Advantages of Synchronous Reluctance Motors

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Abstract — **Synchronous reluctance motors are a new range of standardized electric motors developed by ABB for utilities and industrial consumers to improve their system performance and efficiency along with the benefit of being able to lower their footprint on the environment. These motors, which are delivered to customers in full package combined with frequency converter combines the performance and efficiency of permanent magnet technology with the simplicity, cost-efficiency and service-friendliness of induction motors. An innovative rotor construction brings lower losses and allows to use higher density of power in the motor construction. These motors are delivered in variant with efficiency accordance to IE4 efficiency level and in variant high output, which is characterised with high concentration of density.**

Keywords — synchronous reluctance motors, M3BL, reluctance, efficiency, losses

I. Introduction

The idea of a synchronous reluctance motor is not new, the principle for using the reluctance difference has been known for long time. Before the discovery of the rotating magnetic field by Nikola Tesla in 1887 this first reluctance motor was close to the doubly salient synchronous reluctance motor, which is nowadays known as the switched reluctance motor. The first rotating magnetic field synchronous motor was introduced in literature already from 1923 (Kostko 1923, Douglas 1956, Cruickshank 1966, El-Antably 1985) [1]. This technology was not accepted with general public. The reason was mainly of the frequency drives imperfection which was not yet on at level of effective motor control. Only with the development of semiconductors, with wide expansion of frequency converters and still with the increasing demand for energy savings the world is again turning to this technology. Since ABB is a world leader in electric drives and motors, sufficient amount of time and research has been dedicated in this field for many years for the development on synchronous reluctance technology. After the pilot tests, many of these motors are being offered to customers in the standard series M3BL. Some of the domains where these motors are replacing traditional induction motors are predominantly observed in applications including pumps, fan and compressor systems to name a few, where they are also preferred for applications requiring constant torque. In the year 2011 ABB synchronous reluctance motors received the prestigious award Automation Award in Germany.

A. Theory of synchronous reluctance motor

The synchronous reluctance motor is a three-phase electric motor without permanent magnets and with a magnetically anisotropic rotor structure. In the four-pole version, the rotor has four high- and four low-performance axes. High performance means high magnetic conductivity and higher inductance, while low performance, means lower inductance [7]. When a magnetic field is produced in the air gap by applying exiting currents to the stator winding, the rotor will strive to align its most magnetically conductive axis, the d-axis, with the applied field, in order to minimalize 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 rotor d-axis are not aligned.) The magnitude of the vector field and the speed of its rotation can be controlled by a frequency converter. The high saliency of the rotor means that its angular position can be simply detected by a sensorless control. Expensive absolute encoders, resolvers and other rotational sensors are therefore not required. The sensorless control system keeps track of the rotor angular position in relation to the stator and creates a vector field with accurate magnitude and rotational speed in accordance with the control reference signals dictated by the load. Reluctance is the inverse of permeance and is, in practical terms, magnetic resistance; high reluctance resulting in low inductance. The axes with high performance can be referred as the direct or d-axis, while the axes with high reluctance can be referred to as the quadrature or q-axis. The figures below show the different axes in the rotor.

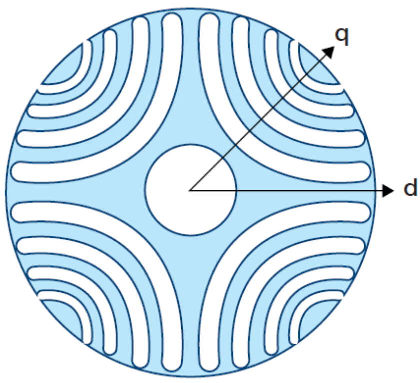

Fig.1. Cross-sectional illustration of synchronous reluctance rotor and definition of the magnetic d and q axes.

Since performance is dependent on information about the position of the rotor, the motor always needs a frequency converter – it will not operate properly direct-on-line. The rotor runs in synchronism with the applied vector field, striving to minimize reluctance in the magnetic circuit that is present, and this functional principle has given its name to the technology – synchronous reluctance. Synchronous reluctance motors run smoothly due to the sinusoidal air gap field distribution and operation with sinusoidal current. [7]

B. Why should we focus on synchronous reluctance motors

Electric motors in industrial applications account for approximately 60 – 65% of consumed industrial electricity [4]. Using of energy effectively by increasing motor efficiency is in the centre of continued motor optimization. Major energy savings are also gained through the use of variable speed drive systems and today this technology is adopted in as many as 30 – 40% of all newly installed motors. Sustainable use and investment also demands increased reliability and lifetime of a motor. The possibility of achieving standard power and torque levels at merely a low class-A temperature rise (60K) improves the lifetime of the motor insulation, and lengthens the bearing lifetime or greasing intervals. [4]

II. SYNCHRONOUS RLUCTANCE MOTOR SERIES M3BL

The series M3BL motors was launched to meet the demand for motors that are optimized for operation with frequency converters and at the same time it will be small, more powerful, high efficiency, with long life and low maintenance. The streamlined rotor structure of ABB synchronous reluctance motors eliminates rotor cage losses and therefore increases efficiency and compactness. These motors are delivered in complete package with frequency converter ACS850 or ACS880 with various options. ABB synchronous reluctance motors are delivered in two variants. First variant is with High efficiency IE4. These motors have energy losses reduced by up to 40% compared to the IE2 efficiency classes. These motors follow Cenelec harmonized size and output combinations. Second variant, witch ABB offers is the High Output. These motors are up to two frame sizes smaller than an induction motor with the same output. The size advantage of synchronous reluctance motors can also be exploited to increase capacity without changes in the motor installation.

conventional, proven stator technology and a totally new, innovative rotor design. Then combine them with a best-in-class industrial drive loaded with new, purpose-designed software. This synchronous reluctance technology combines the performance of permanent magnet motor with simplicity and service-friendliness of an induction motor. The new rotor has neither magnets nor windings and suffers virtually no power losses. In comparison with standard asynchronous motors the losses are lower up to 40%. As you can see on the following Fig. 2. Consequently we can say that standard motors worked at temperature rise F (105K), the ABB Synchronous reluctance motors have lower losses in the rotor and work in the temperature rise A (60K). This fact is shown in figure Fig.3. Thanks the lower winding temperature and also bearing temperature it is possible to reach up to 70% fewer unplanned failures of the electric motor. It causes lower costs of maintenance and operation. Also lower winding-temperature increases the winding-insulation lifetime. The advantage of IE4 Synchronous reluctance motors is that these motors are very easy to replace, because these motors follow harmonized Cenelec size frame and output combinations as a standard asynchronous motors. Currently the IE classes according the IEC60034-30-1 are applied exclusively to motors rated for line operation. This is not in the case of ABB synchronous reluctance motors. Therefore, the motors do not have the IE class marking on the rating plate. We call these motors package as the IE4 because the package efficiency at the nominal operating point is the same, or higher than that of a motor and drive package utilizing a motor with line operated IE4 classification. An additional benefit related to synchronous reluctance motors is their excellent partial load efficiency performance compared to induction motors. For all ABB synchronous reluctance motors ABB

Fig. 2. The Comparison standard asynchronous motor with IE4 Synchronous reluctance motor**.**

A. IE4 Synchronous reluctance motors

IE4 standards for efficiency offer super premium efficiency for synchronous reluctance motors which is the key for energy efficiency. The idea of the IE4 synchronous reluctance motors is very simple. Use of a

can provide accurate payback and as standard ABB is delivering to customer manufacturer statement about SyRM motor package efficiency. The efficiency comparison between the standard asynchronous motor with frequency convertor and the synchronous reluctance motor with a frequency convertor can be seen in Fig.4.

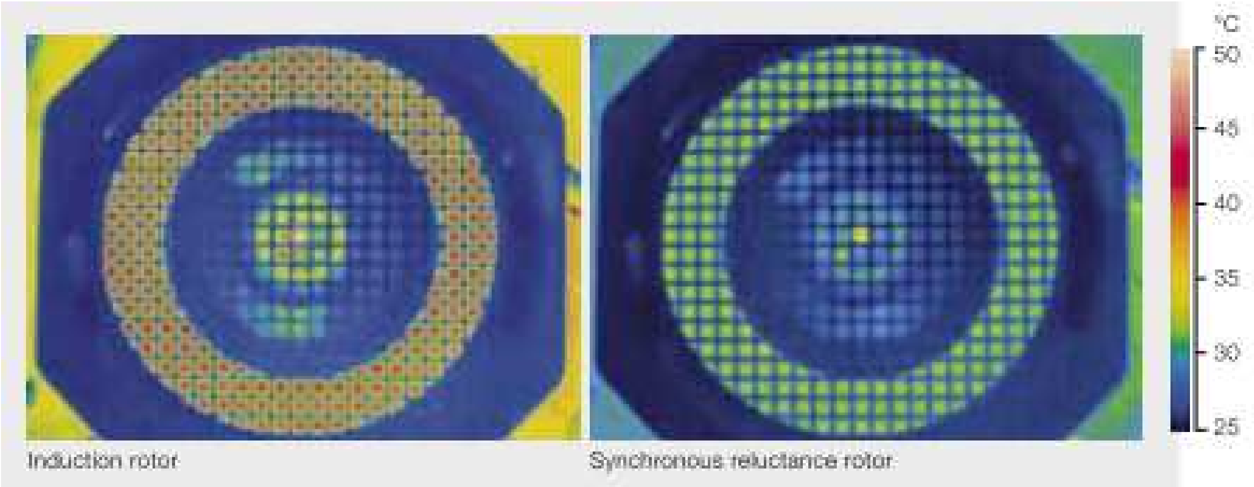

Fig. 3. Temperature distribution of standard asynchronous motor with IE4 Synchronous reluctance motor**.**

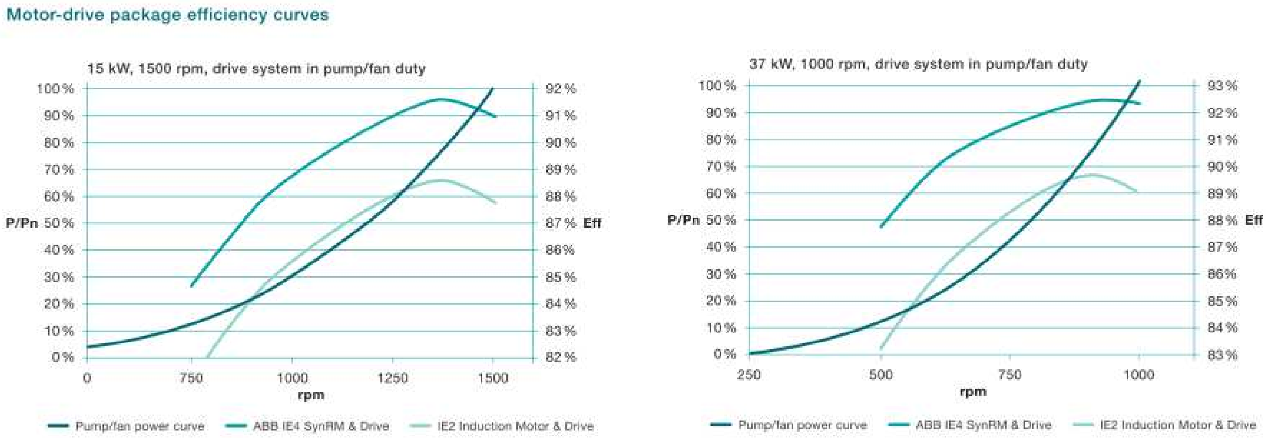

Fig. 4. Motor-drive efficiency comparison of standard asynchronous motor with IE4 Synchronous reluctance motor**.**

B. High output synchronous reluctance motors

High output synchronous reluctance motors deliver better density and higher energy efficiency than you can get with the equivalent induction motors. It makes from these motors powerful, high compact motors, with up to two frame sizes smaller compared to traditional motors. It helps machine builders improve machine performance and design more cost effective machines. The customers appreciate these motors for the compactness, high dynamics that allows provide very efficient solution for installation. For motors with power range 3-4kW it can get in the same frame size get up to 60% more power. For motors with power 60kW this increase is 40% and on motors 220kW the increase is up to 20% in comparison with the standard asynchronous motors. Fig. 5 demonstrates the difference in size-dimension of the standard asynchronous motor in comparison with the High Output SyRM, along with the differences in losses. Fig. 6 compares the package characteristics for standard asynchronous motor and frequency convertor and the SyRM in package with frequency convertor. These motors are focusing on OEM customers who evaluate the compactness and the low rotor inertia.

III. Conclusion

The core innovation of the synchronous reluctance motors is the rotor design, since the stator side of the motor is identical with an induction motor. ABB knowledge and expertise helped to construct a robust, efficient rotor capable of high-speed operation. But drive technology and the matched motor-drive packages and drive algorithms make the system breakthrough possible from a technology perspective point of view. In many ways, synchronous reluctance technology combines the benefits of induction motors and permanent magnet motors. It provides the robustness of an induction motor and the size, efficiency, and synchronous speed operation benefits of the permanent magnet motor technology while eliminating concerns related to permanent technology. The primary benefits of the technology include size, efficiency, and reliability [9].

Fig.5 . Comparison standard asynchronous motor with High Output Synchronous reluctance motor.

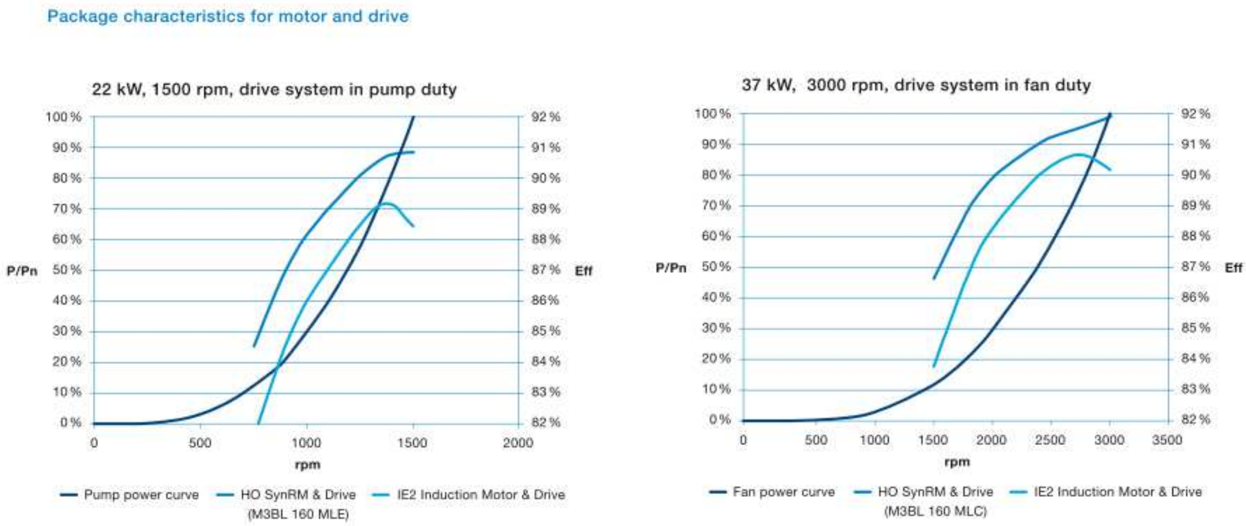

Fig. 6. The Comparison standard asynchronous motor with High Output Synchronous reluctance motor.

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