PJM: Transmission Topology Control
Circuit Breaker Reliability & Maintenance
Circuit Breaker Reliability
Cigré Statistics: Key Definitions

- **Major Failure**
  - Complete failure of a circuit breaker which causes a lack of one or more of its fundamental functions

- **Minor Failure**
  - Failure of a circuit breaker, constructional element or sub-assembly that is not (does not cause) a major failure
Circuit Breaker Reliability
Cigré Statistics: First Inquiry, 1974-1977

- Summary of findings
  - 70% of major failures have mechanical origin
  - 19% of electrical origin, auxiliary and controls
  - 11% electrical, main circuit
  - Operating mechanism responsible for highest number of failures
Circuit Breaker Reliability

- Considered only single-pressure SF6 gas
  - Major failure rate 40% of totals in First Enquiry
  - Minor failure rate +30% from First Enquiry (SF6 loss)
- Failure rate increases greatly with voltage
- Disregard “others”, mechanism and auxiliary controls are 70%
  - Same as in First Inquiry

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>VALUE 2nd Enquiry</th>
<th>UNIT OF MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Failures</td>
<td>0.672</td>
<td>failures/100 cb years</td>
</tr>
<tr>
<td>Minor Failures</td>
<td>4.749</td>
<td>failures/100 cb years</td>
</tr>
<tr>
<td>Major failure leading causes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Component at service voltage</td>
<td>21.0%</td>
<td></td>
</tr>
<tr>
<td>Electrical control and auxiliary</td>
<td>29.0%</td>
<td></td>
</tr>
<tr>
<td>Operating mechanism</td>
<td>43.2%</td>
<td></td>
</tr>
<tr>
<td>Others</td>
<td>4.8%</td>
<td></td>
</tr>
</tbody>
</table>
Circuit Breaker Reliability

- Major failures reduced ≈ 50% since previous study
  - True for all voltages; Especially at higher voltages
  - Mechanism failures follow same pattern
- Component distribution roughly the same
  - Care with operating mechanism
- Minor failures not analyzed; Under reported

<table>
<thead>
<tr>
<th>DESCRIPTION</th>
<th>VALUE 2nd Enquiry</th>
<th>VALUE Present</th>
<th>UNIT OF MEASURE</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Failures</td>
<td>0.672</td>
<td>0.300</td>
<td>failures/100 cb years</td>
</tr>
<tr>
<td>Minor Failures</td>
<td>4.749</td>
<td>N.A.</td>
<td>failures/100 cb years</td>
</tr>
<tr>
<td>Major failure leading causes</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
  - Component at service voltage | 21.0% | 20% |
  - Electrical control and auxiliary circuits | 29.0% | 30% |
  - Operating mechanism | 43.2% | 50% |
  - Others | 4.8% | |
Impact on Circuit Breaker Maintenance
Cost Analysis Assumptions

- Overhaul period operations, not time, based
  - M1 single-pressure SF6 → 2000
  - M2 single-pressure SF6 → 5000
  - Oil and air-blast → 400
    - Mechanical to 750
- Thirty (30) year life expectancy
  - At one (1) operation per week
  - At one (1) operation per day
- Overhaul of oil or air-blast costs 2.5 times estimate for single-pressure SF6 circuit breaker
Impact on Circuit Breaker Maintenance
72.5 kV System Example

- Overhauls in 30 year lifetime

- Overhaul cost in 30 year lifetime
Impact on Circuit Breaker Maintenance
245 kV kV System Example

- Overhauls in 30 year lifetime
- Overhaul cost in 30 year lifetime
Impact of Topology Transmission Control

Other things to consider ……

- Line switching as statistical phenomena
  - Class C0, C1 or C2
- Effects of topology control on system
  - Overload currents and voltages?
  - Higher TRV requirements
- Additional reactor switching
- Standard procedure of open breaker
  - Acts as isolator?
  - Open disconnect switch?
- Impact of condition monitoring
  - Focused on mechanism / controls
  - More accurate for high operations