Converter transformers and reactors

Transformers for variable speed drive applications
Transforming electricity into value
Variable speed drive systems
Reliability and quality

Variable speed drives
Converters are used to control the speed of rotation and the torque of electric motors in many industrial applications. Typically these are pumps, ventilators, compressors, belt conveyors, rolling mills, paper machines and an innumerable amount of different machines employed in manufacturing and other industries. Converters are also operating in power generation and in transportation systems, like ships or railway.

Electric motors consume about 65 % of all electricity used throughout industry. Less than 10 % of those motors are presently fitted with variable speed drives, which allow for significant energy savings. In many cases savings of 50 % or more have been demonstrated. Imagine the energy savings if more motors were controlled by a variable speed drive.

The use of variable speed drives employs more sophisticated methods to allow better control of industrial processes and ensures higher quality and reliability.

Transformers for drive systems
The transformer is the link between the supplying electrical grid and the converter. It is a major component in the transformer-converter-motor chain.

Different converters require different transformer configurations. In many cases a multitude of secondary windings, connected with different phase angles is required and special technical solutions are needed due to the presence of harmonics and voltage transients generated by the converter.

Thinking as a system, not as single components
Drive applications are subject to high technical demand. All components in the chain have to be harmonized. It is therefore essential to handle the application as a combined system and not as a set of single components.

Additionally, environmental and efficiency aspects are getting more and more important and need to be considered and integrated.

ABB recognizes these specific requirements and, thanks to its highest technical and personnel competence, is able to offer optimized solutions, tailored for different application segments. Continuous high investments in R&D enable ABB to use the full scope of technologies and ensure high reliability for products and systems.

Variable speed drives are everywhere: you can find them on board of a dredger, controlling the motors of a dam, in power plants or in mines.
Transformer portfolio for variable speed drive applications

ABB’s comprehensive experience

A pioneer in converter transformers

ABB is a pioneer in designing converter transformers and has a long and proven track record in a broad range of state-of-the-art technologies to ensure a constant stream of benefits for customers. ABB converter transformers have accumulated millions of operating hours worldwide.

Standardized and tailor-made solutions

Characterized by their modular design, ABB converter transformers and reactors provide a competitive edge in the key operating areas of size, weight and reliability for almost any requirement. Support is given by our best experts from our Centers of Excellence for converter transformers. Transformers are built to match the requirements of any drive, from any manufacturer.

Converter transformer portfolio

We offer liquid-immersed and dry-type transformers for low voltage (LV, up to 1.1 kV), medium voltage (MV, up to 36 kV) and high voltage (HV, >36 kV) applications.

<table>
<thead>
<tr>
<th>Primary voltage</th>
<th>Secondary voltage</th>
<th>Liquid-immersed</th>
<th>Dry-type</th>
</tr>
</thead>
<tbody>
<tr>
<td>LV</td>
<td>LV</td>
<td>200 - 10'000</td>
<td>20 - 10'000</td>
</tr>
<tr>
<td>MV</td>
<td>LV</td>
<td>200 - 10'000</td>
<td>100 - 10'000</td>
</tr>
<tr>
<td>MV</td>
<td>MV</td>
<td>500 - 100'000</td>
<td>100 - 40'000</td>
</tr>
<tr>
<td>HV</td>
<td>MV</td>
<td>1'000 - 100'000</td>
<td>on request</td>
</tr>
</tbody>
</table>

The transformers can have natural cooling, forced air cooling or forced water cooling.

Reactors for drive applications

A broad range of dry-type and liquid-immersed, iron-core or air-core reactors for use in power converters or in drive systems are available. Such components are used, for example, in filters or as DC-link chokes.

Global experience - local solutions

ABB is the world’s leading supplier of converter transformers. Building on a worldwide presence with a dozen plants and 30 transformer service centers, we are close to you and able to supply in different regions from local factories and to comply more easily with local requirements, while still using a common global design. With its global network of strong local resources, ABB supports all players in the market with the expertise they need for their projects.

Reliability

ABB converter transformers provide highest reliability, for a safe and undisturbed operation of your drive installation. Transformers are utilized in some of the harshest indoor and outdoor environments imaginable. All transformers are manufactured to the most stringent quality control standards in order to guarantee the full reliability of the product.

Ecology and economy

It is ABB’s policy to provide customers with sustainable solutions, optimized for both, the economical and the ecological aspects. Solutions with low transformer losses and minimum life cycle costs can be provided.
The art of converter transformers
Individual solutions for demanding customers

Requirements for converter transformers
Transformers supplying converter applications are connected on their secondary side to a converter. The converter input can be a passive rectifier or have an active front end using controllable semiconductor switches. These elements create a lot of harmonic frequencies. Different drive types are quite diverse in the amount of harmonics produced.

Therefore, normal transformers, designed and dimensioned for electricity distribution duty do not work satisfactorily in a converter system. Harmonic frequencies increase the thermal, mechanic and dielectric stresses and therefore the transformers must be specially designed for this duty. Over-dimensioning of a normal distribution transformer is not an adequate measure.

Transformer primary voltage
The converter transformer is usually powered by a medium or low voltage network. Powering from a high voltage network is also possible but not common. Only small converters can be directly connected to a LV network without a transformer due to harmonics and EMC requirements. Networks show different sensitivity to harmonics and the decision whether to use an individual supply transformer or not must be made on a case by case basis.

Transformer secondary voltage
The input voltages for LV converters are typically between 190 V and 900 V, and for MV drives are between 1 kV and 7 kV.

Multi-winding transformers
The rectifiers used in LV converters are usually 6- or 12-pulse rectifiers, made of diode bridges, thyristor bridges or power transistor solutions. The 6-pulse rectifier is supplied by a two-winding transformer, whereas the 12-pulse rectifier needs a three-winding transformer, having two separate secondary windings with 30° phase shift.

MV converters and converters with higher ratings specifically require a higher converter pulse number which is used to limit the network harmonic distortion to an acceptable level. Pulse numbers higher than 12 require special phase shifting, multi-winding transformers or several transformers with phase shifts running in parallel. Nowadays the pulse number of a converter system can be up to 48. This requires in total eight phase-shifted transformer windings supplying the converter system.

Harmonics
Transformers supplying converters suffer from the presence of harmonics, whose effects differ, depending on the type of converter. By knowing the harmonic spectrum it is possible to carry out a complete study which will identify hot spots that require special attention during the design of the transformer. The image on the next page highlights the presence of a dispersed flux which can create hot spots at the end of the windings and requires special attention during design.

Transformer ratings
According to IEC 61378-1 rating of a converter transformer is the same as the fundamental rating:
- Fundamental frequency rating: calculated with rated voltage and the fundamental sinusoidal component of the load current, 50/60 Hz – this is used for the indication of the guaranteed loss values and short-circuit impedance
- RMS (Root Mean Square) rating: calculated with rated voltage and total RMS load current
- Equivalent rating: calculated with rated voltage and an equivalent sinusoidal current which gives the same losses in the transformer as the actual load current, including harmonics. The equivalent current is used for temperature rise tests.

According to IEEE C57.18.10 the rating of a rectifier transformer is the kVA drawn from the line. Alternative equivalent rating parameters such as K factor can also be considered.

Electrostatic screen
An earthed screen can be installed between the primary and secondary windings. It is used to capacitively decouple primary and secondary winding and eliminate the effects of high frequency transients on the other winding.

Core
The magnetic circuit is core-type with mitered joints. High-quality grain oriented, magnetic steel is most commonly used. Special core joints, distributed gaps and air gaps may be used in the core construction to avoid direct current (DC) saturation when needed.

Output transformers
For cases where converter output voltage and motor voltage are different an output transformer is needed. These transformers are two winding transformers, but are also exposed to some increased amount of harmonics and transients from converter switching.

Standards
The following main standards govern converter transformers and provide rules for correct definition of rating and specification and for the testing of the transformers:
- IEC 61378-1 (ed. 2.0): 2011, converter transformers, Part 1, Transformers for industrial applications
- IEC 60076 series for power transformers and IEC 60076-11 for dry-type transformers
- Products complying with almost any national standard (GB, GOST, CSA, etc.) or requiring specific certification (e.g. UL, FM or DNV, ABS for marine applications, etc.) can be provided

Testing
Routine tests as per standards are conducted for each transformer unit produced. In addition, extensive type testing programs, e.g. short circuit tests as well as temperature rise test at equivalent rating and impulse testing among others, can be performed for each design of the transformers.

ABB has a long experience and lots of references from different drive applications. The high quality of our reliable products provides an outstanding capability to withstand short circuits. Extensive type and special testing, including aging tests, together with our quality control, guarantee the performance of our products.

Our compact and low-weight transformers fully comply with the customers’ specifications. The products are developed together with the converter manufacturers, ensuring that their special requirements are always met.

1 Diagram of variable speed drives | 2 Converter transformers feeding 12-pulse converter
Outstanding technical features
High compatibility with different systems

ABB’s liquid-immersed transformers

- Mechanical construction
  Transformers for lower power range have mostly corrugated tanks either hermetically sealed or conservator type with flexible cooling fins. However, transformers with ratings of approximately 7,000 kVA and above, have tanks with detachable radiators providing adequate cooling. In order to save space, or for some other special reason, fans can be added to ensure more efficient cooling. Also water-cooled heat exchangers can be used instead of radiators.

- Insulating liquids
  Different insulating liquids can be chosen for VSD supply transformers.
  - Mineral oil-based inhibitor transformer oil for industrial installations
  - Silicone oils (non-toxic and stable, for reduced fire risk)
  - Midel®, a synthetic ester-based insulating liquid (biodegradable and non-toxic, for reduced fire risk)
  - BIOTEMP®, a renewable and biodegradable vegetable oil, for reduced fire risk

- Bushings and enclosures
  The normal bushings used are solid porcelain bushings. Outer core bushings for plug-in type cable terminals are optional.
  Most of the VSD duty transformers are installed in an industrial environment and equipped with air insulated cable termination boxes. These can be used for either HV or LV side, or for both. A variety of standardized cable box constructions are available permitting the cable entrance from below, from above, or from the side. The normal protection degree of a cable box is IP44. It may be higher as an option.

- Protection and monitoring of transformers
  For hermetically sealed transformers used in VSD duty, the recommended protection and monitoring devices are only two:
  - DGPT2, integrated protection device, which combines the gas relay, over-temperature alarm, trip-device and sudden pressure relay functions.
  - Pressure relief device
  For the conservator transformers, the recommended protection and monitoring devices are:
  - Thermometer with alarm and trip contacts
  - Oil level indicator
  - Pressure relief device
  - Buchholz relay
  - Silicagel breather
  Additionally you may select winding temperature indicators, current transformers, surge arresters and different on-line monitoring devices.

- Environmental classifications and surface treatment
  ABB oil-filled transformers can be installed in the toughest environmental conditions ranging from high altitudes with cold temperatures to hot and humid conditions with high corrosivity. Ex-proof designs for hazardous areas are also available.
  Transformers can either be painted or hot-dip galvanized and painted. Environmental classes are available up to C5-M1 ISO classes. The standard color is RAL 7035, light grey. Other shades are optional.

ABB’s dry-type transformers

- Coil technologies: in order to best fit your specific requirements we provide converter transformers with different coil technologies:
  - Vacuum cast coil (VCC): high quality, well-protected windings
  - Vacuum pressure impregnation (VPI): allowing efficient cooling
  - RESIBLOC®: ultimate mechanical strength, qualified for extreme climatic conditions (-60 °C)

- Simple installation: ABB dry-type transformers allow simple installations, can be placed close to the load, are self-extinguishing and contain a minimum of combustible mass.

- Enclosures and cooling: all our transformers can be provided without or with enclosures of any protection degree (IP) or of any NEMA type.
  The enclosures can be ventilated or be equipped with an air-to-air or an air-to-water heat exchanger for cooling purpose. Depending on enclosures and customer requirements natural or forced convection is possible.

- Direct and indirect water cooling: these are transformers and reactors where the windings are directly cooled with water. It allows very efficient removal of the loss heat. If the converter uses deionized water for cooling purpose, the same water circuit can be used for the transformer where the windings are made with hollow conductor. If only normal tap water is available a water-cooled heat sink is installed into the winding.

- Winding temperature monitoring is achieved by Pt100 probes placed in the windings and connected to digital relays. The relays can be equipped with remote reading facilities.

- A large variety of accessories is available to optimize the functionality of the transformers: cable boxes, measurement or protection current transformers, on-board earthing switch, anti-vibrators, etc.

Transformers are built to match the requirements of any drive, from any manufacturer.

Transformers and reactors are also provided for ABB's large family of air-cooled and water-cooled drives

<table>
<thead>
<tr>
<th>LV-drives Series</th>
<th>Drive</th>
<th>Power</th>
<th>Output voltage</th>
<th>Pulse number</th>
<th>Input transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS 550</td>
<td>General purpose</td>
<td>up to 350 kW</td>
<td>up to 480 V</td>
<td>separate</td>
<td></td>
</tr>
<tr>
<td>ACS 800, ACS 880</td>
<td>Industrial</td>
<td>up to 5,600 kW</td>
<td>up to 690 V</td>
<td>6, 12, AFE</td>
<td>separate</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>MV-drives Series</th>
<th>Drive</th>
<th>Power</th>
<th>Output voltage</th>
<th>Pulse number</th>
<th>Input transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACS 1000</td>
<td>General purpose</td>
<td>315 - 5,000 kW</td>
<td>2.3 - 16 kW</td>
<td>12, 24</td>
<td>separate or integrated</td>
</tr>
<tr>
<td>ACS 2000</td>
<td>General purpose</td>
<td>250 - 1,600 kW</td>
<td>4.0 - 9 kW</td>
<td>AFE, 24</td>
<td>direct connection, separate or integrated</td>
</tr>
<tr>
<td>ACS 5000</td>
<td>General purpose</td>
<td>1.7 - 32 MW</td>
<td>6 - 6.9 kW</td>
<td>36</td>
<td>separate or integrated</td>
</tr>
<tr>
<td>ACS 8000</td>
<td>Special purpose</td>
<td>3 - 27 MW</td>
<td>3 - 3.3 kW</td>
<td>12, 24</td>
<td>separate</td>
</tr>
<tr>
<td>LCI</td>
<td>Load-commutated inverter</td>
<td>2 - 72 MW</td>
<td>2.1 -10 kW</td>
<td>6, 12, 24</td>
<td>separate</td>
</tr>
</tbody>
</table>
Our references
A broad variety of installations

Eskom, coal-fired power stations, South Africa
- Total quantity of units: 34 transformers
- Ratings: 5.8 MVA to 11.7 MVA
- RESIBLOC dry-type transformers
- Enclosure: IP54 with air-to-air heat exchanger system
- Pulse: 12-pulse
- Special customer requirements: refurbishment of existing equipment in coal-fired power stations

Esperanza gold and copper mine, Chile
- Total quantity of units: 12 transformers
- Ratings: 19 MVA liquid-immersed transformers for SAG and Ball mills
- Supply duty together with 630 kVA excitation transformers
- Enclosure: IP55, ONAN
- Pulse: 6- and 12-pulse
- Special customer requirements: high altitude 2300 m.a.s.l. with extreme environmental conditions. Special impedance design

Oasis of the Seas
World’s largest cruise ship for 4000 passengers.
- Total quantity of units: 8 transformers
- Ratings: 5.85 MVA to 11.7 MVA
- RESIBLOC dry-type transformers
- Enclosure: IP44, AFWF
- Pulse: 24-pulse
- Special customer requirements: transformer coils exchangeable on-board; limitations for dimensions and weight

ESPO, East Siberia Pacific Ocean pipeline, Russia
- Total quantity of units: 48 transformers
- Ratings: 9350 kVA and 4876 kVA liquid-immersed transformers
- Enclosure: IP66, ONAN
- Pulse: 12-pulse
- Special customer requirements: Full GOST-certification, seismic design, special tank design to withstand -60 °C transportation temperature, well-proven drive specific transformer technology based on long experience and knowledge from special projects failures

Pumping stations in various locations
- Total quantity of units: 24 reactors
- Ratings: 2 x 2 mH / 3600 A VCC dry-type DC-link smoothing reactors
- Enclosure: IP60, WF
- Operating voltage: 5.4 kV DC
- Special customer requirements: single phase, shell-core design. The use of forced water cooling has allowed to reduce considerably the dimensions of this component, which can be designed for voltages up to 15 kV DC and more than 6 kA

Usina de Pelotizaçao, Vitoria (ES), Brazil
- Total quantity of units: 7 transformers
- Ratings: from 2.5 MVA to 10.1 MVA, 13.8 / 6 x 1.92 kV VPI dry-type transformers
- Enclosure: IP54 with air-to-water heat exchangers
- Pulse: 36-pulse, single-core
- Special customer requirements: Primary windings use special conductors to cope with demanding electrical and mechanical parameters

Sammen nuclear power plant, China
- Total quantity of units: 2 transformers
- Ratings: 19.5 MVA, 13.8 / 1.32 kV VCC dry-type transformers (3 x 6.5 MVA single phase)
- Enclosure: IP21, AN
- Static Excitation System Transformer
- Special customer requirements: single phase transformers, assembled at site into three-phase configuration; with a total of 15 CTs on primary and secondary windings for protection and measuring; primary connection through isolated phase duct

Refinery, South America
- Total quantity of units: 1 transformer
- Ratings: 9040 kVA / 7030 kVA, 13.8 / 1.92 kV VCC dry-type transformers
- Enclosure: IP23, AF or AN
- Pulse: 36-pulse, single-core
- Special customer requirements: reduced footprint and low losses, hi-T Plus insulation system for longer lifetime and improved overload performance

Three-phase iron-cored filter inductors for ABB ACS1000 drive
- Total quantity of units: more than 300 inductors
- Ratings: 6.8 mH, 116 A VPI dry-type reactors
- Enclosure: IP00, installed within the drive panel
- Operating voltage: up to 4 kV
- Special customer requirements: horizontal installation, forced air cooling and compact overall dimensions
Note:
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