Application of Customer Exposure Ratio to Distribution Circuits

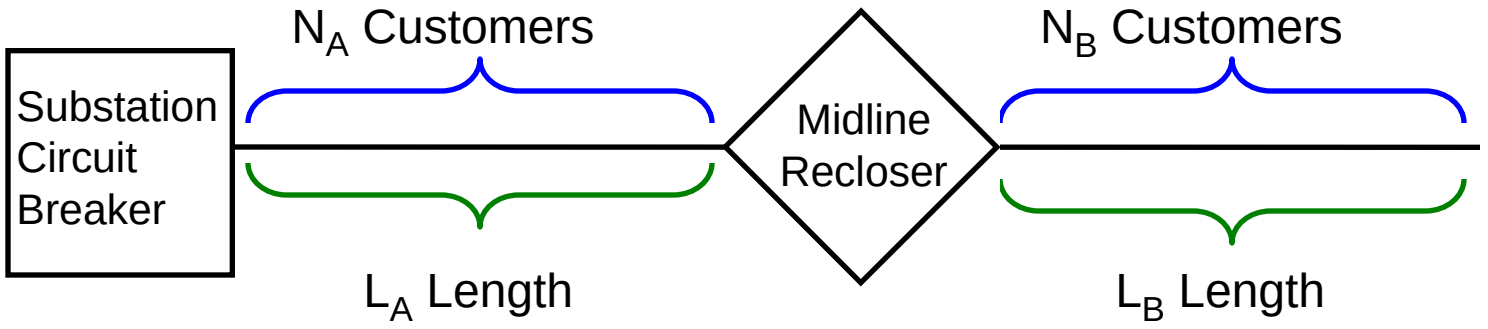
Written By: Ryan A. Melbard
Presented By: Val G. Werner

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

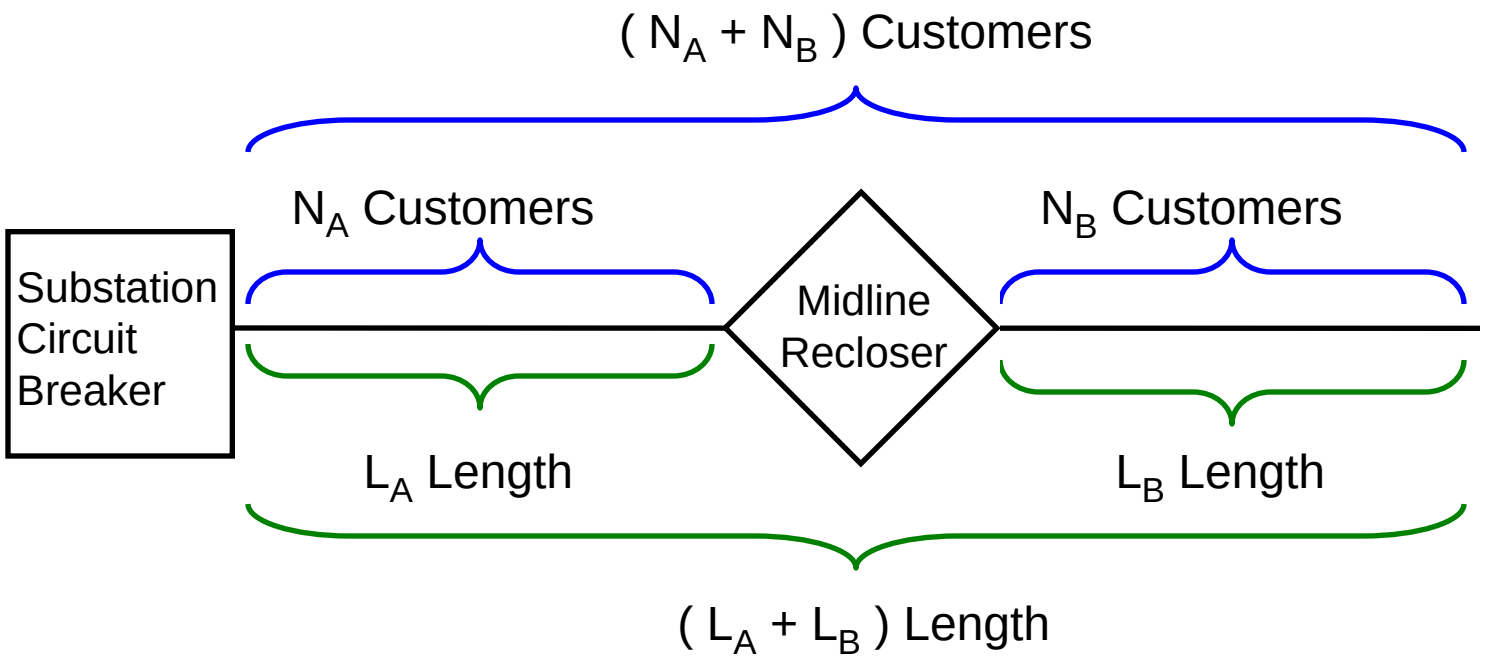
Load Exposure



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



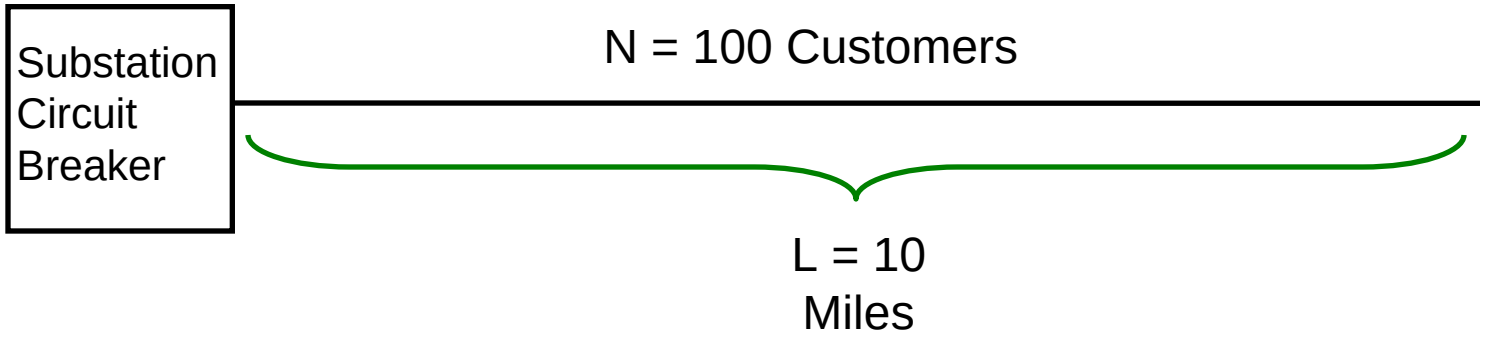
$$LE_{circuit\ w/o\ recloser} = LE_{bkr} = \left(N_A + N_B\right)\left(L_A + L_B\right)$$

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

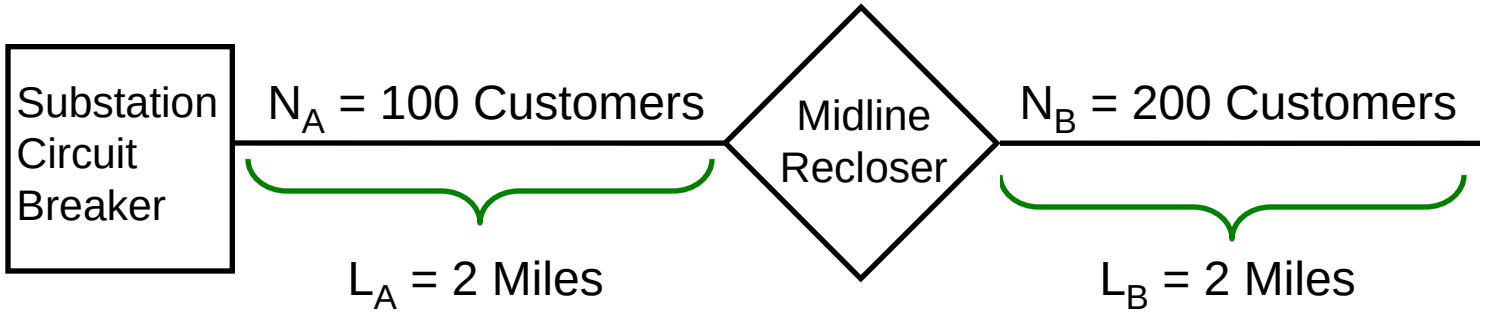
$$LE_{circuit\ w/recloser} = LE_{bkr} + LE_{recl} = \left(N_A + N_B\right)L_A + N_B L_B$$

$$LE_{circuit\ w/\ recloser} = LE_{bkr} + LE_{recl} = N_A L_A + N_B L_A + N_B L_B$$

Load Exposure Limitations



$LE = L \times N = 10 \times 100 =$ 1000 Customers Miles



$LE = LE_{bkr} + LE_{recl} = (N_A + N_B)L_A + N_BL_B = (100+200)2 + 200 \times 2 =$

1000 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

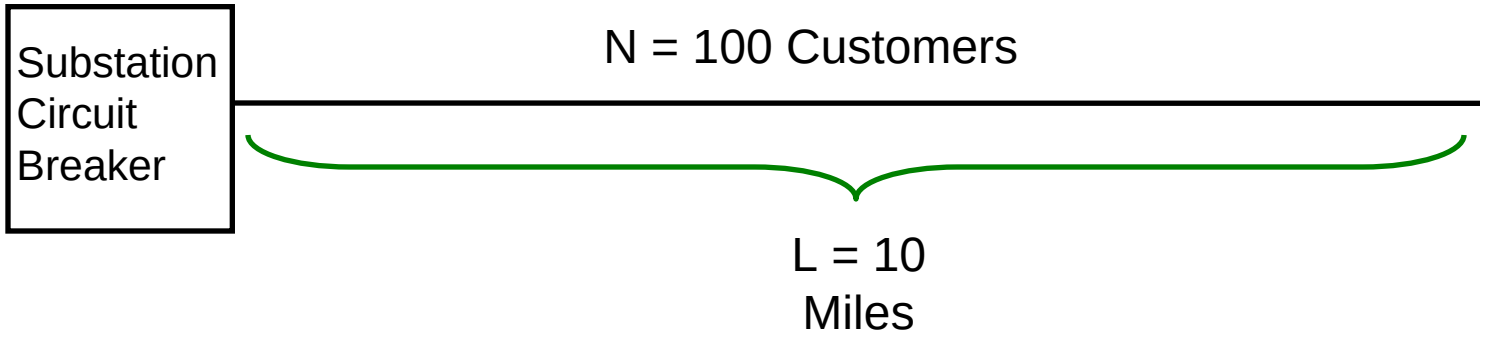
  LE_{MAX} = Circuit Total Miles x Circuit Total Customers

$$CER = \frac{LE_{actual}}{LE_{\max}}$$

Understanding CER

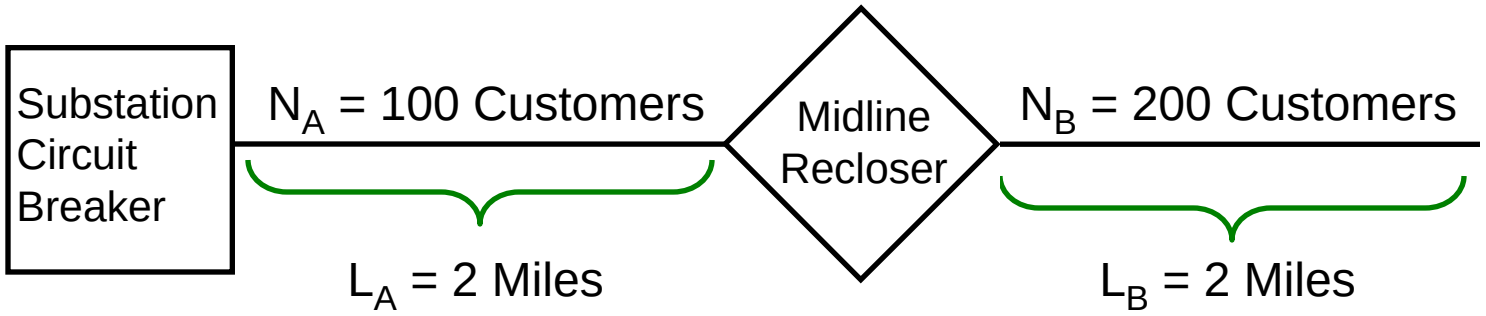
- A circuit with a CER equal to 1 indicates
  - The circuit only has the substation protection device
  - The circuit has no additional line protection devices, such as fuses or reclosers
- A lower CER indicates the circuit is better sectionalized
  - It does not necessarily signify that one circuit has more fuses or reclosers than another circuit
  - It does indicate the protective devices are more effectively located

CER – Examples



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

$$CER = \frac{LE_{actual}}{LE_{Max}} = \frac{1000 \text{ Cust Mi}}{1000 \text{ Cust Mi}} = 1.0$$



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

$$CER = \frac{LE_{actual}}{LE_{Max}} = \frac{1000 \text{ Cust Mi}}{1200 \text{ Cust Mi}} = 0.833$$

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

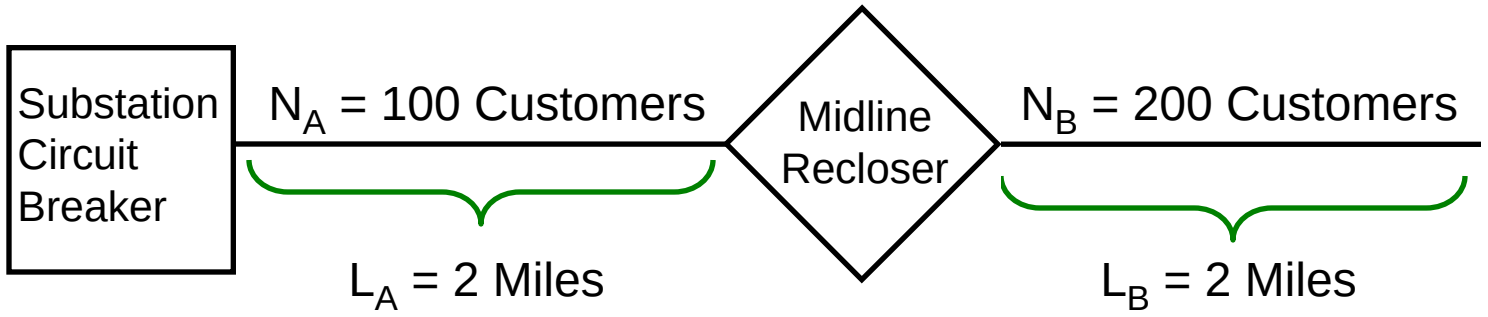
Additional CER Uses

- 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

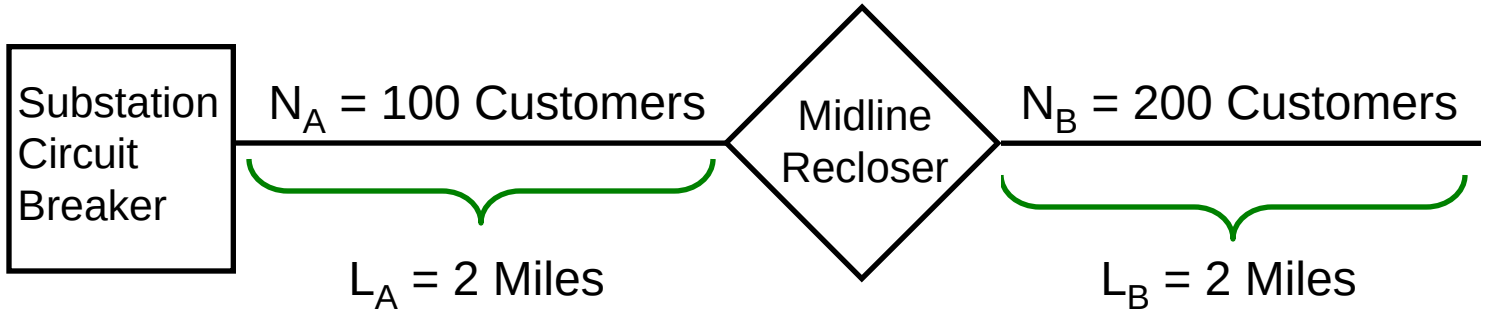
- There is an equal probability of a fault occurring anywhere on the circuit
- All faults are permanent
- All faults are three-phase faults
- All devices operate all three phases
- All lines contain three phases
- Despite these assumptions, CER can be used to provide a quick theoretical estimate of the 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

Average Number of Customers Affected per Interruption Event



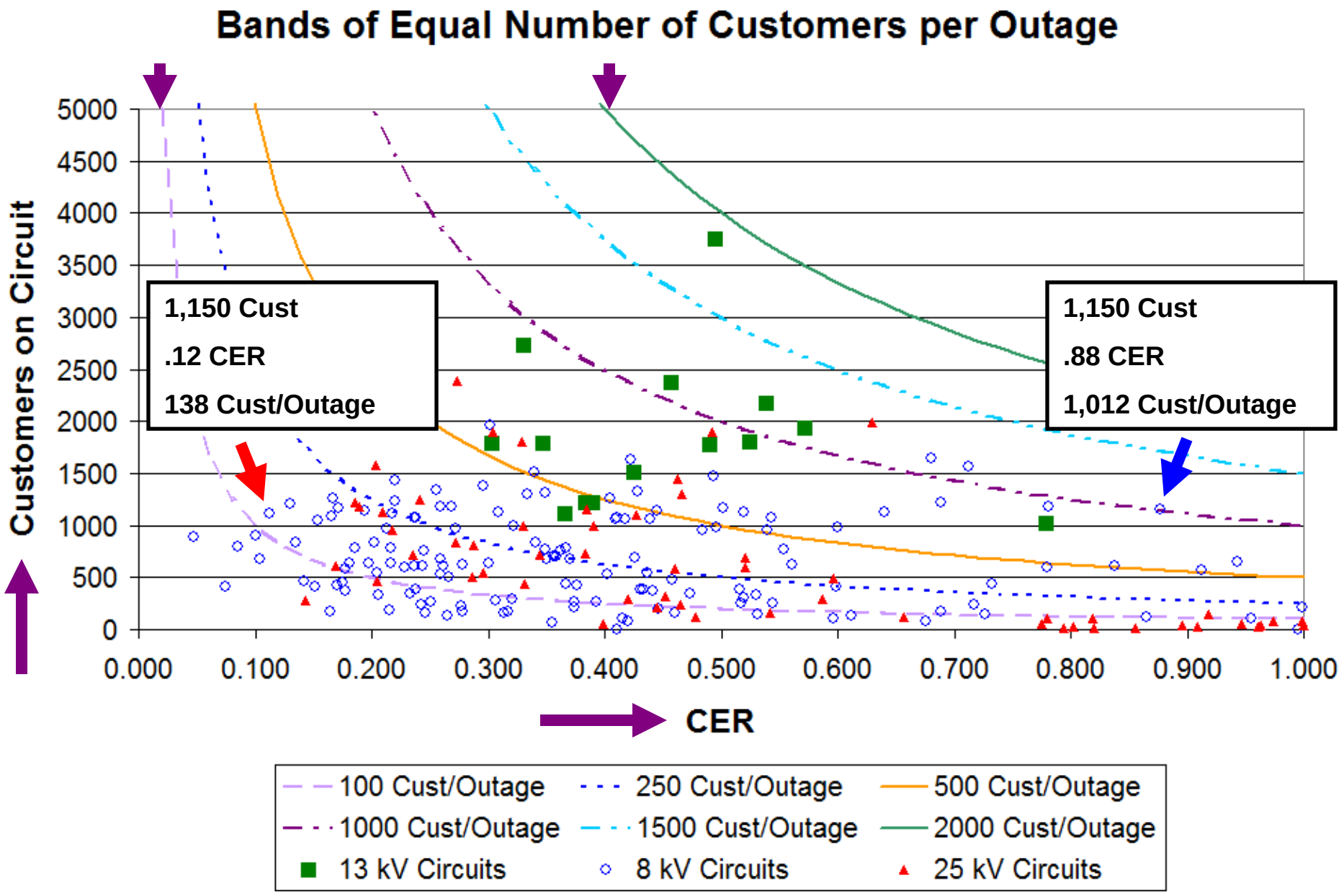
- For a fault on the first part, 300 customers out
- For a fault on the second part, 200 customers out
- Expected number of customers out:

  0.50(300) + 0.50(200) = **250** Customers
- Using CER:

  0.8333(300) = **250** Customers

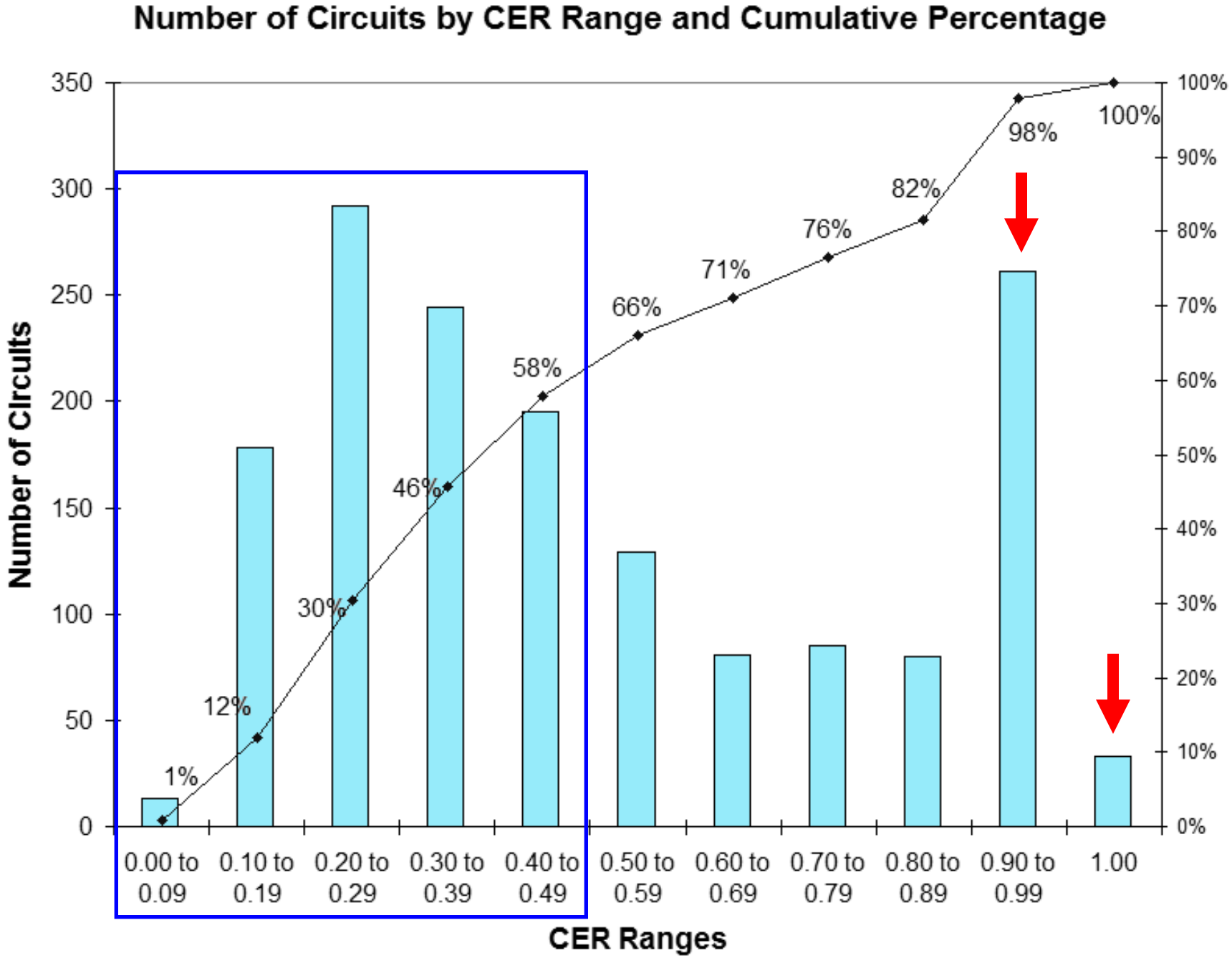
CER – Applications

(Based on Actual Utility Data)

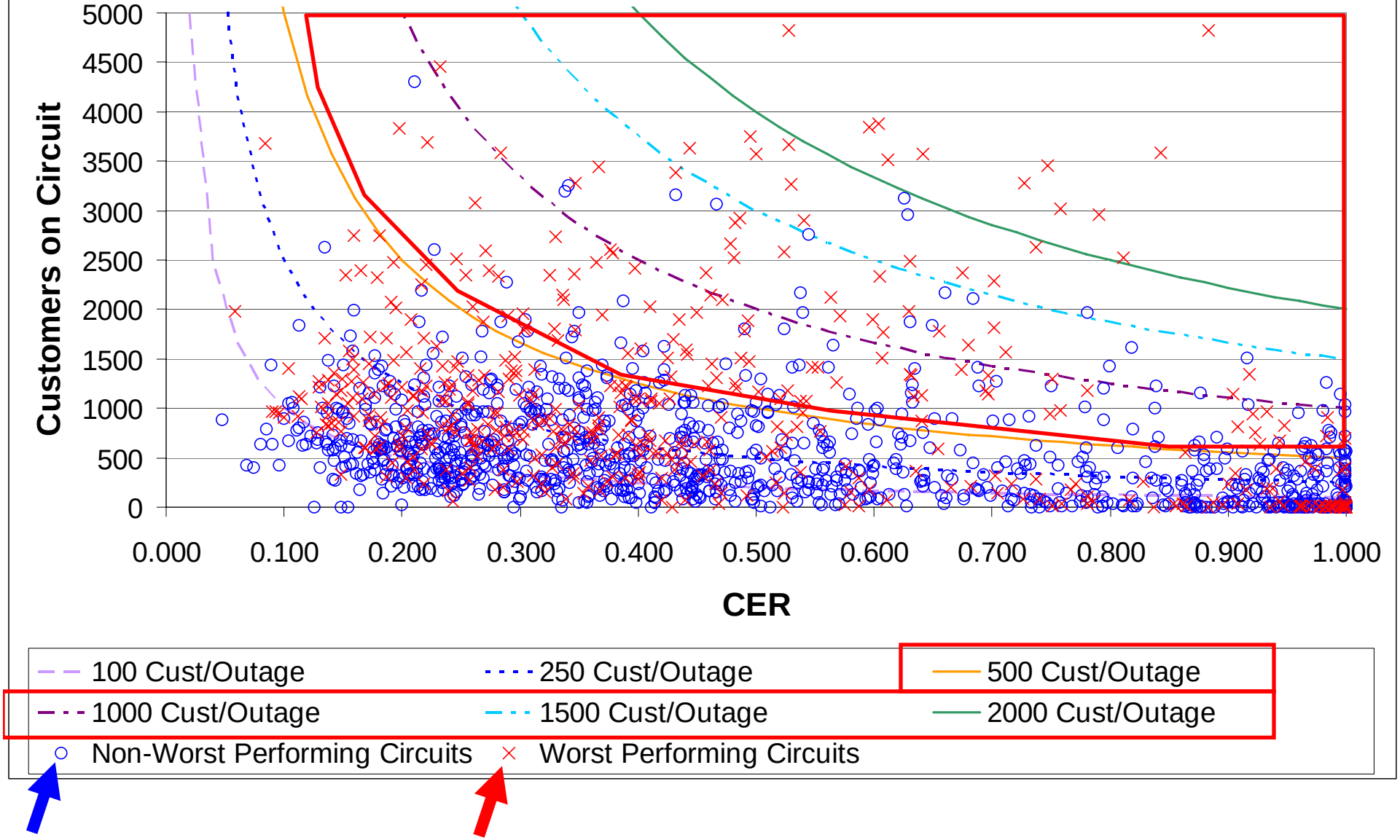

Bands of Equal Number of Customers per Outage
Customers on Circuit
5000
4500
4000
3500
3000
2500
2000
1500
1000
500
0
0.000
0.100
0.200
0.300
0.400
0.500
0.600
0.700
0.800
0.900
1.000
CER
1,150 Cust
.12 CER
138 Cust/Outage
1,150 Cust
.88 CER
1,012 Cust/Outage
100 Cust/Outage
250 Cust/Outage
500 Cust/Outage
1000 Cust/Outage
1500 Cust/Outage
2000 Cust/Outage
13 kV Circuits
8 kV Circuits
25 kV Circuits

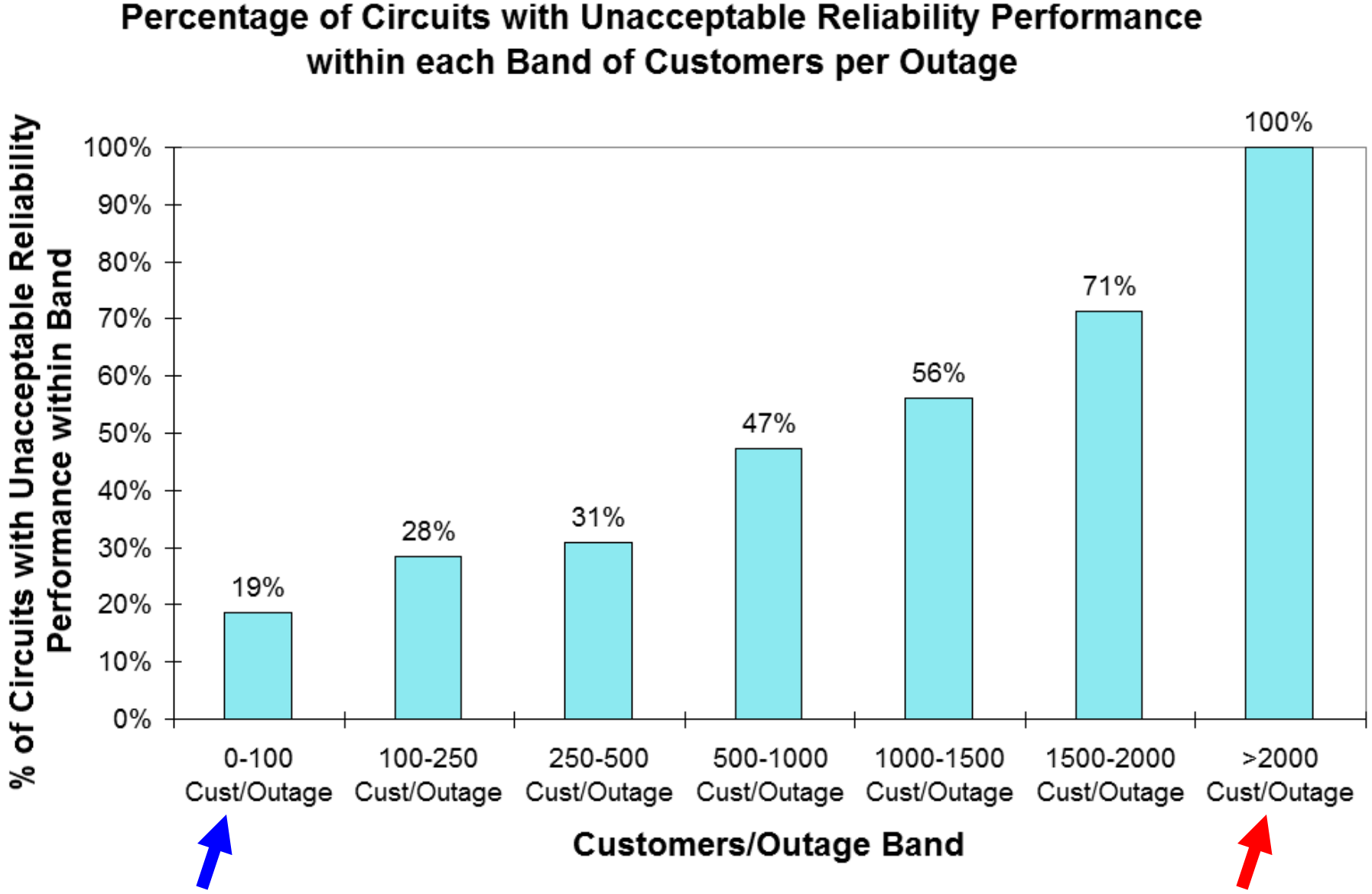
Using the CER Information from the Chart

- 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


Number of Circuits by CER Range and Cumulative Percentage
Number of Circuits
CER Ranges
350
300
250
200
150
100
50
0
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
1%
12%
30%
46%
58%
66%
71%
76%
82%
98%
100%
0.00 to 0.09
0.10 to 0.19
0.20 to 0.29
0.30 to 0.39
0.40 to 0.49
0.50 to 0.59
0.60 to 0.69
0.70 to 0.79
0.80 to 0.89
0.90 to 0.99
1.00

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
100%
90%
80%
70%
60%
50%
40%
30%
20%
10%
0%
19%
28%
31%
47%
56%
71%
100%
0-100 Cust/Outage
100-250 Cust/Outage
250-500 Cust/Outage
500-1000 Cust/Outage
1000-1500 Cust/Outage
1500-2000 Cust/Outage
>2000 Cust/Outage
Customers/Outage Band

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