Overview Online Transformer Monitoring

Voltage, Current, Oil and Ambient Temperature, On load Tap Changer, Gases and Bushing, etc,

“ABB” monitoring system (converts raw data into useful informations)
Overview  Online Transformer Monitoring

Control Room
Short Introduction of the TEC System

- Fiber optic cable
- TCP/IP Ethernet network cable
- Converter box TC 190
- USB Serial adapter
- Remote computer
- Laptop during installation
- RS232 Serial cable
- Optional TEC Server, Modem, etc
- Cables to/from the transformer
Frequent Questions by End User

- Why Transformer monitoring?
- What are the cost benefits?
- When should I install?
- What is the Minimum Size of Transformer to install?
- What are the sensors that I should install?
- What are the functions that I should install?
- Configuration / Communication in the network?
- How many days take to install in the old Transformer?
Benefits of the Monitoring System

- Early identification of a fault evolution.
- Avoid costly unplanned outages.
- Avoid catastrophic failures.
- Extended life time of the Transformer
- Reduces maintenance costs of the Transformer
- Reduced risk of the transformer failure and grid blackout
- Increase the operational availability of the Transformer
- Reduces maintenance costs of the On load Tap changers
- Reduces costs of insurance policy with the insurance company
- Continually assess the operational status of the transformer.
- Enhanced overload capability through intelligent cooling control
- Assist in maintenance planning.
- Store properly a lot of data
Place of Development & Manufacturing

- Over 100 year of Transformer Experience.
- 100% Developed and Manufactured by ABB.
- 04 year of Development
  - 02 year on Laboratory
  - 02 year on Site
- Fingerprint Concept.
- On-line Monitoring Data in real time.
- Friendly device for User

TEC

Ludvika Factory - Sweden
TEC – Transformer Electronic Control

**TEC**
(since 2003)

**TEC Smart**
(since 2011)
More than 1000 units delivered since 2003
Global Reference List 2003 - 2012

Source: PPTR/AT
## TEC Reference List - Chile

<table>
<thead>
<tr>
<th>Dest. Country</th>
<th>End user</th>
<th>Del. Year</th>
<th>Qty</th>
<th>MVA</th>
<th>Voltage kV</th>
<th>ABB Factory</th>
<th>Project</th>
<th>TEC Version</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chile</td>
<td>CODELCA</td>
<td>2007</td>
<td>1</td>
<td>100</td>
<td>220/23</td>
<td>Guarulhos</td>
<td>CODELCA</td>
<td>2.00</td>
</tr>
<tr>
<td>Chile</td>
<td>CODELCO</td>
<td>2008</td>
<td>2</td>
<td>50</td>
<td>100/13.8</td>
<td>Guarulhos</td>
<td></td>
<td>2.00</td>
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<tr>
<td>Chile</td>
<td>Transelec</td>
<td>2009</td>
<td>3</td>
<td>250</td>
<td>525/230</td>
<td>Guarulhos</td>
<td>polpaico</td>
<td>2.01</td>
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<tr>
<td>Chile</td>
<td>Transelec</td>
<td>2009</td>
<td>1</td>
<td>-</td>
<td>-</td>
<td>Guarulhos</td>
<td>polpaico</td>
<td>APC</td>
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<tr>
<td>Chile</td>
<td>Compañía Minera Doña Ines de Collahausi</td>
<td>2011</td>
<td>2</td>
<td>100</td>
<td>220/23</td>
<td>Cordoba</td>
<td>Compañía Minera Doña Ines de Collahausi</td>
<td>2.01</td>
</tr>
<tr>
<td>Chile</td>
<td>Minera Candelaria</td>
<td>2011</td>
<td>1</td>
<td>83.3</td>
<td>220/23</td>
<td>Trapagarán</td>
<td>Minera Candelaria</td>
<td>2.01</td>
</tr>
</tbody>
</table>
Installation Version in the Transformer Tank

TEC

TEC Smart
TEC Cabinet Installation

New Transformers

Old Transformers

Non-ABB Transformers
TEC – Transformer Electronic Control

- It is based on a microprocessor.
- Modular and expandable system.
- Do not need the PC for storage of data.
- Communication of data over fiber optics.
- Easy to install and mount.
- Based on approved technology.
- Bus communication with sensors.
- Reduced cabling on transformer
- Electronic components – Military grade

Protocol board:
- IEC 61850
- IEC 60870
- DNP 3
- Others
## Certificate Tests

### EMC (Electro Magnetic Compatibility) tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Severity</th>
<th>Duration</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Radiation</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conducted</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fast transient</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Electromagnetic fields</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>RF emissions</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Immunity</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Radiated RF fields</td>
<td>15 V/m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Mechanical tests, vibration and seismic

The TEC unit manufactured by ABB in Sweden has been subjected to mechanical testing as specified below.

### Climate tests

#### Operational tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Test equipment</th>
<th>Severity</th>
<th>Duration</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>In operation</td>
<td>-10°C</td>
<td>16 hours</td>
<td>IEC 60068-2-1, Test Ad</td>
</tr>
<tr>
<td>Dry heat</td>
<td>In operation</td>
<td>+55°C</td>
<td>16 hours</td>
<td>IEC 60068-2-2, Test Bd</td>
</tr>
<tr>
<td>Damp heat (steady state)</td>
<td>In operation</td>
<td>+40°C &gt; 93 % non-condensing</td>
<td>4 days</td>
<td>IEC 60068-2-78, Test Cab</td>
</tr>
<tr>
<td>Change of temperature</td>
<td>In operation</td>
<td>+5°C to +55°C</td>
<td>3 cycles</td>
<td>IEC 60068-2-14, Test Nb</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Storage tests

<table>
<thead>
<tr>
<th>Test</th>
<th>Test equipment</th>
<th>Severity</th>
<th>Duration</th>
<th>Standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cold</td>
<td>In storage</td>
<td>-40°C</td>
<td>96 hours</td>
<td>IEC 60068-2-1, Test Ab</td>
</tr>
<tr>
<td>Dry heat</td>
<td>In storage</td>
<td>+70°C</td>
<td>96 hours</td>
<td>IEC 60068-2-2, Test Bb</td>
</tr>
</tbody>
</table>

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June 5, 2013 | Slide 16
User Friendly Interface

No special computer is needed

Dual language support
Display Interface

Important information available at the transformer in real-time

- Press to see next value
- Press and hold (> 3 sec) to see active events
## Design Data – Fingerprint Concept

| RI2 losses high voltage winding | kW | 89.5 | 32.2 |
| RI2 losses low voltage winding | kW | 131.0 | 47.2 |
| RI2 losses tertiary winding | kW | N/A | N/A |
| Eddy losses in high voltage winding | kW | 8.3 | 3.0 |
| Eddy losses in low voltage winding | kW | 9.55 | 3.4 |
| Eddy losses in tertiary winding | kW | N/A | N/A |

### Calculated values for type test

| Top oil temperature rise | °C | 56.5 | 58 |
| Average oil temperature rise | °C | 41.5 | 49 |
| No load loss at test | kW | 124 | 124 |
| Load losses at test | - | 764 | 275 |
| Tap-changer position | - | -2X2.5%(2) | -2X2.5%(2) |
| Current high voltage winding | A | 510.5 | 306.3 |
| Current low voltage winding | A | 1600 | 960 |
| Current tertiary voltage winding | A | N/A | N/A |
| Hot-spot temperature high volt. wind. | °C | 74.3 | 67.5 |
| Hot-spot temperature low volt. wind. | °C | 75.3 | 67.5 |
| Hot-spot temperature tertiary volt. wind. | °C | N/A | N/A |
| Temperature gradient high volt. wind. | °C | 17.8 (3) | 9.5(3) |
| Temperature gradient low volt. wind. | °C | 18.8(3) | 9.5(3) |
| Temperature gradient tertiary volt. wind. | °C | N/A | N/A |

### Mass parameters

| Cu-Mass of high voltage winding | kg | 4461 kg/limb |
| Cu-Mass of low voltage winding | kg | 3337 kg/limb |
| Cu-Mass of tertiary winding | kg | N/A |
| Free oil | kg | 99915 |
| Oil in insulation | kg | 4000 |
| Core steel mass | kg | 89049 |
| Other steel mass (tank, yoke plate, etc.) | kg | 67000 |
| Paper mass | kg | 438 |

### Type test values

| Ambient temperature | °C | - |
| Top oil temperature rise | °C | - |
Temperatures, Gases, OLTC Curves and Event List
Overload Capacity

- Shows overload capacity
- Based on Transformer data, ambient temperature and loading conditions

<table>
<thead>
<tr>
<th>Ageing:</th>
<th>11287300 h</th>
<th>Relative now:</th>
<th>0%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Load ratio</td>
<td>35% (214 MVA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Overload capacity:</td>
<td>128% (795 MVA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>15min</td>
<td>150% (932 MVA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>30min</td>
<td>150% (932 MVA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>60min</td>
<td>143% (886 MVA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>120min</td>
<td>134% (835 MVA)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top oil trend</td>
<td>-10 K/h</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Hot-spot Temperature Calculation – IEC & IEEE

**IEC-354**

\[ \Theta_h = \Theta_o + Hg_r K^y \]

- \( \Theta_o \) = Top oil temperature
- \( Hg_r \) = Hot-spot to top-oil gradient
- \( K \) = Load factor (load current/rated current)
- \( y \) = Winding exponent

No traditional hot-spot thermometer needed

**Hot-spot temperature calculation**

- HV winding
- LV winding
- Terciary winding
Intelligent Cooling Control

Enhancements from traditional cooling

- Control up to 6 cooler groups
- Starts on top oil, hot-spot and forecast
- Remote start of coolers possible
- All cooler groups equally used
- Logic to exercise motors each week
- Time in service shown in station interface
- Time delay between cooler group start
- Reduced noise level
- More stable temperature, reduced breathing

Up to 6 Cooler Groups can be controlled

- Group 1
- Group 2
- Group 3
- Group 4
- Group 5
- Group 6

Traditional top oil thermometer used as back-up start of coolers and for emergency trip
TEC keeps track of the transformer temperatures and compares them with a theoretical model to indicate changes, in the cooling conditions or heat generation, that could place restrictions on the overloading capacity.
Tap Changer Temperature Balance

Keep track of the tap-changer temperature and compare it with a model to indicate over temperatures in the tap-changer.
Cabinet Condition

Temperature and Moisture sensors

Processor board - TC 122

Temperature and Moisture sensors

Processor board - TC 122

Temperature in TEC Cabinet

Humidity in TEC Cabinet

Temperature and Humidity in TEC Cabinet

Time [%]

Temperature in TEC Cabinet

Time [%]

Humidity in TEC Cabinet

Temperature and Humidity in TEC Cabinet

Time [%]
Minimal Functions

1- Transformer temperature:
- Bottom oil, top oil and hot-spot are shown;
- Hot-spot values are calculated for the HV, LV and TV windings;
- Reference temperature are calculated from an internal software model.

2- Transformer loading:
- HV, LV and TV bushing currents are displayed;
- The highest load is used to indicate the load of the transformer.

3- Overload capacity:
- Indicates the highest load under which the transformer can be operated for a certain amount of time without exceeding the preset top oil and hot-spot temp.

4- Tap-changer functionality:
- The tap-changer temperature is calculated and compared with measured values to indicate tap-changer faults;
- The tap-changer position, moisture level and temperature are shown.

5- Gas and moisture content:
- The dissolved gas and moisture content are shown as present values or over time;
- It is also possible to see if a gas change is load dependent, which indicates a possible overheating problem.

6- Cooling control:
- Starts on top oil, hot-spot, and forecast to optimize overload capacity and keep the temperature stable to limit breathing and reduce ageing;
- Up to six cooler groups can be monitored;
- All cooler groups are equally used and started every week to extend their lifetime.
Minimal Scope of Supply

- **Top oil temperature**
  - Hot-spot temperature
  - Load
  - Ageing
  - Temperature balance
  - Cooling control

- **Current transducers**
  - Hot-spot temperature
  - Load
  - Ageing
  - Cooling control
  - Contact wear
  - Temperature balance

- **Ambient temperature**
  - Sun
  - Shadow

- **Overload package**
  - Overload capacity
  - Hot-spot forecast

- **Intelligent Cooling Control package**
  - Controls up to 6 cooler groups
  - Star and stop based on top oil, hot-spot
  - Weekly exercise of cooler groups
  - Back-up in case malfunction

- **Gases and Moisture package**
  - Gases detection / Trends
  - Moisture detection
  - Ageing acceleration due to moisture
  - Data displayed and stored in TEC

- **Bottom oil temperature**
  - Temperature balance

- **Gas sensor**

- **Relay box**
  - Generates up to 8 digital signal from dry contact for different alarms or warnings from TEC
  - Can relay box
Connection with Customer´s Network

Minimum scope of supply
Connection with Customer´s Network

TMU 100 Bushing monitoring
- Capacitance
- Tan delta

DGA device
- Individual 8 gases
- Moisture

TEC system
- Thermal Currents
- Coolers
- OLTC

TCP/IP Connection with Customer’s Network
Connection with Customer’s Network

- IEC 60870
- DNP 3.0
- IEC 61850

SCADA

Client

Corporate Network

192.168.250.xx

Router (optional)

192.168.1.xx

Switch/Hub

TEC Server

Switch/Hub

Router (optional)

192.168.3.xx

Switch/Hub

TEC

TEC

TEC

TEC

TEC

TEC
1) Mount TEC on transformer.

2) Connect sensors and power supply according to drawings and connection tables.

3) Start system.

Note: The display indicates present status and events.
TEC Web page

http://www.abb.com/product/db0003db004283/6242000fec997581c1257b1000211293.aspx
TEC – Transformer Installation
Installation of TEC Basic Version
Installation in the Old Transformer
Installation of TEC Integrate Version
Installation in the Old Transformer
Installation of TEC Smart Basic Version
Installation of TEC Smart Basic Version
Control Room of Substation
Power and productivity for a better world™