Does Every Millisecond Really Count – A Comparison of Protection Based Arc Flash Mitigation Techniques

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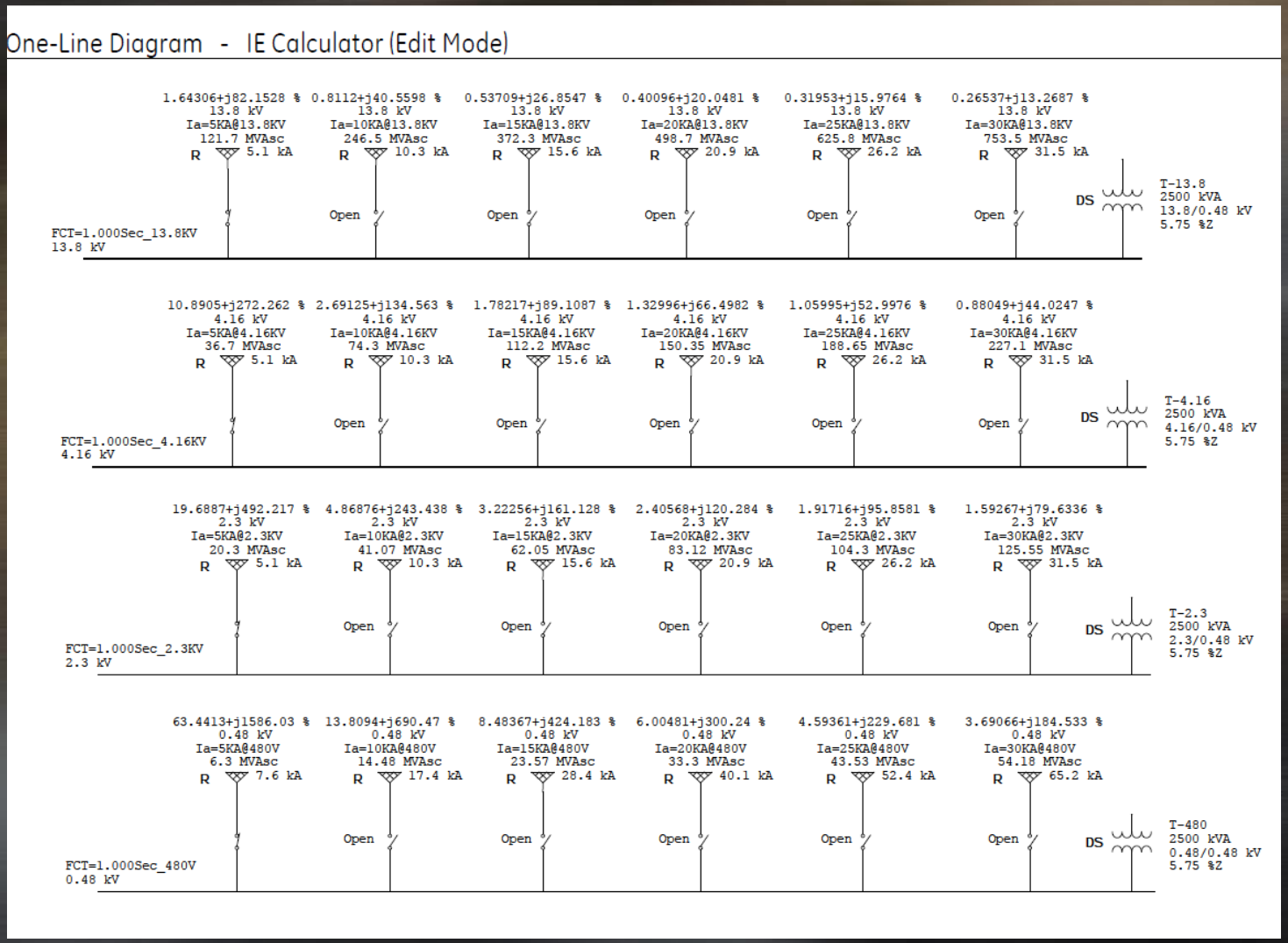
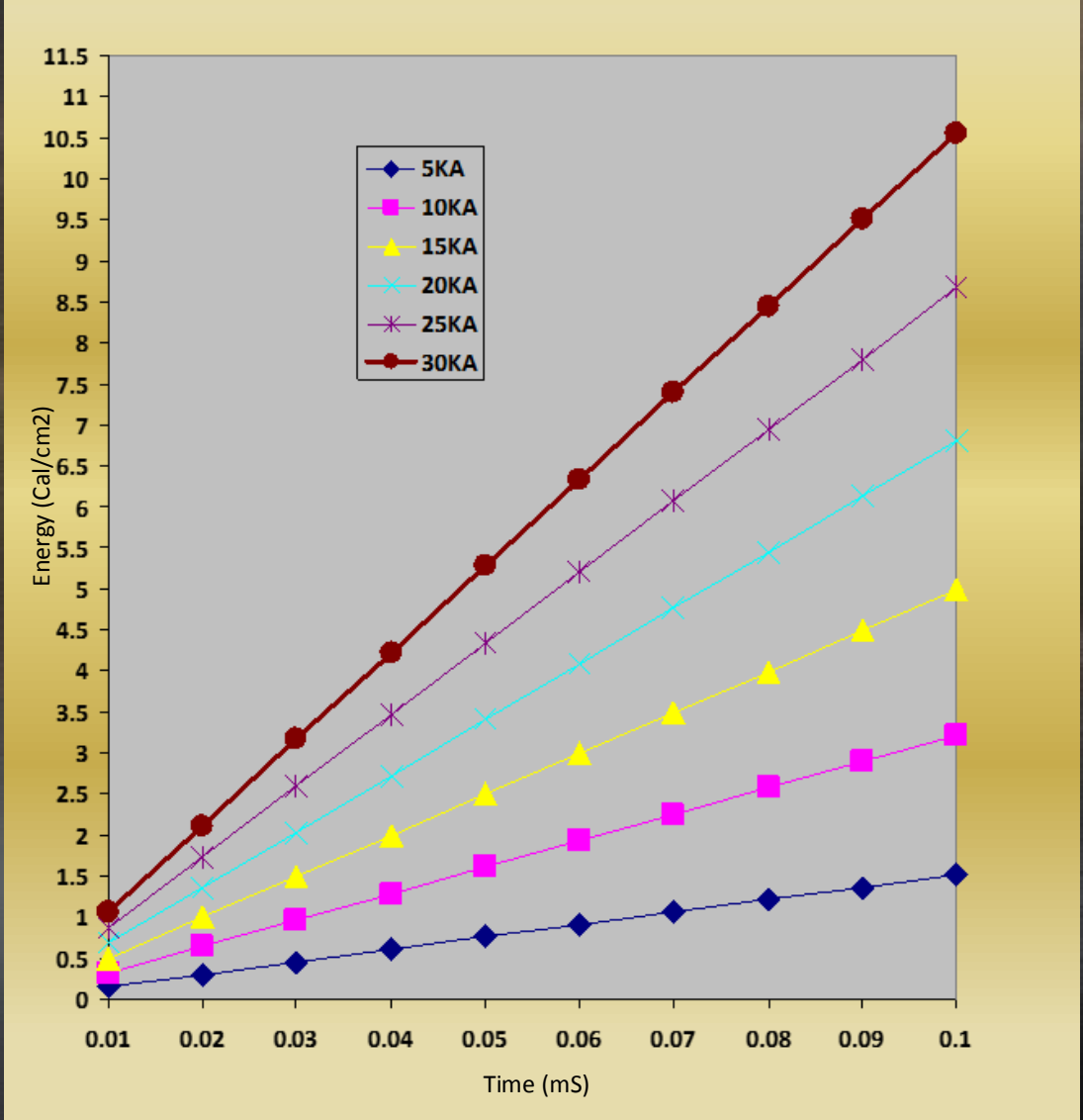
Background


One-Line Diagram - IE Calculator (Edit Mode)
1.64306+j82.1528 %
13.8 kV
Ia=5KA@13.8KV
121.7 MVAsc
R
5.1 kA
0.8112+j40.5598 %
13.8 kV
Ia=10KA@13.8KV
246.5 MVAsc
R
10.3 kA
0.53709+j26.8547 %
13.8 kV
Ia=15KA@13.8KV
372.3 MVAsc
R
15.6 kA
0.40096+j20.0481 %
13.8 kV
Ia=20KA@13.8KV
498.7 MVAsc
R
20.9 kA
0.31953+j15.9764 %
13.8 kV
Ia=25KA@13.8KV
625.8 MVAsc
R
26.2 kA
0.26537+j13.2687 %
13.8 kV
Ia=30KA@13.8KV
753.5 MVAsc
R
31.5 kA
Open
Open
Open
Open
Open
DS
T-13.8
2500 kVA
13.8/0.48 kV
5.75 %Z
FCT=1.000Sec_13.8KV
13.8 kV
10.8905+j272.262 %
4.16 kV
Ia=5KA@4.16KV
36.7 MVAsc
R
5.1 kA
2.69125+j134.563 %
4.16 kV
Ia=10KA@4.16KV
74.3 MVAsc
R
10.3 kA
1.78217+j89.1087 %
4.16 kV
Ia=15KA@4.16KV
112.2 MVAsc
R
15.6 kA
1.32996+j66.4982 %
4.16 kV
Ia=20KA@4.16KV
150.35 MVAsc
R
20.9 kA
1.05995+j52.9976 %
4.16 kV
Ia=25KA@4.16KV
188.65 MVAsc
R
26.2 kA
0.88049+j44.0247 %
4.16 kV
Ia=30KA@4.16KV
227.1 MVAsc
R
31.5 kA
Open
Open
Open
Open
Open
DS
T-4.16
2500 kVA
4.16/0.48 kV
5.75 %Z
FCT=1.000Sec_4.16KV
4.16 kV
19.6887+j492.217 %
2.3 kV
Ia=5KA@2.3KV
20.3 MVAsc
R
5.1 kA
4.86876+j243.438 %
2.3 kV
Ia=10KA@2.3KV
41.07 MVAsc
R
10.3 kA
3.22256+j161.128 %
2.3 kV
Ia=15KA@2.3KV
62.05 MVAsc
R
15.6 kA
2.40568+j120.284 %
2.3 kV
Ia=20KA@2.3KV
83.12 MVAsc
R
20.9 kA
1.91716+j95.8581 %
2.3 kV
Ia=25KA@2.3KV
104.3 MVAsc
R
26.2 kA
1.59267+j79.6336 %
2.3 kV
Ia=30KA@2.3KV
125.55 MVAsc
R
31.5 kA
Open
Open
Open
Open
Open
DS
T-2.3
2500 kVA
2.3/0.48 kV
5.75 %Z
FCT=1.000Sec_2.3KV
2.3 kV
63.4413+j1586.03 %
0.48 kV
Ia=5KA@480V
6.3 MVAsc
R
7.6 kA
13.8094+j690.47 %
0.48 kV
Ia=10KA@480V
14.48 MVAsc
R
17.4 kA
8.48367+j424.183 %
0.48 kV
Ia=15KA@480V
23.57 MVAsc
R
28.4 kA
6.00481+j300.24 %
0.48 kV
Ia=20KA@480V
33.3 MVAsc
R
40.1 kA
4.59361+j229.681 %
0.48 kV
Ia=25KA@480V
43.53 MVAsc
R
52.4 kA
3.69066+j184.533 %
0.48 kV
Ia=30KA@480V
54.18 MVAsc
R
65.2 kA
Open
Open
Open
Open
Open
DS
T-480
2500 kVA
0.48/0.48 kV
5.75 %Z
FCT=1.000Sec_480V
0.48 kV

Background


11.5
11
10.5
10
9.5
9
8.5
8
7.5
7
6.5
6
5.5
5
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
Energy (Cal/cm2)
5KA
10KA
15KA
20KA
25KA
30KA
0.01
0.02
0.03
0.04
0.05
0.06
0.07
0.08
0.09
0.1
Time (mS)

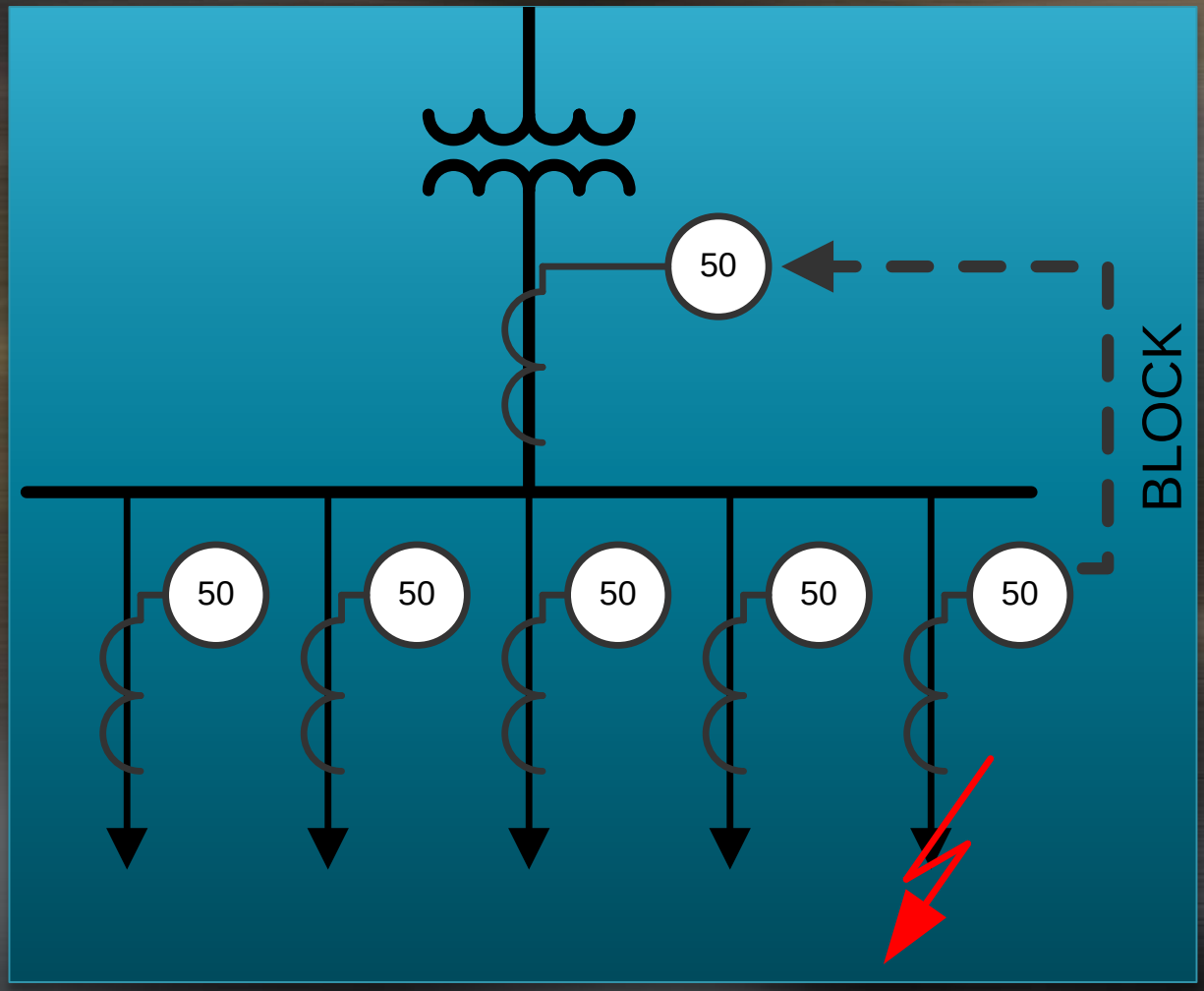
Arc-Flash Relay controlling 3 cycle Breaker

- Total time to clear is influenced by relay as well as breaker
- If lockouts are used, that time should also be included
- Light sensing relays are fast, but must be supervised to prevent mis-operation
- Depending on the supervision, operation of arc sensing relays can take from 4-12ms
- The type of relay output contact should also be considered

Arc-Flash Relay controlling 3 cycle Breaker

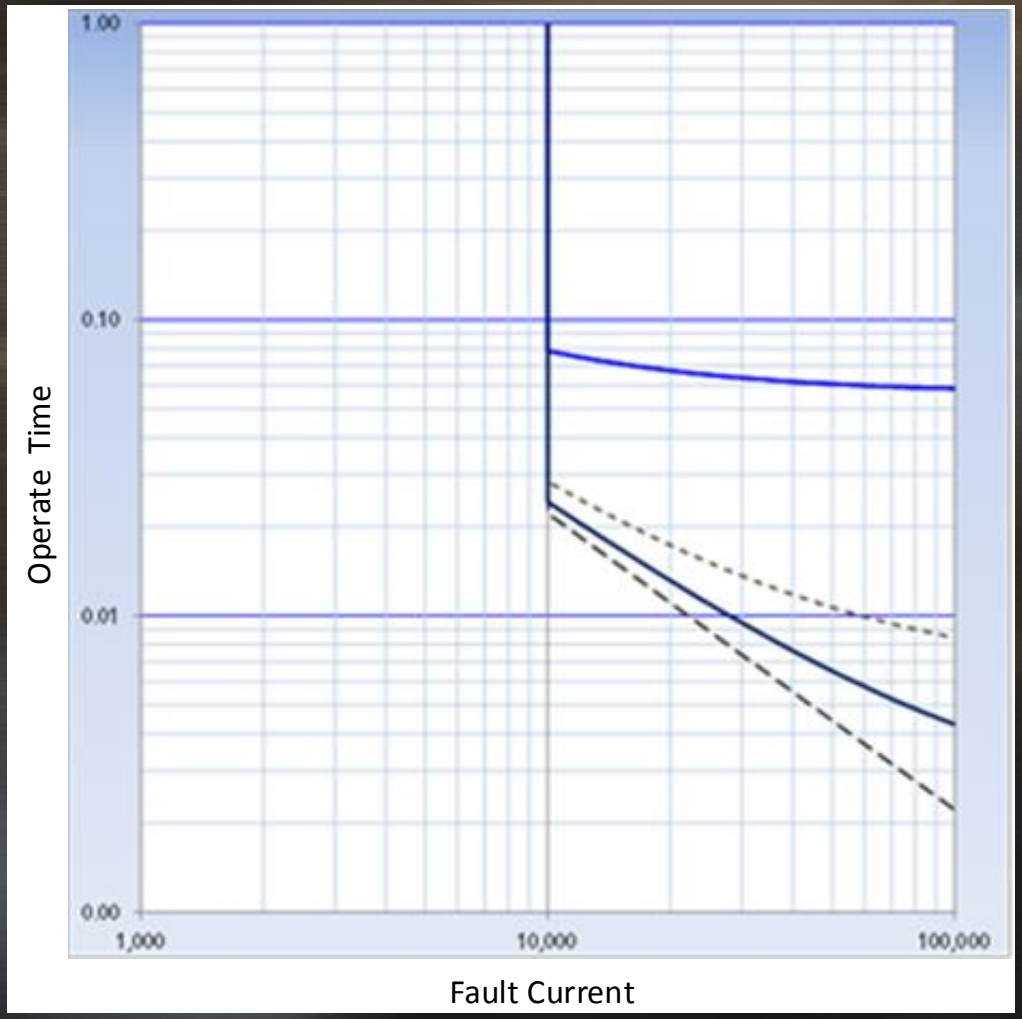
- A relay with a 4ms algorithm and a solid state output controlling a three cycle breaker has a total clearing time of 54.1 milliseconds
- For a 25KA fault on a 480V system this gives an incident energy of 4.8 Cal/cm^2
- A relay with a 8ms algorithm and a solid state output controlling a three cycle breaker has a total clearing time of 58.1 milliseconds and 5.0 Cal/cm^2
- Algorithm matters, but not enough to put you into a different clothing category

Zone-Selective Interlocking & 3 Cycle Breaker



Zone-Selective Interlocking & 3 Cycle Breaker

- $t_{pkp} = \frac{1.33}{MOP}$
- Element operate time
- Blocking signal asserted in logic
- Output contact
- Time to clear with a 3 cycle breaker



Zone-Selective Interlocking & 3 Cycle Breaker

- Similar and dis-similar algorithms require different time delays
- Dis-similar with upstream time to operate 40ms & 4 ms contact. Fault current = 1.8 times pickup, 12ms pickup & 3 cycle breaker total clear = 106 milliseconds. Energy = 7.5@4KV & 12@480V.
- Similar with a time delay of 4ms….operate time is 16ms & TCC of 66.7ms. Energy = 5.8@4KV & 4.0@480V.
- The algorithms determine the time delay which can impact the incident energy

Bus Differential

- Three cycle breaker gives a clear time of 66.7ms
- 5.8 Cal/cm^2 for 25KA & 480V system
- 4 Cal/cm^2 for 25KA & 4KV system

Reduced Energy Let Through

- Operate times will be the same as instantaneous element….about a cycle
- Since has same operate time as a bus differential will have similar incident energy
- Advantages:
  - Easy to configure
  - Works for all faults
- Disadvantages
  - You have to remember or be reminded to turn the switch on and off

Case Study Results

Solution	IE with 3 cycle breaker in Cal/Cm2	Clearing Time in milliseconds	IE with 5 cycle breaker in Cal/Cm2	Clearing Time in milliseconds
480V 4ms Arc-Flash Sensor @ 25KA	4.8	54.1	7.5	87.4
480V 8ms Arc-Flash Sensor @ 25KA	5.0	58.1	8.0	91.4
4KV 4ms Arc-Flash Sensor @25KA	3.4	54.1	5.3	87.4
4KV 8ms Arc-Flash Sensor @25KA	3.5	58.1	5.4	91.4
480V Zone Interlocking 106ms sc@25KA	12.0	106.0	OVER 12	139.3
4KV Zone Interlocking 106ms sc@25KA	7.5	106.0	OVER 12	139.3
480V Zone Interlocking 56ms sc@25KA	5.8	66.7	8.7	100.0
4KV Zone Interlocking 56ms sc@25KA	4.0	66.7	6.0	100.0
480V Low Imp Bus Diff @25KA	5.8	66.7	8.7	100.0
4KV Low Imp Buss Diff @25KA	4.0	66.7	6.0	100.0

Conclusions

- For most schemes, the type of solution you employ won't affect your clothing category
- Care should be taken with zone interlocking to avoid mis-coordination and fast operation
- Understand the advantages and disadvantages of each solution and make decisions based on those parameters

Thank You

Questions?