

Protection of Control Circuit Transformers for applications in North America



Technical Paper
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Powering Business Worldwide

Protection of control circuit transformers and power supplies for applications in North America

– Differing types of protective devices can be used for the protection of control circuit transformers, power transformers, and DC power supplies –

Many IEC based design engineers, who usually do their planning in accordance with IEC and European standards, are mostly unsure of protection requirements for transformers and power supplies in North America. This paper describes one concept for IEC based equipment which would meet local regulations and be suitable for export.

Motor protector or transformer protector

The protection of “motors” and “transformers” in North America is subject to different requirements. In addition, it is particularly important to further differentiate between control(voltage) circuit transformers and power transformers, both of which can be certified to the same standards, UL 5085-1 and UL 5085-2, and can span similar voltage ratings and power ranges. Control circuit transformers can also be certified to UL 1561. Control circuit transformers are typically single phase transformers in North America. This article will mainly deal with the protection of control circuit transformers used in industrial machinery applications.

The type of protection afforded by small and commonly encountered European manual motor protective switches (manual motor controllers) is especially worthy of mention, since these are often mis-applied by IEC based planners involved in the design of electrical control assemblies destined for North America. Motor protective switches are always the first choice in the IEC world when it comes to motor protection. A North American viewpoint is helpful at this time to put things in better perspective: “Motor controllers are called motor controllers because controlling motors is what they do”. The not so subtle limitation conveyed by this message is that these devices are generally not suitable for the protection of loads other than motors, as in the case of transformers for example. It’s also worth noting that typical IEC manual motor controllers or protectors are no longer the component of choice in the IEC world either when it comes to the protection of transformers. That role is now fulfilled by

specially designed protective switches such as the PKZM0-...-T transformer protective switch rated up to 25A.

Important background information:

In the meantime it’s become well known in the IEC world, or it’s been at least well documented in many technical papers on the subject, that IEC style manual motor starters cannot be used in the same manner in North America as they are in IEC based countries, and not even for motor protective applications [1]. The IEC manual motor controller is recognized as fulfilling essentially 4 functions: Disconnect, short-circuit protection, manual controller, and motor overload protection. These 4 functions are also required in North American motor branch circuits, but not all of them can be fulfilled by the same manual motor controller which would have only undergone basic certification.

This explanation “detour” in more precisely defining the permissible applications of a manual motor controller in North America is necessary to clarify, and hopefully avoid, the kinds of mistakes which can happen when selecting the proper type of equipment to protect control circuit transformers.

It should probably be re-iterated briefly that components such as PKZM0, PKZM4, PKE are initially certified under UL 508 as “manual motor controllers” only. In practical terms, that means that the required functions of isolation (main disconnect) and short circuit protection in a North American motor branch circuit are not fulfilled by this basic type of equipment certification. There are additional certification choices for IEC based controllers to expand their application capabilities, and these need to be explained here further in greater detail, because many IEC designers and planners sometimes falsely assume that controllers additionally evaluated with a broader motor protective functionality can also be used for transformer protection. We can already make the point at this stage, that this is simply not the case.

Electrical loads such as motors and transformers behave differently in physical terms. Motors draw current from a supply source and the start phase is normally accompanied by an inrush current. The time duration and magnitude of the inrush current is usually dependent on the type of motor, the starting method and also partly related to how well the starter components

such as star-delta starters, soft-starters etc...have been optimized for the load. Conventional manual motor controllers with a bimetal overload protective function are able to thermally capture the heat rise generated by the motor in order to optimally protect it against potentially damaging overloading conditions. More modern devices, such as the Eaton PKE solid state manual motor controller, offer various trip class selection capabilities in addition to an adjustable dial set to the motor full load current.

Transformers, on the other hand, can generate much higher current peaks and rises upon energization. That is especially the case when the transformer secondary is relatively unloaded. These current peaks can lead to tripping of protective devices such as manual motor controllers equipped with standard level short circuit trips. The motor controller may remain energized 6 out of 10 starts, but may nuisance trip during the other 4. It would make a difference too, if the motor controller happened to be set more towards its upper range rather than its lower settings. In the lower setting ranges the ratio of the set current to the fixed short circuit trip level is much greater, and thus provides more inherent time delay, whereas in the upper portions of the setting range the ratio becomes smaller and would effectively cause the device to be more

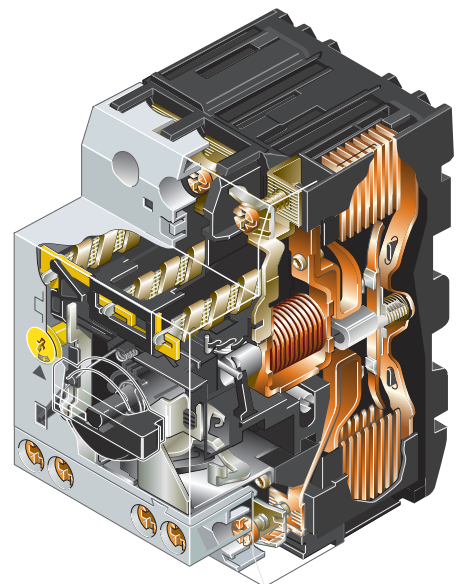


Figure 1: Cut-away view of a best seller. Motor-protective starter (circuit-breaker) PKZM0 is flexible in use and an excellent value for money. Nevertheless, particular operational conditions in North America must be observed. Additional variations, such as the transformer-protective starter (circuit-breaker) 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 <i>PKZM0</i>	Yes	Yes
Use as <i>Type E combination motor starter</i>	<ul style="list-style-type: none"> • Additional terminal <i>BK25...-E</i> required • Lockable thumb-grips are only required for individually enclosed applications • For use in earthed networks, up to 32 A at 480 Y / 277 V or up to 11 A at 600 Y / 347 V 	<ul style="list-style-type: none"> • Additional terminal <i>BK25...-E</i> not required • Lockable thumb-grip always required • 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 <i>Type E combination motor starter</i>	<ul style="list-style-type: none"> • Additional terminal <i>BK25...-E</i> required • Lockable thumb-grips are <i>only</i> required for individually enclosed applications 	<ul style="list-style-type: none"> • Type F is not yet in the Canadian standards! (Description of the combination in CSA report is permissible)
For use as <i>Tap Conductor Protector</i>	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 (in America only 1-phase Control Circuit Transformers are common)	Yes, due to UL evaluation as <i>Tap Conductor Protector</i> , 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 The protection of <i>Power Circuit Transformers and Power Supplies</i> is permissible only with listed molded case circuit-breakers or fuses.	No, not accepted, (Fuses or circuit-breakers only.)	No, not accepted (Fuses or circuit-breakers only.)
Transformer-protective circuit-breaker <i>PKZM0...-T</i>	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.

trip sensitive to sudden inrush current peaks of sufficient magnitude.

These various tripping scenarios provided the impetus to develop and offer the specialized *PKZM0...-T* manual motor controller based transformer protective device for IEC applications. The transformer protector controller features a short circuit magnetic trip that is set higher relative to controller's rated current. The manual motor controller based transformer protector design provides the ideal solution in the IEC world to avoid nuisance tripping in applications where steep inrush current peaks upon energization are normally expected.

The *PKZM0...-T* transformer protector is not available for applications in North America, since it could not be properly certified to meet the protective requirements of devices used for the protection of transformers per the NEC (National Electrical Code) and CEC (Canadian Electrical Code).

Back to application information regarding *PKZM0*, *PKZM4* and *PKE* manual motor controllers:

1. The basic certification allows these devices to be used for the motor overload protective function in association with upstream branch circuit protective devices such as UL489/CSA C22.2 Nr. 5-09 certified circuit breakers or UL 248/C22.2 Nr.

248 branch circuit fuses (Figure 1). The BCPD assumes the short circuit protection and the main disconnect function for the motor branch circuit. The manual motor controllers provide the motor switching and motor overload protective functions required by the electrical codes. Both mounting space and cost aspects exceed equivalent IEC based solutions. Exporters prefer to avoid the use of fuses whenever possible.

2. If manual motor controllers like the *PKZM0*, *PKZM4* or *PKE* are additionally listed for group installation, the branch circuit protective device (see point 1) can protect a group of these motor controllers as long as the NEC/CEC wiring and installation

provisions for such groups (e.g. 1/3 rule) are strictly followed. The BCPD assumes the short circuit protection and the main disconnect function for the group motor branch circuit. The manual motor controllers provide the motor switching and motor overload protective functions required by the electrical codes. Both mounting space and cost aspects exceed equivalent IEC based solutions.

3. In the US, manual motor controllers can be additionally evaluated and applied as Tap Conductor Protectors in group installations. Similarly, there would be a need for a group branch circuit protective device ahead of the protectors, and the NEC rules for wiring and installation (e.g. the 1/10 rule) would have to be followed. In the great majority of cases, these protectors are certified for use in solidly grounded, wye type distribution systems (e.g. normally spelled out as 480Y/277V). This type of certification is not yet recognized by the Canadian Electrical Code. Both mounting space and cost aspects exceed equivalent IEC based solutions.
4. The most advantageous and preferred solution from the perspective of exporters to the North American market involves the use of UL 508 Type E self-protected combination motor controllers. Simply stated, this type of certification allows the controllers to more or less replicate the same kind of protective features for the motor branch circuit afforded by equivalent IEC based devices. Some constructive modifications are required, such as the addition of an Eaton Type BK../3-PKZ../E terminal block on the device's incoming line side terminations (Figure 2). These controllers fulfil the role of the BCPD for the individual motor branch circuit. Multiple controllers can be wired or combined in parallel with appropriately certified wiring accessories under one feeder terminal block. The controllers can be used up to their maximum marked short circuit ratings and normal branch circuit conductor sizing rules spelled out in electrical codes are applicable (Figure 3). In the case of the controller brands described in this paper, their application at maximum voltage would be permitted in solidly grounded wye-type distribution systems only. This solution is the one most preferred by exporters since it closely mirrors IEC based solutions from a cost and panel space point of view. The controllers are suitable for use in motor applications only. A recent change

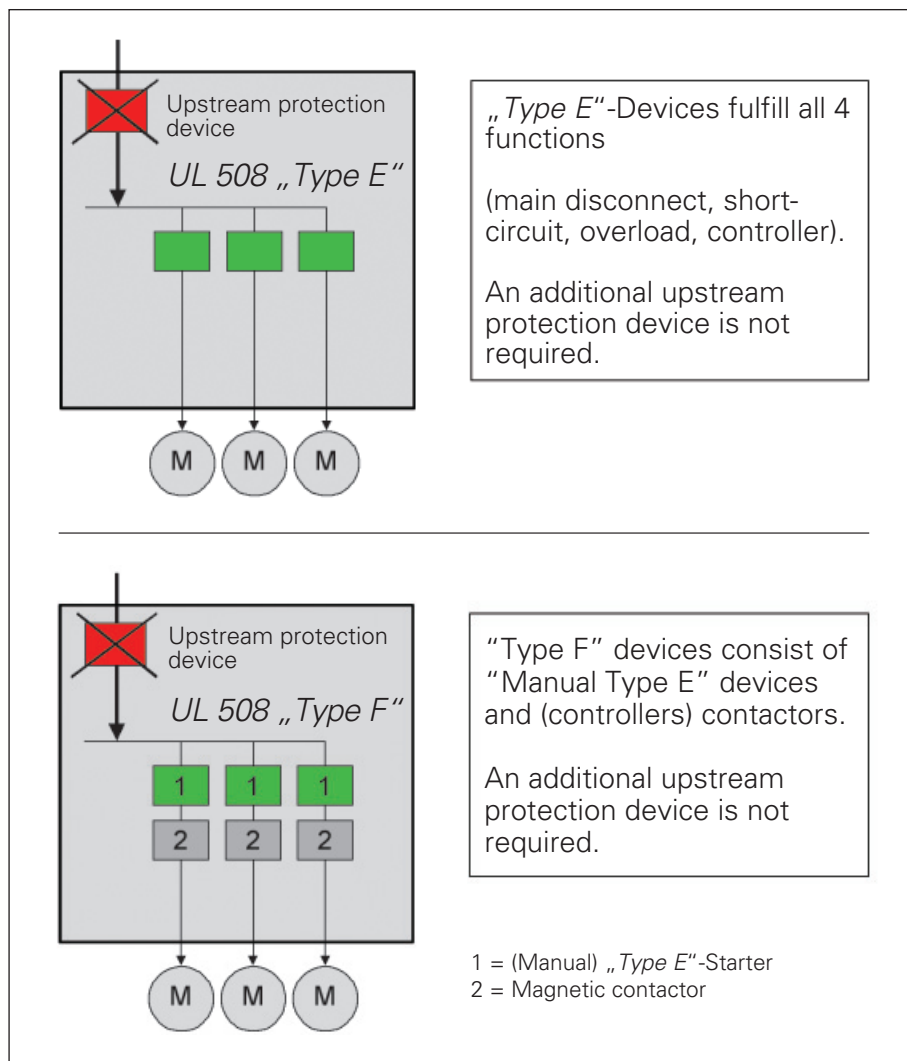


Figure 2: “UL 508 Type E” and “UL 508 Type F” devices fulfil all 4 essential motor starter functions and an additional upstream protective device is not required. “UL 508 Type E” devices are called (Manual) Self-Protected Combination Motor Controllers or Starters.

in the UL 508C standard for power conversion equipment allows Type E controllers to be used as the short-circuit protective device for adjustable speed drives, as long as the drive is appropriately marked to reflect the device used in testing.

5. UL 508 Type E manual self-protected combination controllers (per point 4.) can also be combined with specific motor controllers such as magnetic contactors to form UL 508 Type F combination motor controllers (Figure 4). Again, the great majority of these controllers are also suitable for solidly grounded distribution systems only. This solution is also most favored by exporters since it closely mirrors IEC based solutions from a cost and panel space point of view. (Goal: A unified world-market control panel design).

Summary: Manual motor controllers like the PKZM0, PKZM4 or PKE are

generally not suitable for the protection of transformers since they are certified under North American standards for motor circuit applications only. Tap conductor protectors could theoretically be suitable for the primary protection of control circuit transformers, however, their short circuit trip response levels may make them susceptible to nuisance tripping in the case of extremely high transformer inrush currents. In view of this possibility, their use for this application is not recommended.

Improper usage of motor circuit protective solutions

There are many motors than control circuit transformers to be protected. IEC/EN based designers have learned a great deal in the meantime with respect to motor protection requirements in North American installations. It is thus almost unavoidable for them to often



Figure 3: An array of PKZM0 motor-protective switches with commoning link and incoming terminal accessories. The common power feed terminal BK25...-E provides the increased air and creepage clearances required on the incoming side of UL 508 Type Self-protected combination motor controllers/starters. The terminal block is not necessary for applications in Canada should it be possible to accommodate the necessary supply conductor cross-sections without its usage. All handles must be padlockable in the OFF position. Application of these controllers in motor branch circuits only.

The North American electrical system very much takes into consideration the type of load, e.g. motors, transformers, heaters, lamps etc.... in question in order to determine the viability of the equipment selected to protect these loads. Protective equipment that is certified for one application is not always deemed suitable for other applications, even if sound arguments can be made for its technical merits. Certification to the proper product standard is often the only way to verify the suitability of the equipment for its intended application. One can only hope that, through time and proven performance in motor circuit applications, solutions such as adding terminal blocks with larger spacings on controllers with protective functions can somehow win recognition in other types of applications.

Suitable protective devices for the protection of control circuit transformers

Modern electrical controls for machinery are almost always equipped with a centralized control circuit power source consisting of one or multiple AC voltage

attempt a leap of faith by including the afore-mentioned transformer protective devices for the relatively few control transformers installed in their panel alongside the proper equipment used for motor protection purposes. Unfortunately, doing so amounts to a violation of the NEC and CEC transformer protection requirements.

Based on their acquired knowledge of North American requirements, and sudden confidence in applying it into their designs, many IEC/EN designers are likely to assume that adding a BK25/3-PKZ0-E from a Type E controller to a PKZM0-...T transformer protective switch will result in a protective device that will be deemed suitable for the protection of transformers in North America. But this approach would be incorrect, based on the following two reasons:

1. The PKZM0-...T is not certified for applications in North America. The North American electrical codes do not at present include any provisions for the application of this particular design for control or power transformer protection.
2. Increasing the electrical clearances on the supply side of the device by the addition of a terminal block is a construction feature that is only certified for use in UL 508 Type E and Type F combination motor controllers.



Figure 4: A "Type F Combination Motor Controller" construction results from matching and certifying "Type E" devices with suitable load side controllers such as contactors.

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

taps on the secondary side alongside a DC voltage circuit derived mostly from a DC rated power supply. Ideally, the use of UL 489/CSA C22.2 Nr. 5-09 listed circuit breakers is recommended for use on the primary side of the control circuit transformer to insure that NEC and CEC requirements are met. Exporting manufacturers of industrial machinery prefer the use of fuseless based solutions featuring circuit breakers. Type NZM..1-...-NA molded circuit breakers from Eaton are available in rated currents starting at 15A, but devices with smaller

rated currents are often preferred to more closely match the transformer primary current requirements. Type FAZ-...-NA molded case circuit breakers are available in currents as small as 0,5A up to 32A, with a short circuit interrupting rating of between 10kA and 14kA, for solidly grounded electrical systems rated 480Y/277V, or any system up to 240V. The line of PKZM4-...-CB circuit breakers covers a range of 10A to 32A, with a short circuit interrupting rating of 65kA @ 480Y/277V and 22kA @ 600Y/347V. A viable fuse based alternative consists

of very compact Class CC fuses. These types of fuses enjoy selective acceptance on the part of export machinery and control panel builders.

The North American electrical codes also allow the use of UL 1077/CSA C22.2 Nr. 235 (Eaton Type: FAZ-....) certified supplementary protectors or UL 248-14/CSA C22.2 Nr. 248.14 supplemental fuses to protect the primary of control circuit transformers, as long as the circuit is tapped on the load side of a branch circuit protective device (BCPD). The use of supplementary protectors in this application becomes advantageous whenever the BCPD is too large relative to the control circuit transformer rated primary current (Tables 1a and 1b). Such solutions are very often used in North American control panel designs. The electrical codes (NEC and CEC) provide comprehensive guidelines for sizing of protective devices used for transformer protection.

The basic IEC manual motor controller is, as already mentioned, not suitable for the protection of transformers. Tap conductor protectors, which are derived from these controllers and have undergone additional evaluation, are theoretically allowed for the protection of control circuit transformers, but require upstream protection and adherence to more detailed installation guidelines (Table 2). They are for the most part suitable for use in solidly grounded networks only, and could be susceptible to nuisance tripping when protecting

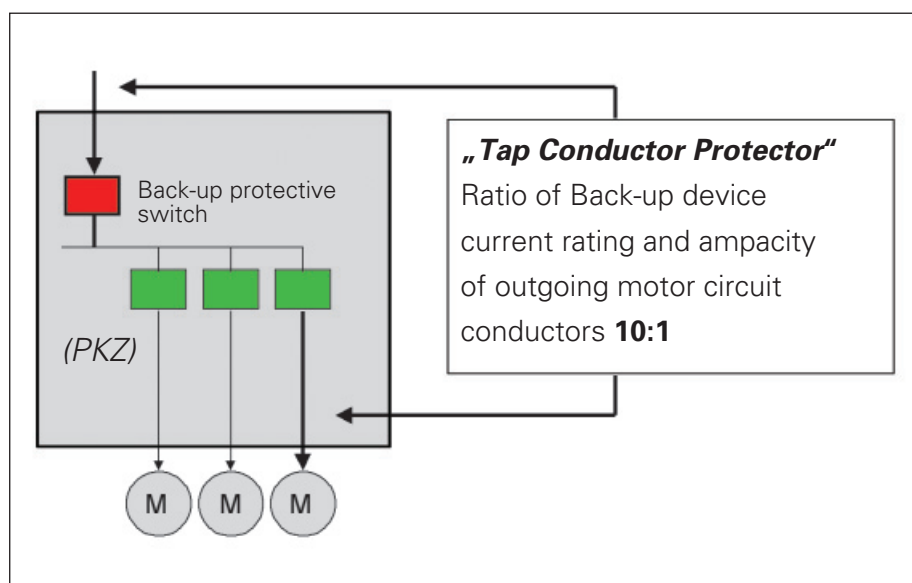


Figure 5: Maximum ratio between the “nominal current of the upstream protective device” and the ampacity of outgoing conductors when “Tap Conductor Protectors” are used. This rule also applies with the protection of control transformers.

potentially high inrush loads such as transformers. They don't represent an ideal solution.

Suitable protective devices for the protection of power transformers

The protection requirements of power transformers are more clearly defined. The only allowable equipment consists of certified molded case circuit breakers (UL 489/CSA C22.2 Nr. 5-09) or fuses (UL 248/C22.2 Nr. 248). No supplemental protective equipment of any kind is permitted. All certified molded case circuit breakers from the Eaton Moeller series such as NZM-...-NA, FAZ-...-NA or PKZM4-...-CB can be used for this application as per their technical ratings. Tables 1c and 1d provide sizing requirements per the North American electrical codes. In the IEC world, protective devices are typically set to the rated primary current of the transformer load.

Suitable protective devices for the protection of DC power supplies

The protection requirements for DC power supplies used for industrial applications and fed from power circuits are also clearly defined. Feeder supply conductors need to be protected with certified molded case circuit breakers (UL 489/CSA C22.2 Nr. 5-09) or fuses (UL 248/C22.2 Nr. 248). No supplemental protective equipment of any kind is permitted. All Eaton products previously described as suitable for the protection of power transformers can be used. These power supplies often include integrated overload protection for their

secondaries. This can lead to a situation in which external overcurrent protective devices located in the secondary aren't able to trip because trip level currents are not able to flow.

Summary:

A small review of motor protection requirements in North America was necessary in view of frequently made errors in the IEC world with respect to the selection of protective equipment for control circuit transformers in that market. The classic IEC manual motor controller, as well as its variants, the UL 508 Type E and Type F motor starters, are generally not suitable for the protection of transformers. The addition of the BK.../3-PKZ...-E large spacing terminal block to these devices makes no difference at all for this application. Tap conductor protectors are possible in some cases, but would be subject to strict installation limitations and may also be susceptible to nuisance tripping in high inrush cases. The use of circuit breakers or fuses, properly sized and certified to the relevant standards, will be acceptable in all cases. The use of supplementary protectors and supplemental fuses is allowed under certain conditions, and could be especially useful in industrial control panels with large decentralized control circuit power sources. They are considered a specialized solution in export related industrial machinery applications. Generally speaking, all components and wiring materials used in North American applications must be certified and installed to meet the requirements of the local electrical codes.

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