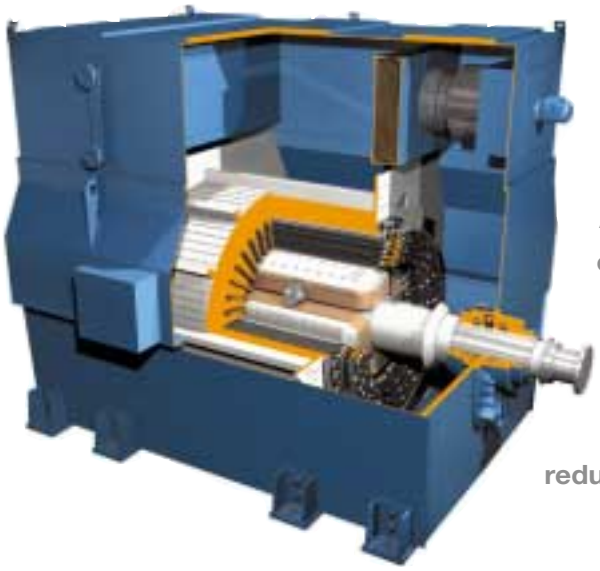
Motorformer™

A new motor for direct HV connection



Cutaway drawing of Motorformer™

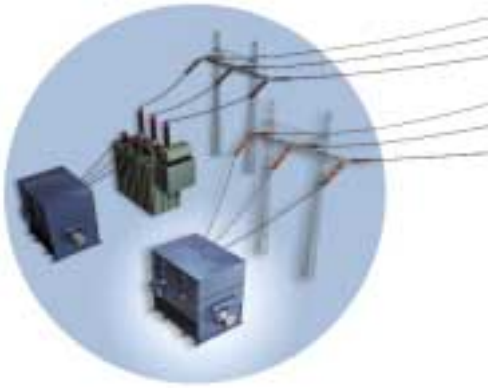
Göran Eriksson

Ever since Powerformer™ was introduced in 1998, ABB's R&D engineers have been seized by the idea of building an electric motor based on the same radical principles. The idea has now become reality: called Motorformer™, the new motor joins Powerformer in making electrical systems simpler, in improving their efficiency and in reducing their cost and environmental impact.

The large electric motors that drive industrial machinery such as compressors and pumps work in the power range of 1,000 to 50,000 kW at voltages of between 3 and 15 kV. Since the voltage of the transmission line from which they take their power is much higher than this, one or more step-down transformers have to be interposed between the grid and the motors.

Besides being a major cost item, these transformers lower the overall efficiency of a plant and pose several environmental risks, such as fire and oil spillage. A motor which can be connected directly to the high-voltage grid, ie without step-down transformers, would obviously overcome all these disadvantages 1. With the development of Powerformer™ [1,2], a technology finally became available with which such a motor could be built. ABB's engineers have seized the opportunity, and now proudly present Motorformer™.

In Motorformer, as in Powerformer, circular conductors consisting of commercially available XLPE cable are used, making voltages of 15 kV and higher possible. In time, Motorformer units rated as high as 150 kV will be



1 Motorformer (bottom) can be connected directly to the HV grid, saving space and eliminating the oil-filled step-down transformers in conventional installations. Motorformer is epoxy-free and can therefore be easily recycled.

2 Stator of Motorformer

made available to the market. Levels above this, while technically feasible, probably will not be commercially attractive. Initially, Motorformer will be of the synchronous type, but an induction version can be added in the future if there is sufficient market demand.

The technical challenges

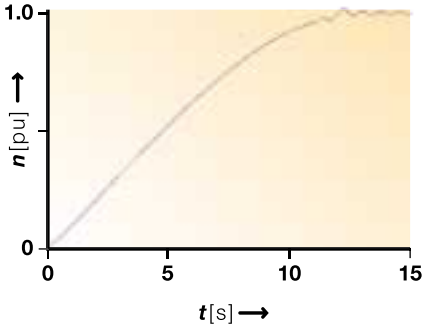
Industrial environments are often dirty so motor customers place a lot of importance on their machines being rugged and durable. By choosing to base its new Motorformer on the proven AMS/GBS range of motors, ABB easily meets this requirement: close to 1000 units from the AMS/GBS series were delivered to industry during the 1990s.

Several motor components, such as the rotor, exciter, stator frame and housing could be taken over and used for Motorformer without having to make changes.

What is totally new about Motorformer is the stator 2. Its winding is made of XLPE-insulated cable, arranged in the core in a totally unique way. The stator is also cooled differently; direct water-cooling or a combination of direct water-cooling and air-cooling is used, depending on the rating.

Keeping cable-to-cable forces low

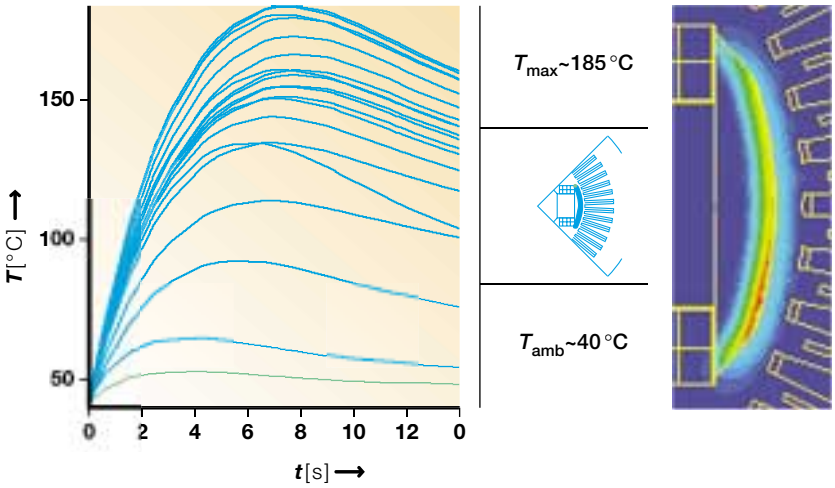
The mechanical support of the cable in the stator and on the overhangs presented a design problem for which Motorformer and the HV concept offered its own, unique solution. The forces between electrical conductors are proportional to the square of the current; in Motorformer the current is reduced in proportion to the increase in voltage, so the cable-to-cable forces are lowered to easily controllable levels.



3 Motor speed during start

n Rotor speed

t Time



4 FEM plot of temperature (T) in pole shoe

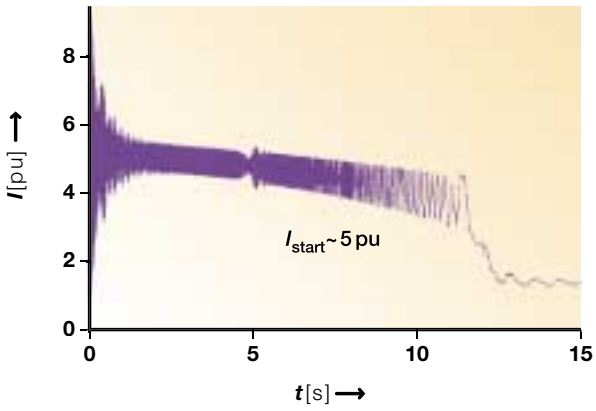
t Time

Inside the slot there is a flexible element between each layer of cables, while on the overhangs simple rope and silicone rubber arrangements are used. The flexibility of the XLPE cable is also a guarantee of safe operation after a short circuit.

The problem with starting

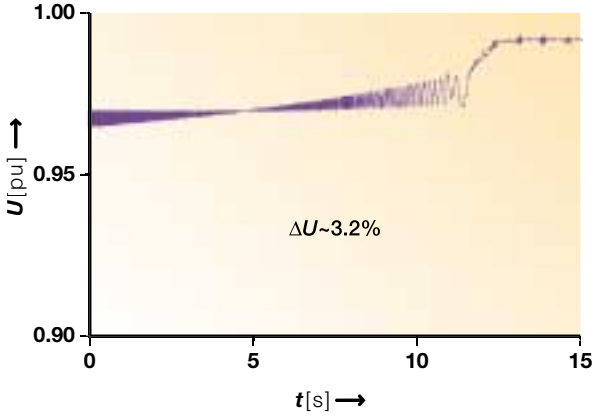
Starting an electric motor for a heavy-duty application is problematic and a critical issue in its design. DOL (Direct On Line) starting is the most cost-effective method, but causes extreme short-term loading of the grid. The inrush current is typically 2–5 times the nominal value.

This challenge is met by dimensioning the motor to suit the application. Designing Motorformer for starting begins with a simulation of the run-up from zero to full speed 3. The model used for the simulation takes into account the mechanical load, the motor's electrical parameters and the power supply grid. The right motor parameters are found by



5 Stator current (*I*) during start

t Time



6 Motor voltage (*U*) during start

t Time

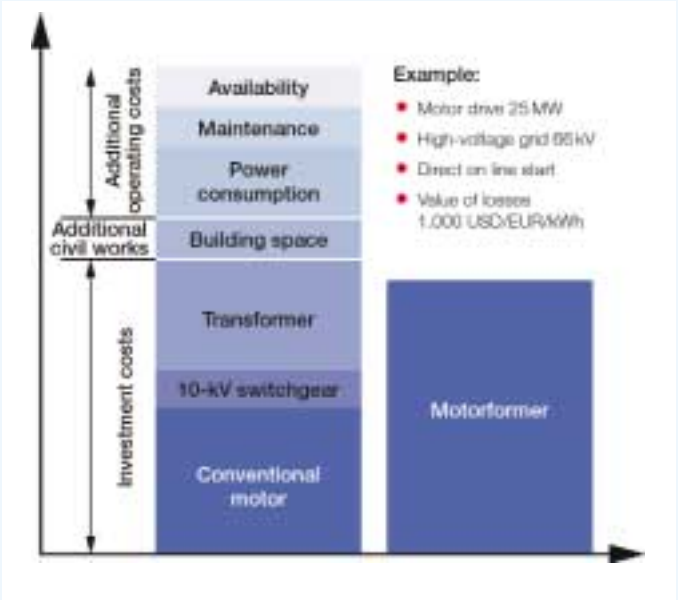
Motorformer™ – Savings through simplicity

Lower investment costs: Motorformer requires no transformer since it takes its power straight from the high-voltage supply. This means fewer system components, generally allowing a saving in total investment.

Space-saving: Another important advantage is that Motorformer takes up less space than a conventional installation. The building can therefore be kept smaller or space is made available for other purposes.

Higher efficiency for lower operating costs: With Motorformer total energy losses are reduced, typically by as much as 30%. Since electrical energy is the major operating cost, this results in a substantial saving.

Less maintenance, better availability: The simplicity of the Motorformer concept, with its fewer components, also reduces the cost of servicing and spare parts. There is less risk of failure and production downtime.



Cost breakdown with Motorformer, compared with a conventional installation

optimizing the mechanical torque and the voltage drop on the grid without causing any overheating of the motor [4].

A result of the direct connection to the HV grid is that a higher short-circuit capacity is usually available. The starting torque is therefore higher, and this has to be taken into consideration to prevent mechanical failure. During the short start sequence Motorformer consumes reactive power from the grid, which leads to a temporary drop in voltage. Using an optimization procedure similar to that used for conventional motors, Motorformer is dimensioned to overcome the problem [5], [6].

ABB recommends the use of capacitor banks or reactors if the requirements cannot be satisfied by DOL starting. ABB can supply these components from its standard range of equipment.

Rotor cooling

Large amounts of energy are dissipated into the rotor during starting, resulting in local heating of its steel surface. This heat energy is transferred by means of a steady airflow to the heat-exchanger at the top of the unit, so there is no risk of the rotor or the cable overhangs overheating.

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References

[1] **M. Leijon:** Powerformer™ – a radically new rotating machine. ABB Review 2/98, 21–26.

[2] **M. Leijon, et al:** CIGRE 1998, paper 11/37.

[3] AMS Synchronous Motors brochure, 3BSM006539, 2001.