COMPARING INTERNATIONAL STANDARDS TO NORTH AMERICAN STANDARDS FOR LARGE ADJUSTABLE SPEED DRIVES

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ABSTRACT

The world of legal responsibility, liability, and safety is driving the industry to have equipment built to an increasing number of standards. End users and specifiers often require Adjustable Speed Drives (ASDs) to be in compliance with many standards like IEC, NEMA, ANSI, CSA, UL, etc. This is done to insure that they are protected in buying products that are built to high standards. Depending on the specifier, European and/or North American standards may be referenced and required to be met. However, what is required to meet these standards is often not understood. Sometimes the details of the standards are in conflict with each other. This paper will attempt to compare major areas of the existing standards for similarity and differences. European IEC standards will be compared to the most applicable North American standards. The goal of the paper will be to help the readers better understand what the standards mean to their plants and how they can then include standards in their specifications that will best meet their requirement, yet do so in a cost effective manner.

INTRODUCTION

In recent years, large medium voltage (above 1000 V_{ac}) ASDs have been applied more and more frequently in the cement industry. Figure 1 shows the trends that have been observed since 2007 and the projections that will continue for medium voltage ASD units up to 2013. The trend estimates that medium voltage ASD installations will increase by approximately 35% between 2011 and 2013. To fulfill this demand, engineering procurement and construction (EPC) firms and original equipment manufacturers (OEM) are likely to receive offerings from several global ASD vendors, each manufacturing drives to different standards. Hence, it will be important for all evaluators in the "decision making" chain to be reasonably familiar with the various standards being used for adjustable speed drives. However, becoming familiar with ASD standards is difficult and generally beyond the scope of most purchasers.

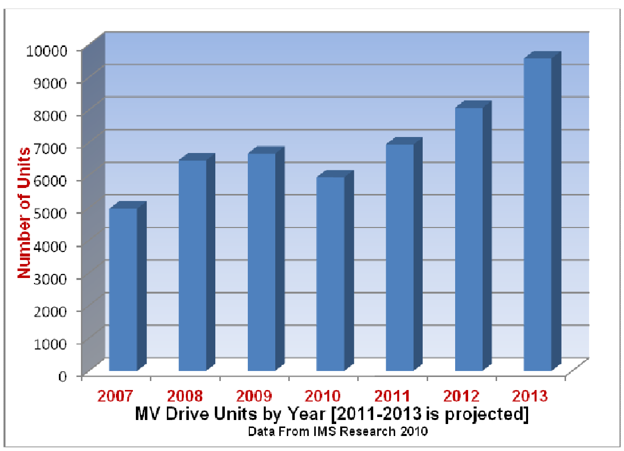

Fig. 1 Medium Voltage ASD unit projections [1]

The common purpose of North American and International standards is insuring that any ASD being installed around the world are reliable, safe and perform as desired, but they approach the issue differently. To that end, users and specifiers must determine whether these two sets of standards arrive at the same result or not. The following sections will compare the major areas of existing European

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International Electrotechnical Commission (IEC) standards and North American standards for their similarities and differences.

The critical need for standards that lead to good, safe performance is made even more urgent because complexity of cement production has led to an increase in equipment size and consequently the power required to operate it. This need for powerful equipment magnifies concerns about cost, safety, and reliability. How does a cement plant know if they are getting quality equipment that will be suitable for their application and give long service life? Fortunately, standards organizations like Institute of Electrical and Electronics Engineers (IEEE), IEC, Underwriters Laboratory (UL) and Canadian Standards Association (CSA) have long been a source of documentation and specifications to help the industry assure the buyer in procuring quality products. The following section gives a few examples of specifications that are often reviewed by ASD vendors from the cement industry.

EXAMPLES OF INDUSTRY SPECIFICATIONS

In the cement industry, specifications for medium voltage adjustable speed drives are derived from many different sources. Some plants have their own corporate specifications, a few utilize engineering firms or consultants to create specifications for them and the remaining research the internet and adopt a specification that suits their needs based on geographic location. There are several versions of specifications available and each one differs in minor ways. However, most specifications make some reference to North American and/or European standards. An example cut from a section of an actual ASD specification from a cement company is shown in Figure 2.

This example specification references multiple international standards like National Electric Code (NEC), American National Standards Institute (ANSI), IEEE, UL, and IEC. Some standards are broadly referenced, with applicable sections not identified. Since many broad-based references were developed for particular markets, it becomes very difficult for any single ASD manufacturer to comply with all standards. Some standards could be met; but most manufacturers would take exceptions, or provide a price adder to meet certain standards which could prove expensive with virtually no benefit to the end user in terms of performance and safety. And some just do not apply! Such a broad list appears to be an attempt to protect the specifier from any possible liability for suitability, while giving no guidance as to the intent of the inclusion.

1.3 REFERENCES

A. Variable Frequency Drive

1. Canadian Standards Association (CSA) "Industrial Control Equipment C22.2 No. 14"
2. American National Standards Institute (ANSI) "Instrument Transformers C57.13"
3. Institute of Electrical & Electronic Engineers (IEEE)
4. Electrical & Electronic Manufacturers Assoc. of Canada (EEMAC)
5. Guide for Harmonic Control and Reactive Compensation of Static Power Converters (IEEE 519-1992)
6. National Electrical Manufacturers Association (NEMA) "Medium Voltage Controllers Rated 1501 to 7200V AC ICS 3-2 (formerly ICS 2-324)"
7. Underwriters Laboratories, Inc. (UL) (High Voltage Industrial Control Equipment 347)
8. UL 347A Medium Voltage Power Conversion Equipment Preliminary Standard
9. International Electrotechnical Commission (IEC) 61800-5 AC Drives Standard
10. European Directives for Safety and EMC
11. National Electrical Code (NEC)
12. Occupational Safety & Health Act (OSHA)

Fig. 2 ASD specification referencing international standards

A similar example that primarily references North American standards is shown in Figure 3.

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National Electrical Manufacturers Association (NEMA)

NEMA ICS 6 – Industrial Control and Systems Enclosures
NEMA ICS 7 – Industrial Control Systems Adjustable Speed Drives

National Fire Protection Association (NFPA)

NPFA 70 – National Electrical Code (NEC)

Underwriters Laboratory

UL 347A – Medium Voltage Power Conversion Equipment

Fig. 3 ASD specification referencing North American Standards

Figure 4 shows a specification that references North American standards, but omits important standards such as the IEEE 519-1992 harmonic compliance specification. This is an example of under-specifying ASDs that could lack harmonic conformance and could result in a harmonic nightmare at the end user's facility.

1.3 REFERENCES

A. Smart Motor Controllers
1. Canadian Standards Association (CSA) "Industrial Control Equipment C22.2 No. 14"
2. American National Standards Institute (ANSI) "Instrument Transformers C57.13"
3. Institute of Electrical & Electronic Engineers (IEEE)
4. Electrical & Electronic Manufacturers Assoc. of Canada (EEMAC)
5. National Electrical Manufacturers Association (NEMA) "Medium Voltage Controllers Rated 1501 to 7200V AC ICS 3-2 (formerly ICS 2-324)"
6. Underwriters Laboratories, Inc. (UL) (High Voltage Industrial Control Equipment 347)
7. UL 347A Medium Voltage Power Conversion Equipment Preliminary Standard
8. European Directives for Safety and EMC
9. National Electrical Code (NEC)
10. Occupational Safety & Health Act (OSHA)

Fig. 4 Example of misspecifying ASD that reference North American Standards

The ASD specification examples shown in Figure 2, 3, and 4 illustrate just a few of the many options for picking the standards and organizations to be applied to a particular project and final installation. From a performance standpoint, miss-specifying ASDs can lead to non-conformance to utility standards, sluggish dynamic operation, or premature failures which are expensive to fix and maintain. The next sections will give overviews of standards applicable to ASDs, both North American and international. Finally a comparison of these two sets of standards will be presented.

NORTH AMERICAN STANDARDS

Standards lists for adjustable speed drives in North America most often reference NEMA, ANSI, IEEE, UL and CSA. While there are literally hundreds of standards maintained by these organizations, the set of standards that can be applied to medium voltage ASDs is much smaller.

One of the primary standards organizations is the Institute of Electrical and Electronic Engineers (IEEE). This organization is made up of many diverse people. In [2], Bill Lockley et. al, indicate that "IEEE standards have input during preparation and balloting from individuals representing users, manufacturers and general interests. The people involved are mostly but not exclusively from North America. The balloting is arranged so that no one interest group can dominate the process" [2]. This ensures that the standard being compiled is unbiased and the end user has their inputs also incorporated.

For example, the medium voltage ASD IEEE 1566 – 2005 "IEEE Standard for Performance of Adjustable Speed AC Drives Rated 375kW and larger" standard was created to offer a way of standardizing drive requirements and minimum performance from the user's point of view [3]. However, this standard does not define how to build a drive; it simply tries to help the user in creating a purchasing specification. This standard is steadily gaining acceptance by some users but is not generally referenced as a standard to which the medium voltage variable frequency drive is to be built. A parallel document for drive application standards is “Application Guide For AC Adjustable Speed Drive Systems” [4]. This comprehensive document also focuses on drive performance and matching drives to real world applications, not specifically on drive construction.

The responsibility of defining how the drives are physically built in North America is dictated by UL, CSA, and ANSI standards organizations. UL, or Underwriter’s Laboratories Inc, is an independent product safety organization based in Northbrook, Illinois. UL develops standards and test procedures for products, materials, components, assemblies, chiefly dealing with product safety.

The Canadian Standards Association, which operates under the name CSA International, also provides certification services for manufacturers who, under the license from CSA, wish to use the appropriate registered CSA Marks on certain products of the manufacturers to indicate conformity with CSA Standards. CSA is a provider of product testing and certification services for electrical, mechanical, plumbing and gas.

The American National Standards Institute, or ANSI, accredits standards that are developed by representatives of standards organizations, government agencies, consumer groups and others. These standards aim at ensuring that the characteristics and performance of products are consistent, that everyone uses the same definitions and terms, and that products are tested in the same way.

ANSI is also a National Organization for Standardization (ONN) that is registered by the DGN (Direccion General de Normas) in the electrical sector and household appliances. DGN develops Mexican Standards (NMX) and collaborates in the development of the Mexican Official Standards (NOM), voluntary and mandatory standards, respectively.

To simplify applying all the relevant sections of these diverse organizations to medium voltage ASDs, the standards organizations of ANSI, CSA and UL have harmonized on UL 347 as a UL/CSA/ANSI Standard. This standard is co-published by UL, ANSI, and CSA. These standards cumulatively reflect the requirements of the US, Canada, and Mexico.

The UL 347 standard for electrical equipment is a very broad standard which covers medium voltage ac contactors, controllers, and control centers. In 2008, UL created a very specific standard, UL 347A, titled “OUTLINE OF INVESTIGATION FOR MEDIUM VOLTAGE POWER CONVERSION CONTROLLERS” [5]. This specification deals directly with details of design and manufacture of medium voltage adjustable speed drives

EUROPEAN STANDARDS

In Europe, the primary standards used are based on the International Electrotechnical Commission (IEC), and these standards differ from North American standards in the sense that IEC standards are written by a group of people having only one representative per country. That representative usually gets input from others, who often represent manufacturers. Balloting for acceptance is on a country by country basis.

For Europe, there are several IEC standards that apply to medium voltage variable frequency drives. Table 1 outlines these applicable IEC standards for adjustable speed drives.

Standard #	Description
61800-3	Adjustable speed electrical power drive systems Part 3 EMC requirements and specific test methods
61800-4	Adjustable speed electrical power drive systems Part 4 General requirements – Rating specifications for a.c. power drive systems above 1000 Vac and not exceeding 35 kV
61800-5-1	Adjustable speed electrical power drive systems Part 5-1 Safety requirements – Electrical, thermal and energy

Table. 1 IEC Standards applicable to Adjustable Speed Drives

The next section of the paper will focus on the standard IEC 61800-4 "Adjustable speed electrical power drive systems Part 4 General requirements – Rating specifications for ac. power drive systems above 1000V_{ac}. and not exceeding 35kV," the standard applicable to medium voltage adjustable speed drives [6]. This is the closest standard that aligns itself with the North American UL 347A standard and is the most referenced IEC standard on medium voltage drive projects for cement applications.

TABLE OF COMPARISION

When comparing two standards it is important to point out both the similarities and differences between them. Tables 2A and 2B show a section by section comparison of UL 347A and IEC 61800-4. It will be seen that there are two primary differences between the standards. First, UL 347A addresses only the medium voltage variable frequency drive itself (Figure 5) while IEC 61800-4 is more broadly written to encompass the total medium voltage system, including the optional equipment like isolation transformers and filters (Figure 6).

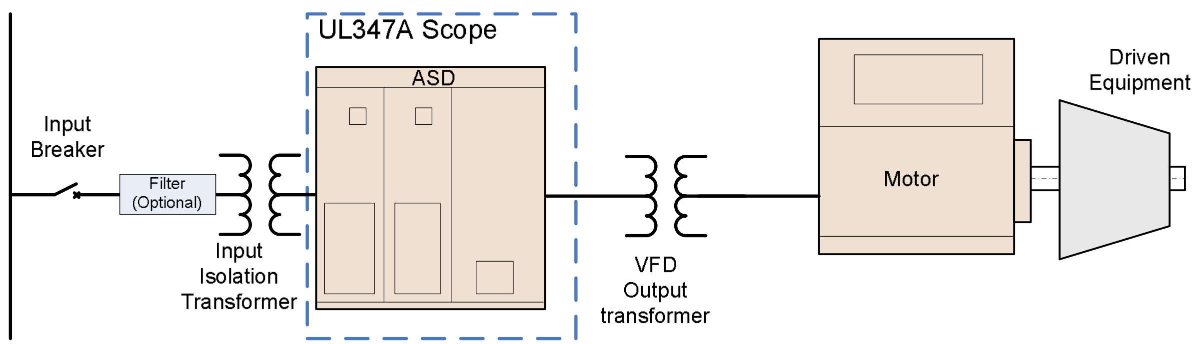

Fig. 5 Scope of items covered by UL 347A standard

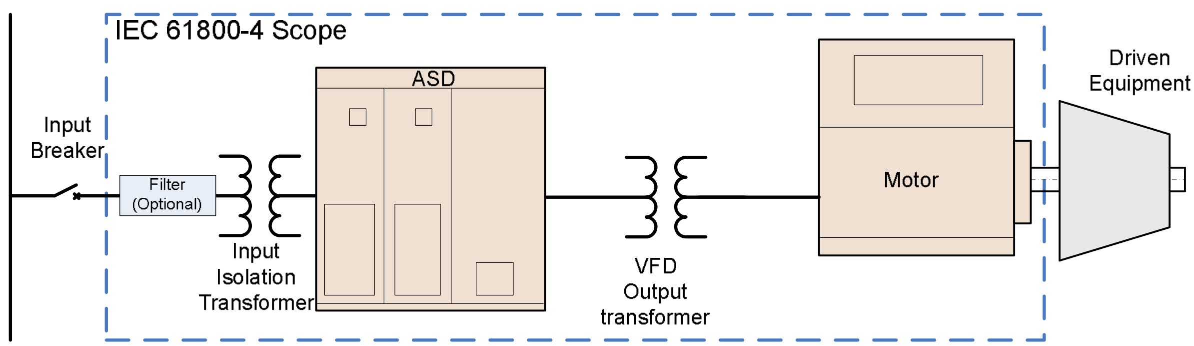

Fig. 6 Scope of items covered by IEC 61800-4 standard

Second, IEC standards give many more recommended ranges of values for design while the UL standard simply refers to the units of measure without defining their ranges. Our comparison will be done under the following major sections:

a) Scope
b) Definitions
c) Environment
d) Transformer
e) Drive Characteristics
f) Motor
g) Grounding
h) Protection
i) Testing

We will look at each area in detail, and then summarize them in the table that follows.

Scope – As illustrated in Figure 6, different scope is a major difference area between UL-347A and IEC 61800-4. The UL standard does not include rotating machinery like synchronous or induction motors, while the IEC standard uses the concept of a Power Drive System (PDS) which includes the motors. The IEC standard also references over 40 other IEC standard documents! This wide scattering of sub-standards seriously impacts the usefulness of IEC 61800-4 as a primary standard since it is very difficult to verify compliance with all 40 referenced documents. Such referencing seems to be insurance to assure that all areas are covered. Instead, it has the effect of creating a document that is too difficult to apply and with which to be in compliance.

Definitions - Both standards provide a long list of useful terms and definitions as they apply to medium voltage variable frequency drives. The IEC standard glossary is over 12 pages and gives some excellent definitions that are useful in learning the vocabulary used in the industry.

Environment - The UL 347A standard does not list specific environmental requirements other than limits on ventilation openings to protect against environmental conditions. Instead it provides a generic requirement that ASDs intended for outdoor installation comply with section 7.2 of UL 347. In contrast, the IEC standard provides detailed specifications covering environmental requirements such as temperature ranges of the cooling medium and the ambient temperature. Moreover, it defines a range on the relative humidity, the maximum operational altitude, as well as dust and solid particle content. Additionally IEC 61800-4 specifies that air cooled systems must have appropriate filters to prevent particles in the air supply from damaging the system. The IEC standard also places limits on acceptable noise generated by the VFD.

Transformer - The UL standard does not discuss transformers in great detail. Instead it states that transformers used in power conversion shall comply with the appropriate standard transformers applied to drives. The IEC standard gives great detail about transformers in the system. It lists specifications and ratings for many aspects of the transformer such as the harmonic current and voltage withstand tolerance, winding arrangements, phase offset requirements, rating nameplate requirements and ambient temperature requirements. Since the UL standard is comparatively generic and the IEC standard is more specific concerning transformers, this is an area where conflict could occur between the two standards.

Drive Characteristics - Another clear difference between the standards arises in defining the drive characteristics. The UL 347A standard makes almost no reference to required ratings, efficiency, overload capability, control dynamics, or interfaces of the VFD. It does however provide requirements for the enclosure and ventilation of the converter. The IEC standard on the other hand covers all these topics at great length. The I/O ratings, torque and power ratings, efficiency and losses, and overload capability are covered for both the ASD and its converter in IEC 61800-4. The IEC standard also covers steady state and dynamic performance requirements. The IEC standard also details analog and digital I/O performance, and defines the performance requirements for communication links, even including the connector and cable type for the physical interface. A comparable North American standard is *IEEE 1566, Standard for Performance of Adjustable Speed AC Drive Rated 375 kW and Larger*.

Motor - As mentioned previously, the UL 347A standard does not cover motor application while the IEC 61800-4 standard does. The IEC standard discusses many different aspects of motor operation and requirements such as: design and performance requirements, mechanical system integration requirements, and limits on voltage stress of the motor winding insulation system. The IEC standard also states that essential data such as rated torque, torque at minimum speed, the motor's minimum/maximum speed, and others are to be provided beyond what is typical on a normal motor nameplate. When referencing this IEC standard, it is important to make sure that it does not conflict with any other motor standards that are being referenced elsewhere in the project. For example: The IEC drive standard 61800-4 states that all motor design requirements, such as the cooling system, envelope, and mounting, are to agree with various sections of IEC 60034. American standards such as API 541, may specify that motor enclosures shall be Totally Enclosed Fan Cooled (TEFC) if available or Totally Enclosed Air to Air Cooled (TEAAC), and not be in agreement with IEC. Another example of conflict between these standards is found in the mounting requirements of API 541 or their customer-specific versions, which states that the equipment supplier must supply AISI 300 or ISO 3506 series shim packs between the mounting plates and the machine feet. NEMA MG1, API 541 and 546 are North American standards corresponding to IEC standards when referring to large AC rotating machinery. Conflicts in a portion of IEC 61800-4 for ASD specification in motor areas must be expected.

Grounding - Both the UL 347A standard and the IEC 61800-4 define requirements for grounding. The UL 347A standard is again more generic as it references section 10 of the UL 347 for grounding requirements. However, UL 347A does describe requirements for identifying present grounding locations within the VFD. Examples include the color and shape of screws intended for connecting a field-installed grounding conductors and the color of insulated grounding and bonding conductors. The IEC standard is generic about proper grounding requirements but includes details as to where grounds should be placed as opposed to how they should be identified.

Protection - Both standards list many required protection functions as they apply to medium voltage VFDs. The IEC standard is more comprehensive than the UL standard and also requires both alarm and/or trip requirements for each protection function. This difference between standards could result in conflict in the specification should both these standards be referenced.

Testing – Both UL 347A and IEC 61800-4 standards require a wide variety of tests to be performed. The UL standard contains ten different tests to be conducted as well as procedures to carry out each test. The IEC standard contains forty-one different tests of which not all may be required. IEC does not detail many of these tests but instead references other IEC standards that contain them. This is another key example of conflict between the two standards. Should a specifier require that both the UL and IEC standards compared here be met, it would be difficult or close to impossible for an ASD manufacturer to determine which tests will be needed to be performed, and to sort out which were not possible to be performed.

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MV ASD Standards
IEC 61800-4 and UL 347A
Categories and Specification Sections List

Standard Category	**IEC 61800-4** **Section reference**	**UL347-A** **Section reference**
Scope	MV Adj speed AC drive systems including power conversion, control **and motor**	MV Adj speed AC drive systems including power conversion and control but **excluding motors**
Definitions/Glossary/Units	3	2, 3 ,4
Drive system Topology	4	Not addressed
Electrical Input/Service Conditions	5.1.1 Details given with level and acceptable range	5 Defines necessary parameters but no levels or ranges
Source Impedance	5.1.1.2	Not addressed
Climate Conditions	5.1.2.1 Defines accepable environment for drive	Not addressed
Mounting/Vibration	5.1.2.2 defines normal vibration requirements for stationary equipment	Not addressed
Transportation & Storage	5.2 and 5.3 Defines environmental, temperature and humidity ranges	Not addressed
Ratings	6	Not addressed
Efficiency	6.1.4	Not addressed
Overload	6.1.5	Not addressed
Control Dynamics	7.1 and 7.2	Not addressed
Interfaces	7.3	Not addressed
Transformer	8.2 detailed	24
converter	8.3	Not addressed
Enclosure/ventilation	8.3.2.1&2	7.2, 42 Marking requirements
Air Cooling	8.3.2.3.2	7.2
Acoustic Noise	8.3.2.4	Not addressed
Motor	8.4	Not addressed
System Integration and Grounding	9 Guidelines for installation of system from switchgear, transformer, drive and motor	System not addressed
Grounding of Drive	9.2.3.2	10
Protective Functions - Alarm and Trip Requirements	9.3 Table 8 Overall	10 & 11 No differentiation between Alarm and Trip requirements
Protective Functions	9.3 phase loss	11.6, 11.10
Protective Functions	9.3 overcurrent	11.3 & 4 & 5, 11.8
Protective Functions	9.3 overload	11.2
Protective Functions	9.3 loss of cooling	11.7
Protective Functions	9.3 overspeed	11.9
Protective Functions	Not addressed	13 Isolating Means
Tests	10	27-37, 44
Efficiency determination	11	Not addressed
EMC requirements	covered by 61800-3	Not addressed
Electrical Safety	covered by 61800-5-1	13, 14, and covered by NFPA 70
Possible duty cycles	covered by 61800-6	Not addressed

Table 2A Standards comparison chart

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MV ASD Standards
IEC 61800-4 and UL 347A
Categories and Specification Sections List

Standard Category	IEC 61800-4 Section reference	UL347-A Section reference
Automatic Restarting	10.3.4.3	15
Overload Relays	Not addressed	12
Wiring	Not addressed	16, 17, and sections of UL 347
Field connected Control Circuit Terminals	Not addressed	18
Spacings	Not addressed	19
Means for switching	Not addressed	20
Capacitors	Not addressed	21 discharge means and protection
Control Circuits	Not addressed	22
Bypass Circuits	Not addressed	23
Cord-Connected Programming and Diagnostic Units	Not addressed	25
Markings (equipment & devices)	Not addressed	38
Protection Markings	Not addressed	39, 40
Cautionary Markings	Not addressed	41

Table 2B Standards comparison chart

CONCLUSIONS

Overall, in spite of differences, there is still substantial agreement between the IEC 61800-4 and UL 347A standards for medium voltage ASDs discussed in this paper. For the user specifying medium voltage adjustable speed drives, specifying too many conflicting standards can lead to confusion and the result is that no manufacturer/supplier can meet all requirements. Faced with this situation, many suppliers may take blanket exceptions to the standards such that the meaningfulness of having a quality specification is lost. It would be a better approach to specify the performance details of the drive (like IEEE 1566) while referencing only the UL or IEC standards that actually will apply at the final installation site.

There continues to be a trend towards harmonization of IEC and North American standards, and the authors' hope this trend continues and will be supported by the various organizations. Once harmonized standards are created, the end user will be protected from using conflicting standards.

REFERENCES

[1] IMS Research 2010. Published market news

[2] Bill Lockley, Rick Paes, Janet Flores, "*A comparison between the IEEE 1566 standard for large Adjustable speed drives and comparable IEC standards*." IEEE PCIC Europe 2007, pg: 1 – 7, 13-15 June 2007

[3] IEEE 1566-2005, *IEEE Standard for Performance of Adjustable Speed AC Drives Rated 375 kW and Larger*, 2005

[4] *Application Guide For AC Adjustable Speed Drive Systems*, National Electrical Manufactures Association (NEMA), Dec. 27th 2007

[5] UL 347A *Outline of investigation for medium voltage power conversion controllers*, Issue # 1, July 29th 2008

[6] IEC 61800-4 *Adjustable speed electrical power drive systems Part 4 General requirements – Rating specifications for a.c. power drive systems above 1000V a.c. and not exceeding 35kV*

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