Substation Engineering
Future of Substations (Part 1 of 3)

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- Course: Substation Engineering (DI04009011)
- Unit 6: Future Trends in Substation Engineering
- Focus: Digital Substations & Process Bus

Agenda

- What is a Digital Substation?
- Evolution from Conventional to Digital
- Non-Conventional Instrument Transformers (NCITs)
- Optical CTs and PTs
- The Merging Unit (MU)
- Station Bus vs. Process Bus
- Benefits of the Process Bus
- Summary

What is a Digital Substation?

- A substation where all data—from primary equipment to protection relays—is digitized.
- Replaces traditional copper signaling cables with fiber optic networks.
- Relies heavily on the IEC 61850 standard.
- Integrates primary process level equipment directly into the digital communication network.

Evolution of Substation Technology

Generation	Protection Type	Communication	Wiring
1st Gen	Electromechanical	Hardwired	Heavy Copper, 100% Analog
2nd Gen	Static/Numerical IEDs	Serial/Modbus	Copper from yard to control room
3rd Gen (SAS)	IEC 61850 IEDs	Ethernet (Station Bus)	Copper from yard, Fiber between relays
4th Gen (Digital)	Fully Digital	Ethernet (Process Bus)	100% Fiber Optic

Limitations of Conventional Transformers

- Traditional CTs and PTs use heavy iron cores and copper windings.
- Prone to magnetic saturation during high fault currents.
- Require thick copper cables to carry analog signals to the control room.
- Open-circuiting a conventional CT secondary is extremely dangerous (high voltage).

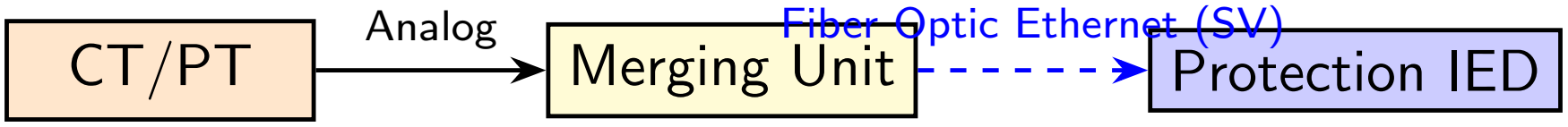
Non-Conventional Instrument Transformers (NCITs)

- Also known as Optical or Electronic Instrument Transformers.
- Use optical sensors instead of magnetic cores.
- Current measurement based on the Faraday Effect (rotation of polarized light).
- Voltage measurement based on the Pockels Effect.

Benefits of NCITs

- No Saturation: Highly accurate for both metering and protection.
- Safety: Output is an optical signal; no high voltage hazards from open secondaries.
- Lightweight: Dramatically smaller footprint and weight compared to oil-filled CTs.
- Eco-Friendly: No insulating oil required (reduces fire and leak risks).

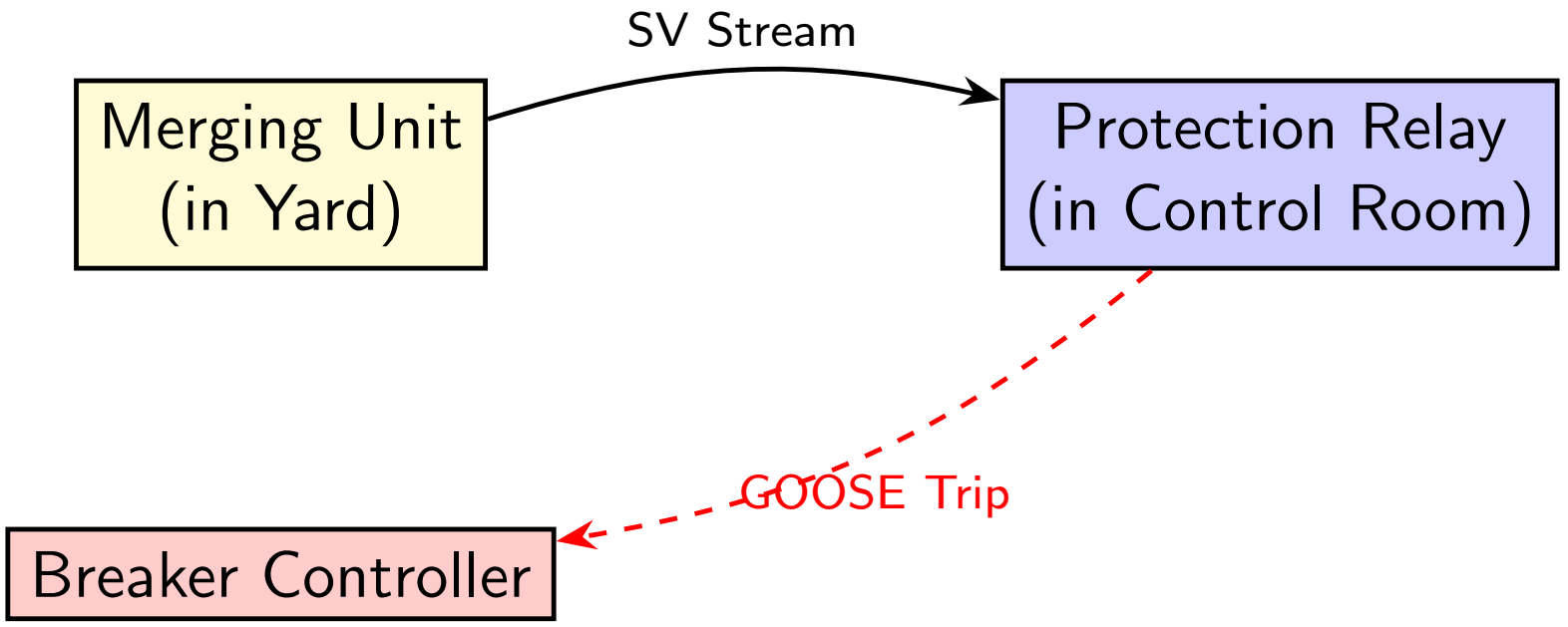
The Merging Unit (MU)



Station Bus vs. Process Bus

Feature	**Station Bus (IEC 61850-8-1)**	**Process Bus (IEC 61850-9-2)**
Location	Control Room	Switchyard to Control Room
Data Types	MMS (Reporting), GOOSE (Tripping)	Sampled Values (SV), GOOSE
Purpose	IED to IED, IED to HMI/SCADA	Primary Equipment to IEDs
Wiring Replaced	Inter-panel wiring	Long yard-to-panel wiring

Process Bus Architecture



Sampled Values (IEC 61850-9-2 LE)

- Continuous stream of digital data representing the AC waveform.
- 'LE' stands for Light Edition (an early implementation guideline).
- Sampling Rate: Typically 80 samples per cycle for protection, 256 for power quality.
- Requires highly precise time synchronization (PTP - Precision Time Protocol).

Advantages of the Process Bus

- Dramatic Copper Reduction: Up to 80% reduction in cabling costs.
- Increased Safety: Complete galvanic isolation; no electrical connection between yard and control room.
- Late Binding: Physical wiring doesn't dictate function. IEDs can subscribe to any MU on the network.
- Easier Expansion: Adding a new bay simply requires plugging an MU into the network switch.

Challenges of Digital Substations

- Network Reliability: The Ethernet network is now mission-critical. Switch failure means lost protection.
- Cybersecurity: Expanding the network into the yard increases attack surfaces.
- Skill Gap: Requires engineers skilled in IT networking, not just power systems.
- Time Synchronization: Loss of GPS/PTP can disrupt Sampled Values processing.

Summary

- Digital substations replace copper wiring with fiber optics and Ethernet networks.
- NCITs use optical properties to measure current and voltage safely and accurately.
- Merging Units digitize analog signals into IEC 61850 Sampled Values.
- Process Bus networks transmit these Sampled Values from the yard to control room IEDs.

Next Lecture Preview

- How do renewable energy sources affect substations?
- Integrating Solar and Wind farms.
- The rise of Microgrids.
- Energy Storage Systems (BESS) at the substation level.