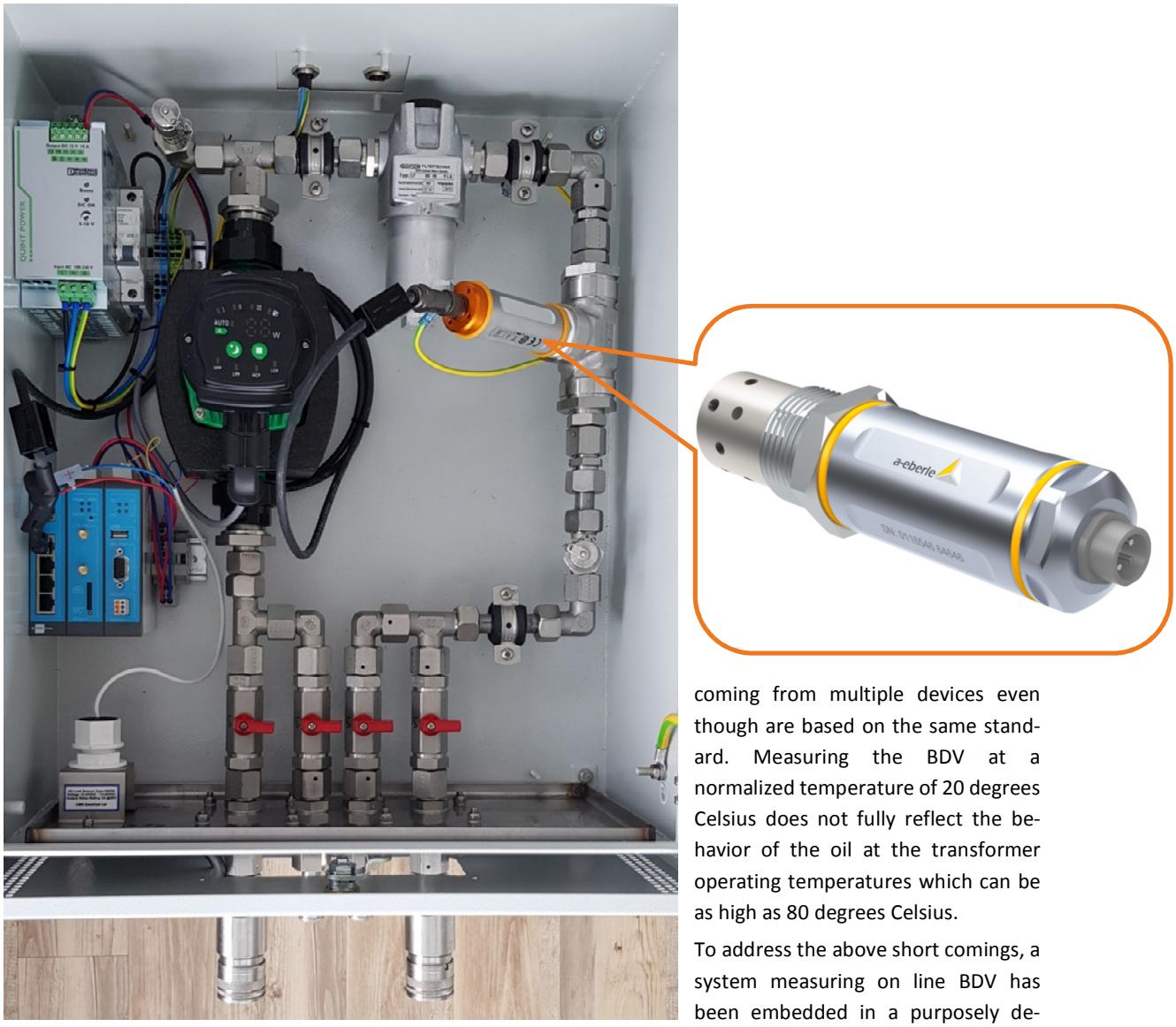
TraCoMo™ / Trafostick™

Online Break Down Voltage (BDV) Measurement System



1. Application

Each transformer is unique due to its own history, ageing stage and loading patterns. The transformer oil is a witness to all the history that a transformer has. An essential parameter of the transformer oil is the Break Down Voltage (BDV). Enhancing power grid operator capabilities by measuring on-line transformer oil BDV is a must, since off-line measurements are generally tainted by unwanted humidity, captured in the oil samples, which are influencing the results. In addition there is a large variability of the measurement outcomes coming from multiple devices even though are based on the same standard. Measuring the BDV at a normalized temperature of 20 degrees Celsius does not fully reflect the behavior of the oil at the transformer operating temperatures which can be as high as 80 degrees Celsius.

To address the above short comings, a system measuring on line BDV has been embedded in a purposely designed cabinet

This measurement system is part of the overall Tranformer Condition Monitoring (TraCoMo™) offering The system is using an innovative TrafoStick™ sensor, a multi-frequency ultrasound spectroscopy based measurement device, designed to work over many types of transformer oils, their humidity and temperature ranges.

2. Benefits

- On-line measurements using multi-frequency ultra-sound spectroscopy
- • World premiere - unique single device simultaneously executing measurements of most important operating parameters of transformer insulation oil:
- – Basic version: On-line breakdown voltage (BDV) determination considering influence of particles, temperature and oil humidity
- – Advanced version: Basic version plus viscosity and density
- • TrafoStick™ is an acoustic spectrometer that covers the full oil temperature range of the transformer
- • TrafoStick™ is specially designed for the content analysis and the corresponding parameters of transformer oils – it is compatible with a wide range of transformer oil types
- • SCADA communication via Modbus TCP

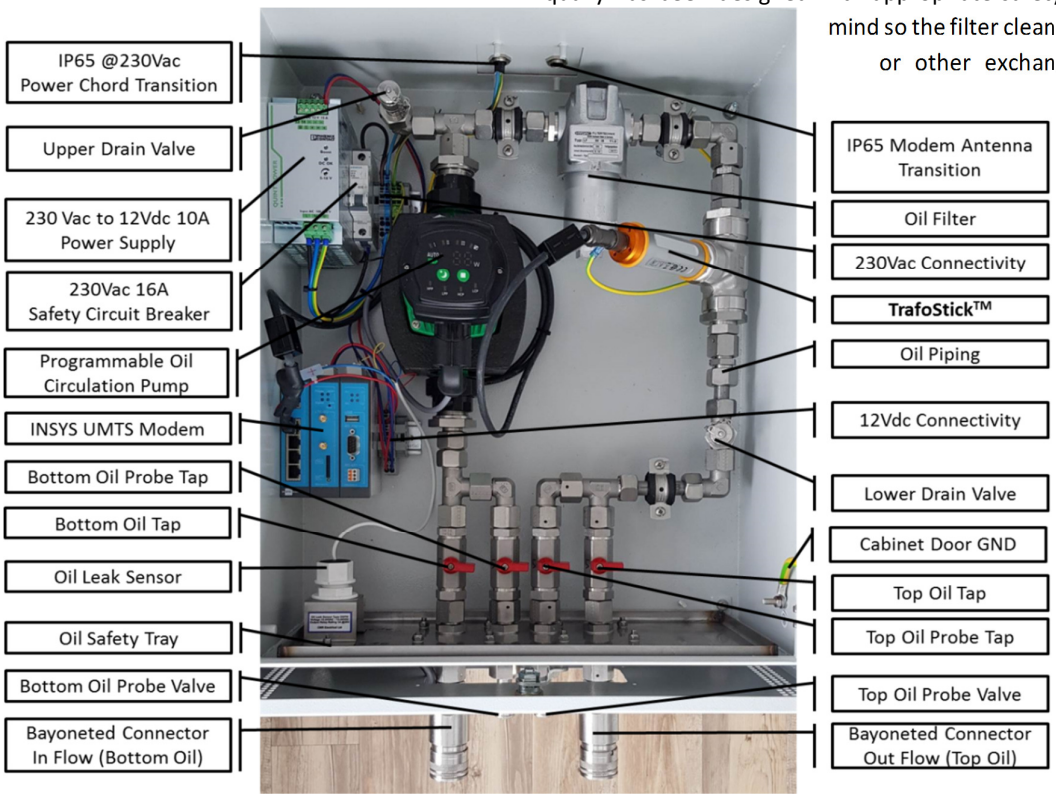
3. System architecture

The overall system architecture is as shown in figure below and it consists of the following major components:

- The Trafostick™ Sensor
- A programmable oil circulation pump
- Specialized bayoneted type valves and taps for easy connection and flow control
- An oil filter
- An oil leak sensor
- An UMTS cyber-secure modem capable for Modbus TCP data transmission and annunciation of oil leaks detected

The TraCoMo™ system has been designed for a seamless connection to the transformer filling oil vanes or to the top and bottom oil probing taps. Since those connection points are going to be in use it has embedded the possibility to collect oil samples for laboratory analysis.

Equally has been designed with appropriate safety in mind so the filter clean-up or other exchanges



can be performed without oil leaks. In addition as an additional safety measure the cabinet has an oil capture tray fitted with an oil leak sensor wired to the binary input of an UMTS modem for email annunciation.

A key component of this cabinet is the INSYS UMTS modem that via a cyber secure encrypted VPN tunnel can forward using the Modbus TCP protocol the BDV measurement at operating temperatures to the Power Utility Operating Center SCADA system or and also provide leakage annunciation. This allows the maintenance personnel to react timely, before the onset of faults both at the level of the transformer but also the device itself.

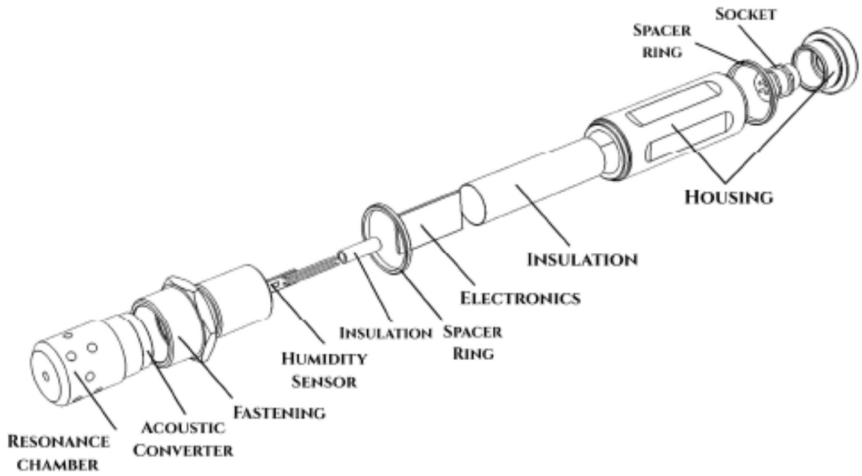
4. Trafostick™

Trafostick™ is the central sensor of the TraCoMo™ BDV cabinet solution and it represents an ultrasound sensor, which measures phase shifts, and signal amplitudes of the sound waves and combines them with humidity and temperature to provide the inference data for the BDV determination.

A TrafoStick™ , as shown in the adjacent exploded-view graphic, has been designed for manufacturing and it sensitive enough to be used as an online sensor but at the same time, robust enough to sustain the everyday the environment of a working power transformer, with several mega volts ampere, for a long time.

The hardware implementation of the acoustic solution relies on an aluminum coated piezoelectric resonator. For this custom engineered solution a suitable built in humidity and temperature sensor from SENSIRION the SHT3x Series (https://www.sensirion.com) has been used. This CMOSens® Technology based sensor combines the strengths of standard CMOS production processes and advanced MEMS technology on a single silicon chip. The temperature sensor is based on a silicon bandgap temperature sensing principle. The humidity sensor is using a capacitor that has its dielectric realized through a polymer, which absorbs or desorbs water depending on the ambient humidity. The capacitive element is designed as interdigitated electrodes.

The rugged and reliable construction has all crucial and fragile components covered and protected by a robust interplay of housing materials. The resonance chamber and acoustic converter located on the lower left end part holds the resonator as well as the integrated humidity and temperature sensor. The fastening is made up of a one inch pipe thread and it is used to secure the sensor in place within the TraCoMo™ transformer mounted cabinet. The electronics are bonded by an insulation made out of a synthetic material. Further housing, spacer rings and a socket are added in order to establish a connection with the sensor via MODBUS



TCP. The sensor is powered by a 12Vdc/0.3mA external power supply. The sensor and the Ethernet available connectivity was designed with a connector cable that has adequate protection built in.

The TrafoStick™ has been also designed to be suitable to long term exposure to transformer oils and hence tested and calibrated by evaluating more than 3800 laboratory collected oil samples coming from over 900 power transformers, all belonging to the same company operating on Shell Diala S3 and S4 oils. The computation, which captures the strong correlation between humidity in oil (Wc), total acid number (TAN), temperature (T) and Break Down Voltage (BDV), has been handled within the sensor by a 32-bit embedded system by a floating-point unit (FPU) via a lookup table. This lookup table is an adequate representation, which also includes already the border behavior of the oil samples. More information about the analytic method

can be find by: „Acoustic hybrid sensor for BDV monitoring in insulating oil“; Ultrasonics Symposium (IUS), 2017 IEEE International; ISBN: 978-1-5386-3384-7

5. Installation & Commissioning

The entire system has been conceived for a seamless installation and commissioning process that does not require taking the transformer off line.

The whole installation process starts with a site survey that involves the geometry of the transformer oil vanes (the ones used for filling or for taking oil samples), the availability of tap fittings, the availability of 230Vac power by the transformer, the best mounting solution (on a pedestal or by the transformer wall itself).

Based on this survey the appropriate oil pipes and fittings are being manufactured as well as the right crew is deployed to ensure the oil and power connectivity. This is followed by the delivery of the TraCoMo™ device including the mounting kit (stand or rail) and the connector pipes and valves including suitable flanges or fittings. As guideline the mounting of the device should happen by the transformer, near the oil vanes, since the maximum length of oil pipes is 5m. After the oil pipe connection, the system aeration and sealing test the connection to mains and test of all electrical devices contained in the cabinet should happen. At this point the functionality of the system is being checked with a local laptop.

Following these steps the connectivity direct to SCADA or via the INSYS UMTS modem with VPN connectivity has to be provisioned. This also involves verifying that the data provided by the device fits the latest laboratory oil analysis as well as it helps ensure that the online monitoring has its alarms settings well provisioned.

A typical installation, when all the required parts are available can take a half day’s work by specialized personnel.

6. Technical characteristic values

Regulations and standards

- EN 61000-4-2:2011
- EN 61000-4-3:2014
- EN 61000-4-4:2013
- EN 61000-4-5:2014
- EN 61000-4-6:2014
- EN 61000-4-11:2007
- CISPR11:2015+AMD1:2016, EN55011:2016+A1:2017, EN55011:2016+A1:2017-06
- EN 60950-1:2007 +A11:2009 +A1:2011 +A12:2011

Measurements quantities	
Temperature	Deg C
Humidity	RS% and ppm (calc)
AcDist	Nondimensional (calc)
BDV @ Op. Temp.	kV (calc)
BDV @ 20 deg C	kV (calc)

Measurement Ranges	
Temperature	-40°C ÷ 120°C (±0,2°C)
Relative Humidity	0÷1 (2%)
Water Content	up to 80ppm (from 0,5% to 7%)
BDV	10÷100kV (from 1% to 5%)

Reference conditions	
Reference temperature	23°C ± 1 K
Input voltage	230Vac +- 10%
Auxiliary voltage	12 Vdc
Frequency	50 Hz
Load	25W
Oil pressure	1 bar (sensor up to 3 bar)

Data acquisition	
Sampling rate	0.1 Hz – Modbus Value refreshing 1 Hz (1 MPS)
ADC resolution	12 bit
Oil Leak monitoring	
Limit values	2mm of oil in collector tray
Response times	20 ms
Binary signal	12 Vdc
Alarm displays	Email - programmable

Electrical safety	
Protection class	I
Degree of pollution	2
Overvoltage category	II
12 Vdc	**230 Vac**
Trafostick™ Oil Leak Sensor INSYS Modem	Oil Pump 12 Vdc Power supply

Power supply		
Feature	**AC Input**	**DC Output**
Voltage	100 ... 264 V	10-15 V
Power consumption.	≤ 25 VA	≤ 15 VA

Electrical safety		
Frequency	50 Hz	
Microfuse	T2 250 V	T2 250 V

Climatic stability	
– Function (housing, sensor, pump, power supply)	-30 °C ... +85 °
– Function (INSYS modem)	-30 °C ... +80 °C (refer to INSYS restricted)
– Transport and storage	-40°C ... +85 °C

7. Mechanical design

Cabinet	
Material	aluminium, RAL 7035 grey
Height	700 mm
Width	530 mm
Depth	265 mm
Weight	≤ 20.0 kg
Mounting	DIN 41494 part 5

8. Ordering information

FEATURE	Design Number
Wall mounted cabinet unit - system suitable for one transformer	100.9062.01
Operating manuals in: 0 German 0 English	 G1 G2

Notes

A. Eberle GmbH & Co. KG

Frankenstrasse 160
D-90461 Nuremberg

Tel.: +49 (0) 911 / 62 81 08-0
Fax: +49 (0) 911 / 62 81 08 96
E-Mail: info@a-eberle.de

http://www.a-eberle.de