SF6 Instrument Transformers

Agenda

- Introduction
- TG – SF6 Current Transformers
- TVI – SF6 Voltage Transformers
- TIP – SF6 SSVT
- TG COMBI – SF6 Combined CT/VT
- Market overview
Introduction

- **ABB S.p.A**
- Power Products Division
- Unità Operativa Adda-HV
Introduction

ABB ADDA History Line (1/2)

Established in 1926

- High Voltage Technology since 80 years
- Production of oil-insulated Current Transformers for more than 50 years

Long & Strong Experience

- GIS technology since 1974
- Production of SF6 stand alone Current Transformers since 1981
Introduction
ABB ADDA History Line (2/2)

Late ’90s

- Pioneering Spirit
- First in the world to conceive Hybrid Switchgears

New Focus Factory 2005

- Worldwide success
- New Focus Factory
## SF₆ Instrument Transformers
### Product portfolio

<table>
<thead>
<tr>
<th>Voltage [kV]</th>
<th>TG</th>
<th>TVI</th>
<th>TIP</th>
<th>TG COMBI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Up to 800kV</td>
<td>Up to 420kV</td>
<td>Up to 420kV / 200 kVA</td>
<td>Up to 245kV</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Type</th>
<th>SF₆ Current Transformer</th>
<th>SF₆ Voltage Transformer</th>
<th>SF₆ Substation Service Voltage Transformer</th>
<th>SF₆ COMBIned Current and Voltage Transformer</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG</td>
<td>TVI</td>
<td>TIP</td>
<td>TG COMBI</td>
<td></td>
</tr>
</tbody>
</table>
TG strengths
SF$_6$ insulation – advantages

- **Explosion proof design**: a pressure relief device protects the apparatus from internal overpressure.

- **Non flammable** gas insulation.

- Life time dielectric **quality** assured (no checks, no treatment).

- Total absence of partial discharges.

- Oil filling and periodical oil samplings are not required.

- Gas leakage < 0.1% a year.

- Remote control of the internal insulation level by means pressure gauge provided with an alarm threshold and lock threshold.

- Totally **maintenance free**.
TG strengths
SF$_6$ insulation – advantages

- Explosion proof design: a pressure relief device protects the apparatus from internal overpressure.
- Non flammable gas insulation.
- Lifetime dielectric quality assured (no checks, no treatment).
- Total absence of partial discharges.
- Oil filling and periodical oil samplings are not required.
- Gas leakage < 0.1% a year.
- Remote control of the internal insulation level by means of a pressure gauge provided with an alarm threshold and lock threshold.
- Totally maintenance free.

Fire and Explosion Failure Frequency
TG strengths
SF₆ insulation – advantages

- **Explosion proof design**: a pressure relief device protects the apparatus from internal overpressure.
- **Non flammable** gas insulation.

  - Life time dielectric **quality** assured (no checks, no treatment).
  - Total absence of partial discharges.
  - Oil filling and periodical oil samplings are not required.
  - Gas leakage < 0.1% a year.
  - Remote control of the internal insulation level by means pressure gauge provided with an alarm threshold and lock threshold.
  - Totally **maintenance free**.
TG – SF6 Stand Alone Current Transformers
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
Introduction

- The modularity of TG design (i.e. several tank sizes, different type of primary windings, makes it possible to meet most of our client requests).
- HV installation fully obtained by means SF6 gas instead of oil & paper.
- Cores and primary re-connections positioned inside and around the top head respectively.
- Fibre glass insulator with silicon rubber shields (porcelain available as alternative)
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability
- Reference list.
Basic Technical data

- System voltages: 72.5kV – 800kV
- Insulation level: up to 2100kV
- Rated primary current: 4.000A
- Rated short-circuit current:
  - thermal: up to 63kA;
  - dynamic: up to 170kA.
- Rated secondary current: 1 or 5
- Accuracy: according to IEC and IEEE
- Ambient temperature: -50°C - +40°C
Basic technical data
Selection view

1. Primary turns.
2. Aluminium alloy head.
3. Terminals.
4. Insulator.
5. Pressure relief device.
6. Densimeter.
7. SF6 gas filling gauge.
8. Earthing screw.
9. Low voltage cable entry.
10. Secondary terminal block.
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon – porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
TG – SF6 Current Transformers

Product range

- System voltages: 72.5kV – 800kV
- Insulation level: up to 2100kV
- Rated primary current: 4.000A

- Rated short-circuit current:
  - thermal: up to 63kA;
  - dynamic: up to 170kA.

Accuracy: according to IEC and IEEE
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
TG “building blocks”
Comparison Top core / Hair pin

- Shorter primary conductor
- Lower thermal losses
- Higher suitability for high rated currents
TG “building blocks”

**Special light alloy**
(total absence of porosity, i.e. total sealing of the SF6)
The head contains:
- passing bar primary winding
- toroidal cores (hot rolled steel strip or mumetal or mix)
- secondary windings uniformly distributed around cores
- internal shields to optimise the distribution of dielectric field

**High strength silicon (or porcelain)**
conforming with the strictest mechanical requirements
(ANSI/CENELEC/…)

**Aluminium**
Functions:
- supports the live part of the CT (with a tube)
- closes the bottom of the insulator
- connects the secondary terminal box
TG “building blocks”
The head

Tap changers

Primary turns
TG “building blocks”
The head

Rupture disk

Internal shield
Double O-Ring
TG “building blocks”
Materials (1/2)

- Hot dip galvanised components.
- Epoxy paint protection for other parts in anticorrosive light alloy.
- Synthetic rubber gasket fit to resist SF$_6$ and thermal variation.
- The metallic head is cast in a special light alloy to assure absence of porosity (complete sealing of SF$_6$).
- High strength composite or porcelain insulator conforming to the strictest requirements (ANSI/CENELEC).
TG “building blocks”
Materials (2/2)

ADVANTAGES OF SILICON RUBBER

- low weight
- excellent pollution and rain performance
- sandstorm resistant
- maintenance free
- cheaper than porcelain (in most cases)
- high degree of safety (crack and explosion resistant)
TG “building blocks”
Base

- Density monitor
- Secondary terminal box
- DILO valve for filling
TG “building blocks”

Cores

- Primary/secondary reconnections.
- Different possibilities in the number of cores.
- Metering/protection cores.
- Burden & Class example:
  - cl. 0.2, 20 VA, FS 5;
  - cl. 5P20, 30 VA;
  - TPX, TPY and TPZ are available.
- Rated continuous thermal current (Rf):
  - 1.0, 1.2, 1.5, … (IEC).
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator)
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
Packing
Different solutions to ensure the safety of the equipment during transportation

- Wooden crate
- Shock Indicators
- Barrier bag
- Metallic structure with anti-vibration rubber supports
- Shock Recorders
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability
- Reference list.
TG quality

- Leverage on other SF$_6$ insulated HV equipment manufacturing **know-how** (AIS, GIS, Hybrid).
- Extensive “in-house” **tests** (special dedicated testing room).
- Integrated system for the management of **quality**
- **ISO** quality certifications.
TG quality
HV test laboratory
TG quality
Integrated system for the management of quality

Inbound Control

Activities:
• Supplier Qualification Process
• Supplier Performance monitoring (Audits…)
• Incoming Inspection
• Statistical Process Control
• Analysis of defects
• Feedback to R&D on technical gaps

Process Control

Activities:
• Definition of procedures for assembling and testing activities
• Definition of operators checklists
• Monitoring of compliancy with procedures
• Defects monitoring and analysis
• Feedback to R&D on technical gaps
• Training
• Weekly quality meetings on shopfloor
• Improvement projects

Testing

Activities:
• Visual checks
• Functional tests
• Mechanical tests
• Leakage tests
• Dielectric tests

Outbound Control

Activities:
• Visual check e completeness of delivery
• Monitoring of packing adequacy
• Customer Claim Management (CCRP)
• Quality Reporting
• Improvement projects
TG quality
ABB Adda ISO quality certifications

2002: ISO 9001 (Quality)
2004: ISO 14001 (Environment)
2008: ISO 18001 (OHS)
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
TG Reliability

DESIGN → PRODUCTION → TESTING

Designed, manufactured and tested to have the best performances in the market of CTs
## TG Reliability

### Dielectric strength

<table>
<thead>
<tr>
<th>Power Frequency</th>
<th>IEC</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG 145-170</td>
<td>275-325</td>
<td>310-360 kV</td>
</tr>
<tr>
<td>TG 245-300</td>
<td>460</td>
<td>510 kV</td>
</tr>
<tr>
<td>TG 330-420</td>
<td>630</td>
<td>680 kV</td>
</tr>
</tbody>
</table>

TG 245 under test
**TG Reliability**

**Dielectric strength**

<table>
<thead>
<tr>
<th>BIL</th>
<th>IEC</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td>TG 145-170</td>
<td>650-750</td>
<td>715-825</td>
</tr>
<tr>
<td>TG 245-300</td>
<td>1.050</td>
<td>1.175</td>
</tr>
<tr>
<td>TG 330-420</td>
<td>1.425</td>
<td>1.550</td>
</tr>
</tbody>
</table>

**TG 420 under test**
## TG Reliability
### Mechanical strength

### TG 145: Vertical Load

<table>
<thead>
<tr>
<th></th>
<th>IEC</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td>class I</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Longitudinal</td>
<td>2.000</td>
<td>3.000</td>
</tr>
<tr>
<td>Transversal</td>
<td>2.000</td>
<td>3.000</td>
</tr>
<tr>
<td>Vertical</td>
<td>2.000</td>
<td>3.000</td>
</tr>
</tbody>
</table>

N
TG Reliability
Mechanical strength

<table>
<thead>
<tr>
<th>TG245</th>
<th>IEC</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>class I</td>
<td>class II</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>2.500</td>
<td>4.000</td>
</tr>
<tr>
<td>Transversal</td>
<td>2.500</td>
<td>4.000</td>
</tr>
<tr>
<td>Vertical</td>
<td>2.500</td>
<td>4.000</td>
</tr>
</tbody>
</table>

TG 245: Transversal Load
TG Reliability
Mechanical strength

TG 420: Longitudinal Load

<table>
<thead>
<tr>
<th>TG420</th>
<th>IEC</th>
<th>TG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>class I</td>
<td>class II</td>
</tr>
<tr>
<td>Longitudinal</td>
<td>4.000</td>
<td>6.000</td>
</tr>
<tr>
<td>Transversal</td>
<td>4.000</td>
<td>6.000</td>
</tr>
<tr>
<td>Vertical</td>
<td>4.000</td>
<td>6.000</td>
</tr>
</tbody>
</table>
TG Reliability
Special Type Tests

- Arcing due to internal fault (class II)
- Seismic test
- Tightness test (-50 °C)
- Lightning Impulse → Chopped Wave
- Dielectric Type Tests → performed with gas mixture (SF6/N2)
TG Reliability
Internal arc test

Video
TG Reliability
Seismic test

TG 420

TG 245

TG 145

Video
Table of contents

Introduction

Technical data
- Basic technical data.
- Product range (silicon - porcelain insulator).
- TG “building blocks”
- Packing.

TG strengths
- SF6 insulation – advantages
- TG quality.
- TG reliability.
- Reference list.
MORE THAN 16,000 INSTALLATIONS

Market features:

- Customers turning to SF6
- Demanding customers
- High rated voltage
- High rated current
- Short-time delivery
TG – SF6 Current Transformers
Reference countries for SF6

TG 362 kV reference customers:

- Terna (Italy)
- Hydro Québec (Canada)
- Eskom (South Africa)
- Energoatom (Russia)
- Ukrenergo (Ukraine)
- TransGrid (Australia)
SF6 Stand Alone Voltage Transformers
Product update: TVI - TIP
SF₆ Voltage transformers type TVI
Product range and main features

Technical data:

- System voltage: 72,5kV – 420kV;
- Insulation level: up to 1.425kV;
- Rated short-circuit current:
  - thermal: up to 63kA;
  - dynamic: up to 170kA.
- Windings suitable for both metering and protection;
- Insulation system designed to guarantee a life cycle of 30 years;
- Gas leakage less than 0.1 % per year.
Substation auxiliary power
Common solutions

Tertiary on Power Transformer

Auxiliary Transformer

Batteries
Substation auxiliary power
SF6 SSIVT - TIP
TIP
SF6 Substation Service Voltage Transformer

- Primary application is to supply control power from substation primary voltage;

- Single-phase installations or three-phase installations

- Cost effective substation control power source;

- Reliable control power option;

- Competitive lead time.
TIP application
Rural electrification

Transmission Line

Village
TIP application
Rural electrification – Solution 1

HV substation

Distribution Line
TIP application
Rural electrification – Solution 2

- Fuse or LV MCB
- Step-up transformer
- Local distribution network
TIP application
Switching station – Solution 1

Control power source?

Distribution Line
TIP application
Switching station – Solution 2

Control power source?

TIP
TIP application
Mobile substation
TIP
SF6 Substation Service Voltage Transformer

Technical data:
- voltage System: 72.5kV - 420kV; (550 kV in 2012)
- insulation level: up to 1425kV;
- nominal power: up to 200 kVA (single phase);
- accuracy according to IEC and IEEE std.;
- gas leakage less than 0.1% / year;
- primary winding connected directly to the high voltage side while the secondary winding supplies the low voltage panels.
TIP

SF6 Substation Service Voltage Transformer

1. **High voltage terminal**, made of highly conductive aluminum (either cylindrical or the NEMA flat type)

2. **Composite insulator**, made of composite material in accordance with IEC 61642, suitable for installation in highly polluted areas (level IV)

3. **Aluminum tank**, made of a corrosion-proof aluminum alloy, in conformity with national vessel standards

4. **Rupture disk**, pressure relief device to limit internal gas overpressure in case of flash over, designed to avoid early bursting

5. **Name plate**, placed on the secondary terminal box, including all the data required by the IEC 60044-2 Standards

6. **Secondary terminal box**, with a protection degree of not less than IP44 according to IEC 60529

7. **Cable gland** for LV cables

8. **Density monitor** temperature compensated density monitor with two electric contacts scaled on alarm and lock out gas thresholds
TIP design review
Tank and inductive part

- Casting tested according IEC
- The windings are made by electrolytic copper.
- The cores are realized by silicon steel lamination with high permeability low losses oriented crystals
TG 362 design review

Insulator

- Fibre glass insulator with silicon rubber sheds
- High mechanical strength
- High pressure strength (according IEC 61462)
- High creepage distance (>31mm/kV)
- HV terminal according NEMA standard
TIP
SF6 system

Pressure data (rel):

- Operating pressure: 0,65 MPa
- Alarm pressure: 0,6 MPa
- Lockout pressure: 0,55 MPa
- Bursting pressure: 1,2 MPa

Gas mixture:

- SF6 38%; N2 62%
**TIP**

**SF6 system**

Gas leakage:
- <0.1%/year

Density monitor temperature compensated with two electric contacts scaled on alarm and lock out gas thresholds (arctic temperatures)

**Rupture disk**, pressure relief device to limit internal gas overpressure in case of flash over, designed to avoid early bursting
TIP Options

Options:

- tap changer
- metering windings
- additional disconnector
TIP
Options

Options:
- tap changer
- metering windings
- additional disconnector
Type tests:

- Dielectric tests
- Lightning impulse withstand voltage test
- Wet power frequency withstand test
- T Rise test
- Short circuit current test
- RIV measurement
- Mechanical tests
- Transmitted overvoltages measurement
- Transformation ratio and phase angle measurement
- Measurement of the short-circuit measurement and of the load losses
- Losses and no load current measurement
- Tightness test
TIP
Transportation

Transportation:

- TIP must be transported/stored in horizontal position
- Minimum pressure of 0,2 bar rel must be kept during transport
- Each unit is closed in a VCI barrier bag for protection during sea transportation
- Shock and tilt indicators placed inside and outside the crate
TIP
Installation and maintenance

**Installation:**
- Open the case and lift TIP
- The product shall be installed vertically on a structure.
- Check pressure and run an insulation test
- Fill in the gas to the rated pressure
- Connect primary and secondary side

**Maintenance:**
- TIP is maintenance free
- Leakage and moisture verification every 5 years
TIP
SF6 Substation Service Voltage Transformer

$\text{SF}_6$ advantages:
- high reliable equipment;
- explosion proof design;
- maintenance free;
- no need of oil samplings;
- remote gas monitoring.
SF6 Combined Transformers
Product update: TG COMBI
SF6 Combined Current/Voltage Transformers

- From the experience on SF6 CTs & GIS VTs

- System voltages: 72.5kV – 245 kV

- Insulation level: up to 1050 kV

- Rated short-circuit current:
  - thermal: up to 50kA;
  - dynamic: up to 125kA

- Accuracy: according to IEC and IEEE
The integration of two functionalities (current transformer and voltage transformer) in one single equipment provides additional benefits in terms of:

- cost of the equipment
- required space
- dimensions of packaging
- time for erection/commissioning
- cables for interconnection
- foundations and structures
SF6 Instrument Transformers
Market overview
Success Stories in 2011
SF₆ Instrument Transformers

- TransGrid in Australia – 10MUSD 3 years frame for 145kV, 362kV and 550kV TGs.

- HQ in Canada – ABB to become second supplier for TGs 330kV and 800kV.

- Ukrenergo in Ukraine – 200 units of TGs and TVIs for 145kV and 330kV.

- Rosenergoatom in Russia – main supplier with reliable high quality perception.

- ATCO in Canada – first SF6 SSVT order in NAM.
Power and productivity for a better world™