AC Variable speed drive systems for the North American market

Technical paper

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Foreword

Eaton Moeller has been successfully supplying electronic drive systems to global markets for over 30 years. With a view to European export business interests and the OEM (*Original Equipment Manufacturer*) industry, the North American market in this respect is one of the most lucrative.

The following paper is geared towards those that are involved in the application, technology, marketing and management of drives and industrial motor driven machinery in the marketplace today. It describes in a straight-forward and practice oriented manner the existing conditions governing the succesful export of equipment from Europe to the North American market, as well as the requirements to insure the proper application of a variable speed drive.

AC Variable speed drives

A drive is considered to be electrical equipment and, as an industrial product, is not meant for private or residential usage.

Drives provide a means of continuously regulating the speed of AC inductive motors:

n ~ f

n = Speed (rpm)
f = Frequency (Hz)

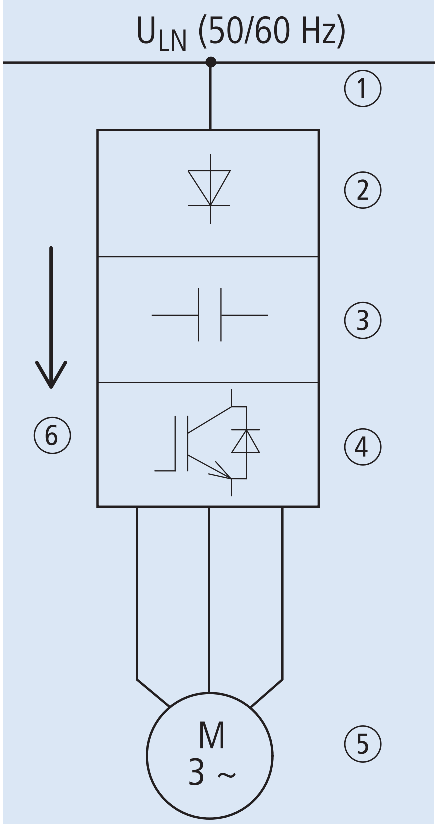
To that end, a supply voltage of a particular frequency and amplitude is converted by an inverter into a 3 phase AC voltage of variable amplitude and adjustable frequency. This frequency modulated voltage is then used mostly to regulate the speed of AC asynchronous motors.

In the energy supply section of the drive the function of the (static) power converter is divided into three groups: A rectifier, a DC voltage intermediate circuit and a transistorized power inverter.

The North American market

The US, together with Canada and Mexico, make up a commercial trading zone referred to by the acronym **NAFTA**, *North American Free Trade Agreement*.

As is the case in European commerce circles, multi-faceted harmonization efforts are currently underway within NAFTA to facilitate trade amongst the respective countries. These would include, for example, broad ranging activities in the area of testing, certification and approval of electrical equipment. On that basis, the information provided herein will largely be based, justifyingly so, on the market situation in the US, since it is the most dominant, from both an economical as well as a technological point of view.



① = incoming AC supply voltage
② = Rectifier
③ = DC voltage intermediate circuit
④ = Transistorized power inverter
⑤ = Asynchronous motor
⑥ = Energy flow

Figure 1: Schematic representation of an AC adjustable speed drive.

Figure 2: NAFTA, the North American free trade zone

The establishment of international standards has been facilitated in great part by the liberalization of commercial regulations world-wide. The provisions which govern export related matters in North America, with respect to regulating the transfer of goods and technology, are comparable to those of the European Union. Laws and standards have been internationally harmonized and English has in many diversified areas (politics, economy, technology, art etc…) established itself as the global communication language of choice.

Nevertheless, existing provisions for national deviations, differing standards requirements and particular domestic market conventions can quite often still lead to misunderstandings, aggravating delays and even costly re-builds. The impression could be conveyed that the North American trade zones and their technical rules are a lot more complicated and different than what is generally the case in the rest of the world.

Not meant to be part of this discussion are the more trivial aspects, like the continued usage in North America of the English system for units and measures such as, for example:

- Inch (1 in = 25.4 mm),
- HP (*Horsepower* = 1 PS = 1.36 kW),
- AWG (*American Wire Gauge*), Conductor cross-section.

Rather, the truly significant differences are much more apparent in the respective safety and product related standards of UL (*Underwriters Laboratories Inc.*), and the IEC (*International Electro-technical Commission*), which dominate both markets. Furthermore, the claim can be made that the laws governing product liability in the NAFTA countries, primarily in the US, are much more prevalent there than throughout Europe.

Safety standards for electrical equipment

By and large, safety related product aspects regulate the import and installation of electrical equipment. The basic premise is: The safety and health of direct users or third parties cannot be compromised and endangered by the manner in which the equipment is meant to be operated, nor should any anticipated mis-application of the product be overlooked in its design and in the end-use for which it is intended.

There are, therefore, binding electrical standards in place world-wide to safeguard the well-being of personnel and safe operation of machinery. However, these standards can vary from place to place and are adapted to particular regional circumstances and cultural considerations. They can range from strict legal enforcement of written requirements, to general recommendations of a more or less unbinding nature. Certain regions will be accepting of self-certification, whereas in others, a state authorized certification process, administered and monitored by independent third party testing orgnizations, is mandated by law.

The basis of safety standards with respect to electrical equipment is safeguarding against potential life threatening dangers such as:

- Electrical schocks involving exposure to dangerous voltage levels,
- Fires resulting from abnormally high temperatures,
- Bodily injuries related to moving parts, sharp edges, unstable assemblies, hot surfaces,
- Chemical hazards emanating from unintended release of health injurious materials
- Exposure to radiation.

Thus, the safety standards see to it that established engineering principles and sound protective requirements are put in place:

- Suitably designed and dimensioned electrical energy distribution networks.
- Protection against indirect contact with live parts,
- Fundamentally sound equipment design criteria and appropriate construction materials,
- Provisions against radiation exposure.

The electrical and constructive safety aspects of adjustable speed drive systems are established by conformity with the product standards IEC 61800-5-1 (*Adjustable speed electrical power drive systems – Part 5-1: Safety requirements – Electrical, thermal and energy*) and UL508C (*Power Conversion Equipment*). UL/IEC 61800-5-1, a planned harmonized version of both documents, will help establish a uniform and globally accepted standard for the future.

IEC (*International Electrotechnical Commission*). International Standards body for electrical equipment.

EN (*Européen Normalisation).* European Norms are regulatory documents which have been ratified by one of the three European standards committees (CEN, CENELEC, ETSI)

CE (*Communauté Européenne*), identifies conformity with relevant standards and directives throughout the European Community.

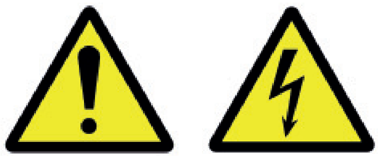


Figure 3: Attention, Dangerous Voltage

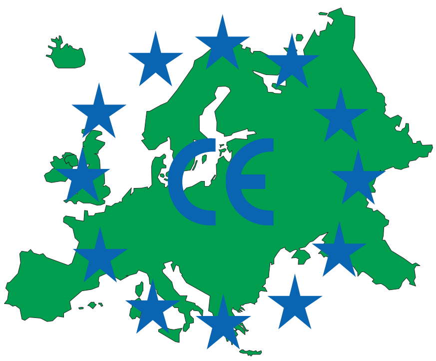


Figure 4: CE-Mark used in the European trading Community

CE and Directives ensure protection against liability

The **IEC** publishes global standards in which the minimum safety requirements for electrical equipment are established. The technical details and constructive solutions to meet these requirements are the responsibility of the manufacturer.

The **CE**-Mark placed on equipment and its packaging provides verification of its conformity with the relevant IEC standards. The mark enables unimpeded access of this equipment in markets throughout the European economical community (EEA = European Economic Area). The manufacturer must provide to this effect a Declaration of Conformity, which serves as confirmation that all of the requirements pertaining to the product under its assigned directive have been met in full.

The **CE** marking for adjustable speed drives is performed under the Low Voltage directive per the IEC/EN 61800-5-1 standard. In addition, the manufacturer's corresponding Declaration of Conformity also indicates compliance with the EMC Directive standard IEC/EN 61800-3 (*Adjustable Speed Electrical Power Drive Systems – Part 3: EMC requirements and specific test methods*).

This particular EMC standard does not just consider the drive as a separate product but looks rather at its functional place in the entire circuit (incl. noise interference filters, power inductors, motor cabling etc...) A so-called *Power Drive System* (**PDS**) is thus evaluated, starting at the energy supply network all the way down to the driven machinery motor apparatus.

The service and installation manuals of adjustable speed drives always include, therefore, information detailing the conditions under which the EMC directive requirements for variable speed electrical drive systems are fulfilled. Generally speaking, this would entail that variable speed drives be installed by experienced individuals, and be housed in suitable control panel enclosures (industrial machinery applications).

The contractor or installer of such industrial machinery assemblies must in turn verify in a separate declaration of conformity that the requirements of the Machinery Directive (2006/42/EG) with respect to the operation of a variable speed drive have been met in full. It would then be deemed sufficient, for any given application, to verify that the drive's characteristics (utilization categories) are matched to the load in question.

All Eaton Moeller variable speed drives fulfill the requirements of the Low Voltage Directive (IEC/EN 61800-5-1) as well as those from the EMC standard (IEC/EN 61800-3) for variable speed electrical drive systems (PDS). The necessary steps to insure a proper installation in this respect are all documented in accompanying sets of installation instructions (AWA) as well as in the associated service manuals (AWB) provided with the product.

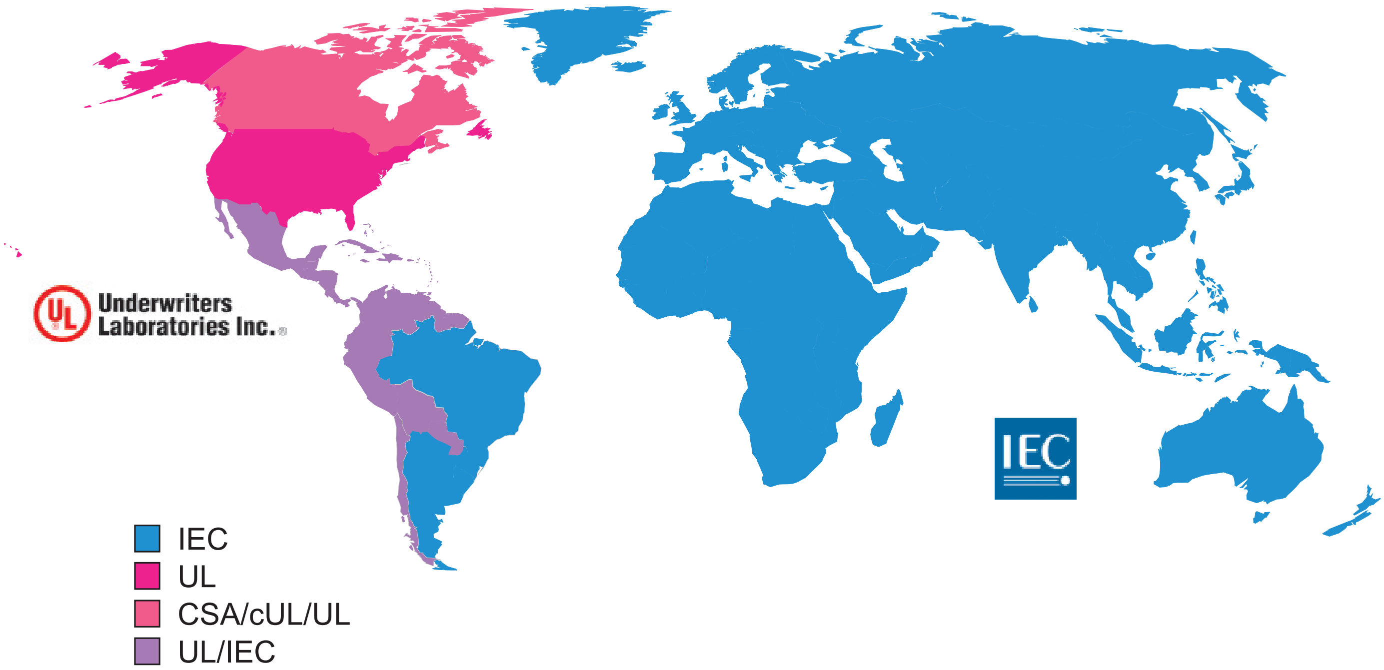


Figure 5: The "certification" world for electrotechnical and electronic products (simplified view from a North American perspective).

UL, or „everything is different in America"

Underwriters Laboratories (**UL**) in the US and *Canadian Standards Association* (**CSA**) in Canada, are the most widely known and recognized testing and certification marks on the North American market.

To this a few basic clarifications:

- **UL** listing is not a legal requirement in the US.
- There are no laws in North America which specifically require UL listing.
- **UL,** is an independent and nationally recognized testing laboratory (**NRTL**).
- **UL** tests industrial electrical equipment on the basis of their electrical and mechanical safety per their safety standards and the general outlines and installation requirements of the **NEC**.
- **UL** is not the only certifier of electrical equipment on the North American market.

The independent test labs are accredited through OSHA and are part of the North American electrical safety system. This safety system serves the needs and interests of government, businesses, users and insurance companies. It encompasses:

- National legal aspects and *Electrical Codes and Standards* (**NEC** and **NFPA** are amongst the most widely known In this respect.)
- Product standards,
- Local building code amendments and supplements, enforced through AHJs appointed by local jurisdictions
- The requirements of **OSHA / SCC (CCOHS)**,
- The approval process through certification of equipment by nationally recognized testing laboratories (**NRTL**, e.g: **UL**, **CSA**),

The common denominators remain:

- Minimize fire risks
- Promote mechanical safety
- Promote electrical safety.

In the electrical safety requirements outlined by OSHA, all electrical equipment and assemblies must be

CSA (*Canadian Standards Association*): independent, nationally accredited testing and certification organization, which also sets standards and norms in Canada. CSA is a nationally recognized testing laboratory (**NRTL**) per **OSHA** in the US.

NEC (*National Electrical Code*), Installation recommendations for electrical assemblies and equipment in the US; **CEC** (*Canadian Electric Code*) is the equivalent in Canada.

NFPA (*National Fire Protection Association*), the recognized authority on fire, electrical and building safety in the US.

NRTL, (*Nationally Recognized Testing Laboratory*), in Canada **CB** (*Certified Bodies*), group of independent and nationally recognized testing laboratories in North America.

OSHA (*Occupatonal Safety & Health Administration*), governmental agency in the US entrusted with ensuring employee health and safety in the workplace. The comparable organisation in Canada is the **CCOHS** *(Canadian Centre Occupational for Health and Safety).* It has not the weighting such as **OSHA**. The legal Accreditation is more in the **SCC** (standards councel of Canada).

UL (*Underwriters Laboratories*), Test lab and certification organization for product safety. Accredited agency (**NRTL**) of **OSHA**. c-**UL** is the mark used by UL to verify product conformity with Canadian standards.

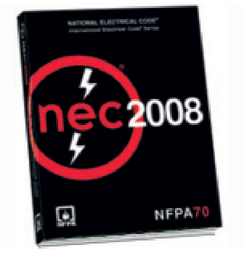


Figure 6: NEC 2008 Edition

approved (29 CFR 1910.301, *Subpart S* und NEC Artikel 90-7, 110-2, 110-3). Approvals are conducted through *„Field* Inspections" by local AHJs and are more easily attained through the use of product and equipment *„Listings"* (e.g. **UL**-Certification) for which testing by accredited agencies are necessary. The associated technical details to this effect, however, are generally made available only to relatively few parties, mostly manufacturers and builders.

The guidelines and product standards related to safety requirements in North America are thus much more detailed, and legal responsibilites are generally much more stringently established. As opposed to the situation in Europe, the responsibilities for machine safety lie with the equipment manufacturer as well as with the property owner and buyer of the equipment. The employer is directly responsible for the safety of personnel at the work place.

The local regulatory process through AHJs

Any person or business dealing with export of electrical equipment and industrial machinery to the US must familiarize themselves with essential aspects of the current edition of the NEC (*National Electrical Code*); the equivalent document in Canada is the **CEC** (*Canadian Electric Code*).

The **NEC** follows a 3 year issuance cycle and its contents provide minimum requirements for installation of electrical equipment and assemblies.

Apart from the minimum installation requirements specified in national codes and standards, the AHJs (*Authorities Having Jurisdiction*) may also need to enforce local amendments and/or supplements enacted by their respective jurisdictions. These may take into account, among other things, local building regulations and regional aspects such as particular geographical location and associated climatic conditions (arctic polar climates in the north versus hot and arrid conditions in the southwest).

An additional factor to consider would be that the nationally current edition of the **NEC** may not become enabled in all states at the same time, or during the same calendar year. This particular situation can make local conditions even more confusing and can often lead to further problems and misunderstandings between involved parties. Lastly, the final say or decision with respect to the acceptability of the electrical equipment always resides with the local jurisdiction (**AHJ**). They make the ultimate approval decision and are the final interpreter of local codes and regulations.

The relationship between these regional approval jurisdictions and *Underwriters Laboratories* (**UL**) thus becomes interesting. In the great majority of cases, and as mandated by the electrical codes, the AHJs will look for the UL mark as a way to justify their approvals, and thereby minimize their chances of making a riskier acceptance choice. You may thus have heard the **UL** mark being referred to in export circles as *„the passport to America"*.

AHJ (*Authorities Having Jurisdiction*) = Local regulatory bodies associated to states, townships, counties and cities. They are responsible to ensure compliance with code rules and requirements applicable in their jurisdictions.

AHJs can be, for example:
- *Dedicated electrical inspectors appointed by cities and towns.*
- *Labour Department* officials
- *Fire Marshals* (Responsible for enforcing local fire laws),
- *Health Department representatives*
- *Building Department representatives*
- *Elevator Inspectors*

Figure 7: UL-mark signifying that both US and Canadian requirements have been met

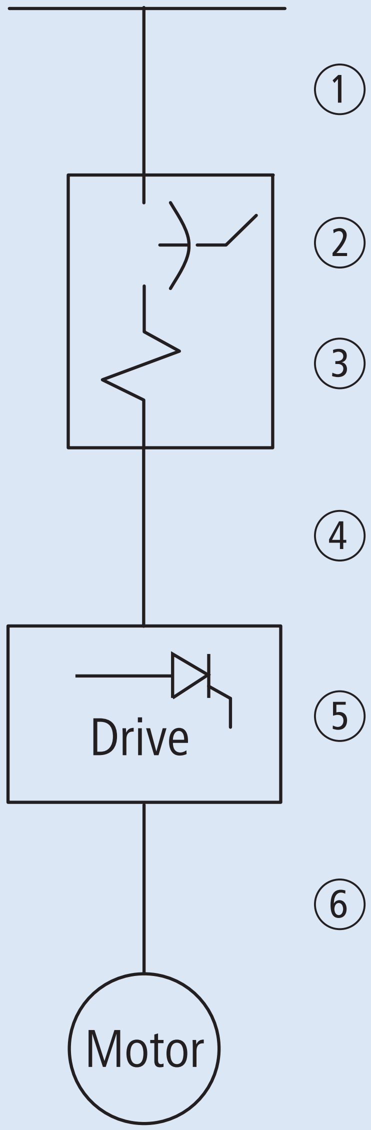
Figure 8: US and Canadian marking UR.

The combination of legally based norms and obligations imposed by the insurance industry mean that both manufacturer and user have a keen interest in making sure that the requirements in all the relevant standards have been dutifully met. Components used in industrial controls technology as an assembly are covered in UL508A (*Standard for Industrial Control Panels*), and UL508C (*Power Conversion Equipment*) is the product safety standard for variable speed drives.

Figure 9: Variable speed drive M-Max with CE-Mark, c-UL-Certification and c-Tick.

In **UL**-parlance the big „L" stands for *Listed*, i.e. a certification which allows the product to be field installed and applied without restriction per its nameplate ratings under the guidelines established in the National Electrical Code.

The inverted „R" stands for *Recognized* and identifies products with application restrictions. These products can end up in UL listed end-use equipment, machinery or assemblies, and are normally assembled by qualified persons in certified manufacturing locations.



① = Over current protection must be per the drive marking (if specifically marked).

② = NEC 430.128, Disconnect amp rating at least 115% of drive unit rated input current. Exception: The power load capacity to supply single-phase (phase and earthed phase) must be at least 125 %.

③ = NEC 430.52(C)(5), Permits *high speed fuses in lieu* of normal branch circuit fuses

④ = NEC 430.22(A), Exception 2, Conductor ampacity, not less than 125% of drive unit rated input current.

⑤ = UL 508(C&E), Permits listing drive units to one of three short circuit protection levels:

1. Standard faults (low): The standard fault current tests the drives at rather low levels of fault current and significant damage to the drive is permitted – the drive does not have to be operational after the testing (**look table 1**).

2. High Faults: The high fault current tests can be at any level of short circuit current above the standard fault current tests. Significant damage to the drive is permitted – the drive does not have to be operational after the testing.

3. Type 2 "No Damage": Type 2 (no damage) protection is the best level of protection.

With this protection, the drive cannot be damaged, and the unit is tested and marked with a high short-circuit current rating. It must be able to be put into service after the fault has been repaired and the fuses replaced. Type 2 protections for adjustable speed drives can only be obtained with high speed (semiconductor) fuses. The reason is that high speed fuses are the only over current protective devices with suitable characteristics (extremely low energy let through under short circuit conditions).
The unit will be marked with the specific semiconductor fuse that is required and these fuses must be used. As detailed in a prior section, the use of high speed fuses for protection of drives can be used in lieu of branch circuit over current protective devices for adjustable speed drives per NEC 430.52(C)(5); the marking for replacement fuses must be adjacent to the fuses.

⑥ = NEC430.124, Additional overload protection for motor circuit not required if drive unit marked that it provides overload protection.

Figure 10: ***Adjustable Speed Drive System*****)**

Certification for serially made products

The overall technical responsibility for serially produced goods or high volume components, which are typically sold through catalogs, lies solely with the manufacturer. UL certification or marking for this type of equipment is better achieved directly at the manufacturing facitility. The relevant product standards can be easily identified and documented as well in the manufacturer's accompanying product literature. The materials used in the basic production (such as plastics) and additional components used in the final assembly (e.g. enclosures), along with the manufacturers of these parts, should be equally covered under their own UL certification. Once the manufacturing facility and its production have met the relevant certification requirements, a procedure report with corresponding file number is issued by UL and the right to apply the UL mark is granted. Example:

In order to verify that products are being manufactured in accordance with their original construction and material specifications, as outlined in the respective procedure reports, UL conducts periodical audits at all

Ratings		Test current
Horsepower	(kW)	Amperes
1.5 – 50	(1.1 -37.3)	5,000
51 – 200	(39 – 149)	10,000
201 – 400	(150 – 298)	18,000
401 – 600	(299 – 447)	30,000
601 or more	(601 or more)	42,000 ....

Table 1: Minimum SCCR-values for drives based on corresponding motor ratings. Source: UL 508C, Table 45.1, Short circuit test current values for devices rated 600 voltes or less.

manufacturing locations with the assistance of field inspectors.

In addition to the well known UL Listing mark, UL also often makes use of the *„Recognized Component Mark"* (valid for the US and Canada in the example shown):

This inverted UR mark is valid for components which are incomplete in certain constructional features or restricted in performance capabilities and are intended for use as components of complete equipment subject to final investigation by UL, rather than for direct separate installation in the field. They are normally assembled by qualified persons in certified manufacturing locations. Examples of recognized components associated with drives could include noise suppression filters, power chokes or field bus connectors.

The Eaton Moeller series of M-Max™ and H-Max™ variable speed drives have all been certified and listed by UL. They additionally fulfil all relevant international requirements and standards per the IEC. The installation instructions (AWA) and associated servicing manuals (AWB) supplied with the product provide all the necessary technical and electrical instructions necessary for proper installation per IEC and UL requirements. All relevant information pertaining to optional accessories for the drives, such as field bus connection means and noise suppression filters, is fully described in respective certification reports, handbooks and data sheets.

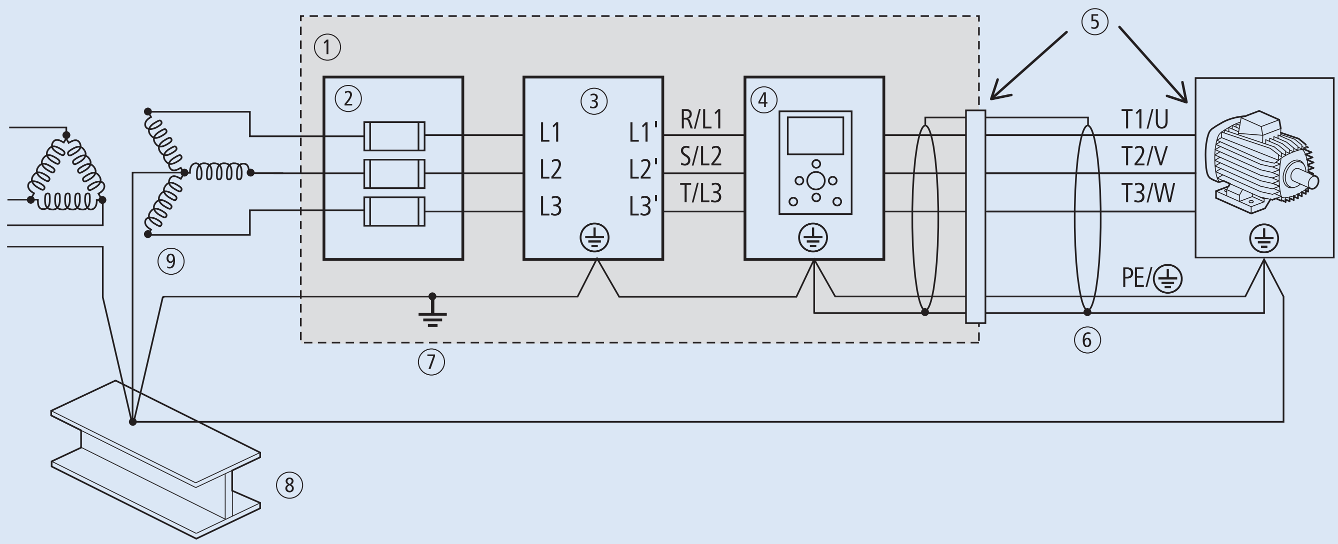
From the series product to machine control

To establish a standard (UL-compliant) machine control it is not enough, only UL-approved products to combine. Crucial to the North American Security requirements the interaction of the devices after the respective standards in the actual environment application.

The electrical connection of a frequency – or speed Propulsion system for the U.S. market is NEC Book (2008). Figure 10 shows this one overview of relevant components in the main circuit (energy flow).

Short circuit current rating (SCCR)

The large majority of industrial control panels in North America, including those for industrial machinery, must now carry a short circuit current rating (**SCCR)** on their nameplates. This value somewhat corresponds to the *I*cw value (short time withstand current) assigned to an IEC engineered assembly. It's necessary in this respect to consider the assigned short circuit ratings of all the components in the power circuit, and not just the short circuit interrupting of the supply circuit protective device (e.g. a feeder circuit breaker). Thus, the overall relevant SSCR value for an assembly will also depend on components as varied as: Contactors, branch circuit protective devices, terminals, bus bar assemblies, the primary side of control circuit transformers, and of course, drives. Note that the internal wiring in this regard is not much of a factor in the overall evaluation.



① = Shielded Enclosure

② = Protective device (*Fuse, Circuit Breaker*)

③ = Noise suppression filter, EMC-Filter (*EMI Filter*)

④ = Variable speed drives (Frequency Inverter, Drives)

⑤ = Shielded, EMC-compatible motor connection in the control panel and at the motor (*EMI Fittings and Metal Conduit*)

⑥ = Shielded Motor Cable.

⑦ = Enclosure Ground Connection

⑧ = Building or structural ground

⑨ = Incoming Supply, Solidly Grounded Wye

EMC = Electromagnetic Compatibility, deals with noise free operation of electrical and electronic equipment in their environment.

EMI = Electromagnetic Interference

Figure 11: EMC-compatible Installation

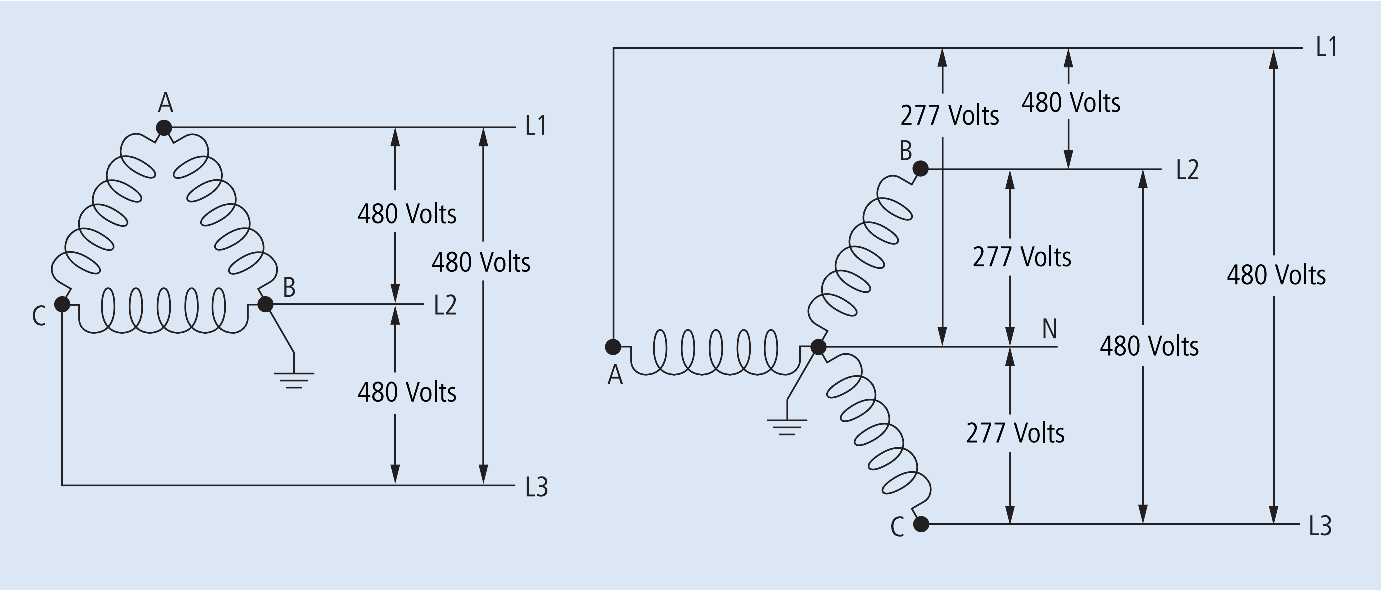


Figure 12: Grounded Delta Network and solidly grounded wye.

The overall SSCR value for a panel will always default to the lowest established rating. The available fault at the panel's incoming supply side should never, therefore, exceed that value.

Variable speed drives have relatively low SCCR values. The standard test value for drives of up to appr. 37kW is only 5kA. (see **Table 1**). In this case, use of such a drive would limit the overall panel rating to that value, and the panel's nameplate would reflect that accordingly.

Higher SCCR values for drives in control panel assemblies are possible to achieve per NEC Article 409 and UL 508A as long as the equipment is tested for a higher value with an appropriate upstream branch circuit protective device. For example, use of a dedicated Type E *„Self-Protected Combination Motor Controller"* as a protective device, or UL listed current limiting fuses such as Class J or RK, **(H oder K)** can help achieve much higher SCCR values for the drive and branch circuits, which would be more in line with higher available fault levels in many control panel installations.

Example: A drive rated up to 50HP (37.5kW, with a standard 5kA rating, see **Table1**) can safely attain an SCCR rating of 50kA when tested (in solidly grounded supply networks) with a Eaton Moeller PKZM0 or PKZM4 manual Type E controller. Any components mounted on the load side of drive, like contactors and power terminals, would naturally also require an equal or greater individual SCCR value in order for the rating to be applicable to the entire branch circuit.

The ampere rating of the upstream disconnect switch would have to be rated at least 115% of the drive's input rated current, and properly selected conductors would be sized at 125%. The associated equipment described in Eaton Moeller manuals supplied with the product already take these sizing requirements into consideration.

EMC-Measures

Independent of the global field and independent of the technical standards (**UL, IEC**), conditional the proper company of a frequency inverter, an electromagnetic compatibility just one installation.

The manufacturers must for this purpose the necessary measures describe and where appropriate necessary Addition outfits (for EMC filter) to designate. The electric connection of an EMC consistent installation conditional in that one Rule the electrical feeding of the **PDS** about a solidly grounded wyes. At that in North America often differently marked network configurations becomes for the adaptation then before the frequency inverter (**PDS**) a transformer switched, with solidly grounded Secondary.

Such a transformer connection also allows other variants:

- Waiver of current harmonics dampening Power reactor,
- Reduction of current harmonics with large port services by the so-called 12-puls circuit (Feeding on two rectifiers, fed from two separate Secondary with electrically 30 degrees phase shift).
- Adjustment of the voltage 480V to 400V.

Special North American supply network configurations

This essay considers exclusively for the frequency inverter access to commercial and industrial Low-voltage networks. The in North America favorite three phase supply voltages are 240 V and 480 V. In addition comes in the industrial area the voltage 600 V, but not to be. The nominal frequency all tensions is 60 Hz. In a combined tolerance "B" (B Range) are the maximum tolerance firmly established: ± 10% voltage, frequency ± 3%.

There are many popular supply network configurations in North America which differ markedly from thos in Europe (Bibliography [1]).

In the field of industrial and utility buildings (Industry and Commercial), there are in addition to the Star networks (Solidly Grounded Wye) also Triangle networks (Grounded Delta). This grounded Delta networks are important for the operation of frequency inverter. Here is an transformer with grounded secondary winding required for adjusting the frequency inverter.

The star network (Solidly Grounded Wye) is in Europe known TN-S networks.

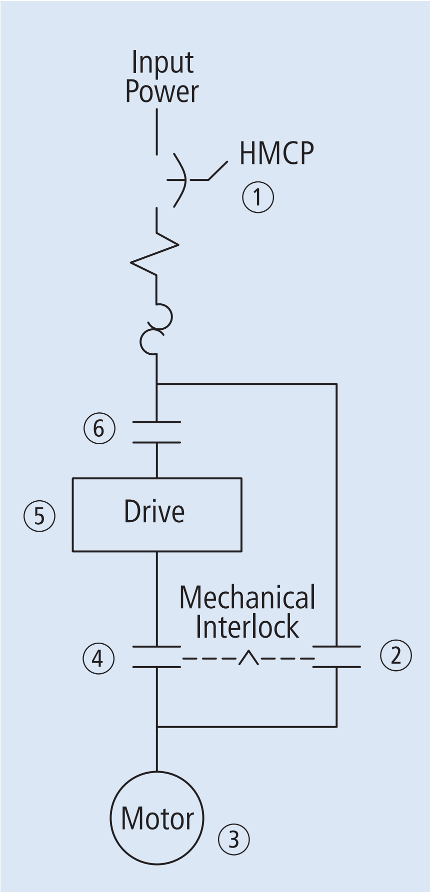
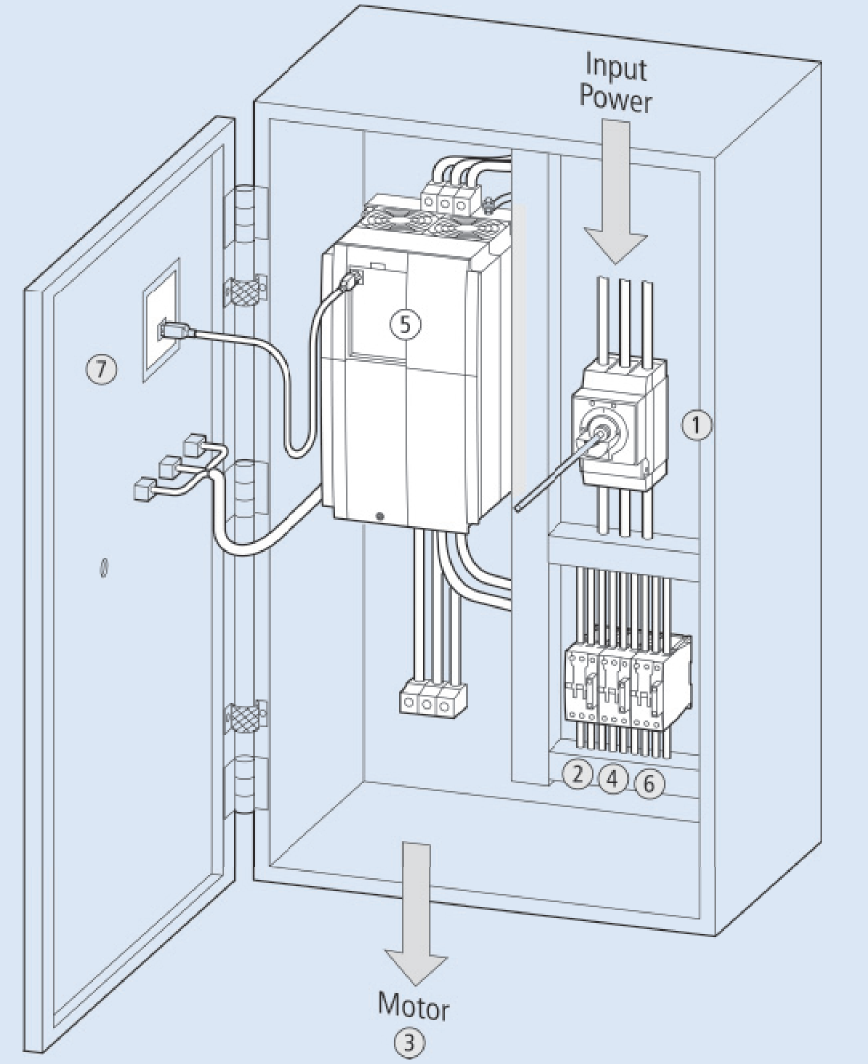


Figure 13: Example: Frequency pump drive with bypass contactor frequency

There is however no PEN core. For PE (Grounded Conductor) and N (Neutral) are always separate cores. PE may is no electricity. To avoid confusion, are always all voltages, in the respective web form occur. Thus, the voltage indication grounded in the centre of power for example, in 480Y / 277 V. "Y" is marked value the voltages between the phases the value after the slash, Tension between phase and neutral conductor (N) or against PE. Notwithstanding the mains power (240, 480, 600 V), consumers are tensions normalized to 230 V, 460 V and 575 V. Also here are the permissible Deviations ± 10% down. From a European perspective, this different voltage information often misleading. The higher voltage value (e.g. 480 V) is that of the energy guaranteed value in the feed-in supply point public and private electricity networks. The lower levels of consumer power (460 V) taken into account already a possible Voltage drop in the transmission in the often very extensive, line exported consumer networks North America – in contrast to the ring-structured and several Pages fed, European Electricity networks.

With the wide supply voltage areas of 180 V to 264 V (± 0%) and 342 V to 528 V (± 0%) guarantee the frequency inverter



① = Main disconnect/Branch circuit protection

② = Bypass-contactor, optional

③ = Motor

④ = Motor-contactor, optional

⑤ = Drive

⑥ = Inverter Input Contactor.

⑦ = Door with built-in operator interface (*Keypad*), Pilot and Control Circuit devices and main disconnect switch/ branch circuit protection operator

Figure 14: Frequency inverter cabinet, schematic structure according to figure 13.

to Eaton Moeller electrical connection to almost all AC commercial networks in North America and the world (50/60 Hz ± 3%).

Frequency inverter in the application

Frequency inverters are on the mainly North American market pre-wired in a control cabinet fitted. Those Cabinets include frequency inverters all the necessary components (Main switches, fuses, transformers, EMC filters, controls etc.) for the safe operation a PDS in a proven and known application. They are examined (UL certificate) and with a numbered "Listing label". In addition, they take into account the local Voltages and mapped Engine performance. And

Rated motor current to normal four pole, internally-ventilated and enclosed fan-cooled three-phase asynchronous motor (1800 rpm)					
230 V, 50 Hz		220-240 V, 60 Hz		at U_{LN}=1 AC 230V/240V, 50/60 Hz	
[kW]	[A]	[HP]	[A]	Part no.	[A]
0.25	1.4			MMX12AA1D7…	1.4
0.37	2	1/2	2.2	MMX12AA2D4…	2.4
0.55	2.7			MMX12AA2D8…	2.8
0.75	3.2	3/4	3.2	MMX12AA3D7…	3.7
1.1	4.6	1	4.2	MMX12AA4D8…	4.8
1.5	6.3	1-1/2	6	MMX12AA7D0…	7
		2	6.8	MMX12AA7D0…	7
2.2	8.7	3	9.6	MMX12AA9D6…	9.6

230 V, 50 Hz		220-240 V, 60 Hz		at U_{LN} = 3 AC 230 V/240 V, 50/60 Hz			
[kW]	[A]	[HP]	[A]	Part no.	[A]	Part no.	[A]
0.25	1.4			MMX32AA1D7…	1.4		
0.37	2	1/2	2.2	MMX32AA2D4…	2.4		
0.55	2.7			MMX32AA2D8…	2.8		
0.75	3.2	3/4	3.2	MMX32AA3D7…	3.7	HMX32AG3D4…	3.7
1.1	4.6	1	4.2	MMX32AA4D8…	4.8	HMX32AG4D8…	4.8
1.5	6.3	1-1/2	6	MMX32AA7D0…	7	HMX32AG5D6…	6.6
		2	6.8	MMX32AA7D0…	7	HMX32AG8D0…	8
2.2	8.7	3	9.6	MMX32AA011…	11	HMX32AG011…	11
3	11.5					HMX32AG012…	12.5
4	14.8	5	15.2			HMX32AG018…	18
5.5	19.6	7-1/2	22			HMX32AG024…	24.2
7.5	26.4	10	28			HMX32AG031…	31
11	38	15	42			HMX32AG048…	48
15	51	20	57			HMX32AG062…	62
18.5	63	25	68			HMX32AG077…	77
22	71					HMX32AG077…	77
30	69	30	80			HMX32AG088…	88
		40	104			HMX32AG106…	106
37	117	50	130			HMX32AG143…	143
45	141					HMX32AG143…	143
		60	154			HMX32AG170…	170
55	173	75	192			HMX32AG208…	208
75	233	100	248			HMX32AG261…	261
90	279	125	312			HMX32AG310…	310

400 V, 50 Hz		440-480 V, 60 Hz		at U_{LN} = 3 AC 400 V/480 V, 50/60 Hz			
[kW]	[A]	[HP]	[A]	Part no.	[A]	Part no.	[A]
0.37	1.1	1/2	1.1	MMX34AA1D3…	1.3		
0.55	1.5	3/4	1.6	MMX34AA1D9…	1.9		
0.75	1.9	1	2.1	MMX34AA2D4…	2.4		
1.1	2.6	1-1/2	3	MMX34AA3D3…	3.3	HMX34AG3D4…	3.4
1.5	3.6	2	3.4	MMX34AA4D3…	4.3	HMX34AG4D8…	4.8
2.2	5	3	4.8	MMX34AA5D6…	5.6	HMX34AG5D6…	5.6
3	6.6	5	7.6	MMX34AA7D6…	7.6	HMX34AG8D0…	8
4	8.5			MMX34AA9D0…	9	HMX34AG9D6…	9.6
5.5	11.3	7-1/2	11	MMX34AA012…	12	HMX34AG012…	12
7.5	15.2	10	14	MMX34AA014…[1]	14	HMX34AG016…	16
11	21.7	15	21			HMX34AG023…	23
15	29.3	20	27			HMX34AG031…	31
18.5	36	25	34			HMX34AG038…	38
22	41	30	40			HMX34AG046…	46
30	55	40	52			HMX34AG061…	61
37	68	50	65			HMX34AG072…	72
45	81	60	77			HMX34AG087…	87
55	99	75	76			HMX34AG105…	105
75	134	100	124			HMX34AG140…	140
90	161	125	156			HMX34AG170…	170
110	196	150	180			HMX34AG205…	205
132	231	200	240			HMX34AG261…	261
160	279	250	302			HMX34AG310…	310

[1] MMX34AA014... only with reduced motor load for motors with 7.5 kW (400 V).

Table 2: Motor rated currents and assigned frequency inverter

they are in the Rule in the vicinity of the engine up (brief engine lines).

Example of such a standard solution is shown in Figure 13 frequency pump drive. In case of need the pump also unregulated on a bypass contactor operated. Approval (UL approval) and numeric "Listing label" (accompanying Report) are the basic prerequisite easy acceptance of a machine control by local Authorities (AHJ).

For the export of a machine control to North America and the local Admission is still the effort much more extensive. Even when the project must standard compliant and market combinations and regional and local Special features on site considered will. Examples include the general standard different climatic conditions, specific requirements of each customer to the industry Fire safety and spare parts procurement (e.g. set Fuses, filters in cabinet fan).

For a quick and easy approval in North America, it is advisable the machine controls in the European Manufacturers already confronted tested. Can draw support experienced professionals and bodies (e.g. UL, TUV Rheinland, etc.).

Any modifications can be beneficial under their own responsibility and own Manufacturing facilities carried out will. A "remote" Modification in North America caused always much higher costs. In Cases of doubt, but it can also often only the timely contact with the plant operators (end user) and the licensing authority (AHJ) mounting place to a clarification.

A relatively safe way to Export control to a machine North America and the local registration, is the approval. The machine control must be in a UL and CSA inspectors monitored Workshop be built. After successful and final test Acceptance allows the UL certificate then be admitted to their actual Applications. The certification the machine control is However, high costs and makes only at high volumes Sense.

Asynchronous motor and frequency inverters

The execution of most three-phase asynchronous motors is now the IEC und NEMA (UL)-specifications. With the rated power:

- **UL**, 460 V, 60Hz (NEMA MG-1, UL, CSA)
- **IEC**, 400 V, 50 Hz (IEC 60 034)

f [Hz]	U [V]	P [kW]	I [A]	n [rpm]	cos φ	M [Nm]
50	400	7.5	14,4	1450	0.87	49.4
60	460	8.6 (~ 10 HP)	14.2	1750	0.86	47
120 %	115 %	115 %	~ 100 %	120 %	~ 100 %	~ 96 %

Table 3: Tax levels for asynchronous motor (50/60 Hz)

NEMA: *National Electrical Manufactures Association* = the Association of Electrical and Medical Imaging Equipment Manufacturers.

and permitted areas of, for example, 380 to 480 V ± 10%, they can almost all known worldwide Electricity networks can be connected.

In North America entails, compared Europe (50 Hz) 20% higher frequency network also a 20% increase in speed and about 15% higher voltage has a 15% increase in wave power; at almost the same rated current (see the example in **Table 2**).

The assignment of a frequency inverter to AC motor should therefore always on the assessment of the motor current and not on his mechanical shaft power.

When frequency AC motor may be offset by the decoupling on the DC link, the rotation frequency for the motor can set regardless of the network frequency. The permissible frequency and speed areas and its torque characteristics the motor must be be taken into account (details motor manufacturer).

Overload protection

Motor overload protection is implemented directly on the frequency inverter on frequency-controlled three-phase motors (individual drives). This entails an exact transfer of the motor data (rating plate) into the corresponding parameter of the frequency inverter (motor model, protective function).

As direct overload protection (bimetal relays, PKZM, NZM, etc.) is not visible for the end user, marking on the frequency inverter is often required in North America: "Overload Protection provided". This requirement is justified to the operator with "Marking Location H and F" of the UL 508C, Par 56.1. This does not apply for frequency inverters; however, the manufacturers have gone over to printing this information in set up instructions and operating manuals or to providing a printed label and/or including a label for printing on the CD accompanying the product.

On multiple-motor drive systems – parallel connection of several drives to a frequency inverter output – each motor feeder must be protected by a separate motor overload protection (bimetal relay, PKE). The overload protection is set to the rated current of the assigned motor.

Conclusion

Frequency inverters for the North American have the necessary market approvals (UL, CSA) demonstrate. For the use of a frequency inverter in a machine control ranges it does not matter if the frequency inverter and all other, applied Products approved. Crucial is the collective work of the devices according to the application of standards in the actual application environment (certified machine control).

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Other sources of information

Internet:
www.ansi.org
www.csa.ca
www.iec.ch
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