 100 mV, proportionally to the measured current.

In the presence of a short circuit or overload, the voltage saturates at 250 mV regardless of the current level reached.



The Diris Digiware I-xx, F-xx, and R-xx PMD, when used with these sensors, accept an input voltage of up to 1V, which is four times the maximum value delivered by the sensors. Therefore, there is no risk of damage to either the sensor or the data logger. Il en est de même pour les compteurs Countis P44-xQCT associés aux capteurs QCT. The same applies to Countis P44-xQCT counters associated with QCT sensors.

Behavior of indirect meters in the presence of overcurrents (cont.)

Case of Diris Digiware S and BCM measurement units

The Diris Digiware S and BCM power meters integrate current measurement into the unit itself. These devices are therefore installed in series in the circuit, just like direct meters, but since the technology used for current measurement is based on Rogowski (voltage equal to the derivative of the changing magnetic field induced by the passage of current through a conductor), they remain immune to overloads and short circuits

Internal tests have been carried out and have shown that the device can withstand up to 94,500 A, or 1,500 times the I_n value (63 A), without any damage to the electronics. At this current level, the protective device would have tripped well before then.



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appl_1086.eps

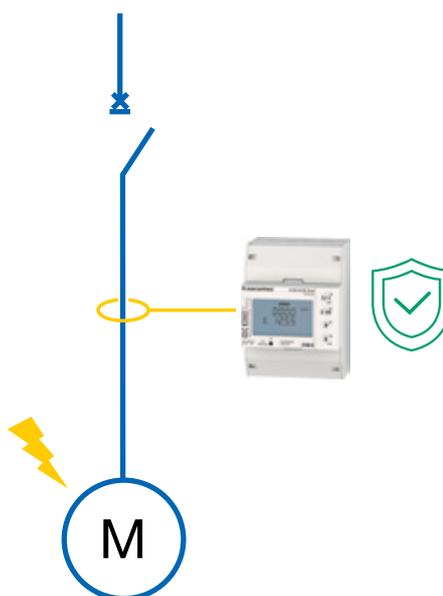
The Diris Digiware S and BCM products therefore appear as the ideal solution, particularly for Datacenter applications, because they are robust, reliable, compact and immune to overloads and short circuits.

Behavior of indirect meters in the presence of overcurrents (cont.)

Conclusion on indirect meters

Indirect meters have the advantage of being completely isolated from the measurement circuit thanks to the use of current transformers. Regardless of the nature of the event (overload or short circuit), protection will always activate before the transformer suffers any damage.

The Diris Digiware S and BCM power meters combine the advantages of direct meters (compactness and ease of installation) and those of indirect meters (immunity to overloads and short circuits), thus offering a robust and versatile solution.



In summary

Direct meters for low currents are often preferred due to their lower cost and simpler installation compared to indirect meters. However, this solution presents significant risks, particularly in the event of a short circuit or overload. Indeed, during an overcurrent, the direct meter generally cannot withstand the mechanical and thermal constraint limited by the line protection, which can lead to irreversible damage or even compromise the safety of the installation (risk of fire).

Coordination result for the Countis P34 direct meter:

Main metering unit (Main board)				
ICC presume	Protection rate	Long overload	Short circuit	Coordination
10 kA	80 A	No	No	No
10 kA	50 A	Yes	No	No
4 kA	50 A	Yes	Yes	Yes
Individual Counting (distribution board)				
ICC presume	Protection rate	Short overload	Short circuit	Coordination
10 kA	80 A	Yes	No	No
4 kA	50 A	Yes	Yes	Yes

To address this issue, a thorough study can be conducted to validate the coordination between the protection system and the meter. However, Socomec recommends using indirect meters, which, by design, are immune to short circuits and overloads.

- Use of current sensor (Diris Digiware I-xx, Countis P4x)
- Integrated sensor (Diris Digiware S)

Coordination result for indirect counter Countis P44-4QCT:

Main metering unit (Main board)				
ICC presume	Protection rate	Long overload	Short circuit	Coordination
10 kA	80 A	Yes	Yes	Yes
10 kA	50 A	Yes	Yes	Yes
4 kA	50 A	Yes	Yes	Yes
Comptage individuel (TD)				
ICC presume	Protection rate	Short overload	Short circuit	Coordination
10 kA	80 A	Yes	Yes	Yes
4 kA	50 A	Yes	Yes	Yes

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