An International Wind Turbine Gearbox Standard

Bill Bradley

The wind industry has been waiting for a definitive gear box standard for almost a decade.

(Printed with permission of the copyright holder, the American Gear Manufacturers Association, 500 Montgomery Street, Suite 350, Alexandria, Virginia 22314-1560. Statements presented in this paper are those of the author and may not represent the position or opinion of the American Gear Manufacturers Association.)

Industrial gear standards have been used to support reliability through the specification of requirements for design, manufacturing and verification. The consensus development of an international wind turbine gearbox standard is an example where gear products can be used in reliable mechanical systems today. This has been achieved through progressive changes in gear technology, gear design methods and the continual development and refinement of gearbox standards.

Standards' Role

Standards are a common language through which manufacturers and users can specify and evaluate products. In business, a prudent buyer can assess cost effectiveness and the technical and manufacturing expertise of various supplier bids by the establishment of consistent engineering specifications for equitable bidding. Standards serve this role. They are also used as trade and marketing tools by manufacturers, either in penetrating new markets or protecting established ones. ANSI/

AGMA/AWEA 6006-A03—*Stan*dard *for Design and Specification of Gearboxes for Wind Turbines*, is a prime example of the development of a consensus application standard to fill the role required. The standard's foreword briefly states the why and who of its development:

"The operation and loading of a wind turbine speed increasing gearbox is unlike most other gear applications. The intent of this standard is to describe the differences. Much of the information is based on field experience. This standard is a tool whereby wind turbine and gearbox manufacturers can communicate and understand each other's needs in developing a gearbox specification for wind turbine applications. The annexes present informative discussion of various issues specific to wind turbine applications and gear design. A combined committee of AGMA and AWEA members representing wind turbine manufacturers, operators, researchers and consultants, as well as gear, bearing and lubricant manufacturers, was responsible for the drafting and development of this standard."

Some could state that a consensus development process results in a standard that is the "lowest common denominator" and not necessarily good for advanced development of a highly technical industry. The content of ANSI/AGMA/AWEA 6006-A03 will be discussed later in this article, but first let us take a look at the history of its development.

The finalization of an international gearbox standard should serve to answer existing questions on the part of designers and builders of wind turbines (courtesy Winergy Drive Systems).

History

AGMA standards development has been predominantly market-driven, ever since the first rating standard appeared in 1919 and the first gear quality standard was established in the late 1930s.

The number of standards progressed steadily and had a surge in the 1960s and 1970s, when much of the technical content for today's gear standards was documented.

A "milestone" was achieved in the 1980s, when the American National Standards Institute (ANSI) approved AGMA as the accredited national developer for gear standards, and as Technical Advisory Group Administrator for establishing national positions on international gear standards. Another was achieved in 1993, when AGMA—through ANSI—was approved as the Secretariat of Technical Committee 60 (TC 60), Gears, by the International Standards Organization (ISO).

Therefore, AGMA is responsible for the administration of gear-related standards development worldwide.

Coincidentally, in 1993 an AGMA/AWEA committee first met to develop AGMA 921–A97: an Information Sheet on the "*Recommended Practices for Design and Specification of Gearboxes for Wind Turbine Generator Systems*." The needs for the document were recognized by AGMA members who were working within this newly developing industry. The document was approved by the AGMA/AWEA Wind Turbine Gear Committee on October 25, 1996 and by the AGMA Technical Division Executive Committee on October 28, 1996.

Through the 1990s and into this century, wind turbine gearbox failures continued to slow the development of the industry. It was clear that a standard was needed, and the first draft of ANSI/AGMA/AWEA 6006-A03—to supersede AGMA 921–A97—was developed in March, 2000. The standard was approved by the AGMA membership in October, 2003 and approved as an American National Standard on January 9, 2004.

After becoming a National standard, the ANSI standard was presented to ISO as a draft international standard, using the verbatim "fast-track procedure." In October 2005, ISO 81400-4:2005 (as ANSI/AGMA/AWEA 6006-A03) was adopted, with approval by the national bodies of both ISO and IEC. The resulting ISO 81400-4 is part of the IEC 61400 Wind Turbine series. Some "turf" fighting between ISO and IEC, as to committee responsibility, resulted in the formation of a Joint Working Group (JWG) between the ISO/TC 60–*Gears* and IEC/TC 88–*Wind Turbines* technical committees (*see ISO vs. IEC sidebar*). AGMA's and ISO/TC60's operating procedures have developed

continued

ISO vs. IEC Standard Development

In July 2003, an ANSI/AGMA committee meeting was held that completed the American National Standard ANSI/AGMA/AWEA 6006-A03. The committee intended to fast-track the standard as an ISO standard as soon as it was approved (October 2003) by ANSI. However, in May 2003, a new international work item proposal (NWIP), citing the AGMA 6006 document, was balloted on the same topic within the International Electrotechnical Commission (IEC) Technical Committee (TC) 88. This NWIP was approved by IEC/TC 88 in October independent of ISO, which is normally responsible for "gear" standards. Therefore, in the interest of harmony between ISO and IEC, it was determined that the development of an international wind turbine gearbox standard would be accomplished by a JWG between ISO/TC 60 and IEC/TC 88. The JWG organizational meeting was held May 27-28, 2004, by mutual agreement in Geneva, Switzerland.

There were 45 persons at the meeting representing ISO, IEC and their central secretariats. The chairman of IEC/TC 88 was the convener. Discussions of member status and resolutions of issues in the absence of consensus resulted in the recommendation that each country be represented by each of its National Bodies (ISO, IEC, or both) that were present in any meeting. Other interested persons could attend, but in the absence of consensus a country would have a maximum of two votes in resolving issues. At this meeting, this resulted in 16 official votes from 10 countries represented.

It was agreed that the JWG should produce one standard that would have both ISO and IEC designation numbers. Methods of recording decisions and editing were discussed. It was agreed that the standard draft ballot comments should be reviewed by the JWG for resolution.

The JWG reviewed a proposed outline of the standard and developed work assignments for the next meeting, which was scheduled for October 2004. Because of the need internationally, it was discussed that the ANSI/AGMA/AWEA standard should be fast-tracked as a first edition while the JWG document was being developed. The U.S. delegation was asked to fast-track its document as an ISO/IEC document as soon as possible, by a vote of 10 approvals, five disapprovals and one abstention.

Issues unresolved at the first JWG meeting were who would convene the JWG, what organization would be the "parent committee," and which organization would be responsible for maintenance of the publication. The decision on the convener could not be made by consensus of those present at the meeting and a vote was not taken by the (IEC) chairman. Many of the ISO delegates present were disappointed that a convener and a "parent committee" for the JWG could not be elected. It was assumed that the management boards of ISO and IEC would solve these issues. It was later resolved that an IEC representative would convene the meetings, ISO would publish the first fast-track document and administrate the development meetings, and the revision of the publication would be by IEC.

—Bill Bradley

sidebar). AGMA's and ISO/TC60's operating procedures have developed comprehensive standards from start to finish in two or three years. The JWG is chaired by IEC and has been working on the next revision/replacement since 2004, which will be issued as IEC 61400-4 when finished.

Therefore, the timeline for the International Wind Turbine Gearbox Standard development:

- AGMA Information sheet started in 1993, completed 10/1996;
- National Standard started 3/2000, completed 10/2003;
- ISO/IEC "fast-track" adoption started in 12/2004 and finished 10/2005;
- IEC replacement (up-date) started in 10/2004 and is still working after five years.

At their last meeting, in April 2009, the JWG developed the first full committee draft (CD) for initial ballot within ISO/TC 60 and IEC/TC 88. The question could be asked, "What has occurred over the past five years?" and, "Why so long?" The answer, as it often occurs, is not due to one reason but many interrelated conditions. Experience has shown that some of the reasons could be: too much text-related information that is not necessary as requirements of the standard; delegations coming to meetings unprepared to make consensus decisions; time spent in meetings to study issues rather than deciding on content; and operating in a manner that make resolutions difficult (*see sidebar on standards development*).

Although its revision has been time consuming, ISO 81400-4:2005–*Wind Turbines/Part 4*: *Design and Specification of Gearboxes*—as developed by AGMA/AWEA—contains many items that collectively form the most comprehensive application gearbox standard in the world.

Content

The committee responsible for ANSI/AGMA/AWEA 6006-A03 development was somewhat unique, being made up of wind turbine manufacturers, users, researchers, consultants, gear and bearing manufacturers, plus lubricant

and system suppliers from around the world, who brought many years of experience with this application to the meetings.

A wind turbine is one of the—if not the most—demanding applications for a gearbox. It requires a relatively small, compact, high-power-density gear drive and electric generator to transmit fluctuating loads in a very demanding environment of deflections, high vibration and temperature extremes.

The present standard applies to gearboxes for wind turbines with power capacities ranging from 40kW to 2MW and higher. It applies to all parallel-axis, one-stage epicyclic and combined one-stage epicyclic and parallel-shaft designs. It provides requirements on specifying, designing, manufacturing, operating and monitoring reliable wind turbine gearbox systems. Some of the more comprehensive gear application sections include:

- how the system loads and environment shall be specified and gear capacity calculated;
- manufacturing, inspection, testing and documentation requirements;
- advanced gear tooth contact analysis and verification;
- extensive information on the application and capacity of rolling element bearing types;
- lubricant and lubrication system requirements.

In addition, annexes supply information on wind turbine architecture; wind turbine load description; quality assurance; operation and maintenance; minimum purchaser and gearbox manufacturer ordering data; and lubrication selection and condition monitoring.

The revised standard at its present stage of development has updated all the sections of the original document, plus some additions and modifications, as follows:

- scope changed to cover drive-trains with a power rating in excess of 500 kW;
- sections on design lifetime and reliability, design process, wind turbine load calculations, gearbox components, design verification validation, operation, service and maintenance requirements;
- new annex material.

It can easily be imagined that the size of this document has increased substantively.

At this stage, it is hard to determine exactly what will be retained after the three ISO/IEC ballot stages are completed, which could take two to three years—or more—if additional changes are incurred. In the meantime, it is believed that the advent of the ANSI/AGMA/AWEA standard has improved gear reliability. However, bearings still seem to need additional work.

Standards Making

The development and balloting of both ISO/IEC and AGMA/ANSI standards is a consensus process. However, individual positions may be expressed that can enhance the contents. Members of AGMA develop new—and continue to revise—the many standards and information sheets. They are also responsible for determining the U.S. position on ISO standards. AGMA standards development has relied heavy on the actual experience of gear system performance in related applications, whereas some others are based on theoretical and laboratory research data.

(*Bill Bradley was vice president of AGMA's Technical Division and currently serves as a technical editor for* Gear Technology. *As a consultant, he can be reached at (303) 350-9374, or via e-mail at* billb111@att.net.)