Switchgear of the Future
Presentation & Demonstration of the State of the Art in Switchgear Design

Presented by: James K. Stacy
For: IEEE
This presentation focuses on medium voltage AC electrical distribution systems with voltages above 1 kV, up to and including 52 kV.
History of MV Switchgear
Medium Voltage Switchgear Evolution

Fixed oil filled circuit breakers were difficult & dangerous to use & maintain

Oil filled circuit breakers were put into withdrawable switchgear in order facilitate maintenance but reliability was still an issue.

SF6 & Vacuum circuit breakers increased the reliability of MV circuit breaker switchgear in the 1970’s. Metal clad today has very little differences compared to metal clad from the 70s. It is large and expensive.

Main drivers of innovation:
• Service continuity
• Safety
• Compactness
• Cost reduction

Optimization of trouble shooting
Fault prevention
Existing MV Switchgear Technology - AIS

Air Insulated Switchgear

- Very mature technology…so mature, can we do better?
- Uses air as the dielectric…very sensitive to the environment
- Largest of the switchgear types
- Requires most maintenance of the switchgear types
Gas Insulated Switchgear
Existing MV Switchgear Technology - GIS

Gas Insulated Switchgear

- No maintenance in the MV circuit by having a clean electrical atmosphere (Isolation)
  - Particles
  - Small animals
  - Salt
  - Dusty environment
  - Humidity
- Accidental - touch safe
- Reduced risk of internal arc

Sealed Pressure System
Existing MV Switchgear Technology - GIS

Table 1: Overview of failure causes

<table>
<thead>
<tr>
<th>Causes of failures in air-insulated switchgear</th>
<th>Share of air-insulated switchgear failures</th>
<th>Failure causes not relevant to gas-insulated switchgear</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermocycling</td>
<td>7%</td>
<td>✅</td>
</tr>
<tr>
<td>Mechanical structure failure</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Mechanical damage from foreign source</td>
<td>7%</td>
<td>✅</td>
</tr>
<tr>
<td>Shorting by snakes, birds, rodents, etc.</td>
<td>3%</td>
<td>✅</td>
</tr>
<tr>
<td>Malfunction of protective device</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Above normal ambient</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Exposure to chemicals or solvents</td>
<td>3%</td>
<td>✅</td>
</tr>
<tr>
<td>Exposure to moisture</td>
<td>30%</td>
<td>✅</td>
</tr>
<tr>
<td>Exposure to dust or other contaminants</td>
<td>10%</td>
<td>✅</td>
</tr>
<tr>
<td>Exposure to non-electrical fire</td>
<td>7%</td>
<td></td>
</tr>
<tr>
<td>Normal deterioration from age</td>
<td>10%</td>
<td></td>
</tr>
<tr>
<td>Severe weather condition</td>
<td>3%</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4%</td>
<td></td>
</tr>
</tbody>
</table>

>50% of the failures are not relevant
High percentage of the remainder reduced:

- Less mechanical efforts
- It is an indoor equipment
- Fixed components reduce the possibilities of “hot points”
- Maintenance is not needed in MV parts

## Existing MV Switchgear Technology - GIS

### Common causes of arc flash in AIS | GIS

<table>
<thead>
<tr>
<th>Human error</th>
<th></th>
<th>GIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Careless cover or device removal</td>
<td>Fully insulated /</td>
<td>Only the cable compartment is accessible</td>
</tr>
<tr>
<td>Dropped tool</td>
<td>Fully insulated /</td>
<td>Only the cable compartment is accessible</td>
</tr>
<tr>
<td>Installing cabling or components live</td>
<td>Switch disconnector</td>
<td>to ground the section prior maintenance</td>
</tr>
<tr>
<td>Test instrument misapplied</td>
<td>Integrated test</td>
<td>instruments for voltage test / Switch</td>
</tr>
<tr>
<td></td>
<td></td>
<td>disconnector to ground the section prior</td>
</tr>
<tr>
<td></td>
<td></td>
<td>maintenance</td>
</tr>
<tr>
<td>Other human intervention</td>
<td>User-friendly &amp;</td>
<td>intuitive operation together with fully</td>
</tr>
<tr>
<td></td>
<td></td>
<td>integrated mechanical interlocking system.</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Limit human intervention to the minimum due</td>
</tr>
<tr>
<td></td>
<td></td>
<td>to HV part maintenance free</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Equipment failure</th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Misalignment of moving contacts</td>
<td>Fixed breaker /</td>
<td>No moving contact and shield</td>
</tr>
<tr>
<td>Breakdown of insulating</td>
<td>Insulating (SF6)</td>
<td>system monitored</td>
</tr>
<tr>
<td>Conductive linkage contacting live parts</td>
<td>Compartment</td>
<td>sealed for life</td>
</tr>
</tbody>
</table>
Moving from Withdrawable to Fixed Mounted Medium Voltage Circuit Breaker Switchgear
Moving to Fixed Mounted Switchgear - Drivers

- Racking circuit breakers is a known cause of electrical arc flash events and is cited multiple times in IEEE 1584 Annex C.
- NFPA 70E PPE tables require higher levels of PPE for racking operations.
- Fixed circuit breaker switchgear eliminates racking and therefore eliminates one potential risk.
- Generally, racking problems are uncommon. When they do occur, they are often due to improper breaker reinstallation. They can increase in frequency with lack of maintenance and age of the equipment.
### Moving to Fixed Mounted Switchgear - Drivers

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Fixed Circuit Breaker Switchgear</th>
<th>Withdrawable Circuit Breaker Switchgear</th>
</tr>
</thead>
</table>
| Design & Operability | • Isolation via disconnect  
• Compact design w/ front access                                                               | • Isolation via breaker withdrawal from cubicle
• Larger design requiring rear access                                                          |
| Safety             | • Has grounding switch  
• Interlocked to prevent entry until system is grounded  
• Has some level of arc resistance  
• Removes risks associated w/ removing withdrawable components                                   | • Requires manual grounding via hot stick & cable assemblies  
• Allows access while switchgear is energized  
• Arc resistance construction is a unique design  
• Retains the risk associated w/ racking operations                                                |
| Reliability        | • Intuitive interlocked operation  
• Has no complex racking mechanism or shutter assemblies                                        | • User dependent manual steps to withdraw the breaker to isolate circuit  
• Requires use of racking mechanisms and shutter assemblies                                     |
| Cost               | • Lower in both capital & operational expenses                                                  | • Higher in both capital & operational expenses                                               |
Shielded Solid Insulated Switchgear (aka SSIS or 2SIS)

The Newest Category of Medium Voltage Switchgear
Shielded Solid Insulated Switchgear (aka SSIS or 2SIS)

What is 2SIS (shielded solid insulation system)

● A new class of MV switchgear

● Entire MV live circuit path is grounded
  ● “accidentally touchable” per IEC…user safety
  ● No more exposed conductors
    – Likelihood of internal arc is extremely limited

● Protected against the environment
  ● Dust, pollution, condensation, humidity, aggressive atmosphere, etc.
  ● Removes risk of ineffective or no maintenance…no need for cleaning
  ● No electric fields = no tracking, no partial discharge
Shielded Solid Insulated Switchgear (aka SSIS or 2SIS)

1. Low Voltage cabinet
2. Cable test
3. Top connections
4. Core unit
5. Bottom connections
6. Bottom compartment
7. Sensors (CTs and VTs)
8. Gas exhaust duct
Shielded Solid Insulated Switchgear (aka SSIS or 2SIS)

Solid insulation covered by a conductive layer

Conductive layer
Insulating layer
Main conductor
Central screw

Flat interface cross-section
Shielded Solid Insulated Switchgear (aka SSIS or 2SIS)

2SIS vs SIS

- No field in ambient air for 2SIS
- Field in ambient air for SIS

Circuit breaker/Load Break Switch

Shield
Shielded Solid Insulated Switchgear (aka SSIS or 2SIS)

- Busbar Connections
- Busbars with Solid Insulation
- Busbar Connection to Circuit Breaker
- Elbow Cable Connections
Core Unit

Vacuum Circuit Breaker

Grounding Isolation Switch

Completely Epoxy Insulated & Shielded
SSIS Space Savings
Small Footprint and Front Accessible

Total Footprint:
211 sq. ft.
SSIS Space Savings
Small Footprint and Front Accessible

Total Footprint: 82 sq. ft.

60% Footprint Savings!

18 in. Air Clearance
36 in.
29.5 in. 14.75 in.
Working Space 5 ft.
9.5 ft.
8.6 ft.

14.75 in.
Sensor Technology

LPVT

MV Connection up to 15kV

Converts Voltage up to 120V Signal

Voltage Protection Scheme

V_{in}: 0.2 to 4V

V_{out}: \frac{100}{\sqrt{3}} = 120V

Resistive divider

LPVT

Converter

Protective Relay

MV Connection up to 15kV

Converts Voltage up to 120V Signal

Voltage Protection Scheme

V_{in}: 0.2 to 4V

V_{out}: \frac{100}{\sqrt{3}} = 120V

Resistive divider

LPVT

Converter

Protective Relay
### SSIS Environmental Impact – Core Materials

<table>
<thead>
<tr>
<th>Product</th>
<th>SSIS</th>
<th>AIS</th>
<th>Metalclad</th>
</tr>
</thead>
<tbody>
<tr>
<td>Product weight</td>
<td>148.3</td>
<td>326.0</td>
<td>923.0</td>
</tr>
<tr>
<td>Steel</td>
<td>73.0</td>
<td>154.0</td>
<td>732.4</td>
</tr>
<tr>
<td>Copper</td>
<td>9.0</td>
<td>45.0</td>
<td>95.2</td>
</tr>
<tr>
<td>Aluminium</td>
<td>10.0</td>
<td>10.0</td>
<td>10.6</td>
</tr>
<tr>
<td>Epoxy Resin</td>
<td>34.0</td>
<td>52.0</td>
<td>60.1</td>
</tr>
<tr>
<td>Other</td>
<td>22.3</td>
<td>65.0</td>
<td>24.7</td>
</tr>
</tbody>
</table>
SSIS Environmental Impact – CO2 Contribution

**Global Warming (g ~CO2)**

*M+D+U, 20 years, 30%In*

- **SSIS**
- **AIS**
- **Metalclad**
Questions?
THANK YOU.