# Protection of Control Transformers for use in North America


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Technical Paper

**Dipl.-Ing. Wolfgang Esser**

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**Protection of Control Transformers and Power Supply Units for use in North America**

– Differing types of protective devices are used for control transformers, power transformers and/or DC power supplies –

Many design engineers, who usually work according to IEC and European standards, are rather unsure of protection requirements when it comes to transformers and/or DC power supplies for use in North America. This article describes the most common and suitable concept for export to that continent.

The protection of "motors" and "transformers" in North America is subject to different standards.
In addition, it is particularly important to further differentiate between control (voltage) transformers and power transformers, both of which can span similar voltage ratings and power ranges. This article will mainly deal with the protection of control transformers.

The type of protection afforded by small European motor-protective starters is also worthy of mention. New North American motor-starter combinations known as *"Motor Starter Types E and F"* have in the meantime become well established in Europe and other IEC countries [1]. However, there is still a certain amount of confusion amongst specifying engineers because solutions involving added air and creepage clearances on the incoming supply side terminals of these products are seemingly not providing any additional relief with respect to the protection of control transformers. In the USA for example, the better solution is often to simply rely on the general approval of the Moeller *PKZM0* as a *Tap Conductor Protector* for the purpose of providing protection of control transformers.

In order to avoid any engineering pitfalls, **Table 1** describes various differences within the North American standards on a point by point basis. The divergences in the Canadian standards will likely be harmonised in the future to correspond more with the UL standards. Until then, strict adherence to each respective standard with respect to certain component based differences must be observed in order to ensure a problem free acceptance of engineered systems and assemblies. The solutions presented reflect in part Moeller's ability to achieve specific component approvals made possible by the use of special constructive features. Similar products of other makes do not necessarily feature the same approvals and application possibilities.

Moeller has retracted its previous UL listing for the transformer-protective starter type *PKZM0-..-T* as the limitations presented by its approval made it difficult to apply in a manner more appropriate to its design. An adhesive label featuring a required marking, which was also deemed necessary at the time, has also been discontinued. The *PKZM0-..-T* is now applied solely outside North America and continues to be used to protect a variety of transformers.

**World-wide standards differ for the European motor-protective starter**

The European motor-protective starter – e.g. the *PKZM0* from Moeller (**Figure 1**) – has proven itself millions of times around the world. Excellent value for the money, exceptionally compact dimensions and all the benefits of fuseless based switchgear concepts have all contributed to greatly enhance the popularity of this switch. This viewpoint is not quite as widely shared and accepted in North America. Yet, the many potential American customers who have already been confronted by the "little wonders" on machine exports from Europe have now become thoroughly convinced of its economic advantages. The combination of these motor-protective starters with modern busbar adapters now allows for huge savings in mounting time and provide for a particularly efficient use of panel space. Adaptation to the North American standards is, on the other hand, a little more painstaking and steps towards full harmonization of global standards are still ongoing, making uniform usage world-wide still a difficult task. Exporting manufacturers of machines and systems also wish to use the small motor-protective starters in North America for the protection of control transformers.

Still, the following characteristics, peculiar to the North American market, must be observed.

**Motor protection takes a step further towards the IEC world**

In the US and Canada a differentiation is made between devices for *Energy distribution (such as Molded Case Circuit Breakers*, standard: UL 489) and those for *Industrial Control (Industrial control equipment*, standard: UL 508). Typically the standards, such as those mentioned, place differing demands on the construction and sizing of switching and protective devices. This type of differentiation is very uncommon in the IEC world and is often the source of fundamental misunderstandings in how these devices are properly applied in each market.
**Note:** For the sake of brevity, the standards referred to in the text are those applicable to the US. In actual fact, the contents of UL 508 are very similar to the Canadian standard CSA-C22.2 No. 14. UL 489 and CSA-C22.2 No. 5-02 have also been harmonised in the meantime. Small divergences with

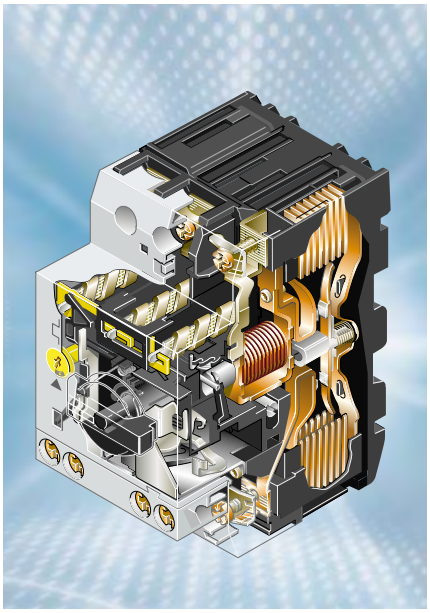

**Figure 1: Cut-away view of a best seller. Motor-protective starter (circuit-breaker) *PKZM0* is flexible in use and an excellent value for money. Nevertheless, particular operational conditions in North America must be observed. Additional variations, such as the transformer-protective starter (circuit-breaker) *PKZM0-T*, cannot be fully utilized to the same extent as in the IEC world.**

| Feature | Use and acceptance | |
|---|---|---|
| | in the **USA** | in **Canada** |
| **Motor-protective starter *PKZM0*** | Yes | Yes |
| Use as *Type E combination motor starter* | • **Additional terminal *BK25...-E* required**<br>• Lockable thumb-grips are only required for individually enclosed applications<br>• **For use in earthed networks**, up to 32 A at 480 Y / 277 V or up to 11 A at 600 Y / 347 V | • Additional terminal *BK25...-E* not required<br>• **Lockable thumb-grip always required**<br>• **For use in earthed networks**, up to 11 A at 600 Y / 347 V or up to 32 A at 480 Y / 277 V |
| Use as *Type E combination motor starter* | • **Additional terminal *BK25...-E* required**<br>• Lockable thumb-grips are *only* required for individually enclosed applications | • **Type F is not yet in the Canadian standards!** (Description of the combination in CSA report is permissible) |
| For use as *Tap Conductor Protector* | Yes, need to apply per the 10 : 1 dimensioning ratio rule. Network and voltage limitations may also apply. | No, currently not recognized by the Canadian standards |
| For use as a transformer-protective device for control **voltage** transformers<br>*(in America only 1-phase Control Circuit Transformers are common)* | Yes, due to UL evaluation as *Tap Conductor Protector*, used in conjunction with additional upstream protective devices, need to apply per the 10 : 1 dimensioning ratio rule. | No, not allowed on either the primary or secondary |
| Protection of **power** transformers and power supplies<br>The protection of *Power Circuit Transformers and Power Supplies* is permissible only with listed molded case circuit-breakers or fuses. | No, not accepted,<br>(Fuses or circuit-breakers only.) | No, not accepted<br>(Fuses or circuit-breakers only.) |
| **Transformer-protective circuit-breaker *PKZM0-..-T*** | No | No |
| Protection of control transformers | No longer approved, use not permissible | Not approved, use not permissible |
| Protection of motors | No longer approved, use not permissible | Not approved, use not permissible |

**Table 1: Areas of application for motor-protective *PKZM0* starters and the IEC transformer protective circuit-breaker *PKZM0-..-T*. Representation of the differences in the performance evaluation between predominant standards in the US and in Canada.**

respect to motor and transformer protection are described in the article. UL 248 and CSA-C22.2 No. 106 are the applicable standards for fuses.
In principle 4 basic functions are required for all motor branch circuits:

- Isolation (main disconnect switch),
- Short-circuit protection,
- Load switching (contactor),
- Overload protection.

A significant difference from global approvals is that the small, European motor-protective starters (circuit breakers), such as the *PKZM0* or similar devices in America known as *"Manual Motor Controllers"*, can only assume the motor **overload protective** function. These small motor-protective starters are nearly always evaluated as UL 508 devices, even if they occasionally do partly feature electrical clearances conforming to UL 489. As such, they are normally not applicable as stand-alone disconnect switches and **short-circuit protective** devices beyond their association within

the scope of combination motor starter *types E* and *F* described later.
**Note:** The motor-protective starter/ circuit-breaker *PKZM0* can never be used as a stand-alone circuit-breaker (*branch circuit protective device*, UL 489 and CSA-C22.2 No. 5-02) per the NEC [1] and CEC [2]. This is particularly the case for non-motor loads, such as conductors, heaters, power transformers and the like.

A further contrast from international branch circuit solutions is that the functions of "Main Disconnect" and "overcurrent (short-circuit) protection" are often fulfilled separately in America, and by devices which can be typically installed in different locations. These afore-mentioned functions are classically assigned to *"Distribution equipment"*, for which larger electrical clearance distances are considered essential constructional elements.

Over time many of these North American standards have been influenced by various established constructive solutions available in international markets. Case in point: *"Self-Protected, "Type E" combination motor starters"*. All permissible combination motor starter variations in UL 508 are assigned a successive letter (currently known as *Construction Types* A ... F). An expansion within the standard some years ago introduced the *"Self-Protected Construction Type E"* to its classification of *Combination Motor Controllers*. This IEC based starter still retains its compact design and features a typically high short-circuit breaking capacity, but constructionally, these devices need to incorporate the larger electrical clearances on their incoming supply side in order to eliminate the need for an additional upstream short-circuit protective device in the motor branch circuit (**Figure 2**).

The following benefits are achieved by the use of the *"UL 508 Type E"* Combination Motor Starters:

- Simple engineering, as the need for additional upstream short-circuit protection devices in the branch circuit is no longer necessary.
- Savings in panel space.
- Lower component and engineering costs.

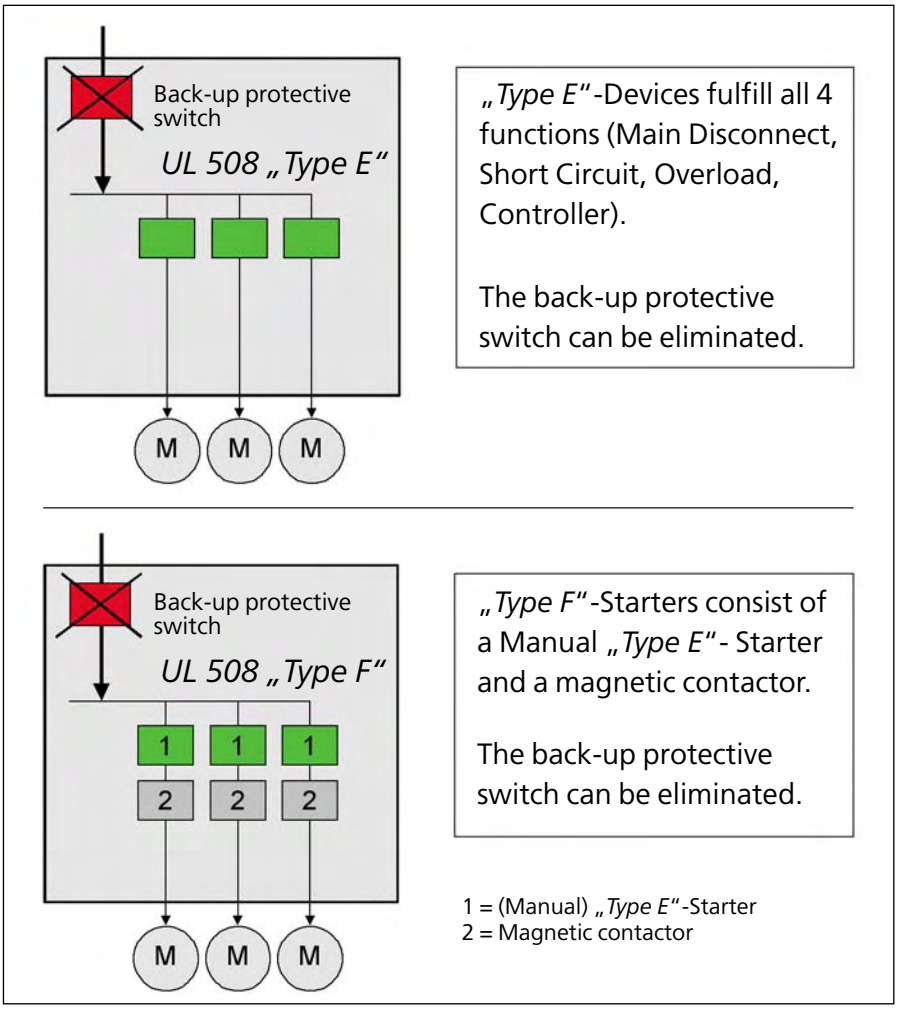


**Figure 2:** ***"UL 508 Type E"*** **and** ***"UL 508 Type F"*** **devices fulfill all 4 functions of a combination motor starter and, accordingly, the upstream protective device is not required.** ***"UL 508 Type E"*** **devices are called** ***Self-Protected Combination Starters*****.**

- Additional wiring between discretely mounted components is eliminated.
- A design more closely harmonized with global practices in the IEC world.

Panel builders who export their products wish to benefit from the same advantages when protecting control transformers.

The solution (pictured in **Figure 3**) is very much in line with international wiring methods, as it provides for several "off-the-shelf" motor-protective starters/ circuit-breakers connected with three-phase bus (commoning) links on the incoming supply side. The combined load is handled by the incoming power feed terminal *BK25...-E* which features larger electrical clearances and is used to feed the three-phase bus (commoning) links. All Moeller three-phase bus (commoning) links have UL and CSA approvals. The incoming power feed terminals with larger clearances are not a requirement in Canada, but they are freely accepted there. Thus, a common engineering solution for all of North America is made possible with respect to the use of power feed terminals in such assemblies.
The combination of manually operated *"UL 508 manual Type E" self-protective* devices with specifically assigned magnetic contactors result in the formation of *"Type F Combination Motor Starters"* (**Figure 4**), which also do not require additional upstream protective devices in their respective branch circuits as shown in **Figure 2**. All permissible device combinations are described in approval reports and appear as markings on the components. For builders of machinery and panels destined for export, fuseless

[1] *NEC = National Electrical Code*
[2] *CEC = Canadian Electrical Code*


**Figure 3: Motor-protective starters/circuit-breakers *PKZM0* with power feed side three-phase bus commoning links. The common power feed terminal *BK25...-E* constructionally fulfills the larger supply side clearances needed for *"UL 508 Combination Motor Starters of Construction Type E"*.**

Combination Motor Starter variations such as:

- *UL 508 Type E , Self-Protected Combination Motor Controllers, and*
- *UL 508 Type F Combination Motor Starters*

provide solutions which are equally applicable in the IEC world. This is especially relevant when there is a requirement for a common control panel layout for installation world-wide. Naturally, all other applicable North American requirements with respect to the entire installation, including wiring materials and conventions, need to be considered. Refer to additional publications from Moeller [1] on this subject.

### Tap Conductor Protector

In addition to the types E and F combination starters, there is yet another approval variation in the USA for small IEC based motor-protective devices called *"Tap Conductor Protector"*. The Canadian standards do not yet recognize this new category of protective components. These devices are not subject to larger electrical clearances and fall under the scope of standard industrial control equipment per UL 508. In practical terms, a standard "off-the-shelf" motor-protective starter/circuit-breaker *PKZM0* is additionally tested and evaluated for the purpose, and is marked accordingly. In order to be used for the protection of control transformers the product's accompanying documentation (set of Installation Instructions referred to by Moeller as "AWA") must also contain instructions for proper wiring and setting of the device to meet the intent of the NEC. On devices with single-phasing sensitivity (*PKZM0*) the primary rated current of 1-phase transformers must be passed through all 3 phases in order to insure proper protection and eliminate nuisance tripping. The motor-protective device *PKZM0* generally features approval as a *Tap Conductor Protector* in earthed networks rated at 480 Y/ 277VAC. The smaller devices rated up to 11 A are suitable in similar networks up to 600 Y/ 347VAC.

*Tap Conductor Protectors* provide **overload and short-circuit protection for outgoing tapped conductors** as well as the **overload protection for the equipment to be protected** without the need for the larger spacing terminal *BK25...-E*. The disadvantage of this solution is that there must always be an upstream branch circuit protective device. Suitable upstream protective devices consist generally of listed fuses (UL 248), or listed molded case circuit-breakers (UL 489) such as *NZM-...-NA, PKZ2-...-CB or FAZ...-NA*. Practically speaking, this means that Tap Conductor

**Figure 4: Examples for *"Type F Combination Motor Starters"* which result from tested combinations of self-protected manual *"Type E"* devices and magnetic contactors.**

Protectors do not replace the need for branch circuit overcurrent protective devices. The upstream protective device requirement means that this approval is not that advantageous for use in combination motor starters, but it really lends itself well for the primary protection of control transformers. Usually, the incoming feeder and branch circuits will always feature properly sized and installed protective devices which can then combine with Tap Conductor Protectors in a manner fully compliant with the intent of the NEC.

When used as a *Tap Conductor Protector*, the ratio between the rated current of the upstream protective device and the ampacity of the outgoing conductors must not exceed 10:1, as indicated in **Figure 5**. As an example:

- An AWG 14 conductor can be loaded with **20** A,
- A *NZMH2-A**200**-NA* may be used as an upstream protective device.

Of course, the use of higher ampacity conductors than necessary with respect to the load current can lead to an increase in the rating of the upstream protective device. There are ways to optimize sizing possibilities between an incoming circuit-breaker and the power wiring on outgoing circuits in order to make a better permissible match with the supply side protective device. The approvals now allow for more economic solutions in the protection of motor starter groupings.

**Motor-protective starters *PKZM0* or transformer-protective starters *PKZM0-...-T***

The transformer-protective devices *PKZM0-..-T* have been derived from the motor-protective *PKZM0* starter. They feature the same dimensions and share the same accessories. They differentiate only by the trip setting of their built-in magnetic trips.

Transformers cause higher inrush current peaks than motors, particularly when they are unloaded on the secondary. "Standard" motor-protective *PKZM0* starters with their lower magnetic trip settings could be subject to more frequent nuisance tripping when energized under such load conditions. In order to optimize the device for this application the trip level of the PKZM0-…-T was deliberately set higher to make them more suitable for this application.

For the IEC world the transformer-protective starters/circuit-breakers *PKZM0-..-T* are generally the optimum solution for these applications. **Unfortunately, the switch can not be used in North America** because it does not have the proper approvals as a transformer protector, and the current situation with respect to standards in the US and Canada does not suggest any impending changes in the immediate future which would allow its use in this manner.

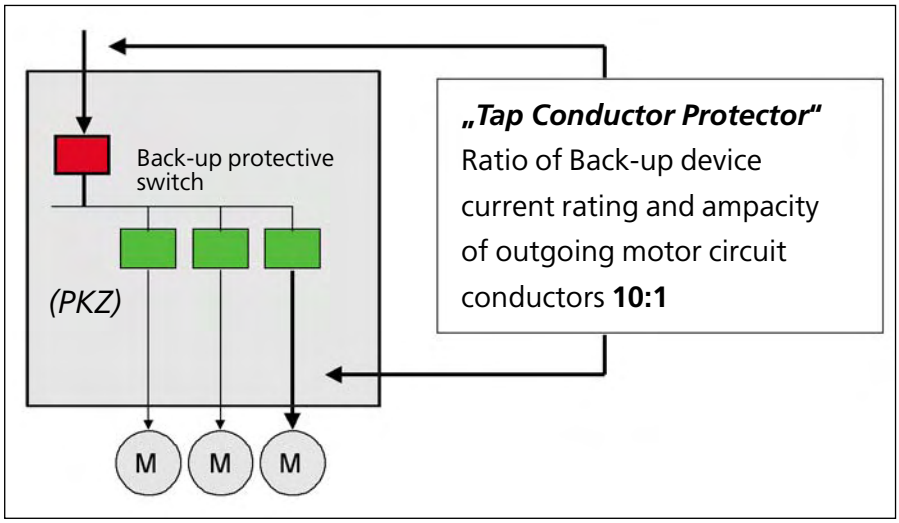


**Figure 5: Maximum ratio between the "nominal current of the upstream protective device" and the ampacity of outgoing conductors when "Tap Conductor Protectors" are used. This rule also applies with the protection of control transformers.**

This highlights the major difference in the US between the motor-protective *PKZM0* starter and the transformer-protective circuit-breaker *PKZM0-..-T*. As mentioned in the previous paragraph, only the motor-protective *PKZM0* starter has been additionally evaluated as a *Tap Conductor Protector* per UL and thus, only the *PKZM0* can be used on the primary of a control transformer whenever the 10 : 1 ratio rule between the rating of the **upstream branch circuit protective device** and the tapped conductor cross-section is being applied. In Canada, the *Tap Conductor Protector* is not yet part of the standards and its scope of application, therefore, is generally not recognized by the Canadian authorities.

**Quick Summary of the facts:**

The protection of single-phase control transformers in Canada is still generally realized with the use of fuses certified per CSA C22.2 No. 106, or with molded case circuit-breakers per CSA C22.2 No. 5-02, on the primary side, whereas in the US, small IEC type motor-protective starters additionally evaluated and marked as *Tap Conductor Protectors* (**Table 2**) can also be used. In reality, the use of molded case circuit breakers for these applications, with their generally higher rated nominal current ratings, is generally limited to larger, more centralized control power sources. Small motor protective starters, on the other hand, are generally available as low as 0.1A and thus much better suited as a fuseless alternative for these applications. An adjustable Tap Conductor Protector must be set to the primary current rating of the single-phase control transformer. 3-phase control transformers are uncommon in North America.

In North America, *Type E* and *Type F* Combination Motor starters listed to *UL 508* are applied per the NEC in individual motor branch circuits only. When used solely for the protection of control transformers, the large spacing terminal *BK25...-E* used in the construction of the Manual Type E device would not offer any added benefit. It certainly would be permissible to use them for this purpose should their benefits, incl. ease of mounting,

small size, common set of accessories etc…lend itself well for the application at hand, however, in an individual branch circuit, it is unlikely that a single device may be able to provide adequate protection for both the motor and the transformer. Space and economical factors may also dictate the need for a more cost efficient solution.
The IEC based transformer-protective circuit-breaker *PKZM0-..-T* cannot be used in North America for that purpose since its current approval does not make that possible. **Table 1** provides an overview of standards in the US and Canada which are currently in effect and relate to the application of these motor protective starters in those markets.
Centralized control voltage supplies are commonly found in electrical control panels for industrial machinery in North America. In *Motor Control Centers* (MCCs), on the other hand, control transformers are typically located in each motor starter unit compartment to satisfy individual branch circuit requirements. Due to the small transformer power involved and for reasons of space, these control transformers will usually be most economically protected by a set of small fuses.

Power transformers and power supplies used in North America must either be protected by listed molded case circuit-breakers (per UL 489), such as *NZM-...-NA, PKZ2-...-CB* or *FAZ...-NA*, or with listed fuses (per UL 248). The aforementioned devices are ideal for building fuseless based systems, which are particularly advantageous in America due to the widely divergent fused based systems encountered in those markets.

| **Primary protective device** | **Control (voltage) transformers**<br>*Control Circuit Transformers* | | **Power transformers**<br>*Power Transformers* | | **DC power supplies**<br>*Power supply units* | |
|---|---|---|---|---|---|---|
| | USA | Canada | USA | Canada | USA | Canada |
| **Fuses**<br>UL 248 / CSA C22.2 No. 106 | X | X | X | X | X | X |
| **Circuit-breakers**<br>*NZM-...-NA, PKZ2-...-CB, FAZ...-NA*<br>UL 489 / CSA C22.2 No. 5-02 | X | X | X | X | X | X |
| **Motor-protective starters**<br>with Tap Conductor Protector approval<br>PKZM0 UL 508 / CSA C22.2 No. 14 | X | - | - | - | - | - |

**Table 2: Overview of the most frequently used protective options for control transformers, power transformers and DC power supplies, for use in North America. The table indicates generally preferred solutions for Export and does not take into account specialized solutions deemed acceptable through special evaluation.**

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