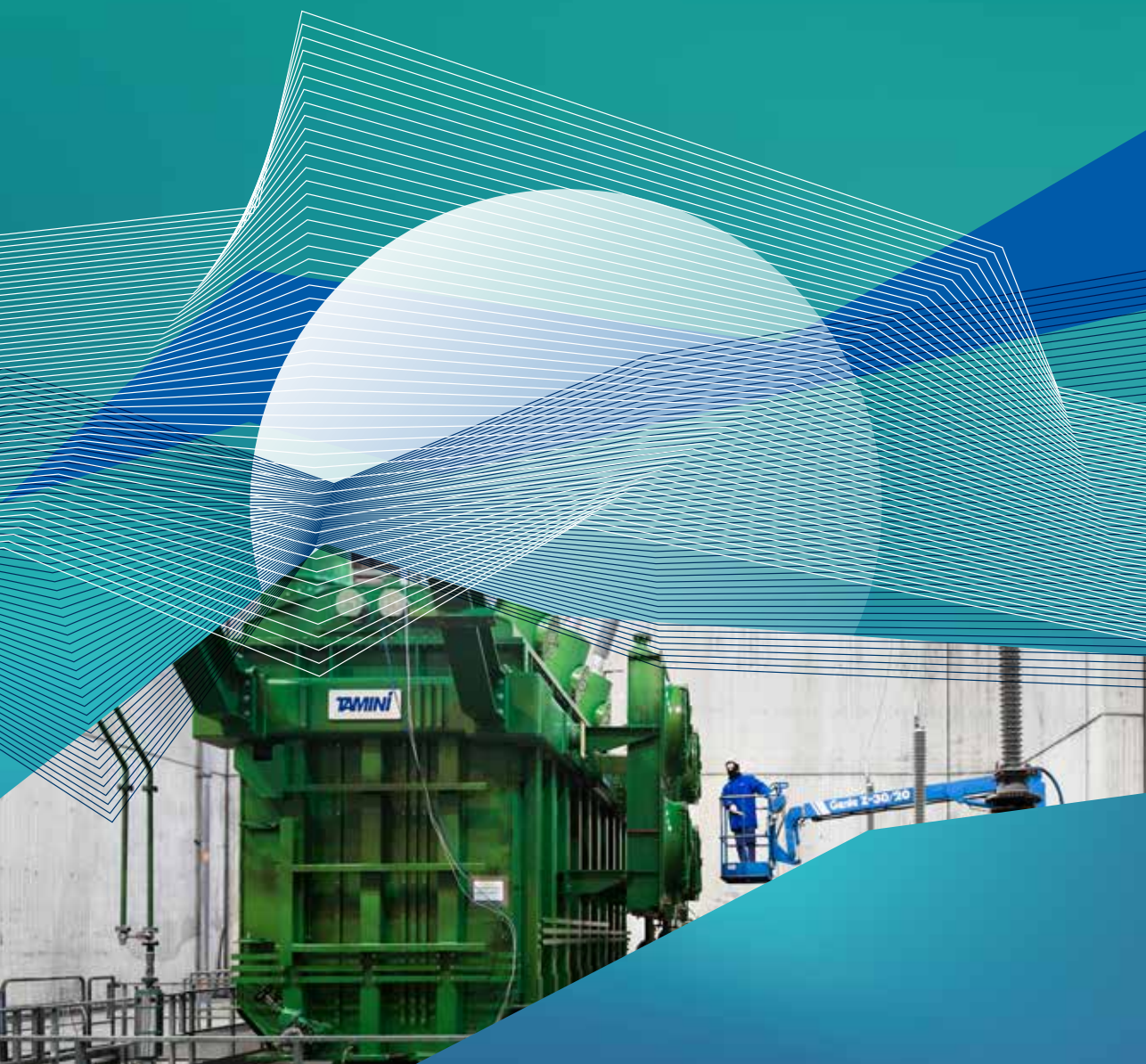


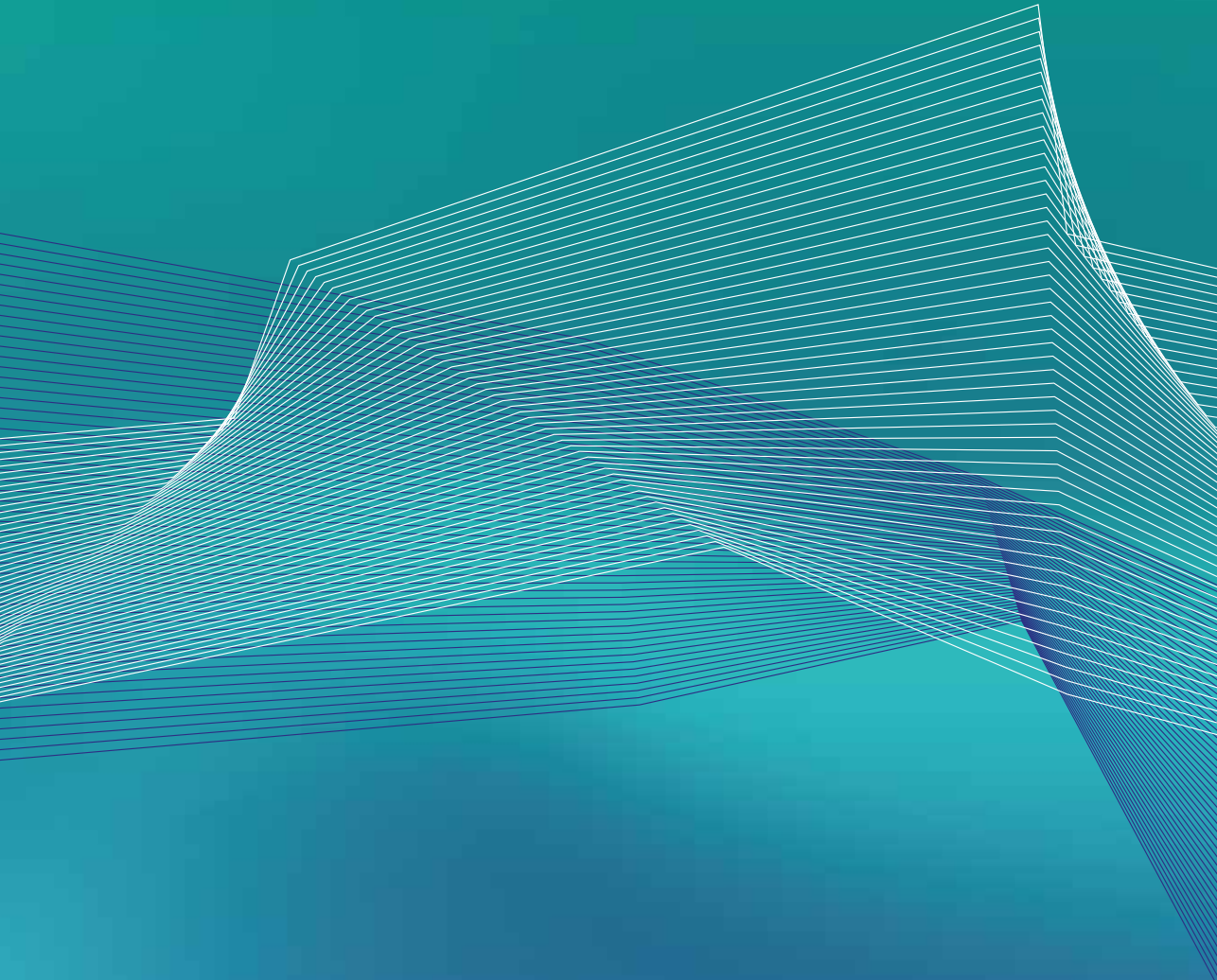
Tamini Green Solutions

The Italian tailor made



TAMINI
ENERGY TRANSFORMERS

 **Terna Energy
Solutions**
MORE VALUE, TOGETHER.



TAMINI
ENERGY TRANSFORMERS

 **Terna Energy Solutions**
MORE VALUE, TOGETHER.

Green Solutions

**Unique solutions,
developed on
customer needs.**

Unique in Quality

Our transformers are the result of a unique mix: the artisan excellence of Made in Italy combined with the best available technology.

Unique in Technology

We have unique research and development methodologies to ensure the highest standards of products and services for our customers.

Unique in Customization

We meet the specific needs of each client through our ability to customize each solution, backed by more than a century of experience in the industry.

Unique in Design

Our experienced and qualified team designs unique products, thanks to the incomparable know-how gained Worldwide.



Green Solutions

Tamini designs and manufactures *Green Transformers* for both industrial and power applications, offering safe solutions with low environmental impact.





Transformers for Green Solutions

Tamini designs and manufactures *Green Transformers*, filled with natural (or synthetic) esters, for the distribution, transmission and production of electricity from both conventional and renewable sources.

The *Green Transformers* are also available for industrial applications (i.e. furnace and rectifier transformers) with the aim to be fire-safe and eco-friendly.

The Company's products are designed to provide tailor-made solutions for specific customer needs, effectively responding to the ongoing technological progresses in the electricity generation, transmission and distribution systems, meeting the increasing demand for the interconnection of different national networks, with a particular attention to the environmental aspects.

Tamini can supply the new *Green Transformers* or, alternatively, it can provide for the revamping of the mineral oil transformers with retrofilling with natural (or synthetic) esters by the Service department. Using *Green Transformers* can help to achieve main installation cost savings by enabling a minor substation footprint, reducing or avoiding the need for additional fire suppression systems (sometimes reducing insurance costs) and reducing the need for containment to prevent leakages on site.

Tamini successfully installed the first large prototype unit 250/375 MVA Autotransformer, 400/135±10% kV in 2017 and the unit is in regular operation since then.

This Autotransformer passed all the Routine, Type and Special Test, including the Short Circuit Withstand Test in CESI Laboratory in Rondissone-TO (Italy).

- Dedicated service packages can be provided to meet specific Customer needs;
- Servicing performed worldwide;
- Transporting transformers and equipment all over the world, including customs clearance.



Research & Development



The goal of the Research and Development activity is to achieve the best possible life cycle cost of the Tamini products, thinking about preserving the Environment from the risks of pollution and fire, by a continuous improvement of the design criteria.

Investigation on *Green Transformers*, filled with natural (or synthetic) ester, includes the following activities:

- Distribution of electric field analysis;
- Thermal-hydraulic network model analysis;
- Materials and components environmental friendly with improved characteristics and performances;
- Diagnostic systems;
- Analysis of electrical stress due to fast-transient over-voltages;
- Ester fluid dynamics.



Quality, environment and safety integrated systems



Integrated Systems are carried out and certified according to ISO 9001:2015, ISO 14001:2015 and OHSAS 45001:2018 Standards.

Quality Controls are performed at every step:

- engineering,
- manufacturing cycles,
- procurement, testing and
- on site installation.

All Tamini's factories have their own testing facilities suitable for the routine, type and special tests in accordance with IEC or IEEE (ANSI) and other worldwide recognized Standards (ASA, CSA, BSS, SEV etc.).

Tamini definitely complies with the most updated International Legislation for Safety and Environmental protection.



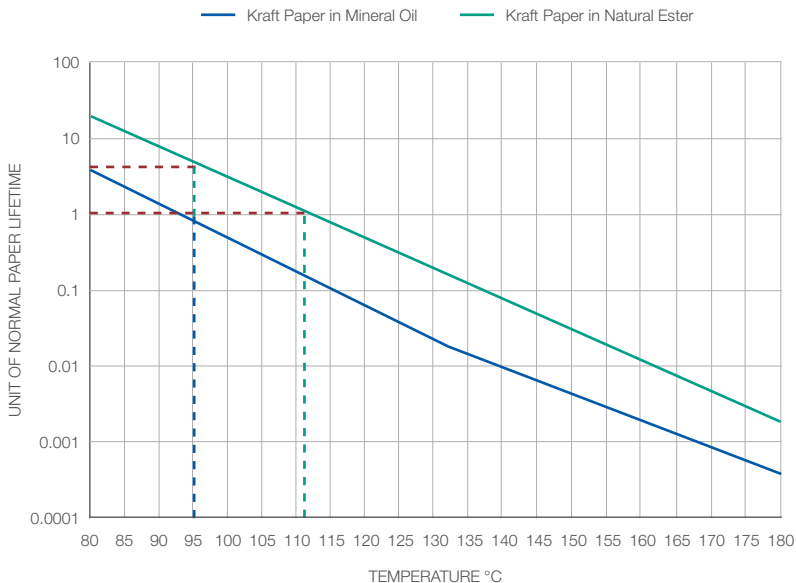
Natural ester: characteristics and strengths

Natural esters are extracted from vegetables. Most common sources are rapeseed, soya or sunflower.

The properties of natural esters fluids are: fire safety (high fire point), environmental protection (readily biodegradable) and transformer performance improvement (extended paper life and high moisture tolerance) are the most famous.

Green Transformers enable customers to save money while mitigating the risk of fire and environmental damage, with the concept of Safety:

- **Safety for people** living and working near the transformers;
- **Safety for the environment** around the transformers;
- **Safety for the buildings and business** close to the transformers;
- **Safety for the investment** in critical assets like transformers.



**Natural ester:
characteristics
and strengths**



One of main technical advantage of natural ester is due to the good water solubility, it's extracts water from cellulose materials.

The ageing rate of the transformer is then reduced! IEC 60076-14 Standard define a higher thermal class for ester filled transformers.

The same cellulose insulation has an improved life expectancy when aged in natural ester instead of mineral oil.

At the same working temperature using natural ester instead of mineral oil the thermal life expectancy shall be much longer.

In the same way, working at higher temperatures, at equal life expectancy the power rating shall be much higher.

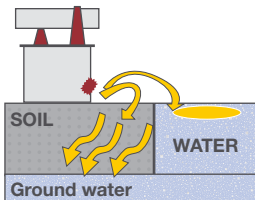
FLUID	FLASH POINT ISO 2719	FIRE POINT ISO 2592	CLASSIFICATION TO IEC 61039
Mineral Oil	150°C	170°C	0
Synthetic Ester	260°C	316°C	K
Natural Ester	> 260°C	>350°C	K

Mineral oil vs Natural ester

Environmental impact

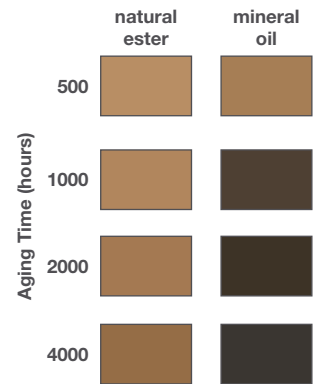
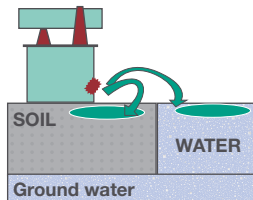
MINERAL OIL

- Fast infiltration in soil;
- May reach water reservoir;
- Very slow biodegradation;
- Very high remediation costs.



NATURAL ESTER

- Very slow seepage;
- Non-toxic;
- Completely biodegradable;
- Very low remediation costs.





Transformers and Solutions for Power Applications



Generator Step-Up (GSU) Transformers

GSU transformer is an essential component of a power plant since it links the generation system to the transmission grid.

Product scope:

- System voltage up to 550 kV;
- Power rating up to 900 MVA;
- Three-phase and Single-phase units;
- Customized design for spare GSU transformers that can be used in different power plants.

Besides the step-up ones, in a power generation plant there are other transformers to supply the power station auxiliary system for starting up the boiler/turbine generator unit or gas turbine/generator and for supplying those loads, which are not specifically associated with the generating unit.

Transmission Transformers

Transmission transformers are used to interconnect high voltage transmission systems.

Product scope:

- System voltage up to 550 kV;
- Power rating up to 900 MVA.

Transformers and Solutions for Power Applications

Autotransformers

These are particular units where primary and secondary windings are not separated but with a portion in common.

Product scope:

- System voltage up to 550 kV;
- Power rating up to 900 MVA.

Shunt Reactors

Shunt reactors are used in a power system to compensate the capacitive reactive power required by the large HV grids.

Product scope:

- System voltage up to 550 kV;
- Power rating up to 300 MVAr;
- Three-phase and Single-phase units.

Distribution Transformers

Distribution Transformers are used wherever it is necessary to connect systems for distribution and utilization of electrical energy.

They are nowadays used as well in mobile substations, needed to feed energy where a standard substation is not or cannot be built.

Tamini's experience has allowed the company to become a leading brand both nationally and abroad in the HV/MV and MV/MV distribution transformers market. The company's products are used across a wide spectrum of applications by a plethora of major clients.

Distribution transformers for energy distributions are usually three or single phase, fluid immersed, with different cooling methods, with conservator technology or sealed construction (with or without nitrogen/ air filling), with either off-circuit tap changer or on-load tap changer.

Furthermore, transformers for railway application with various loading cycles can be manufactured.

HV/MV Transformers

Product scope:

- System voltage up to 550 kV;
- Power rating up to 900 MVA.

MV/MV Transformers

Product scope:

- System voltage up to 52 kV;
- Power rating up to 100 MVA.



Phase Shifting Transformers (PST)



Following the deregulation of the energy sector, modern power grids have an articulated structure covering large areas, often in different countries.

Energy is no longer produced and consumed in the same country, in the same area, but it is traded on a large scale between different countries and areas. Therefore, it is necessary to manage the energy flow according to the supply contracts and not to the natural path determined by the physical parameters of the interconnected networks.

A Phase-Shifting Transformer (PST) is a special unit, specifically used for managing the power flow through complex interconnection lines. This goal is achieved by controlling the phase displacement between the input and the output voltages of the transmission lines interconnected through the PST. Both the magnitude and the direction of the power flow can be controlled by varying the phase shift.

Similar considerations can be made about the reactive power flow, but based on the in-phase regulation of the voltages. In order to satisfy these requirements, several design solutions of PST are available.

The most common types are:

- Two-core design in symmetric and asymmetric configuration;
- Single-core design in symmetric and asymmetric configuration.

Both of them allow a possible addition of an in-phase voltage regulation, to compensate the net voltage fluctuation or to combine in-phase and quadrature regulation.

Product scope:

- System voltage up to 550 kV with in-phase regulation if required;
- Through-put rating up to 1800 MVA.

Phase Shifting Transformers (PST)

Some examples of PSTs

Here below a short description of the most important PSTs manufactured by Tamini over the years.

- a) One core design with both in-phase and shifting regulation, 75 MVA:
 - Primary side: 154.5 kV +18/-10 x 1.97 kV with on load tap changer for in-phase regulation;
 - Secondary side: 138 kV \pm j16 x 3.84 kV allowing a no load shifting capability of $\pm 24^\circ$ with on load tap changer.

- b) One core design with both in-phase and shifting regulation, 62.5 MVA:
 - Primary side: 236 kV +18/-10 x 2.95 kV with on load tap changer for in-phase regulation;
 - Secondary side: 160 kV \pm j16 x 4.045 kV allowing a no load shifting capability of $+29^\circ -14.1^\circ$ with on load tap changer for the symmetrical range of regulation, plus an off circuit tap changer to extend or reduce furthermore the angle regulation range.

The above mentioned units have been the first ones installed in the world with a special winding arrangements to obtain in-phase and angle regulation with only two three-phase tap changers and with several working possibilities.

- c) Tamini one core design record is a 160 MVA PST 230 kV +24/-4 x 2.726 kV primary side (with OLTC for in-phase regulation) and secondary side 132 kV \pm j17 x 5.426 kV to obtain $\pm 35^\circ$ of shifting capability with on load tap changer. The transformer is OFAF type. The unit is also equipped with a tertiary winding for feeding auxiliary equipment. The weight of the unit is approximately 240 Tons.

- d)** Another special application developed by Tamini is an autotransformer 150/200 MVA with primary voltage 330 kV and secondary voltage 161 kV $\pm 8 \times 1.25\%$ (with on load tap changer for in-phase regulation). This is also equipped with additional off circuit tap changer $\pm 2 \times 12$ kV which allows shifting capability of $\pm 6^\circ$. This autotransformer is the only installation in the world with this capability.
- e)** Two core design with both in-phase and shifting regulation, 160 MVA, obtained by coupling a main unit with a booster unit
- Primary side: 230 kV $+16/-8 \times 1.24\%$ with on load tap changer for in-phase regulation;
 - Secondary side: 155 kV $\pm j16 \times 2.54\%$ allowing a no load shifting capability of $\pm 22^\circ$ with on load tap changer. Total weight of the two assembled unit is 366 tons.
- f)** The biggest units manufactured by Tamini (Two-core symmetric design among the largest in the world) have a throughput power of 1800 MVA with maximum shift angle of $\pm 17,5^\circ$. Each unit is composed by two transformers, connected together with inlet and outlet voltage of 400 kV and angle shift adjustable by a 33 positions OLTC. Moreover, in order to invert the phase angle, an “advanced-retard” switch (ARS) is installed.



Special applications in electrical energy distribution



Short-Circuit Test Room Transformers

Short-circuit test room transformers are used in test laboratories to check the short-circuit withstand capability of electric devices such as circuit-breakers, switches, transformers, etc.

An extremely solid design is required for this type of transformers, for which the short-circuit is their operating condition.

Mobile Substation Transformers

Mobile transformers are used when power needs to be temporarily supplied in a particular place and situation, like in cases of a system failure, system maintenance or civil construction.

A typical mobile substation is electrical fully equipped and installed on one or more trailers, to be transported by road according to customer requirement. An optimum solution in terms of design is always a path to be walked side by side by the end-user and the manufacturer.

Product scope:

- System voltage up to 245 kV;
- Customized power rating related to trailer dimensions, maximum transportable weight, cooling system and thermal class.



Transformers for Industrial Applications

Tamini is a leading market player within the field of Industrial Transformers of high quality and reliability: Tamini Industrial Transformers are designed to satisfy the most diverse and complex technical requirements.

A large share of its resources is devoted to the development of special transformers for any industrial application, such as furnace transformers, reactors, power transformers for industrial distribution and rectifier transformers.

In the last ten years, Tamini has manufactured more than 1.000 transformers. Among them approximately one third are industrial transformers and the majority is exported all over the world.

Thanks to decades of experience, research and development, Tamini has the possibility to provide its customers with ester oil filled transformers in compliance with the tightest requirements of regulations and quality.

AC and DC Furnace Transformers

The Electric Arc Furnace and Ladle Furnace Transformers are the key equipment in a steel plant, therefore specific engineering solutions are adopted in order to guarantee over time the best performances under the dielectric, thermal and mechanical stresses which daily involve these transformers.

Furnaces transformer's life is affected by heavy stresses during operation. Tamini pays special attention to this issue adopting a specific design and manufacturing procedures to guarantee a stronger transformer insulating structure (e.g. improved procedures for windings pressing and thermal treatment operation).

Different solutions can be adopted according to the customer requirements:

- Single or double core “booster” solution;
- LV delta closure either inside or outside the tank;
- LV bushings either in copper bars or water-cooled pipes;

Tamini also provides:

- Special furnace transformers as Submerged Arc Furnace (SAF), Electroslag Remelting (ESR) and Smelter Transformers used to power furnaces for the production of special iron alloys. These alloys often require the deployment of three single-phase furnace transformers instead of a single three-phase transformer in order to balance the total phase impedance through an equilateral-triangle layout of the units or in applications of modern steel processes.
- Regulating transformers, with either stepped or stepless regulation of the output voltage, for those applications/processes where a fine regulation is needed.

Series Reactors for Furnace Applications

Series reactors connected to Furnace Transformer are often used to stabilize the arc current. In order to achieve better efficiency of the melting process, series reactors may have tapplings to adjust the reactance in coordination with arc furnace needs. Series reactors can be designed as Gapped-Core Reactors or Coreless Reactors (with core-frame). Tamini has designed and successfully supplied many different types of transformer-reactor solutions.

Reactors are used in the furnace operation with the purpose of:

- Arc stability and power regulation;
- Optimisation of electrodes consumption;
- Limitation of current during melting process;
- Reduction of flicker on the feeding network.

Product scope:

- Up to 150 Mvar

Rectifier Transformers

The rectifier transformer is the link between the electrical grid and the AC/DC converter. Therefore, it has the aim to provide the number of phases, the voltage shifts needed to realize the conversion and to adjust the rectifier input to vary the DC output voltage.

To do it, the rectifier transformer is often coupled with components as regulating transformers (or autotransformers), saturable reactors and interphase transformers.

All these components may be assembled in one or in separate tanks for transportation optimization and site restrictions.

Typical applications are for: DC arc furnaces, electrolysis, scrap melting furnaces, aluminum smelter, graphitizing furnaces, traction substations, metal refining and inverters for variable speed drives.

Product scope:

- Rated power up to 250 MVA;
- L.V. current up to 150 kA

Distribution Transformers

Distribution transformers for industrial applications are used wherever it is necessary to connect systems for transmission, distribution and utilization of electrical energy, which function at different voltages, in order to transfer large quantities of active and reactive energy between these systems.

Tamini's experience has allowed the company to become a leading brand both nationally and abroad in the HV/MV and MV/MV distribution transformers market.

The company's products are used across a wide spectrum of applications by a plethora of major clients.

Distribution transformers for industrial applications are usually three or single phase, fluid immersed, with different cooling methods, with conservator technology or sealed construction (with or without nitrogen/ air filling), with either off-circuit tap changer or on-load tap changer.

Furthermore, transformers for railway application with various loading cycles can be manufactured.

HV/MV Transformers

Product scope:

- System voltage up to 550 kV;
- Power rating up to 900 MVA.

MV/MV Transformers

Product scope:

- System voltage up to 52 kV;
- Power rating up to 100 MVA.



Service

After-Sales Assistance

The after-sales service includes all maintenance, diagnostic, investigation and monitoring activities on transformers, in order to guarantee the needed reliability and malfunctioning predictive remedy actions to avoid unplanned outages to the customer's production cycles.

Tamini Service has dedicated means and resources to promptly react in case of troubles to support our customers.

Dedicated service resources can tap into a pool of experienced personnel from different production plants to offer enhanced flexibility taking advantage of 100 years of experience.

The capabilities of providing all the transformer spare parts, including the adaption materials for the installation of new available components, complete the after-sales assistance service offered by Tamini, that guarantees its customers high-quality technical assistance and training in each phase of the transformer's life.

Installation and Commissioning

A team of experienced and qualified specialists guarantees the full support to deliver, assembly and install both network and industrial products with high-quality and on-time to the customer's plants.

The capabilities to deliver transformers and equipment all over the world, including customs clearance and the complete chain of support service providers for tools and equipment's availability make the Tamini's service as the best in class for transformers installation and commissioning.

Repair and Upgrading

The specialized experience in on-site and in-house preventive, routine and advance maintenance of any transformer together with the continuous commitment to technological innovation, makes the Repair and Upgrading services the Tamini's points of excellence.

Revamping or powering means working on the active parts and reviewing machine engineering without modifying the existing structure or those parts that do not require to be changed.

The process of upgrading increases remarkably the performances of transformers being used and it is carried out not only on damaged machines but also on working ones, which, because of changes to the production processes, are eventually no longer suitable.

These services are offered on both own products and third party's ones and ensure correct results through a strict final testing carried out at Tamini Lab.

Emergency Services (24 Hours/7 Days)

The emergency services include the activities and materials needed to react the fastest to customer's critical requests.

Tamini exclusive emergency service, backed by the most advanced diagnostic investigation techniques for the detection of faults or malfunctioning, allows solving any problems with installed transformers and restoring in very short time normal working conditions. Furthermore, a large stock of reconditioned transformers ready for use can be made available to customers on flexible rental or purchase conditions.

Partnerships worldwide

Tamini has established a network of certified partners to support in the assembling, installation and commissioning of new transformers and to provide the availability of qualified repair shops for testing and resolving service issues on Tamini transformers.

We are present with our service partners in U.S., Canada, Bulgaria, Egypt, India, Mexico, Spain, Belgium, Algeria and South Africa.

Oil Refilling

Within the activities provided by Tamini, a special remark is given by the Oil Refilling on site to replace the oil of any Transformer (both from Tamini and from any other manufacturer) with Natural Ester Oil.

Thanks to 100 years experience of Tamini in assisting its customers worldwide on site, we give full guarantee of a state-of-the-art service to all customers that need to improve the environmental capability of their fleet, including but not limited to a comprehensive feasibility study, “green” oil refilling, sealing tightness assessment and recover, ancillaries assessment and so on.

Workshop 24/7

The availability of a workshop entirely dedicated to Service, with a team of skilled technicians, assure the reduction of intervention time to restore the functionality of any customer’s transformers.

Housed in a covered area of 4.000 sqm in the hinterland of Brescia – Rodengo Saiano – the factory is designed for repairing, upgrading and the routine or extraordinary maintenance of any type of transformers, even produced by other manufacturers.

Activities carried out in the Workshop 24/7:

- 4.000 m² entirely dedicated to Service;
- Active part drying system;
- Disassembly, assembly and rewinding area;
- Oil treatment and vacuum filling area;
- Check and testing room;
- Laboratory for the execution of chemical-physical and gas chromatographic oil analyses (DGA);
- Skilled technical staff.



Main Accessories



Bushings

Usually the bushings for *Green Transformers* are fluid/air type. HV bushings are usually of the condenser type with resin-impregnated paper.

The gasket used in the bushings are compatible with the fluid used (e.g. natural ester).

Cooling System

The *Green Transformers* can be designed for any applicable cooling system following the requirements of the end user. The most used cooling systems for power transformers are ONAN and ONAF. These systems are achieved by radiator banks, mounted on the sides of the transformer tank, or in separate banks, with or without cooling fans.

The cooling can also be OFAF (or ODAF) and OFWF (or ODWF) with coolers assembled on the transformer tank or in a separate bank.

Tap-Changers

The *Green Transformers* can be equipped either with a proper on-load or with no-load tap changer usually fitted on the HV side.

The on-load tap-changers are specifically designed for transformers and suitable for local and remote operation and are fitted with all the accessories and with a marshalling cabinet mounted on the transformer tank.

They can feature a device for parallel operation.

Main Accessories



Tank and liquid expansion tank

A stiffened structure to support full vacuum and over-pressure. The internal walls are painted with a hot fluid resistant coating; the external surface is painted according with Tamini Quality Assurance procedure. The gasket used are compatible with the fluid used (e.g. natural ester).

In the *Green Transformers* the conservator is equipped with rubber-bags to avoid contact between natural ester and environmental air.

Ancillaries

The *Green Transformers* usually are equipped with several fittings and accessories:

- Air breathers for the conservator sections;
- Fluid level indicators with electric contacts for the conservator sections;
- Buchholz relay with alarm and trip contacts;
- Fluid drain, filling and filtering valves;
- Fluid thermometer complete with alarm and trip contacts and, on request, a device for remote temperature monitoring;
- Current transformers;
- Over-pressure protection;
- Lifting lugs for core and winding;
- Lifting lugs for the complete transformer;
- Marshalling box for signaling and protection auxiliary circuits;
- Earthing terminals;
- Fluid sample valve;
- Fluid Monitoring System;
- Etc.



Tamini Trasformatori S.r.l.

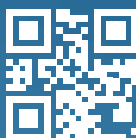
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