Advanced Motors

THE LEADING EDGE OF ELECTRO-TECHNOLOGY

ELECTRIC MOTORS AND INDUSTRY

Electric motors represent the largest load on most electric power systems. In 1993, Ontario Hydro estimated that 75% of the electricity used by industrial facilities, and about 50% of the electricity supplied to commercial buildings was used to drive electric motors.

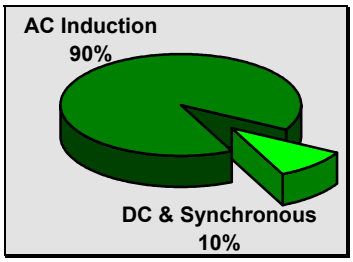

Figure 1 - *Estimated energy use by motor type*

Electric motors provide motive power, by converting electrical energy to mechanical energy, to a wide variety of domestic and industrial machinery. Their versatility, reliability, and economy cannot be equaled by any other form of drive.

Polyphase, AC induction motors, particularly squirrel-cage designs, have long been the workhorses of industry. Induction motors are simple, durable, inexpensive, reliable and easy to manufacture. Their major drawback is that they operate at constant speed, though this problem is easily overcome with the addition of an adjustable speed drive (ASD).

Although AC induction motors have a stranglehold on the industrial motor market, they are not necessarily the best choice for every application. New, specialized motor designs are being developed that can offer advantages over induction motors in certain applications.

WHAT IS AN ELECTRO-TECHNOLOGY?

An electro-technology is defined as a new technology used in an electricity-consuming device that has not gained wide-spread market acceptance due to certain barriers, be they technical, economic or market based.

Advanced motor designs are a perfect example of electro-technologies. Although there are some perceived technical barriers to advanced motors, the main roadblocks to increased use and acceptance are economic in nature. Since these motors are not manufactured in large quantities, they do not enjoy the economies of scale that help to lower the price of induction motors. As a result, advanced motor designs are typically cost-prohibitive even though they may be the best choice for an application in terms of both performance and efficiency.

In addition to the economic barriers, one of the major reasons for the lack of market acceptance of these new motor technologies is a lack of information. The typical industrial engineer will most likely not be aware that any of these electro-technologies are market ready — not to mention that suppliers, availability and practical applications of advanced motor technology are not common knowledge.

UNREALIZED POTENTIAL OF ELECTRO-TECHNOLOGIES

Economic barriers keep some of these benefits of advanced motor technology from being realized in the industrial motor market:

- Integrated speed controller and motor with higher efficiencies than an induction motor/ASD combination
- Ability to match speed/torque characteristics of the motor to the requirements of the load
- Higher startup torque for a given unit size
- Lower losses and increased reliability
- Wide range of operating speeds

ADVANCED MOTORS: THE NEXT GENERATION

New generations of advanced motors are proving to be technically superior to induction motors in terms of speed control, matching torque requirements of the load and even efficiency. Permanent magnet and switched reluctance motor designs are ideally suited for precise speed control and applications where the speed-torque characteristics are difficult or expensive to achieve with induction motor technology.

Advanced motor designs are typically programmable to match the load requirements of a given application. This can result in even greater savings when direct integration and curve matching are used to take full advantage of the drive by matching its capabilities with the requirements of the application — this is especially true when dealing with cube-law loads, such as centrifugal pumps or fans where a small reduction in speed can result in a significant reduction in power consumption.

PERMANENT MAGNET MOTORS

Electronically commutated, permanent magnet motors have been around for some time and they are the most widely accepted of the advanced motor designs. These "brushless" DC motors contain magnets bonded to the rotor and use an electronic commutator to switch the DC input to the stator from coil to coil. This design eliminates the rotor losses inherent to induction motors as well as the often troublesome commutator brushes in conventional DC motors.

The result is improved efficiency and precision speed control over a wide range of speeds and loads without the high maintenance costs and downtime of a conventional DC motor — in fact, permanent magnet motors offer even greater reliability than induction motors.

In terms of costs, permanent magnet motors compare very favourably with induction motor/ASD combinations. Economic playback can be very attractive, especially in new installations.

SWITCHED RELUCTANCE MOTORS

Although the concept of "switched reluctance" has been around since the 1800's, the switched reluctance motor is a relatively new breed of brushless drive. Switched reluctance technology eliminates the need for any rotor coils or permanent magnets. Instead, the rotor is made entirely of laminated iron and it spins in synchrony with the rotating field from the unidirectional currents in the stator windings. The switched reluctance motor's simple, yet rugged design should make it less costly than its competitors in mass production.

ADVANCED MOTOR

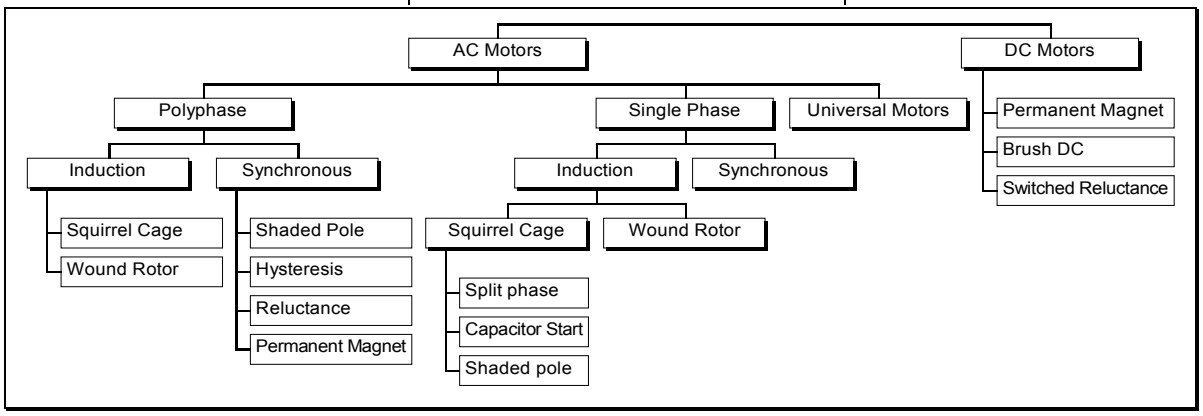

Figure 2 - *Motor family tree*

Designs

Much of the information currently available on advanced motor designs is theoretical in nature. Where practical information is presented, it is often vague or very general in describing practical applications of the technology in field conditions. This lack of information makes it difficult for users to understand the benefits and limitations of these new technologies.

Permanent Magnet Motors

Features

Some of the features of permanent magnet motor designs include:

- *Permanent magnets bonded to the rotor*
- *Electronic commutator controlled by an optical or magnetic angular-position sensor on the rotor*
- *Sizes up to 600 hp in standard NEMA frame sizes*
- *Precise speed control with no slip*
- *Lower operating temperatures*
- *Control function can be added to electronic commutator enabling the motor to match speed and torque for variable loads*
- *High power factor*

Benefits

The design and construction of permanent magnet motors result in several benefits, including:

- *Elimination of rotor losses – total losses about 17% - 35% less than for comparable induction motors*
- *Resistance losses further reduced due to lower temperatures*
- *No need for ASD, which adds its own inefficiency to the system*
- *Losses are almost entirely load dependent, which means efficiency curve is flat over greater range of loads*
- *Increased reliability and reduced maintenance costs (elimination of brush maintenance)*

Switched Reluctance Motors

Features

Switched reluctance motors include the following features:

- *Simple, rugged design*
- *Laminated iron core – no coils or magnets*
- *Can be programmed to run at speeds up to 100,000 rpm*
- *Wide range of operating speeds for individual motors: typically 100:1 speed range, but 1,000:1 is available*
- *Run forwards or backwards as either a motor or generator*
- *Each stator winding is independent of the others*
- *Torque and speed are independently controllable in real time over a wide range*

Benefits

Some of the benefits offered by switched reluctance motors include:

- *Lower cost in mass production than other advanced motor designs*
- *Higher torque and efficiencies over a broader speed range*
- *Extremely versatile in terms of ability to deliver required torque at wide range of speeds*
- *Deliver two to four times the startup torque of a comparable induction motor – allows the use of smaller motor to start the same load*

APPLICATION OF ADVANCED MOTOR TECHNOLOGY

Although in some cases advanced motors offer certain advantages over induction motors, they are not always the best motor for a given application. Advanced motor designs are best suited for variable speed applications that would normally be handled by an induction motor in combination with an ASD. This type of application will take full advantage of the features of a permanent magnet or switched reluctance motor without the additional inefficiencies of an ASD. In addition, switched reluctance motors are well suited for high starting torque applications that would normally require an oversized induction motor.

It should be noted that a well-sized high-efficiency induction motor is usually still the best choice for constant speed, constant load applications. As the speed and load requirements start to vary, induction motor performance over the full operating range will start to drop off and the application becomes a good candidate for and advanced motor design.

PERMANENT MAGNET MOTORS

Permanent magnet motors are well suited for a variety of applications, some of which are listed below:

- *HVAC systems – GE's ECM motor can be programmed to provide constant air volume, variable air flow, and have a soft-start capability*
- *Fractional hp motors for appliances, furnaces, heat pumps refrigeration, fans, compressors*
- *Industrial pumps, fans, blowers, compressors – variable speed/load applications typically served by ASD/induction motor combinations*

SWITCHED RELUCTANCE MOTORS

Some of the current applications of this relatively new technology include:

- *High-precision plotters and automotive cruise controls*
- *Aerospace actuators and servomechanisms*
- *Refrigeration and HVAC systems*
- *Friction welding machines*
- *Textile spinning machines*
- *Coal mining/shearing machines and conveyors*
- *General purpose industrial*
- *High inertia loads*

MANUFACTURERS OF ADVANCED MOTORS

Canadian manufacturers have been at the forefront in developing market ready advanced motor designs:

- Powertec Industrial Corp. (Mississauga, Ontario) – brushless DC motors for industrial applications
- Dynamic Power Corporation (Concord, Ontario) – near market ready switched reluctance motors (30 - 100 hp)
- GE and Emerson Electric (USA) – direct drive electronically commutated motors (ECM) for heat pumps and furnace blowers, high-end silent ceiling fans, and induced draft motors for top-end gas furnaces
- U.S. Motors (Suffolk, UK) – industrial switched reluctance motors (3 - 30 hp)
- Allenwest Electrical Ltd. (UK) – switched reluctance motors (10 - 100 hp)
- Allied Signal Aerospace Co. (USA) – switched reluctance motors (5 - 200 hp)
- British Jeffrey Diamond (UK) – switched reluctance motors (30 - 400 hp)
- Switched Reluctance Drives Ltd. (Leeds, UK) - leader in switched reluctance technology