DMI – a new milestone in the development of *DC motors*

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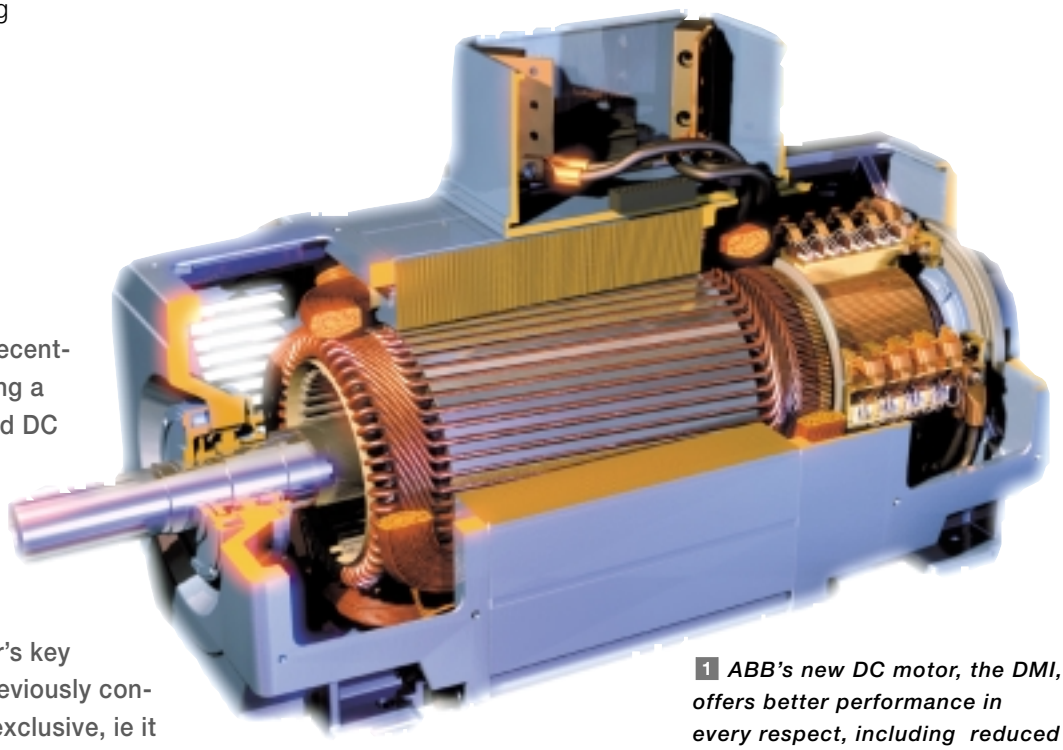


1 *ABB's new DC motor, the DMI, offers better performance in every respect, including reduced maintenance.*

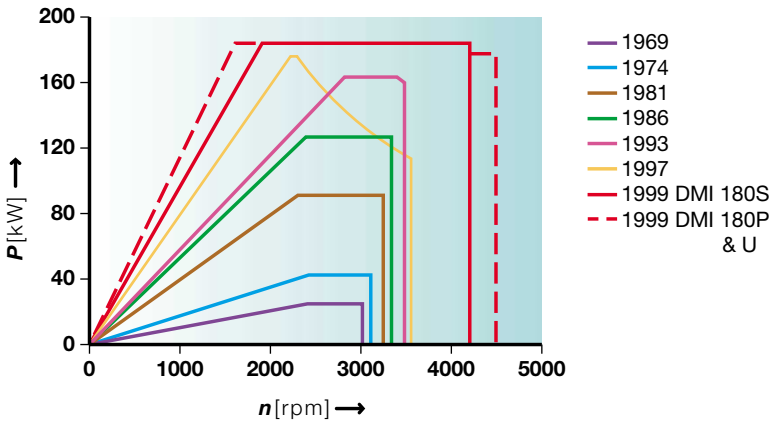
ABB Motors has recently started marketing a new, medium-sized DC motor offering significantly better performance in a number of important areas. Many of the motor's key attributes were previously considered mutually exclusive, ie it was not possible to combine them in the same machine. Thanks to the new motor range, which is named DMI, customers can take advantage of high power, a wide speed range, high torque, small dimensions, high overload capacity or low moment of inertia simultaneously, and no longer have to forgo any of these important features. The improvements are important enough to justify calling DMI the beginning of a new era in DC motor technology.

DC motors have existed for more than a century, and at least twice during that period they have been popularly regarded as doomed to extinction. The first time this happened was when three-phase AC supply came onto the scene around the turn of the century. Thanks to their good regulatory properties DC motors nevertheless survived and, during the last few decades, have become more popular than ever, largely due to thyristor converters making it easy to capitalize on the advantages of DC technology. However, in the last few years, the doomsayers have come knocking again, this time predicting the demise of the DC drive because it is possible nowadays to approach its precision and responsiveness with frequency converters and standard squirrel-cage AC motors. Once more, the prophecy does not seem to have materialized; sales of ABB DC motors in recent years have remained stable; and what is more, thanks to the introduction of the new DMI motor **1**, ABB anticipates significant growth in this sector.

DC motor development

The stiff competition in the field of DC motors has led to ever more 'stressed' designs. While performance in terms of output power, torque and maximum speed has increased over the years, it has been at the expense of the electrical margins and speed range at rated output power. This in turn has led to a greater need for maintenance of brushes and commutators and to a reduction in lifetime 2.

The challenge for the DMI project team was therefore to turn the development of DC motors back towards ideal characteristics, including a wide speed range at constant output power, low electrical stress levels and, as a result, less need for maintenance.



2 *Although DC motor performance improved in terms of output power (P), torque and maximum speed over the last few decades, it was at the cost of a reduced speed range (n) at rated output, smaller electrical margins and a greater need for maintenance. ABB Motors developed the new DMI motor to break with this trend.*

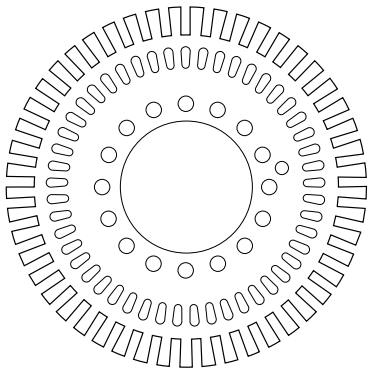
ABB's approach

A few years ago, sales of the DMI's forerunner, the DMG motor, gave ABB Motors reason to contemplate the future of their involvement in DC machines. The company decided it wanted to reverse the market trend towards increasingly restrictive designs and, based on its broad know-how, experience and state-of-the-art design tools, develop an ideal motor with respect to its mechanical and electrical properties. Specifically, this meant higher output power, higher torque, higher speed, a wider speed range, lower moment of inertia, better low-speed properties and lower electrical and mechanical stresses.

Two possible avenues were open: start with the current motor series and improve it, or design an entirely new machine. The first was less risky and less costly, but also less promising; the second, although it obviously entailed more risk and higher costs, held more promise. After careful analysis, ABB chose the second path and laid plans to design an entirely new series of motors. This was done because its potential by far outweighed the greater risks and higher development costs. The result – the new DMI motor – proved to be the right choice. Compared with the forerunner, the new motor exhibits approximately:

- 50 % higher output power
- 90 % higher torque
- 30 % higher maximum speed
- 30 % wider speed range

3 *Armature laminations of the new DMI motor. Larger cooling channels, which have been moved closer to the winding slots and are located symmetrically in relation to them, provide more efficient cooling and better magnetic balance.*

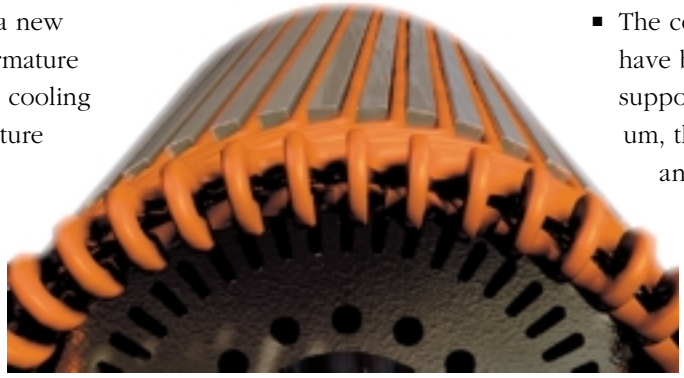


4 *Symmetrical positioning of the armature cooling channels in relation to the winding slots results in a better magnetic balance between the armature coils.*

New solutions

The development project spawned a number of novel technical solutions, for which several patents have since been applied. The most important development is a new principle for cooling the armature windings which moves the cooling channels through the armature laminations closer to the winding slots, while at the same time significantly widening the overall cooling area. Because of this, the cooling capacity is considerably better. In addition, the magnetic balance of the armature is improved by the fact that the cooling channels are located symmetrically in relation to the winding slots 3.

The symmetry of the magnetic flux in the armature circuit, which ensures that no armature coil is subjected to higher electrical stress than any other, was one of the aspects examined during the computerized optimization of the magnetic circuit 4 shows an example of the way the results of flux calculations were presented.



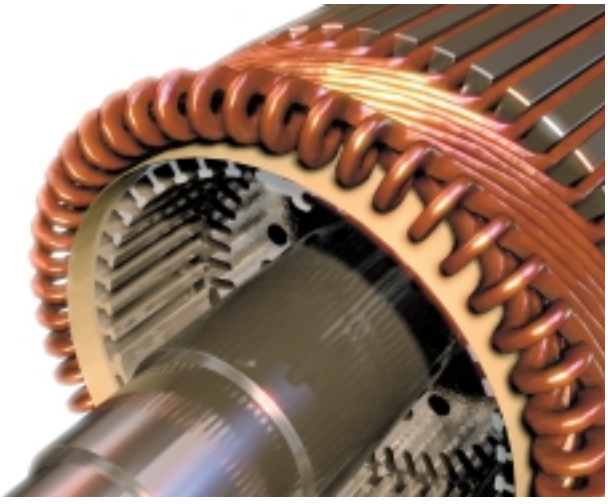
5 *The armature coils are skewed for smoother running at low speeds and less noise.*

Other improvements to the armature were:

- The manufacturing process for core laminations has been refined to reduce the variations in magnetic polarization of the electrical steel used. This measure has resulted in smoother running at low speeds.
- The armature coils have been skewed, resulting not only in smoother running at low speeds but also in lower noise levels 5.
- The coil ends of the armature have been mounted on rigid support rings made of aluminium, thus reducing vibrations and contributing to the high speed limit of the DMI motor. The arrangement also improves the cooling of the coil ends, a weakness in many older designs which directly affects the durability of the insulation 6.
- The motor shaft is overdimensioned to further reduce vibrations and contribute to the high speed capability of the motor.

The stator has also been improved. More space has been created for the windings and the magnetic balance is better, as is the temperature distribution. All of this was made possible by computerized optimization of the mag-

6 *The coil ends of the armature are mounted on sturdy support rings made of aluminium. This arrangement contributes to the high speed capability of the DMI motor and improves cooling.*



7 *The DMI stator has also been significantly improved. More space has been created for the windings and the magnetic balance has been improved, as has the temperature distribution.*

netic circuit, more compact coils and improved manufacturing methods 7.

The commutator has also been redesigned. Its diameter has been reduced and it has been made more sturdy. Consequently, it too contributes to the motor's high speed capability and wide commutation margin (ie, its capacity to conduct current without sparking) 8.

8 *The commutator has a small diameter and therefore a low peripheral speed, ensuring that it will run properly even at high speeds.*

Dramatically improved performance

The above-mentioned improvements were introduced to boost the output power of the motor without compromising the commutation margin. However, the results far exceeded the expectations. Despite a boost in power of up to 70 %, the commutation stress level fell significantly.

The performance boost compared with conventional DC motors on the market is evident from 9. The horizontal section of each diagram represents the 'shunting range' giving a good indication of the commutation margin of each motor at rated load.

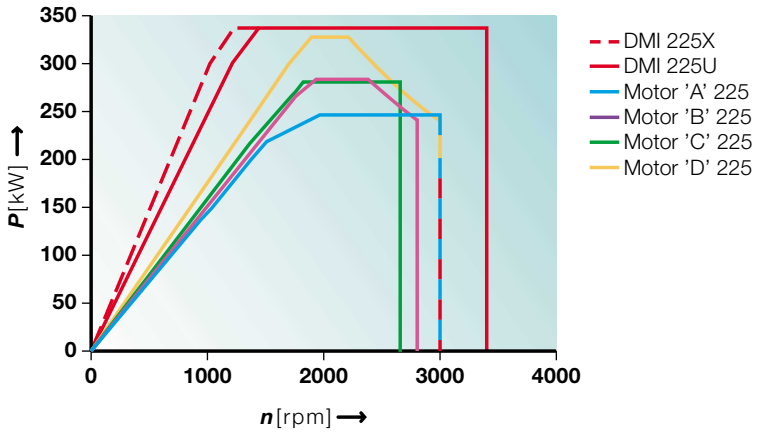
Commutation margin: the key to high reliability

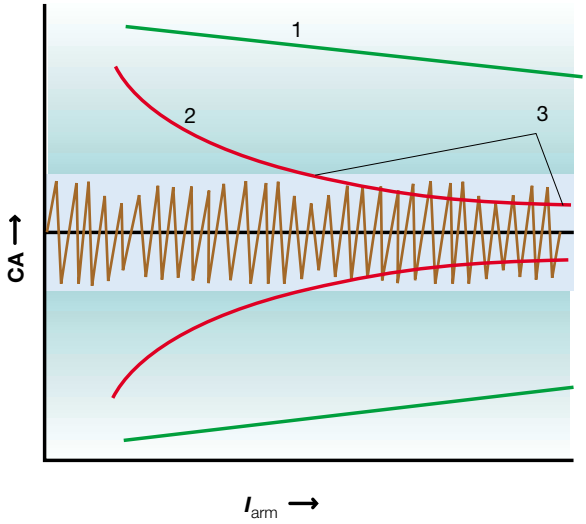
The commutation margin is a measure of the ability of DC machines to conduct currents between the brushes and the commutator without sparking. Consequently, it is one of the most important properties governing operational reliability and maintenance requirements. The commutation margin is affected by factors such as current ripple, vibration, temperature, load and contaminants in the cooling air – all factors which, in different ways, have been attended to in the DMI motor. The commutation ability of the DMI has been verified with converter supply, which is significantly more demanding than a smoothed DC supply. An extremely wide commutation margin ensures high operational reliability and minimal maintenance for the motor 10. In reasonably stable operating environments, the commutator and the brushes need not be overhauled more often than the bearings. Suddenly the DC motor is on par with squirrel-cage AC motors in terms of maintenance intervals.

Insulation: the key to long life

Different materials are used for the insulation of the DMI motor to extend the life of the motor for as long as possible. For example, materials with high temperature indices – far higher than Class H – are used where the temperature is

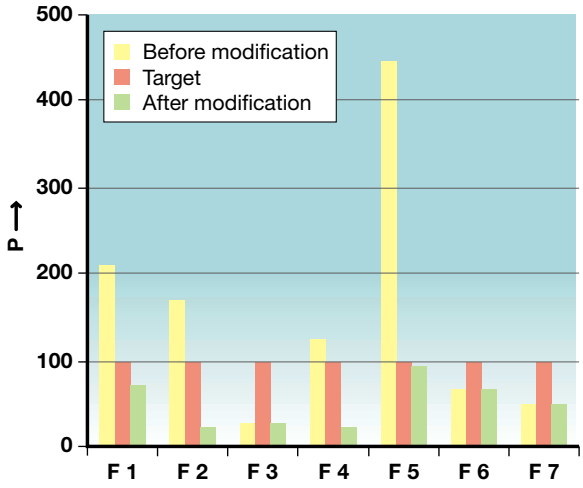
9 *Power (P) and speed range (n) of the DMI motor compared with some well-known conventional DC motors on the market*





10 *The wide commutation ability (CA) of the DMI motor improves operational reliability and reduces the need for maintenance. The shaded area in the center of the diagram represents disturbances that are always present during normal operation and affect the commutation margin of the motor.*

1 *DMI motors*
2 *Other motors*
3 *Insufficient commutation*
I_{arm} *Armature current*



11 *Failure mode and effect analysis (FMEA) was used throughout the design and production engineering phases to ensure that the set quality and reliability objectives were reached.*

P *Probability index*
F1–F7 *Failure modes*

high, and mechanically stronger materials where temperatures are lower. In this context it is important to point out that ABB calculates temperature margins for the DMI on the basis of the actual temperature during operation, not the temperature some time after shut-down, which the IEC 34-1 standard permits. ABB temperature tests are also based on the more demanding converter supply.

At the same time, the risk of hot spots developing is eliminated thanks to near-ideal electromagnetic dimensioning and improved cooling.

FMEA – a systematic approach to achieving high quality

A systematic approach to identifying the measures required to reach the set quality objectives is offered by 'Failure Mode and Effect Analysis' (FMEA). This method was therefore used throughout the development and production engineering phases of the new motor 11.

Long-term viability foreseen for DC technology

Designing electric motors, like so many other design assignments, is largely a matter of finding the best balance between desirable, but conflicting, properties. In the case of DC motors, the desirable properties include high output power, high torque, high speed, a wide speed range, small dimensions, low weight and minimal maintenance. Different motors, not least from different manufacturers, have traditionally been good at different things; none has been good at all of them. Now, thanks to unique human resources in its design department side, new computer-based design tools and a good measure of innovative thinking, ABB has, with the DMI motor, come up with a product which is significantly better on all counts. This is good news for all involved, and for the ability of DC technology to remain viable in the long term. ■

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