

# ARC FURNACE POWER TRANSFORMERS

## Power Transformers up to 300 MVA

For over 40 years, GE Vernova's Electrical Arc Furnace (EAF) power transformers have been meeting the very high current supply needs of the steel industry's arc furnaces around the world. By producing the first four references above 200 MVA, GE Vernova is now among the indisputable worldwide leaders in extra-high power EAF transformers.

Arc furnace transformers deliver high currents over a wide range of voltages. Power ratings between 10 to 300 MVA and secondary currents of more than 100 kA are quite common. These AC or DC transformers have special features for handling the load requirements of electrical arc furnaces, especially for very high load currents.

### EAF Power Transformers: Designed for Specific Needs

GE Vernova's design is based on decades of experience, expert calculations and CAD tools. GE Vernova offers electrical arc furnace power transformers that are precisely adapted to thermal, mechanical and dielectric constraints. Our R&D experts validate all design and production phases to ensure the suitability to specific harmonics and high currents in accordance with your industrial requirements.

The quality and performance of GE Vernova's EAF power transformers are field-tested every day at steel production sites around the world. Major metal producers trust our design and manufacturing techniques. GE Vernova has produced the highest rated EAF transformer ever made.

The reliability of GE Vernova's products is based on our quality manufacturing procedures, our innovative design techniques and our highly experienced technical staff. Our special power transformer factory in Turkey is also Grid Solutions' global Competence Centre for special industrial application power transformers, supporting the needs of our other two factories in China and India.

## Special Furnace Transformers

Furnace load cycles vary widely, depending on size and metallurgical requirements. Many furnaces have load cycles falling within the range of several hours, varying depending on whether the supply is for melting or refining. The melting period is characterised by heavy current fluctuations caused by arc instability and movement of the charge, with less fluctuations occurring during refining.

Utilities supply power at very high voltages which must be converted to low voltages suitable for the furnace arcs. EAF transformers receive the primary low current, high voltage current, high voltage power and transform this to a high current, low voltage power for use in the EAF.



### Key Features

- Among the highest rated EAF transformers available on the market
- Customer-oriented solution
- Life time of at least 30 years
- More than 4 decades of field- proven experience



GE VERNOVA

## Mastering Challenges with Innovative Solutions

Combining the most innovative designs with the reliability of a field-proven technology, GE Vernova has mastered the challenges for global solutions that fit customers' specific needs. With a broad technical expertise, GE Vernova optimises power transformer design to perfectly match your industrial needs – with integrated reactors in the tank or in parallel – for efficient and economical AC or DC supply.

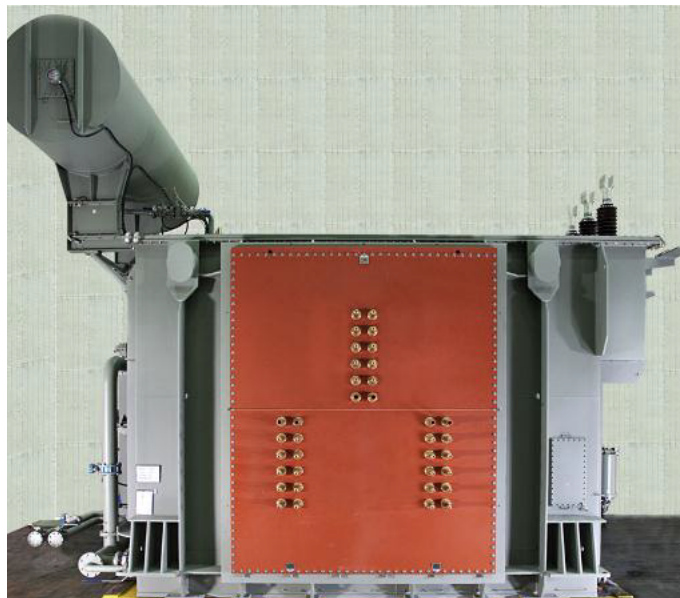
## AC and DC Electrical Arc Furnace Transformers

Reliable industrial operations totally depend on the quality and reliability of the EAF transformers, many of which are rated above 100 MVA.

The AC furnace transformer must be specially designed to withstand frequent short circuits on the secondary side. Currents drawn in the arc furnace are characterised by wide fluctuations and unbalanced conditions, leading to voltage drops, harmonics, etc. These effects can be reduced by supplying furnaces directly from a high capacity, high voltage transmission line through a furnace transformer, while also taking suitable measures to protect the secondary winding from transferred voltages from the HV primary winding. DC furnace transformers have a higher efficiency and the added advantage that there are less disturbances returning into the supply system.

## Furnace Reactors

To improve the efficiency of the service currents, reactors may be added to maintain stability. In large furnace installations, the low voltage connections usually provide the necessary reactance. Series reactors, which can be housed in the furnace transformer tank, are usually provided with taps so that the reactance value can be varied for optimum performance. The reactance of the furnace reactors can be changed from 0% up to 100% with the use of no-load or on-load tapchangers.



*The highest rated 300 MVA EAF power transformer, built for MMK / ATAKAS in 2010*

## Regulation Types

GE Vernova offers a wide selection of regulation types and the best compromise between cost and regulation needs for your specific situation.

### Direct Regulation (Variable Flux Voltage Regulation)

For all furnace transformers within the usual regulation ranges, the common voltage regulation arrangement consists of taps at the neutral end of the primary winding. This type of EAF power transformer is the most compact and economical solution.

### Regulation with an Auto-transformer

For larger furnace applications, a separate auto transformer is used for the voltage regulation. The auto transformer, which may be supplied directly from a 66 or 132 kV system, reduces the voltage down to the furnace transformer's primary winding level. Auto transformers and furnace transformers may be housed in common or separate tanks.

### Regulation with Auxiliary Transformers (Booster Regulation)

For medium and large power furnace applications with a very wide regulation range, one of the popular arrangements is the furnace transformer with a booster arrangement. The booster transformer increases the output of the fixed secondary voltage of the main transformer. The booster transformer solution offers an optimised OLTC operating condition that is also less expensive.



*Regulation transformer*

## Furnace Transformer Windings

Due to the non-linear aspect of arc resistance, frequent arc reignition can lead to inrush currents with high magnitudes. Consequently, high force occurrences in the furnace transformer windings are normal.

The high voltage windings are similar in construction to power system and generator transformers, though they are more complex due to the tapping winding needed for the wide regulation range.

Design rules and field-proven experience allow GE Vernova to offer solutions with a wide regulation range. This minimises variations of the percentage reactance over the entire tapping range, by optimising the tapping winding arrangement between the HV and LV windings and their relative positions.

## Cooling

For large ratings, the optimal cooling choice is forced oil cooling with an oil-to-water heat exchanger. It generally operates at a low oil temperature, which avoids any excessive service life reduction due to thermal stresses, even under overload conditions. For installations with space restrictions, water cooling is the logical solution.

## Some References

CUSTOMER	COUNTRY	TRANSFORMER RATING
KRUPP NIROSTA	Germany	135 MVA, 33 kV / 1.200 ... 0.700 kV
IÇDAS	Turkey	168 MVA, 34.5 kV / 1.300 ... 0.705 kV
EGE ÇELİK	Turkey	90 MVA, 34.5 kV / 0.998 ... 0.500 kV: Electrical Arc Furnace Transformer and 32.4 MVA series reactor in the same tank
MITTAL	Germany	205 MVA, 33 kV / 1.404 kV ... 0.802 kV with OLTC and 46 MVA EAF reactors in the same tank
DANIELI	China	60 MVA, 35 kV / 0.929 kV
Various Customers	India	10...40 MVA, 33 kV / 0.325 kV with OLTC
COLAKOGLU	Turkey	265 MVA, 34.5 kV / 1.616 ... 0.800 kV with OLTC
MMK / ATAŞAS JV	Turkey	300 MVA, 34.5 kV / 1.683 kV ... 1.110 kV with OLTC
IÇDAS	Turkey	230 MVA, 34.5 kV / 1.599 kV ... 0.901 kV with OLTC

## Special Transformer Bushings

### Copper Bar Bushings

Bushings made of flat copper bars can be used up to certain current levels. Several bushings can be used in parallel. When the currents are lower than 80 kA LV, output is through the tank cover, while for higher currents up to 120 kA, LV outputs are through the tank wall.

## Connections

When designing arc furnace transformers, due to the asymmetric loading requirements of the three phases, it is usually necessary to provide separate voltage regulation for each phase and therefore single-phase circuit breakers. Delta connected secondary windings are preferred and reduce the current being carried.

Sometimes both ends of each secondary winding phase are brought out through the terminals and the delta connections are made at the furnace (Open Delta), a common solution for Ladle furnaces.

The LV connections carrying high currents up to 80 kA and more are brought out through the tank wall. The choice of quality materials and oil-tight seals for the water-cooled tubular elbows offer an efficient, cost-effective connection.

The secondary winding terminals located on the vertical side of the tank offer reduced connection lengths, reduced stray losses and lower transformer cost. For lower currents, the secondary winding can be brought through the tank cover with normal high current busbar bushings.

### Water Cooled Bushings

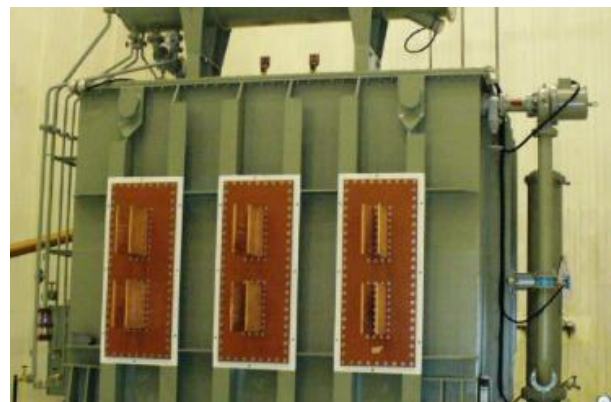
When the current reaches values such that the low voltage connections require water-cooled cables, it is possible to use bushings fitted with special tubing to enable re-circulated water. This smaller system cools the bushing more rapidly. This type of bushing is normally used on furnace transformers and several bushings can be used in parallel.

## Technical Characteristics

	FURNACE TRANSFORMERS (EAF AND LF)	FURNACE REACTORS
<b>Rated power MVA (fundamental)</b>	up to 300 MVA	up to 110 MVar (using air-core technology)
<b>Regulation type</b>	There are three regulation types: > Direct regulation on the primary winding (standard applications) > Regulation with auto transformer > Regulation with regulator transformer	Not applicable
<b>Vector group</b>	<b>HV:</b> Primary is either star or delta connected depending on customer request and reacting <b>LV:</b> Secondary is delta connected with either internal or external connected	Connected in series with the HV side of the main EAF transformer
<b>Primary voltage</b>	Up (Um) + 72.5 kV	Up (Um) + 72.5 kV
<b>Secondary voltage</b>	Up to 1,700 V	Not applicable
<b>Electrode current</b>	Up to 120 kA	Not applicable
<b>Regulation and tapping</b>	OLTC and OCTC	OLTC and OCTC (A regulation between 0% and 100% can be achieved)
<b>Mechanical design</b>	Separate tank solution or integrated with series reactor in one single tank solution depending on transportation and civil work constraints	Separate tank solution or integrated with furnace transformer in one single tank solution
<b>Oil-immersed transformers</b>	With conservator	With conservator
<b>Type of cooling</b>	OFWF or ODWF	OFWF
<b>Short circuit withstand</b>	High resistance to high amounts of short circuits and over-voltages during melting processes	
<b>HV &amp; LV terminals</b>	<b>HV:</b> air bushing with increased insulation class due to highly polluted environments <b>LV:</b> water-cooled pipe type bushing or seal-off busbar bushings	
<b>Equipment</b>	Standard and special equipment according to customer needs and specifications	

## Special Testing Features

EAF transformer testing methods are the same as for regular power transformers, except for the special short circuit equipment requirements for temperature-rise tests. For temperature-rise tests on large furnace transformers with very high currents on the LV side, appropriate equipment is necessary for the short circuit connection to supply the necessary connection cooling.



PEAF transformer equipped with flat copper bar bushings

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