# Interview with R V Talegaonkar, President at CTR Manufacturing Industries Ltd.

## CTR, a market oriented company

CTR Manufacturing Industries Ltd., established in 1964, manufactures and distributes engineering and electronic products with manufacturing facilities at Pune, Aurangabad and Nasik in India.

We have recently built a state-of-the-art HV electrical lab, which allows us to conduct extensive tests to validate materials and the design of tap-changer applications up to 400 kV.

Biodegradable green solutions, higher safety and economical solutions are major drivers for technological advancement, and this is what engineers are required to understand and address. Our engineering is focused on these market requirements. Together with our partners – our suppliers and our clients – we are working on major problems and developing greener, safer, and more economical solutions for transformers.

## Partnership for advanced technology development

One such recent project was the development of two types of natural ester-filled tap-changers: the flange-mounted and the in-tank tap-changer, which was done with the support from Cargill, who provided the Envirotemp™ FR3™ fluid for the experiments.

Some newly developed tap-changers by other manufacturers account for a significant portion of the overall transformer price. While developing countries cannot afford such expenditure, we need an advanced technology which is cost-effective at the same time.

TATA Power also recognized this and encouraged the CTR research team to work on an ester oil-filled on-load tap-changer. TATA Power and other utilities have come forward with advanced technology for green transformers in new tenders.

Our test lab was valuable for testing ester oil-filled on-load tap-changers and Cargill supported the project.

## Extensive experimentation

Over the last two years we have been conducting extensive experiments, looking at the effectiveness of natural ester for the tap-changer application. As a result, we have designed two types of FR3 natural ester-filled tap-changers with the help of transformer manufacturers. There is no doubt the new technology will be accepted by the market. There are a lot of reasons why natural ester has already been accepted worldwide, but it is necessary to develop economical natural ester-based solutions. For tap-changers, as it is a critical component for the transformer, the stability of the fluid was an important criteria in our overall solution.

Our state-of-the-art HV lab has the test facilities for running the short circuit test, dielectric tests at the power frequency, impulse test, temperature rise test and more. So we were able to conduct all these tests and experiments required for this project. In addition, we tested the viscosity of the fluid and, most importantly, the switching duty at the rated current and rated voltage.

The experiments, which were led by R. Nagarajan, Technical Head of CTR, were very extensive and lasted for more than 5,400 hours. They were very successful and confirmed the compatibility of natural ester with all tap-changer components. In this way we were able to prove FR3 natural ester worked in the tap-changer application.

For each tap-changer design, we conducted reference tests with mineral oil, followed by tests with natural ester. This provided data for comparison, which clearly indicated the superiority of natural ester. All tests were conducted in line with the latest IEC 60214-1 standard.

According to the results of all experiments, the tap-changer designs were optimized.

## Dielectric tests

High-voltage tests for the flange-mounted tap-changer were successfully conducted at 70 kV for one minute, which is the standard requirement. Then the voltage was

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**CTR's engineering is focused on market requirements, and the major global requirement today is for biodegradable green solutions, higher safety and more economical solutions**

**Both types of tap-changers were subjected to extensive tests, which confirmed the suitability of FR3 fluid for the tap-changer application**

increased to 80 kV, and there was no PD noise detected. Subsequent tests were conducted at 88 kV for 30 seconds and then at 90 kV. No carbonisation was observed. The impulse test was carried out at 170 kV peak and all parameters were above the required values.

The in-tank tap-changer was tested at 140 kV rms for one minute, and also impulse tested (1.2/50 µs) at 350 kV peak. This type of tap-changer has fibre-glass components, and it could withstand the dielectric stress. We took into consideration the difference in permittivity of the mineral oil and natural ester in the design of our tap-changers.

A critical aspect for dielectric behaviour is the uniform distribution of the electric field. The distribution depends on the mechanical design of the tap-changer, and our tests confirmed that the tap-changers withstand the electric field stress. Analysis of the electric field stress within tap-changers were also conducted, which enabled us to compare the simulation results with the results from dielectric tests.

"Power frequency and impulse tests are very important dielectric tests, which not only proved that these particular tap-changers filled with FR3 fluid can withstand the required tests, but also helped us discover that the dielectric behaviour of a natural ester-filled tap-changer is superior to mineral oil-filled tap-changer, ensuring a higher safety margin," said R. Nagarajan.

## Switching duty test

The tap-changer is the most important transformer component. It contains over 70 groups of parts such as contacts, gaskets, springs, etc. We tested the reaction between the fluid and contacts, the behaviour of the electric field and according to all results, we were able to optimize the mechanical design.

We conducted another important test - the switching duty test. After every 5,000 operations, all the components were checked and all mechanical parts were in order.

## Viscosity test

Viscosity depends on temperature, and information about natural ester- and mineral oil viscosity is already available in the literature. In India, the ambient temperature is around 30-40 °C. The viscosity of natural ester at these temperatures is very close to the viscosity of the mineral oil, and therefore it is suitable for use in the OLTC. But temperatures of 5 °C and lower, there is a big difference between mineral oil and natural ester. While the viscosity of natural ester does increase some at temperatures below 10 °C, compared to mineral oil, natural ester maintains its dielectric strength. Our designs took into consideration this viscosity difference.

"We have successfully tested solutions with stronger spring force suitable for colder climate conditions, such as the Himalayan region where temperatures reach values down to -20 °C, and we are developing a solution for application in even colder climate conditions, so that even at high viscosity, the tap-changing and the switching time will be at an acceptable level," R. Nagarajan further revealed.

## DGA test

DGA is another test that was conducted on the samples from the tap-changer after certain intervals of operation, for which we obtained good results. We looked at a different number of operations – 5,000, 10,000, and 15,000 – and measured the gases, looking at the gas formation for mineral oil and ester. We analysed the gas results by the respective Duval 2 triangle and assessed the behaviour of the tap-changer in the mineral oil and ester. When compared for the same number of operations, the gas generation in the mineral oil was five times higher than in natural ester. We believe that this might indicate that the lifetime of the FR3 fluid-filled tap-changer could be longer than that of the mineral oil-filled tap-changer.

## Contacts resistance test

Tap-changers have different types of contacts. In the FR3-fluid filled tap-changer, the pressurized joints did not display any issues because the fluid could not penetrate through the joint area. Even after 5,000 hours of operation, the contacts were very clear.

However, on the sliding contacts where one side of the contact area is open and the other is continuously exposed to the fluid, resistive films were formed. As the tap-changer switches from one tap to another

**For the same number of operations, we detected five times lower gas generation in the FR3 fluid-filled tap-changer compared to mineral oil**

**Newly developed advancements in FR3 fluid-filled tap-changers are a reliable technology, meeting the latest requirements for safety and environment protection**

and after hours of contact exposure to the fluid, the resistance increases especially in the case of copper to copper joints.

We repeated the same experiment with silver-plated joints. Silver-plated joints are stable, so there was no observable increase of the contact resistance, which solved the issue. Even after a long period of switching of silver-plated contacts in natural ester, the average value of contact resistance remained stable. As the number of operations increased, we also observed that the standard deviation became lower and lower.

The film formation on the contacts is a phenomenon occurring in the mineral oil as well. The IEEE provides the guidelines for film formation on the copper contacts in the mineral oil, instructing what needs to be done on the tap-changers. So, this phenomenon occurs both with natural ester fluids and in the mineral oil, where it is even more graduate. Therefore, copper joints may be used in many places in the mineral oil-filled tap-changers without any problems, and this is a proven solution.

Copper contacts in the mineral oil also display an increase in resistance, but this is not an issue.With natural ester fluid, this is a consideration as the resistance variation is very high, going from micro ohms to milliohms. Considering that the contact resistance must be in the range of micro ohms, a solution was sought and discovered in silver-plated contacts.

While contacts in natural esters need to be taken into consideration, using silver plated contacts avoided any issues.

## Exposing FR3 fluid to air

At the end of the compatibility test, natural ester was exposed to the air for some time to investigate how the break-down voltage reduces. After 5,000 hours, 5,248 to be exact, the break-down voltage was 28.3 kV, which is acceptable by the ASTM standard. FR3 fluid does not deteriorate that fast, which was the basic impression earlier when it was believed that with exposure to the air, the oxygen will attack the molecules of the long chain of the ester. If there are thin films due to polymerization, this is a result of a number of days' exposure to air during routine maintenance, not in normal operation. Therefore, following the mandatory manufacturer instructions when storing and handling natural esters will mitigate any potential issues.

## Enhanced performance

Some utilities retrofit OLTCs, replacing the mineral oil by FR3 fluid and changing the contacts with our assistance. In one case of a transformer equipped with the 11 kV OLTC, after reconditioning the tap-changer and changing the contacts, the OLTC performed 98,000 operations in FR3 fluid without any disturbances or any repair or service work. When the OLTC contacts were opened, they looked as if they had only had 20,000 operations in mineral oil, because the carbonisation was much lower than in the mineral oil. This indicates that contacts life is extensively enhanced.

## Great market response

Having presented these results at a recent international conference, we received a great feedback from a leading global transformer OEM who was convinced by our research and development, which endorsed the use of FR3 fluid for tap-changers up to 400 kV. From here, we are ready to extend our experience from India to the global market.

CTR can offer FR3 fluid-filled tap-changers with enhanced performance, based on the oil quenching technology which is 100 years old, and proven.

Developing our new FR3 fluid-filled tap-changers, we took care that we have a solution that is based on advanced technology but is economical at the same time, which is what the end customers require. At the same time, we have addressed the issue of today's great concern about the environment and its protection, meeting the world-wide requirement for the use of biodegradable fluids such as FR3.

R. Nagarajan, Technical Head of CTR

Newly developed FR3 fluid-filled tap-changers use a reliable technology, meeting the latest requirements for safety, environmental and more.

Today we have a global after-sales support, and collaborating with our partners, we can operate globally.

**R V Talegaonkar** is an electrical engineer with a 35-year professional experience. He joined CTR Manufacturing Industries Ltd. in 1991, where he headed the Marketing Department for almost a decade. From 1999-2000 he was the Tap-changer Divisional Head and he successfully handled the turnaround of the division. In 2003-2004 he was in charge of a new product 400 kV in-tank tap-changer. He was promoted to the President, Group I in 2009-2010. His major contributions are establishment of the second manufacturing setup at Aurangabad in 2004-2005 and the Research Development Centre for type testing of electrical equipment, including tap-changers, at Nasik in 2012-2013. He has represented the company in international and national forums and was a member of the FICCI delegation in China. He is a member of Large High-Voltage Electric Systems (CIGRE). Mr. Talegaonkar is associated with an NGO working with slow learners.