On Line Monitoring of Circuit Breakers
Brief Overview
HV Circuit Breaker
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- Types of Circuit Breaker
- Time Base Maintenance
- Condition Base Maintenance techniques

Condition Base Maintenance Solutions
- **Air blast** were the dominant circuit breaker technology in the 1960’s.
- **Oil as interrupting and insulating medium** 1970’s to early 1980’s.
- The first circuit breakers using **SF₆ gas** as an interrupting and insulating medium were developed in the late 1960’s. Commercially available in the late 1970’s, SF₆ gas circuit breakers became the dominant circuit breaker technology in the 1980’s and still remain until today.
- **Vacuum circuit breaker** technology was first introduced in the 1960’s.
Types of Circuit Breaker

According to their services the circuit breaker can be divided as:

1) Outdoor circuit breaker
2) Indoor breaker

Outdoor type air insulated circuit breakers are classified as:

1) Dead tank type circuit breaker
2) Live tank type circuit breaker
1) Dead tank type circuit breaker

In dead tank type CB, the switching device is located, with suitable insulator supports inside a metallic vessel(s) at ground potential filled with insulating medium.

DTB has current transformer build in and tend to use larger control cabinet when compared with Live Tank Breakers.
2) Live tank type circuit breaker

In live tank circuit breaker, the interrupts are located in an insulated busing, at the system potential. The live tank circuit breakers are cheaper and required less mounting space.
Types of Circuit Breaker – Live Tank Breaker
One or two Interrupter per phase

- One breaking element
  - 1 interrupter
  - 1 support insulator
  - 1 mechanism housing
  One Interrupter: up to 300kV

- Two breaking elements
  - 2 interrupters
  - 1 or 2 support insulator(s)
  - 2 mechanism housings
  Two Interrupters: from 362 to 550kV

NOW 550kV is available with “ONE” interrupter unit
GIS
According to the operating mechanism of circuit breaker they can be divided as:

1) Spring operated circuit breaker
2) Pneumatic circuit breaker
3) Hydraulic circuit breaker
Spring mechanism leading the market

Part 2 – Reliability of High Voltage SF6 Circuit Breakers

Figure 2-7: CB service experience per kind of operating mechanism / present survey

Spring Mechs is leading the market
Auxiliary Switch

Closing Driver Arm

Trip Latch

Close Latch

Operating Rod to CB Poles

Opening Damper

No Close Damper!
Inspection and maintenance requirement’s

- **Visual Inspection:**
  - Inspection intervals – every 1 / 2 years
  - External Cleaning
  - Verify heating element
  - SF$_6$ pressure
  - Fittings / valve verification
  - Structure Torque confirmation
Maintenance:
- 5, 10, 15 years maintenance
- Limit of operations or 10/15 years – Overhauling
- Adjustment’s in M/S – Velocity and MS – Timing
- Contact Resistance
- Dynamic resistance
- Density Monitor Calibration inspection
- DewPoint of the SF₆ and Purity of the SF6
- SO2 Levels – Contamination
- Search for SF₆ Leakage
- Protection re-commissioning
Close / Open Operation Analysis

- Total Travel (Distance mm)
- Speed Calc. Zone
- Contact Velocity
- Contact Travel
- Reaction Time
- Mechanism Time
- Close Coil Time
- Trip Coil Time
- Close Coil Energization
- Trip Coil Energization

[Graph showing the timing and travel aspects of a circuit breaker operation.]
Dynamic Contact Resistance Test

- **µΩ**
- **mm**
- **μΩ**
- **ms**

- Start of mechanism movement
- Contact separation for main contact
- Static resistance of main contact
- Length of arcing contact

FIG. 1
Issues with Time Based Maintenance

- Difficult to keep up with maintenance schedules consequently maintenance intervals are increasing
- Maintenance on a breaker is not always necessary and sometimes can do more harm than good!
- Record keeping is sometimes an issue. This is important to monitor long term trends on specific breaker types
- Good to have an on line system to look in between the extended maintenance periods and emulate where possible the off line tests
- Good to have software to automatically analyse results and look for trends
- Eventually on line condition monitoring will replace time based maintenance
CBM Strategy

Performance and reliability vs. time graph showing:
- No maintenance
- Risk and condition-based maintenance
- Upgrade or retrofit solutions
- Repair

Qualitrol: Defining Reliability
Breaker Online Monitoring

Interrupter Wear

Mechanical System

SF₆ Gas System

Electrical Controls & Auxiliaries

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<table>
<thead>
<tr>
<th>Monitoring Category</th>
<th>Details</th>
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<tbody>
<tr>
<td>Coil Continuity (Integrity)</td>
<td></td>
</tr>
<tr>
<td>Total Travel (Stroke)</td>
<td></td>
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<tr>
<td>Contact Velocity (Meters/s)</td>
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<tr>
<td>Reaction Time (ms)</td>
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<tr>
<td>Coil Energization Time (ms)</td>
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<tr>
<td>Contact Wear (I²T)</td>
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<tr>
<td>Trip Count (Oper. Counter)</td>
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<tr>
<td>Auxiliary contacts (ms)</td>
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<tr>
<td>Motor Current Signature</td>
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<tr>
<td>Motor – Charging time</td>
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<tr>
<td>Pump start counts</td>
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<tr>
<td>Tank/Gas Temperature</td>
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<tr>
<td>Mech./Cab. Temperature</td>
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<tr>
<td>Heater 1 (On all the time)</td>
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<tr>
<td>Heater 2 On (heater w/o thermostat)</td>
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<tr>
<td>RMS Current</td>
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<tr>
<td>Voltage (Fault Recording)</td>
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<tr>
<td>Re-strike detection</td>
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<tr>
<td>Smart SF6 sensors</td>
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<tr>
<td>Leak Rate (%)</td>
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</table>
- Ring or Split Core CT’s
- Ratio = 5000:1
- Nominal Values:
  - 1.0 A
  - 2.0 A
  - 5.0 A
Interrupter Wear Calculations

Arcing Contacts
Aux. Nozzle
Main Nozzle

Arc initiation

Contact Travel

Phase Current

Contact Wear

$I^2$

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Qualitrol
Defining Reliability
SF₆ Monitoring – Density, Pressure, Temperature & Dewpoint

Sensors RS-485 / 4-20mA
Modbus / DNP 3.0
SF₆ Monitoring – Density, Pressure, Temperature & Dewpoint
- Measure Heater Current
- Determine on/off condition
- Assemblies of 2 and 4 CT’s Optional
- Ratio = 1000:1
- Ring or Split-Core
Resistive temperature devices (RTD)

- Resistance change: 38.5 Ω/ 100 °C

- Mounting locations: tank, mechanism or cabinet
Coil Continuity (Integrity)

- Does not trip breaker
- Tolerates additional coil monitoring measures
- Works with variety of coils
- Coil Current
- Reaction time, coil fingerprint

Diagram:
- Shorted Coil
- Open Coil
- Good Coil
- Threshold
- 200 μs
- 12 V

Images:
- Equipment with coils and connections
- Electrical panel with coils and connections

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Other Connection Points

- Auxiliary Switches
- Motor Current
Real Time Monitoring – NEW FEATURE
Breaker Shot Record – Open Operation

DIGITAL DATA: 9 channels

- Spare - Not Used
- Trip Input 1
- Trip Input 2
- Heater 1 Input
- Heater 2 Input
- Breaker Aux 52A Input
- Close Input
Breaker Shot Record – Close Operation
Concept of Fingerprint with Alarm

• A breaker trip or close operation is stored as a reference of a good operation
• If measured parameters deviate by programmed limits during subsequent operations then an alarm is raised to allow more detailed inspection of the results
• Off line software collects regular data and looks for trends, for example, the early identification of SF6 gas leaks or changes to motor run time indicating problems with spring charging
Example of on line Breaker Condition Monitor

Description  Qualitrol's BCM is a continuous (24x7) on-line condition monitoring system for 11kV to 1200kV Circuit Breakers. Our solution can provide monitoring for single breaker to multi-site for thousands of breakers with centralized comprehensive monitoring and reporting.

Application  The BCM system provides continuous monitoring for the overall health of circuit breakers:

- Allows corrective actions to be taken before any failure occurs
- Optimize maintenance visits based on actual condition
- Optimize or reduce replacement or repair expenditures
- Ensure compliance to EPA SF₆ monitoring

QUALITROL  Defining Reliability
Thank You