

Standard Updates for Adjustable-Speed ac Drives



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THE PERFORMANCE STANDARD FOR
DRIVES RATED 375 KW AND LARGER

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THIS ARTICLE PRESENTS THE MAIN REVISIONS, UPDATES, and additional materials that have been included in the IEEE 1566 adjustable-speed drive (ASD) standard first published in 2005. This revised standard includes suggestions and additions received from end users, manufacturers, and consultants that reflect both field experience and advances made over the past ten years.

Also addressed in the latest revision of the standard are the data sheets that have been extensively revised and defined and are now available in Excel for an easier exchange of information between the purchaser and manufacturer. For example, to aid the user, a new section, “Technical Data Sheet Guide,” explains the various terminologies used in the standard. Finally, the working group has identified areas for future work.

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The Creation of an IEEE Standard

One of the principal activities of the IEEE is the creation of standards. The institute’s mission statement includes the following: “IEEE’s core purpose is to foster technological innovation and excellence for the benefit of humanity” [1]. IEEE’s vision for the organization is that it “will be essential to the global technical community and to technical professionals everywhere and be universally recognized for the contributions of technology and of technical professionals in improving global conditions” [1]. Therefore, it is logical for standards to be one of the primary ways that the IEEE will achieve this goal. One of the organizations within the IEEE is the Standards Association (IEEE SA), which is responsible for developing global standards for many industries, including power and energy, biomedical and health care, information technology and robotics, telecommunication and home automation, transportation, nanotechnology, information assurance, oil and gas, and many more.

Process Overview

The standards-development process has been well defined and documented and is available to all members on the IEEE Standards website. As part of the process of creating a standard, the IEEE ensures that every effort is made to solicit and address balanced input from all entities who will be utilizing the standard and whose work it will directly affect.

Figure 1 depicts the overall standards-generation process. Once a standard has been published, it is required that it either be revised or withdrawn after a set period of time to ensure that the standard remains current. When IEEE Standard 1566 was established in 2005 [2], that timeline spanned five years. As shown in Figure 1, this five-year timeline has recently been extended to ten years.

Synopsis of the 1566 Standard

IEEE Standard 1566-2015 [3] applies to ac ASD systems rated above 375 kW (500 hp) and above a 750-V output voltage, as used in petrochemical and similar applications. These systems are also referred to as *variable-frequency drive*, *variable-speed drive*, and *power-drive* systems. The standard covers the performance requirements for an ASD system including, but not limited to, the input switching device, input impedance (transformer or reactor), power electronics, control interfaces, cooling system, and motor. Figure 2 shows the elements that could apply to a generic block diagram of an ASD system [3].

The standard covers requirements for power quality, engineering analysis, startup assistance, train-

Once a standard has been published, it is required that it either be revised or withdrawn after a set period of time to ensure that the standard remains current.

ing, and spare parts. It is important to note, however, that the standard intends to define and specify the performance of the ASD system rather than to dictate the detailed design of various components. In the medium-voltage drive category covered in the standard, there are a number of topologies currently available, each with its own strengths and application considerations. Key to the standard are the associated data sheets in Annexes A and B. While the body of the standard provides guidelines to be followed and met in the design and performance of a drive system, Annexes A and B contain technical data sheets that provide essential design criteria to be completed by

the appropriate parties, exchanged at the onset of the project, and maintained throughout the project. For example, if specified in the data sheets, certain features and scope items, such as the motor, switchgear, or transformer, may be required or excluded from the scope of vendor supply. The responsibility for completing Annex A lies with the purchaser of the equipment as it is essentially a list of requirements. Completion of Annex B is the responsibility of the equipment manufacturer in response to Annex A, and contains information relating to the application and the selected ASD.

Additionally, the working group for this revision sought to change the format of the data sheets from a static pdf form to an electronically diverse, user-friendly version. For this reason, the data sheets are now available as in an editable Excel format as well as in pdf form.

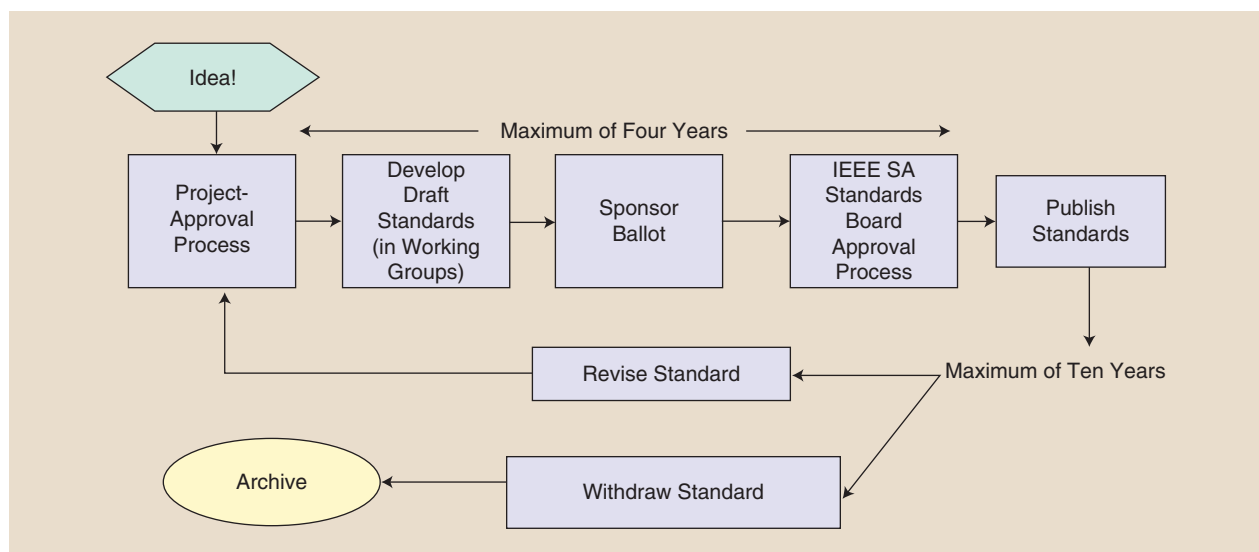


FIGURE 1. The IEEE standards development process.

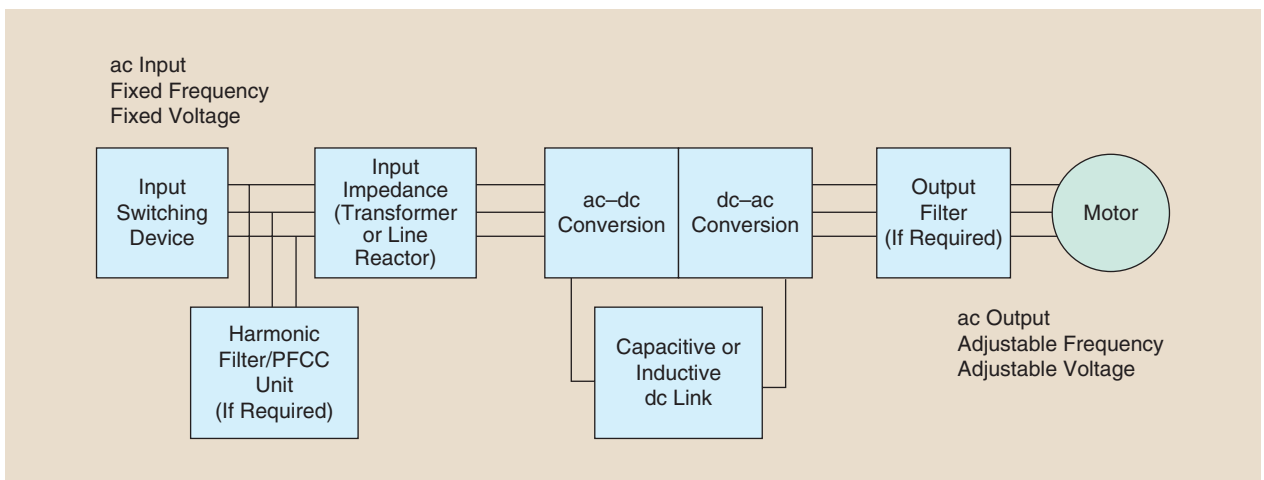


FIGURE 2. A generic block diagram of an ASD system. PFCC: power factor correction capacitor.

What was originally Annex C has been changed to Annex D. The new Annex C is a data sheet guide that gives further insight into the items and requirements in Annexes A and B, including an explanation of each item and of why certain information is required. Annexes D, E, and F are informational sections that provide guidance on engineering studies, cover specialized applications, and include the standard's reference bibliography, respectively.

Information on the Working Group

The IEEE SA is not a government-affiliated entity but a community. The standards-development process established by the IEEE SA is intended to ensure balance, openness, fair procedures, and consensus.

The IEEE 1566 working group is one of the larger groups in the standards association. It is made up of volunteers having various backgrounds, ranging from manufacturers to end users, whose purpose is to contribute to their profession through the generation of standards documents. To ensure that fairness is maintained, the IEEE standards-approval process requires that there be checks and balances in the process, with equitable participation and consensus representation. Because the standard is often the starting point for fostering future development, balance in a working group is important to ensure that the viewpoints expressed throughout the standard's development are without bias.

Intended Users

IEEE Standard 1566 is intended for anyone working with ASDs but particularly those in roles that require the procurement of specified equipment. While beneficial as a procedure to those with experience, the standard is particularly helpful to those who are less experienced because it provides an effective guide based on the accumulated knowledge and experience of many colleagues.

This is particularly important when considering the significant increase of medium-voltage drives used in recent years. The use of ASDs has risen so much since their initial introduction in the 1970s that a number of manufacturers today produce more such drives in a single manufacturing facility in one year than the entire demand recorded for the year 2000.

In addition to streamlining the order entry process, a further significant benefit of the standard is that it provides key target design information for manufacturers. It was recognized when the standard was first established that existing ASD designs would be unlikely to meet all the requirements of the standard. Since that time, manufacturers have recognized the requirements and either enhanced their existing products or designed new equipment with the IEEE Standard 1566 requirements in mind.

Why a Revision Was Needed

A revision was required to ensure that the standard remains current, addressing changes identified by the 1566 working group. Areas of the IEEE 1566 standard requiring attention included the following:

- the introduction of new and revised drive-related standards since the 2005 revision that required the update and addition of new references to keep the standard current [4]
- new ASD technologies introduced to the market since the completion of the standard
- increased industry focus in the areas of arc flash and safety
- other enhancements identified by the working group during the use of the standard.

During the course of determining the proposed revisions, new topics arose that the working group captured to consider in the next revision of the standard.

Modifications to the Standard: Technical Content

IEEE Standard 1566 [2] has been modified and updated to reflect growing knowledge and experience in the

industrial application of ASDs. Such increased knowledge and experience have enabled a restructuring of the standard to offer better and firmer guidelines. It is strengthened by cross references to other standards, feedback from manufacturers and end users, and other appropriate inclusions, given that ASDs are now widely used in many industries. This overview of the updated modifications to IEEE Standard 1566 is intended as a summary only and can be used as a guide to point out specific changes that should be read in full in the actual standard.

Application

The “Application” section of the standard includes modifications and additions in the areas of minimum availability, mean time between failures (MTBF), and mean time to repair (MTTR). Minimum availability is now defined as 99.8% over a five-year run.

Concerning MTBF, the standard now states, “For the purposes of reliability predictions MTBF parameters shall be verified by analysis and supported by field experience.” Additionally, it is noted that for a drive to achieve five years of 99.8% availability, it should be designed to achieve an MTBF of no fewer than eight years.

With respect to MTTR, external events not directly related to ASD failure, e.g., utility power supply failure or operator error, are not to be included in the reliability and availability data. The expected performance of an ASD engineered to IEEE Standard 1566 [3] requires that a parts change should be completed within 1 h and that the system should be returned to operation at a 95% confidence level within 3 h. These expected times do not apply when external constraints extend the time, e.g., isolation and return to operation.

Normative References

So that only up-to-date information is used, issue dates are no longer included in the standard’s normative references. It is the responsibility of all users of the standard to seek the latest edition of the normative references. Note: in IEEE Standard 1566, P519 is now a fully issued standard and has become IEEE Standard 519 [5]. IEEE Standard 1566 [3] contains two new power-quality normative references relating to voltage sags: IEEE Standard 1250 [6] and IEEE Standard 1564 [7].

Definitions, Acronyms, and Abbreviations

The definitions section of the standard has been expanded to include acronyms and abbreviations used throughout the standard with the intention of allowing readers to familiarize themselves with the language to better understand the standard as a whole.

Unit Construction

When specified, electronic boards shall have conformal coating applied. There is a requirement for the nameplate

to include the number of phases, nominal input current, and maximum short circuit rating.

Adjustable-Speed Operation

The “Adjustable Speed Operation” section of the standard relates to the core operation of an ASD. A new section addresses ride through, while two sections represented in the previous publication of the standard (capacity and acoustic noise level) are extensively improved. Additionally, there are changes to the sections relating to power supply, transient overvoltages, voltage sags, loss of voltage, swells, voltage distortion, and harmonic distortion.

- **Power supply:** There is a clarification of responsibility in the provision of power, acknowledging that the responsibility for providing power to external output logic devices lies with the end user.
- **Capacity:** The capacity of the system is considered in some detail to avoid system unreliability and satisfy economics. This section addresses both supply voltage tolerance and load requirements. It is widely accepted that the system operates on a continuous thermal safety margin of 10%. However, the standard acknowledges that, while a 10% safety margin is advisable, there are situations when the load does not require such a buffer, so this 10% requirement may not be needed. Nonetheless, the magnitude and duration of the overload must be selected according to the specific application and take into account specific torque requirements (variable/constant). The overload must be appropriate for the application. The motor must be provided with sufficient breakdown torque, with a margin appropriate for the application. Once selected, the information is to be noted in Annex A.
- **Transient overvoltages:** Transient overvoltages from the electrical supply are addressed as potentially damaging. It is the end user’s responsibility to provide transient protection for severe instances of overvoltage beyond those described in the standard, e.g., lightning protection and surge suppression (Figure 3).
- **Voltage sags:** Additional information about voltage sags has been added: “Unless otherwise specified,

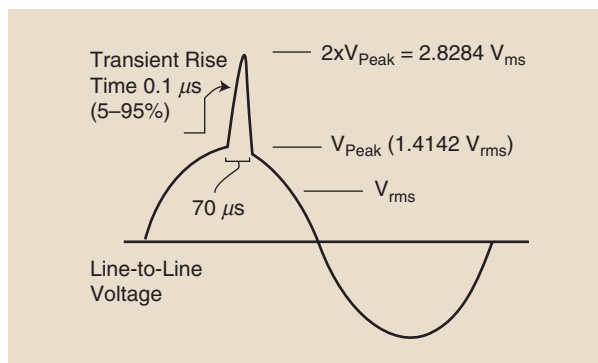


FIGURE 3. An instantaneous voltage transient (not to scale).

the drive system shall ride through and maintain control of the motor during an input power and/or control supply voltage sag down to 65% of nominal on one or more phases for a duration of 500 ms.” The implication is that an uninterruptible power supply (UPS) should be considered for the control supply. Additional information about voltage sags is available, as set out in [6] and [7].

- **Supply voltage ride through:** ASD supply voltage ride through is new to this publication of IEEE Standard 1566 [3]: “The intent of this requirement is to achieve safe and predictable operation during a power and/or control supply voltage sag or loss event (severe sag). ... The sag event could be: any phase-to-phase, any phase-to-ground, any phase-to-neutral, multiple phases, multiple phase-to-ground, or multiple phase-to-neutral.” In essence, it is necessary to understand and quantify all potential utility disturbances and make appropriate provisions in the ASD logic. The ride-through section of the standard explores this subject and provides mitigating strategies. Figure 4 is an illustration of a sag event with useful terminology.
- **Loss of voltage:** According to the standard, “The drive system shall withstand a 100% loss of voltage in one or more phases of the input power supply for 2 s or longer without losing control capability. In this case, the drive shall cease output and, upon restoration of supply, shall have the capability to restart, catch, and reaccelerate the spinning motor to its original speed.” When considering loss of voltage, it is likely that a UPS will be needed for the ASD auxiliary control power in the case of 100% loss of voltage.
- **Three-phase voltage swells:** The equipment shall operate continuously during a three-phase voltage swell to 115% of nominal for a period of 500 ms. The standard cautions that an automatic restart should be avoided under swell conditions to avoid drive component damage.
- **Voltage distortion:** The voltage distortion section includes a cautionary note stating that the occurrence

The standard intends to define and specify the performance of the ASD system rather than to dictate the detailed design of various components.

of voltage distortion may result in noncompliance with IEEE Standard 519 [5]. Such distortion is not covered by IEEE Standard 519 [5], as the distortion is likely to originate from a utility voltage event unconnected to the operation of the ASD. It should be noted that the IEEE has issued an errata to correct the numbering duplication in the original print.

- **Voltage unbalance:** The standard requires that the ASD operate at its full rated output with 3% voltage unbalance. To give the ASD vendor some flexibility, the following

note has been added: “For some ASD topologies, meeting a voltage unbalance requirement as high as 3% may lead to additional cost. In those cases where the anticipated unbalance is expected to be significantly less, it may be advisable to stipulate this to the supplier to avoid unnecessary additional cost.”

- **Harmonic distortion:** When considering harmonic distortion, it is necessary to identify the specific location of the ASD in the electrical system, i.e., the point of common coupling (PCC), to predict harmonic distortion. This, in turn, will aid in the correct application of IEEE Standard 519 [5]. In locations other than the PCC, an applicable standard may be International Electrotechnical Commission (IEC) 61000-3-6 [8]. The chosen standard must be identified in Annex A.
- **Acoustic noise:** The acoustic noise-level section has been expanded to clarify the noise level measurement methods. Essentially, when measuring equipment noise, any transformers or filters mounted in the same location as the drive should be included in the noise measurements. A minimum of four measurements should be taken and averaged. Cautionary notes warn that ambient noise in a test area or on site could interfere with correct assessments of noise levels.

Control

In the section dealing with control, the local and remote control sections have been reformatted with bullets for easier reading.

Input Transformer or Reactor

The minimum requirement for primary winding taps has been changed to “two (off-load operated) 5% taps: one above and one below nominal voltage.”

Motor

An additional requirement has been placed on the motor driven by the ASD: “In the event the motor is to be installed in a classified area, refer to Annex D.” Additionally, a new

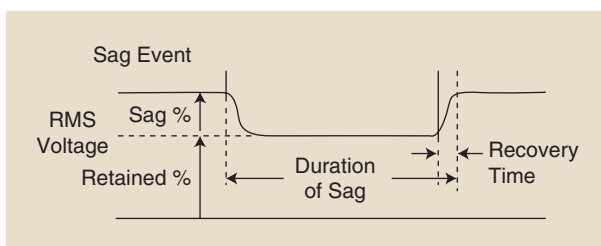


FIGURE 4. An instance of voltage sag (not to scale). RMS: root mean square.

warning has been added to the synchronous motor section: “A constant voltage power supply, such as a UPS, is often desirable to maintain voltage to the field during transient power occurrences.”

Cooling System

- *Air cooling:* For the air-cooling requirements, an additional recommendation has been made: “The fan motors shall have an L10 bearing life of 50,000 h per ANSI/ABMA [American National Standards Institute/American Bearing Manufacturers Association] [9]. Additionally, the standard warns that the air drawn into a drive must be carefully evaluated for chemical vapor hazards. Should vapors be present, the air should be suitably filtered, and circuit boards should be treated with conformal coating for protection. The presence of chemical vapor hazards should be stated in Annex A.
- *Liquid cooling:* For liquid cooling, the range of temperature has been extended below -40°C . Should such a condition be expected to be encountered, it must be stated in Annex A.

Engineering Studies

The addition to Annex C, “Technical Data Sheet Guide,” has caused the “Engineering Studies” section to be renamed Annex D and the “Bibliography” section to be renamed Annex F. A new Annex E has been created to address specialist applications that include classified areas, long cable distances, marine environments, and local generation and limited supply capacity.

Inspection and Factory Tests

- *High potential (hipot) tests:* Hipot tests are now required to be completed in accordance with UL 347 [10].
- *Production tests and control:* An additional recommendation is made that, should the specified motor not be available, the ASD vendor is to supply a suitable substitute load. Such a load may not be sensitive to phase rotation, and so additional care should be taken in evaluating the test results.

Shipping, Handling, and Storage Requirements

This new section deals with practical aspects of transportation and delivery. The purpose is to avoid pitfalls associated with the transporting, handling, and storing of equipment. This section includes a comprehensive summary and contains practical advice based on first-hand knowledge and experience.

Commissioning and Startup Assistance

In field testing, there is a warning that hipot testing is a destructive test. Should such testing be required, a mutually agreed test level should be applied. A statement, previously a note, has been made a direct requirement of the field testing: “When specified, the ability of the ASD to ride through temporary voltage disturbances shall be verified as

part of the commissioning procedure. The vendor and the purchaser will jointly develop this method of verification.”

Data Interchange

The “Data Interchange” section has been reformatted to improve readability.

Arc Flash

The importance of covering the dangers of arc-flash events, considered in conjunction with supply rating and grounding, was recognized by the team and is included in Annex C. Annex C also notes the intention to further expand the section on arc flash in the next revision.

Data Sheets

The working group expended considerable effort reformatting the data sheets to capture key information, make them easy to complete, and reflect the requirements listed in the body of the standard in chronological order. Also, each data sheet’s layout was revised for use as a stand-alone document that may be separated from the main body of the standard for easy exchange of information between the purchaser and manufacturer: Annex A is to be used by the purchaser to complete the technical data information, and Annex B is to be completed by the ASD manufacturer. Figures 5 and 6 show an extract of Annex A and Annex B, respectively. For clarity, a section or subsection number is included beside each line item.

The data sheets presented in both Annex A and Annex B represent a checklist for both the purchaser and manufacturer to complete. It is recommended that this information be provided at the outset of a project as well as for costs quotation and that the data sheets clearly note the number of requirements that must be addressed during the course of a project. The data sheets are intended to be used to avoid potential scheduling delays and cost overruns.

Both Annex A and Annex B were thoroughly revised, incorporating changes to reflect reviewers’ feedback since the original standard was published in 2005. In addition, for ease of use, both annexes are now available from the IEEE SA as Excel spreadsheets. The working group collaborated with the IEEE Standards staff to provide this new data sheet format, and it is believed this is the first time that such a useful feature has been offered in an IEEE standard. Note that each sheet for Annex A and Annex B is a separate tab in the file, for ease of navigation. Visit the following website to download the Excel format of Annexes A and B: <http://standards.ieee.org/downloads/1566-2015/>.

Annex A: To Be Completed by the Purchaser

For clarity, the items discussed here are referenced to the actual sheet number, line number, and either left or right column in the standard. For example, A1-15L refers to sheet 1, line 15, and the left column to be completed

ANNEX A, SHEET 1 OF 3 — TO BE COMPLETED BY THE PURCHASER	
6	System of Units <input type="radio"/> SI <input type="radio"/> SI plus US standard
7	
8	Supply System Voltage (6.1, 6.6)
9	<input type="radio"/> 2400 V <input type="radio"/> 3300 V <input type="radio"/> 4160 V <input type="radio"/> 6600 V <input type="radio"/> 6900 V <input type="radio"/> 13800 V
10	Other: _____ V ± _____ %
11	3 ϕ Short-Circuit Level: _____ kA at PCC _____ at drive
12	Line Frequency: <input type="radio"/> 60 Hz <input type="radio"/> 50 Hz
13	3 ϕ Short-Circuit Level: _____ kA _____ at drive
14	Line Frequency: <input type="radio"/> 60 Hz <input type="radio"/> 50 Hz
15	3 ϕ Symmetrical Short-Circuit Level at Drive Input for Arc Flash Calculations:
16	_____ Maximum kA _____ Minimum kA Duration: _____ ms
17	
18	ASD Auxiliary Three-Phase Power (6.1):
19	60 Hz: <input type="radio"/> 208 V <input type="radio"/> 480 V <input type="radio"/> 600 V <input type="radio"/> Other: _____ V
20	50 Hz: <input type="radio"/> 400 V <input type="radio"/> Other: _____ V
21	
22	Control Power (7.1)
23	<input type="radio"/> From Input <input type="radio"/> UPS <input type="radio"/> Battery <input type="radio"/> Voltage _____ V
24	Redundant Control Power Supplies: <input type="radio"/> Yes <input type="radio"/> No
25	UPS or Battery Supplied by: <input type="radio"/> Vendor <input type="radio"/> Purchaser
	Harmonics (6.2, 6.16):
	Impedance versus frequency data supplied at PCC? <input type="radio"/> Yes <input type="radio"/> No
	Point of common coupling (PCC): _____ Voltage at PCC: _____ V
	Required telephone influence (L.T) at PCC: _____
	Average Demand Current (I _L): _____
	Other harmonic requirements: _____
	Harmonic Compliance to IEEE 519: <input type="radio"/> Yes <input type="radio"/> No
	Harmonic Compliance to IEEE 61000-3-6: <input type="radio"/> Yes <input type="radio"/> No
	If "No" to both of the above, state voltage THD requirement at PCC: _____
	System Grounding (65):
	System Ground method: <input type="radio"/> Solid <input type="radio"/> Resistance at: _____ A
	<input type="radio"/> Other: _____
	Ground fault detection provided in upstream switchgear: <input type="radio"/> Yes <input type="radio"/> No
	Relevant National/Local Codes (4.1)

	Site Environment (1.3):

FIGURE 5. An extract of a data sheet from Annex A, to be completed by the purchaser. SI: International System of Units; THD: total harmonic distortion.

ANNEX B, SHEET 1 OF 3 — TO BE COMPLETED BY THE MANUFACTURER	
3	General Information
4	Vendor: _____ Manufacturing Location: _____
5	Model Number _____
6	
7	ASD rating (5.3):
8	kW: _____ Input Voltage: _____ V Output Voltage: _____ V
9	
10	Arc flash incident energy based on maximum and minimum kA fault level provided at Annex A (see Annex A for further guidance:)
11	Drive input cabinet: _____ cal/cm ²
12	Power electronic cabinet: _____ cal/cm ²
13	Drive Output cabinet: _____ cal/cm ²
14	
15	
16	Supply system voltage (6.1):
17	<input type="checkbox"/> 2400 V <input type="checkbox"/> 3300 V <input type="checkbox"/> 4160 V <input type="checkbox"/> 6600 V <input type="checkbox"/> 6900 V <input type="checkbox"/> 13800 V
18	Other: _____ V ± _____ %
19	Line Frequency: <input type="checkbox"/> 60 Hz <input type="checkbox"/> 50 Hz
	Enclosure (4.2.1):
	<input type="checkbox"/> Indoor, IP21 <input type="checkbox"/> Other, Specify: _____
	Gland Plate Location:
	Incoming Power Cables: <input type="checkbox"/> Top <input type="checkbox"/> Bottom
	Size _____ Number per Phase: _____
	Motor Cables: <input type="checkbox"/> Top <input type="checkbox"/> Bottom
	Size _____ Number per Phase: _____
	Control Cables: <input type="checkbox"/> Top <input type="checkbox"/> Bottom
	Finish: <input type="checkbox"/> Manufacturing Std. <input type="checkbox"/> As Specified
	<input type="checkbox"/> Outside Colour: _____
	<input type="checkbox"/> Inside Colour: _____
	Rear access required: <input type="checkbox"/> Yes <input type="checkbox"/> No
	Drive weight: _____ kg
	Drive dimensions (W × D × H: _____ mm
	Rectifier (5.4):
	Pulse number: <input type="checkbox"/> 6 <input type="checkbox"/> 12 <input type="checkbox"/> 18 <input type="checkbox"/> 24 <input type="checkbox"/> 36

FIGURE 6. An extract of a data sheet from Annex B, to be completed by the manufacturer. IP: ingress protection.

by the purchaser on the Annex A data sheet. The letter R stands for the right column. The following are the key changes that have been made:

- A1-15L: This item deals with the minimum and maximum three-phase short fault levels at the drive input and the respective clearing time for arc-flash calculations.
- A1-22L: The responsibility for providing auxiliary control power and UPS was clarified.
- A1-27L: An option was provided for choosing an ASD continuous rating as a percentage of the motor full-load rating at 100%, 110%, or other. However, the magnitude and duration of the overload capability must be selected according to the application.

- A1-06R: Harmonic compliance is expanded to include the PCC, average demand current, compliance with IEEE 519, IEC 61000-3-6, or as noted by the end user.
- A1-16R: This section includes information about system grounding covering: solid, resistance, or other.
- A1-25R: The site environment section is expanded to cover any potential contamination and ensure that the electronic circuit boards have conformal coating.
- A2-22L: This section deals with noise level as measured in the factory, taking into account the entire ASD assembly.
- A2-28R: Isolating transformer and motor protection is discussed in this section.
- A2-33R: This item involves isolating the transformer tap at $\pm 5\%$ or other.
- A3-36L: Factory acceptance testing was expanded to include the options of drive-only testing, drive/motor testing, or drive/motor/load testing.
- A3-3R: A new section was added regarding shipping, storage, and handling.

Annex B: To Be Completed by the Manufacturer

For clarity, the items discussed here are referenced to the actual sheet number, line number, and either left or right column in the standard. For example, B1-11L refers to sheet 1, line 11, and the left column to be completed by the manufacturer in the Annex B data sheet. The following are the key changes that have been made:

- B1-11L: Based on data provided by the end user, the vendor is expected to provide values of arc-flash incident energy in calories (cal)/cm² at ASD input, power electronic cabinet, and drive output cabinet.
- B1-21L: This section discusses ASD auxiliary power requirements for various components, including control power, cooling fans, and pumps.
- B1-30L: This item deals with the ASD continuous capacity and overload capability for 1 min.
- B1-37L: The ASD ride-through capability is addressed in this section.
- B1-41L: This item involves the ASD MTBF and MTTR and addresses whether the ASD is suitable for a minimum of five years of continuous operation.
- B1-32R: The dc link inductor and capacitor replacement frequency are discussed here.
- B2-15L: This section deals with harmonic compliance to IEEE 519 or IEC 61000 and values of voltage and current total harmonic distortion at the PCC.
- B2-3R: For this item, the manufacturer must explain whether an isolating transformer or line reactor is used and disclose information about the winding material and whether the component is air or liquid cooled.
- B2-30R: The ASD vendor is to state if motor derating is required and provide the peak voltage at the motor and the maximum allowable cable distance between the ASD and the motor.
- B3-3L: External ASD cooling requirements are detailed here.
- B3-20L: This item includes information about the overall ASD efficiency and power factor at preselected speed and load.
- B3-3R: This section involves the ASD current harmonic spectrum up to the 49th order.
- B3-11R: Instructions for lifting, handling, and reassembly of the ASD on site are explained here.
- B3-18R: Recommended spare part lists are provided.
- B3-21R: This item offers commission and startup assistance.

Technical Data Sheet Guide

Some users of the original standard (1566-2005) [2] had commented that the data sheets were difficult to complete, and vendors reported problems with the data sheets they received. To address this situation, the team produced the “Technical Data Sheet Guide” as Annex C of the standard. The “Engineering Studies” annex was moved from Annex C to Annex D so that the data sheet guide could directly follow the data sheets. The guide includes suggestions that advise the purchaser regarding each section of the data sheet. Note that Annex C is a guide only and does not necessarily address all uses that may arise.

The data sheet guide starts with a general outline that lists all the components covered by the standard. It then continues in line with the order of the items on the purchaser data sheet and offers suggestions for each point on the data sheet where a decision is required. Some of the areas covered by Annex C are as follows:

- *General:* In the introductory section, a system block diagram is included. It shows all the components, such as input switchgear, harmonic filters, input transformer/impedance, rectifier, dc link, inverter, output filter, and the motor. Not all the listed components are required for each application, owing to the ASD topology. The purchaser may also decide to use items, such as switchgear or motor, that are not included in the particular order.
- *Single-line diagram:* The supplier of the drive system needs to know how the single-line diagram relates to the overall power system. It is also important to understand how it will enhance plant operations and what actions may need to be taken to meet the necessary requirements of the application.
- *Power system data:* The voltage at the drive input affects the transformer design, and that, at the PCC, determines the allowable harmonics, per IEEE 519; the short circuit level affects the allowable harmonics that can be exported to the external power system. In addition, the range of available short circuit levels is required when calculating arc-fault levels.
- *Auxiliary and control power:* ASDs need control power for operation, and this can be derived from external sources such as a motor control center, a UPS, or a battery; from the ASD itself; or from redundant sources. Because there is a range of possible ac and dc voltages, the vendor must know what is required to

make an accurate offer. Three-phase auxiliary power is used mostly for cooling fans and pumps and usually represents the voltage and frequency used for low-power applications on site. Redundant supplies are often used, and, if so, this should be specified.

- **Continuous rating:** Typically, users like to have the power electronics rated for 110% of the motor current. However, some users prefer to save money by using a 100%-rated drive. If process requirements increase, this can at some point cause capacity limitations. If the 100% capacity is specified, we recommend a detailed analysis of the requirements.
- **Type of load/application:** Centrifugal loads, such as fans, centrifugal compressors, and pumps, tend to have a torque requirement that varies roughly in proportion to the speed squared, while loads such as reciprocating compressors and conveyors tend to have torque requirements essentially independent of speed. These differences, plus load inertia, affect the design of the ASD and so should be provided to the vendor.
- **Power system harmonics:** Although IEEE 519 is most commonly used as a standard harmonics requirement, some utilities, including isolated systems, may have more stringent requirements. In addition, although IEEE 519 calls for the PCC to serve as the connection to the utility, internal plant requirements may require harmonic limits at a system location closer to the ASD itself.
- **Environment and enclosure:** The ambient temperature, both indoors and outdoors, along with pollution, dust, and humidity affect the heat-transfer capabilities of the ASD and thus the internal temperature of the semiconductors. In addition, the thinner air at higher altitudes reduces both the heat-transfer and voltage-withstand abilities of the air. Any issues here must be known by the vendor. In many cases, especially those where site labor is expensive, it is often more practical to install the ASD and associated equipment in a prefabricated building at a fabrication yard and transport the entire building and drive to the site. Most vendors can supply these prepackaged systems if requested.
- **Cabling:** Input and output power cables may enter the ASD from either the top or the bottom, and, although most suppliers can accommodate either, they do need to know which is required, as well as their number, area, and voltage ratings. In some cases, their inductances, capacitances, and lengths are required for drive performance reasons.
- **Redundancy:** For increased reliability, redundant electronic system components may be specified so that failure of a single component will not cause a drive shutdown. Not all topologies can supply this redundancy, so a careful review of actual requirements is needed.
- **Ride through and flying restart:** When there is a reduction in the supply voltage to the drive, the available torque also decreases; if the reduction is large enough, the motor may not be able to drive the load. Additionally, the drive's auxiliaries, such as fans and pumps, may cease operating, and the loss of control power may affect operation. The default requirement is for the drive to withstand a sag of supply volts to 65% of nominal for 0.5 s. Various options are available to address more extreme situations; these should be specified (e.g., a complete shutdown, followed by an operator-initiated restart when the supply is again healthy, or a flying restart, where the drive catches and reaccelerates the motor). For most restart situations, battery or UPS supply of control volts is required.
- **Communications:** Modern digital communications mean that an ASD can receive and supply almost unlimited quantities of information to the outside world, which helps when troubleshooting the associated process and the drive itself. The drive vendor should know what protocols and capabilities are required.
- **Bypass operation:** One common method of operation is to have a bypass mode available, where the motor can be supplied either at a fixed frequency from the utility or from the ASD, with transfer between modes. This can improve system availability and allow multiple motors to be started sequentially using one ASD. For example, some pipeline applications used three or four motors and one ASD, with the ASD starting the first pump then transferring it to the utility and starting another.
- **Input transformer/reactor:** Most medium-voltage ASDs use either an input-isolating/phase-shift transformer or a series reactor. The default is for the transformer/reactor to meet the relevant IEEE standards, but other options are available. The ASD supplier should be told what is required.
- **Motor:** There are some motor requirements, such as critical speed locations, voltage withstand, and torque/speed requirements, that are unique to motors operating on an ASD. The American Petroleum Institute motor specifications have clauses that discuss these requirements, and these documents are recommended; however, in some retrofit situations, an existing motor may be used. The supplier needs to know whether the motor is induction or synchronous and must be informed of all the other requirements, such as speed range and torque requirements.
- **Cooling:** The solid-state devices, bus work, transformers, and reactive components are all subject to deterioration from excessive temperatures, and the solid-state devices are usually the most sensitive. On lower-power systems, air cooling is usually practical, but on higher-power systems, direct liquid cooling is needed. Redundant fans and pumps are recommended.

- **Testing:** It is desirable to do as much testing as practical in the ASD vendor's plant to minimize startup issues. This extends to operating the whole system, including the input transformer, the drive, and the motor as a package, which can be expensive; however, if it is practical, such action can shorten site time.
- **Shipping, storage, and handling:** Shipping from the plant and on-site storage and handling issues should be worked out between the supplier of the drive system and the eventual owner.
- **Services:** The ASD vendor can provide engineering services during the manufacturing, application, and analysis phases of the project and will likely be needed for startup on-site. These roles and expectations should be defined clearly.

Specialized Applications

As mentioned previously, Annex E has been added to the standard. This section provides additional application insights and guidelines that will be helpful to the system designer. Pertinent applications include the following:

- hazardous locations for either the motor or the drive
- long cable runs
- marine applications
- operating off local generation.

For particular situations such as these, more information needs to be shared with the ASD supplier so that the design can be optimized. Annex E discusses each specialized application and includes listings of the extra information the vendor requires for each application.

Future

The team is looking at the next edition of the standard and intends to address additional topics that are either not yet covered or need to be expanded upon, such as the following:

- **Arc-flash mitigation and withstand capabilities:** The 2015 document started in this direction with the addition of short circuit levels and durations being required of the purchaser (Annex A). The next revision will expand on this with more requirements listed.
- **Drive protection zones:** The protective elements will be defined, including coverage in the scope of drive protection.
- **Additional information:** IEEE Draft Standard P1662, *Recommended Practice for the Design and Application of Power Electronics in Electrical Power Systems* [11], includes many useful sections on improving the standard that will assist IEEE in the next revision.

We encourage interested users and vendors to get involved in the next revision cycle; the standard will benefit from diverse input with a wide base of experience.

Conclusions

IEEE Standard 1566 has been updated in the second edition to reflect present-day technology and now covers

an array of areas not fully addressed in the first edition. Users will find it to be an up-to-date reference document that can be followed as a specification for medium-voltage ASDs of all ranges and applications.

We strongly encourage purchasers to use the standard either as a stand-alone document or as the basis of a company specification. The data sheets to be completed by the purchaser and manufacturer are now available in Excel format for ease of completion and can be downloaded via a hyperlink provided in the standard. Filling in the data sheets is essential, and only mentioning IEEE 1566 without completing the data sheets is not very useful.

Acknowledgments

We gratefully acknowledge the efforts of the team who spent many hours working on writing and editing the standard. Those who contributed to the completion of the latest release of the standard, including the IEEE staff, are recognized on sheets vi and vii of the current standard [3].

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