

IEEE STD 1566 - THE NEED FOR A LARGE ADJUSTABLE SPEED DRIVE STANDARD

Copyright Material IEEE
Paper No. PCIC-2006-3

Bill Lockley
Fellow, IEEE
Lockley Engineering
7 Edcath Rd. N.W.
Calgary, AB T3A 4A2
Canada
lockley@ieee.org

Barry Wood
Fellow, IEEE
Chevron
100 Chevron Way
Richmond, CA 94802
USA
bmwood@ieee.org

Rick Paes
Member, IEEE
Rockwell Automation
6223 2 St. S.E.
Calgary, AB T2H 1J5
Canada
rhpaes@ra.rockwell.com

Frank DeWinter
Fellow, IEEE
Siemens Large Drives
14320 63 Ave
Edmonton, AB, T6H 1S4
Canada
fadewinter@ieee.org

Abstract – IEEE Std 1566, Standard for Performance of Adjustable Speed AC Drives Rated 375 kW and Larger, was written by users, consultants and manufacturers to provide a common performance standard for large adjustable speed AC drives. The standard is a stand alone document which lists the performance requirements of all aspects of an adjustable speed drive system. It includes data sheets for the purchaser and the user plus some tutorial information. It is expected that the use of the standard will lead to less confusion and work in selection of drives, plus eventually a more durable drive system.

Index Terms — Large AC Drives, Adjustable Speed Drive, ASD, Standards

I. INTRODUCTION

IEEE Standard 1566: Standard for Performance of Adjustable Speed Drives Rated 375 kW and larger, has been written to assist users, consultants and manufacturers of large adjustable speed drives (ASDs). Users and consultants can use it to specify a high quality drive system and more easily compare proposals, while manufacturers have a standard specification which will make their proposals easier to produce and compare.

The standard is written to specify required performance of a drive system as used in process industries, and it defines the basic requirements for drive operation. In most areas it does not specify technology to be used to achieve the performance requirements. It specifies some demanding requirements, which will likely not be met in all instances by all suppliers. While most manufacturers are constantly looking to improve their product designs which should involve soliciting feedback from their customers, this document will also serve to outline what is important to users and help to direct improvement in currently available drive designs.

The standard uses data sheets to define particular requirements and equipment offerings. Users are strongly encouraged to fill in the appropriate sections of these data sheets so that vendors know exactly what is required of their product. And vendors are strongly encouraged to complete the applicable sections of the data sheet so users will know exactly what is being offered.

The standard consolidates various existing drive standards so that it can be used as a stand alone document without having reference other standards. Other required references are given in the document itself. It should also act as a guide

for those specifying drives for the first time as well and provide a useful reference for more experienced users.

It provides industry wide alignment of terms that are commonly used in drive discussions as well as descriptions of common drive functions and requirements. During the course of discussions held in the making of this document, it was apparent that these definitions and descriptions plus the roles and responsibilities in the creation of a drive system required clarification.

II. HISTORY

Adjustable Speed Drives have been used in process applications for some time on applications into many tens of MW and from below 300 rpm up to about 20000 rpm. Some of the reasons for this are improved process control, improved process efficiency due to reduced fluid throttling, ease of starting on weak power systems, avoidance of the need for gearboxes in some cases, and smooth process operation. An indication of the increasing use of ASDs is shown in Fig. 1 below, using data from one vendor.

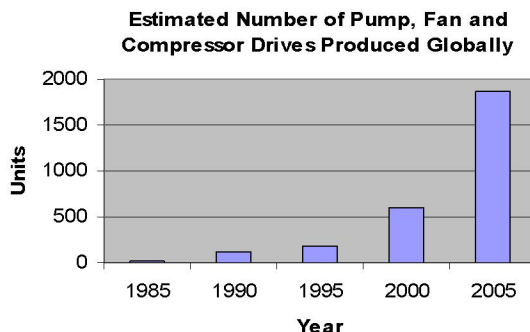


Fig. 1 Drives Built per Year

However, some concerns have arisen with applications over time. Among the concerns are relatively low reliability when compared with other less complex industrial electrical components such as switchgear and transformers; difficulty in getting service and parts for equipment that is over 10 years old due to the rapid changes driven by ASD development; engineering costs and time spent during the application and selection process; problems with the interface between the ASD, utility and the driven motor and process; plus difficulty in determining the exact application requirements.

In an attempt to pursue improvements in these directions and facilitate specifying, bidding, purchasing and application

of drive systems, a group comprising users, vendors and consultants was formed. Work started in 2000 on an IEEE standard for large ASDs. There were meetings at conferences as well as a number of web conferences, with 22 drafts being prepared before the document was balloted in early 2005. After ballot review, further revisions to the document and two recirculation ballots, the standard was approved in late 2005 and published in 2006.

III. REQUIREMENTS OF THE STANDARD

IEEE recognizes 3 levels of requirements in the standards program. A Guide is the first level and gives ways of achieving an objective. The word "may" is commonly used in Guides. A Recommended Practice is the next level and considers that there is more than one way to achieve something. However it often recommends a preferred method using the word "should" extensively. A Standard gives specific requirements without allowing alternatives, using the word "shall" to describe requirements. The working group (WG) chose to generate a standard for this document, so as to define requirements as closely as possible.

From experience in similar situations, the WG felt that some features of IEEE 1566 should include:

1. As far as practical, it should be a performance standard. The technologies used by drive vendors vary significantly between vendors, and future technology trends are not predictable with any certainty. A prescriptive document could hinder development by limiting new technologies, and it was felt that as far as possible it was preferable to specify performance requirements, leaving the method of achievement to qualified vendors.
2. It must be usable as a specification by a user either as is, or with only a minor overlay. This means that a purchaser should not have to generate a voluminous extra document to specify a drive.
3. It should use data sheets for both the purchaser and vendor. This should clarify what is wanted and offered, to help reduce misunderstandings.
4. It should encourage improvement in ASD performance and reliability by providing direction for users, consultants and manufacturers alike in system design.

The WG believes that the IEEE Std 1566 has achieved these requirements. As a first edition, there are probably areas that could have been better covered, and the WG welcomes constructive suggestions for improvement.

IV. CONTENTS OF STANDARD

Some areas covered by the standard are listed below. Some of the key issues in these areas will be discussed in following sections of the paper:

- Enclosure requirements
- Safety
- Grounding and bonding
- Solid state power component ratings
- Load capabilities
- Performance during power disturbances

- Harmonics generation
- Controls
- Transfer to and from fixed speed operation
- Drive cooling
- Associated switchgear, transformer and motor
- System coordination
- Testing
- Startup
- Spares and continued support

Some of these issues will be discussed further below.

The standard references various other standards, both North American based and IEC as required. There should be minimal requirements for users to specify further documents. In addition, the standard provides some tutorial information to assist purchasers decide what should be specified.

V. ADJUSTABLE SPEED DRIVES

A. Developments

ASDs for pump control in industrial processes have been used for about 30 years. Improved process efficiency and reduced installation and maintenance costs along with many other benefits are justification for ASDs to become the main control element used in a wide variety of applications. These applications range from pumps, compressors and fans to more challenging installations such as conveyors. The continuously reducing footprint as shown in Fig. 2 has helped gain broader acceptance of ASDs for many applications.

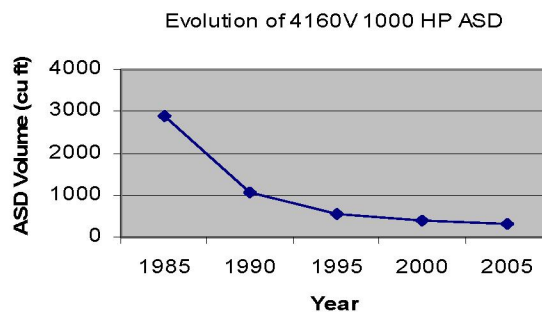


Fig. 2 Evolution of Drive Volume

Today, the AC ASD has mostly displaced other alternatives such as wound rotor and DC drive systems originally employed for certain tasks. This has primarily been due to the effort by manufacturers to develop a broad spectrum of AC drives sufficient to meet the wide range of units required, from fractional horsepower up to thousands of horsepower along with associated improvement in reliability, cost effectiveness and user friendliness. There is no question that great strides have been made particularly in the areas of performance, reliability and ease of use since the introduction of the first ASD but additional work is warranted and continues. Much of this advancement has been driven by one particular aspect – silicon. The advances in semiconductor technology which have occurred

since initial implementation have led to vast improvements in processing speeds and memory storage needed for drive control as well as the extension of switching device power device ratings. These advancements allow for larger drive designs with improved control and reliability to be realized.

B. Control

Present day technology has provided a tremendous increase in processing and data storage capability. Original units had capabilities in terms of kHz and kilobytes while present systems are in terms of GHz and gigabytes. This increased processing and data storage capability when taken to ASD drive control allows extremely complex firing techniques and protection schemes to be realized which serve to produce better harmonic compliance, increased performance and diagnostics and enhanced user friendliness. The information which can be taken from an ASD for process control along with diagnostics and troubleshooting is extensive. A drive failure can now be identified to the component level and the events prior to and after the event can be trended to determine factors, both internal and external to the equipment, which may have contributed to the failure. In addition to the advancements in information processing, leading manufacturers are also adopting a broader perspective to the ASD installation overall, providing the end user programmable options which allow for operational contingencies. Early drive development focused on the protection of the drive itself. However some of the more recent innovation in control concepts is toward failure mode and effect analysis and contingency scenarios where the drive is able to take corrective measures or allow alternative operation in the event of a process or system upset to avoid interruption of the process. This is of particular importance to the user. While the drive itself is a substantial capital investment, the processes which these drives control are likely to be critical to the user and their operation. The impact of an immediate shutdown of the process without advance notice may be far greater than the cost of or risk to the ASD system itself.

C. Power Semiconductors

While the improvements in technology allow for better utilization of switching techniques, user interface and drive control, the greatest factor in drive development is undoubtedly the ongoing development of power semiconductors. When a new drive design is being considered, one of the first steps, if not the first, is to look at the available semiconductors available to the designer along with their characteristics and limitations. Switching devices have come a long way from the original diodes and silicon controlled rectifiers (SCRs) which are still in use today.

In recent years, the most notable advancement has been with respect to new devices that have been developed leveraging on these initial designs. These devices are capable of not only being switched on but the time at which conduction can be terminated or switched off can also be controlled. This ability has allowed the implementation of pulse width modulated switching techniques that serve to more closely approximate a sine wave and effectively reduce harmonic distortion which is one of the primary considerations

when using drive technology.

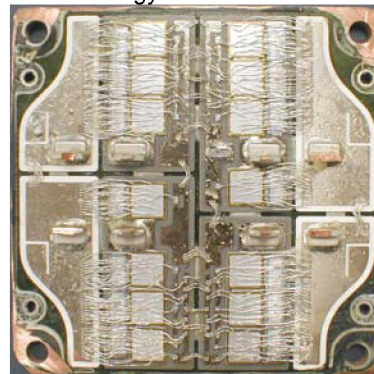


Fig. 3 IGBT device cross section

As of yet, the ideal semiconductor which would have unlimited switching capability, require no gate drive components and not have associated switching losses has not been produced. However the increasing world demand for ASDs continues to drive semiconductor development. Until then, device limitations and characteristics ultimately define the ASD design which may be achieved.



Fig. 4 GCT device

The predominant devices in use at the time of writing, in addition to the previously mentioned diode and SCR, are the insulated gate bipolar transistor (IGBT) (refer to Fig. 3) and the gate commutated thyristor (GCT) (refer to Fig. 4) due to their availability and range of voltage and current capability. The gate turn off thyristor (GTO) is now being replaced by the GCT and is being used less often.

The key device criteria which will ultimately determine the overall drive topology and available ratings are the device voltage and current ratings. Refer to Fig. 5 for an assessment of available devices to the market as of late 2005.

Further to this, the manner in which the devices may be utilized – series or parallel, the device failure in time (FIT) rate, failure mode for the device shorted or open rupturing or non-rupturing, and the device construction will play a major role in drive packaging.

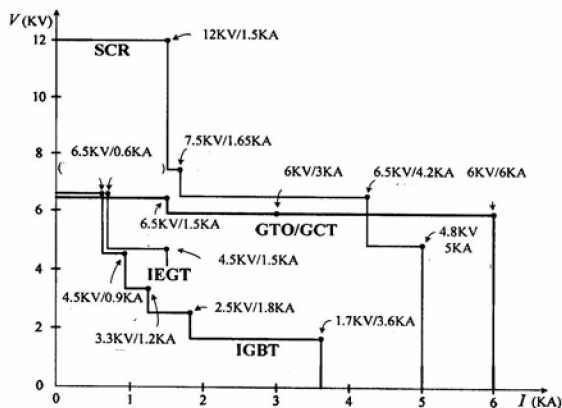


Fig. 5 – Device Availability November 2005 [2]

It is apparent that the drive topologies and designs which are currently available are the result of numerous design factors coming together, the improvement in semiconductors, the techniques which are utilized with these devices, and the specific innovation and direction taken by different manufacturers. This has led to a variety of drive topologies each with their own specific strengths and limitations being available to the user. However this also indicates the need for a base design standard which provides the minimum requirements for industry as defined by users and manufacturers. This allows the user to evaluate the use of a specific design as first meeting his absolute needs and then evaluating further on additional factors leaving the door open for manufacturers in terms of innovation and design beyond these fundamental requirements.

D. Safety

The enclosure and internals of a drive must prevent injury to operators or maintenance people when they are performing their normal duties. To that end the enclosure is required to prevent access to live parts of the main power circuit and to be able to withstand bolted internal faults. If power capacitors are used they shall have discharge resistors, and interlocks shall prevent access until all voltages have declined to a safe level. Control circuits must be arranged so that measurements can be safely taken while the drive is operating. Cooling water pumps must be safely changeable without shutting down the drive.

E. Durability

The WG felt that long term durability and availability of the drive was essential. Most other major industrial electrical items such as large motors, transformers and switchgear have a life of at least 20 years, and it was believed that a similar figure was desirable for a drive. Present experience with large drives has not always been satisfactory in this area. The standard lists a 20 year service life with 5 years continuous operation between shutdowns and requires vendors to list what spare parts will be necessary to achieve this figure. Availability of trained service people during this period is also required. These requirements have probably not been generally met at this time. However the WG also

recognized that there is a tradeoff much like other electronic devices such as computers that the user must consider. With the rapid changes in technology, the next generations of drives will see further improvements in size, cost and performance such as has been the case with computers where it would no longer be practical to service and maintain a computer of a 20 year old vintage.

F. Performance

The drive must be able to accelerate the load and provide full output power continuously with input voltages between 90% and 110% of nominal. In addition it shall provide 110% motor full load current continuously with a short time overload capacity of 110% continuous rating (i.e. 120% motor full load current) for 1 minute in every 10. The WG's experience has been that many process applications have load requirements that change from those originally expected, and these output requirements will reduce the need for replacing drives when new requirements arise, plus generally give a cooler running and probably more durable drive.

Redundancy of solid state components ("N-1") is listed as an option. If it is selected, the drive will not shut down on a failed device or module but will actuate an alarm and continue operating. Redundancy is one of the more common approaches taken to address a larger subject which is fault avoidance in general. One of the areas where there has been a disconnect in the past between manufacturers and users is with respect to protection. Suppliers of ASDs tend to focus on protecting their product. Their goal had been to protect the ASD from damage at all costs, preferring to shutdown the process rather than subject the ASD to less than ideal conditions. However the cost to the end user if an application shuts down in mid process can be very significant and in fact, could be far more than the cost of repairing the ASD. Manufacturers are realizing this, and recent enhancements in some drive products are towards options which allow the drive take corrective action rather than shut down. There are obvious benefits to providing these options to the owner and should be considered when making a choice. Examples of such options include operation with the loss of a device at reduced capacity, reducing switching patterns to lessen drive losses perhaps to allow for continued operation in the event of a cooling system malfunction. The above items are examples where the user can choose an option to allow continued operation at his discretion.

G. Power Quality

Power Quality in the standard covers both what the drive does to the power system, and what power system situations the drive should withstand. IEEE Std 519 [3] is used as the default harmonic generation standard, with the purchaser specifying such items as the telephone interference level, point of common coupling, and any extra requirements. Acceptable levels of electromagnetic interference and radio frequency Interference are also specified. In this area it should be noted that over the last 20 years the input and output harmonic currents produced by a drive have been dramatically reduced so that where total harmonic distortion (THD) of the current was about 25% with early models,

design improvements have reduced it to less than 5%. This has greatly reduced utility and motor problems.

The standard also requires that the drive design be more tolerant of disturbances. The requirements include satisfactory operation on transient over-voltages (2.8 x nominal voltage with a 0.1 microsecond rise time); voltage sags (65% nominal for 500 milliseconds); total loss of voltage (total loss for 2 seconds, after which the drive will bring the motor back to original speed setting); voltage swells (115% for 0.5 second); the switching of nearby capacitor banks (a decaying transient with a frequency between 300 Hz and 800 Hz); total harmonic voltage distortion of 10% with a crest factor of 2.5, and a specified notch level); and unbalance (3% continuously). The requirements are made with the intent of specifying performance that most industrial users need. In many cases this will require input surge protection and a UPS for the control power.

H. Interfaces

The requirements for drive system interface with the outside world vary significantly between users. The technology available for control and communication is steadily developing. Therefore the standard has been written to allow various control and communication options without specifying the methods any more than necessary.

I. Drive Cooling

The two most common ways of cooling drives are air and liquid methods. Smaller drives can be cooled by fans moving air over the components, but the higher forward drop and switching losses of larger drives make liquid cooling more practical for larger units. In addition the drive's environment (temperature, dust etc.) affects the cooling method selected.

In critical applications, redundant fans are recommended for air cooled applications with the failure of a single fan causing a changeover to the other unit plus an alarm annunciation. In addition an automatic fan changeover every 30 days is required. No shutdown is permitted during a fan changeover. A fan motor L₁₀ bearing life of 50000 hours is required. Replaceable air filters are also required.

Modern liquid cooled drives use either de-ionized water or a de-ionized water/glycol mixture for coolant. In addition to being cooled the liquid must be filtered and kept at a low conductivity. Most de-ionizing systems work in the bypass mode, only working on a small portion of the liquid. The filter and deionizer must be changeable while the drive is operating, which means valves must be included to isolate the removable components. A conductivity monitor is required to determine when the deionizer requires replacement. In addition, it shall be possible to top up the coolant reservoir without shutting down the drive. These requirements essentially mean the cooling system must be in a cubicle that can be accessed while the drive is operating and that the plumbing be arranged to avoid air locks after a changeover.

The coolant is pumped to either a liquid/air or a liquid/liquid heat exchanger. The drive pumps and any heat exchanger pumps and fans should be redundant and changeable with the drive running. There is also a requirement for the pump motors to have a bearing L₁₀ life of 50000 hours to minimize the number of pump changes.

J. Serviceability

One of the requirements of a drive operating in industrial situations is that it must be easy to service. To that end, the standard requires all test points and terminals to be easily accessible from the front of the drive, and any devices or modules that are likely to require changing shall be removable from the front by two people.

To assist troubleshooting, storage and annunciation of alarms and shutdown data is necessary. In many cases this information can be made available to a remote location by a digital link, and this is encouraged.

K. Synchronous Motor Applications

On some larger or slower speed applications, a drive is required to control the speed of a synchronous motor. In these cases a power supply for the motor excitation is usually included as part of the package. At standstill the regular DC field arrangement of a brushless exciter will not work, since there is no change of flux in the exciter armature when the armature is stationary. Therefore a controllable AC power supply to the exciter stator is usually supplied so the flux in the exciter armature will be changing, which induces voltage in the exciter rotor at zero speed.

L. Data Sheets

The WG believed it is essential that the purchaser tell the vendor exactly what is required and that the vendor tell the purchaser exactly what is being offered or supplied. Therefore to reduce confusion, purchaser and vendor data sheets are included that cover the requirements and offerings.

The other benefit which this approach provides is that it should put all options for an ASD system solution on the same basis so that relative costs can be assessed.

VI. ADJUSTABLE SPEED DRIVE SYSTEMS

A. Drives versus Drive Systems

An ASD in the context of IEEE Std. 1566 essentially comprises the equipment required to take a fixed frequency and voltage input from the facility power system and convert it into a controllable frequency and voltage output. The standard defines an ASD System as: "An interconnected combination of equipment that provides a means of adjusting the speed of a mechanical load coupled to a motor." Therefore a drive system comprises the drive plus auxiliary apparatus such as switchgear, transformer, and motor.

The standard gives requirements for the associated switchgear, transformer or reactor, and motor and outlines the requirements for interconnecting these components as parts of the drive system.

B. Incoming Switchgear

The drive vendor may or may not be required to supply the switchgear associated with the drive. If the vendor does not supply the switchgear, he should specify any particular

requirements for it. Depending on the application the switchgear may be an isolating switch, a circuit breaker or a contactor, and the relevant ANSI/IEEE standards are referenced in IEEE Std. 1566.

C. Input Transformer or Reactor

Almost all large drives use an input transformer or reactor. Depending on the drive topology the purposes include one or more of:

- isolate the drive from the power system;
- reduce available fault current to levels that the components can handle;
- provide phase shifting and harmonic cancellation;
- reduce possibly damaging common mode voltages on the motor;
- provide the required voltage if the supply voltage is not what is required by the drive system.

The transformer / reactor may be either dry type or liquid filled depending on the application. ANSI/IEEE standards are used as the basis of the specifications, and drive generated harmonic currents and common mode voltages must be considered in the design. The drive supplier has the responsibility to specify the connection and impedance of the transformer or reactor to meet the particular requirements of the drive.

D. Motor

The standard permits either synchronous or induction motors as required by the user or by system constraints. The purchaser has the responsibility to specify the motor, and the standard encourages the use of API 541 [4] and API 546 [5] for induction and synchronous motors respectively, as these standards have been found to provide durable machines.

To achieve long motor life, harmonic currents should be considered for heating and torsional issues. These concerns are becoming less for most present day applications because of the close approximations to a sine wave that most modern drives achieve.

The standard requires that temperature rise limits of motors should be the same (Class B rise with Class F insulation) as they would be for a motor on utility supply. One situation that can arise occurs when a motor has to provide relatively high torque at speeds significantly below base speed. In this case, heat generation is close to what it is at full power and speed, but if the motor uses shaft mounted fans, the heat dissipation is reduced due to slow fan speed, and the motor may overheat. Sometimes a separate fixed speed fan is required to keep temperature rises within limits, and the standard requires the owner and vendor to work together to resolve these situations.

In addition, common mode voltages and rapid voltage changes (high dV/dt) can be concerns in some applications and should be considered in the motor insulation design.

Retrofit applications where an ASD is being applied to an existing motor require the vendor and the purchaser to work together to ensure the motor and drive are compatible.

E. Drive Bypass and Synchronizing

In some applications, the drive is required to bring a motor up to the speed at which it would operate on the utility power source, then to transfer the power supply over to the utility. It is often also useful to be able to transfer from the utility source back to the drive. These situations may occur when:

- There is more than one motor being used in an application, and only one is required to operate at an adjustable speed. For example where one or more pumps run at fixed speed, adjustment of throughput (trim) may be achieved by adjusting the speed of the last motor only.
- If the utility is too weak to allow a motor to start either without excessive bus voltage drop or because of insufficient torque, and an ASD is not needed for process control, the choice may be to use the ASD simply for starting duty only. In this case the drive is used to perform the start and the motor is transferred to utility bus (fixed speed operation) once acceleration is complete. For this weak source condition, a drive improves the starting performance of motors so that these motors can supply high torque (near breakdown torque) with very low current.

The standard specifies the requirements for bringing the two power supplies together and synchronizing them before the transfer. One concern during transfers is that the frequency, voltage or phase angles may not match exactly, causing torque and current transients. The standard puts a limit of 120% full load current on any transient current.

F. System Coordination

The standard considers the ASD system vendor responsible for the overall performance of the drive, power system, switchgear, cables, motor and load. This can be the manufacturer of the ASD if these other components are included in their scope of supply. When these components are not part of the scope of supply, it is the responsibility of the ASD vendor to assist and provide guidelines to the party packaging the system in the manner of specifications, guidelines and application information. The standard outlines some of the studies that may be required to achieve successful operation of the overall equipment package.

VII. ASD SYSTEM TECHNICAL SUPPORT REQUIREMENTS

A. Engineering Studies

The standard lists the engineering studies that are often required to ensure a successful application. These include process and driven equipment requirements; power system questions; mechanical constraints; thermal questions and reliability analysis. Not all may be required in every situation, but the requirements are outlined.

B. Factory Tests

Solving equipment problems in the factory is almost always faster and cheaper than solving them once the equipment gets to the field. This indicates that factory inspection and testing is very important to a successful installation. The standard lists the tests that are considered necessary to

ensure a quality product such as testing of individual components and subsystems; high potential tests; system temperature rise tests; and testing of alarms, protection, and controls. Completion of these tests should reduce on-site issues.

For critical applications where more than just the drive is part of the package, a combined drive/motor test has proven useful in many cases, and is strongly recommended. The motor performance (temperature rise, vibration, losses) can be determined; the overall system efficiency determined; the controls, communication and annunciation verified; the transformer and switchgear performance verified; and any problems discovered can be remedied relatively easily, making the subsequent startup less difficult. Some of the tests are not covered by existing standards, so discussions between the purchaser and vendor are usually required.

C. Commissioning and Training

The minimum requirements for startup testing and commissioning are listed. The tests include insulation and high potential testing, speed control, pressure tests on liquid cooling systems, noise level tests, measurement of input and output harmonics, and control and trip/alarm function verification. Commissioning includes tests through as much of the specified speed range as practical. If a bypass scheme is included it shall be tested in all functions. A factory trained field service engineer is capable of supplying the support necessary during the startup and can also assist with training of plant people who will have to operate and maintain the drive through its life.

Indicating in the data sheets that commissioning and training are required in the scope of the project allows manufacturers to begin planning for this process earlier in the project. This is especially important where the ASD will be installed in a remote area of the world where coordination of commissioning and training personnel is difficult. In many cases, training for local facility personnel can be scheduled to coincide with the start up commissioning.

D. Post Startup and Warranty Support

One of the intents of the standard is to achieve a useful life of 20 years for the system. Present experience indicates that this is a difficult but not impossible requirement to meet if the proper discussions are held during the course of the project. Some areas where there have been problems are the life of certain electronic components such as electrolytic capacitors, availability of spare parts and trained service people over time.

The standard requires that the vendor provide a listing of components that will require replacement during the 20 year life span plus ensure that trained people are available for that time. Expected mean time between failures (MTBF) and mean time to repair (MTTR) data is required for this assessment to be accurate over this time period. With this information, the user and vendor can make an informed choice of the spare parts which must be available to support the product over this period. This will likely involve either maintaining an inventory of parts on hand or entering into a service / parts management agreement with the vendor to insure that the equipment is regularly maintained and the

parts are regularly rotated and updated as required. It may also be advisable to provide periodic refresher training to site personnel involved with the ASD since long periods between problems is expected.

To achieve this equipment life objective will require an open and honest working relationship with all parties. The equipment supplier must be willing to share with a potential purchaser some possible shortcomings inherent to their product in order to provide realistic coverage over this period. This may require the supplier trusting that sharing this information will not negatively influence their prospective sale. Both the user and supplier must also realize and accept that this will come at a price, require long term commitment by all, and continuing dialog.

VIII. HOW TO USE THE STANDARD

A. Decide what is needed

There are a number of reasons why the end user would choose to adopt an AC ASD to control a process. Once the decision has been made that an ASD is the proper approach, how does one go further particularly if this is first time this technology has been considered at a facility? IEEE Std 1566 was written from a comprehensive industry perspective benefiting from the experience of many contributors and as such, should cover most items that the user of the standard should encounter. The document covers a practical approach to ratings, construction, performance and testing involved in the manufacturing and procurement of the components required by a drive system. The manner and degree to which the standard is used will likely be dependent on the experience of the user and that of his organization.

The standard brings visibility to numerous aspects of purchasing a drive which the specifier or user should be aware of when entering into a project. However, the ultimate choice concerning the expense and merit of some of the choices must be made by the purchaser.

The choice this standard offers any individual is to either use the standard in its entirety if it reflects their requirements or as a reference to draw from in the creation of their own particular specification. If used in its entirety, comments to the specification may be made by each particular manufacturer in cases where clarification or exception may be necessary. This provides the user the opportunity to review these comments and determine if they agree with the particular approach taken by the individual supplier or if further investigation or action is required. An example of weighing out the cost versus benefit which the user must consider is the portion of this standard which requires vendors to provide a drive rating of 110% of the motor continuous rating with a 120% overload capability. The purpose of this requirement is to ensure that in the event of sustained under-voltage conditions the drive system will still be able to compensate by providing additional current without reducing load, overheating or tripping off line. Also it enables use of some overload capability inherent in many motors. The merit of purchasing this capability must be tempered with the cost of providing this extra margin and how conservative the motor maximum present and future load requirements have been defined

Another aspect of IEEE Std. 1566 is to have all bids meet the same basic requirements and put them on the same level. This is an advantage to manufacturers also since it establishes what they must meet and that competitors will need to do so as well. Otherwise a manufacturer may be hesitant to put forward all requirements to adequately address the application due to concerns of being non competitive with lesser proposals.

In many cases, a drive manufacturer may have more than one possible solution for an application, which requires that the user decide the best option for his facility. One particular benefit of IEEE Std. 1566 is that it does not specify a particular design and does allow alternatives. This will help ensure that the final ASD decision considers as many pertinent factors and alternatives as practical. For today's facility electrical engineer, who must be familiar with a broad range of equipment but is often inexperienced with drive technology, this will help assure that the best alternatives are provided for consideration.

B. Fill in the Data Sheets

The data sheets presented at the end of the document represent a checklist for the user which takes into account a number of requirements that must be addressed during the course of a project. These items will eventually need to be known and addressed. It is highly preferable to address these items up front when they can be included in the project planning, budget and schedule most effectively. Otherwise schedule delays and cost overruns may occur.

The data being requested in Annex A is information which must be provided by the purchaser. Included in this information is the system data required in order to

- perform a harmonic analysis
- determine the auxiliary supply power needed to meet the requirements for the ASD
- determine the services to be included with the supply of the drive such as harmonic and torsional analysis, training, special testing, etc.
- identify drive and system related options
- properly rate the drive for the defined application which includes the necessary environmental data.

With respect to the last item, one of the most important items which must be addressed when selecting an appropriate drive is the rating required. As mentioned earlier, one of the benefits of an ASD is the improvement of motor performance. Reduced voltage starting methods also reduce system disruptions due to starting transients and provide soft starting however, this is at the expense of output torque. In the case of larger machines, locked rotor or starting torque is relatively low, typically 50 to 80% of rated torque, which may make it difficult to start some loads even with full voltage starting. Further reduction of output torque, a consequence of reduced voltage starting, simply makes this method not suitable for many load types. ASDs have the ability to utilize the motor on the right hand side of the motor speed torque curve since motor slip is controlled as shown in Fig. 6. This makes it possible to achieve rated torque as standard and a high percentage of motor breakdown torque (90 % or higher) with the addition of an encoder for rotor speed and position

feedback. This may provide the best solution for starting in some cases and allow for use of a smaller standard motor in other cases.

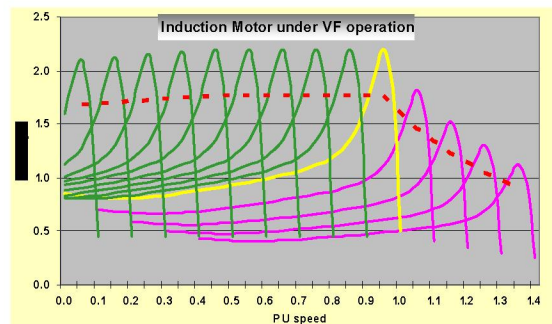


Fig. 6: Motor Performance With ASD

High starting torque requirements and constant torque load profiles make particular use of this drive benefit. To achieve higher than rated torque will likely require additional current rating or de-rating of the ASD. The current which must be provided will be roughly proportional to the torque required as indicated in Figure 7. Providing the information required by IEEE Std. 1566 Annex A, particularly motor data (FLC, speed torque profile, etc.) is essential to ensuring the proper ASD selection is made.

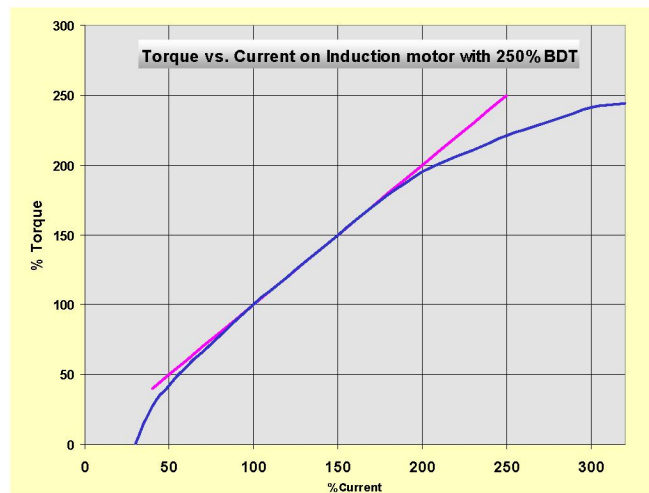


Fig. 7: Current Versus Torque Relationship

Annex B requests information which is to be provided by the manufacturer to the user. This includes

- definition of the drive topology being proposed
- drive system component weights and dimensions to define installation, shipping and handling requirements
- special motor and drive output considerations such as insulation, output filters, cable ratings and cable distance limitations

Annex C addresses engineering studies. Section C1 points out the system design studies which must be performed to

match the ASD system to the load requirements. Once the drive system has been defined, integrating the ASD system into the electrical power system will require further engineering analyses. These analyses include load flow, short circuit, motor starting, harmonic and protective device coordination studies to mention some. These studies must include any electrical system modifications necessary to accommodate the new drive system load. For example the ground fault protection system may need to be modified to include filtering that eliminates non-fundamental currents which can cause nuisance operation of protective relays. Mechanical system studies such as lateral critical speed and torsional natural frequency analyses must also be performed to verify satisfactory performance of rotating equipment.

Finally, Annex D is a bibliography which brings a number of ASD related documents to the drive user. These additional documents serve as further reading and references on the subject of ASDs and provide additional perspectives from international standards and other specific equipment standards.

IX. CONCLUSIONS

The "Standard for Performance of Adjustable Speed AC Drives Rated 375 KW and Larger" was written by an experienced group of IEEE members encompassing a cross section of users, vendors and consultants. The standard is intended to be a guide for those not as familiar with ASD systems that may choose to use the document in its entirety and a resource for those who are more experienced. For the more experienced, they may choose to draw specific references or topics to enhance their own specifications. Possibly even more important is the fact that this standard is a working document which is reviewed and updated on a regular basis and will influence the ASD industry. In order for this document to continue to reflect the needs of the industry, it is imperative that changes and suggestions from users are brought to this review process so that the document will become more comprehensive and represent the changing perspective of this growing field. The authors encourage users to use the document and attend future meetings of the WG to ensure that future versions continue to reflect the needs of industry. This is also important for manufacturers of this equipment since it helps to determine what is important to those who put their product in operation. All items laid out in the standard will not be met by all manufacturers initially as mentioned earlier but these requirements will help to direct future product development.

X. ACKNOWLEDGEMENTS

The authors gratefully acknowledge the work done by the members of the WG, which comprised:

Leo Berg	Nick Cicero
Gabe D'Alleva	John Dickin
Frank DeWinter	Bob Ellis
Miles Griggs	Bob Hanna
Greg Hartzo	Mike Johnson
Yuri Khersonsky	David Kiger
John Kleinecke	Hans Krattiger
Mario Lanaro	Roger Lawrence

Victor Minak	Justus Mylius
Richard Nailen	Richard Paes
David Rains	John Rama
Rob Robertson	David Smith
David Waddington	Laszlo Weress
Barry Wood	

XI. BIBLIOGRAPHY

- [1] IEEE, 2006, *IEEE Standard 1566: Standard for Performance of Adjustable Speed AC Drives Rated 375 KW and Larger*. Piscataway, NJ: IEEE.
- [2] Bin Wu, "High-Power Converters and AC Drives", *IEEE Press and John Wiley ISBN: 0-4717-3171-4*.
- [3] IEEE, 1992, *IEEE Standard 519 Recommended Practices and Requirements for Harmonic Control in Electrical Power Systems* Piscataway NJ IEEE
- [4] American Petroleum Institute 2004, *API Standard 541: Squirrel Cage Induction Motors – 500 HP and Larger* Washington DC API.
- [5] American Petroleum Institute, 1997, *Brushless Synchronous Machines- 500 kVA and Larger* Washington DC API.

XII. VITA

Bill Lockley is a 1966 Electrical Engineering graduate of Sydney University (Australia) He is a Fellow Member of IEEE and is a Professional Engineer in the Province of Alberta. He worked for utility, defense, manufacturing and service organizations before starting his own consulting business in 1988. He is a member of various IEEE and API standards working groups and is an author of previous PCIC and other papers.

Barry M. Wood received the BSEE degree from Virginia Tech, Blacksburg, and the MSEE degree from the University of Pittsburgh in 1972 and 1978 respectively. He is a Fellow Member of IEEE and a Professional Engineer in California and Pennsylvania. Mr. Wood has been with Chevron since 1987 where he is currently a Senior Staff Electrical Engineer with Chevron Energy Technology Company, Richmond, CA. His primary responsibilities include consulting for company facilities worldwide in the areas of electrical power systems, adjustable speed drives, motors and generators.

Richard H. Paes received his degree in electrical/electronic engineering technology from Conestoga College, in Kitchener, Ontario Canada in 1981. Since graduation, he has been employed with Rockwell Automation in Cambridge, Ontario. His primary roles include the application of various motor starting methods, including medium voltage drives, for medium voltage induction and synchronous motors. He is a member of IEEE and was a committee chair for the 2001 PCIC conference in Toronto and is currently Vice-Chair of the PCIC transportation subcommittee and chair of the 2007 Calgary IEEE IAS Mega Projects committee. Mr. Paes is a Certified Engineering Technologist in the Province of Ontario.

Frank A. DeWinter received his B.Sc. degree in electrical engineering from the University of Alberta in 1980. He is a Fellow member of IEEE and is a registered Professional Engineer in the Province of Alberta. He is the Manager for Siemens Canada Large Drives Robicon and has worked for

many years with design and application of large drives. He was the conference chairman for the 2001 PCIC conference in Toronto and is presently Chair of the PCIC papers review subcommittee.