SDG&E Experience With Distribution Synchrophasors and Catching Falling Conductors

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SDG&E Distribution System

- 22,000 miles of lines
- 60% underground and 40% overhead
- 12.47, 12.0, and 4.16 kV voltage levels
- Grounded at substation with three- and four-wire systems

Advanced SCADA Planning
More Than 60 Cases Defined

- Falling conductor protection (patent pending)
- Voltage profile monitoring and control
- Selective load shedding and restoration
- Power quality monitoring
- Apparatus and system condition monitoring
- Secure communication

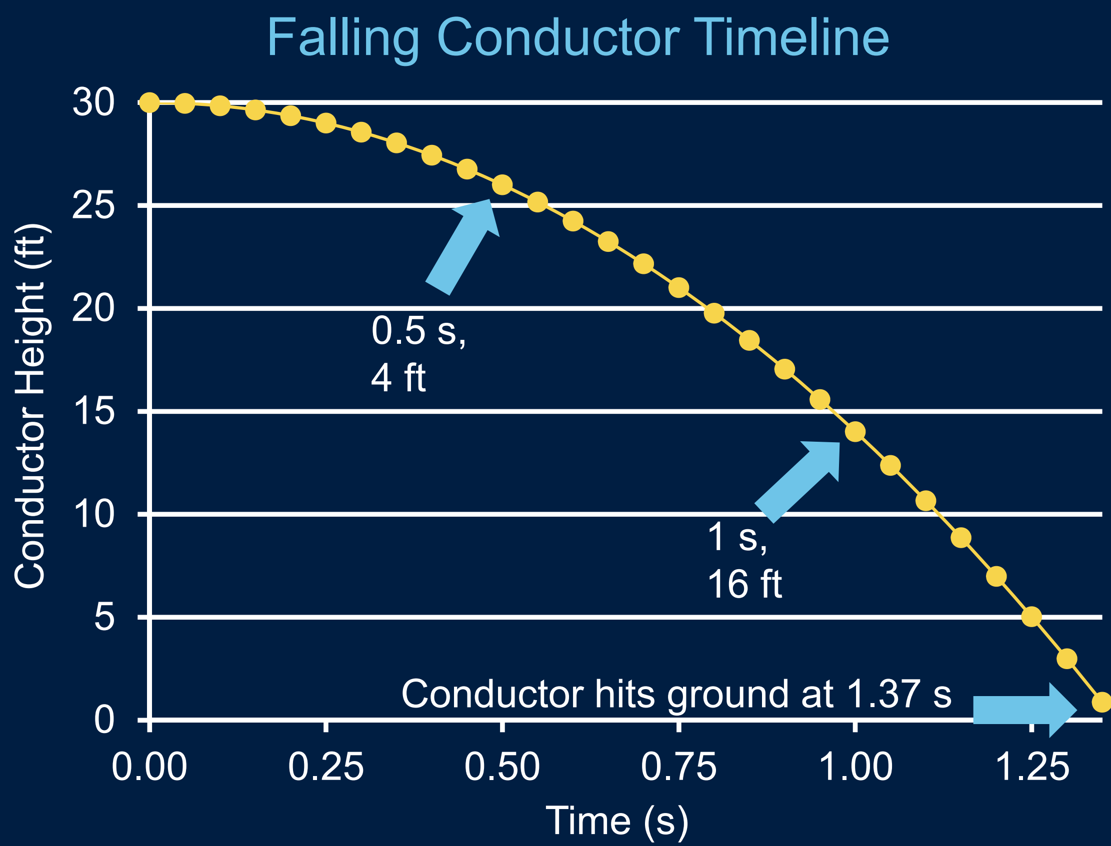
Advanced SCADA Features

- Increased accuracy – voltage and current sensors
- Phase angle
- GPS time-stamped data
- Remote engineering access and event reports
- High-speed, near real-time control

Advanced SCADA Features

- Advanced visualization
- Improved security
  - Log and audit access
  - Active directory passwords
  - Network anomaly detection sensor and technology

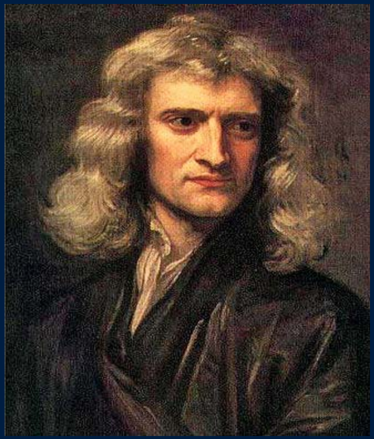
Detect Broken Conductor and Trip Circuit Before Line Hits the Ground?



$$d = \frac{1}{2} g t^2 \rightarrow t = \sqrt{\frac{2d}{g}}$$

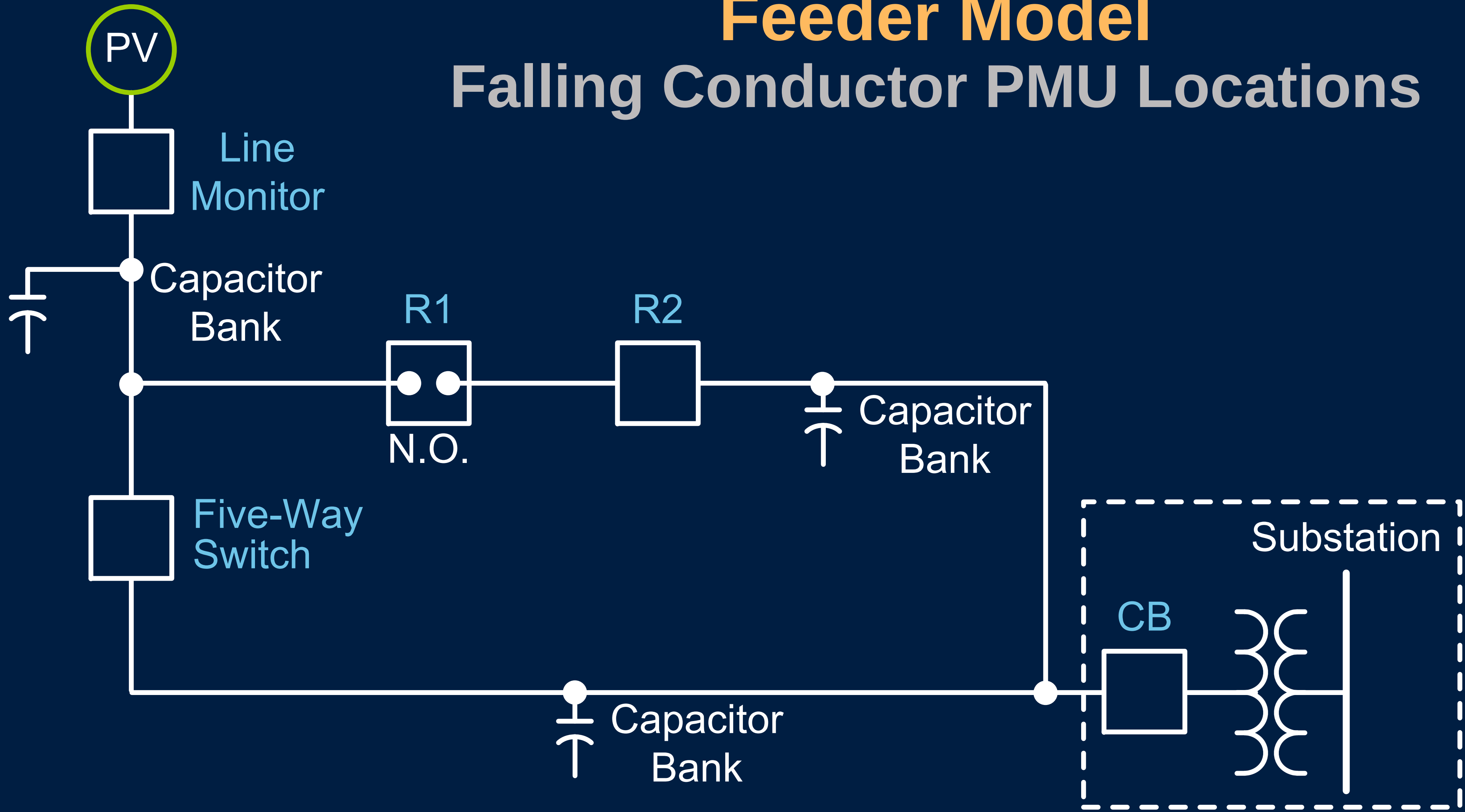
$$t = \sqrt{\frac{2(30)}{32.2}}$$

$$\text{time} \approx 1.37\,\text{s}$$

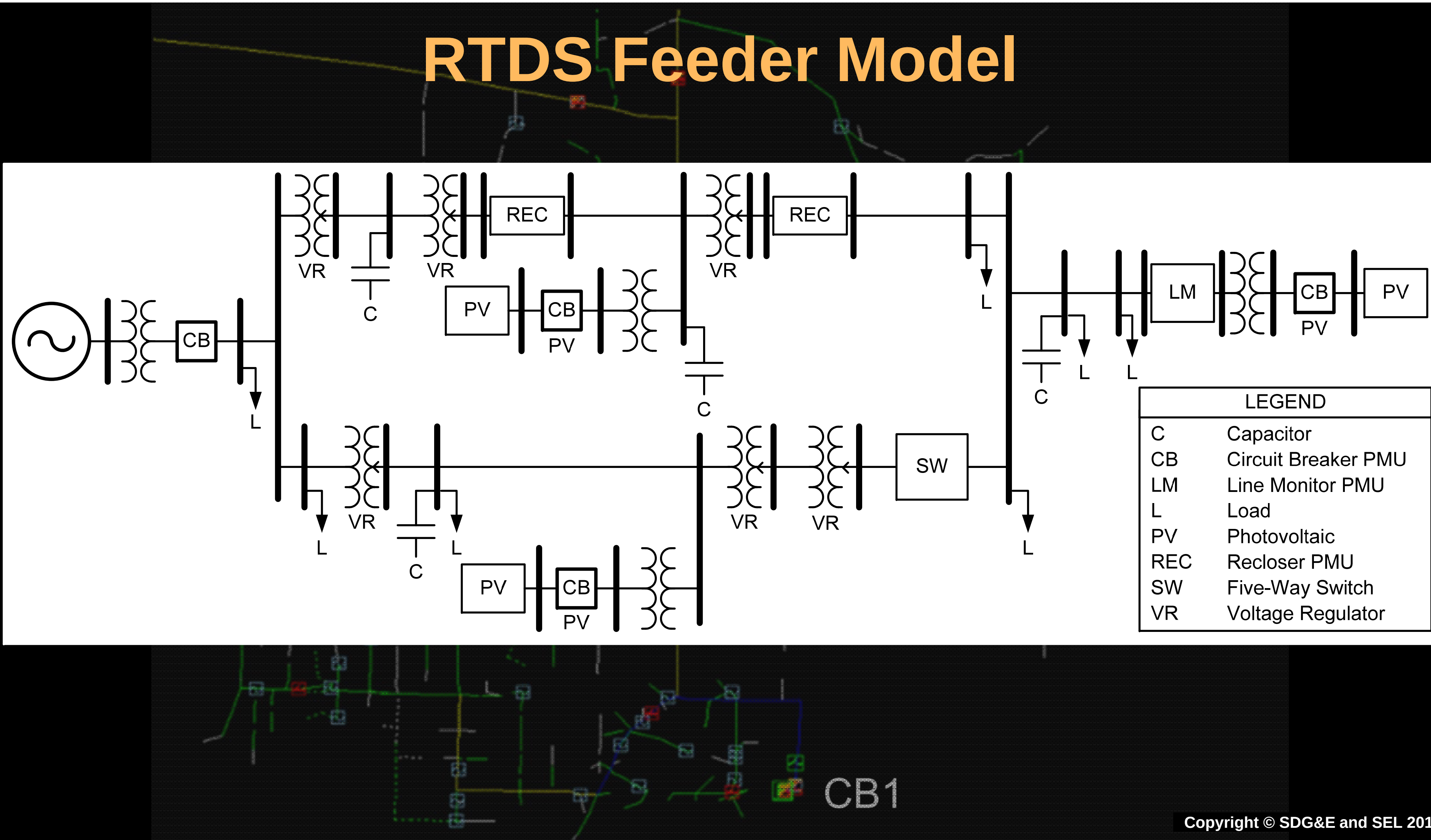


Feeder Model

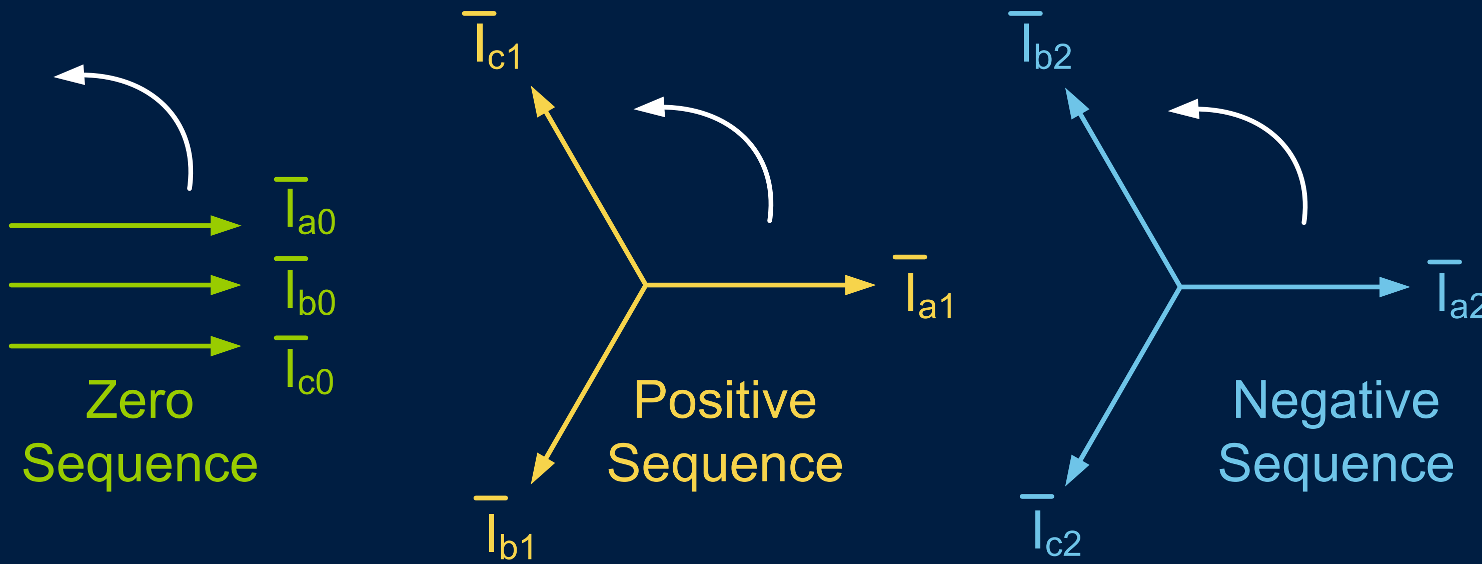
Falling Conductor PMU Locations



RTDS Feeder Model



Sequence Components Analysis



Single Phase

$\overline{I}_{a0} = \overline{I}_{b0} = \overline{I}_{c0}$

Balanced

$\overline{I}_{b1} = a^2\overline{I}_{a1}$

$\overline{I}_{c1} = a\overline{I}_{a1}$

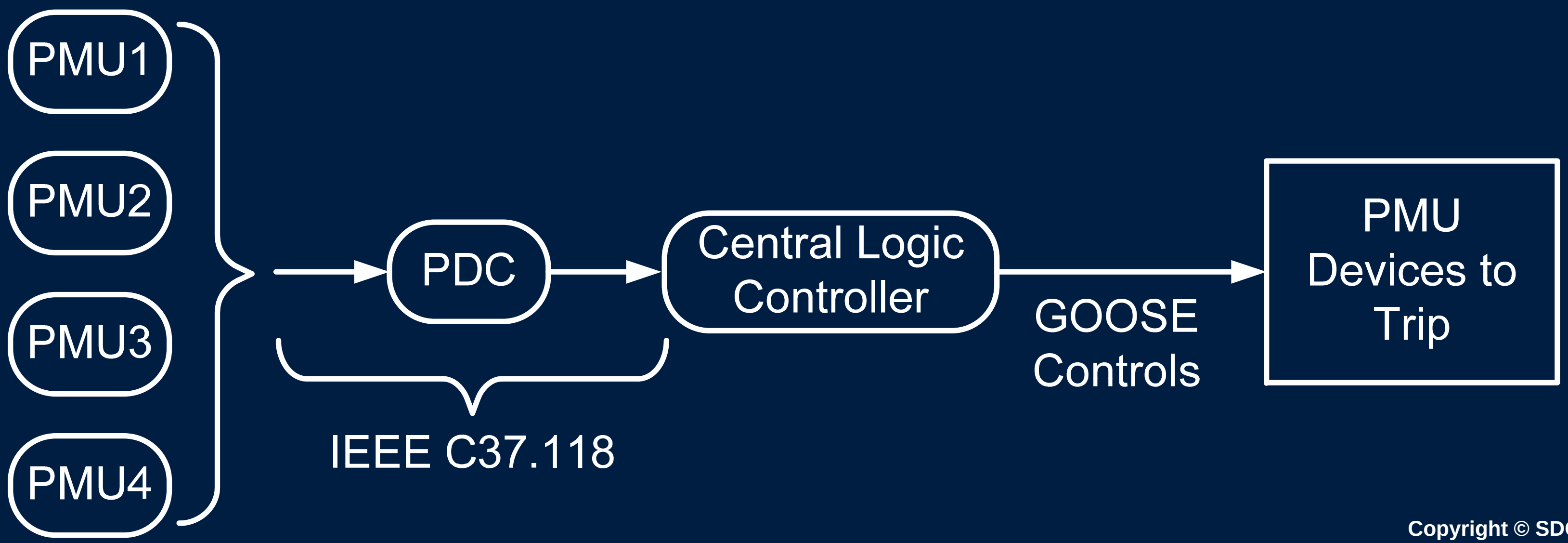
Balanced

$\overline{I}_{b2} = a\overline{I}_{a2}$

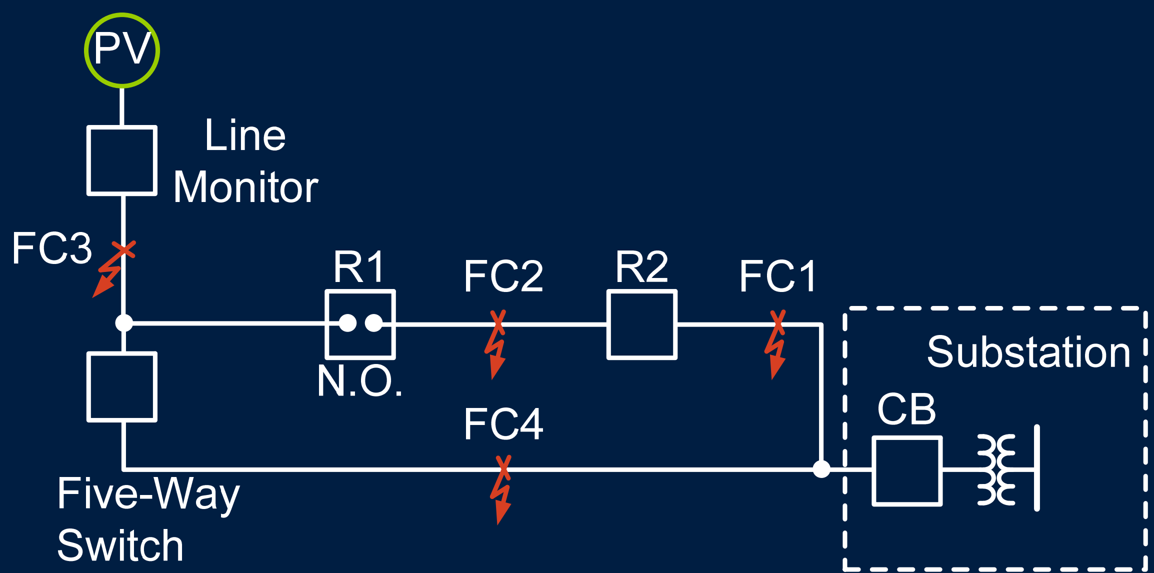
$\overline{I}_{c2} = a^2\overline{I}_{a2}$

Detection Methods

- dV/dt (change detection)
- V0 and V2 magnitude
- V0 and V2 angle



Example Lab Test Results



PV Off, Loop Open

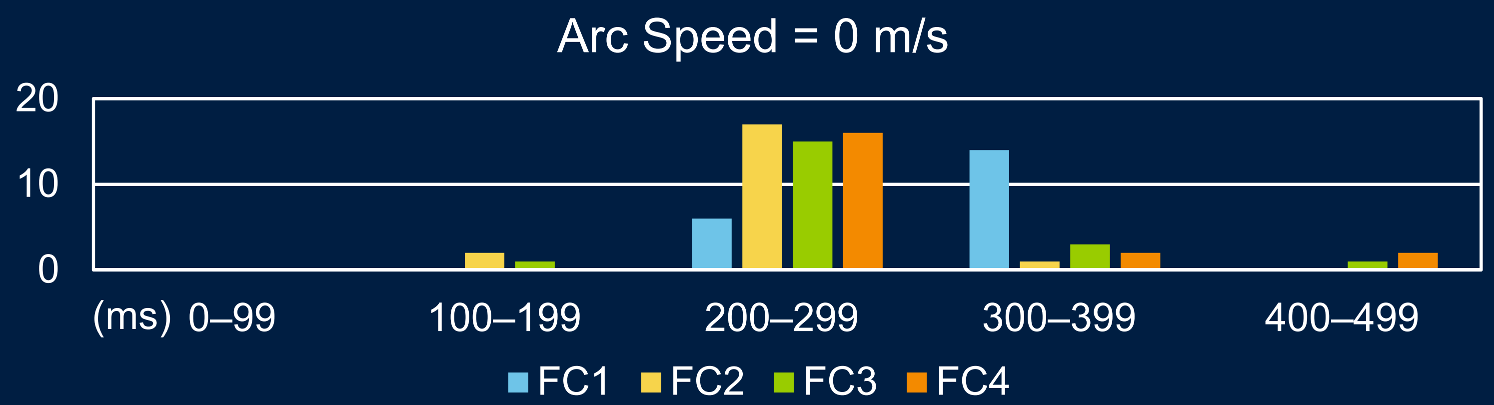
Load %	FC1	FC2	FC3	FC4
100	3	3	3	3
75	3	3	3	3
25	3	3	3	3

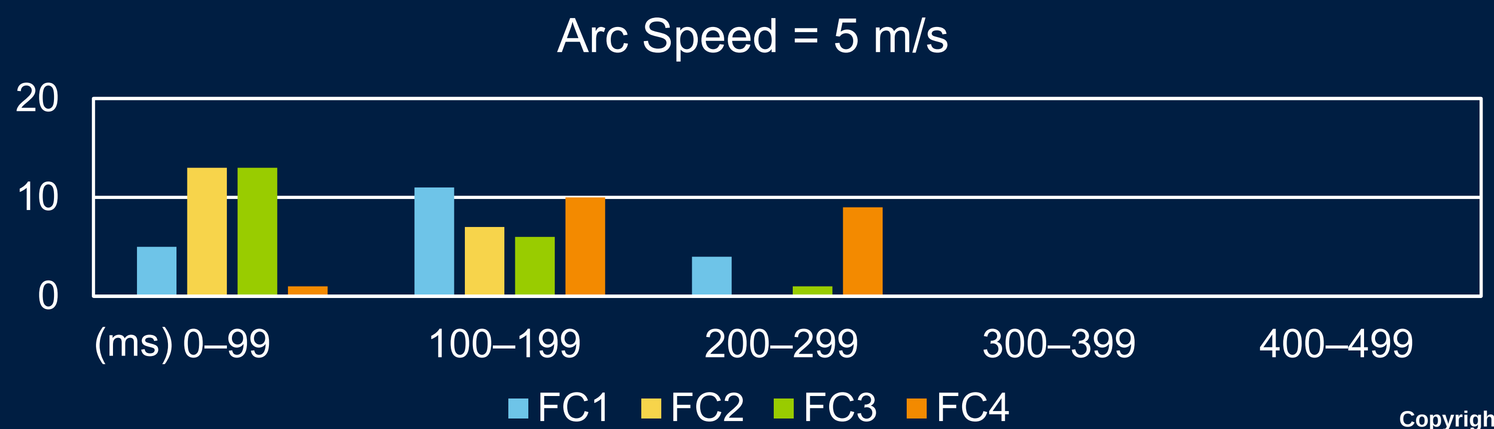
PV On, Loop Open

Load %	PV%	FC1	FC2	FC3	FC4
100	100	3	3	3	3
	75	3	3	4	4
	50	3	3	3	3
	25	3	3	3	3
25	100	3	3	3	3
	75	3	3	3	3
	50	3	3	3	3
	25	3	3	3	3

Arc Speed and Results Comparison

Number of Test Cases Versus dV/dt Pickup Times



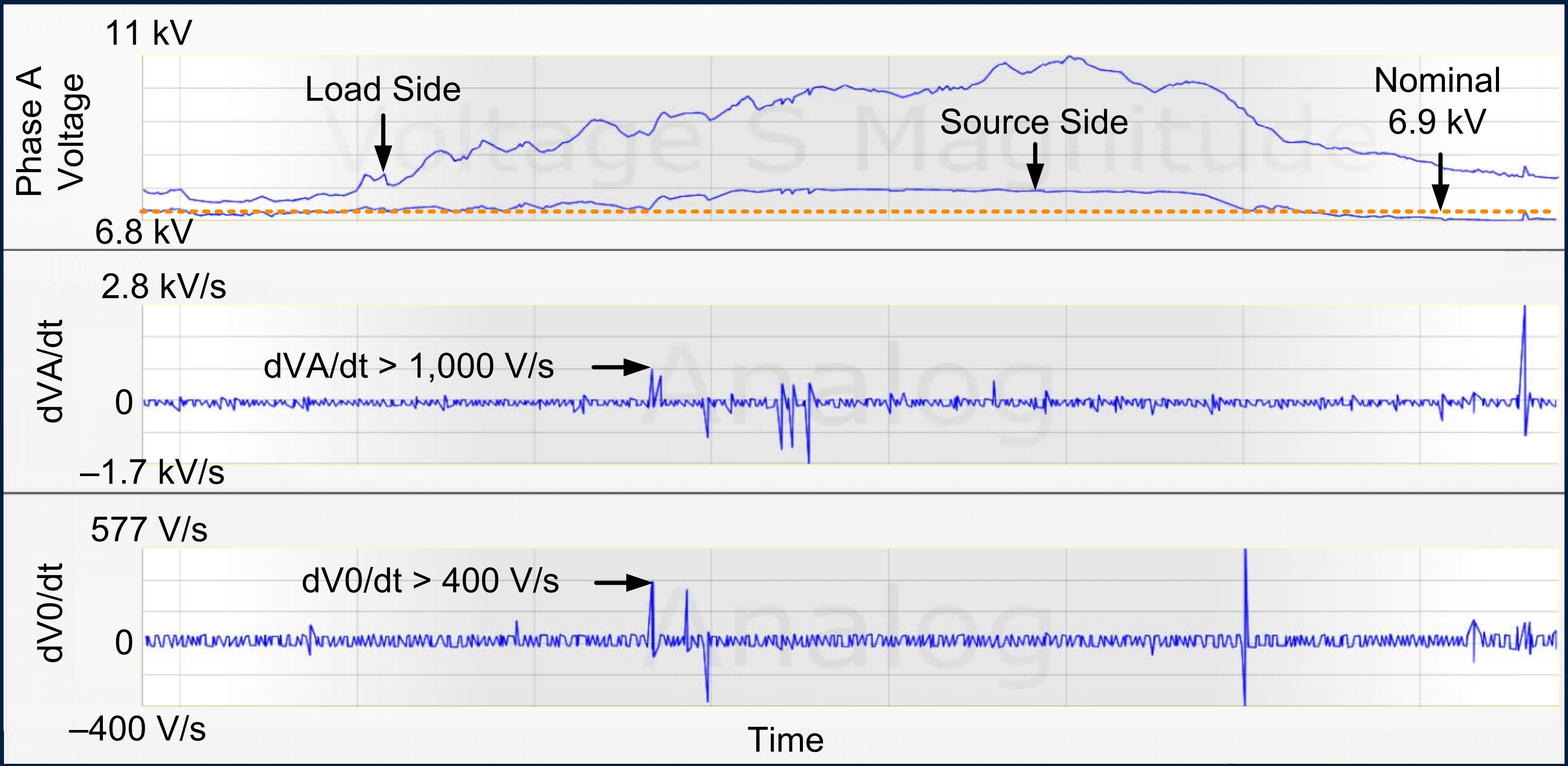


Field Installation and Testing

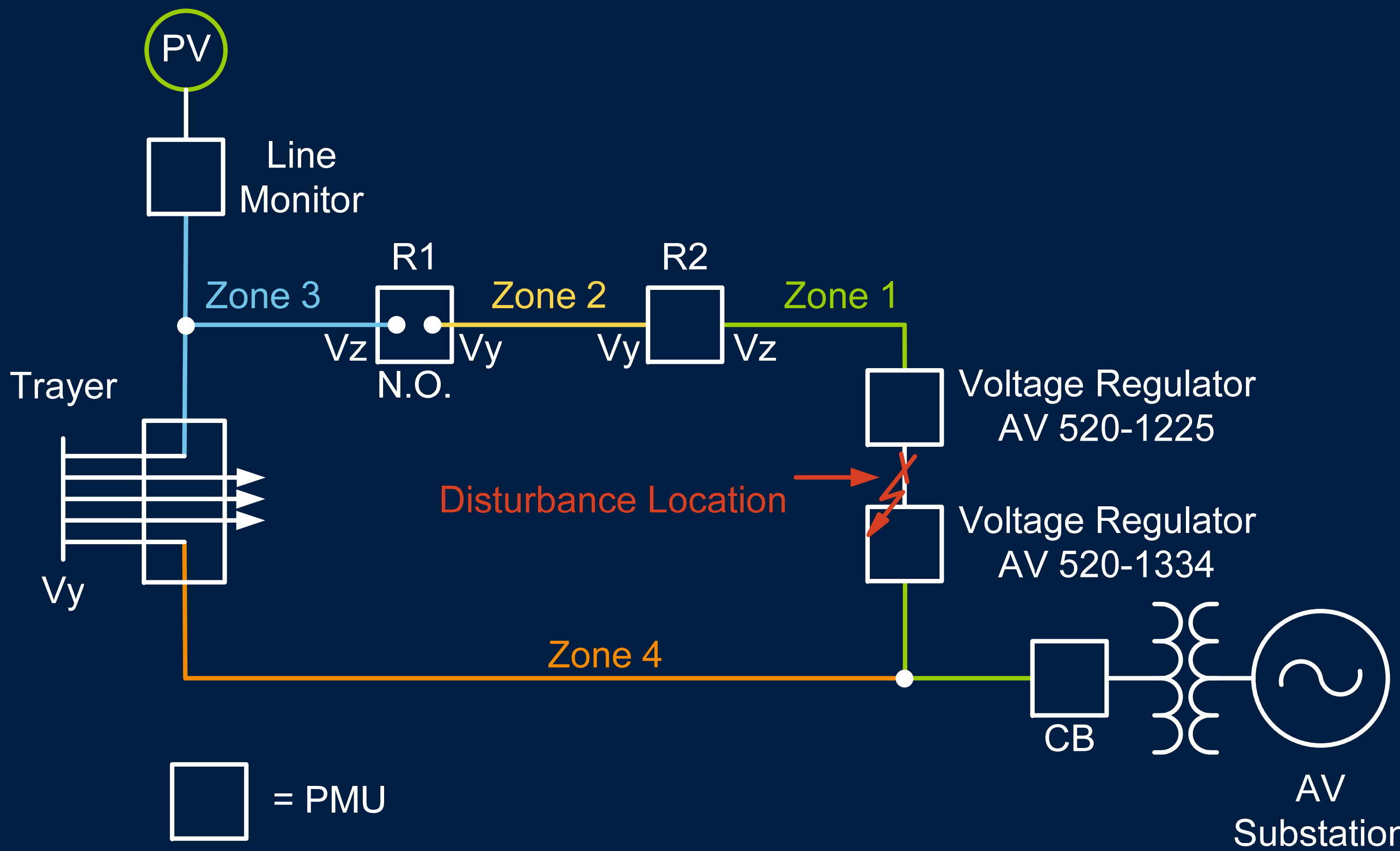
- First system installation in January 2015
- Falling conductor protection (FCP) in monitoring mode
- Simulation of conductor breaks with disconnect switch opening on recloser
- 100% correct operation
- Ethernet radio tuning required

dV/dt Operation

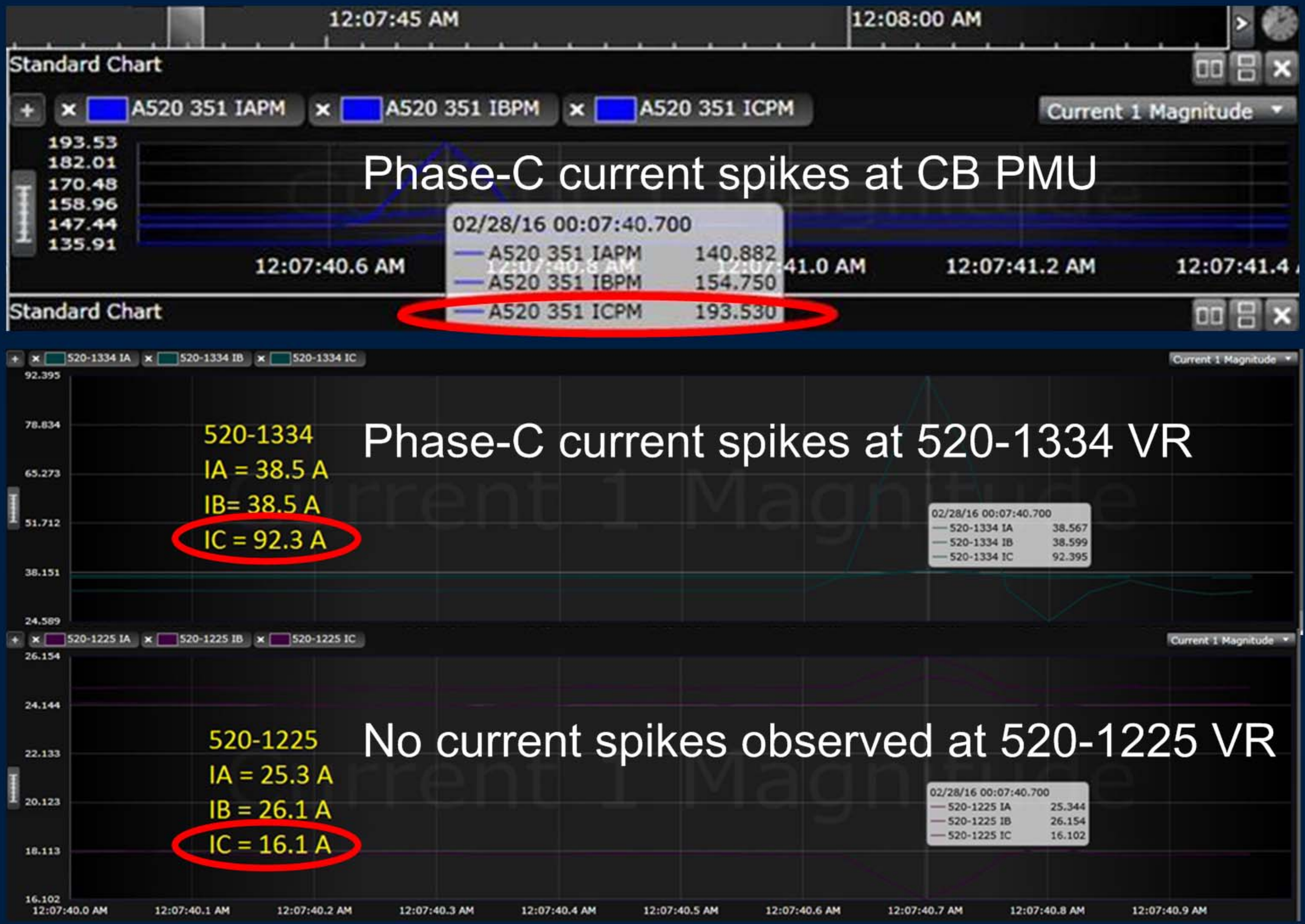
Capacitive Voltage Sensors

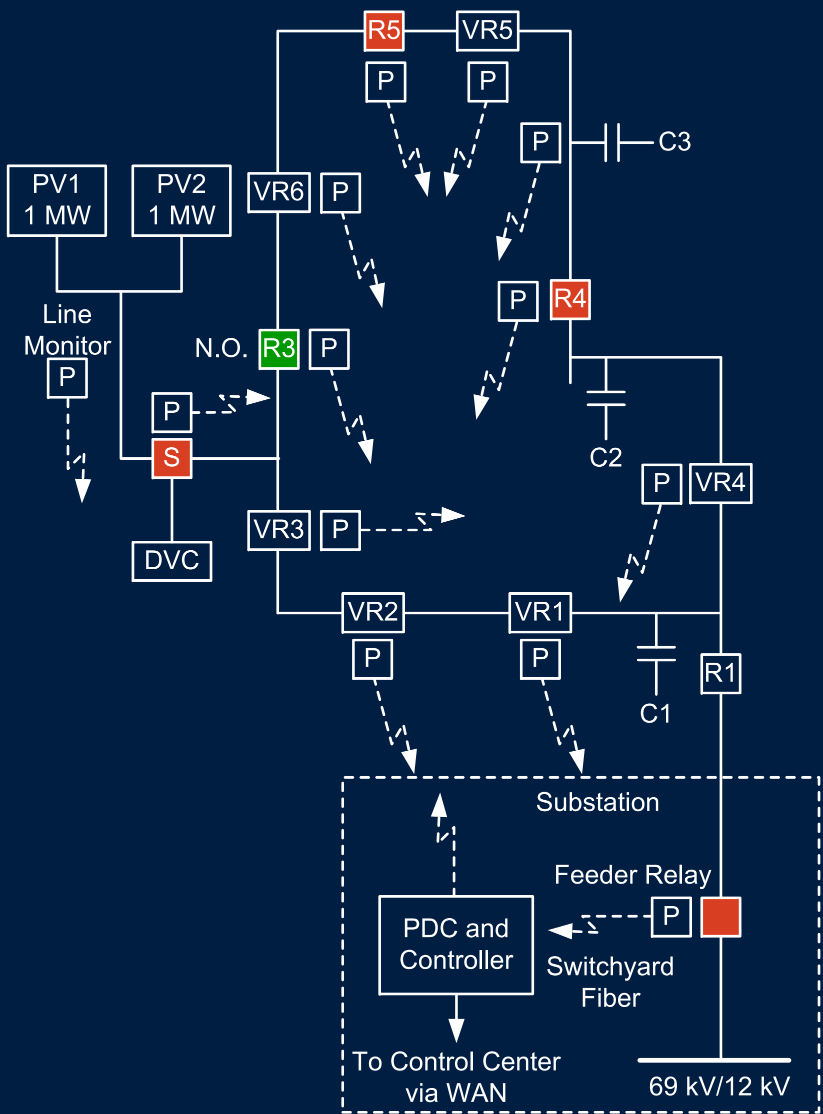


FCP Detects CT Insulation Failure



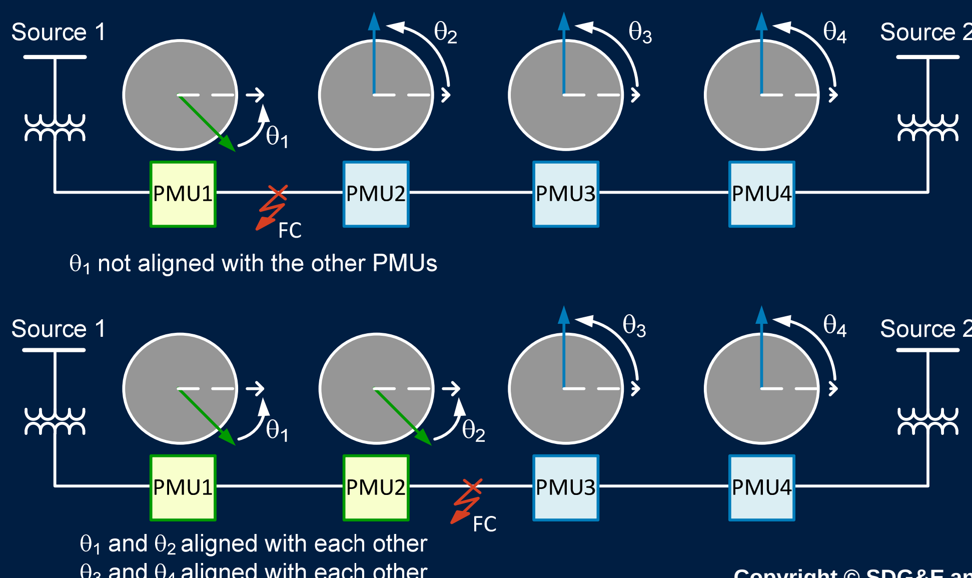
Nuisance Trip Diagnostics and Analysis





Ease of Application

- Key requirement achieved – no circuit-dependent application settings
- FCP logic only needs topology of circuit and PMU IEDs



Conclusions

- Falling conductor takes ≈1.4 s to reach the ground
- FCP methods detect and isolate in ≤0.7 s
- Change detection and steady-state detection algorithms operate in parallel

Conclusions

- Change detection picks up reliably for almost all falling conductor test cases
- Steady-state sequence methods (magnitude and angle) back up change detection in case of data packet loss
- Dependable falling-conductor detection observed in lab and field

Conclusions

- FCP tripping is being enabled at first installation
- Scalable design works on all studied circuits and needs only circuit layout information
- Twelve more circuits to be commissioned in 2016, with more to come

Questions?