Spark-free safety

Synchronous and induction motors and generators with guaranteed spark-free operation

GÖRAN PAULSSON, JOHAN KARLSSON, JUSSI RAUTEE – Electrical motors and generators are the backbone of our industrial society, driving compressors and pumps and generating electricity. But because these appliances are electrical, they pose enormous risks when used in situations where explosive gases are present. The oil and gas extraction industries are one example. A spark, a hot surface or a high electrical field such as a corona (the buzzing sound that sometimes can be heard under a high-voltage power line) are all potential threats to safety in an explosive gas-rich environment. ABB's large synchronous and induction motors and generators are certified according to the latest and most stringent of safety requirements – the IEC international standards – guaranteeing spark-free operation.

The design and certification of ABB's large high-voltage synchronous and induction motors brings faster startup times and reduced maintenance requirements.

For years, ABB has taken design and manufacturing steps to exceed official standards of quality and safety, both of which are paramount for its customers. In 2010, all of its large synchronous motors and generators were certified according to the most stringent international standards (IEC 60079-15:2010 and IEC 60079-7:2006); now, the company's complete range of low- and high-voltage motors and generators are certified for operation in hazardous areas ➔ 1.

Customers using equipment that is not tested or certified usually equip the motor with a pressurizing system. This means investing in high-capacity air compressors, piping and a ventilation control unit. By testing and certifying its motors, ABB helps customers streamline their risk assessment processes.

Benefits of the ABB approach include reduced initial capital expenditure, lower operating costs and faster motor starting. Reliability also improves, as no additional components are required. Certification can greatly impact costs. For example, in a refinery, ventilating a motor for even 30 minutes costs enormous amounts of money in downtime and lost production. Using ABB's certified equipment makes it possible for customers to avoid such expenses.

Despite great advances in automation, making an electric motor that weighs up to 80 tons is still a manually intensive job.

The development of IEC 60079 standards began after several serious explosive incidents, which were related to motors operating in hazardous areas in and around North Sea oil and gas fields, occurred in the 1980s and 1990s ➔ 2. Together with the German national institute; Physikalisch-Technischen Bundesanstalt (PTB) and Shell, ABB presented a paper [1] at a large IEEE PCIC [1] Europe conference in 2008. The standards they presented in the paper were developed by the International Electrotechnical Commission (IEC), an over 100-year-old organization that focuses on international regulations and standards ➔ 3. Over the years, the organization's standards and tests have become something like a license for the electrical motor manufacturing industry to produce and sell electrical motors that are safe and efficient to use.

Footnote

1 IEEE PCIC are the Institute of Electrical and Electronics Engineers and the Petroleum and Chemical Industry Committee

1 Principles of explosion protection

The atmospheres in which operations in the chemical, oil and gas industries are carried out are categorized as either hazardous or nonhazardous. Hazardous environments contain potentially explosive constituents such as gases, vapors, mists or dust. These atmospheres are classified into risk categories, based on the presence and concentration of explosive substances:

- Zone 0 – An explosive atmosphere is present continuously.
- Zone 1 – An explosive atmosphere is present less than 1,000 hours/year.
- Zone 2 – An explosive atmosphere is present less than 10 hours/year.

For a machine placed in a hazardous area, a different kind of protection is needed to prevent ignition of any explosive gas that may be present. International standards define the types of protection that make industrial operations possible in two zones – zones 1 and 2. The aim of all protection is to avoid potentially explosive sources, which are typically hot surfaces and sparks.

One of the most important considerations when placing the coils inside the stator is to allow enough space between them to avoid corona discharges.

2 Protection types "n" and "e"

IEC 60079–15:2010 specifies requirements for the construction, testing and marking for Group II electrical equipment with protection type "n" (nonsparking), intended for use in explosive gas atmospheres in zone 2. This standard applies to electrical equipment where the rated voltage does not exceed 15 kV rms AC or DC.

IEC 60079–7:2006 specifies the requirements for the design, construction, testing and marking of an electrical apparatus with protection type "e" (enhanced safety), intended for use in explosive gas atmospheres in zones 1 and 2. This standard applies to electrical apparatus where the rated voltage does not exceed 11 kV rms AC or DC.

3 IEC standards

On September 15, 1904, delegates to the International Electrical Congress in St. Louis, Missouri, USA, adopted a report that included the following sentence: "Steps should be taken to secure the cooperation of the technical societies of the world by the appointment of a representative commission to consider the question of the standardization of the nomenclature and ratings of electrical apparatus and machinery."

Accordingly, the IEC was officially founded in June 1906 in London. Since then, the IEC has been involved in developing standards, safety guidelines, testing and specification of components for the world's electrotechnical industries. The group's mission includes everything from capacitors, resistors, semiconductors, radio communication and electrical equipment to electric motors.

In 1930, the IEC was instrumental in establishing the Hertz (Hz) as a unit of frequency, the gauss (G) as a unit of magnetic flux density and the gilbert (Gi) as a unit of magnetomotive force, among other units.

In 2005, the IEC published a multilingual dictionary of more than 20,000 electrotechnical terms in 13 languages.

4 Cross section of an insulated high-voltage coil

5 Wound and impregnated stator ready for further assembly

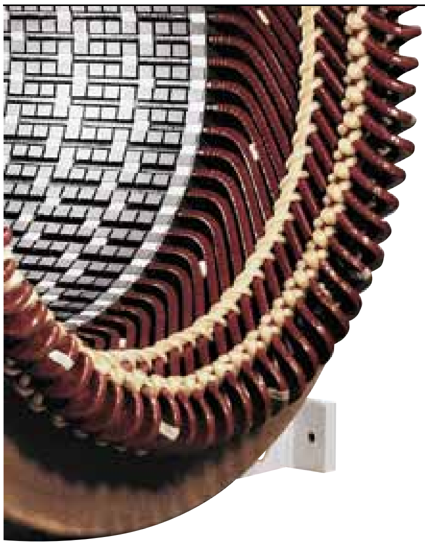

ABB and standards

ABB produces two types of high-voltage electrical motors – synchronous and induction – at factories in Sweden, Finland, Italy, South Africa, China and India. A synchronous electric motor is an AC motor distinguished by a rotational speed proportional to the frequency of the AC-voltage power supply; ie, the motor is running synchronously. The magnetization of the rotor is normally done by an external unit. These motors can be designed to run continuously in zone-2-rated atmospheres, classified as "Ex nA, non-sparking machines."

An induction or asynchronous motor is an AC motor in which the rotor is magnetized by means of electromagnetic induction, but its rotational speed is slightly below the synchronous speed; ie, the motor is running asynchronously. These motors can be designed to run in zone 1, also known as "Ex e, increased safety machines."

On January 28, 2010, new IEC standards, for equipment placed in an explosive atmosphere, came into effect. Based on previous development and testing, the majority of ABB's product range of synchronous and induction HV motors and generators were compliant with these standards. The rest were made fully compliant during 2010.

6 The test

Compliance with the IEC 60079–15: 2010 standard for nonsparking motors and generators requires a three-minute test of the stator in an explosive gas environment. The test is mandatory for motors with a rated voltage of more than 1 kV operating in environments where there is a presence of, for example, hydrogen, ethylene or acetylene, and above 6.6 kV for motors working in environments where there are traces of propane, diesel fuel, acetone, ethane, ammonia or any of a dozen other explosive gases and vapors.

During the test, a stator winding is covered with a layer of plastic, which is then filled with an explosive gas such as hydrogen mixed with air, as shown in the picture on the right. The stator is then subjected to varying and increasing voltages (sinusoidal) up to the specified test level. If a gas explosion happens, caused by a small spark in the stator winding, the plastic will break and let the pressure wave escape. The specified test voltage is 1.5 times the rated voltage. To pass the test, ignition of the explosive gas mixture must not occur.

According to the test performed in Germany at the Physikalisch-Technischen Bundesanstalt (PTB) in 2004 and 2009, ABB's stators are spark-free up to and including 13.8 kV for hydrogen (representative for gas group IIC) and 15 kV for both ethylene and propane (representative for gas groups IIB and IIA).

For an induction motor with a cage rotor, the rotor is also tested in an explosive gas environment for possible sparking from the rotor bars. Such a rotor ignition test is not needed for a synchronous rotor, due to its different construction.

The same standard, IEC 60079, also specifies the respective test for induction motors of the enhanced safety protection type.

Despite great advances in automation, making an electric motor that weighs up to 80 tons is still a manually intensive job. At the ABB factory in Västerås, Sweden, for example, about 200 motors and generators are tailor-made each year to customers' precise specifications. There, workers use a machine to painstakingly bend index-finger-sized strands of mica-insulated copper into the required exact shape → 4. In the next step, the ready-formed coils are insulated with an additional layer of mica before being placed in the stator.

The physics of electrical motors are relatively basic and are well understood by many; where it gets tricky, however, is in the insulation of the copper coils that are wound into the stator and tied together with fiberglass rope. The whole stator is subsequently impregnated with an epoxy resin, called a vacuum pressure impregnation, or VPI. After impregnation, the stator is cured in an oven to get its final electrical and mechanical properties → 5.

This Micadur®-Compact Industry (MCI) insulation system ensures sealed and homogenous insulation, resulting in low dielectric losses, high electrical and mechanical strength and excellent heat transfer inside the stator. While this insulation is a tried and proven system, one of the most important considerations when placing the coils inside the stator is to allow enough space between them to avoid corona discharges. If the coils are too near each other, there is risk of a corona buildup. Having enough air between the coils and optimizing the way they are laid out enables maximum use of the machine. The use of corona-suppressing materials is also essential.

The design and certification of ABB's large high-voltage synchronous and induction motors brings faster startup times and reduced maintenance requirements. While faster payback time and reduced maintenance costs are certainly beneficial, what is essential is that ABB's certified motors also offer proven safety, as testing represents the only way to verify that equipment really is safe → 6.

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References

[1] Rautee, J., Lienesch, F., Liew, T. (2008). Safety improvements of non-sparking and increased safety motors. *Petroleum and Chemical Industry Conference Europe – Electrical and Instrumentation Applications*, Weimar, Germany.

Title picture
An oil and gas platform is an environment with strict spark prevention requirements. The motors used must pass a demanding certification.