Agenda

Definition and specifications
- Smart Grid
- Needs from transformer owners

Smart Transformer
- e-Accessories
- Sensors
- Platform
- Models

Applications and examples

Take away
Features and requirements of Smart Transformer
Features of Smart Grids

- Demand vs Supply
- Sustainability
- Reliability
- Efficiency
Transformer requirements to fulfill Smart Grid functions

<table>
<thead>
<tr>
<th>Smart Grid Functions</th>
<th>Smart Transformers Spec.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Energy flow</td>
<td>Cooling Control tuned to load profile</td>
</tr>
<tr>
<td>Power Quality</td>
<td>Voltage Regulation</td>
</tr>
<tr>
<td></td>
<td>Reliability</td>
</tr>
<tr>
<td></td>
<td>Fault prediction - detection</td>
</tr>
<tr>
<td>Environment</td>
<td>Energy efficiency</td>
</tr>
<tr>
<td>Asset Management</td>
<td>Condition Assessment Communication</td>
</tr>
</tbody>
</table>
Transformer owner challenges today

- **Reliability & Availability**
  - Society highly dependent on reliable energy supply
  - Integration of renewable energy sources

- **Overload**
  - Increased energy consumption, new consumption patterns (electrical cars)

- **Maintenance planning**
  - Optimize maintenance costs and reduce downtime

- **Life extension**
  - Ageing infrastructure – plan / postpone replacements

- **Company image**
  Strong focus on reliability
  → Knowing the condition of the unit allows informed decisions
Asset management and maintenance planning

Commissioning → Transformer Operation → Tests & Checks

TBCM → CBM → OLCM → TBM → Condition Assessment

Maintenance Strategy (TBM, CBM, RCM)

Normal?

Yes → Interpretation
Apply Special Tests and/or Intensive Monitoring (if needed)

No → Ok

Major work
Scrap & Replace
End of Life

Minor work
Corrective Maintenance
Refurbish or Repair
Technical & Economic Evaluation

Major Work On-site or in Workshop
Moving from diagnosis to On-Line Monitoring

Normal Operation

- **Transf. in service**
- **Is the operation normal?**
  - Yes: 90% → **No action**
  - No: 10% → **Is it a serious problem?**
    - No: 5% → Maintenance needed
    - Yes: 5% → Normal Operation

Abnormal Operation

- **Precise analyze / Quantification → Status**
- **Risk assessment**

Monitoring (transformer is on-line)

- Detection of latent defect / Evaluation
- Trends analysis & Overall supervision /Control

Diagnostic (transformer is off-line)
Protection & Smart Accessories
COMEM e-Accessories

- Buchholz relay
- Over-pressure relay
- Oil level indicator
- Temperature sensors
- Self Dehydrating Breather
- All devices equipped with Modbus and 4-20 mA or PT100 output
Sensors
Sensors to catch the prime failure modes

- Top transformer failures from Doble statistics
  - 43% winding insulation
  - 19% bushings
  - 16% tap changers
  - Pollution, dust & debris affecting bushings & cooling systems
  - Cooling System inefficiency
  - Blocking or Wedging

From CIGRE A2.37
Sensors
Monitored parameters

- Load, Voltage
- Temperatures:
  - Top oil and Bottom oil
  - Ambient
  - (Hot Spot with Fiber Optic)
- Gas in oil:
  - Composed gas
  - Multi-gas (DGA)
- Moisture
- Bushing
  - Tan Delta and Capacitance
- OLTC:
  - Position, Temperature, Contact wear
- (Partial Discharge)
New sensors
Bushing monitoring

- Novel technology
  - Can measure changes in capacitance and Tan δ on the same phase of different transformers, traditional technology compare three different phases (voltage unbalanced)
  - No need for cable between transformers: Very tight time synchronization of measurements using GPS clock

- Strengths
  - Detect latent defect earlier
    - Achieves very high accuracy: similar to offline measurement
    - Noise can be better filtered out (Parallel units see same voltage)
TEC platform – key benefits

- User friendly web interface – no additional software needed on users computer
- Based on a microprocessor and Modular design, possible to add the sensors that the customer requests with additional hardware
- Very strong mechanical stability and temperature endurance => Long lifespan
- Reliable and proven technology (longest serving unit has >10 years in the field)
- Compact and easy to install
- Support for standard communication protocols, including IEC 61850 (certified by SGCC)
Web Interface - dual language support
10 translations available
Web Interface - graphs with data
Easy overview of remotely downloaded historical data
Information VS Data

Top oil 57°C  Bottom oil 42°C  Ambient sun 21°C  Ambient shadow 17°C  Hot-spot HV 65°C  Hot-spot LV 67°C  Load 50%
Peak load 51%  OLTC pos 5L  OLTC temp 52°C  Operations 23654 Time to contact exchange 2545 days  Operations to
contact exchange 256675  Days to contact exchange 456 days  Operations to service 53670 Coolers 23 Cooler1 236h  Cooler2 240h  Cooler3 230h

Aging rate 0.02%  Aging 25687h  Moisture in oil 2ppm  Hydrogen 32ppm

SCADA system

PC with web browser remote or in station

- Diagrams
- Diagnoses
- Overview
- Event log
- Historical data
- Prediction

DNP3, IEC 61850 or other protocols

Overload forecasts

Dry contacts to SCADA system

Monitoring cabinet
- OLTC IED
- Bushing IED
- DGA IED
...
- Partial Discharge IED

Overload capacity 147%

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How TEC Models can support?
Examples of actionable information provided by TEC

- Gas in oil, trend and analysis
- Temperature trends and balance
- OLTC usage pattern
- Overloadability / Hotspot forecast
- Bubbling Temp.
- Anticipated coolers start
- OLTC maintenance forecast
- Cooler runtime & bank rotation
- Moisture in solid insulation
- Transformer insulation ageing
- Gas in oil, trend and analysis
- Annual status report
On-Line Monitoring
From raw data to actionable information

Most of the utilities/industries report us the following:
- Massive amount of data
- Limited resources and time to look at and draw conclusions
- No compatibility between system from different vendors
- Need advises to take actions while existing systems provide mainly data
- Need for centralized information with access through web browsers
- Need for migration service / upgrade
- Several stake holders: Managements / Asset Management / Maintainance

ABB solutions: Asset Health Center:
- Merge off-line and on-line data from several transformers and substations
- Health/Reliability Index: Intelligent models to assess overall condition of each unit
- Dashboards: Fleet overview with drilldown capabilities for each stake holder

Dashboard – network overview

Drilldown

Health Index
Messages & Notifications
Trending & Analysis
Smart Transformer Applications and examples
Increasing reliability and availability

Catastrophic failures reduced from 0.7% down to 0.3%
Securing availability / Avoiding failure
Hydro Power Plant to keep supplying key customer

- **Preventive actions requested by the customer**
  - Condition Assessment on one strategic 40MVA Transformer

- **Condition Assessment results**
  - Advanced paper degradation (High moisture and acidity)

- **Recommendations**
  - Oil treatment / filtration and drying
  - Purchase a new unit
  - Monitoring of the transformer until its replacement
  - Do not switch off the unit (risk of free water)

- **Monitoring with remote supervision**
  - Allowed to supply needed energy during peak season (supply of a sky resort in winter)
  - Keep the sick transformer running during 9 more months until replacement
  - Avoid penalty
Planning maintenance
Latent failure detected by monitoring

- Increase of dissolved gasses due to an increase of oil temperature while constant load

- The monitoring system allowed ABB experts to detect the blocking of a OFWF heat exchanger (mineral buildup)
Summary

- On-Line Monitoring can support asset owners who need more “real” time information to:
  - Avoid unexpected failures (reliability)
  - Plan maintenance (availability)
  - Maximize utilization of assets (loading/life extension)
  - Plan investments (financials)
  - etc

- ABB Smart Transformer philosophy is to:
  - Use as few sensors as possible and proven technology to increase the robustness of the system
  - Provide as much information as possible from these sensors using intelligent models