Unit of power

Cutting-edge motor design redefines power density

THOMAS EK, KARITA FORSS, TIMO HOLOPAINEN, JANNE IKONEN, OLLI LAHTINEN – ABB has introduced a new generation of motors based on the successful, high performance rib cooled motor range, type HXR. These new motors are named “High voltage rib cooled motors, NXR” and they achieve new levels of power density. The new motors feature improved internal and external cooling, cutting-edge coil manufacturing methods, a state-of-the-art frame design and unprecedented levels of adaptability and serviceability. The design offers a better solution for the wide range of applications in which totally enclosed fan-cooled motors are customarily used. The improvement in power density means that it will often be possible to use a motor with a smaller frame size to achieve the same output as previous, larger designs. Initially, the motors will be available in 355 and 400 frame sizes.

These motors are designed to become the new benchmark for the industry, while still complementing the existing range.

All rotating electrical machines generate heat as a result of the electrical and mechanical losses inside the motor. Losses are particularly high during starting and they also increase with increased loading. Cooling is, therefore, necessary to continuously transfer the heat to a cooling medium, such as the surrounding air. So important is cooling to motors that different cooling methods for rotating machines are officially defined in an IEC standard.

There has always been a demand from industry for motors to become more compact and, at the same time, deliver more power. This throws down the challenge to produce a motor design that is mechanically smaller and more powerful but that stays cool. This is not all: the motor should also operate within mechanical vibration constraints, be service-friendly and be flexible so as to simplify commissioning.

Perhaps the main innovation that contributes to improved efficiency is the motor's cooling system.

The new ABB motors described here are the result of a long period of research and development in which various parameters have been optimized to ensure that the motors will become the new benchmark for the industry, while still complementing the existing range. Not only do they produce more power per kilogram than previous designs, but they also have longer service intervals and more flexibility.

Innovative cooling

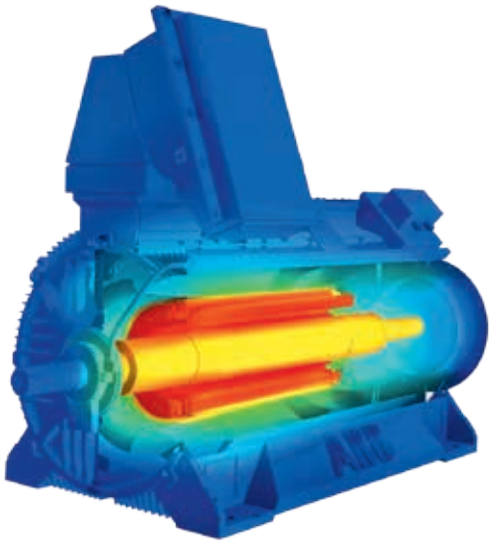
The innovation that contributes most to improved efficiency is the motor's cooling system.

Title picture

Optimized design of cooling, coils and casting allows more motor power to be packed into a smaller volume than before. And service and commissioning become easier too.

The coil has also been improved with better use of its active materials and re-dimensioning – making the coil more compact and thus increasing its power output.

1 Internal cooling as imaged by a thermographic camera



It is difficult to predict thermal efficiency, so the development team analyzed existing motors, constructed computational fluid dynamics (CFD) models, called in external partners to carry out simulations and developed analytical calculation methods that could be used to finalize the design. Further, the CFD models had to be both challenged with real measurements and interpreted correctly in order to turn the models and calculations into functioning motors. In this step, the expertise and experience of the ABB team and its partners played a crucial role.

ABB's innovative internal cooling system increases air circulation through the motor and routes air through channels in the stator and rotor, assisted by a fan → 1. An internal fan has been a feature of other ABB motors, but has never been so thoroughly exploited before.

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The motor's end shields are designed to be both rigid and light, with an inner surface that facilitates internal cooling circulation. In addition, the interplay of the cooling channels and the external cooling areas have been optimized – for example, the air channels do not interfere with the rib cooling. While most motors have four air channels, the new motor has only three.

Upgraded cooling ribs

One way in which external cooling has been improved is with the increased number of cooling ribs. The ribs have also been lengthened and their pitch and angle optimized, with all obstructions reduced → 2. For example, the bolts and screws that hold the end shields in place are designed to not obstruct the air flow; a cable tray ensures that auxiliary cables are well stowed; the ribs are made so as to be easily cleaned; and the fixing points are positioned so that accessories are mounted on the side of the motor and do not affect the air flow. In addition to preventing obstacles to air flow, the outside ring of the end shield is finished with a 30 degree chamfer to direct the air more effectively.

2 Front view of the optimized rib construction

The ribs have been increased in number, lengthened and had their pitch and angle optimized, with all obstructions reduced.

The research carried out to optimize the cooling process is also of benefit when it comes to the modeling required to customize individual motors: Full-scale CFD modeling can take hours or even days but parameters from the CFD modeling and measurements can be extracted to allow the rapid calculation of temperature change for a particular motor design. More accurate temperature predictions mean that motors can be tailored precisely to their requirements, thus ensuring better performance.

Lowering vibration

The new, more powerful motors are longer than their predecessors and this has necessitated further work to ensure that their greater length does not result in more vibration. Here, too, designs were developed using computers, but the virtual prototyping – in this case the finite element method (FEM) – was unable to satisfactorily predict the characteristics of the new design. So, components such as the rotor, the stator and the end shields were modeled and manufactured. The manufactured components were then measured and the FEM models were validated against the measured data of each component. In an iterative process, these two were validated against each other until the most effective designs could be identified. The final design avoided all the significant resonances that may be caused by mechanical and electrical excitations → 3.

Increased rigidity reduces vibration. One way to increase rigidity is to increase the axial and transverse dimensions of the mounting holes. More important for the rigidity, however, was the optimization of the mechanical design.

The objective of this optimization was to reduce the use of material while still complying with the vibration requirements of the main industrial standards. In the past, rigidity would have been achieved by simply adding more metal. This solution is no longer acceptable – strength and rigidity have to be achieved by the intelligent shaping of the material and not by extra mass. But the design of the various elements of a motor is not an exact science. For example, the panel between the feet serves two purposes: It houses one of the three air channels and also provides rigidity to help transfer the horizontal forces from the stator to the feet. Calculating the best size for the air openings at either end on the inside of the air channel or the optimum thickness of the cast iron is not straightforward, especially if the amount of material and the weight of the motor are meant to be reduced. The development teams worked with suppliers to achieve a casting process that met design requirements and optimized the use of material.

One of the aspects that was considered in the modeling of this new motor was how it would function on different foundations – since problems with vibration

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3 Modelling of rotating electromagnetic traction to predict mechanical vibrations

are often caused by the interaction between the motor and the foundation on which it stands. It makes a considerable difference whether a motor is mounted on a concrete block or on a steel skid. The new motor can be used with a wide variety of foundations.

New coil manufacturing

The coil has also been improved, with redimensioning and better use made of its active materials. Making the coil more compact increases its power output. New tools have been developed that allow better control of coil-end shaping in the manufacturing process, which has improved quality and repeatability so that every coil is now closer to perfection than was previously possible.

The new coil manufacturing process is already having an influence on production methods in other ABB motor ranges.

Flexibility of deployment

One of the most immediately noticeable innovations is the option of fitting the main terminal box on either side or on either end of the motor. In the case of the 400 frame size, it can also be fitted in the middle. Changing the position of the box simply involves exchanging it for the hatch that covers the desired position → 4.

The mounting of the auxiliary terminal box is also extremely flexible – it can be fitted on either side of the motor and in several locations along its length.

Improved cooling ensures that the motors will last longer and require servicing less frequently because lower temperatures in the bearings will mean less frequent lubrication.

Thus, a change of factory layout does not mean that a new motor needs to be bought merely because the power comes in from the side opposite the cable connection. And, especially in industries where motors are used on either side of a production line (metal or paper industries, for example), one spare instead of two can be enough to meet backup needs. There is no need to send the motor in for modifications – ABB service personnel can do all the work on-site.

A wide range of options is built into the basic design and this type of flexibility helps to improve lead times. For instance, the end shields are pre-engineered to accommodate accessories like

4 Flexible deployment

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the waste grease box and instrumentation, allowing faster and easier customization.

Serviceability

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To ensure that any problems are dealt with early, the new motor can also be equipped with ABB's condition monitoring system, ABB MACHsense-P, or its remote monitoring system, ABB MACHsense-R. The motor includes provisions for the installation of sensors and, for ABB MACHsense-R, fixing points for a monitor.

Additionally, it is now possible to examine the coil ends without removing the bearing shields. The bearings themselves can be examined with an endoscope and without removing the bearing shields.

All this helps to increase reliability and decrease costs.

More power and know-how per kilo

The innovations in the new motor (type designation NXR) mean that it can often provide the same output power as a motor one, or even two, frame sizes larger. In extreme cases, this can result in a weight reduction of 40 percent.

These new motors embody more than 100 years of ABB's experience in the field combined with the latest design and manufacturing technology. Also, the developments described benefit more than just this range of motors: Already the new coil is being used elsewhere in ABB – and the new cooling developments will almost certainly have an influence on other cooling designs. The calculation tools, which are derived from virtual prototyping and confirmed by validation measurements on actual prototypes, look set to be adopted within ABB.

The new range of motors, which currently targets 355 and 400 frame sizes, will soon be extended to include other frame sizes and additional features.

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