ABB Transformers
For reliability, efficiency and minimum environmental impact
Transformers are all around us in different segments
You will find ABB transformers…

… in buildings and in the airports we use when traveling,

… crossing oceans and on the sea bed,

… in substations that power our industrial areas,

… on the trains we ride and in the facilities that process our water,

… in wind turbines, solar fields, urban areas and house-holds.
Transformers
One-stop shop supplier

- Around 17000 employees
- Global capabilities: 73 sites
- Global presence: revenues in more than 100 countries
- Complete range of power and distribution transformers, components and services
- Service organization in place for global customer support of all installed bases
- Voltage range up to 1000 kV AC and +-800 kV DC
ABB’s transformer heritage
A long pioneering history

The combined experience of 700 years of transformer manufacturing

- Asea
- Ansaldo/Ital Trafo/IEL/OEL/OTE
- BBC
- GE, USA
- National Industri
- Strömberg
- Westinghouse
- Kuhlman
- Trasfor (in 2011)
- ...
BU Transformers
Present in 34 countries worldwide

Production unit(s):

Americas
• Brazil
• Canada
• Colombia
• Mexico
• USA

Europe
• Finland
• Germany
• Italy
• Poland
• Russia
• Slovakia
• Spain
• Sweden
• Switzerland
• Turkey

India, Middle East and Africa
• Egypt
• India
• Saudi Arabia

Australasia
• Australia
• China
• Korea
• New Zealand
• Singapore
• Thailand
• Vietnam

© ABB Group
June 16, 2015 | Slide 5
Transformers
Complete portfolio – product offering

Whatever you need from our broad portfolio -> ABB is your “one-stop shop” supplier

**Large, medium, small power**
Generator step up, System intertie, shunt reactors, phase-shifting, HVDC, etc. AC transformers also with Shell type technology.

**Industrial and special**
AC furnace, DC furnaces, DC electrolysis process (Al, Cl), AC series reactors, etc.

**Traction transformers**
AC/DC operations, multi-systems, ground installations, rolling operations, etc.

IEC, ANSI and IEEE standards

© ABB Group
June 16, 2015 | Slide 6
Transformers
Complete portfolio – product offering

Whatever you need from our broad portfolio -> ABB is your “one-stop shop” supplier

**Liquid filled distribution**
1ph, 3ph, mineral, silicon, midel, BIOTEMP®, pole, pad, ground, sub-sea, cooling, etc.

**Dry-type**
Vacuum cast coil (VCC), RESIBLOC®,
Open Wound, VPI, VPE
EcoDry, HiDry™, TriDry, PoleDry, etc.
Air/iron-core reactors, LV transformers, direct water-cooled products

**Insulation and components**
Bushings, tap changers, mechanical components, pressboard, specialty dielectric insulating fluids, etc.

**Service**
Engineering solutions, assessment, remanufacturing, TrafoSiteRepair™,
advanced field services, TEC®, installation and commissioning, etc.

IEC, ANSI and IEEE standards
Dry-type transformers

- Conventional dry-type: ABB transformers and reactors for LV, MV and HV applications which do not use any kind of liquid for cooling

- Special portfolio adapted to every customer needs:
  - **EcoDry**: ultra-efficient transformers with optimized variants depending on application: EcoDry_{Basic}, EcoDry_{99plus}, EcoDry_{Ultra}
  - **hi-T Plus**: based on the cast coil technology with upgraded insulation level: class H (180ºC)
  - **TriDry**: triangular transformers with reduced noise and losses
  - **HiDry_{72}**: high voltage and large power transformers, with or without on-load tap changer, up to 72.5 kV and 63 MVA
  - **PoleDry**: IP00 pole mounted dry-type transformers
  - **Direct-water cooled**: most efficient removal of heat from transformers and reactors
  - Reactors and transformers for rolling stock

- The products provide premium safety features, are virtually maintenance free and manufactured in accordance with industry and international standards including, IEC 60076-11, ISO 9001 and ISO 14001
The first delivered unit 1.6 MVA, 11/1.04 kV from 1998, in operation since 2000

Product highlights SPT
Offshore technology – Subsea transformer

- Makes continuous production of oil and gas possible at depth of several kilometers
- Development work started already at 80's. The first unit has been in operation since 2000
- Subsea transformer applications:
  - Step down transformers for feeding subsea pumps and compressors
  - Transformers for subsea pipeline heating
  - Transformers for SEPDIS (Subsea distribution system)
  - Transformers for subsea frequency converters
  - Transformers for Wave Hubs = connection points of wave power stations to grids
  - Transformers for Tidal turbines
  - Transformers for offshore windmill parks
Transformer Insulation & Components
Main Products Overview
Oil Transformer Main Part

- Bushing
- On Load Tap Changer
- Winding
- Core
- Dehydrating Breather
- Bucholz
- Control Cubicle
- Cooling System
Transformer Insulation and Components
Product Portfolio

- High voltage bushings
  - Oil- or resin-impregnated
- On-load tap changers
  - Vacuum or conventional
- De-energized tap changers
- Distribution and power transformer components
- Smart Grid monitoring devices
- Transformer protection and preservation systems
- Cellulose insulation material
- Flexible and rigid laminate insulation materials
- Hollow core composite insulators
- Renewal and replacement parts
- Oil treatment plants

Leading and robust technology for the most demanding applications
Transformer Insulation and Components
On-load tap changers

- Full product portfolio offering for IEC and IEEE / ANSI standards
  - In-tank resistance types
  - On-tank reactance types
- Designed with focus on customer requirements
  - Clean and simple designs for ease of use
  - Leading technology for monitoring and control systems
  - Plug-and-play solutions for retrofit applications
# Transformer condenser bushings

- Comparison

<table>
<thead>
<tr>
<th>Technology</th>
<th>OIP</th>
<th>RBP</th>
<th>RIP</th>
<th>RIS</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main insulation:</strong></td>
<td>Oil Impregnated Paper</td>
<td>Resin Bonded Paper</td>
<td>Resin Impregnated Paper</td>
<td>Resin Impregnated Synthetics</td>
</tr>
<tr>
<td><strong>Oil-free</strong></td>
<td>No</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes ✓</td>
</tr>
<tr>
<td><strong>Paper-free</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes ✓</td>
</tr>
<tr>
<td><strong>Moisture resistance</strong></td>
<td>Yes</td>
<td>No</td>
<td>No</td>
<td>Yes ✓</td>
</tr>
<tr>
<td><strong>Ease of storage</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes ✓</td>
</tr>
<tr>
<td><strong>No cellulose decomposition</strong></td>
<td>No</td>
<td>No</td>
<td>No</td>
<td>Yes ✓</td>
</tr>
<tr>
<td><strong>Non-fragmenting design</strong></td>
<td>No</td>
<td>No</td>
<td>Yes</td>
<td>Yes ✓</td>
</tr>
<tr>
<td><strong>IEC 60137 (ABB value)</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>tan delta in %</strong></td>
<td>&lt; 0.7 (&lt; 0.55)</td>
<td>&lt; 1.5</td>
<td>&lt; 0.7 (&lt; 0.4)</td>
<td>(&lt; 0.35) ✓</td>
</tr>
<tr>
<td><strong>PD at 1.5xUm/√3 in pC</strong></td>
<td>&lt; 10 (&lt; 5)</td>
<td>&lt; 250</td>
<td>&lt; 10 (&lt; 2)</td>
<td>(&lt; 2 ) ✓</td>
</tr>
<tr>
<td><strong>temperature class</strong></td>
<td>105°C</td>
<td>120°C</td>
<td>120°C</td>
<td>120°C ✓</td>
</tr>
</tbody>
</table>
Why dry bushings?

The reasons are well known

- Fully dry, oil free technologies
- Excellent electrical, thermal and mechanical characteristics
- Fire and explosion resistant
- High safety for personal and equipment
- Environmental friendly
- Maintenance- and check-free
- Low life-time costs
- Fulfilling and surpassing the highest technical requirements
- Transportation, storage and installation at any angle
- Can be energized immediately after installation
What is SDB?

Self-Dehydrating Breather

- Maintenance-free air breather
- Continuously monitoring silica gel moisture content
- Automatic silica gel regeneration as necessary
- Dual chambers with silica gel for guaranteed dry air intake
- Reduced maintenance and environmental impact
- Smart Grid enabled for easy connection and monitoring
SDB maintenance-free air breathers

Installation Examples
Enhanced availability and sustainability of transformers
Transformer service
Why a session on availability and sustainability? Top utility concerns

Source: Black & Veatch’s 2011 Strategic Directions Survey Results
Our every day necessities

- Ever growing population
- Energy consumption to double within 30 years
- Sustaining a power-hungry world
- Ensure the reliability & availability of an ageing grid infrastructure
- Concern about climate change
- Green solutions - providing energy efficient products and service
- Economic environment

Areas of power consumption reflected on the earth's surface

More than ever, the need of energy efficient products and reliable grids.

ABB's transformers support the systems that keep our world running.
Utility and Industry challenges
Asset management with new challenges

- Ensure high reliability of aged assets
  - Avoid unplanned power outage
- Optimize assets performance
  - Increase production output

- Optimize capital expenditure and increase return on assets
  - Reduce Life Cycle Costs – Lowest operation and maintenance costs
- Extend lifetime of existing assets while looking for sustainability
  - Delay investments while considering green solutions

→ Move towards Condition Based Maintenance / Reliability Centered

→ Need for tools to decide based on technical & economical criterias

Failure probabilities (Network Transf.)

<table>
<thead>
<tr>
<th>Age (years)</th>
<th>Probability</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.02</td>
</tr>
<tr>
<td>6</td>
<td>0.04</td>
</tr>
<tr>
<td>11</td>
<td>0.06</td>
</tr>
<tr>
<td>16</td>
<td>0.08</td>
</tr>
<tr>
<td>21</td>
<td>0.10</td>
</tr>
<tr>
<td>26</td>
<td>0.12</td>
</tr>
<tr>
<td>31</td>
<td>0.14</td>
</tr>
<tr>
<td>36</td>
<td>0.16</td>
</tr>
<tr>
<td>41</td>
<td>0.18</td>
</tr>
<tr>
<td>46</td>
<td>0.20</td>
</tr>
<tr>
<td>51</td>
<td>0.22</td>
</tr>
<tr>
<td>56</td>
<td>0.24</td>
</tr>
</tbody>
</table>
How to enhance availability and sustainability?

- Avoid unexpected failures
- Plan maintenance and repair during low load periods
- Efficient maintenance actions reducing downtime
- Solutions to shorter repair time
- Retrofit solution to increase personal and asset safety
- Green footprint
Most typical approach to substation maintenance today

- Use online sensors & instrumentation to determine condition of equipment & perform predictive maintenance: 3%
- Inspect equipment and perform predictive maintenance based on those results: 29%
- Schedule maintenance tasks based on equipment loading or number of operations: 27%
- Schedule most maintenance work using time based requirements or on a fixed time schedule: 35%
- Fix it when it breaks: 6%

Source: McDonnell Group Research on 100 utilities
Enhanced availability
On-Line Monitoring - TEC
TEC platform – key benefits

- User friendly web interface – no additional software needed on users computer
- 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, for instance Chinese
Web Interface - graphs with data
Easy overview of remotely downloaded historical data
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
Enhanced availability
Condition Assessment
Condition based maintenance
Assess the condition / withstand capability

Source: CIGRE

<table>
<thead>
<tr>
<th>Thermal ageing</th>
<th>Mechanical ageing</th>
<th>Electrical ageing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Temperature</td>
<td>Delta temperature</td>
<td>Over voltage</td>
</tr>
<tr>
<td>Moisture</td>
<td>Over current</td>
<td>Over current</td>
</tr>
<tr>
<td>Oxygen</td>
<td>Vibration / Number of operation</td>
<td>Harmonics - VFT</td>
</tr>
</tbody>
</table>

Fault Occurs
Retrofit
End of Life
Without Retrofit
End of Life With Retrofit

Margin

STRENGTH

STRESS

OPERATIONAL LIFE
Condition Assessment
Three steps: Optimize ratio Accuracy / Costs, Time

Transformer fleet

→ Basic Diagnostics
→ History

→ Advanced Diagnostics
→ Design Review

Step 1
Transformer Fleet Screening
Number of unit: 20 - 100+
Objective: Maintenance Strategy & Budget

Step 2
Transformer Design & Condition Assessment
Number of unit: 10 - 20
Objective: Maintenance Plan & Actions per unit

Step 3
Life Assessment / Profiling
Number of unit: 1 - 10
Objective: Troubleshooting / Upgrade proposal
### Electrical tests and DGA Diagnostic matrix

#### Type of Problem

<table>
<thead>
<tr>
<th>Magnetic Circuit Integrity</th>
<th>Magnetic Circuit Insulation</th>
<th>Winding Geometry</th>
<th>Winding/Bushing/OLTC Continuity</th>
<th>Winding/Bushing Insulation</th>
<th>Winding Turn to Turn Insulation</th>
</tr>
</thead>
</table>

#### Diagnostic Technique

<table>
<thead>
<tr>
<th>Electrical</th>
<th>Basic Electrical</th>
<th>Advanced Electrical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Frequency Response of Stray Losses</td>
<td>Frequency Response Analysis</td>
<td>Partial Discharge Analysis (PDA)</td>
</tr>
<tr>
<td>Winding Ratio</td>
<td>Winding Resistance</td>
<td>Bushing Power Factor</td>
</tr>
<tr>
<td>Magnetisation current</td>
<td>Capacitance and DF/PF</td>
<td>OTC Vibration</td>
</tr>
<tr>
<td>Leakage Reactance</td>
<td>Insulation Resistance</td>
<td></td>
</tr>
<tr>
<td>Core Ground Test</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

- Overall condition
  - Oil, DGA, Furans
- Mechanical condition
  - Frequency Response Analysis (FRA)
- Thermal condition
  - Dielectric Frequency Response (DFR)
- Electrical condition
  - Partial Discharge Analysis (PDA)
- Accessories
  - Bushing Power Factor
  - OTC Vibration
# Transformer condition assessment

## Typical output and recommendations

### Plant 1 - Results of condition assessment and action plan

<table>
<thead>
<tr>
<th>TFO</th>
<th>Mechanical</th>
<th>Electrical</th>
<th>Thermal</th>
<th>Accessories</th>
<th>Overall</th>
<th>Risk Mitigation - Actions</th>
</tr>
</thead>
<tbody>
<tr>
<td>TFO 2</td>
<td>Winding</td>
<td>Arcing</td>
<td>Heating</td>
<td></td>
<td>95</td>
<td>Visual Inspection and repair in factory / rewinding</td>
</tr>
<tr>
<td>TFO 5</td>
<td>Tank</td>
<td></td>
<td>OLTC heating</td>
<td></td>
<td>80</td>
<td>Repair on site and OLTC overhaul</td>
</tr>
<tr>
<td>TFO 1</td>
<td></td>
<td>Aged oil</td>
<td>Bushing</td>
<td></td>
<td>70</td>
<td>Oil regeneration / filtration and advanced diagnosis / change HV bushing</td>
</tr>
<tr>
<td>TFO 6</td>
<td>Arcing</td>
<td></td>
<td>Thermometer</td>
<td></td>
<td>50</td>
<td>Exchange TopOil - thermometer / on line monitoring of DGA</td>
</tr>
<tr>
<td>TFO 3</td>
<td></td>
<td></td>
<td>Silicagel</td>
<td></td>
<td>40</td>
<td>Exchange Silicagel</td>
</tr>
<tr>
<td>TFO 7</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>25</td>
<td>Standard maintenance actions and controls</td>
</tr>
<tr>
<td>TFO 8</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>15</td>
<td>Standard maintenance actions and controls / 10 % overload capabilities</td>
</tr>
<tr>
<td>TFO 4</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>10</td>
<td>Standard maintenance actions and controls / 15 % overload capabilities</td>
</tr>
</tbody>
</table>
Condition assessment – success story
Steel mill, Venezuela

- **Customer need**
  - Solution to increase availability of electrical supply
  - 5 major failures within 3 years on furnace transformers
    ➔ Important loss of production

- **ABB response**
  - Condition assessment level 2 on 12 non-ABB 100 MVA furnace transformers
  - Recommendation for maintenance, upgrade
  - Remote monitoring of 4 units with monthly report
Spend money on the right assets at the right time
Assess the condition to prioritize investments

Transformer Unit Nr.

RISK OF FAILURE PER TRANSFORMER
MAINTENANCE COST PER TRANSFORMER

UNDERSpending
US

OVERSpending
OS

$ $ $ $ 

50% OF MAINTENANCE ACTIVITY IS UNNECESSARY (CIGRE 2000)

OS = US: keep maintenance budget, spend on risky units
OS > US: reduce maintenance budget with less risks
OS < US: increase maintenance budget to reduce risks

© ABB BU Transformers
June 16, 2015 | Slide 41
Enhanced availability
Reduce outage time for Maintenance
Low Frequency Heating Drying (LFH)
Slow down ageing by removing moisture

- Reduced downtime
  - Up to 70% faster compared to hot oil and vacuum

- Efficient drying
  - Remaining moisture down to 0.5%

- Proven method
  - 200+ units dried out
  - Up to 750 MVA / 500 kV
Low Frequency Heating (LFH) - success story
Utility, Canada

- Customer need
  - Drying of wet unit 750 MVA / 500 kV
  - Short downtime
- ABB response
  - LFH drying at site
- Customer benefits
  - High quality of drying - 0.5 % moisture
  - Extend remaining life time by 33%
  - Record time drying
    - 10 days versus 40 days usually
Enhanced availability
Reduce outage time for repair: On-Site Repair
TrafoSiteRepair™
Bring the factory at site

- Benefits
  - Reduced overall repair costs
  - Reduced transportation time and associated risks
  - Reduce outage time typically by 30 - 90 days

- Important criteria to be considered
  - Clean environment: floor, over pressure, dry air
  - Lifting capability
  - Efficient active part drying
  - High Voltage testing mobile platform
  - Strong logistic
  - Strict quality process and experienced supervisors

- References
  - Shell & core types up to 800 kVAC and 600 kVDC
  - 400+ units repaired at site over last decade
High Voltage Site Testing
Verify the reliability at site under full voltage

- **Applications**
  - For Condition Assessment and troubleshooting
  - After the shipment & erection of new or repaired unit
  - After a transformer repair at site

- **Measurements**
  - Applied voltage test up to 500kV
  - Induced voltage test up to 90kV (LV side)
  - Partial Discharges
  - No-load losses
  - Load losses with reduced current
  - Heat Run Test
Customer need
- Repair of a 470 MVA / 400 kV GSU
- Time challenge to secure the power for the winter peak

ABB response
- TrafoSiteRepair™
  - Untanking and dismantling
  - Exchange windings
  - Reassembly
- Drying out
- Testing
- Commissioning

Customer benefits
- Total repair time: 3 months
- 1 month saved compared to repair in factory

“The fast response of ABB, the dedication of their resources, (and) their capacity to adapt to the complex site and inclement weather made it possible for Iberdrola to fulfill the needs of the Spanish electrical system.”

- Federico de la Hoz, director of thermal production, Iberdrola Generation
TrafoSiteRepair™ - success story
Power Producer, Ireland

- **Customer need**
  - Repair of a GSU transformer 146 MVA, 118/11 kV
  - Repair of low voltage connection requiring untanking
  - Time challenge to avoid loss of production

- **ABB response**
  - TrafoSiteRepair™
    - Untanking and dismantling of the unit
    - Repair of low voltage connection
    - Reassembly and drying out
    - Commissioning

- **Customer benefits**
  - Total repair time: 2 weeks
  - 4 weeks shorter than a repair in factory
Enhanced sustainability
Green Retrofit
## TrafoSustainableRetrofit™
Beyond the Green

<table>
<thead>
<tr>
<th>Sustainable</th>
<th>TrafoSustainableRetrofit™ features</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental</td>
<td>Renewable, biodegradable</td>
</tr>
<tr>
<td>Health and Safety</td>
<td>Less flammable, lower consequences of a failure</td>
</tr>
<tr>
<td>Technical</td>
<td>Reliability, life extension and overloadability</td>
</tr>
<tr>
<td>Economical</td>
<td>Lower maintenance costs and higher revenues</td>
</tr>
<tr>
<td>Financial</td>
<td>Reduce of delay re-investments</td>
</tr>
</tbody>
</table>
Reduce environmental footprint
New materials and components to go green

- “New” materials
  - Ester oils - BIOTEMP®
  - Aramid solid insulation - NOMEX
  - Dry bushings
  - Vacuum tap changer

- Features
  - Reduce risk of fire / explosion
  - Reduce ground contamination if leakages
  - More power within same footprint
  - Significant overload capability
  - Increased life time and reliability. Limited thermal ageing
TrafoSustainableRetrofit™ - success story
Utility, Brazil

- Customer need
  - More power on a 15 MVA / 145 kV transformer with the same footprint
  - Low risk of fire

- ABB response
  - TrafoSustainableRetrofit™

- Customer benefits
  - Upgrading to 25MVA (+66%)
  - Overload during 6 hours up to 43 MVA (+70%)
  - Biodegradable fluid reduces pollution in case of oil leaks and risk of fire and toxicity of fumes
Enhanced availability and sustainability

Conclusion

- Combining
  - Latest condition assessment
  - Efficient maintenance solutions
  - TrafoSiteRepair™
  - TrafoSustainableRetrofit™

- Allows utilities and industries to
  - Increase asset availability
    - Avoid unexpected failures
    - Better plan maintenance, repair and replacement
    - Reduced outage time for maintenance and repair
  - Increase asset sustainability
    - Safer
    - Reduced environmental footprint (losses, leakages, fire)
    - Recycle existing equipment and enhance performance
Contact Persons

- Name: Semuel Sondakh
  - Email: semuel.sondakh@id.abb.com
  - Phone: 0818 950 171 (Mobile)
    (021) 2551 5542 (direct line)
  - Fax: (021) 2551 5566

- Name: Danang Birowo
  - Email: danang.birowo@id.abb.com
  - Phone: 0816 1892 787 (Mobile)
    (021) 2551 5302 (direct line)

- Name: Bram Azarya
  - Email: bram.azarya@id.abb.com
  - Phone: 0838 5761 1133 (Mobile)
    (021) 2551 5400 (direct line)
Power and productivity for a better world™