Breaker VTB Model

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Date: November 3, 1999

Model name: Breaker

DLL name: Breaker.DLL

Version number: 1.0

Report errors or changes to: cokk@engr.sc.edu

Pictorial Representation of Model

Figure 1

Brief Description of Model

The breaker is modeled as a device with three possible states:

- Closed
- Arcing
- Open

The breaker is always initialized in the closed state. In this state, it behaves as an ideal resistor of a user specified value.

The breaker state changes from closed to arcing, when the RMS current through it exceeds its current rating. The RMS current is evaluated as the average of the square of the breaker current over a user specified time interval.

While in the arcing state, the breaker is modeled as a constant voltage source. The voltage magnitude is user specified (arcing voltage parameter). The polarity of the voltage is the same as the current flow direction.

The breaker finally switches from arcing to open state, when the current falls below the extinction current.

While in the open state, the breaker is modeled as an ideal resistor (Off-Conductance).

Model Validity Range and Limitations

Rated current, trip time, arc-voltage, and on-conductance values must be positive. Off-Conductance can be zero or positive.
List of Model Parameters

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Default Value</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rated Current</td>
<td>The breaker current rating</td>
<td>10</td>
<td>Amperes</td>
</tr>
<tr>
<td>Trip Time</td>
<td>The time required for tripping the breaker at rated current.</td>
<td>0.5</td>
<td>seconds</td>
</tr>
<tr>
<td>On-Conductance</td>
<td>The conductance of the breaker while in the closed state</td>
<td>100</td>
<td>Mhos</td>
</tr>
<tr>
<td>Off-Conductance</td>
<td>The conductance of the breaker while in the open state</td>
<td>$10^{-5}$</td>
<td>Mhos</td>
</tr>
<tr>
<td>Arc Voltage</td>
<td>The voltage across the breaker while in the arcing state</td>
<td>100</td>
<td>Volts</td>
</tr>
</tbody>
</table>

List of Accessible Internal Variables

<table>
<thead>
<tr>
<th>Name</th>
<th>Description</th>
<th>Units</th>
</tr>
</thead>
<tbody>
<tr>
<td>Voltage</td>
<td>Voltage across device. Polarity is $V_A - V_B$.</td>
<td>Volts</td>
</tr>
<tr>
<td>Inst-Current</td>
<td>Instantaneous current through device. Positive flow is from node A to node B.</td>
<td>Amperes</td>
</tr>
<tr>
<td>RMS-Current</td>
<td>RMS current through device. Positive flow is from node A to node B.</td>
<td>Amperes</td>
</tr>
<tr>
<td>Breaker-State</td>
<td>0, 1, or 2 for closed, arcing, and open states respectively.</td>
<td>N/A</td>
</tr>
</tbody>
</table>

Assumptions in Model Derivation

See model description.

Mathematical Description of Model

While in the closed state, the breaker is represented by an ideal resistor (of on-conductance value). In order to determine when the breaker must be tripped, the RMS current is continuously computed over a sliding time window as follows:

$$i_{RMS}(t) = \frac{1}{T} \int_{t-T}^{t} i^2(\tau) d\tau$$

where: $T$ is the *Trip-Time* parameter

In order to achieve high computational efficiency, the integral is computed using a recurrence formula:...
\[ i_{\text{RMS}}(t) = \frac{1}{N} \left( N \cdot i_{\text{RMS}}(t - \Delta t) + i^2(t) - i^2(t - T) \right) \]

where \( N = \frac{T}{\Delta t} \)

When the \( i_{\text{RMS}} \) value exceeds the \textit{Rated-Current} parameter, the breaker switches to the arcing state. While in this state, the breaker is modeled by a time varying resistor of value:

\[ R(t) = \frac{V_a}{i(t)} \]

where \( V_a \) is the \textit{Arc-Voltage} parameter.

and \( i(t) \) is the current through the device.

Note that while in the arcing state the model is non-linear.

The breaker switches to the open state when the current falls below the extinction current. The extinction current is defined as one thousandth of the current at the instant the breaker trips.

\section*{Example of Model Use}

N/A

\section*{Model Validation}

Model was validated by comparing VTB results to analytic solutions.