VSD transformers
Converter duty transformers
for variable speed drive application
ABB has years of experience, many references and a global footprint to manufacture special transformers

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

Input and output transformers are manufactured for all kinds of converters and applications such as mining and minerals, marine, metals and pulp and paper. Needs of each segment are respected and followed to ensure proper suitability for customer need. For example Ex-certified transformers are specially designed for oil and gas industry or for other applications where explosion-proof requirements exist.

The high quality of ABB’s reliable products provides an outstanding capacity to withstand short circuits. Special type tests and quality control ensure safe operation while ABB’s product support and service network guarantee free and easy use of the products.

Safety
Special attention is always paid to safety issues. Liquid transformers with gas relays and overpressure tripping ensure the safety of personnel. In addition, special insulating liquids eg, Midel can be used for improved environmental safety and reduced fire risk.

Terminology
In this brochure, the acronym VSD is used for Variable Speed Drive. Other acronyms commonly used are AFD and VFD standing for Adjustable Frequency Drive and Variable Frequency Drive.

The term converter is used because it is the term defined in the IEC standards for this purpose. The term converter is also commonly used in this brochure because it is more common in spoken English.

Standards
The following standards govern variable speed drive transformers giving the rules for correct rating, specifying and testing of transformers of that type.

- IEC 61378-1: 1997, Converter transformers, Part 1, Transformers for Industrial Applications, is the most recent.

Testing
Routine tests as per standards are conducted for each transformer unit produced. Extensive type testing programs can be performed for each design of the transformers to fulfill the requirements of the customers.

ABB has capabilities on various type and special tests such as temperature rise test, lightning impulse test and short circuit test.

References
ABB supplied VSD transformers for several countries in all market:
- Minerals and mining
- Chemical, oil and gas
- Water and waste
- Metals
- Power generation and transmission
- Pulp and paper
- Transportation
- Marine and offshore

More detailed reference lists are available on request.
Variable speed drives (VSD)
Variable speed drives are used to control the speed of rotation of electronic motors in many industrial applications. Typically these are pumps, ventilators, compressors, belt conveyors, rolling mills, paper machines and an innumerable amount of different machines used in manufacturing and other industries. VSDs are also used in power generation and gas expanders.

A variable speed drive takes the electric power from the feeding network at the standard network frequency. In the first stage the alternating current (AC) is rectified to direct current (DC) in a rectifier unit. This rectifier can be either a diode bridge or a thyristor bridge, depending on the drive system. Then the DC current is processed in a thyristor or a power transistor bridge type inverter back to an alternating current. This output alternating current has a frequency that can be adjusted and controlled with high precision and speed by means of control circuits and microprocessors in each drive.

When this adjustable frequency current is fed to a normal fixed speed electric motor, adjusting the frequency can control the motor velocity.

Supply transformer function in VSD
The VSD supply transformer covers several different tasks:
- Galvanic isolation between the frequency converter and the feeding network.
- Voltage reduction from the feeding MV or HV network to the rectifier input level.
- Suppression of harmonics generated by the frequency converter, thus protecting the feeding network from harmonic contamination.
- Protection of ambient and the feeding network against radio-frequency interference produced by the rapidly commutating semiconductors.
- Provision of suitable reactance to ensure the correct commutation of the semiconductors.
Requirements for transformers in VSD supply duty
Transformers supplying variable speed drives are connected on their secondary side to a VSD, which causes a lot of harmonic frequencies. Therefore, the normal transformers, designed and dimensioned for electricity distribution duty in a utility or industrial distribution network, do not generally work satisfactorily in a VSD supply duty.

Harmonic frequencies increase the mechanical and dielectrical 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 ratings in IEC 61378-1 contain:
- Fundamental kVA (kVA is calculated with rated voltage and the fundamental component of the load current, 50/60 Hz).
- RMS kVA (kVA is calculated with rated voltage and total RMS load current).
- Equivalent kVA (kVA is calculated with rated voltage and defined equivalent sinusoidal current which will give the same losses in the transformer than the actual load current, when all its harmonic components are considered in relation they cause losses in the transformer).

Scope of manufacture for ABB drives:
LV-drives: MV-drives:
- ACS 600
- ACS 800
MV-drives:
- ACS 1000
- ACS 2000
- ACS 5000
- ACS 6000
- Cyclo-converters
- LCI (load-commutated inverter)

Transformers are built to match the requirements of the drives of different types. They are specially designed and developed together with the converter manufacturers within ABB.

Transformers are also manufactured for various non-ABB drives up to 170 kV and 100 MVA. Pulse numbers are covered from 6 to 72 pulse.
Supply transformers for variable speed drives

Primary voltage
The VSD supply transformer is usually fed by a medium voltage network, but sometimes the transformer primary voltage may be at the LV voltage level. Feeding from an HV network is also possible but rare.

Only small VSDs can be connected to an LV network without a transformer due to harmonics and EMC requirements. The different drive types are quite diverse in the amount of produced harmonics and so are the networks in their sensitivity. The decision whether to use an individual supply transformer or not must be made case by case.

Transformer secondary voltages
The input voltages in LV drives are usually between 380 V and 900 V, depending on the drive type. The input voltages in MV drives are from 1 kV to 36 kV.

Two-, three- or multi-winding transformers
The rectifiers used in low voltage VSDs are usually both 6-pulse or 12-pulse rectifiers, and they may be diode bridges, thyristor bridges or power transistor solutions.

The 6-pulse rectifier is supplied by a two-winding transformer and the 12-pulse rectifier needs a three-winding transformer, having two separate secondary windings with 30° phase shift.

Especially with higher ratings, a higher converter pulse number is needed 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 72. This requires multiple phase-shifted transformer windings supplying the converter system.

Power range
Transformers for low voltage VSDs are typically from 200 to 4000 kVA for two-winding transformers, and from 160 to 5000 kVA for three-winding transformers. The power range for MV drives is typically 500 kVA - 40 MVA.

Trend of increasing power range is well covered within ABB Transformers as references can be found up to 100 MVA converter transformers.

Mechanical construction
The transformers for low voltage VSD duty are all corrugated tank style. There are two choices:

- Hermetically sealed flexible corrugated tank. This solution is recommended by ABB whenever possible. The tank is full of oil, without a gas cushion, and the oil volume variation is permitted by the flexible tank.
- Oil conservator style tank, also corrugated, but the oil expansion takes place in the conservator, and there is no pressure variation in the tank itself. Air breathing into the conservator is realized through a dehydrator.

Transformers for lower power range have mostly corrugated tanks. However, transformers with ratings of approximately 5000 kVA and above, have tanks with detachable radiators providing adequate cooling. In order to save space, or for some other special reason, also water-cooled heat exchangers can be used instead of radiators.
Core and windings
The magnetic circuit is core-type with mitered joints. High-B grain oriented, 0.3 mm magnetic steel is most commonly used.

The windings may either be copper, aluminum or mixed. If the customer does not have a preference, ABB chooses the optimum material for each case. Low voltage windings are always foil windings in these transformer sizes. Foil windings are mechanically extremely strong, which is important in transformers for VSD duty.

An earthed screen is installed between the primary and secondary windings. It is used to eliminate radio frequency interference.

The reinforced mechanical bracing of the core and windings is specially designed and tested to withstand the stresses in VSD duty.

Special core joints, distributed gaps and air gaps may be used in the core construction to avoid DC saturation when needed.

Tap changer
It is recommended by ABB, especially with applications with >12 pulse, to select a construction with no tap changer. This provides the customer with the most economical solution.

Typically an off-circuit tap changer is provided. Its location is in the HV windings and the tapping range is ± 2 x 2.5 percent.

Insulating liquids
Three different insulating liquids can be chosen for VSD supply transformers.
- Mineral oil based inhibited transformer oil for industrial installations
- Silicone oils (non-toxic and stable, for reduced fire risk)
- Midel®, synthetic ester based insulating liquid (bio-degradable and non-toxic, for reduced fire risk)

Bushings
The normal bushings used are solid porcelain bushings according to IEC. Outer cone bushings for plug-in type cable terminals are optional.

Cable boxes
Most of the VSD duty transformers are installed in an industrial environment and equipped with air insulated cable termination boxes. These can be used in either HV or LV side, or in 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 IP 44. 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 and trip device, and the sudden pressure relay functions.
- Pressure relief device. This device prevents the tank from breaking and spilling oil in the case of an internal fault in the transformer to give time for the circuit-breaker to open with the command received from DGPT2.

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

Painting and surface treatment

The corrugated tank transformers can either be painted or hot-dip galvanized and painted. The standard color is RAL 7035, light grey. Other shades are optional.

References

ABB has years of experience in the development of drives for all present and previous VSD product generations. The design of today's transformers for VSD drives utilizes all accumulated experience from the very beginning of the VSD breakthrough history.

Further details on factories, design and references will be provided upon request. Please feel welcome to contact us.
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