Time Synchronization in Power Applications

Tutorial

Werner Abt – SW Engineering Manager / Meinberg USA
werner.abt@meinberg-usa.com

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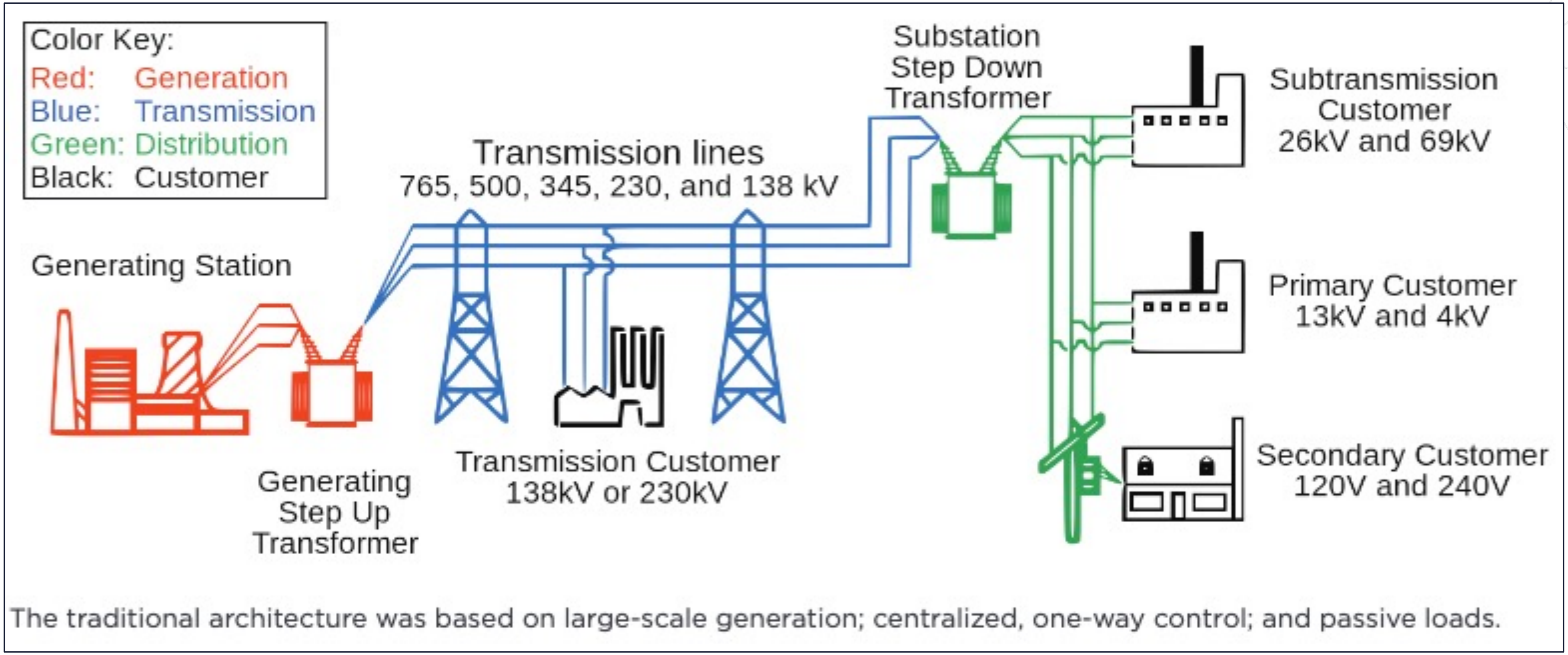
The Synchronization Experts.

The Electrical Power System

- ❑ Three categories: Power generation, Transmission and Distribution
- ❑ Highly complex



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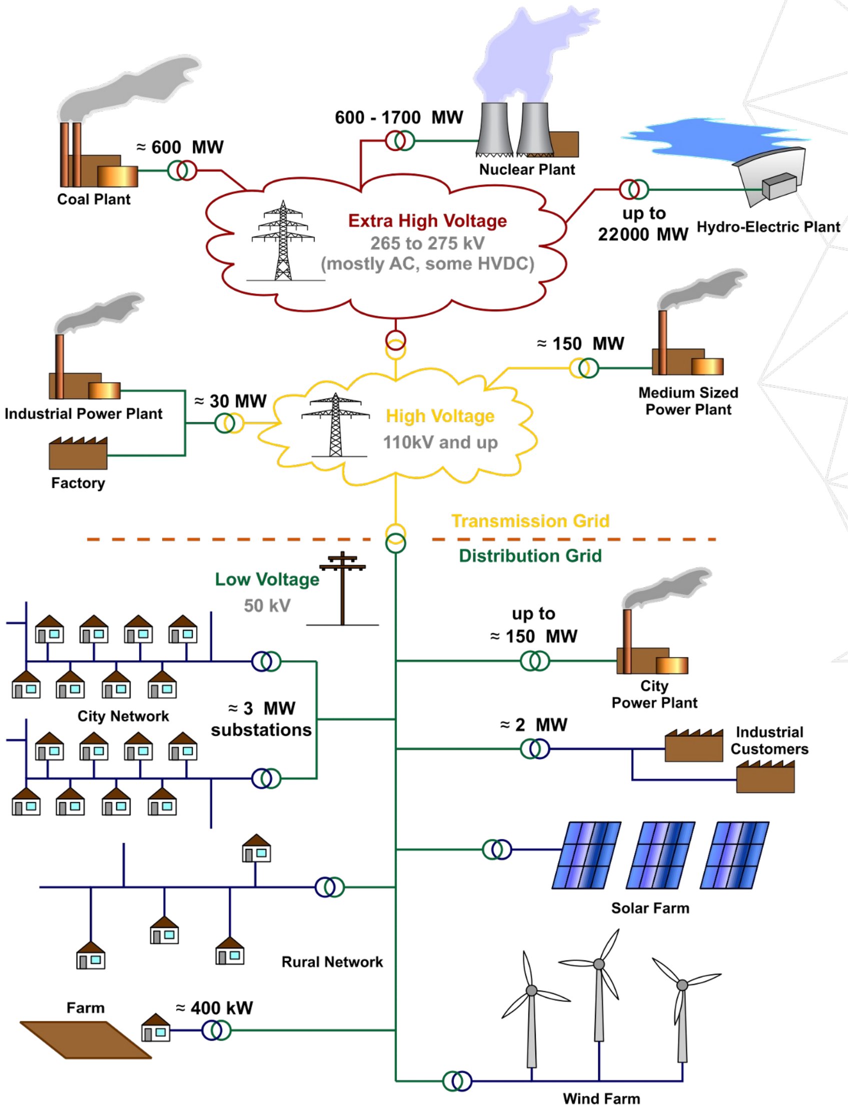
Source: US DoE 2015 Quadrennial Technology Review https://www.energy.gov/sites/prod/files/2017/03/f34/qtr-2015-chapter3.pdf

The Electrical Substation

- Most logic of the power grid is implemented in the **Substations**
- 3 Types of substations
  - Step-up substation
  - Step-down substation
  - Distribution substation



Use cases of time synchronization

Inside the substation

- Sequence of event recording
- Digital Fault recorders
- The Digital Substation
- Busbar protection

… and between substations

- PMU - phase measurement units (WAMPAC)
  - Grid monitoring and balancing
  - Falling conductor detection
- Traveling wave fault detection
- Powerline protection

Fault Recorders & Sequence of Events

- ❑ Sequence of event recording
- ❑ Timestamp and track events
- ❑ Provide system or area-wide Snapshot of Events / Faults to determine event timeline
- ❑ Used for post-mortem data analysis

→ Goal: **System improvement**

→ Timestamps needed for correct sequence of events

→ Without time correlation, the collected data is useless

The digital substation – IEC61850

- ❑ Analog wiring exchanged by packet based Ethernet bus system
- ❑ IEC 61850 is the comprehensive standard
- ❑ The logic moves from the bay level down to the process level to the IEDs and partially up to the SCADA
- ❑ Events must now be timestamped by IEDs for event recording
- ❑ To eliminate discrete wiring, data AND time must be on the same bus system

➔ IEC P1588 (PTP IEEE1588-2008)

➔ IEC 61850-9-3 (PTP IEEE1588-2008 profile)

Control Room A - Battersea Power Station | Photo: James Parsons

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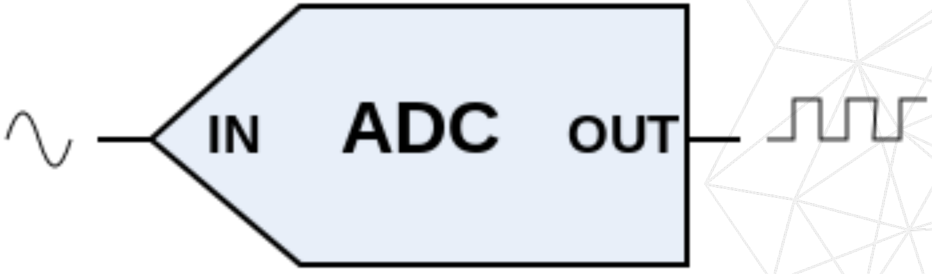
The digital substation – Merging units

- The merging unit is a specialized multichannel analog to digital converter for substation automation
- Critical component in the digital substation architecture
- Interface to analog sensors – CT’s and VT’s
- Digitizes signals and communicates it on the IEC61850 process bus
- Communicates via IEC61850-9-2 (sampled values)



Source: Wikipedia / common domain

➔Time sync needed to timestamp the measurements


Source: https://www.siemens.com/global/en/products/energy/energy-automation-and-smart-grid/protection-relays-and-control/siprotec-5/merging-unit.html

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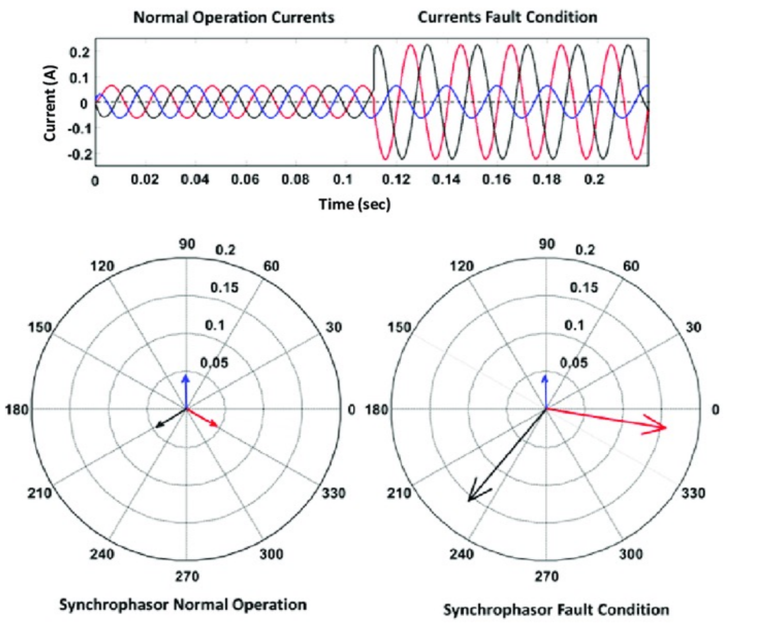
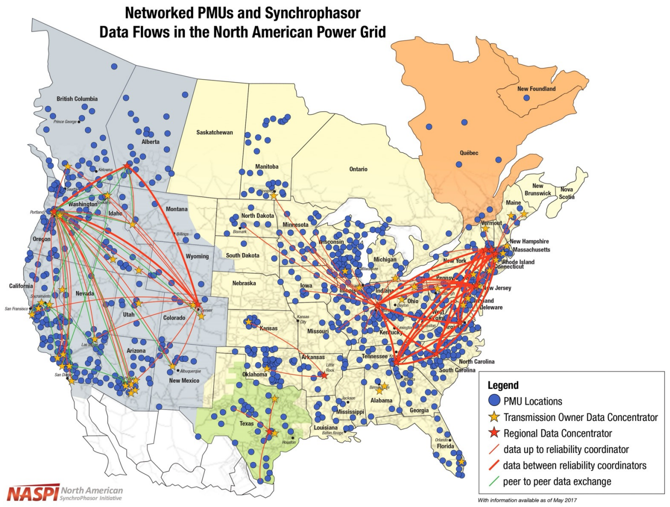
Phase measurement units - Synchrophasors

- Synchrophasor: Vector measurement (magnitude, angle, time)
- PMU = phasor measurement unit
- Series of high frequent timestamped measurements
- For correlation, synchronized time is key
- Synchrophasor measurements typically at 48 samples per second
- Scada systems used to measure all 4 to 6 seconds
  PMU’s measure in much higher frequencies



Heterogeneous Wireless Networks for Smart Grid Distribution Systems: Advantages and Limitations - Scientific Figure on ResearchGate. Available from: https://www.researchgate.net/figure/Current-waveforms-and-synchrophasor-measurements-during-normal-operation-and-a-fault_fig7_325114808 [accessed 9 Oct, 2022]

- NASPI = North American Synchrophasor Initiative
- Main goal:
  Situational awareness as basis for counteractions of balancing authorities



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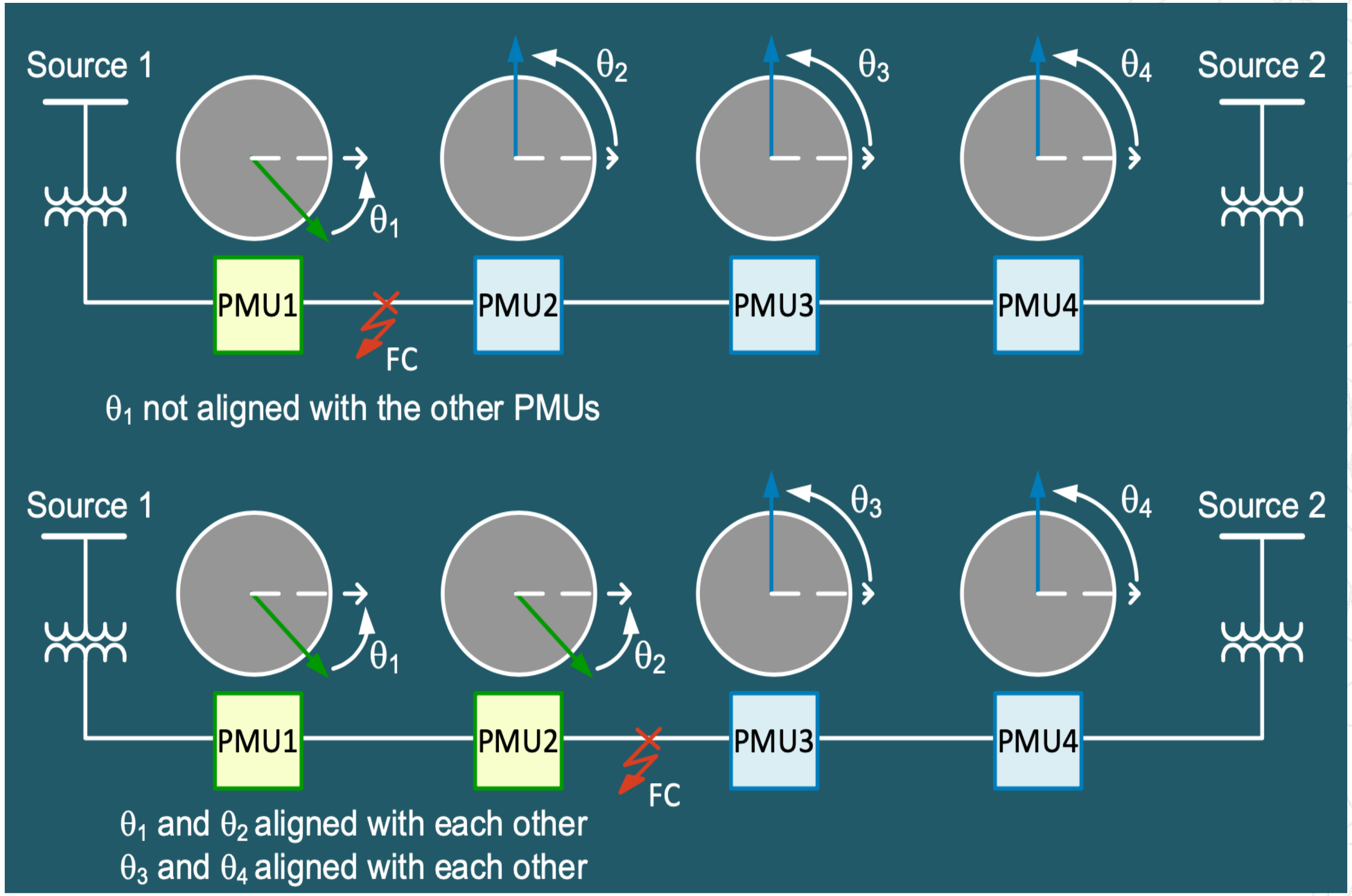
Wildfire Prevention - Falling Conductor Protection

- Newest application – patented by San Diego Power & Gas
- Wildfires sometimes started by means of the power grid
- One cause are breaking power lines
- "Falling Conductor" event can be measured by comparing synchrophasors
- Line can be tripped before it hits the ground

→ No sparks when hitting the ground

→ No wildfire



Eric Udren: Distributech 2022 – Utility University / UU307 The Business Case for IEC 61850 and Cybersecurity

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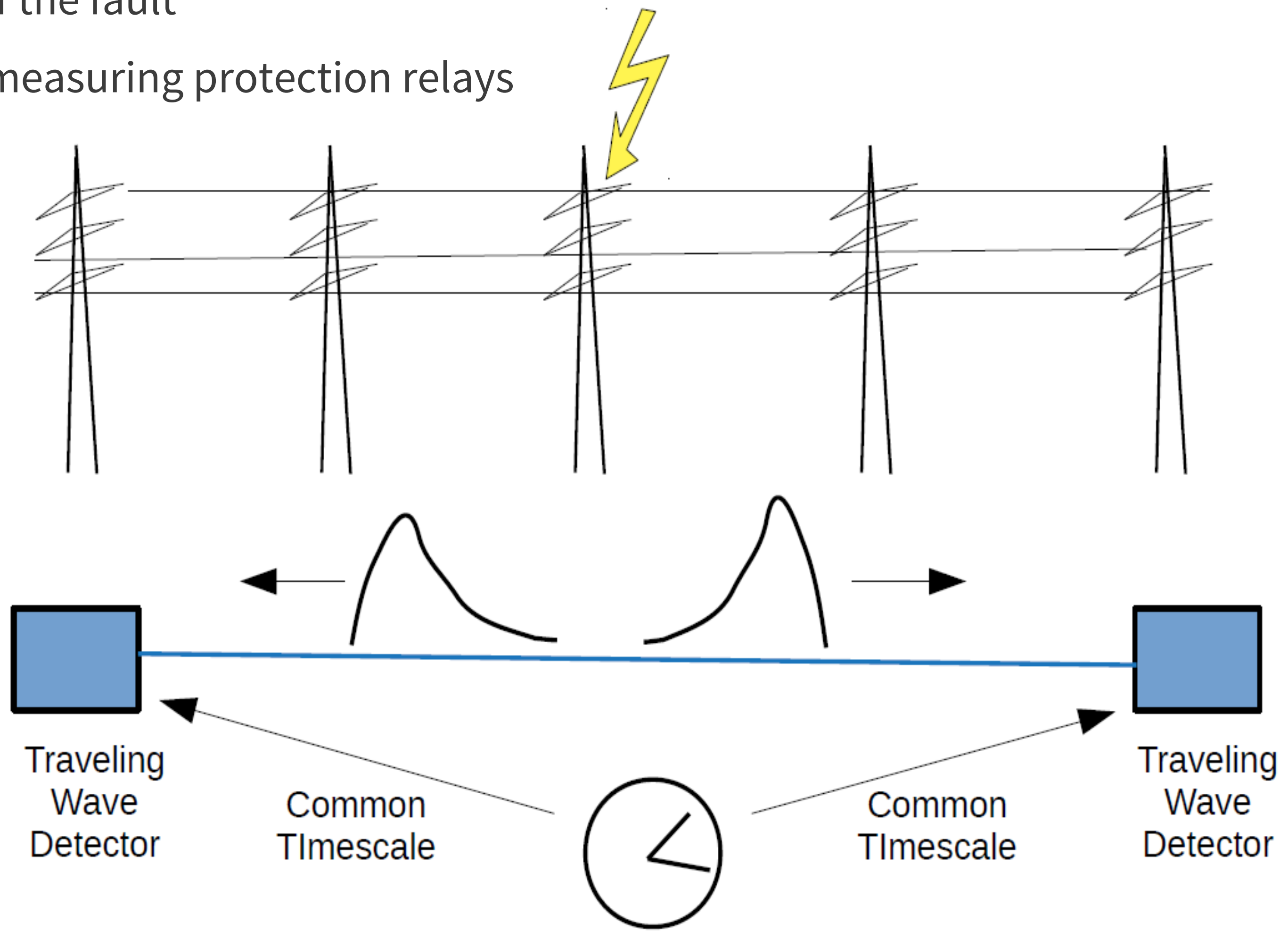
Fault Location – Traveling Fault Detection

- ❑ Locating faults on transmission lines
- ❑ Traveling wave is generated at the point of the fault
- ❑ Wave takes different time to travel to the measuring protection relays
- ❑ Coordination of 2 protection relays
- ➔ Repair crews can spend less time finding the damaged equipment
- ➔ Uptime of the transmission line improves
- ➔ **Time is money!**



Time synchronization technologies

- IRIG-B
  - Network delays need to be calibrated
  - Requires a dedicated timing network in addition to the data network
  - Delivers 1 usec synchronization accuracy reliably
- NTP – Network time protocol
  - Network delays are determined by the protocol
  - Over data network
  - Typical synchronization accuracy: 1 msec
- PTP – Precision time protocol
  - Next step in time synchronization over the data network
  - The network infrastructure components (e.G. network switches) participate in the time synchronization
  - Much more configuration options compared to NTP
  - Profiles define subsets of those options for specific use-cases
  - Delivers 1 usec synchronization accuracy and better reliably

Important Standards & Specs – IEC 61850 as umbrella

IEC 61850
Communication networks and systems for power utility automation

- specifies technology itself
- references to existing technology – from timing perspective, those are
  - **IRIG Standard 200-04**
    Inter-Range Instrumentation Group (IRIG)
  - **IEEE C37.118-2011 (former IEEE 1344-1995)**
    Standard for Synchrophasors for Power Systems
  - **IEC61850-5:2013 (SNTP)**
    Communication Requirements for Functions and Device Models
  - **IEEE1588-2008 – IEC 61588 (PTP – Precision Time Protocol V2)**
    Standard for Precision Clock Synchronization Protocol for Networked Measurement and Control Systems
  - **IEC 62439-3:2016**
    Industrial communication networks - High availability automation networks - Part 3: Parallel Redundancy Protocol (PRP) and High-availability Seamless Redundancy (HSR)
    - PRP – Parallel Redundancy Protocol
    - HSR – High-availability Seamless Redundancy

Applicable power profiles for IEC P1588 - PTP

- **IEEE C37.238-2011**
  Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications
- **IEEE C37.238-2017** (successor of IEEE C37.238.2011)
  Standard Profile for Use of IEEE 1588 Precision Time Protocol in Power System Applications
- **IEC/IEEE 61850-9-3:2016 (Power Utility Profile) or PUP**

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Synchronization accuracy requirements

Function	Purpose of timing	Accuracy required
Control Room	Log file coordination	1 second
SCADA system	Grid wide monitoring and control	1 ms
Synchrophasors	Measurements more precise than SCADA system. Monitor grid stability. Predict faults	1 μs
Travelling wave fault detection	Location of faults to within 100s of meters Improves maintenance efficiency	300 -1000 ns

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Thank you!

Meinberg USA Inc.
111 Santa Rosa Avenue Suite 401
Santa Rosa, CA 95404
USA

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werner.abt@meinberg-usa.com