A Tale of Two Out-of-Phase Synchronizing Events at BC Hydro

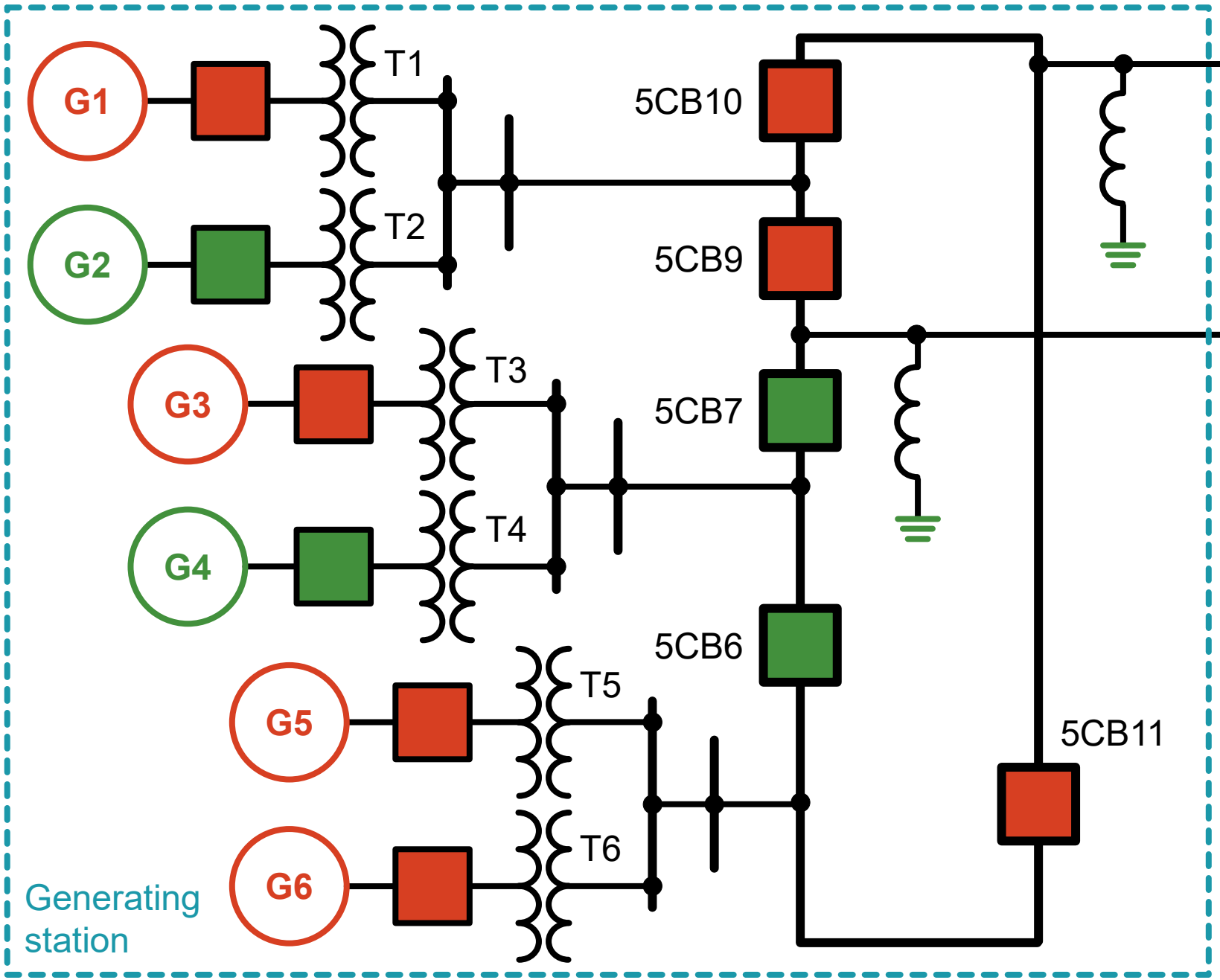
Mukesh Nagpal and Lesley Gu
BC Hydro

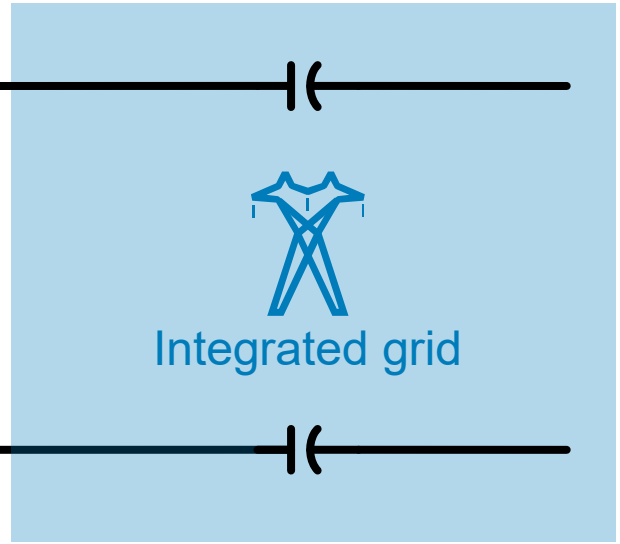
Ralph Barone
Barone Technical Consulting Services Ltd

Ritwik Chowdhury and Michael Thompson
Schweitzer Engineering Laboratories, Inc.

Outline

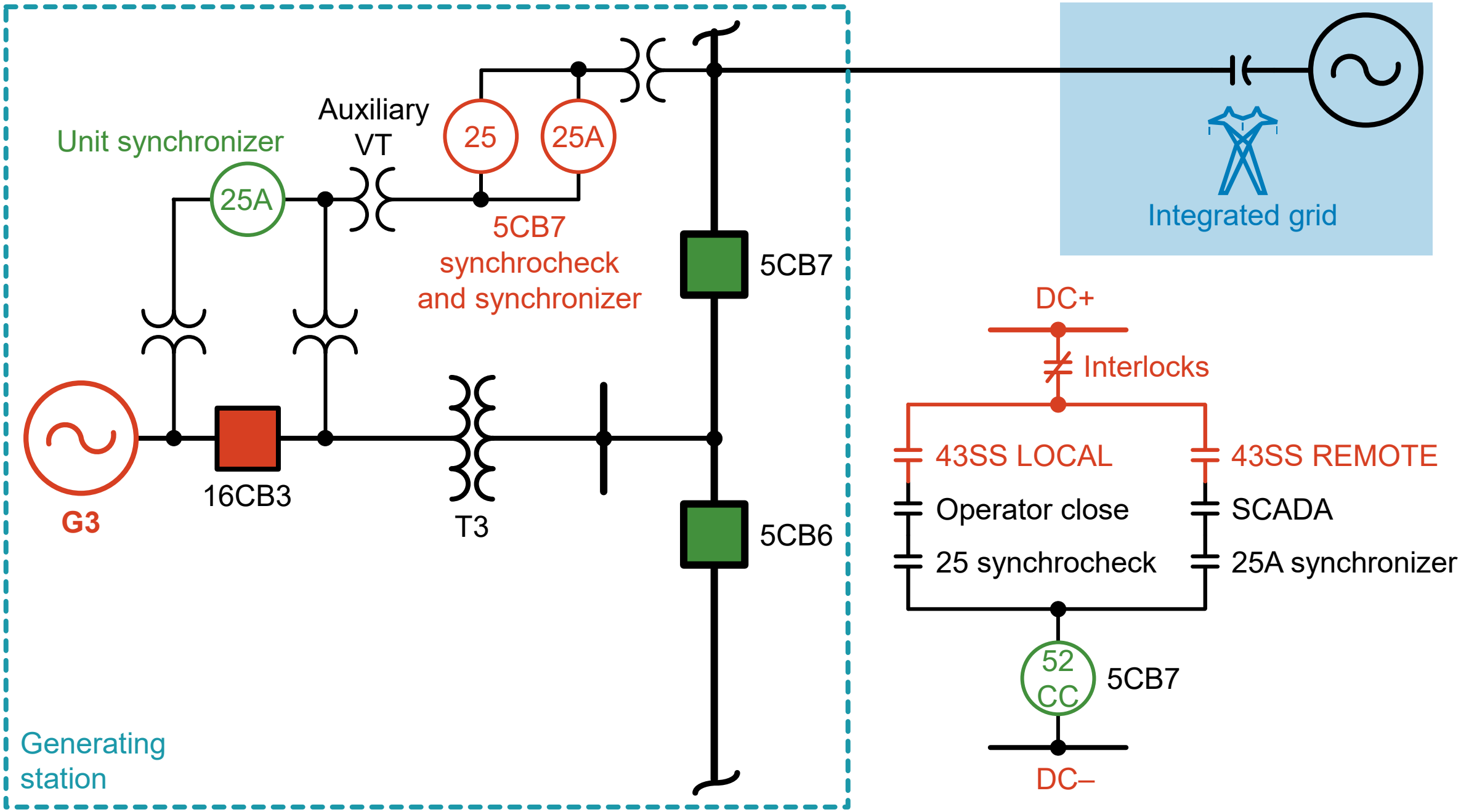
- Tale of two OOPS events
- Event analysis
- Protection performance
- OOPS protection
- Life after poor synchronizations
- Conclusion



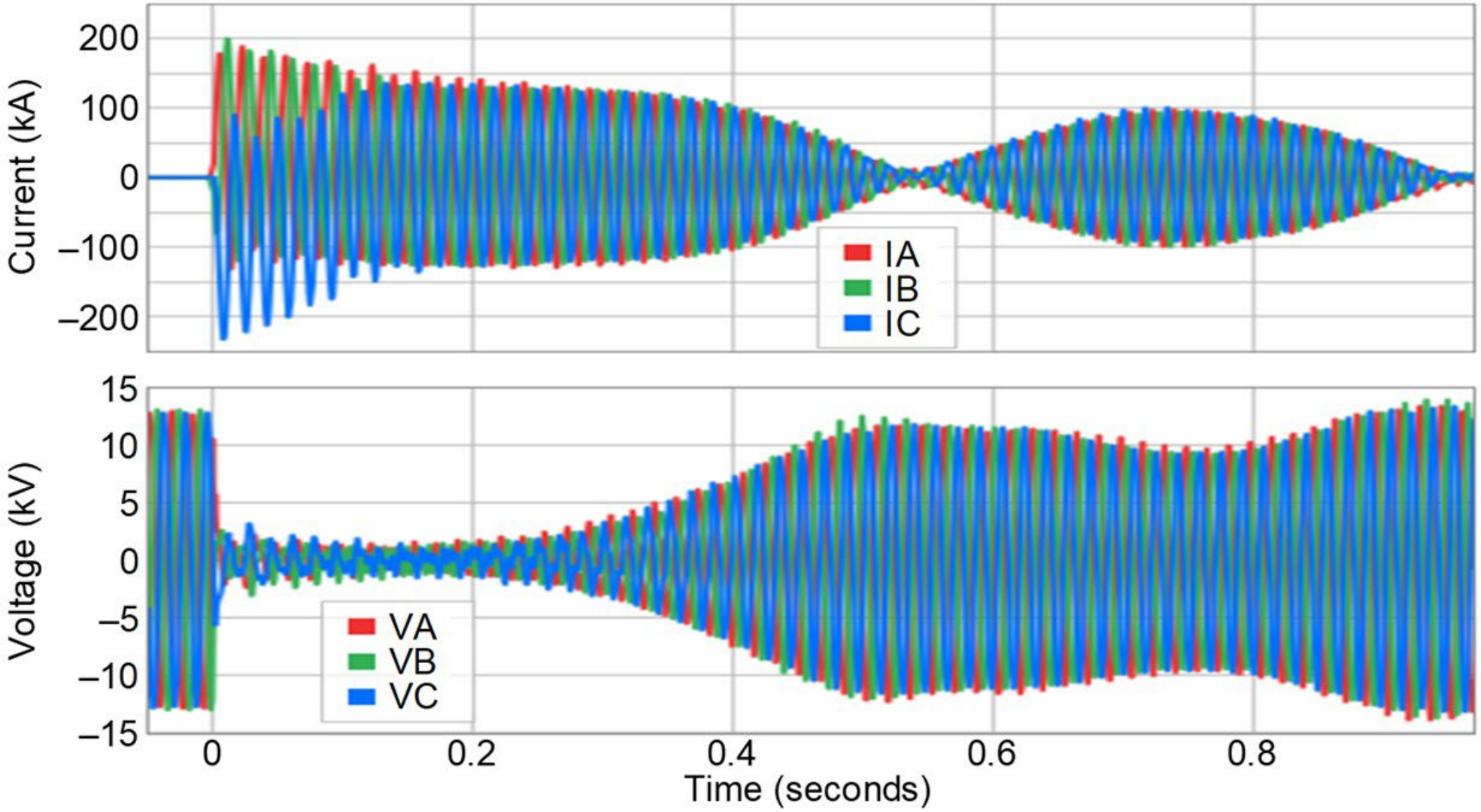


Two OOPS events occurred (December 3 and 7, 2021) when G3 and T3 were synchronized to grid across 5CB7

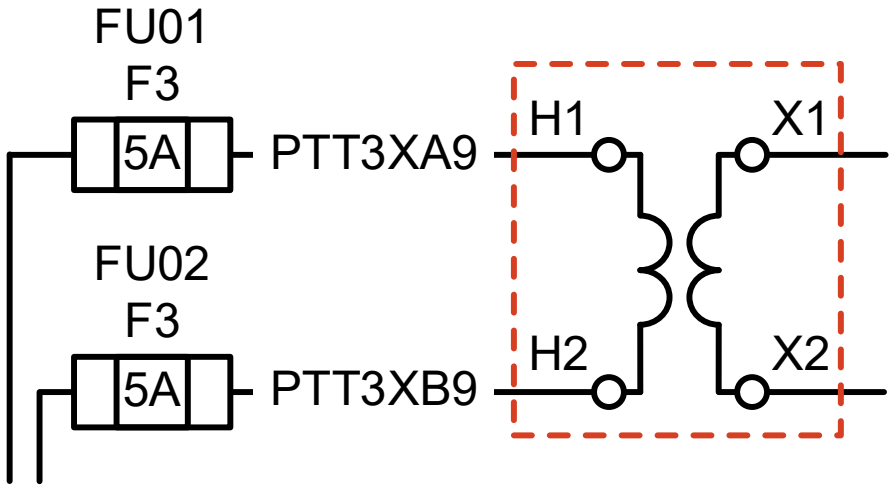
In earlier switching operation, G4 and T4 were correctly synchronized to grid across 5CB7

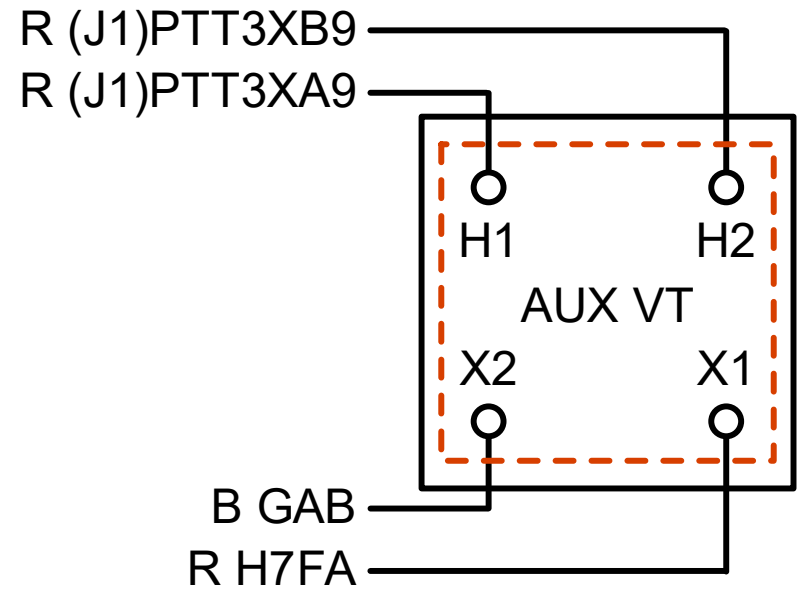

Integrated grid
Unit synchronizer
25A
Auxiliary
VT
25
25A
5CB7
synchrocheck
and synchronizer
5CB7
G3
16CB3
T3
5CB6
Generating
station
DC+
Interlocks
43SS LOCAL
43SS REMOTE
Operator close
SCADA
25 synchrocheck
25A synchronizer
52
CC
5CB7
DC–

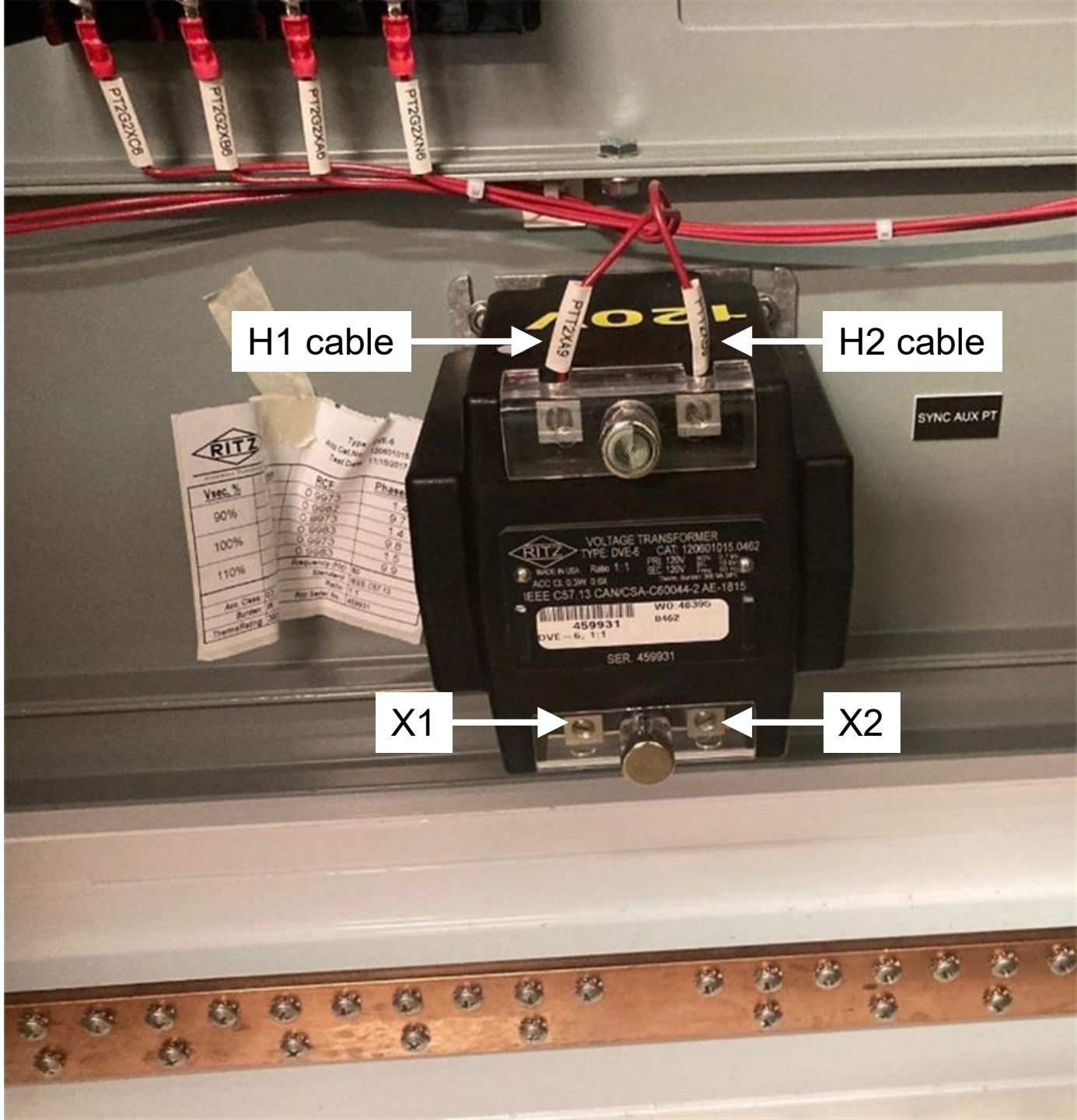
OOPS event on December 7, 2021



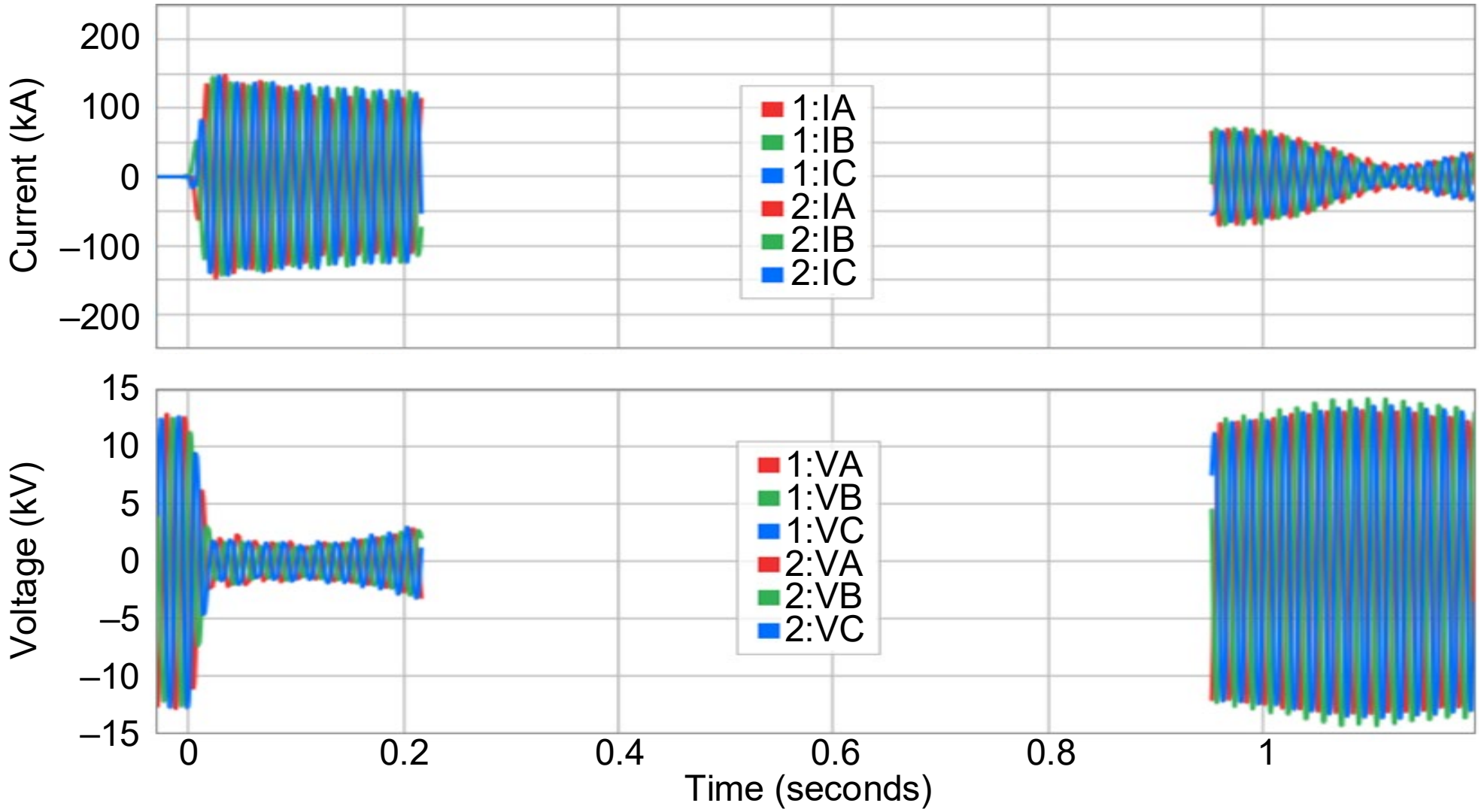
Root cause


FU01
F3
5A
PTT3XA9
FU02
F3
5A
PTT3XB9
H1
X1
H2
X2

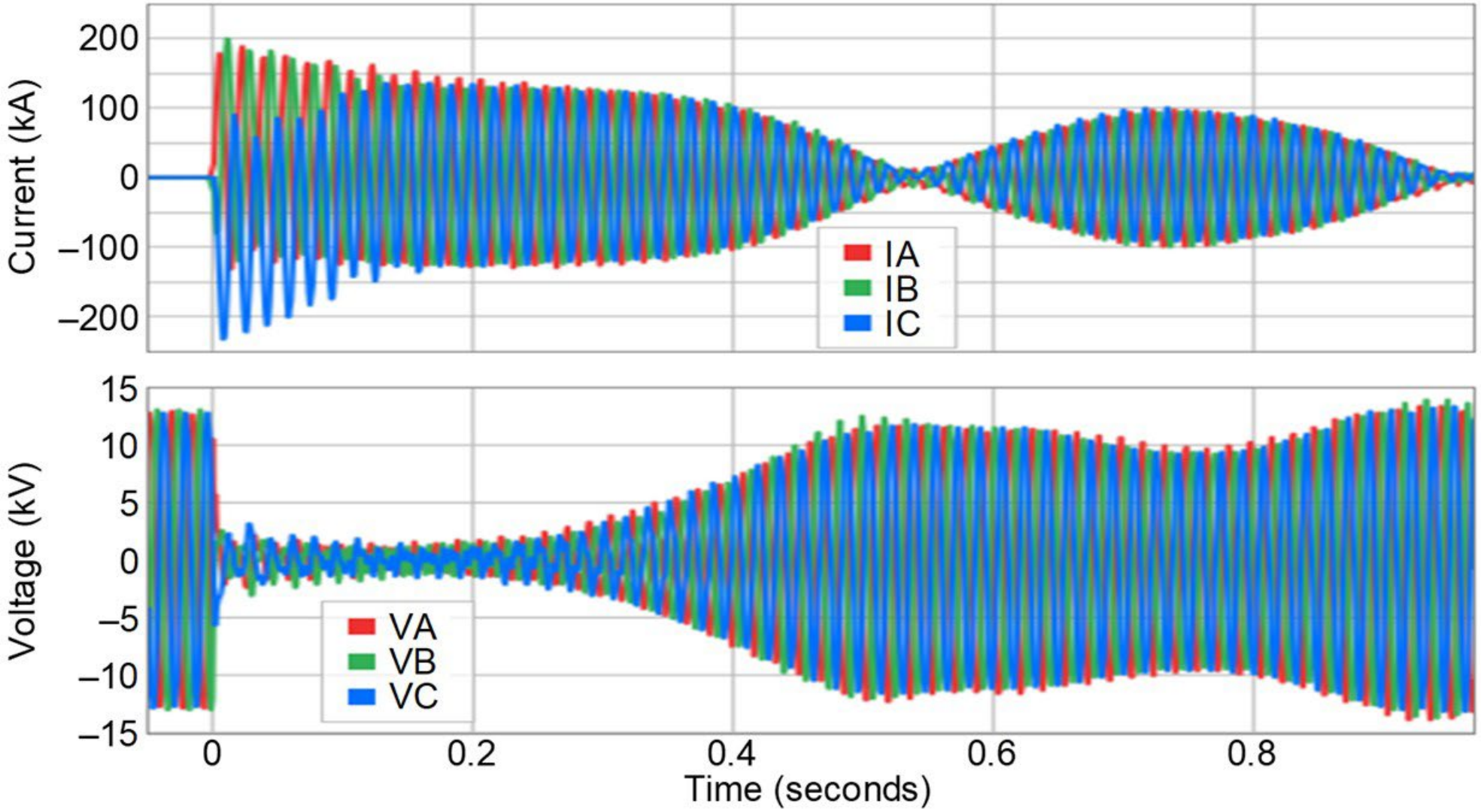

R (J1)PTT3XB9
R (J1)PTT3XA9
H1
H2
AUX VT
X2
X1
B GAB
R H7FA


H1 cable
H2 cable
X1
X2
SYNC AUX PT
RITZ
VOLTAGE TRANSFORMER
TYPE DVE-6
IEEE C57.13 CAN/CSA-C60044-2 AE-1815

OOPS event on December 3, 2021

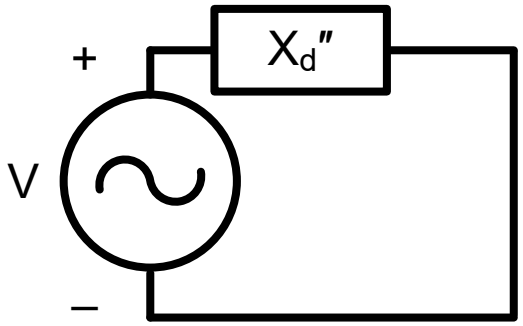


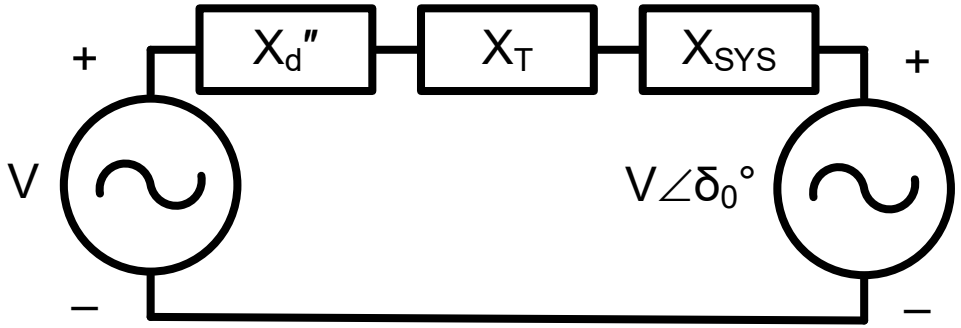
OOPS event on December 7, 2021

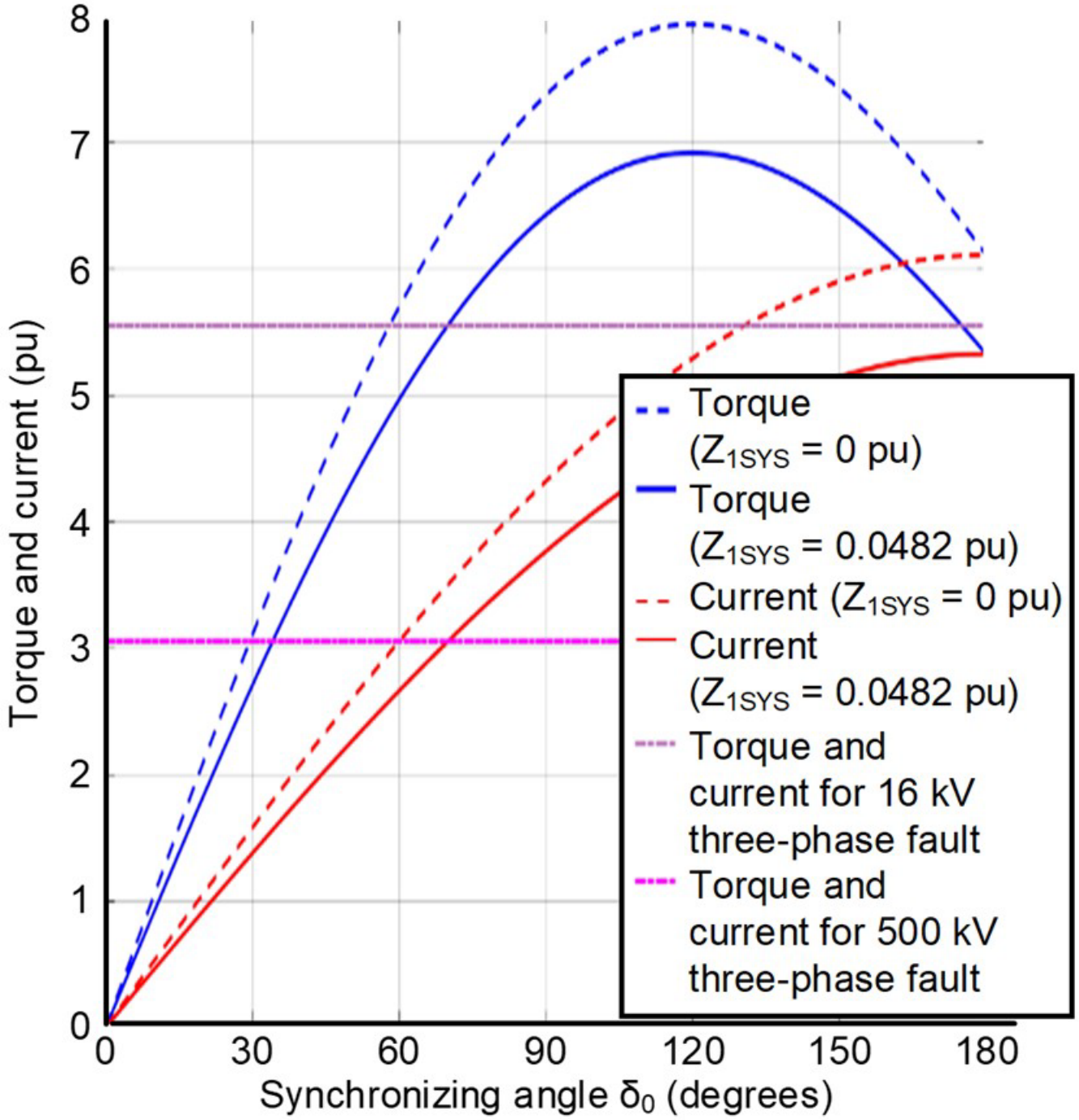


Event analysis

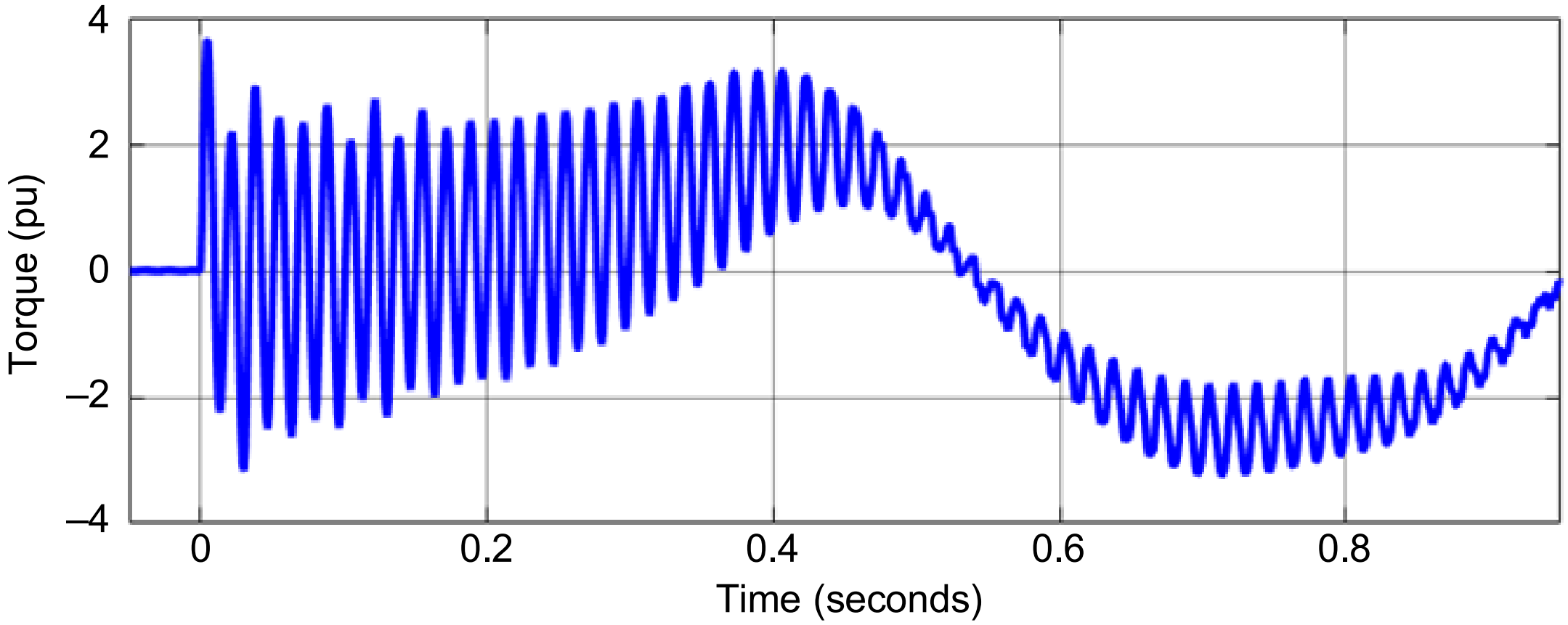
OOPS event vs. fault



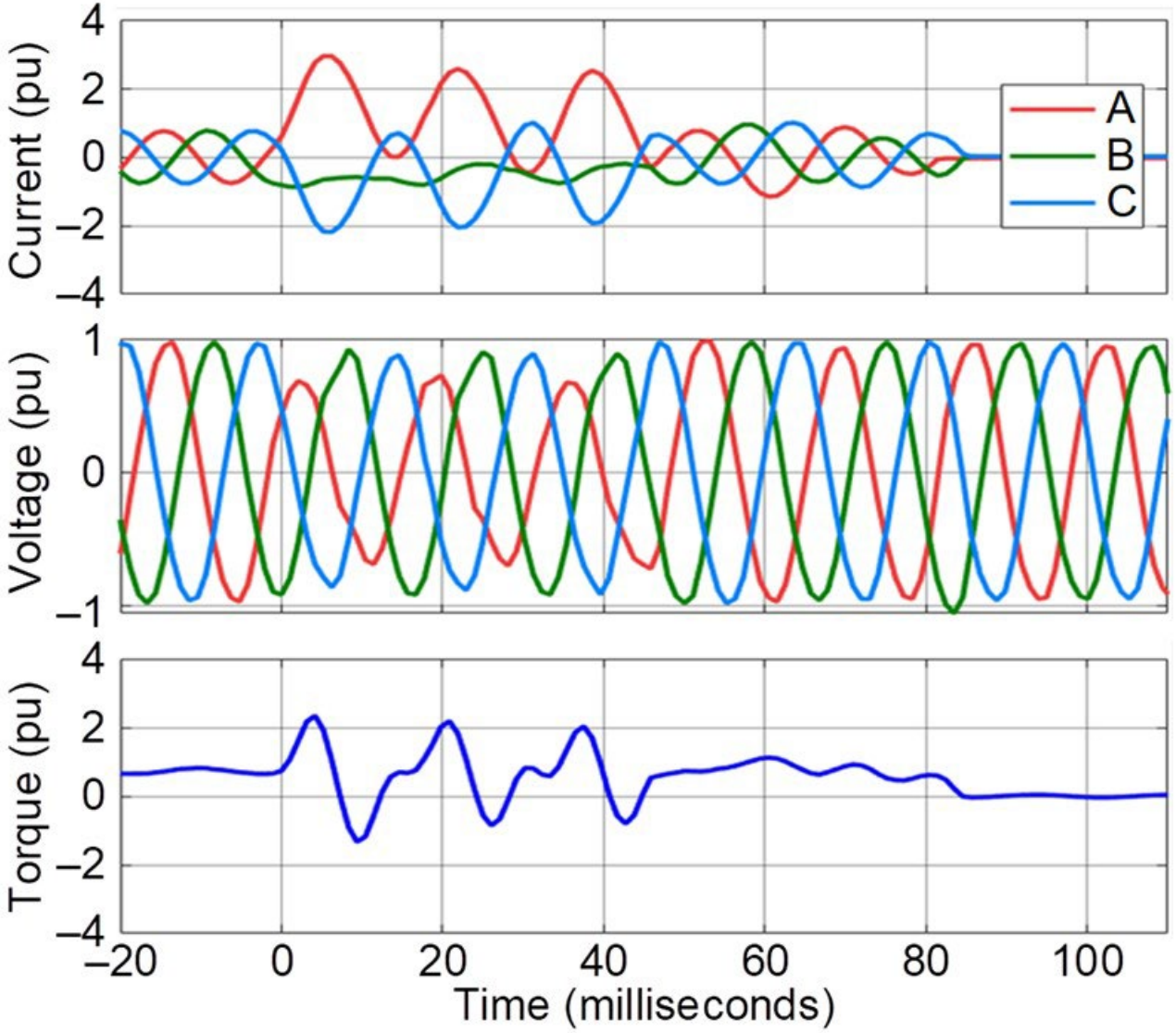


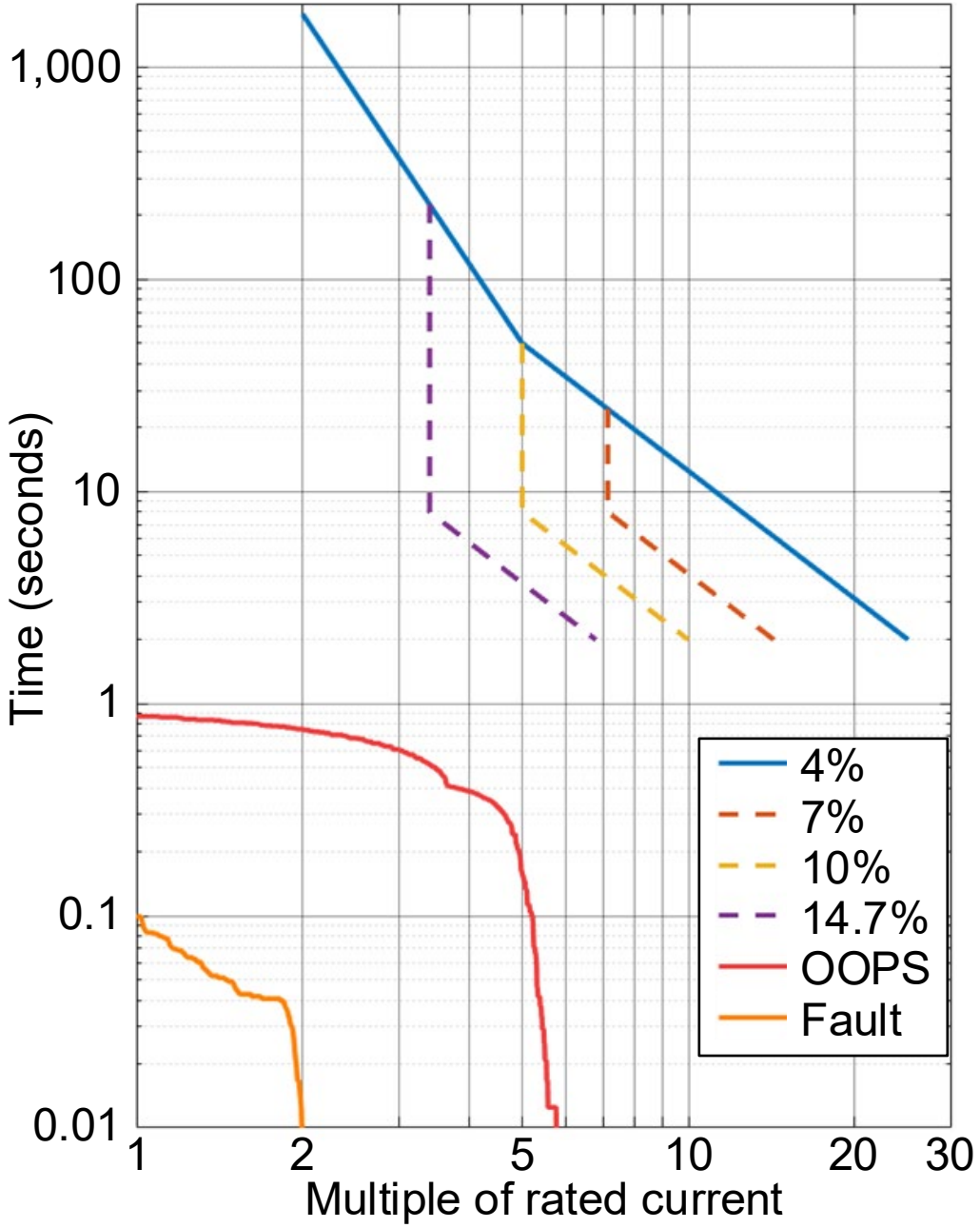


Electromagnetic torque

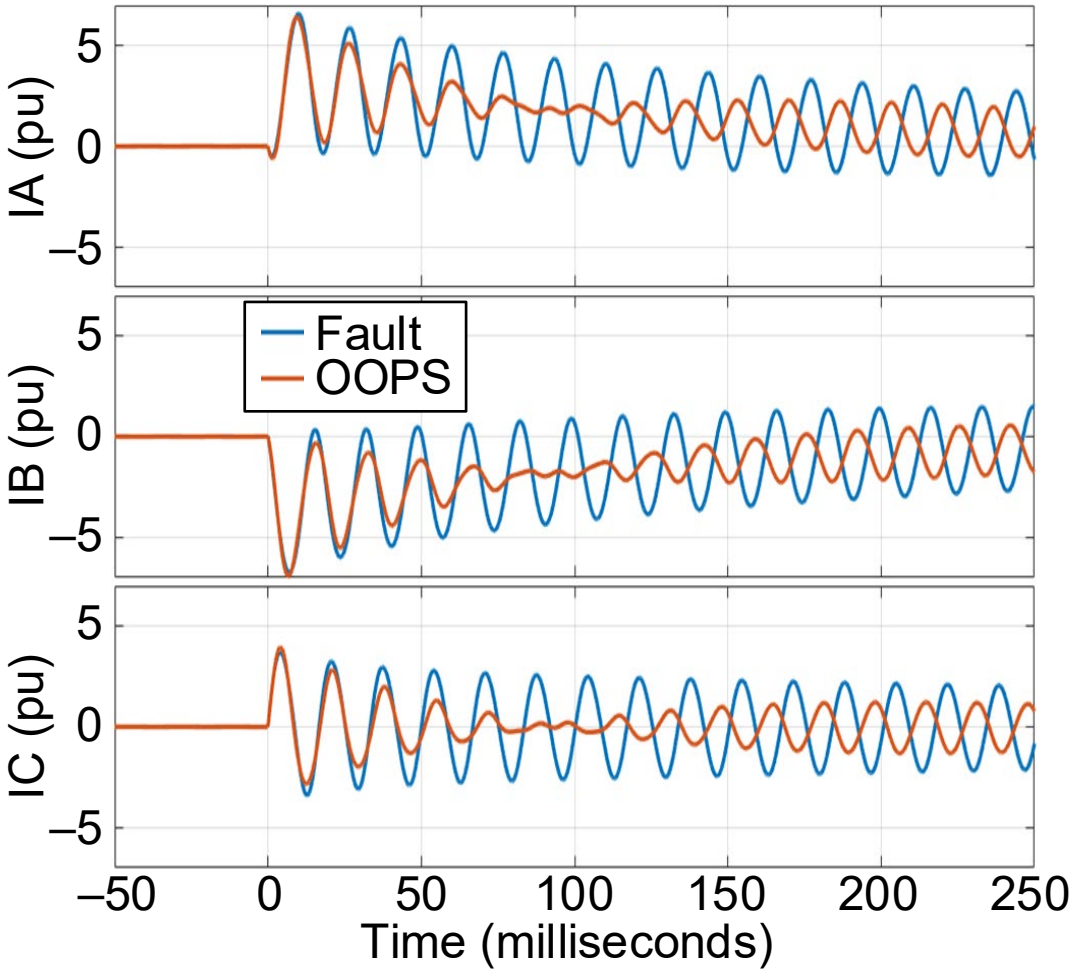


Currents

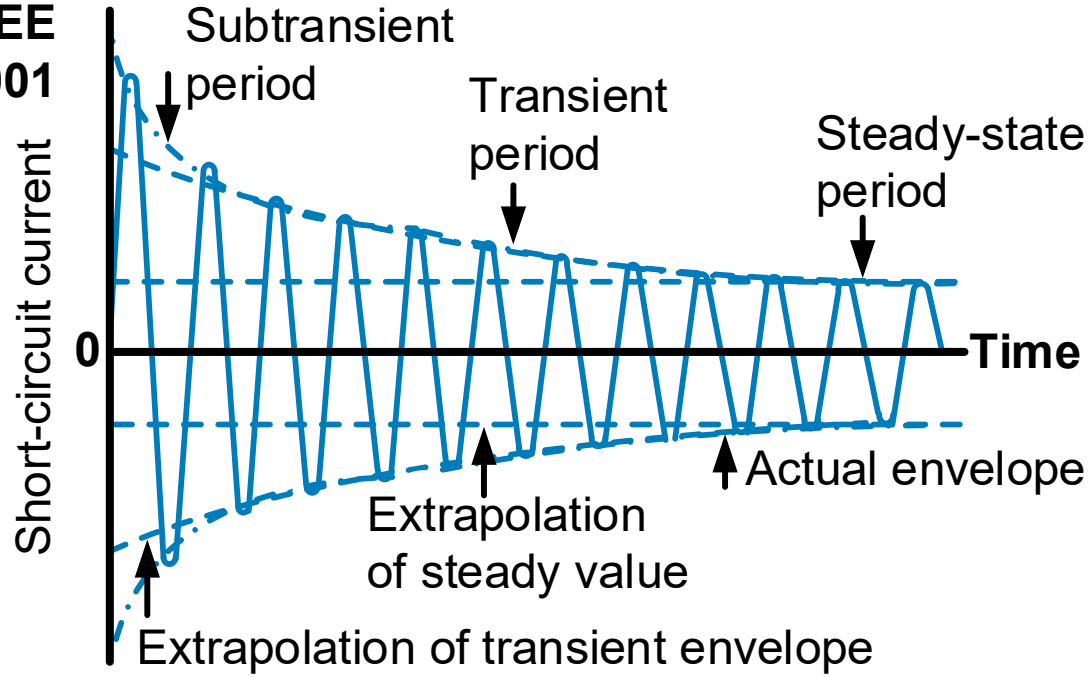

Current (pu)
Voltage (pu)
Torque (pu)
A
B
C
Time (milliseconds)


Time (seconds)
Multiple of rated current
4%
7%
10%
14.7%
OOPS
Fault

Delayed zero-crossings



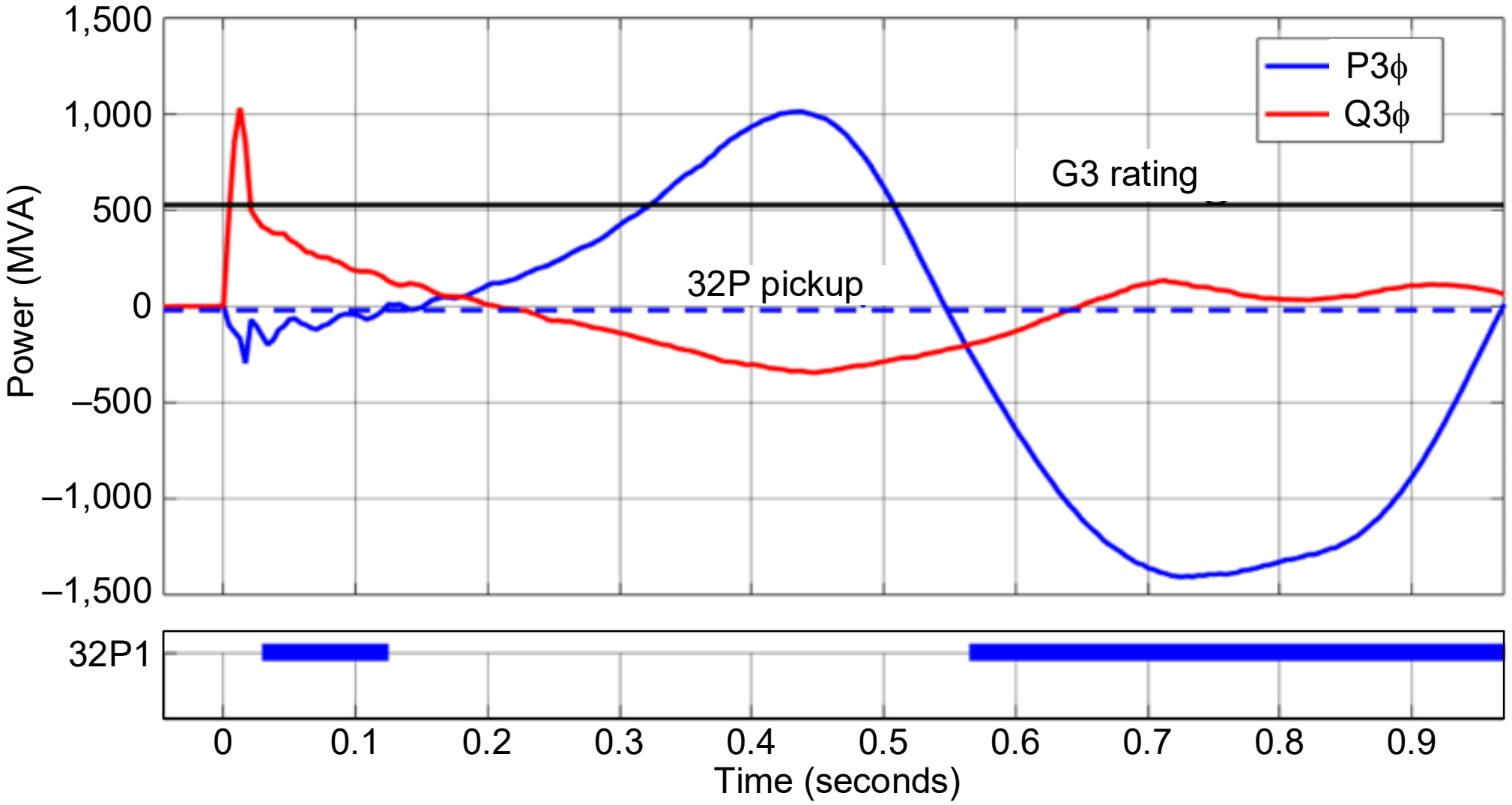
Source: IEEE PESTP1001



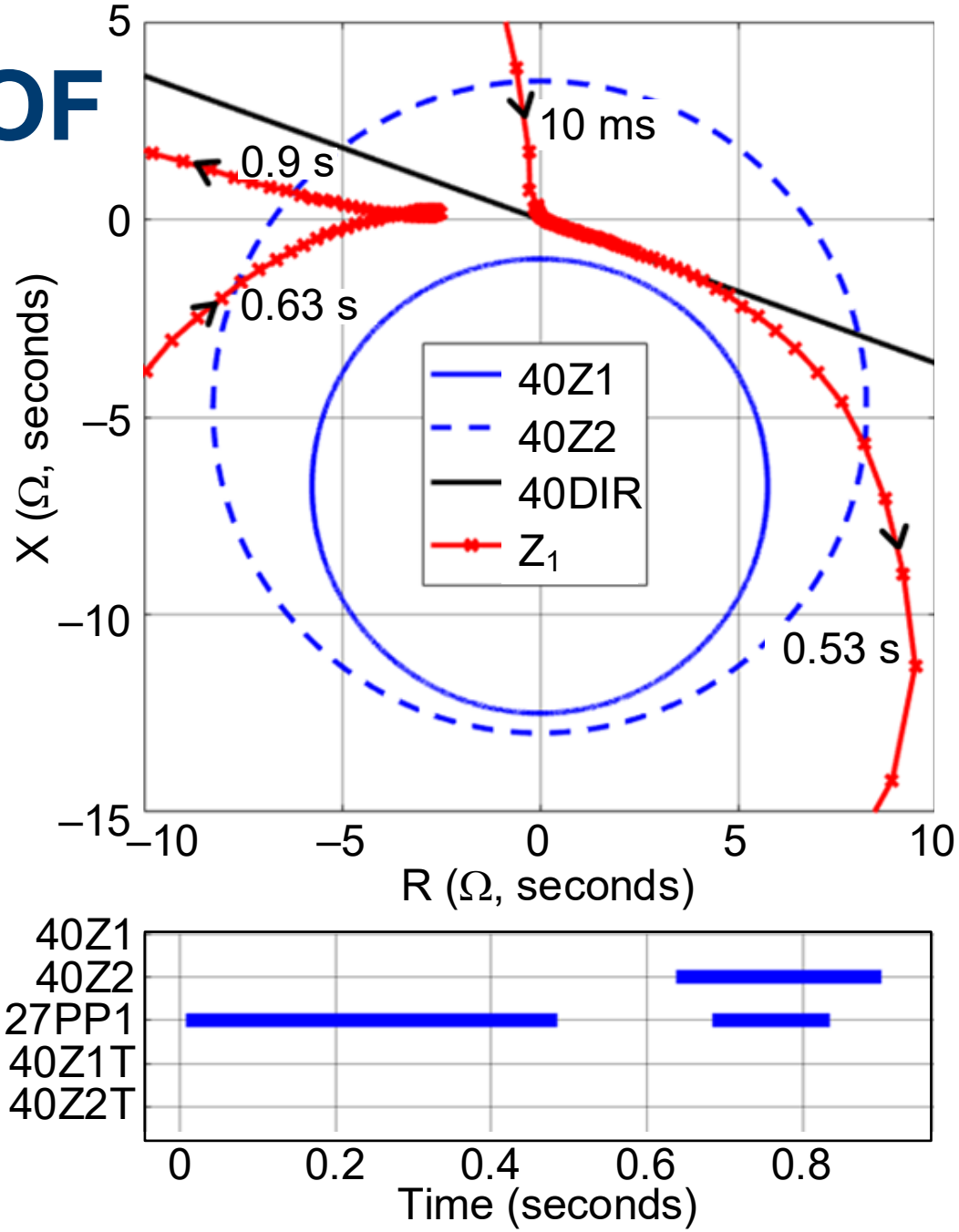
OOPS driving voltage:

Protection performance

Reverse power

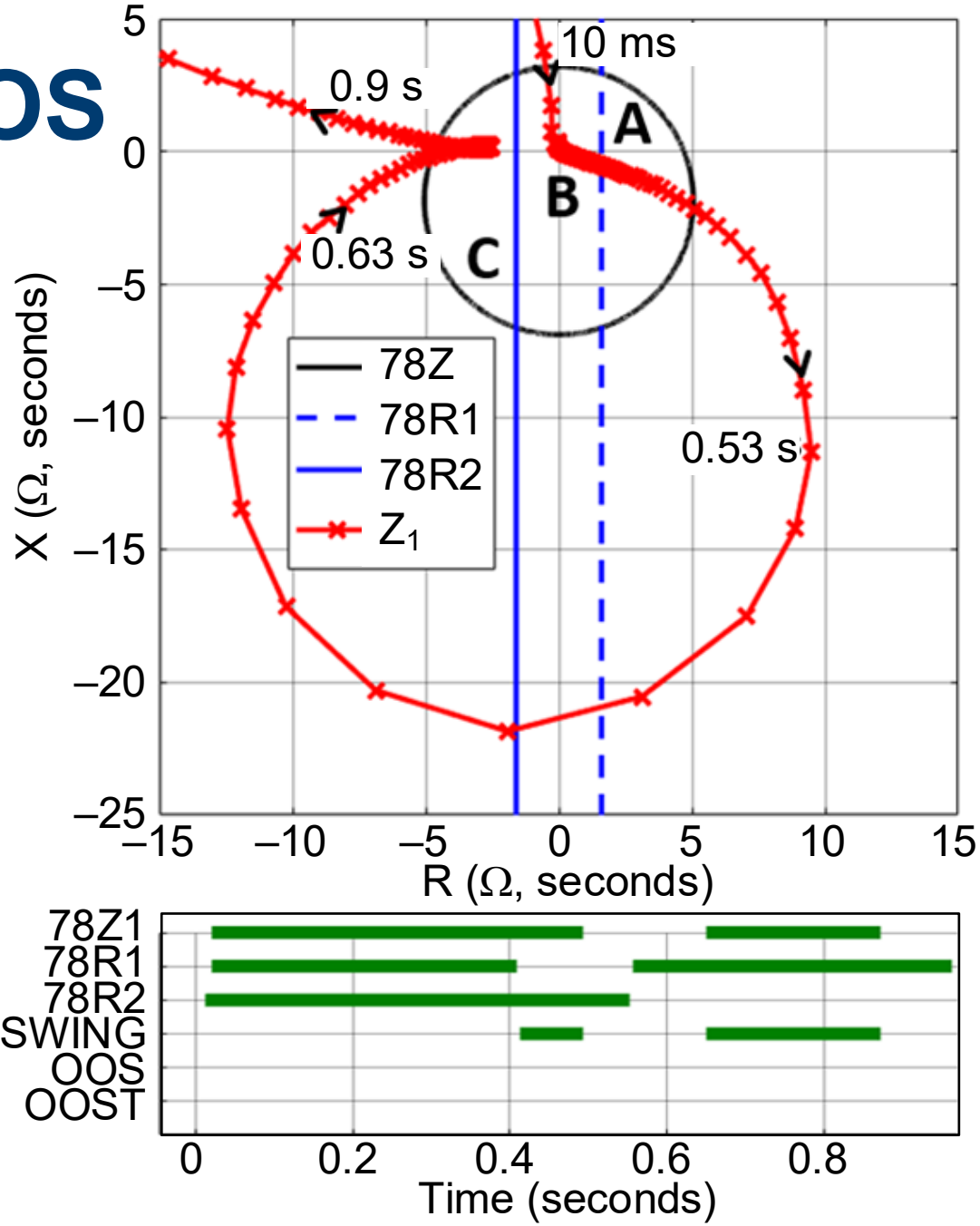


LOF


10 ms
0.9 s
0.63 s
0.53 s
40Z1
40Z2
40DIR
Z_1
X (Ω, seconds)
R (Ω, seconds)
5
0
−5
−10
−15
−10
−5
0
5
10

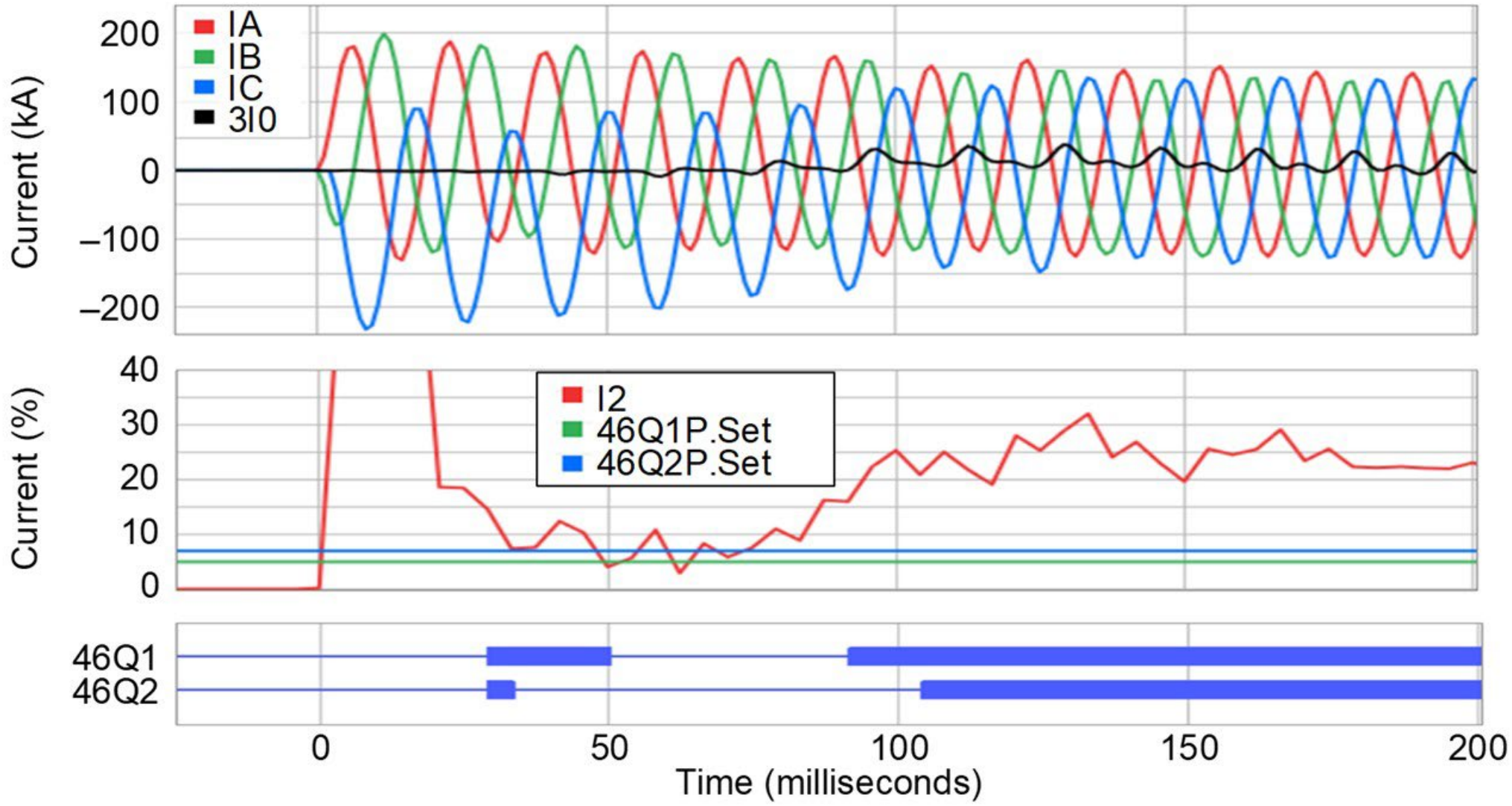
40Z1
40Z2
27PP1
40Z1T
40Z2T
0
0.2
0.4
0.6
0.8
Time (seconds)

OOS

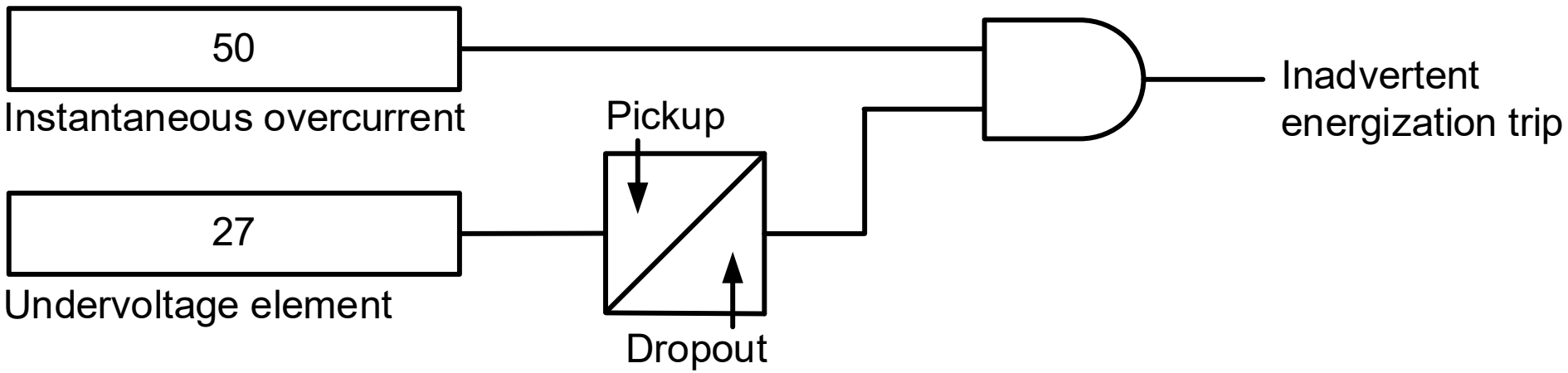

10 ms
0.9 s
0.63 s
0.53 s
A
B
C
78Z
78R1
78R2
Z_1
X (Ω, seconds)
R (Ω, seconds)
5
0
−5
−10
−15
−20
−25
−15
−10
−5
0
5
10
15

78Z1
78R1
78R2
SWING
OOS
OOST
0
0.2
0.4
0.6
0.8
Time (seconds)

Current unbalance due to CT saturation

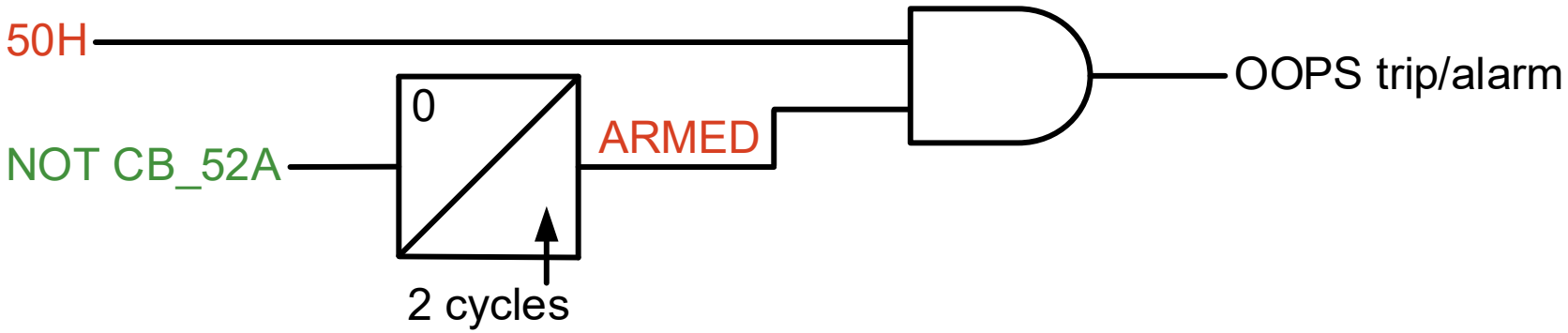


Inadvertent energization

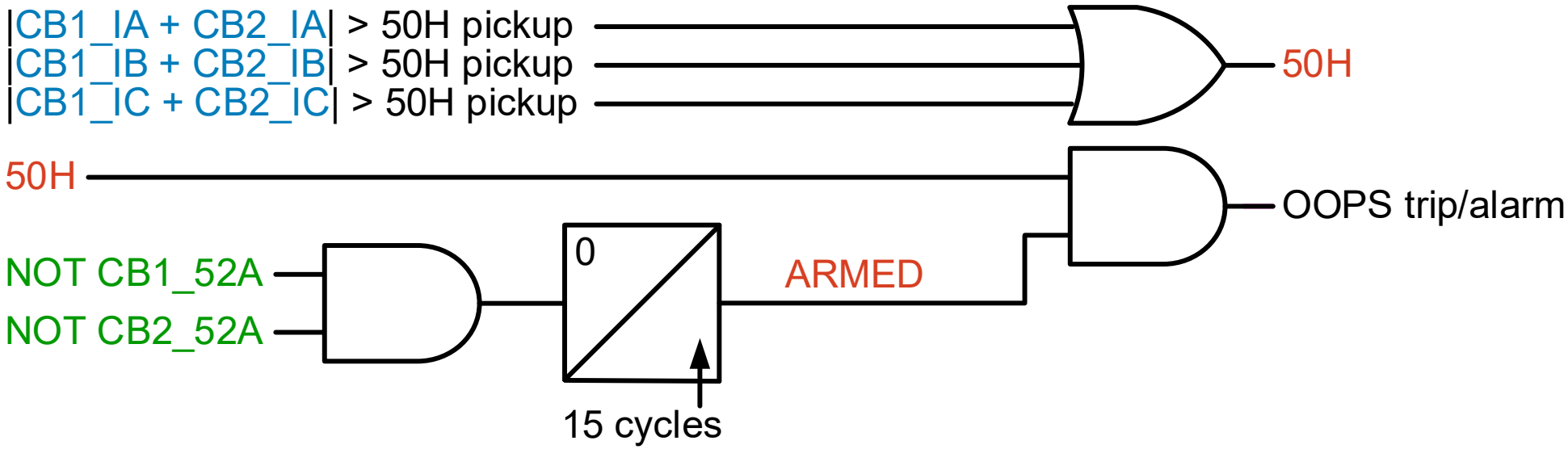


OOPS protection

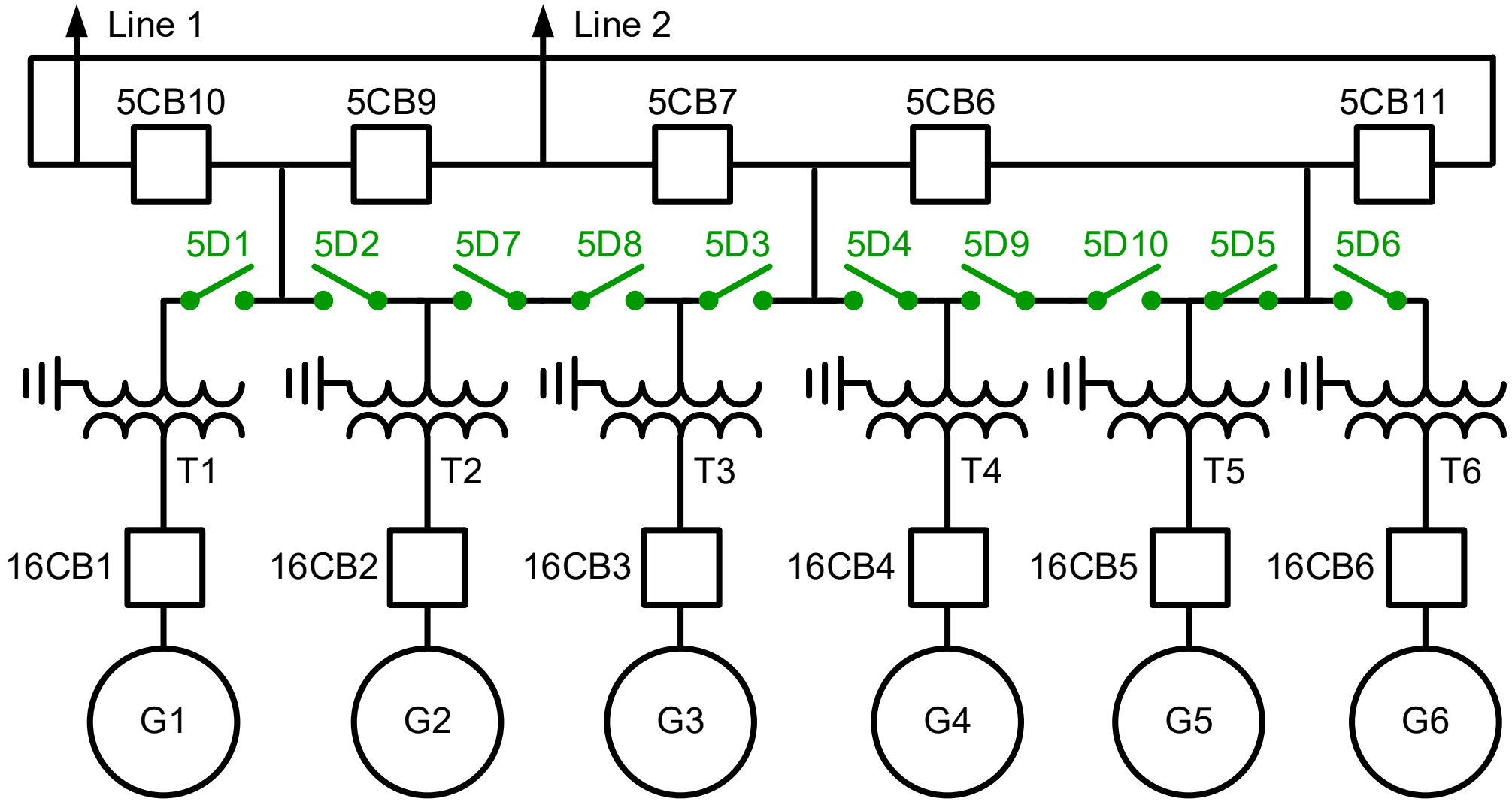
OOPS scheme



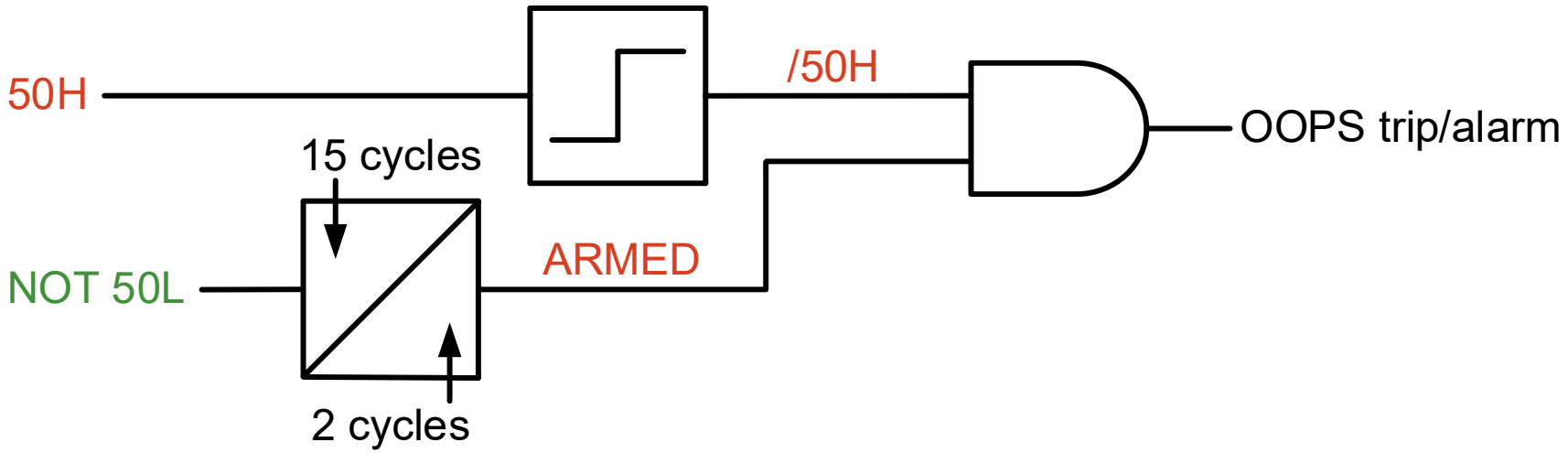
OOPS dual-breaker scheme



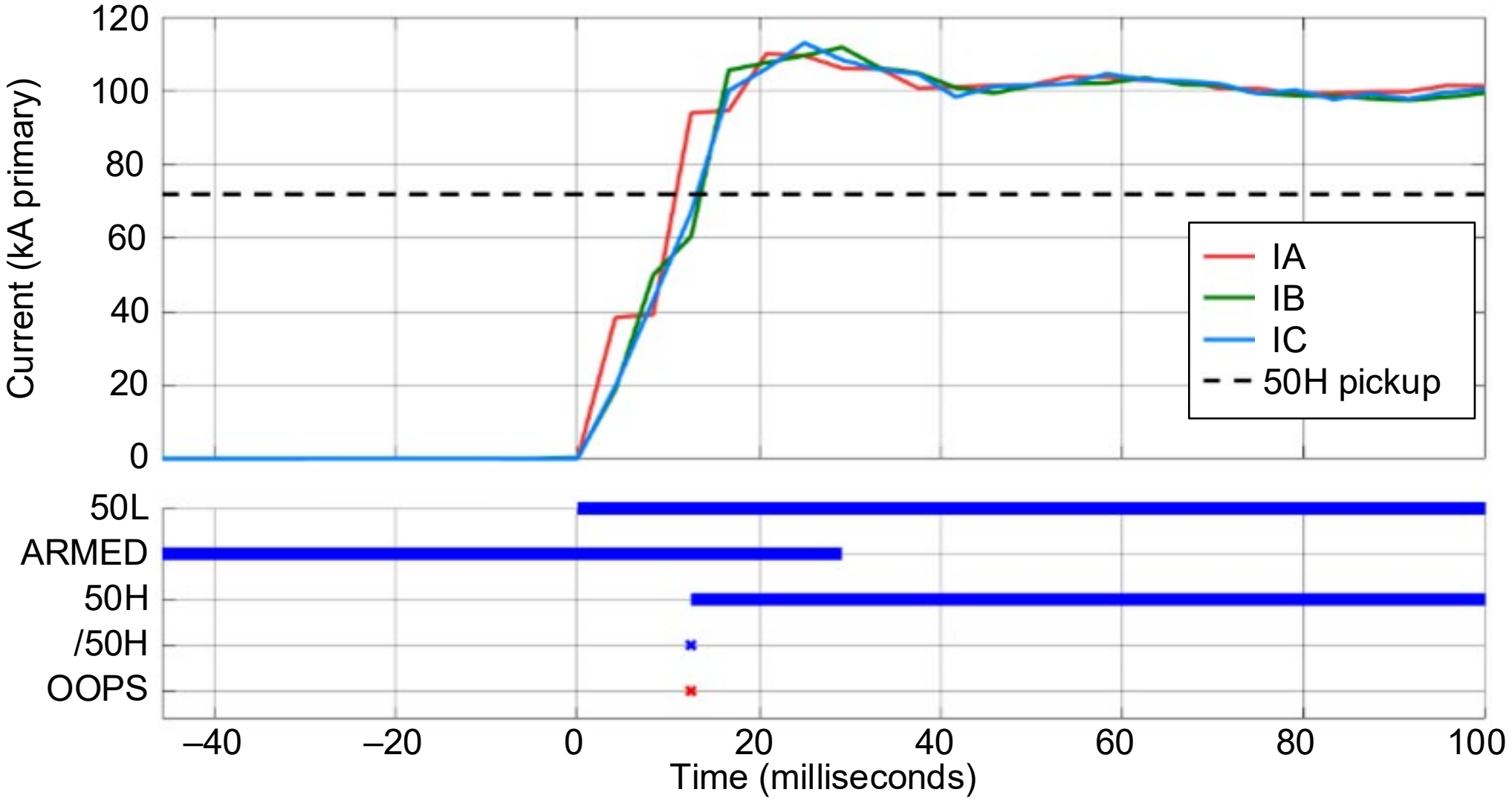
OOPS flexible or complex scheme



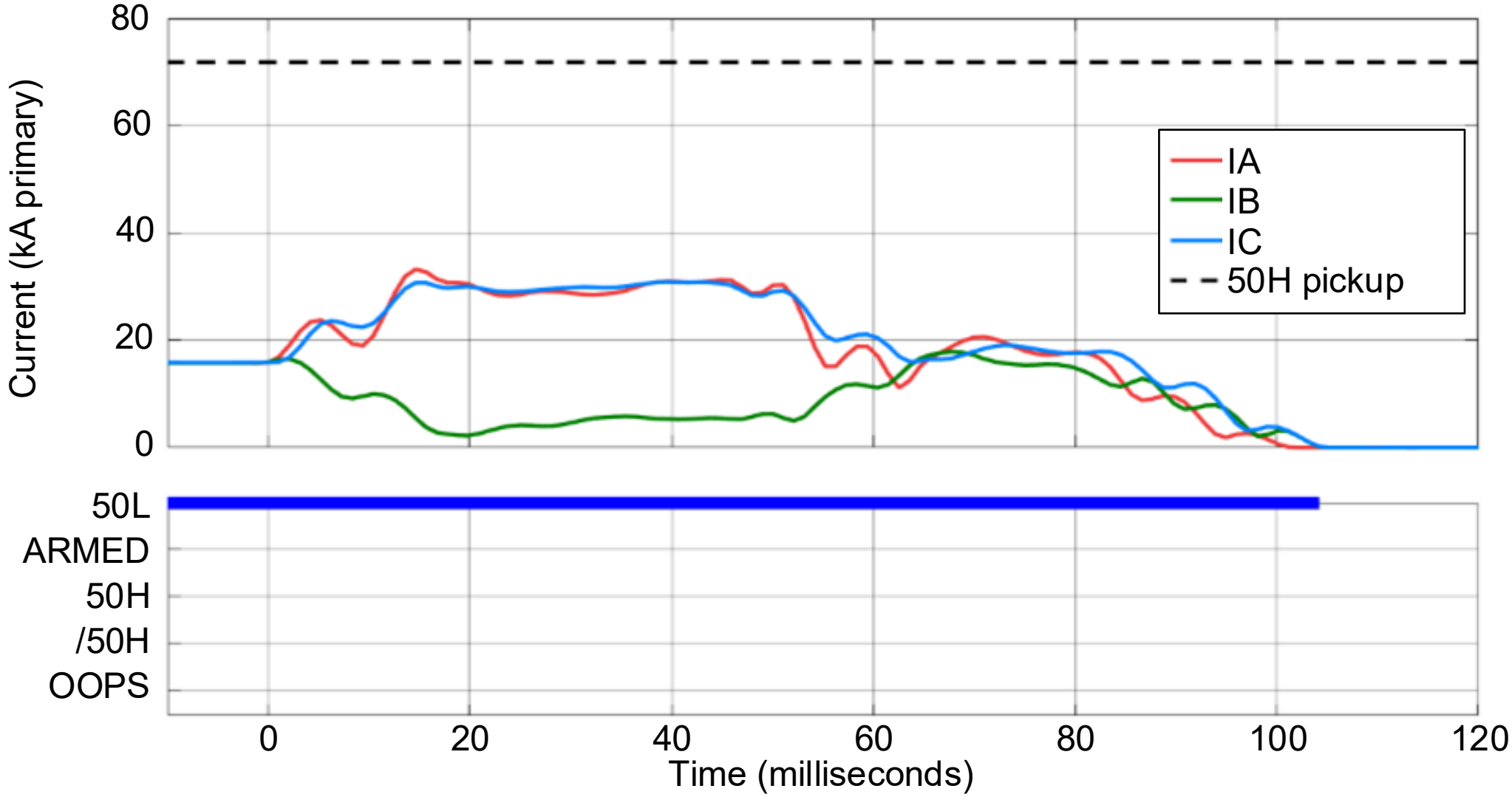
OOPS flexible or complex scheme



Dependability of OOPS protection



Security of OOPS protection



Life after poor synchronizations

Physical and electrical testing

Test	Result
Heat runs	Good
Exciter, governor, generator, GSU, and GCB	Good
IPB A-phase bushings that failed HiPot	Replaced
Sole plates inspection (using pole camera)	Good
Stator and rotor winding resistance	Good

In other news

OOPS event on 800 MVA STG

- Outage span of 98 days
- Total cost of $16 million
- Repair, transport, and labor costs of $7 million

Lessons learned

Avoid common-mode failures in system

Use independent circuits for synchronizer and synchronism-check devices

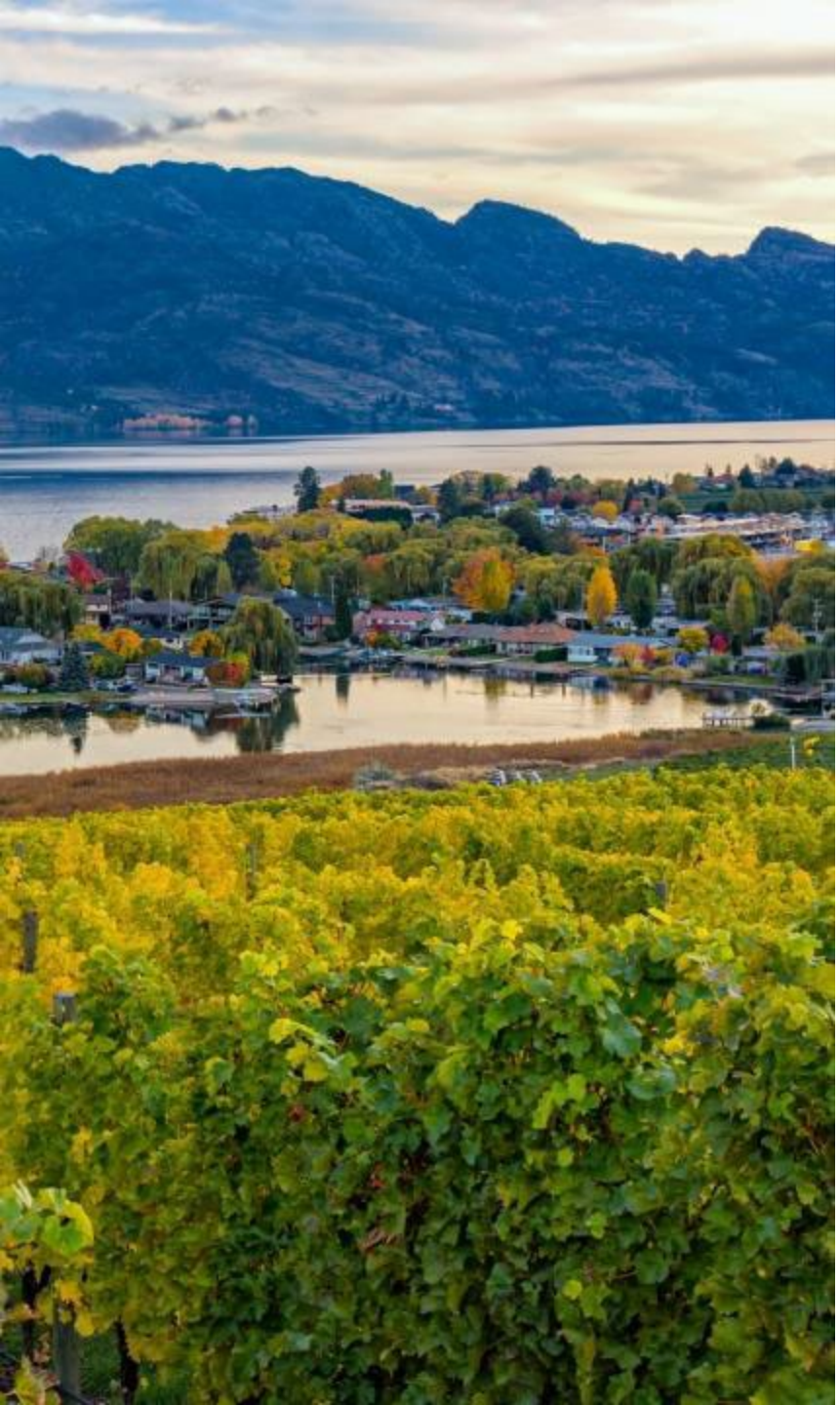
Verify synchronizing circuits after modifications

Verify when unit is running and is synchronized using another system that is known to be functional

Energize from same source using back-feed, black-start (forward-feed), or primary injection

Conclusion

- Be aware that generator protection elements might not detect OOPS events
- Use dedicated OOPS scheme for proper targeting, protecting, and alarming
- Avoid common-mode failures
- Verify synchronizing circuits



Questions?