



Tironi 400 kV Natural Ester Autotransformer:

The Successful Short Circuit Withstand Test

The summer of 2019 has been a tremendous one for Elettromeccanica Tironi with two very important achievements having been accomplished within a mere 60-day period in June and July.



The first accomplishment was a successful **short circuit withstand test** performed on a 400 kV autotransformer, an important step to becoming recognized as one of the few large autotransformers' manufacturers' to have done so. But Elettromeccanica Tironi enters into a very reduced elite class with the second consecutive success: **Another short circuit withstand test successfully passed, on the first attempt, of a 400 kV autotransformer filled with Cargill's Envirotemp FR3 natural ester fluid derived from renewable vegetable oils.**

This 250 MVA, 400/135±5x2% kV, KFAF autotransformer, successfully tested at the CESI lab in Rondissone, Turin (Italy), is one of the largest high voltage transformers filled with natural ester. Ordered 20 months before the testing, this unit is the prototype for Terna Rete Italia, the Italian grid management and transmission operator.

In less than two years Tironi – the Italian transformer manufacturer established in 1960 in Modena – was able to design and manufacture the prototype, overcoming several difficult challenges that required both engineering and technological/industrial innovations.

New engineering was necessary to design a completely new unit taking into consideration the characteristics of FR3 natural ester in comparison to the historically used mineral oil. Investment in the Modena plant was necessary in order to have a fully separated and dedicated oil plant for natural ester along with a new Oil Lab.

In less than two years Tironi was able to design and manufacture the prototype of a 400 kV autotransformer filled with natural ester, overcoming several difficult challenges that required both engineering and technological/industrial innovations.

New Design

The main goal for Tironi engineers was to develop a new design of the 400 kV auto-transformer, taking into consideration all of the peculiarities of Cargill's Envirotemp FR3 fluid. Tironi was able to accomplish this by using their internal experience and design skills to produce a completely original Tironi design.

The main design implications that the engineers had to overcome were twofold:

1. The different viscosity and dielectric permittivity of the Envirotemp FR3 compared to mineral oil
2. The different stability of FR3 relative to oxidation

Dielectric design

As to the dielectric design considerations, the main characteristic considered was the greater dielectric permittivity ϵ_r of natural ester compared to that of mineral oil (typically 3.2 vs 2.2). This leads to a more uniform distribution of the electric field throughout the insulation, with a reduction of the electric field in the oil channels and an increase in the electric field in the paper. This gives different proportions between oil and solid insulation if we compare it with an identical unit in mineral oil.

Cargill FR3 fluid is a natural ester derived from renewable vegetable oils – providing improved fire safety, transformer life/capability, and environmental benefits that are superior to mineral oil and unsurpassed by any other dielectric coolant. Because it is derived from renewable raw materials, it has a neutral carbon footprint – unequalled by any other dielectric fluid option.

A transformer filled with FR3 fluid can operate 20°C warmer than the mineral oil equivalent while maintaining the same life expectancy of the insulating materials. Compared to mineral oil at the same operating temperature, FR3 fluid actually protects the insulating paper up 7.4 times longer than mineral oil.

This high temperature capability enables:

- Increased load capability in about 20% in comparison to traditional transformers
- For space constrained locations, utilities can increase capacity while keeping same footprint
- For growing population areas, utilities have increased load capability to better handle the increasing demand, especially for peak hours
- Design smaller, more efficient transformers that could use less fluid and less construction materials

FR3 fluid has a fire point of 360°C, more than twice the fire point of mineral oil. This greatly improves the fire safety for any transformer, either indoors or outdoors installations. This is particularly important in heavily populated areas such as restaurants, malls, and urban communities.

FR3 fluid not only provides reliable performance and increased fire safety, but it is also an excellent option to help utilities protect the environment in their communities:

- Made from 100% renewable engineered vegetable oil;
- Readily biodegradable as designated by the Environmental Protection Agency (EPA);
- Non-toxic in both oral toxicity tests and aquatic toxicity tests;
- Has a neutral carbon footprint – 56x less carbon emissions than mineral oil.

Thermal design

The thermal design of the autotransformer is considerably influenced by the higher viscosity of the natural ester fluid which reduces the flow speed and therefore the flow rate. This aspect is partially compensated for by the higher thermal conductivity compared to that of mineral oil; but to maintain an equivalent thermal dissipation with the same temperature gradients, it is necessary to dimension the oil channels differently.

Mechanical design

Considering the different stability to oxidation of natural ester fluids compared to mineral oils, it was also necessary to take some precautions in the mechanical design, foreseeing the use of the rubber bag membrane in the conservator or an airtight tank with nitrogen cushion. Large power transformers, like this for Terna, already have the rubber bag but it is also important to remember to install a “membrane rupture relay” with an alarm to the control associated with the urgent intervention signalling (IU).

Compared with the “sister unit” with mineral oil, with the same power and voltages, this new design – which was made with Tironi’s own software and also verified through third party finite elements software – shows some minor differences in the oil and overall weights (approx. 55 and 200 tons) while assuring the benefit of using a natural ester fluid like the Cargill’s Envirotemp FR3.

Oil Plant

A new important investment allows Tironi to have a completely separate oil plant for natural ester fluids, which allows for a fully independent storage and treatment plant with separate oil pipes to the filling area. The storage is composed of three separate compartments of 25,000 litres each, with heating elements and nitrogen generators. The treatment is composed of an adjustable OTP up to 6,000 lt/h.

This investment has created a duplicate, although of smaller dimensions, of the existing system for mineral oils, which assures excellent conservation of the oil. This in turn avoids any possible contamination between the two oils.





Tironi Lab

Another significant new asset of Tironi is their new Oil Lab, a full capability chemical lab operating within their Quality Management structure. This new lab has been instrumental in testing new natural esters.

Lab tests, including 11 gas DGA tests, are performed in real-time, and results immediately shared and analysed with plant technicians. These tests proved extremely valuable in assisting the decision process during all development phases. Fine-tuning of treatment settings, definition of operational procedures, monitoring dielectric efficiency during each treatment step; all took advantage of the Tironi Lab's readily available data.

This analytical support has proven priceless, resulting in both steady development of treatment practices and straightforward, error free transition from experimental to operational phases.

Finally, analytics performed during the experimental phase turned into first-hand "knowhow", which is currently being applied to production parameter monitoring, ensuring the processes keep within fixed boundaries.

Today, the Tironi Lab has developed fundamental competencies in natural esters dielectric features and has grown into a prominent facility capable of supplying consistent, real-time diagnostics.

Thanks to the accomplishments outlined above, Elettromeccanica Tironi enters into a very elite group of companies capable of designing, manufacturing and testing a 400 kV unit filled with natural ester. With these accomplishments Tironi enters into an even more selective club of companies who are capable of passing a short circuit test for such a high voltage level.

This remarkable success describes very well Tironi's capabilities in engineering and manufacturing and it marks a great starting point for 2020, a year in which Elettromeccanica Tironi will celebrate its 60th Anniversary. That is a remarkable achievement in and of itself.

 **TIRONI**
power transformers

CONTACT **ELETTROMECCANICA**
TIRONI S.r.l.
Via Emilia Est, 1303/D
41122 Modena, Italy
+39 059 282282
sales@tironi.com

