streamer®
keeping the light

TRANSEC

CL series

Online Moisture monitoring
& drying solutions
for oil insulated
transformers

2020

The issue: Moisture is threatening the transformer

Moisture is one of the major cause of failures for power transformers and one of the main degradation factors for the insulation paper. It is therefore increases the risks of operation failures and shortens the life expectancy of the asset.

Unfortunately, moisture can appear in a transformer from several sources which are external or internal and it has a complex dynamic between the oil and paper within the transformer.

The use of silica gel breathers, sealed tanks, or nitrogen blankets can avoid all or at least the most part of moisture from the atmosphere affecting the transformer. However, when the transformer is energized, the production of water inside the power transformer is a natural and inevitable occurrence over time due to the depolymerization of the cellulose paper.

Effect on safety:

As shown on the figure 1, the higher the relative water saturation, the lower the breakdown voltage (BDV) of the oil. As water migrates between the solid and liquid insulation in a transformer with changes in load and, therefore, temperature, so does the relative water saturation in oil. Peaks of relative saturation are usually observed during transformer changes of state (high to low temperature or reverse). Moisture reduction is therefore a key effort to be made to increase safety, especially for Transformer with short and frequent load changes

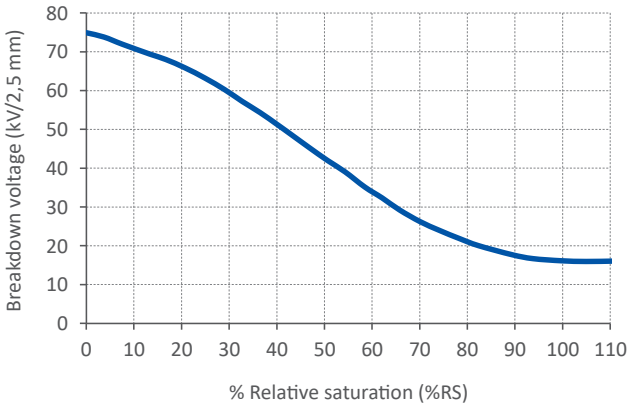


Figure 1. Dependency between breakdown voltage and water content in insulating liquid *

Effect on transformer life expectancy:

The insulation paper mechanical strength is defined by the degree of polimerization, also called DP, which represents the average length of cellulose chains in the paper. A new transformer typically has a DP between 1200 and 1000 while the end of transformer life is considered when the DP falls to 200. This degradation cannot be stopped but its speed will depend on the water content in paper (see figure 2).

In CIGRE brochure D1.01.10 (2007) “Fallou showed that the rate of degradation of the paper at initial value of 4% water content was 20 times greater than that at 0.5 % water content.”

Moisture is having a huge effect on the speed of paper degradation and therefore on its life expectancy.

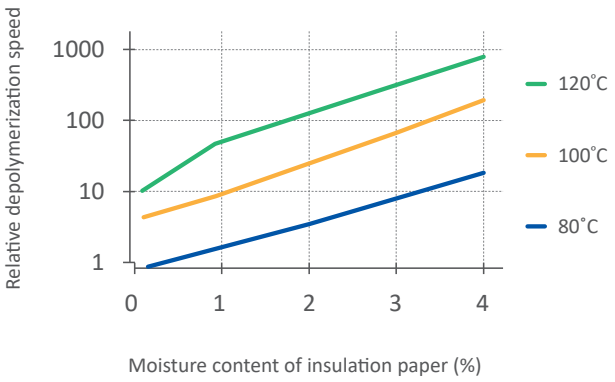


Figure 2. Cellulose depolymerization speed dependence on moisture content in insulation paper for different temperatures **

* CIGRE Moisture measurement and assessment in transformer insulation - evaluation of chemical methods and moisture capacitive sensors, page 10
** CIGRE Moisture measurement and assessment in transformer insulation - evaluation of chemical methods and moisture capacitive sensors, page 14

The solution: Maintaining a dry transformer by continuous filtration

Maintaining a low level of moisture in a transformer provides significant benefits in terms of operations and risk as it maintains a constant high insulation level. It is therefore possible to load the transformer at a higher level and to make this load vary without risking of damaging the transformer.

Also it has consequent financial benefits since it elongates the life of the asset by slowing down the paper degradation. This degradation creates particles or even sludges. Finally moisture is also responsible for the creation of acids in the oil. Hence keeping a low level of moisture will lower the maintenance costs.

Only continuous filtration is efficient in removing moisture from a transformer

As moisture is created continuously and as it is one of the major concern for the transformer safety and life expectancy, it seems counter intuitive to apply a temporary solution for this continuous problem.

Also it is important to note that more than 98% of the water in a transformer is in the paper while a very low amount is dissolved in oil. The diffusion time of water from paper to oil is very slow. This is why punctual filtrations are not solving the moisture issue.

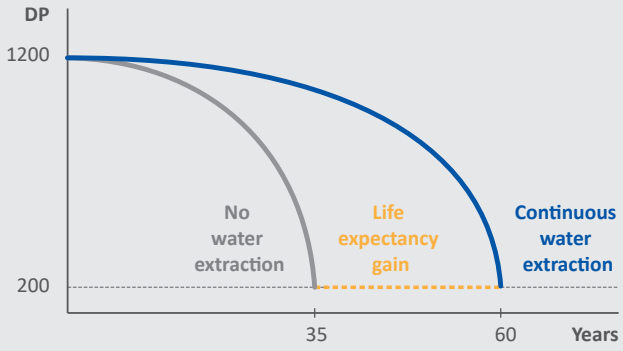


Figure 3. Benefit of continuous online drying system

	Oil filtration	LFH or similar method	Online drying system
Solution type	Temporary	Temporary	Continuous
Transformer live during process	Up to user risk assessment (oil flow >500l per hour)	NO	YES
Dries oil	YES	YES	YES
Dries paper	NO	YES	YES
Improves Breakdown voltage	Temporarily (months)	YES	YES
Extend life expectancy	NO	YES	YES
Dissolved Gasses level maintained	NO	NO	YES
Operator free process	NO	NO	YES
Cost	$	$ $ $	$

The solution: TRANSEC online drying system

1. Outflow to transformer
2. Deaerator
3. Outflow sample valve
4. Outflow PPM/Temp sensor
5. In-line particle filter
6. Intermediate air bleed valve
7. Quick release connection
8. Molecular Sieve removal cylinders
9. Optional moisture monitoring box
10. Outlet air bleed valve
11. Optional particle pre-filter
12. Inflow PPM/Temp sensor
13. Oil Flow Indicator
14. Pump
15. Inflow sample valve
16. Inflow from transformer
17. Optional standing frame

TRANSEC Online Drying System uses molecular sieves in order to extract moisture from the oil. These granules (non chemical) contain many pores of 3 Angstrom diameter which is the exact size to catch water molecules. That way other components like gases molecules with larger or smaller diameter are not filtered by these sieves.

	CL1	CL3
Recommended transformer size	Below 10 MVA	10 MVA and above
Water extraction capacity before cylinder change	3 to 4 litres	10 to 12 litres
Flow rate	60 to 90 litre per hour	
Particule filter	10 microns; 5 microns in option	
Material	304 grade stainless steel	
Oil temperature range	0°C to 105°C	
Acceptable environment condition	0°C to 80°C (below 0°C please consult us)	
Protection class	IP55	
Power Supply	240V 50Hz or 110V 60Hz	
Pump	Canned Rotor circulation pump Max current 0.8A @240V & 1.5A @110V Nitrile BA70 gaskets	
Monitoring	Available in option. See page 7	
Size	1950 x 455 x 320	1950 x 705 x 320
Installation weight (including cylinders)	90 kg	170 kg
Installation time	5 to 6h with 2 people	
Manufacturing type test	3 bar pressure @ 110°C for 1h	
Manufacturing routine test	2 bar pressure @ 60°C for 30 min	

The issue: Assessing the amount of water in the transformer

1. More than 98% of the water present in the transformer is contained in the paper insulation while less than 2% is in the oil. Unfortunately the insulation paper is not easily accessible for water assessment.

2. Water solubility in oil varies depending on oil temperature and therefore PPM varies also. Hence it is not possible to just check the PPM value to define the amount of water in paper.

3. If PPM and oil temperature are known some curves exist (see Oomen curves figure 4) in order to link the water PPM in oil and the water content in paper. But these curves are only really valid at equilibrium which is in general never reached on a running transformer.

4. As the water diffusion time is faster from the paper to the oil than the opposite it is possible to reach on a same transformer several very different PPM values for the same oil temperature even at a few days difference (see figure 5).

5. As a result of the previous points, taking an oil sample once or twice per year in order to assess the moisture level in the transformer seems irrelevant.

6. Furthermore, oil samples can be contaminated at the sampling time or in the laboratory. As the moisture level is anyway very low in oil, any contamination (simple contact with the ambient air) will affect the sample ppm result. The chart (figure 6) shows PPM analysis results of 7 different laboratories on 3 different oil samples. It is clear that for moisture analysis the error range is very wide.

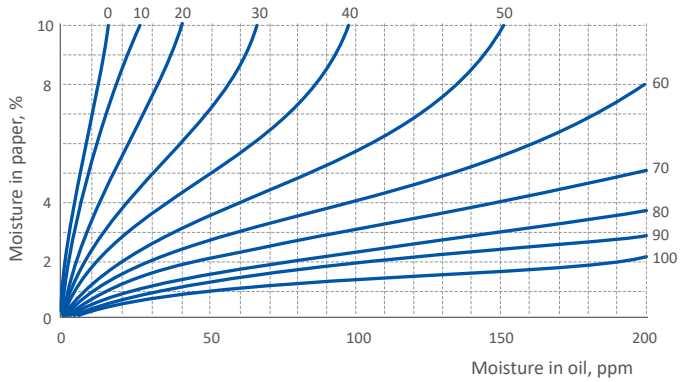


Figure 4. Moisture Equilibrium curves* (Oomen)

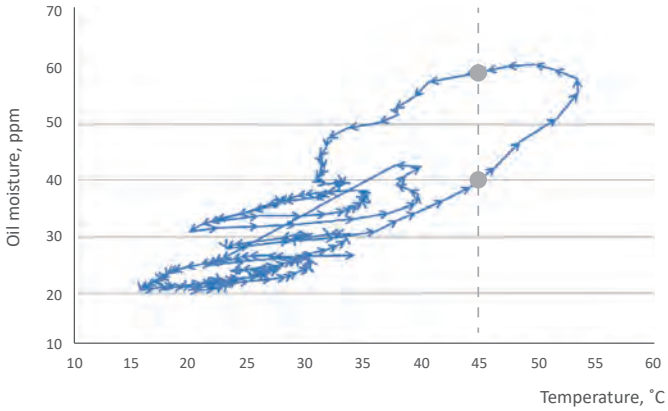


Figure 5. Moisture dynamics: hysteresis**

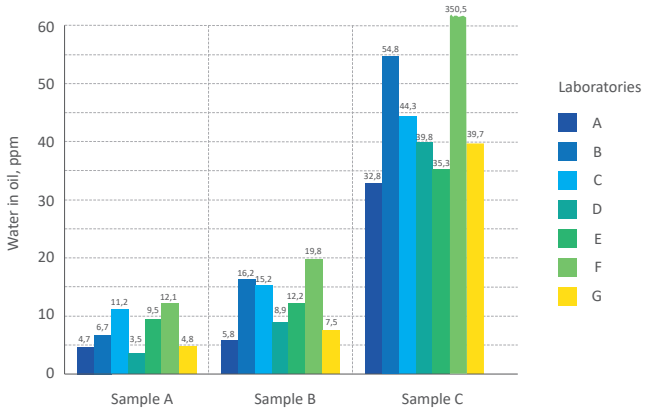


Figure 6. Reliability and Improvements of Water Titration*** by the Karl Fischer Technique

M. Koch1, S. Tenbohlen1, J. Blennow2, I. Hoehlein3*

* CIGRE Moisture measurement and assessment in transformer insulation - evaluation of chemical methods and moisture capacitive sensors, page 74
** Moisture in transformer Oil Behaviour, page 14
*** Reliability and Improvements of Water Titration by the Karl Fischer Technique, page 4

The Solution: Continuous moisture assessment

1. Moisture and temperature sensors within the oil

TRANSEC Online Moisture Monitoring system uses the moisture and temperature sensors MMT162 from VAISALA on the inlet and on the outlet of the system in order to monitor the PPM and temperature of the oil flowing through the TRANSEC. This data is transferred to the TRANSEC monitoring box for analysis.

As the sensors are immerged in oil there is no risk from external contamination and as the sensors are not changing the repeatability is ensured.

VAISALA MMT162

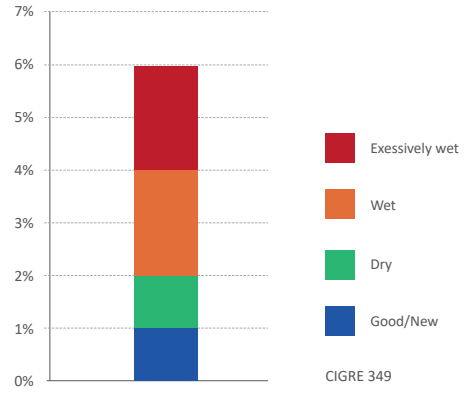


Figure 7. Water content in paper in %

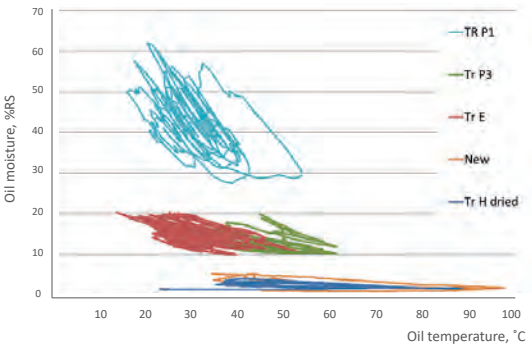


Figure 8. Hysteresis loops of %RS vs temperature in transformers with different moisture level*

* CIGRE Moisture measurement and assessment in transformer insulation - evaluation of chemical methods and moisture capacitive sensors, page 100

2. Continuous checking

Thanks to the constant sampling from the MMT162, the PPM and temperature can be followed remotely on the webserver which allows assessment of the moisture level in the transformer and to observe the effect of the filtration.

- Based on the Oomen curve calculation the trend of the water content in paper can be followed (see figure 7)

- Monitoring the PPM vs Temperature hysteresis enables observation of its shape. A narrow shape below 20% moisture shows a healthy transformer while a broad hysteresis exceeding 20% relative saturation (TR P1) on the picture below is a sign of a moist transformer.

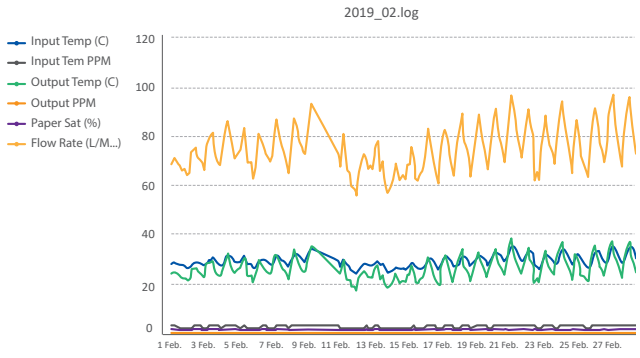


Figure 9. Transec webserver downloadable logs

The Solution: Continuous moisture assessment with the TRANSEC monitoring

Streamer offers 3 types of moisture monitoring cabinets:

- The basic type is with a local display showing the PPM of moisture and the oil temperature from two VAISALA MMT162 sensors. This data can also be transferred remotely through 4-20 mA analog outputs.

- The second version is similar to the basic cabinet except that the data is transferred through fiber optic

- Finally an advanced type with an integrated webserver offering a comprehensive view and analysis of the moisture situation within the transformer. It is also possible to access the data remotely, save it and to set alarms. Data is available locally on the display or remotely via a connection RJ45 or Ethernet

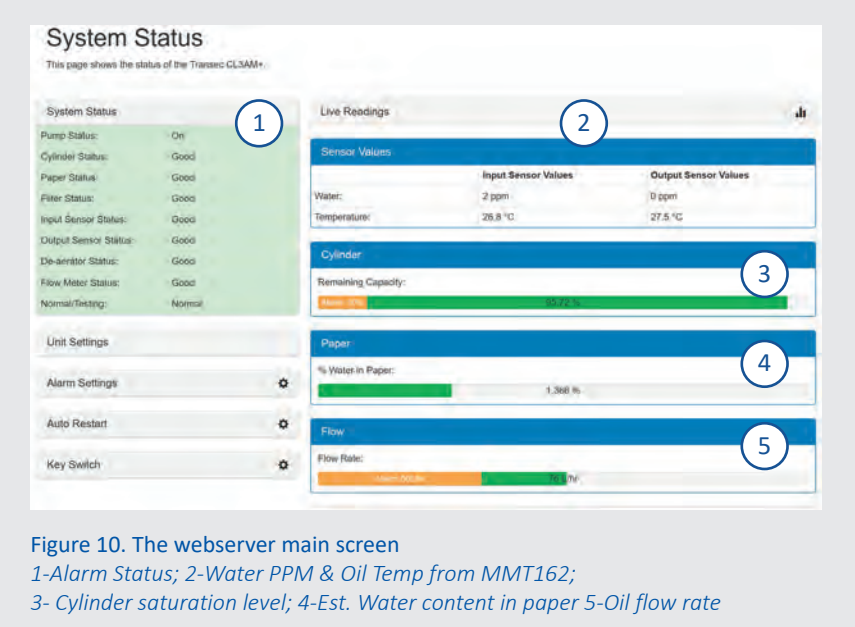
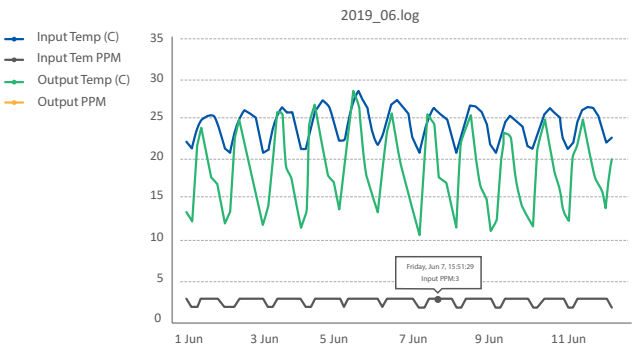


Figure 10. The webserver main screen
1-Alarm Status; 2-Water PPM & Oil Temp from MMT162;
3- Cylinder saturation level; 4-Est. Water content in paper 5-Oil flow rate

Figure 11. The Webserver Monitoring cabinet



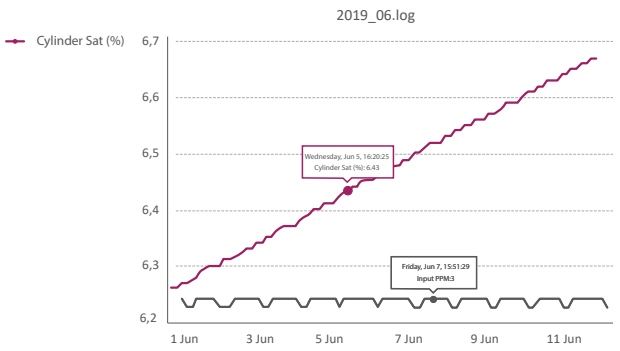


Figure 12. Examples of available logs on the webserver:
Left: the values of PPM of moisture and oil temperature of the input & output of a Transec unit
Right: The cylinder saturarion percentage over 2 weeks

What to do when the moisture extraction cylinders are saturated?

The first thing to do is to contact your local representative of Streamer Electric AG. Streamer make an effort to find companies close to you in order to support you efficiently. Local representatives are hold a stock of ready cylinders which they can provide to you.

TRANSEC units can typically extract between 3 to 4 liters of water per cylinder before saturation. The rate of extraction is directly linked to the amount of water available in the transformer. The higher moisture content and the warmer the oil is, the faster the extraction will be. You can find typical saturation time below.

The cylinder saturation can be determined either by the TRANSEC monitoring system or by comparing water PPM in 2 oil samples (inlet & outlet).

A set of saturated cylinders can be removed and replaced while the transformer is online by new cylinders within 30 min.

Characteristics

	Typical time for extraction of 10 litres of water
New transformer water content <1%	5 years
Old/Wet transformer water content >3%	6-12 months
Moderately wet transformer water content = 2%	2 years

Possible accessories for a Transec unit:

PREFILTER

An additional pre filter can be installed in case of a heavy-sludge transformer to extract solid impurities from the transformer oil before entering to the cylinder sieves.

ENCLOSURE

In the requirement of special protection and aesthetics, a metal enclosure made of either Aluminium or Stainless steel can be installed to cover the unit.

SLAM SHUT VALVE

In the event of a leak, detected by a pressure sensor, the control circuit trips the pump, simultaneously closing the Solenoid valve, thus shutting the inlet pipe connection to the TRANSEC unit.

Product Selection guide

TRANSEC UNIT	TR.CL.	X	X X	X	X	X	X	. 0
Amount of Cylinders	1 cylinder (4 liters of water extraction)	1						
	3 cylinder (12 liters of water extraction)	3						
	3 cylinder (12 liters of water extraction)- Webserver ready	W						
Monitoring	No Monitoring		0 0					
	Monitoring with local display & Analog output		A M					
	Monitoring with local display & Fiber optic IEC61850		F O					
	Monitoring with local display & Ethernet & webserver IEC 61850*		W S					
Standing Frame	No standing frame. Installation on transformer or a on wall			0				
	Standing frame to be bolted on the ground			1				
	Standing frame «free standing» without bolting			2				
Pump/Power Supply	50Hz 240VAC				5			
	60Hz 120VAC				6			
Oil inside cylinders	Un-inhibited napthynic oil IEC 60296					U		
	Inhibited napthynic oil IEC 60296					I		
	Other (please specify)					O		
Filters	Standard 10 micron in-line filter						0	
	IDLD SS In-line filter 10 microns						1	
	IDLD SS In-line filter 10 microns + PALL UR219 pre-filter 5 microns						2	
	Standard 10 micron in-line filter + PALL UR219 pre-filter 5 microns						3	
Version								0

* only available for Webserver ready products

MONITORING UNIT

TR.MT.00AM.00.WW	Monitoring box AM with local display & Analog outputs
TR.MT.00FO.00.WW	Monitoring with local display & Fiber optic IEC61850
TR.MT.00WS.00.WW	Monitoring with local display & Ethernet & webserver IEC 61850*
TR.SR.MONI.UP.WW	Service for Monitoring box installation

ACCESSORIES

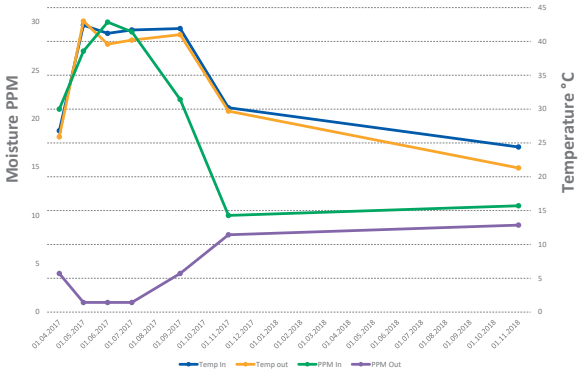
TR.AC.NCYL.03.WW	3 new cylinders
TR.AC.IKIT.00.WW	Installation kit: 2x Male Stud Couplings, 1x Reducing tee, 1x Brass stud coupling, 3m copper tube, 1x Non return valve, 2x 2m tube SS 15mm cold annealed
TR.AC.FLAN.15.WW	Flanges for installlation DN15
TR.AC.FLAN.25.WW	Flanges for installlation DN25
TR.AC.FLAN.50.WW	Flanges for installlation DN50
TR.AC.FLAN.00.WW	Flanges for installation (size to be specified)
TR.AC.GGAU.00.WW	Glass Gauge on deaerator*
TR.AC.SLSV.00.WW	Slam Shut Valve
TR.AC.ENCL.AL.WW	Aluminum Enclosure

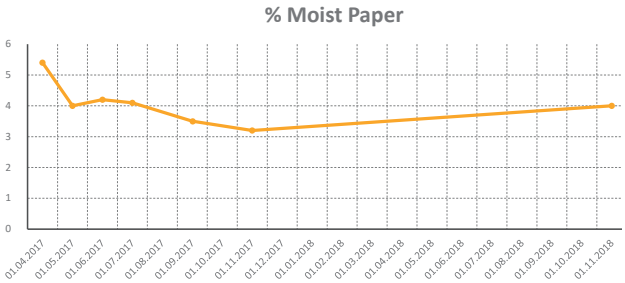
SERVICES

TR.SR.REGE.03.WW	Regeneration of 3 cylinders
TR.SR.SINS.00.WW	Installation Supervision
TR.SR.INSP.00.WW	Transformer inspection
TR.SR.MONI.UP.WW	Service for Monitoring box installation
TR.SR.MODI.00.WW	Product modification service

More than 15 years of successful experience

A TRANSEC unit was installed in November 2017 on 40 MVA General Electric 3 phases transformers in the Dammam region, Saudi Arabia. This 115kV/13.2kV transformer from the 1970s had reached a very high water content in paper (above 5%) and needed urgent drying. Once installed the TRANSEC started removing moisture from the oil immediately. It provided a positive effect on the breakdown voltage value. In a second step water started to get extracted from the paper as the oil got dried out after a few weeks. Over the 1st year you can see on the 2 graphs that the PPM inflow and the water content are dropping. Within that year the water content in paper went from 5% to about 3% (much more acceptable level). We can also see that during the second year of operation the PPM values of inflow and outflow were almost matching which is a sign of water saturation in the Transec unit. This is confirmed by the water content increasing again to 4% at the end of the second year. The saturated TRANSEC extraction cylinders are then replaced by new ones in order to restart the filtering process. They had extracted about 12 litres of water from that transformer within 1 year.

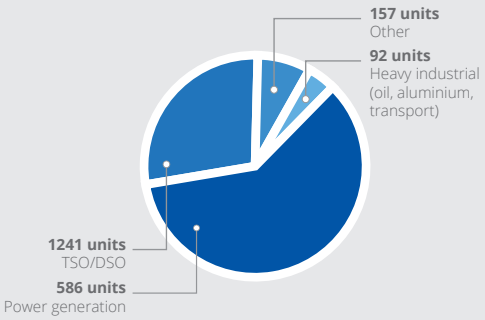




More than 2500 units installed by end of 2019

Major Clients:

ALSTOM · e·on · ABB · BRUSH · BHEL · EDF · UK Power Networks Delivering your energy · dubal Dubai Aluminium · Power Grid Corporation of India · Gaz de France



For notes

Streamer Electric AG, HQ

Masanserstrasse 17
CH-7000
Chur, SWITZERLAND
Phone: +41 81 2500525

office@streamer-electric.com
www.streamer-electric.com

Streamer Asia-Pacific

Asoke Towers- The Pride, Room 203
219/2 Sukhumwit 21, Asoke
Klong Toel Nua, Wattana
10110 Bangkok, THAILAND
Phone: +66 (0)2 1209600

Streamer China

You Town Center Block A
Chaoyang Qu,
Beijing Shi, CHINA
Phone: +86 8565 1663

Streamer Indonesia

Wilson Walton Building
Jl. Raya Tanjung Barat 155 Jagakarsa,
Jakarta, INDONESIA
Phone: +62 21 7884 0737

Streamer Electric AG

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