Standardizing the traction motor

ABB's innovative modular induction traction motor sets new heights in adaptability

PETER J ISBERG, MARK CURTIS – Trains are frequently custom made to accommodate the individual technical specifications of different rail service providers. Each new design requires a variety of unique, train-specific components that are supplied by additional independent original equipment manufacturers (OEMs). Traditionally the traction motor is among the many custom made components required by train manufacturers. These motors are intensively engineered to ensure function and quality, which results in increased complexity throughout the value chain and adversely affects their manufacturing lead time. To overcome these problems, ABB has developed a new range of induction traction motors with built-in flexibility so that customer-specific requirements can be met using a single modular design.

The traction motor is an electric motor used to power the driving wheels of a railway vehicle. Traditionally each traction motor was custom made to fit a specific vehicle. This inevitably resulted in long lead times to accommodate the design, engineering, product-specific supply chain logistics, quality assurance and the creation of new production line facilities.

ABB's new series of modular induction traction motors is the result of several years of product design and development. The project was initiated in 2007, not only to create a traction motor with universal appeal to train builders, but also to enable effective engineering, supply and production processes, and to maintain ABB's lead as an independent supplier of traction motors. An interdisciplinary team of engineers, suppliers, production specialists and researchers were brought together to create a new traction motor that would not only satisfy a wide variety of customers, but would also streamline production and the sourcing of supplies, reduce the cost of poor quality (COPQ) and ultimately lower the total costs throughout the product's life cycle, where energy consumption is a dominant factor. During this design phase, special attention was given to energy efficiency, reliability, and fast and easy maintenance to help lower operating costs for customers. During the design process all aspects of the traction motor could be freely manipulated with one exception. To maximize scalability, the new range of traction motors had to comply with the standard IEC (International Electrotechnical Commission) frame sizes specified for ABB's low-voltage (LV) motors. The frame sizes in the new series were designed to provide partial overlap in performance (power and torque) so that customers could be provided with the optimal traction motor to fulfill their needs concerning space and performance ➔ 1.

Highly adaptable

To accommodate a variety of performance demands, ABB's new series of traction motors has an innovative modular design that provides flexible customized construction. A major feature of its adaptability is that drive and non-drive ends of the motor are not predefined. In addition the length of the motor can be adjusted to meet specific space and operation demands and the position of the terminal box and air in-take and outlet ducts can be adjusted to optimize performance and space constraints. Furthermore, the unit can be cooled either by open self ventilation (OSV) or by open forced ventilation (OFV) according to the customer's wishes. The flexible design means that an OFV can be converted to an OSV simply by adding an elongation ring and a fan and extending the shaft, providing customized traction motors from standardized modular components. This provides a standard structure for traction motors with different cooling methods so that the service and access to spare parts is simplified.

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1 ABB's new modular traction motor

Cooling setup and mechanical interfaces are defined building blocks that ensure the major structure of the motor is standardized. Several positions are available for air intake or power cable connections on the housing providing great flexibility.

Flexible mounting

The modular induction traction motor range has mounting brackets that can be fitted in a variety of positions so that vehicle builders are free to fit motors by any method (suspended or non-suspended) to any bogie [1]. This means the optimal position of the motor can be found to integrate the motor within the least amount of space giving train manufacturers and OEMs the freedom to fit or retrofit ABB traction motors to both new and existing designs. The whole structure including the brackets and their associated attachment is designed to fulfill IEC 61373 (shock and vibration) standards without having to reduce the motor's mechanical performance.

Durable and versatile

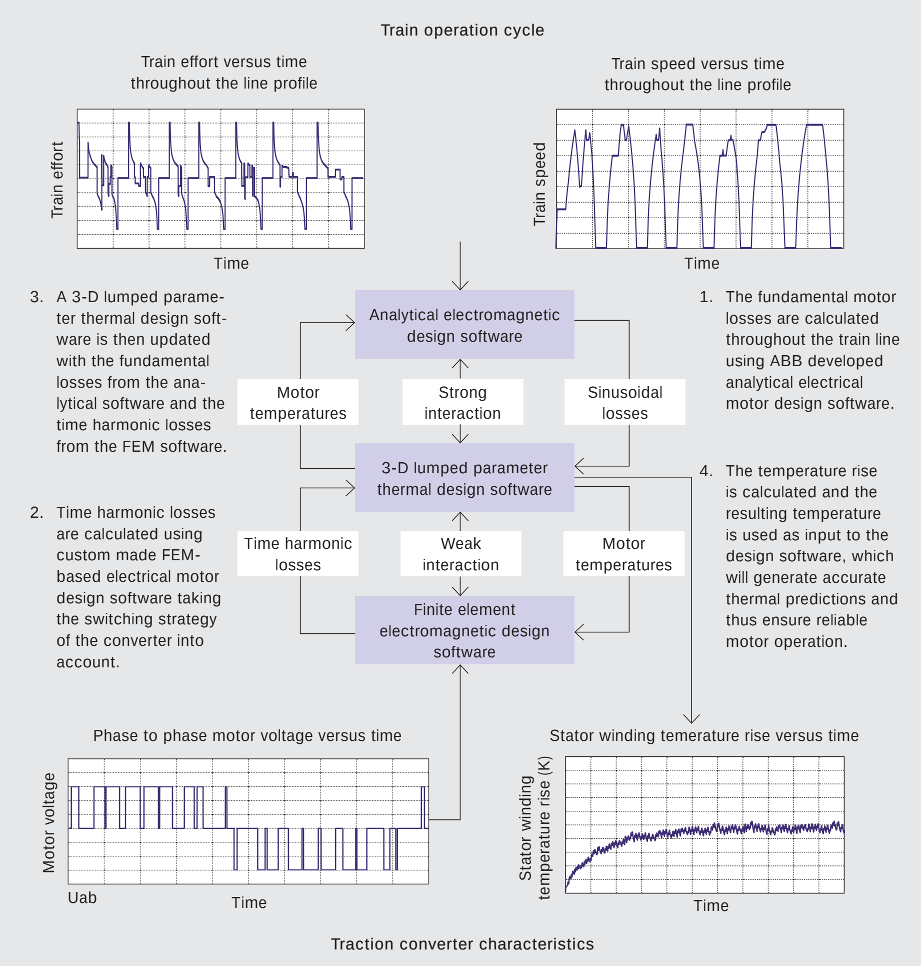
The modular induction traction motor series is designed to be durable and versatile. Many parts have integrated functions to help reduce the number of components and ensure the product is compact and robust. They are designed to endure extreme temperatures and polluted environments.

Customers want traction motors with the lowest possible weight and compact design, while at the same time providing a

Footnote

1 A bogie is a wheeled wagon or trolley. In mechanics terms, a bogie is a chassis or framework carrying wheels, attached to a vehicle. It can be fixed in place, as on a cargo truck, mounted on a swivel, as on a railway carriage or locomotive, or sprung as in the suspension of a caterpillar tracked vehicle.

2 Schematic picture representing tools and processes for the optimization of traction motors



high power and torque output over a lifetime of up to 20 to 30 years. In order to achieve high power density and reliability, it is not enough to only optimize the cooling capability and the electrical design. All aspects of the motor's design must be optimized.

Energy efficiency and reliability

The traction motor features a new electrical design, optimized for high energy efficiency and a competitive performance/weight ratio. A key design feature is that the rotor cage is made of aluminum, die-cast directly into the rotor laminations without the presence of any soldered interfaces. This is a robust and proven design that enhances the reliability of the product. Alternatively, the motor can be equipped with a copper rotor cage if slightly higher energy efficiency is desired. The traction motor is powered by a converter feeding the motor with voltage and frequency.

During the electrical design of traction motors it is essential to optimally match the motor and converter. The traction motors and traction converters fulfill very high specifications designed to meet precise requirements. In traction applications the switching frequency of the converter is usually low, which makes the harmonic effects in the motor more pronounced. With the help of state-of-the-art FEM (finite element method) software (developed by the Helsinki University of Technology and optimized solely for electrical machines), it was possible to get the best electrical design for the converter by taking into account its characteristics and certain optimization criteria:

- Torque ripple minimization [2]
- Low noise and vibrations
- High efficiency
- Low current
- Efficient cooling capability

Thermodynamic design

The temperature rise and thermal design is critical in traction motor applications. Very accurate estimations of the temperature rise of critical parts of the motor are crucial to its reliability. By coupling analytical electrical design software, FEM-electrical design software and 3-D thermal network software it is possible to simulate the expected motor temperature during its service with great accuracy. The structure of the software can be seen in ➔ 2. Inputs are the line simulation of the train and the switching characteristics of the converter and outputs are the temperature rise of critical motor parts, such as stator winding and bearing temperature.

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Special effort has been made to decrease harmonic losses, noise and torque pulsations, in a robust design and with production methods that ensure high quality standards. The insulation system contains corona resistant materials [3], has low water absorption properties, complies with temperature class 200 [4], and takes advantage of ABB's knowledge and experience having delivered traction motors since 1909.

Computational fluid dynamics (CFD)

Special care was taken to optimize thermal design. The output of the motor is thermally limited and the motor needs to be cooled efficiently. Cooling ducts (stator and rotor) and the fan have been optimized with respect to cooling efficiency as well as noise. Using CFD modeling, along with the electromagnetic computations, it was possible to predict the likely

Footnotes

2 The amount of torque measured by subtracting the minimum torque during one revolution from the maximum torque from the same motor revolution.

3 A corona resistant insulation material has higher resistance against deterioration when a high-voltage electrostatic field ionizes.

4 Temperature classification (also known as temperature class) defines the maximum continuous temperature that an insulation system can sustain in degrees Celsius.

3 Sectional CFD analysis of a fan

Contours of velocity magnitude (m/s)

location of hot spots in the event of motor overload, which helped identify areas in which modifications were made to improve cooling and reduce losses.

Furthermore CFD simulation of a fan provides a complete picture of its operation. It can identify areas where there are recirculation problems and determine the flow rate, but more importantly, it can help establish the cause of problems and reliably direct design improvements. The fan design can then be optimized to minimize energy consumption, lower losses, reduce noise levels, optimize blade number, prolong component life and provide greater flexibility in the traction motor system.

Optimized design

The structural design of the product provides a variety of options to further enhance or monitor the performance of the motor. ABB provides all types of bearing solutions from the traditional c4 steel bearings to more advanced hybrid bearings with ceramic ball and roller elements, including HUB solutions (hybrid bearings greased for life). New air filtering techniques are under development and thermal sensors can be placed in a variety of positions, eg, in the windings, stator core or bearings, the latter providing early indications of bearing failure. Integrated speed sensors help keep the motor compact, while allowing the sensors to be replaced without detaching the motor from the bogie. The modular design simplifies maintenance procedures for all parts. By taking into account the service needs of a bogie-mounted motor at the design stage and standardizing spare parts, the new traction motor can be partly serviced in the bogie helping to reduce operational downtime and costs over the product's life cycle.

Currently ABB is working to extend traction motor products to serve a range of transport needs from LRV (light rail vehicles) to locomotives. The focus is to further standardize the structure, increase the energy efficiency and reduce maintenance. Synchronous motor topologies are also under development, eg, permanent magnet motors, but despite the obvious advantages of such topology (ie, energy efficiency and torque density) there are also several disadvantages. These include greater sensitivity to shock, overheating, and complex production and maintenance procedures. ABB aims to strengthen the advantages and minimize the disadvantages with its future synchronous products.

ABB has been manufacturing industrial motors for more than 130 years; traction motors for 100 years and has supplied more than 30,000 traction installations during the last few decades. These installations range from heavy locomotives for intercity expresses through to light metropolitan tramways. The new series of modular induction traction motors will add to ABB's reputation as a global leader in power and automation technologies, providing a truly versatile traction motor designed to fit a wide variety of locomotives, enabling rail operators to improve performance while lowering their environmental impact.

The ABB series of traction motors with their wide range of specifications and modular design are poised to meet increasing demand for energy efficient electric traction motors in the rail industry.

ABB is ready to meet increasing demands for energy efficient electric traction motors in the rail industry.

Peter J Isberg
ABB Machines, Discrete Automation and Motion, ABB AB
Västerås, Sweden
peter.j.isberg@se.abb.com

Mark Curtis
ABB Review
Zurich, Switzerland
mark.curtis@ch.abb.com

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