Application of Customer Exposure Ratio to Distribution Circuits

Written By: Ryan A. Melbard
Presented By: Val G. Werner

We Energies
Introduction

• Customer Exposure Ratio (CER)
  – Utilities can use CER to compare how well a circuit is sectionalized compared to their average circuit
  – Utilities can create a list of circuits that could benefit from extra protective devices for the purpose of improving reliability
  – Utilities can determine the optimal placement of protective devices on circuit using CER to improve reliability
  – Aids in determining where investment in protective devices have the largest reliability improvement
  – Based on Load Exposure (LE) concept
    • LE is a measure of the average interruption exposure for customers on a particular circuit
    • Typically
      – Circuits with high LE indices will have higher SAIFI
      – Circuits with low LE indices will have lower SAIFI
Load Exposure

Device Level – Product of the number of customers fed through the protective device and the length of the circuit to which the device is exposed.

Circuit Level – Summation of the Load Exposures of all devices on the circuit
Load Exposure – Examples

\(( N_A + N_B ) \) Customers

Substation

Circuit

Breaker

N_A Customers

Midline

Recloser

N_B Customers

L_A Length

L_B Length

\(( L_A + L_B ) \) Length

\[ LE_{\text{circuit w/o recloser}} = LE_{\text{bkr}} = (N_A + N_B)(L_A + L_B) \]

\[ LE_{\text{circuit w/o recloser}} = LE_{\text{bkr}} = N_A L_A + [N_A L_B + N_B L_A + N_B L_B] \]

\[ LE_{\text{circuit w/recloser}} = LE_{\text{bkr}} + LE_{\text{recl}} = (N_A + N_B)L_A + N_B L_B \]

\[ LE_{\text{circuit w/ recloser}} = LE_{\text{bkr}} + LE_{\text{recl}} = N_A L_A + N_B L_A + N_B L_B \]
Load Exposure Limitations

N = 100 Customers

L = 10 Miles

LE = L x N = 10 x 100 = 1000 Customers Miles

\[ LE = LE_{bkr} + LE_{recl} = (N_A + N_B)L_A + N_BL_B = (100+200)2 + 200 \times 2 = 1000 \text{ Customers Miles} \]
Customer Exposure Ratio

• Customer Exposure Ratio (CER) is used to normalize load exposure

• CER is calculated by dividing the circuit’s LE by the circuit’s largest possible LE

\[ \text{LE}_{\text{MAX}} = \text{Circuit Total Miles} \times \text{Circuit Total Customers} \]

\[
CER = \frac{\text{LE}_{\text{actual}}}{\text{LE}_{\text{max}}}
\]
Understanding CER

• A circuit with a CER equal to 1 indicates
  – The circuit only has the substation protection device
  – The circuit has no additional line protection devices, such as fuses or reclosers

• A lower CER indicates the circuit is better sectionalized
  – It does not necessarily signify that one circuit has more fuses or reclosers than another circuit
  – It does indicate the protective devices are more effectively located
CER – Examples

Substation Circuit Breaker

N = 100 Customers

L = 10 Miles

LE_{\text{Max}} = N \times L = 1000 \text{ Cust Mi}

CER = \frac{\text{LE}_{\text{actual}}}{\text{LE}_{\text{Max}}} = \frac{1000 \text{ Cust Mi}}{1000 \text{ Cust Mi}} = 1.0

Substation Circuit Breaker

N_A = 100 Customers

L_A = 2 Miles

N_B = 200 Customers

L_B = 2 Miles

LE_{\text{Max}} = (N_A + N_B)(L_A + L_B) = (100 + 200)(2 + 2) = 300 \times 4 = 1200 \text{ Cust Mi}

CER = \frac{\text{LE}_{\text{actual}}}{\text{LE}_{\text{Max}}} = \frac{1000 \text{ Cust Mi}}{1200 \text{ Cust Mi}} = 0.833
LE vs. CER

• LE measures exposure of the circuit
• CER measures the protection on the circuit
• LE is measured using the units of Customer-Miles
• CER is a value between 0 and 1 without units
  – Values close to 1 indicate few or no protection devices
  – Values close to 0 indicate a high degree of sectionalization or well-placed protection devices
Additional CER Uses

- CER can be used to estimate the number of customers that might experience interruptions due to a fault on the circuit.
- More specifically, CER can be used to determine the average number of customers affected per interruption event.
- The average number of customers per interruption event = CER x (the total number of customers on the circuit).
CER Assumptions

- There is an equal probability of a fault occurring anywhere on the circuit
- All faults are permanent
- All faults are three-phase faults
- All devices operate all three phases
- All lines contain three phases
- Despite these assumptions, CER can be used to provide a quick theoretical estimate of the amount and effectiveness of the protection on a circuit
Average Number of Customers Affected per Interruption Event

- The probability of the fault occurring in a particular part of the circuit is the Length of that segment divided by the circuit’s total length.
- The probability of a fault in either the first or second part of the circuit is 50% or 0.50.
For a fault on the first part, 300 customers out
For a fault on the second part, 200 customers out
Expected number of customers out:
\[0.50(300) + 0.50(200) = 250\] Customers
• Using CER:
\[0.8333(300) = 250\] Customers
CER – Applications

( Based on Actual Utility Data )
Using the CER Information from the Chart

• Identify circuits that require more sectionalization, which may allow for better prioritization of projects

• Identify circuits that have too much sectionalization or could use reconfiguration

• Pinpoint circuits where additional spending and reconfiguration would not provide significant improvement in reliability
Customers per Outage for Circuits with Acceptable and Unacceptable Reliability Performance
Percentage of Circuits with Unacceptable Reliability Performance within each Band of Customers per Outage

% of Circuits with Unacceptable Reliability Performance within Band

<table>
<thead>
<tr>
<th>Customers/Outage Band</th>
<th>% of Circuits</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-100</td>
<td>19%</td>
</tr>
<tr>
<td>100-250</td>
<td>28%</td>
</tr>
<tr>
<td>250-500</td>
<td>31%</td>
</tr>
<tr>
<td>500-1000</td>
<td>47%</td>
</tr>
<tr>
<td>1000-1500</td>
<td>56%</td>
</tr>
<tr>
<td>1500-2000</td>
<td>71%</td>
</tr>
<tr>
<td>&gt;2000</td>
<td>100%</td>
</tr>
</tbody>
</table>
Optimal Recloser Location

• Required: Circuit model with customers located in the model
• For a single circuit
  – Apply recloser in several locations on the circuit model
    • Based on rules of thumb or tribal knowledge or
    • Every possible location
  – Choose the location that results in the greatest improvement in CER
Summary

• Modern mapping programs could allow utilities to quickly calculate the LE and CER for circuits
• Utilities can use CER to compare how well a circuit is sectionalized compared to their average circuit
• Utilities can create a list of circuits that could benefit from extra protective devices for the purpose of improving reliability
• Utilities can determine the optimal placement of protective devices on circuit using CER to improve reliability
• The protective devices could come from circuits that are deemed to be “over-protected”, i.e. have a very low CER
Questions?
Customers per Outage for Circuits with Acceptable and Unacceptable Reliability Performance

- Customers on Circuit
- CER

Legend:
- 100 Cust/Outage
- 250 Cust/Outage
- 500 Cust/Outage
- 1000 Cust/Outage
- 1500 Cust/Outage
- 2000 Cust/Outage

Non-Worst Performing Circuits
Worst Performing Circuits