Continuous innovation in large drives for rolling mills

The Simovert ML2 converter is the latest in a long line of innovations in rolling mill drives and is particularly suited to highly dynamic applications, especially at high speeds. It provides high torque accuracy and dynamic control response, coupled with very low supply system perturbations.

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As one of the most successful companies in the electrical engineering sector, Siemens has a long tradition of continuous research and development and high standards of product quality and reliability which characterise drive systems for rolling-mill applications. Siemens is well aware of client requirements with regard to availability and reliability of rolling mill installations, and to ensure that these demands are satisfied our innovative technology and new products are subject to tough inspections and comprehensive test routines before releasing them in the market place.

The most recent innovation is the development of the Simovert ML2, an Integrated Gate Commutated Thyristor (IGCT) converter which expands our drive portfolio for rolling mill applications. The development phase was completed by a back-to-back test involving connecting two drive systems in a motor/generator configuration and subjecting them to a rigorous programme of continuous output and dynamic load response tests.

THE HISTORY OF CONVERTER DEVELOPMENT

Silicon semiconductor technology expanded the potential range of applications for variable-speed drives. Using line-commutated thyristor converters and analog closed-loop controls, it was possible to build highly dynamic, variable-speed DC drives. To overcome the problem of the high maintenance required by DC motors, converters and control systems for three-phase AC motors were developed (see Figures 1 and 2). As early as 1969, Siemens had developed the first voltage-source DC-link converter for a variable-speed AC motor with a specially designed and patented transvector control.

In 1975, six years after its initial launch, a transvector control for cycloconverter-fed three-phase AC motors became available. Five years later the first rolling-mill main drive equipped with analog transvector control was built. This three-phase AC solution offers important advantages in terms of reduced maintenance, improved dynamic response due to low moment of inertia and a virtually unlimited power output. In the years that followed, it almost completely replaced the DC drive.

As thyristor technology advanced, the cycloconverter became the standard converter for low-speed motors. Key characteristics of these converters are their high power density, relatively small number of components and high availability. They are still a tried and tested alternative to more recently developed and considerably more complex drive technologies (see Figure 3).

NEW DRIVE CONCEPTS

Further advances in semiconductors led from the line-commutated thyristor to the Gate Turn-Off Thyristor...
Consequently, 2-level inverters with high switching frequency have become the accepted solution for low-output voltage-source DC-link converters. Almost all of these are provided with IGBT modules which have been available since 1987. 3-level inverters, which can achieve a significantly higher output voltage by virtue of a ‘quasi’ series connection of two 2-level inverters, are finding application in medium-voltage converters in the higher power range. This higher voltage level at the converter output makes it possible to obtain an excellent sinusoidal output current with a semiconductor device operating at low semiconductor switching frequency.

As early as 1987, Siemens was operating a GTO 3-level inverter with a 1MW motor in its development department. The knowledge gained from these trials was applied to developing the air-cooled Simovert ML of identical design which was installed in 1996 as the first GTO 3-level inverter in a cold rolling mill.

As innovation cycles on the semiconductor market speed up, the care and foresight with which semiconductors for industrial applications are selected is becoming increasingly important. Apart from good reliability, further important factors to consider include availability, future outlook as regards spare part stocking, replacement type and second source supplier. Availability of the drives in our customers’ plants is wholly dependent on our commitment to researching every angle.

Today, IGBTs are the semiconductor most favoured for low-voltage converter applications. Their chief characteristic is their excellent reliability and they are readily available on the market. There are several suppliers who make standardised, and consequently to some extent replaceable, semiconductor elements.

For high output applications, there are basically two semiconductor valves which are replacing the classic GTO:

1. The Press Pack IGBT (IGBT in ceramic housing) is marketed by Toshiba as the IEGT (Injection Enhanced Gate Transistor). This switch has similar performance characteristics to the GCT.

2. The Hard Driven GTO, also referred to as the Gate Commutated Thyristor (GCT), is the next stage of the GTO. Like the GTO, the GCT is made of a single silicon wafer and in order to apply the high switching currents instantaneously to the gate, the gate driver module is constructed in a low-inductance connection around the ceramic housing.

Voltage-source DC-link converters for high speeds, and cycloconverters for low speeds, are the preferred solutions for modern rolling-mill main drives. Current-source DC-link converters cannot fulfill the requirements for torque accuracy and dynamic control response in rolling mill applications. With their limited dynamic behaviour and high torque ripple, they are particularly unsuitable for operation at low frequencies.

SYNCHRONOUS MOTORS

With the development of three-phase AC converters, most DC motors have been replaced by low-maintenance AC motors. In addition to asynchronous motors for low outputs, the main drives in rolling mills are normally
synchronous machines. They are ideal for such applications by virtue of their high efficiency, wide field-weakening range and high torque accuracy. Siemens added the robustly compact cylindrical rotor to its classic range of salient-pole synchronous motors, and since 1985 all Siemens motors for rolling-mill applications have been designed as salient-pole machines. Permanent-field synchronous motors are increasingly the preferred drive for low-output as well as high-output applications such as marine propulsion systems.

SIMOVERT CONVERTERS
Simovert D cycloconverters and Simovert ML2 voltage-source DC-link converters are the first choice for high-output rolling mill main drives. The Simovert D is a cycloconverter for low-speed, highly dynamic drives of about 5MW and higher. Its output frequency ranges to about 25Hz, hence this design is highly suited to special applications such as roughing stand drives.

Simovert ML2 voltage-source DC-link converters are suited to highly dynamic applications, especially at high speeds. The water-cooled Simovert ML2 (see Figure 4) is an enhancement of the air-cooled Simovert ML GTO converter which has been in operation since 1996. With its robust IGCT technology and integrated AFE (Active Front End), it is ideally suited to rolling mill applications. The power section is water cooled so as to render this medium-voltage converter resistant to detrimental environmental conditions.

Simovert ML2 converters are designed for use in both single and sectional drives. In sectional drives, a number of inverters are supplied by a common DC link bus bar which has a positive influence in terms of both overall system efficiency and investment costs. The output of a basic converter unit is 10MVA at an output current of 1,750A. This applies to both the Active Front End (AFE) and Diode Front End (DFE) variants. Thanks to optimum cooling of the semiconductors, continuous output virtually corresponds to maximum permissible output. 10MVA basic units can be connected in parallel to obtain an output of 27MVA. The main technical data are given in Table 1.

REDUCED AND OPTIMISED TASK ORIENTATED SWITCHING (ROTOS)
To ensure optimum utilisation of the power semiconductors, the ROTOS valve control method was developed and implemented in the control system. ROTOS can deliver the ideal combination of low switching frequency and minimum current ripple (see Figure 5). The pulse patterns required to control the IGCTs are generated in a sophisticated off-line process. Combined with further optimisation of pulse pattern transitions designed to avoid...

<table>
<thead>
<tr>
<th>Description</th>
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<tbody>
<tr>
<td>Voltage</td>
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<tr>
<td>Current</td>
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<tr>
<td>Output</td>
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<tr>
<td>Topology</td>
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<td>Technology</td>
<td>IGCT (Integrated Gate Commutated Thyristor)</td>
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<td>Water</td>
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<td>Control</td>
<td>Closed-loop TRANSVECTOR® control with ROTOS</td>
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<td>Options</td>
<td>Common DC bus for energy exchange with up to 3 motors, reactive power compensation with AFE</td>
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<td>Efficiency</td>
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<tr>
<td>Typical features</td>
<td>High-end performance, high dynamic response and energy recovery, low and high speeds, low harmonics into line supply</td>
</tr>
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Table 1: Technical data of Simovert ML2 converters
FORMING PROCESSES

Fig. 6 Schematic of back-to-back test

Transient phenomena, the merits of this process have already been substantiated in Simovert ML applications in which it has demonstrated its advantages, namely:

- Low current and torque ripple
- Low semiconductor switching losses
- High output voltage (3.3kV)
- Optimum motor and converter utilisation

EQUIPMENT RELIABILITY

Siemens' priority is to supply customers with systems which are always safe and reliable in service, thus the highest standards are set for the quality of products and solutions. Innovations are subjected to numerous inspection and test routines before they are approved for installation in customers' plant. In keeping with this policy, a complex, three-month test was performed for the Simovert ML 2 using two original converters from the Handan project, a new large continuous tandem cold mill, coupled to a pickling line.

Figures 6 and 7 show the arrangement of the test set-up in which the motors were coupled and operated back to back in motor/generator mode. This layout simulated the most extreme loads in continuous operation and included duty cycles in a hot-rolling mill, such as initial pass and unloading, and extreme loading associated with roughing and finishing stands, such as rolling with roll gap blockage. The cold rolling simulation tested responses to set point changes on starting, additional thickness control set points and additional torques of a coiler eccentricity compensation.

In addition to the operating characteristics, the performance data, efficiency and protection concept of the converter were also verified. During the three month test period, not a single semiconductor defect occurred, even though the converter was operated beyond its specified rating as part of the test.

With the conclusion of the back-to-back test, the development of the power section was complete. The next step in the continuous development process is the control system upgrade and, in order to incorporate all Siemens drive know-how into the control as well as the converter, the large drives are now being upgraded with the Sinamics closed-loop control developed for use in low-voltage equipment. This compact closed-loop control will be used across the full range of Siemens drives.

SUMMARY

With the Simovert ML2 converter, Siemens has taken a further step in the continuous development of its drive technology and is taking its place in a long list of innovative drive system products and solutions brought to the market. A comprehensive test routine helped to verify the reliability of the power section.

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