

The leading edge of motor development

FREDDY GYLLENSTEN, DMITRY SVECHKARENKO, REZA RAJABI MOGHADDAM – ABB has developed a revolutionary technology called the synchronous reluctance motor – or SynRM, for short. The design of SynRM electric motors makes them inherently reliable, highly efficient and able to pack high power levels into a small volume.

The induction motor (IM) dominates industrial applications, even in variable-speed applications such as the water pumping illustrated in → 8. This is because an IM will start directly on the grid – historically the way of starting and one that continues to this day, even after the introduction of modern frequency converters. However, the IM has some inherent drawbacks as a result of its asynchronous operation that result in relatively high rotor losses, and heating of bearings and windings that impacts maintenance intervals and shortens the lifetime of bearings and insulation.

The synchronous reluctance motor does not have these drawbacks and is much better suited to variable-speed operation.

SynRM motor technology

Although long known, permanent magnet AC motors only became competitors to IMs in the 1980s with the creation of a new generation of permanent magnets based on rare-earth elements (REEs). A prerequisite for the introduction of these new magnets into motors was the parallel advancement of the AC drives that were needed to control and operate the motors.

The drawbacks of an IM are absent in a synchronous reluctance motor and it is much better suited to variable-speed operation.

However, REEs are costly and can be subject to price variations. Also, their strong magnetic rotor field can make servicing – a key feature of a mainstream industrial motor – more difficult. Enter the REE-free synchronous reluctance motor.

The synchronous reluctance motor is a three-phase electric motor with a magnetically anisotropic rotor structure comprised of stacked electrical steel plates with punched holes as flux barriers. In the four-pole version, the rotor has four high-permeance and four low-permeance axes. High permeance means high magnetic conductivity and higher inductance while low permeance means lower inductance. Reluctance is the inverse of permeance and is, in practical terms, magnetic resistance; high reluctance

results in low inductance. The axes with high permeance (iron) can be referred to as the direct or d-axis while the axes with high reluctance (air) can be referred to as the quadrature or q-axis → 9.

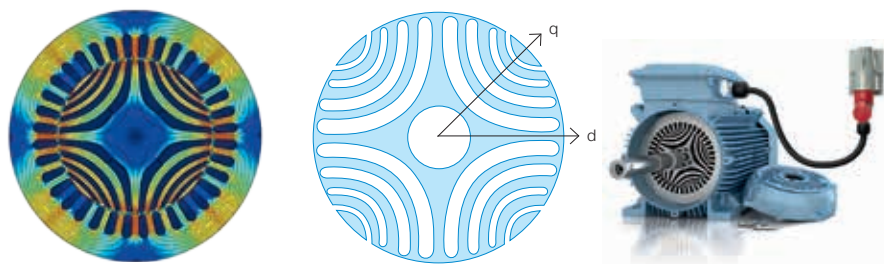
When a magnetic field is produced in the air gap by applying excitation currents to the stator windings, the rotor will strive to align its most magnetically conductive axis, the d-axis, with the applied field, in order to minimize the reluctance in the magnetic circuit. In other words, torque is produced in the air gap between the stator and rotor whenever the applied field vector and the d-axis of the rotor are not aligned. This causes the rotor to rotate. The rotor runs in synchronism with the applied magnetic field, striving to minimize reluctance in the magnetic circuit. This functional principle has given its name to the technology – synchronous reluctance.

As the rotor has no windings and, consequently, no joule losses, it runs considerably cooler and with better efficiency and reliability than an IM. Synchronous reluctance motors run smoothly due to the sinusoidal air gap field distribution and operation with sinusoidal current. One drawback is that the motor cannot be started with a direct-on-line supply as the rotor position must be known.

8 Industrial LV motors pumping water



9 Four-pole synchronous reluctance motor



9a Cross-section of a four-pole synchronous reluctance motor

9b Definition of the magnetic d- and q-axes of the rotor

9c Motor assembly

History of SynRM motor development

ABB's involvement in SynRM took off in 2004 when new opportunities for synchronous reluctance motors in the thriving VSD-based market were identified. The technology would enable higher efficiency and reliability without the need for REE permanent magnets. The favorable results of initial explorations eventually led to a technology project starting in 2007. At the same time, the market appetite for the product was tested.

To deepen understanding, an MSc activity on the motor concept was initiated in 2006. This work was subsequently continued into a PhD.

By 2009, good technical progress had been made – for example, bearing failure and rotor sheet failure had led to comprehensive durability testing and failure mode analysis – and in 2011, develop-

ment was far enough advanced to unveil SynRM at the Hannover Fair. In that same year, the technology won the Automation Award at Germany's SPS IPC Drives trade show. The first products were launched in 2012.

An expansion to the SynRM product palette – SynRM2 – was introduced in 2014. A unique feature of this motor – mainly developed by ABB's key SynRM contributors Alessandro Castagnini, Pietro Savio Termini and Giulio Secondo – is that it uses ferrite (Fe_2O_3) magnets, which are generally more cost-effective and more readily available than REE magnets. This results in a very powerful product that is economical and ecologically sustainable.

The following year, 2015, the SynRM family was extended once more with the technology introduction of DOL SynRM,

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which can start directly on the grid since it is equipped with a squirrel cage inside the SynRM rotor barriers.

SynRM has come a long way since its early days but is still a relatively young technology for commercial use. Current ABB products have the potential to improve their performance even more with updated designs and constructions, and thus offer optimized solutions for customer needs many and varied.

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