Transformer and Line Protection

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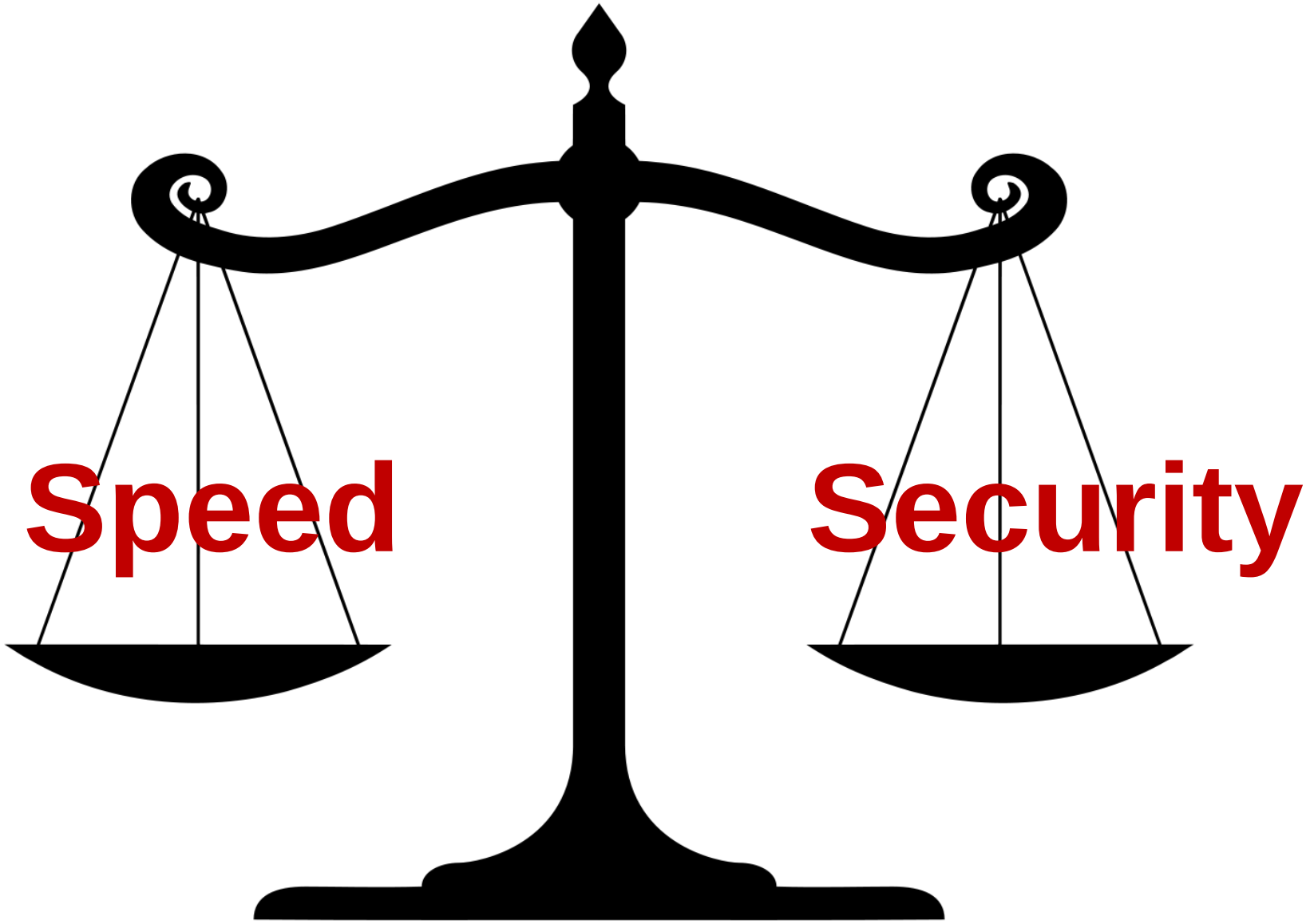
Do We Have to Balance Speed and Security ?



Security Enables Speed – And Speed ***Can*** Improve Security

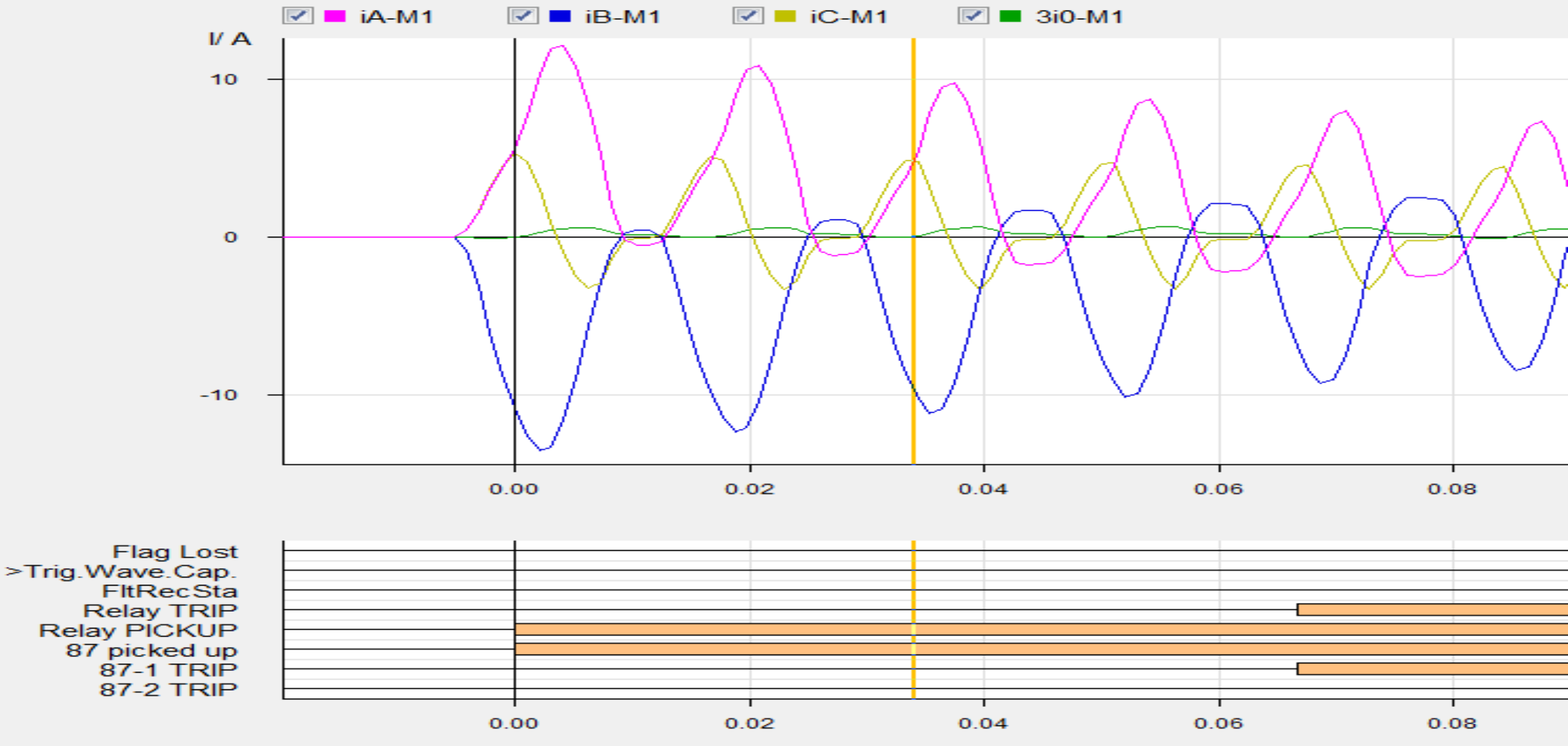
Let’s Talk Security

Inrush
Through Fault
Saturation
Wiring Error
Relay Failure
Cyber Security

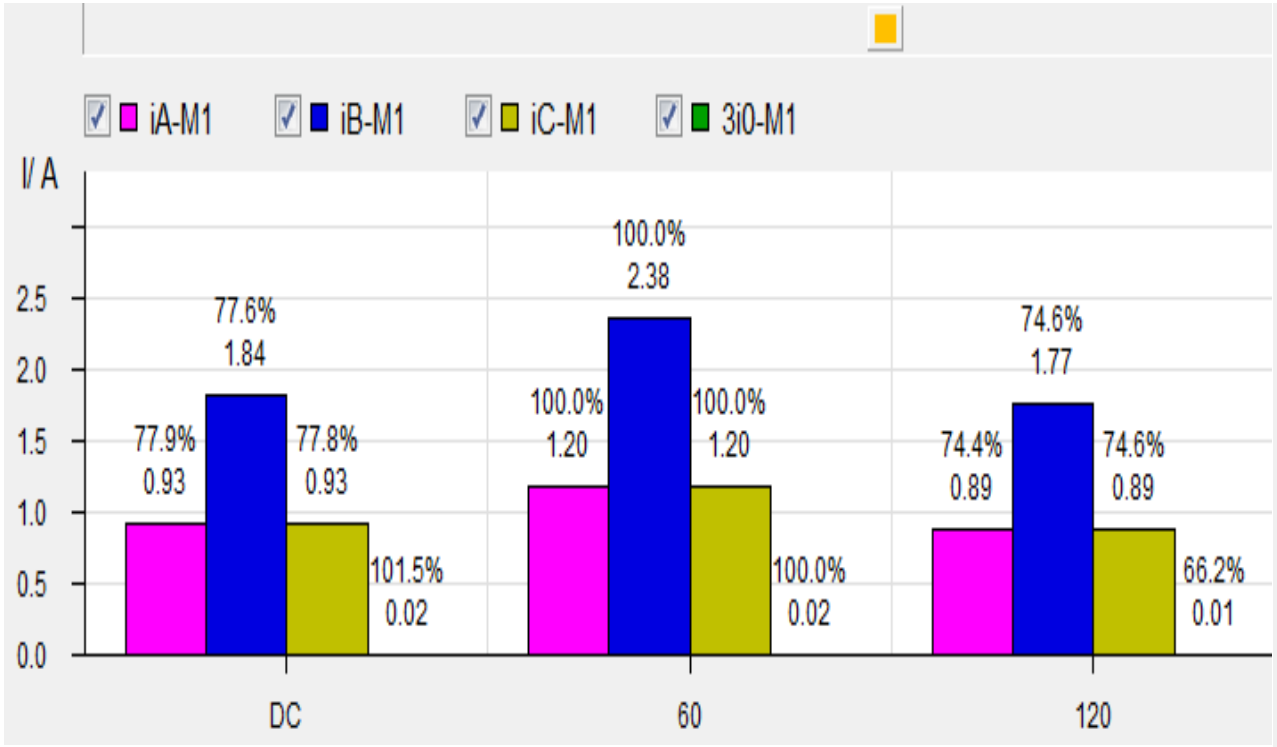
Transformer Construction is Changing

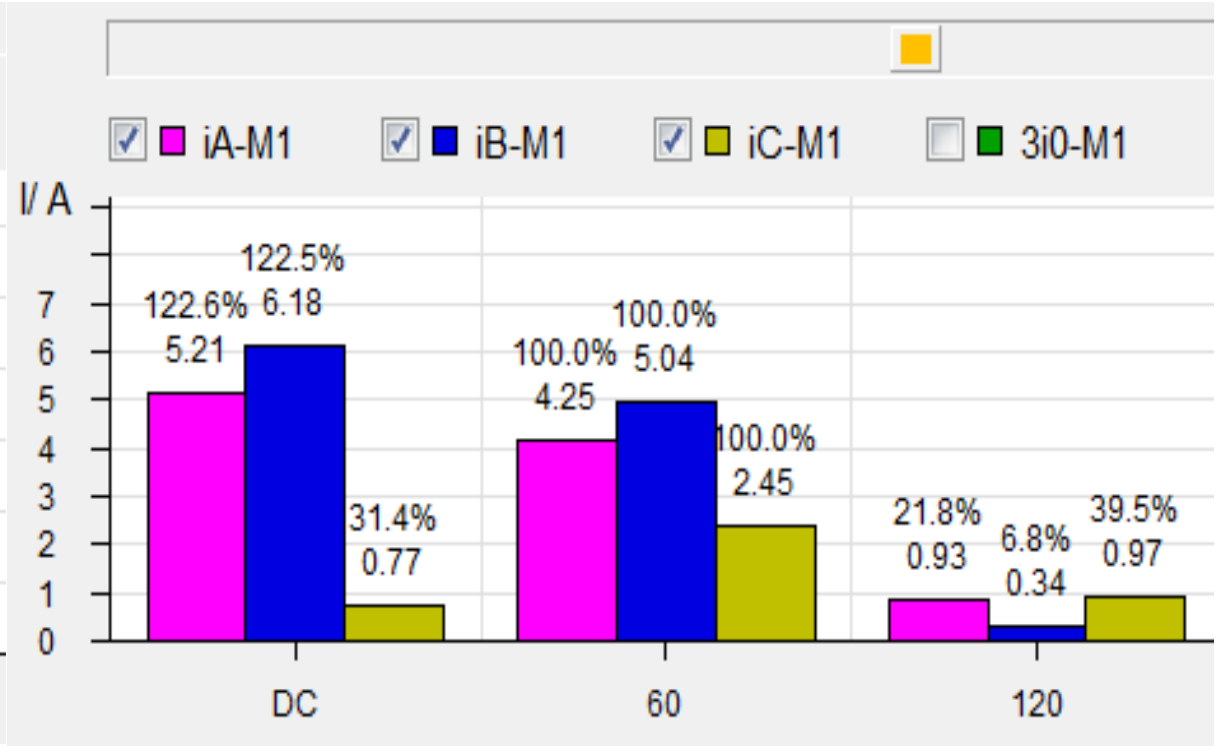
- Lower Losses Specified
- Low Noise Specified
- Laser Etched
- Amorphous
- Improved Stacks
- Super Conductor?

Actual False Trip Event



Harmonics at Energization and Trip

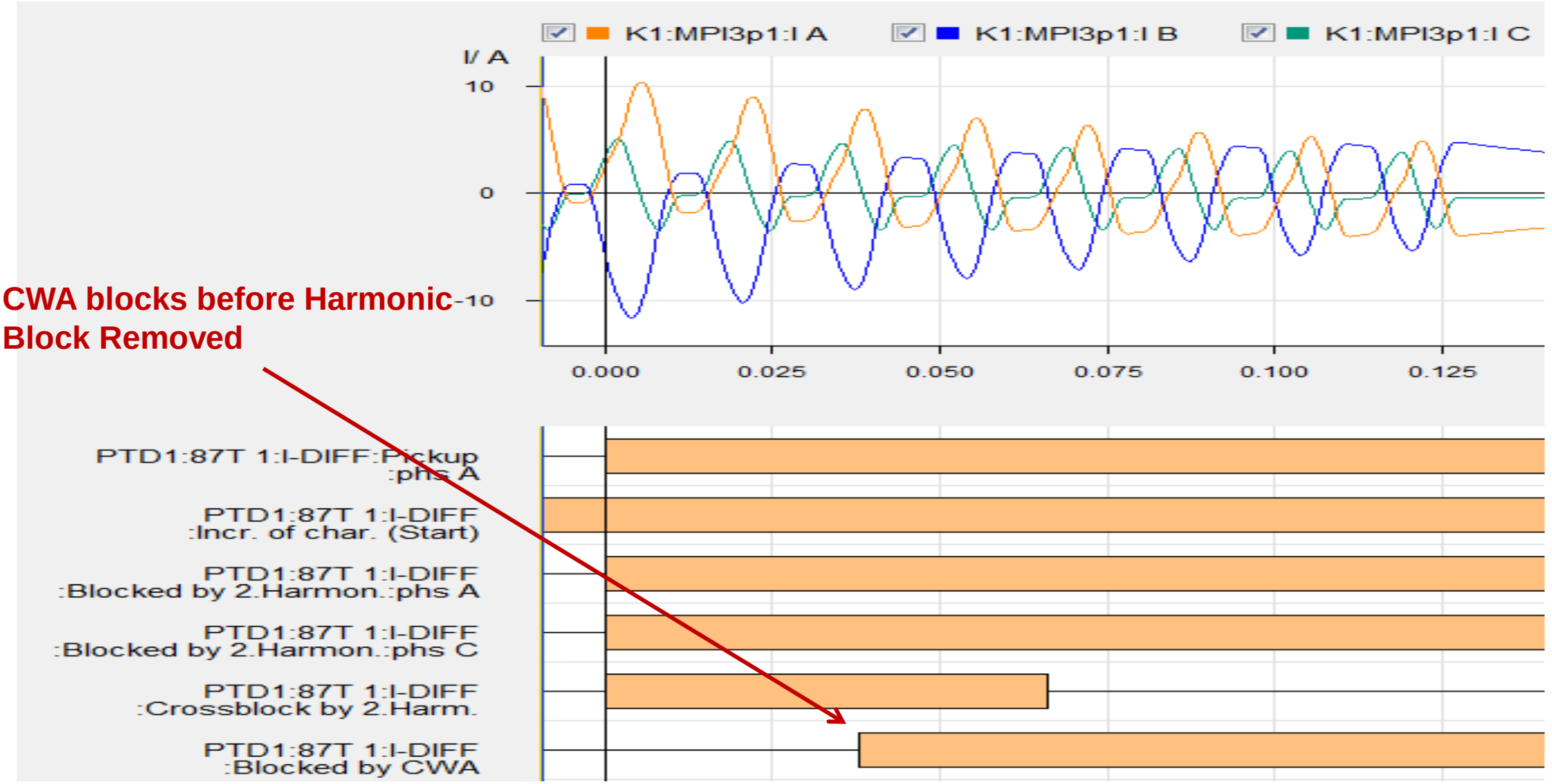




Blocking Early, Unblocking Later

00501	Relay PICKUP	ON	0 ms
05631	87 Differential protection picked up	ON	0 ms
05657	87 Crossblock by 2.Harmonic	ON	15 ms
05644	87 Blocked by 2.Harmon. A	ON	15 ms
05646	87 Blocked by 2.Harmon. C	ON	15 ms
05682	87-1 Phase B (without Tdelay)	ON	66 ms
00511	Relay GENERAL TRIP command	ON	67 ms
05691	87 TRIP by 87-1	ON	67 ms
05657	87 Crossblock by 2.Harmonic	OFF	67 ms
05701	Diff. curr. Ph. A at trip without Tdelay	1.54 I/InO	67 ms
05704	Restr.curr. Ph. A at trip without Tdelay	1.63 I/InO	67 ms
05702	Diff. curr. Ph. B at trip without Tdelay	1.82 I/InO	67 ms
05705	Restr.curr. Ph. B at trip without Tdelay	1.95 I/InO	67 ms
05703	Diff. curr. Ph. C at trip without Tdelay	0.83 I/InO	67 ms
05706	Restr.curr. Ph. C at trip without Tdelay	0.83 I/InO	67 ms
05645	87 Blocked by 2.Harmon. B	ON	108 ms
05682	87-1 Phase B (without Tdelay)	OFF	108 ms
05644	87 Blocked by 2.Harmon. A	OFF	191 ms

Replay with Current Waveform Analysis (CWA)



CWA blocks before Harmonic Block Removed

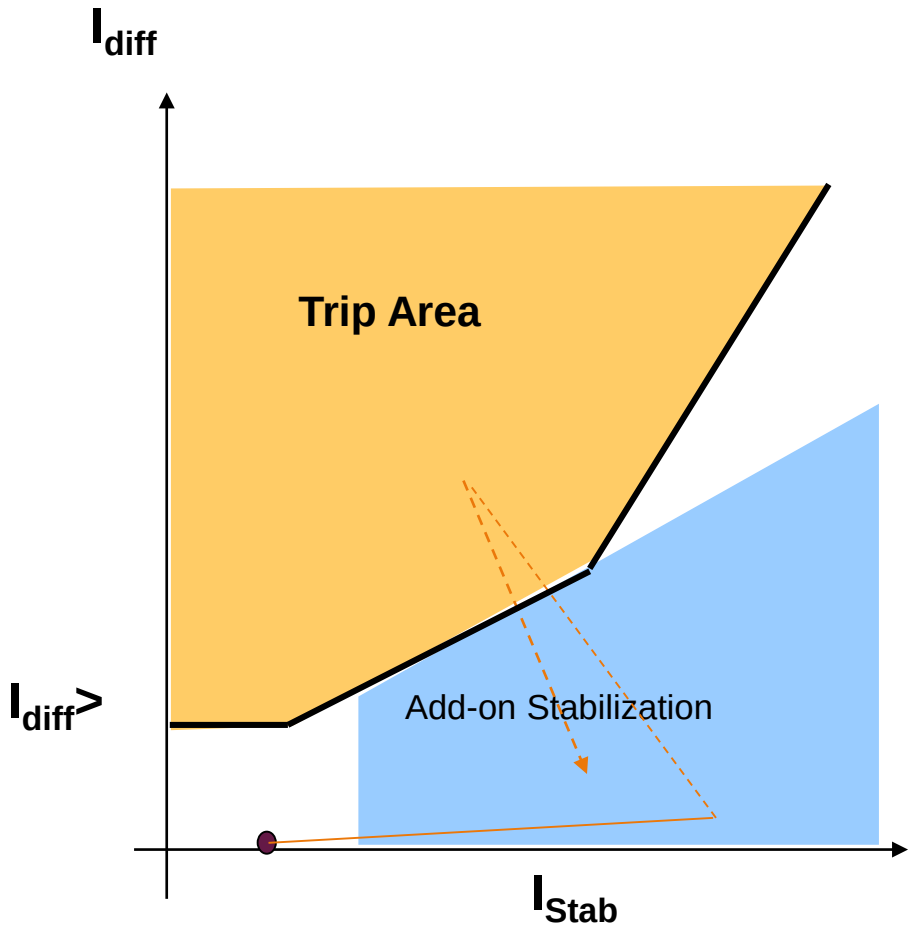
Lessons Learned

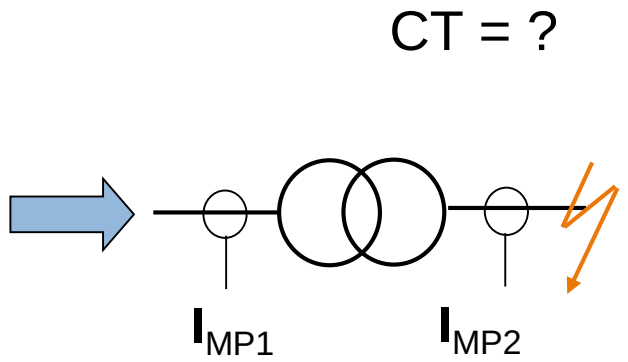
- Inrush is Difficult to Predict
- Inrush is not Consistent
- Changes in Transformer Design and Construction Change Inrush
- Multiple Blocking Principles Increase Security and Speed

How Does Increased Security Increase Speed ?

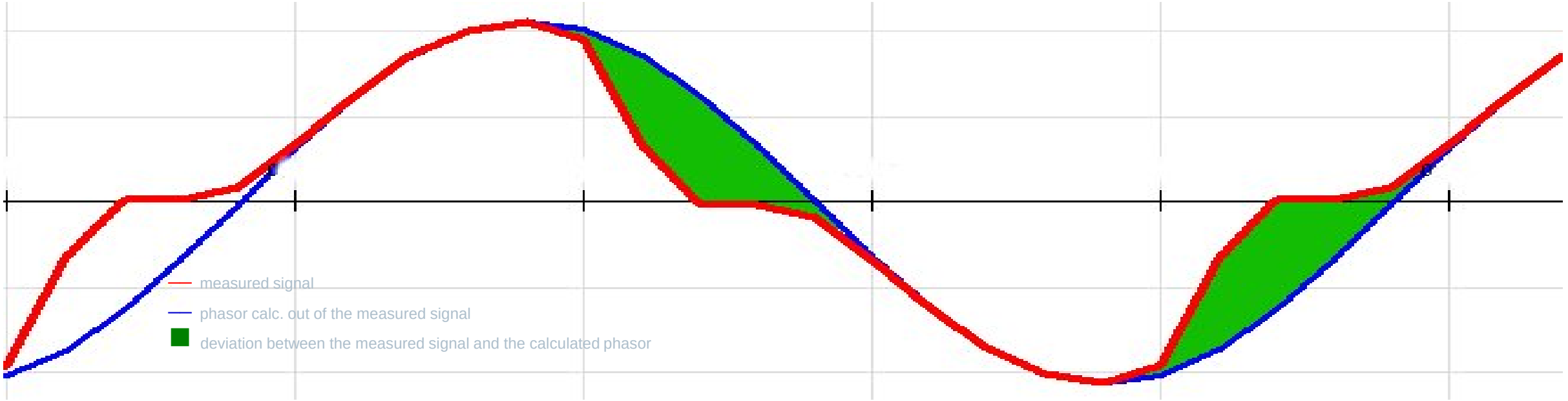
Relay Operating Characteristics are Changing

- Trajectory Based
- Improved Quantities
- Error Detection/ Correction



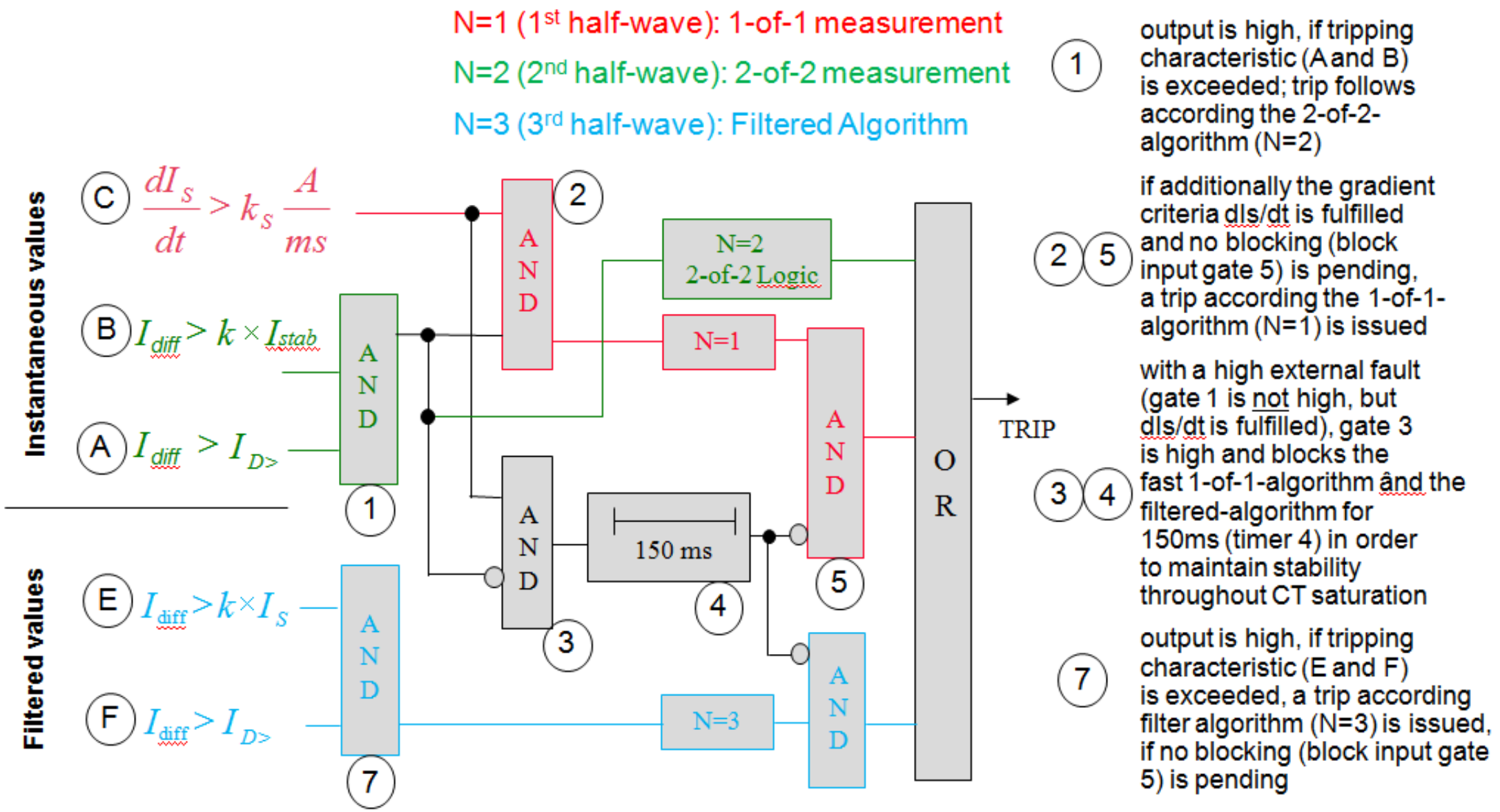


Restrained current due to CT saturation



- relay measures a distorted current signal (red curve)
- relay calculates the fundamental frequency component (blue curve)
- deviation between both curves (green area) is a criteria for signal distortion
- relay determines restrained current depending this signal deviation

Application of Multiple Algorithms



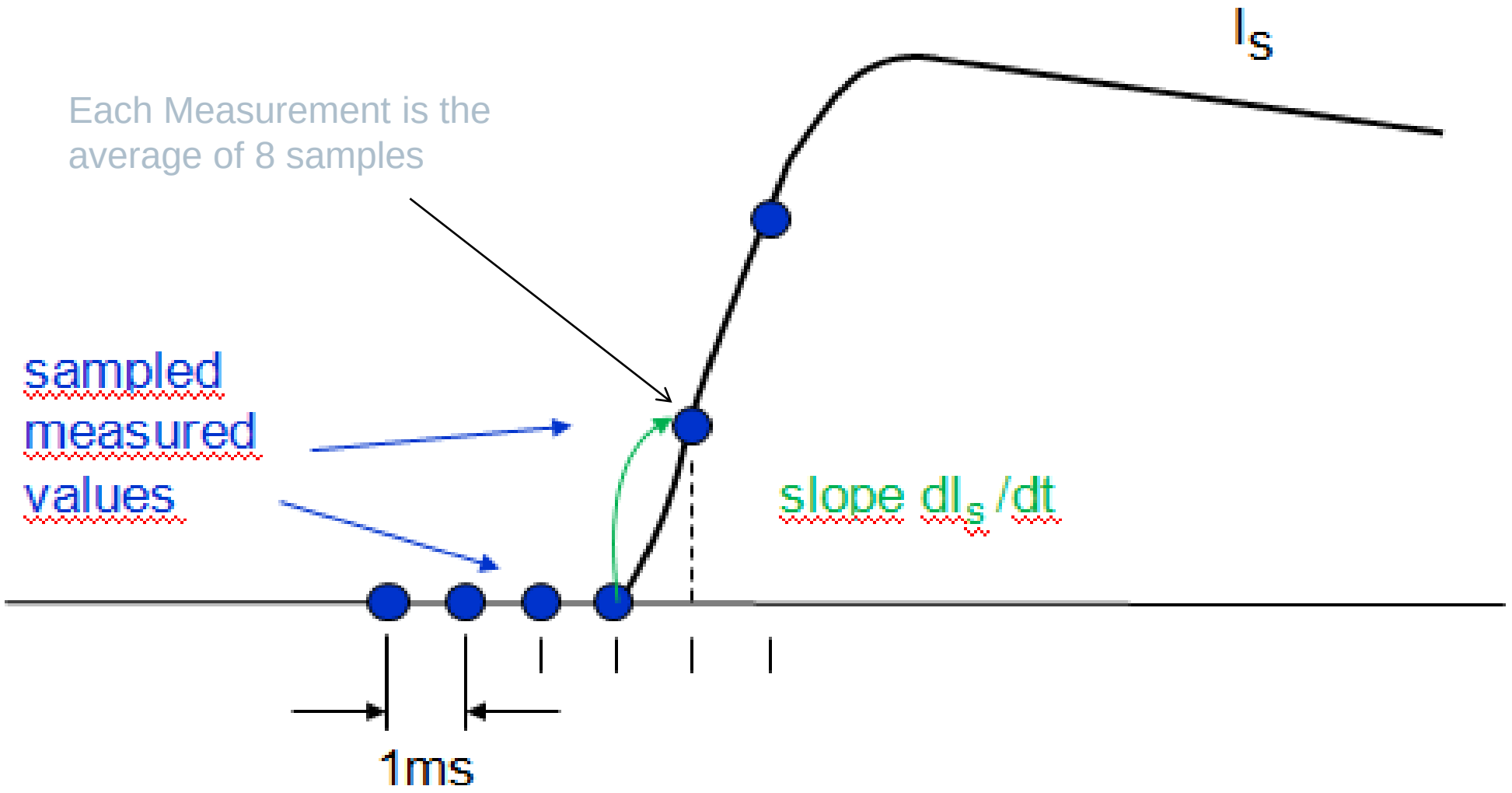
1 output is high, if tripping characteristic (A and B) is exceeded; trip follows according the 2-of-2-algorithm (N=2)

2 5 if additionally the gradient criteria dIs/dt is fulfilled and no blocking (block input gate 5) is pending, a trip according the 1-of-1-algorithm (N=1) is issued

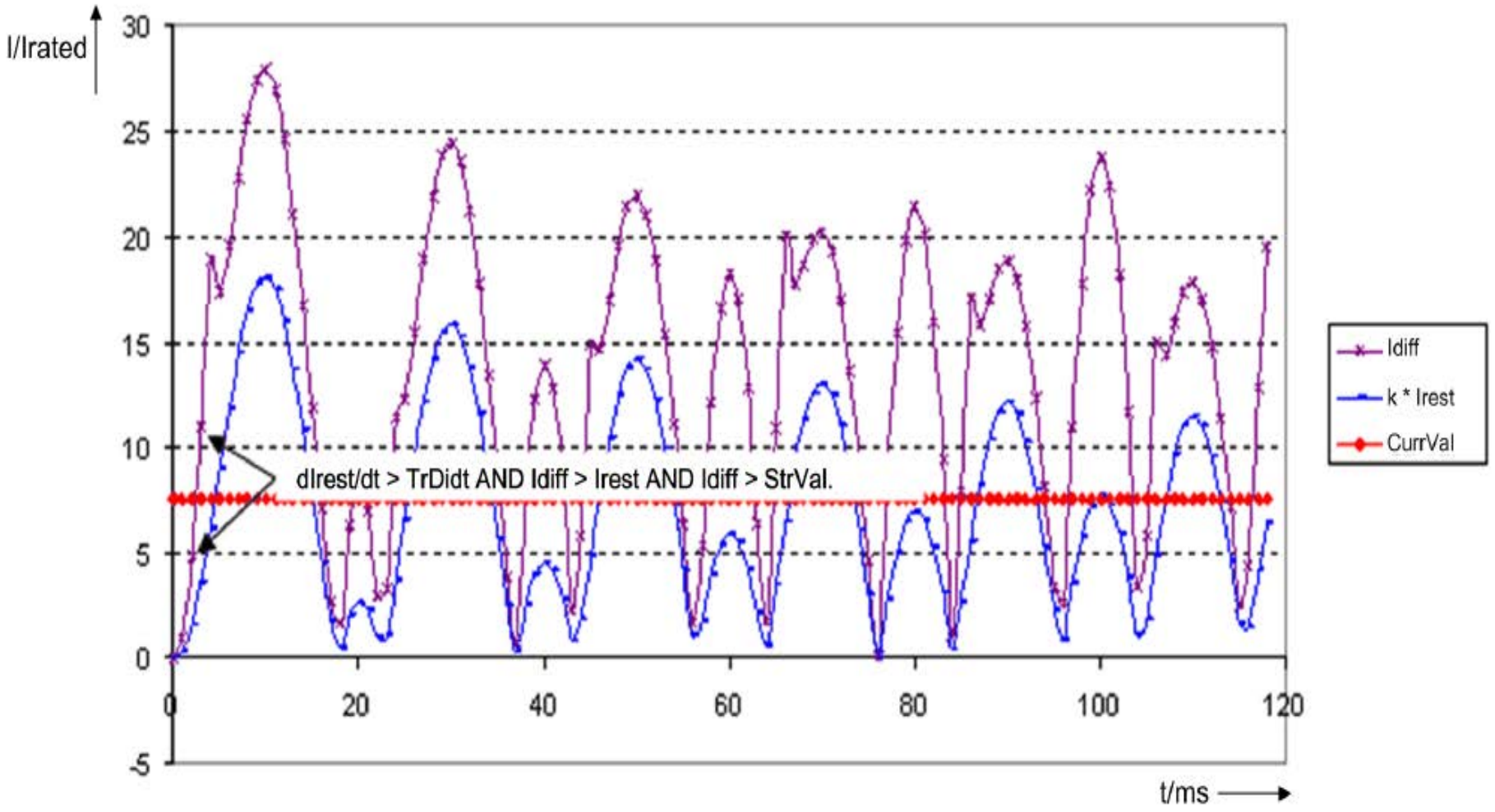
3 4 with a high external fault (gate 1 is not high, but dIs/dt is fulfilled), gate 3 is high and blocks the fast 1-of-1-algorithm and the filtered-algorithm for 150ms (timer 4) in order to maintain stability throughout CT saturation

7 output is high, if tripping characteristic (E and F) is exceeded, a trip according filter algorithm (N=3) is issued, if no blocking (block input gate 5) is pending

Rate of Rise of Stabilizing Quantity

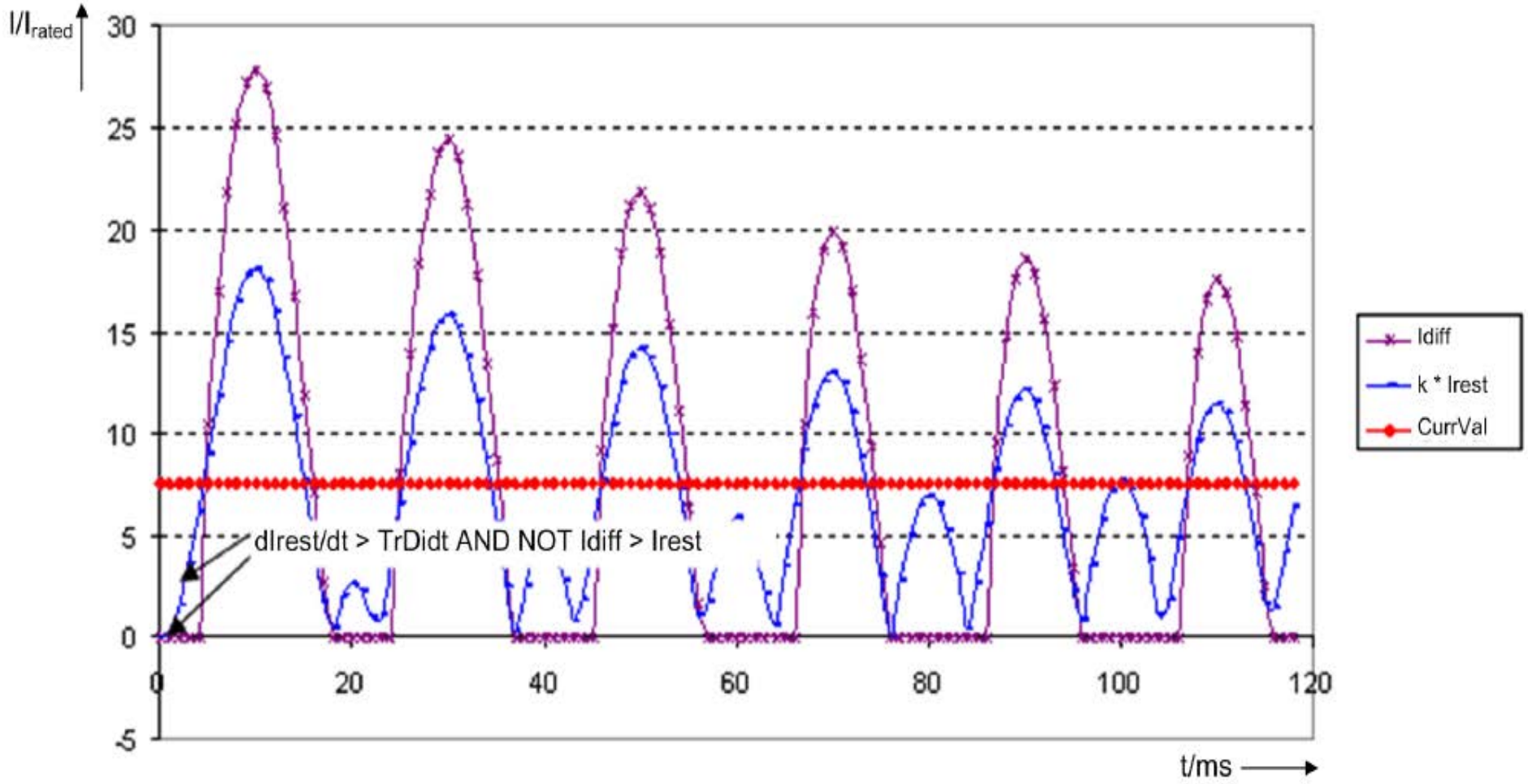


Di/dt



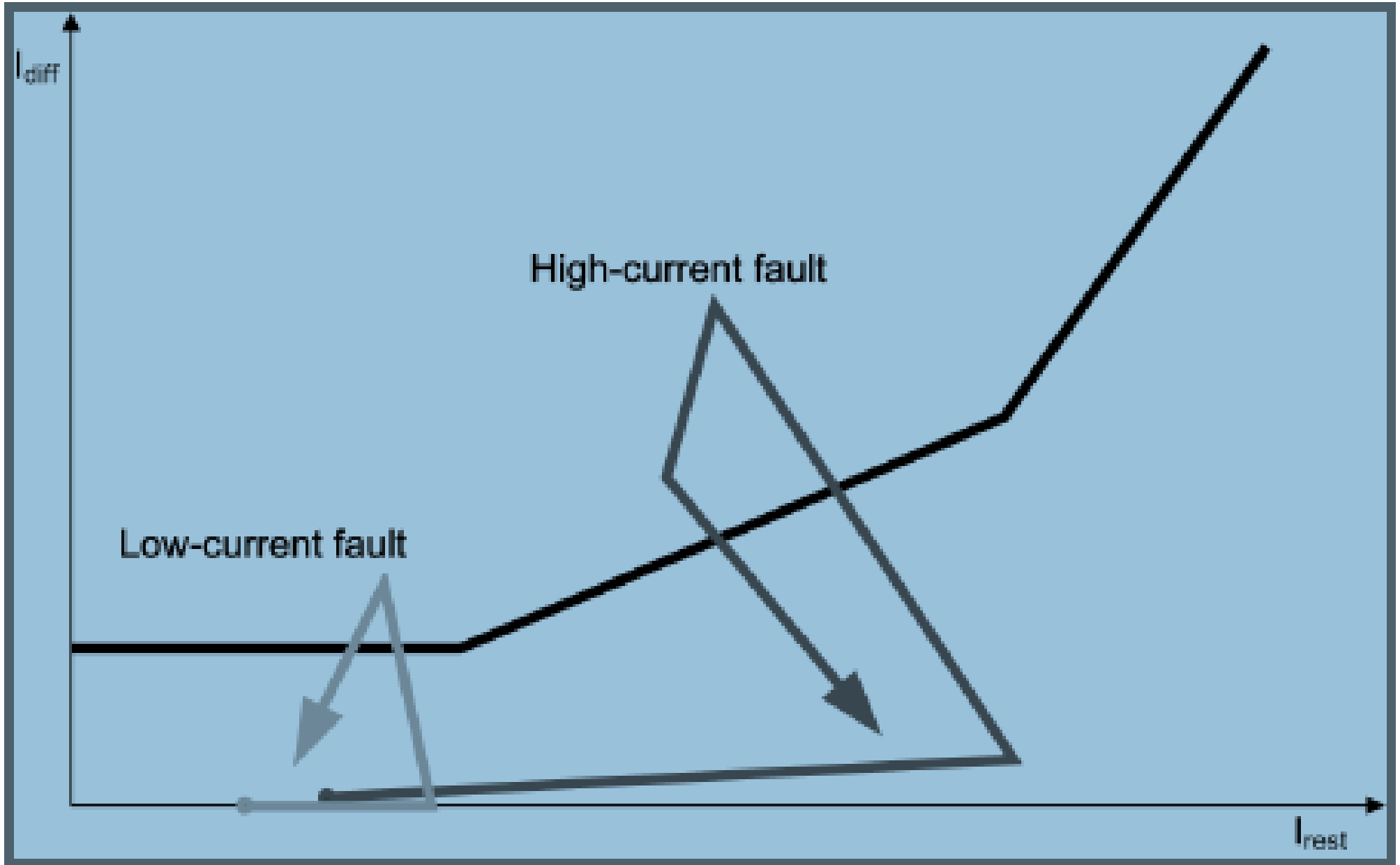
Internal Short Circuit with Transformer Saturation

Di/dt

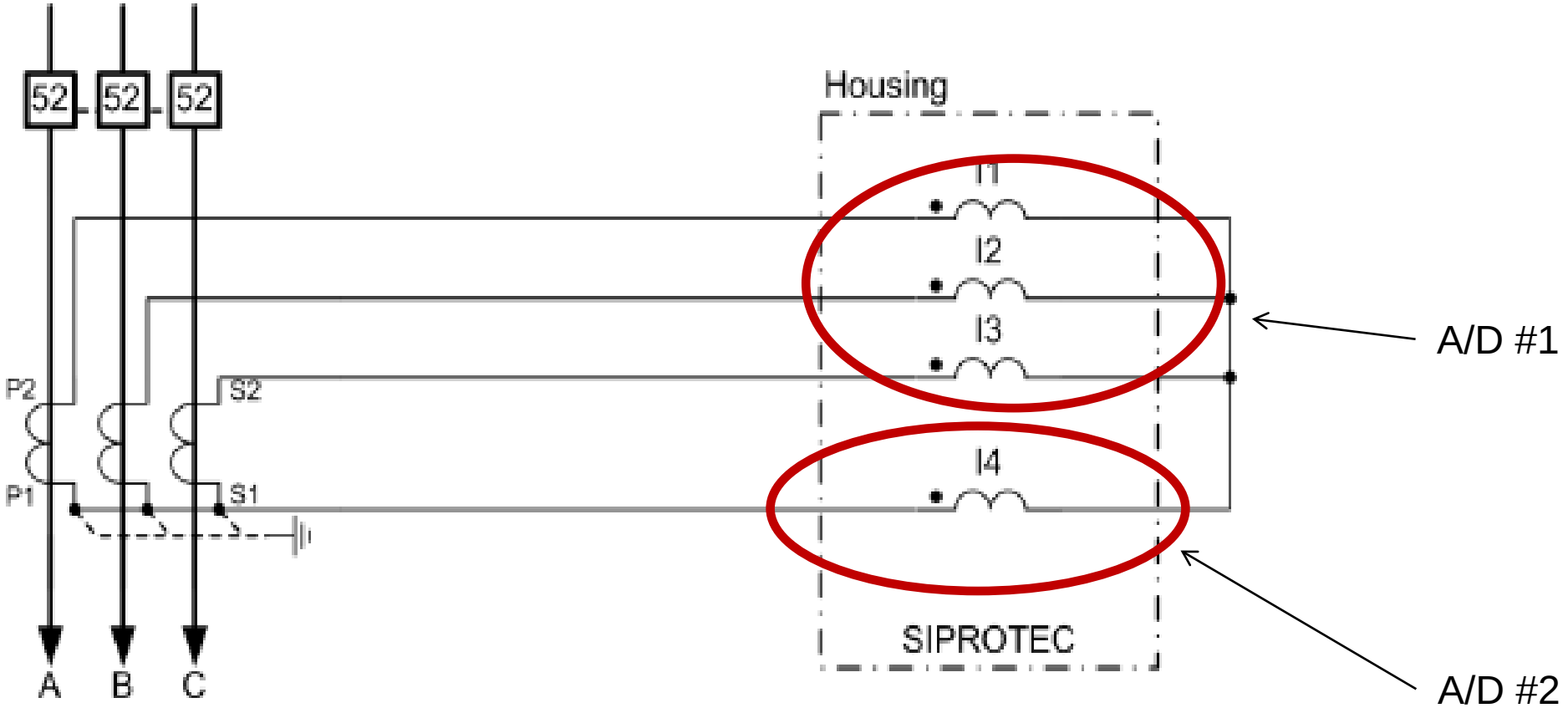


External Short Circuit with Transformer Saturation

Trajectory Based Restraint – External Fault with Saturation

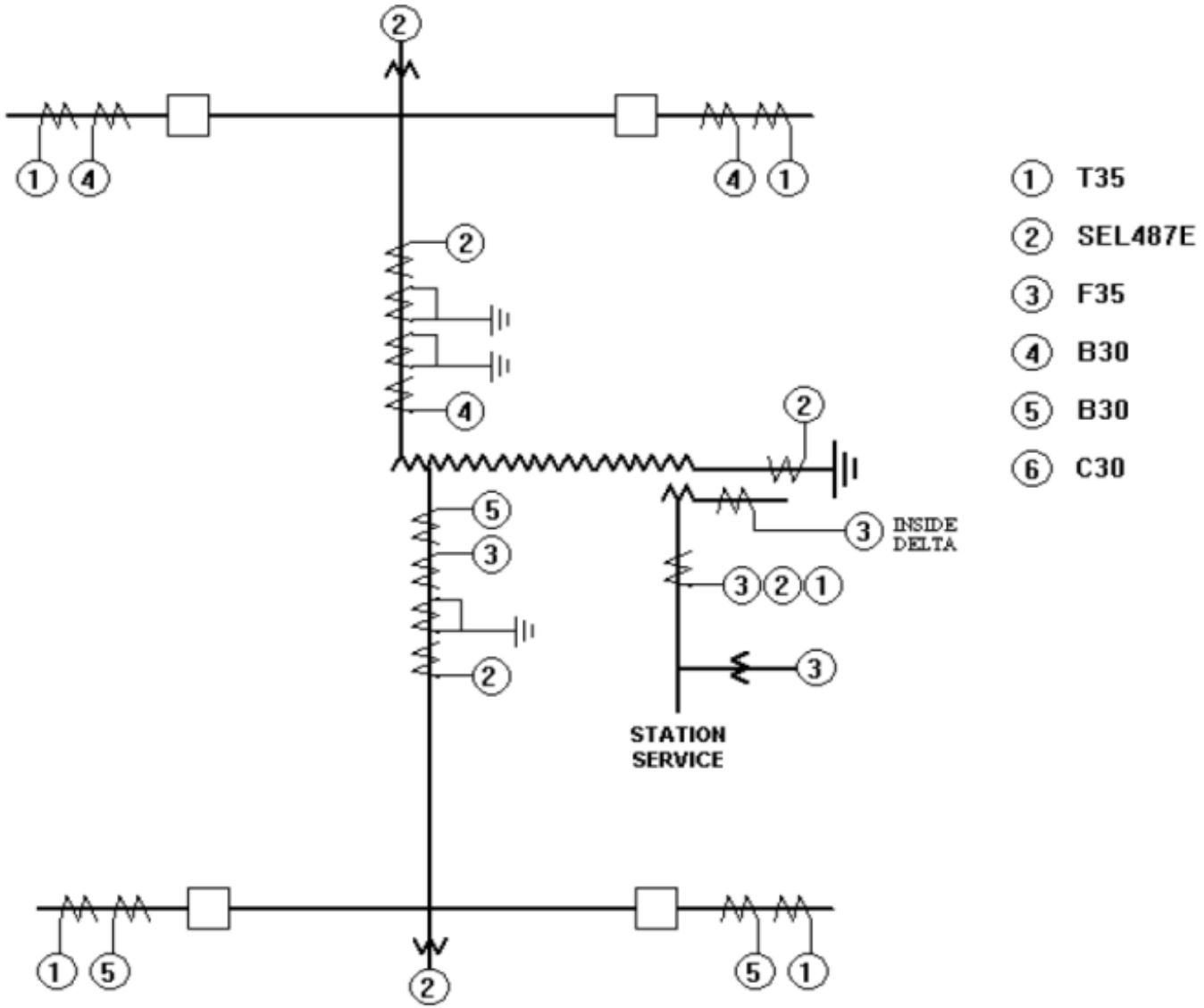


Multiple A/D Crosscheck Adds Security

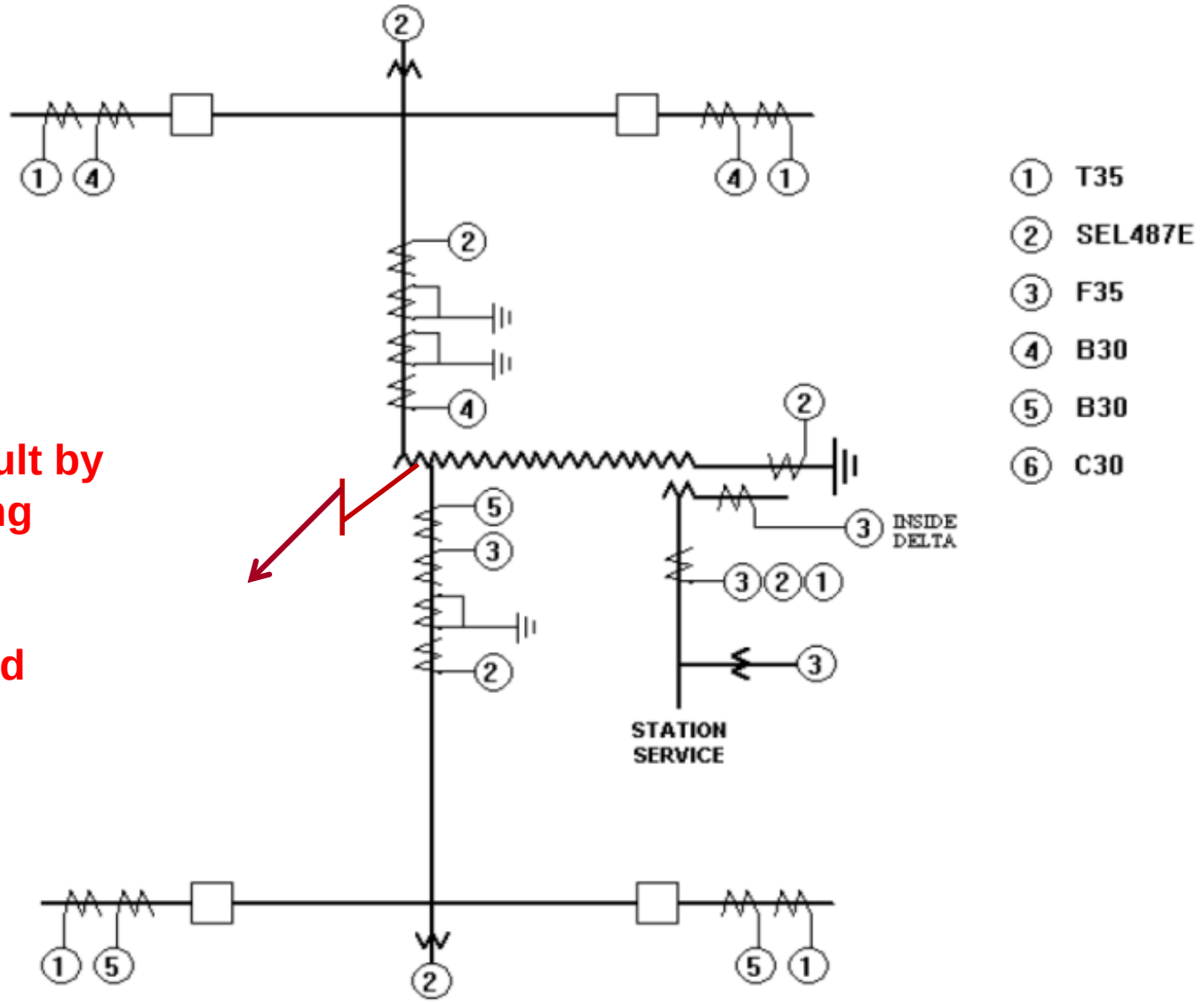


Bad Things Can Happen When Tanks Rupture

Case Study


STATION SERVICE
INSIDE DELTA
1 T35
2 SEL487E
3 F35
4 B30
5 B30
6 C30

Case Study

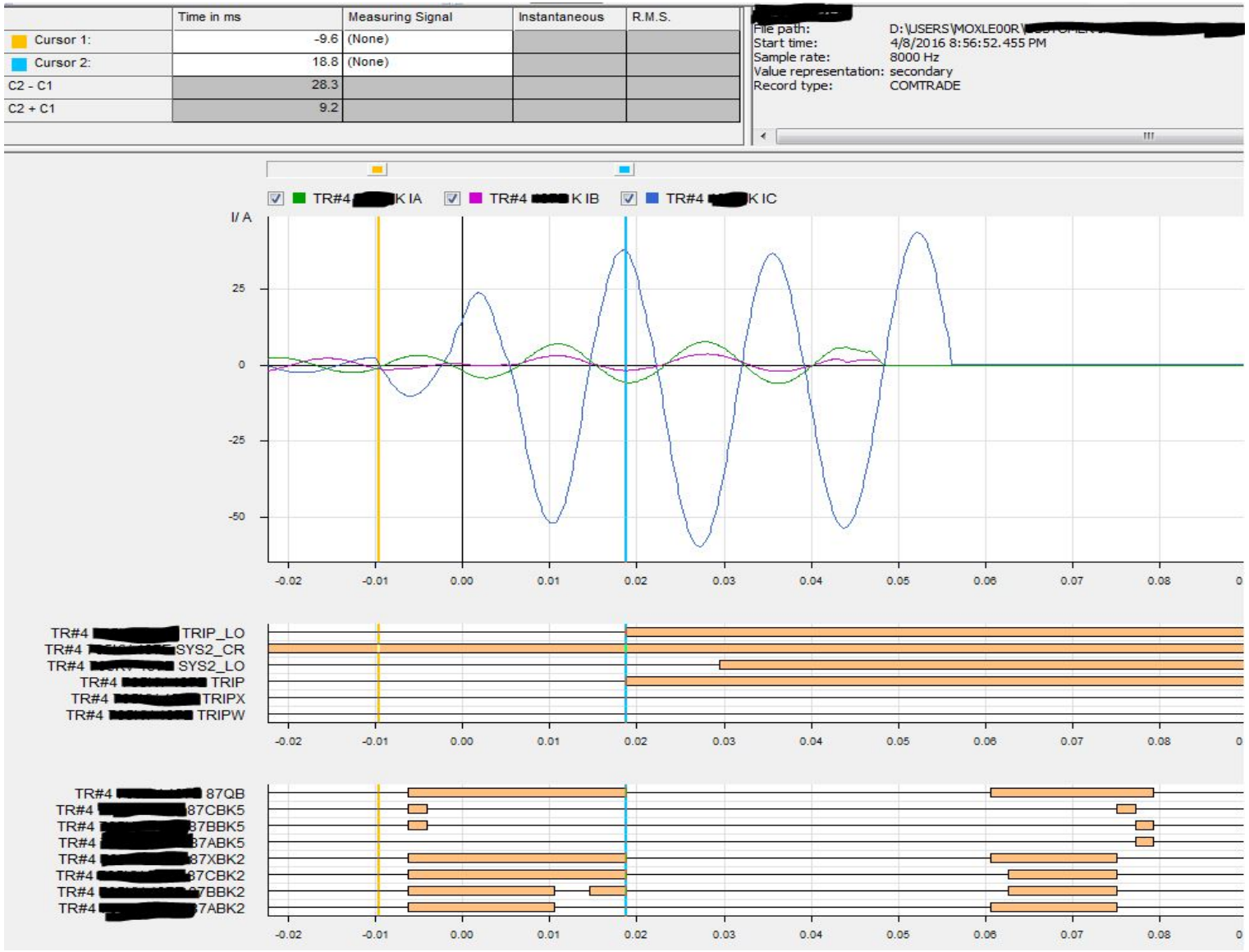


Single Phase Fault by Low Side Bushing

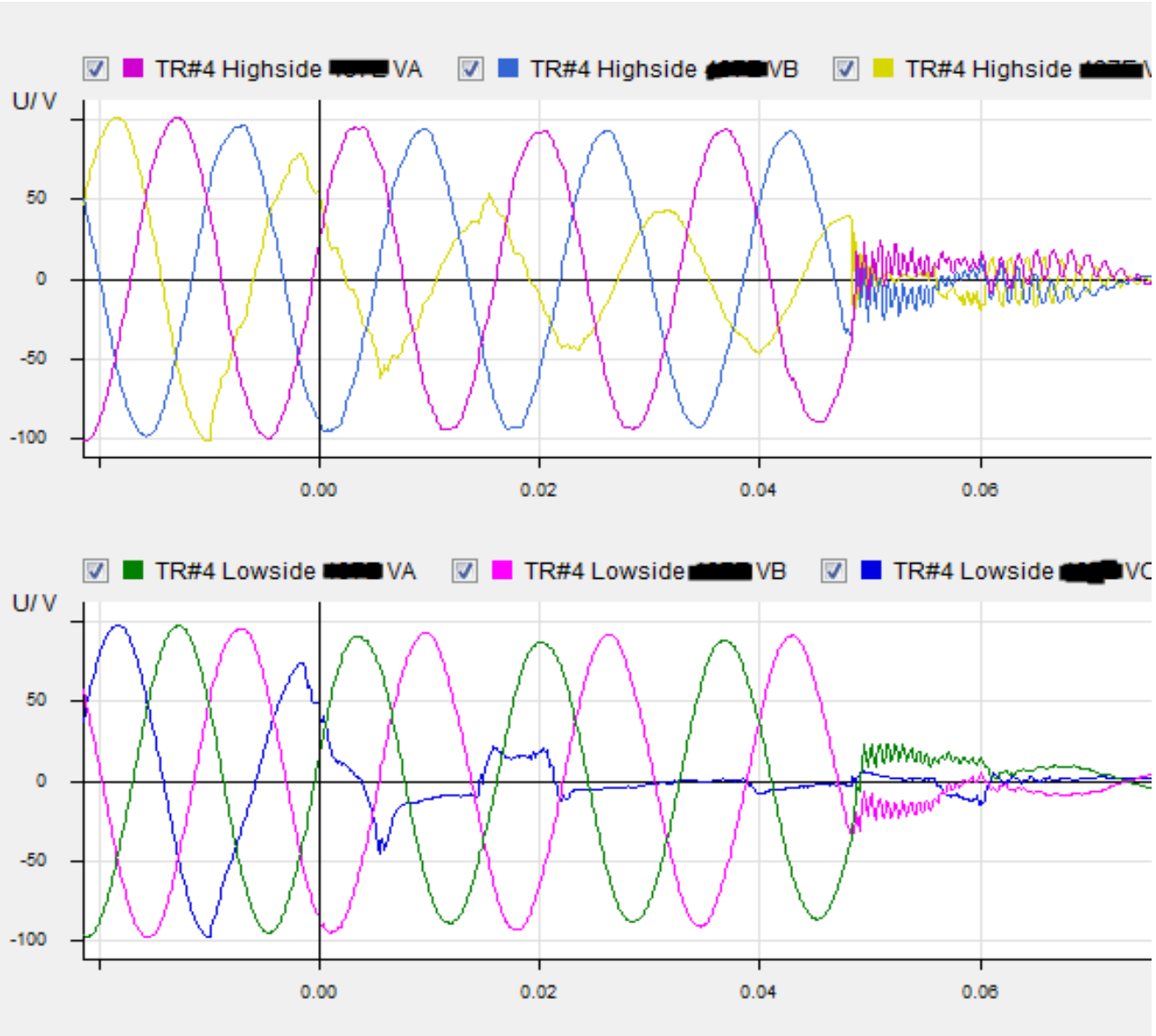
30,000 gal spilled

No Fire

Fault Record Combines with Physical Examination



Combine Voltage, Current, Time and Location



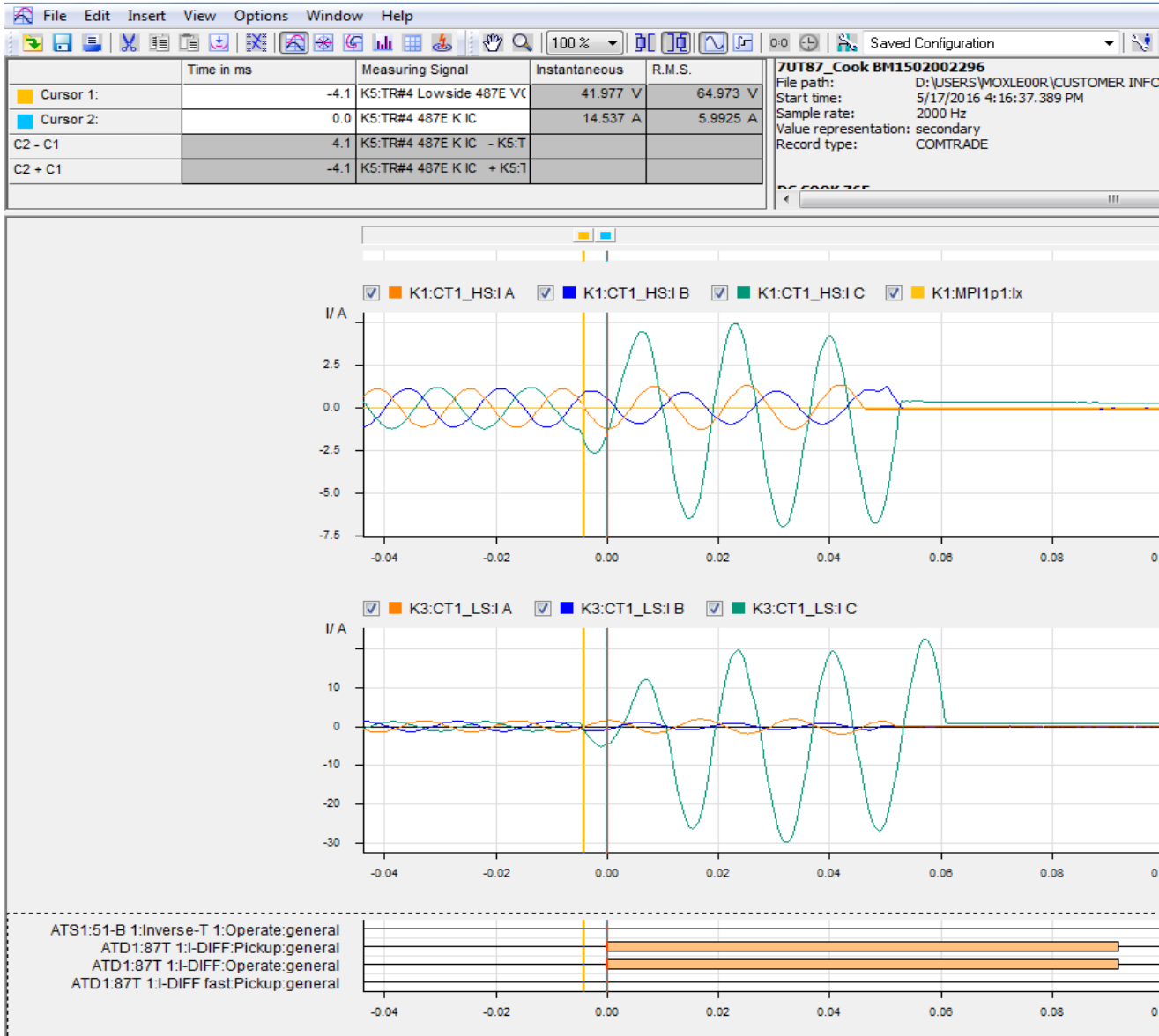
53,900 Amps

78 kV (at fault location)

= 70,000 kJ per cycle

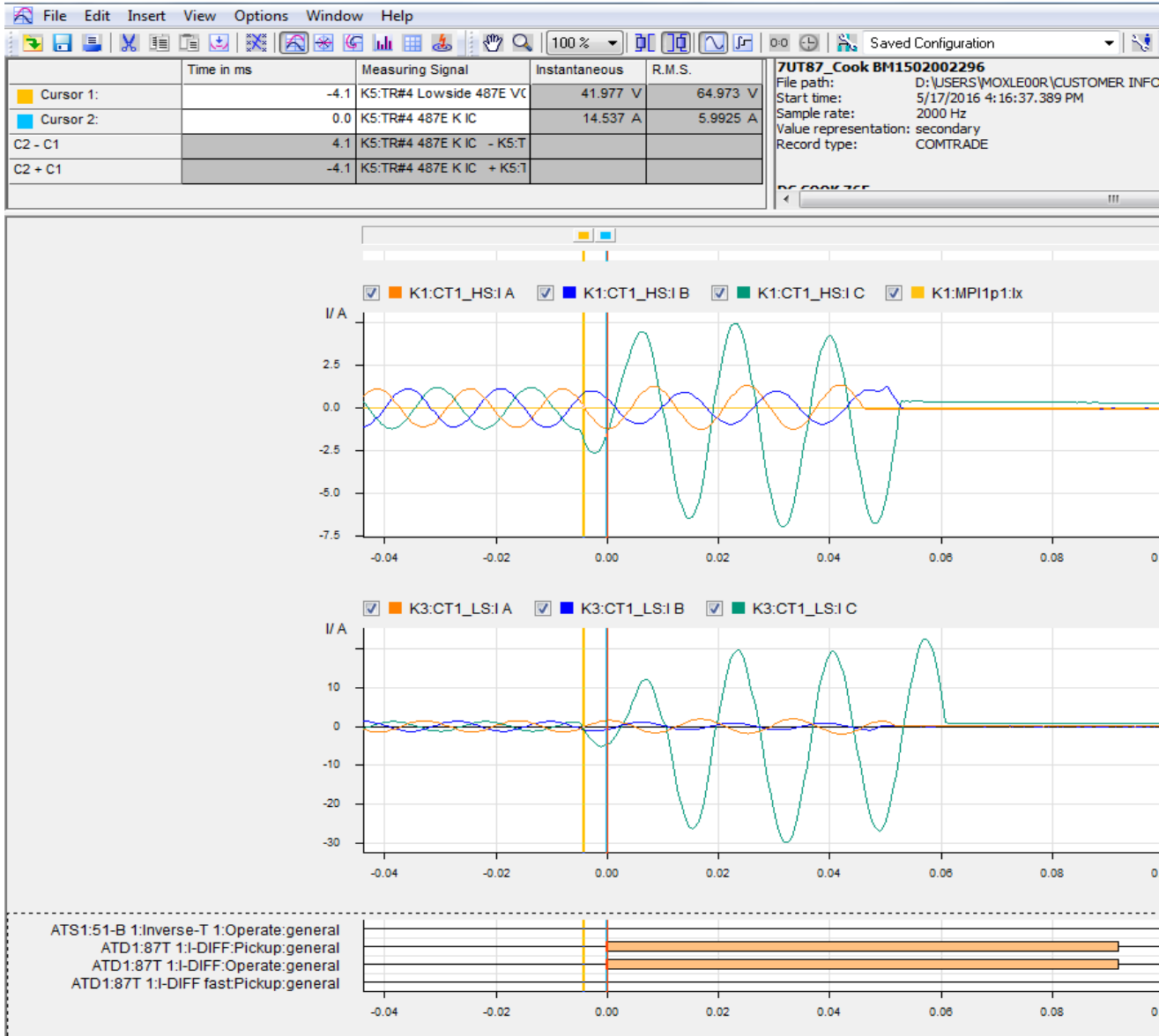
Could Tripping Have Been Faster ?

Fault Playback through a test set into a more modern relay provides options



Could Tripping Have Been Faster ?

- Tripping in 4-20 ms vs 28 ms
- Clearing ½ – 1 ½ cycle earlier (depends on test set)
- 35,000 – 105,000 kJ energy reduction
- Tank saved ?



Questions

Contact

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