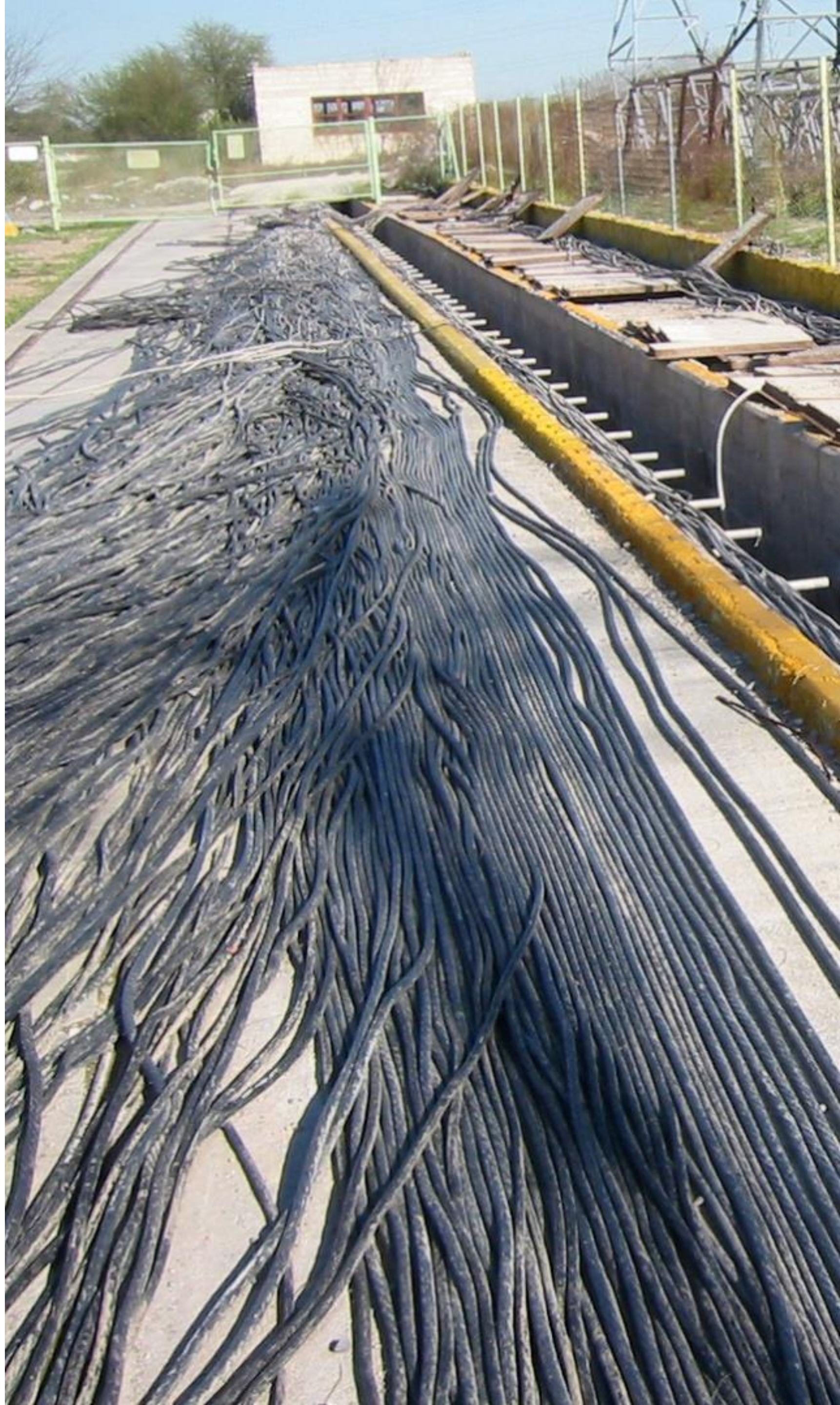
Applying Digital Secondary Systems to Optimize Power System Reliability

John Bettler
Commonwealth Edison

**David Dolezilek, David Bowen,
Shawn Westervelt, and Josh LaBlanc**
Schweitzer Engineering Laboratories, Inc.

MUs digitize primary equipment connections

- Field measurements converted to digital signals and vice versa
  - Status, alarms, and positions
  - Sampled temperatures, levels, currents, and voltages
  - Analog and digital outputs
- Mirrored Bits communications, RTD, IEC 61850 GOOSE and SV, IEC 61158, and purpose-built protocols



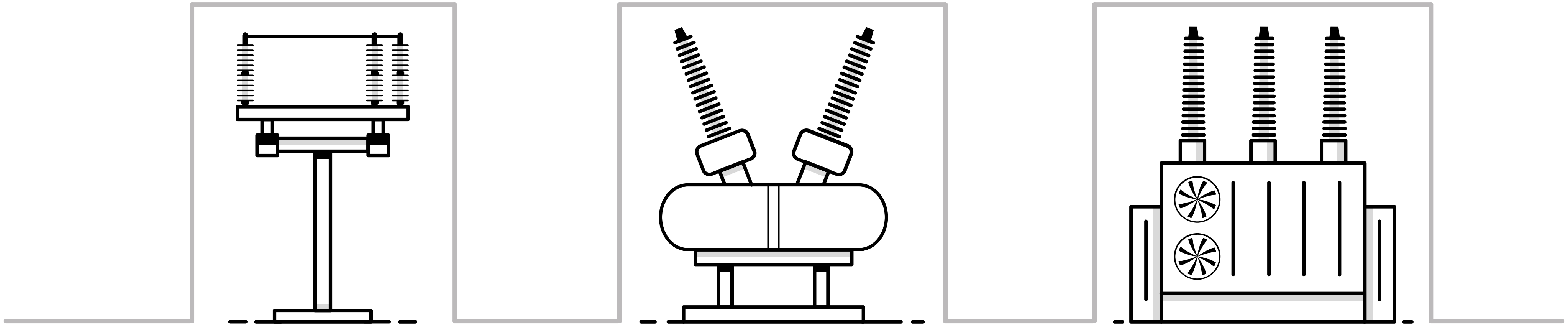
IEEE Std 1427-2020

Recommended electrical clearances in air-insulated electrical power substations

Creepage is distance between two conductors in yard or along surface of insulating material

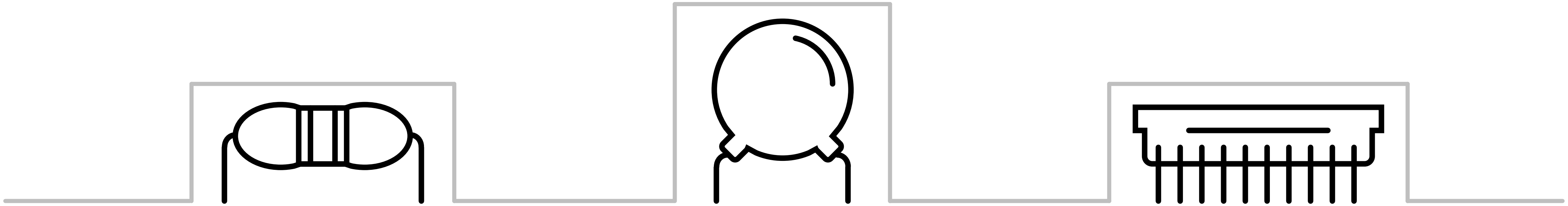
Clearance is line-of-sight distance between two conductors through air

NEC 110.26 provides clearance distances for test and maintenance

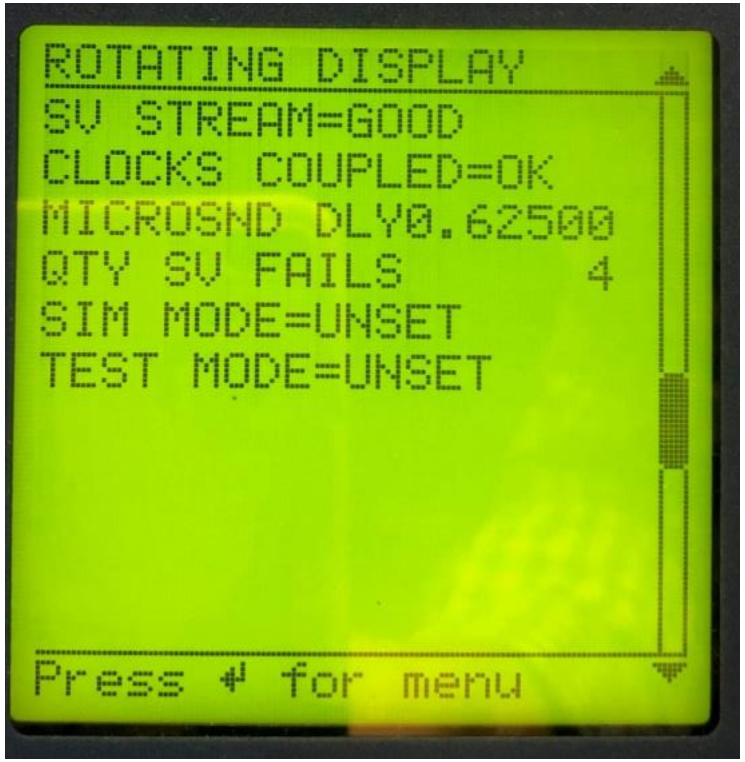


MU miniaturization is possible, but is it necessary or recommended?

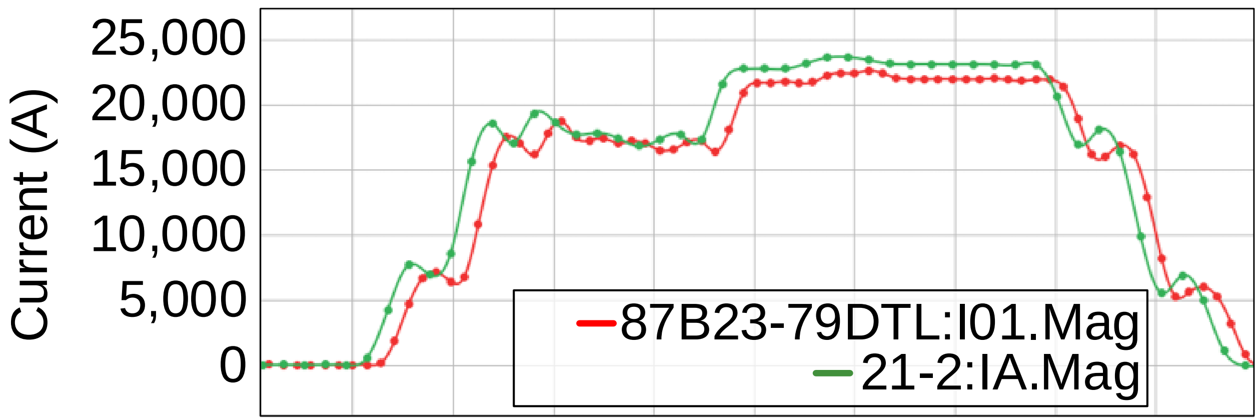
- Creepage is distance between two conductors **on surface of board** or along surface of insulating material
- Clearance is line-of-sight distance between two conductors through air
- Manufacturing and testing work simpler and faster with clearances for components
- Devices are intrinsically more resilient because spacing creates safety

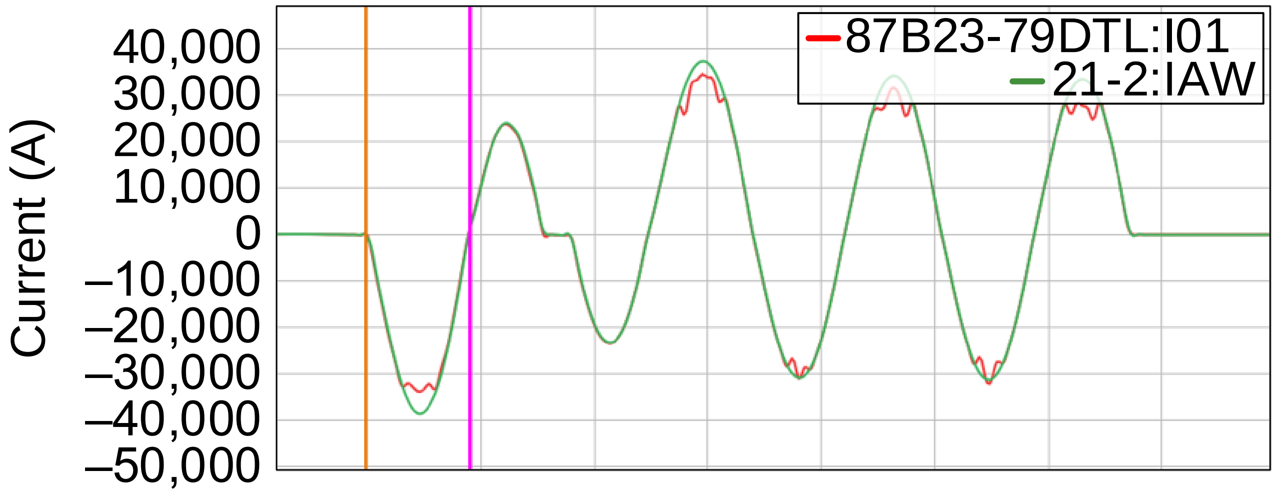


Fully featured IMU front panel allows technician to control and troubleshoot

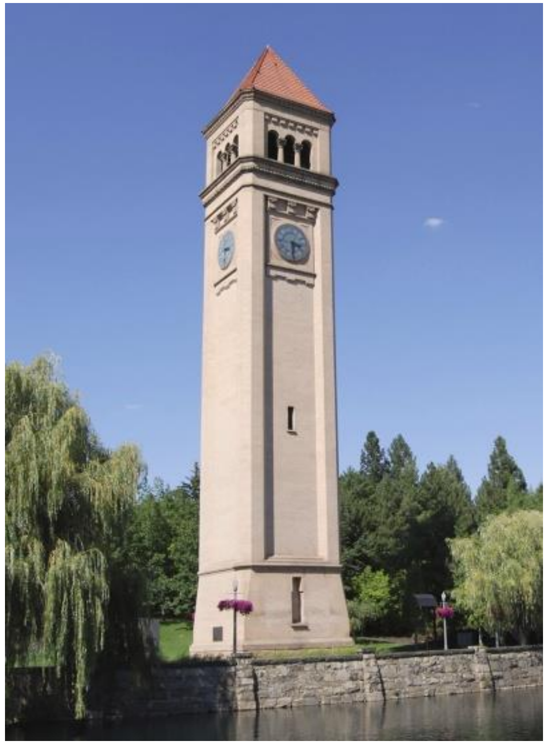


Intelligent device near primary equipment is troubleshooting aid





Power system impacts



Availability

Complexity

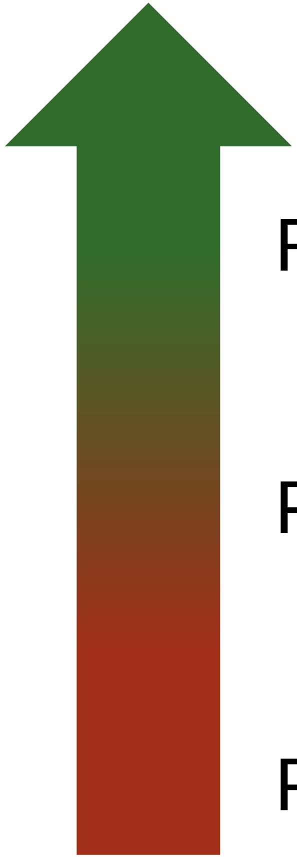
Speed

Resolution

Understand impact of adding fiber from yard

- Even engineered networks reduce data flow availability
- Data flow monitoring reduces risk of undetected failure
- Data flow monitoring improves availability and prompts corrective action
- P2P architecture provides improved performance over network

Availability changes with architecture



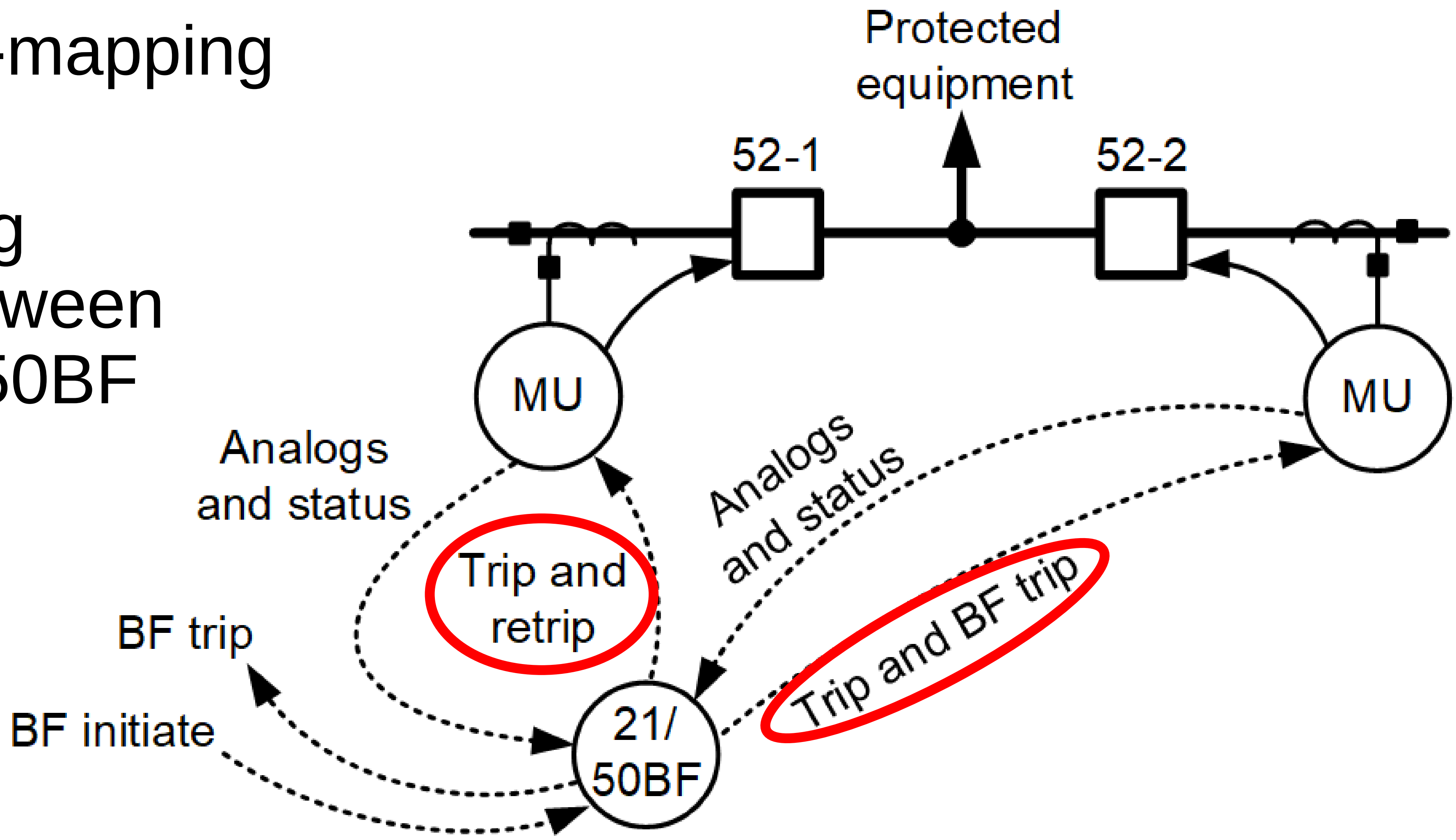
Relay in the yard

Purpose-built point-to-point protocol

Packetized IEC protocols

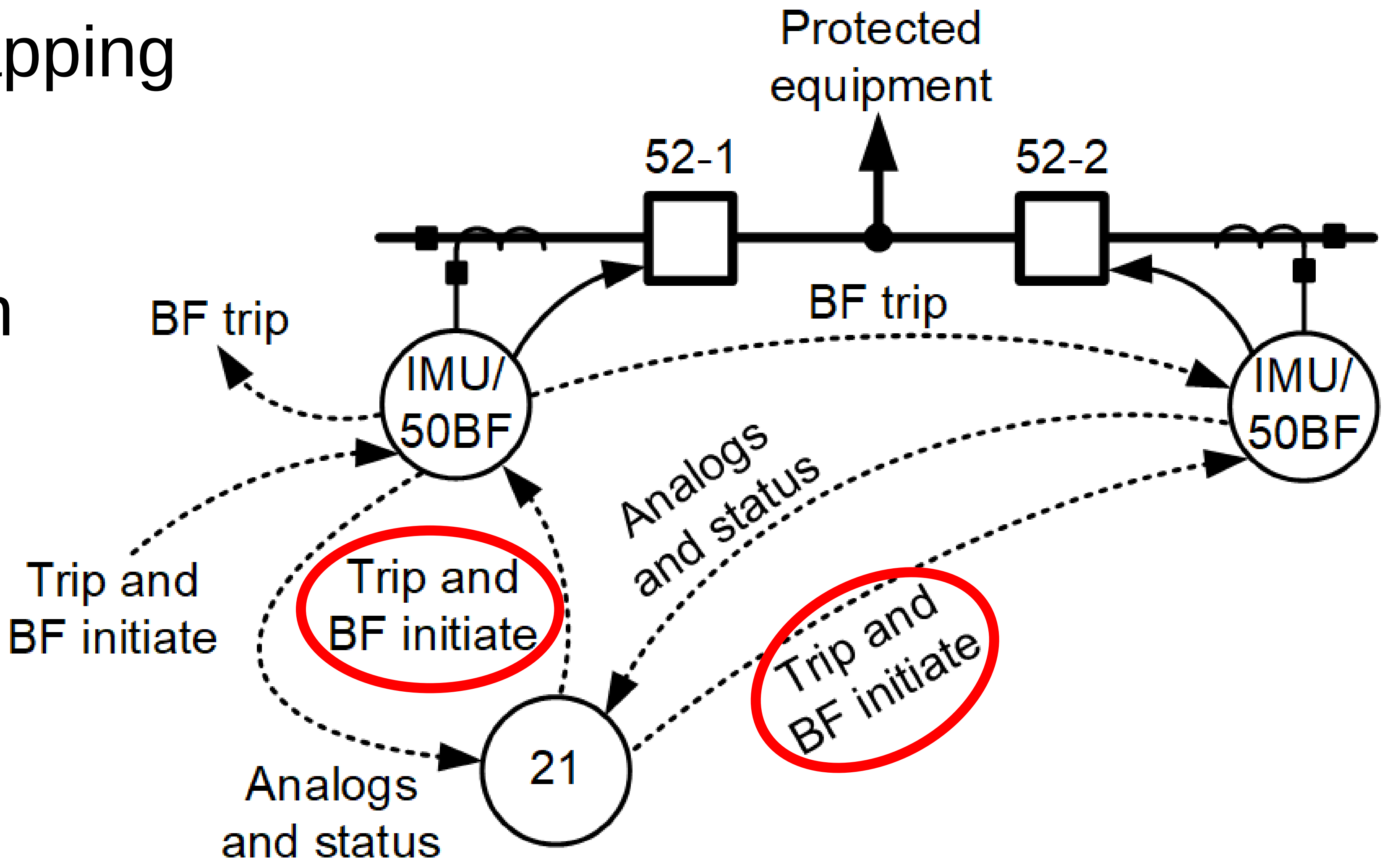
Complexity – simple MU example

- Highest point-mapping requirements
- Point-mapping difference between MUs and 21/50BF



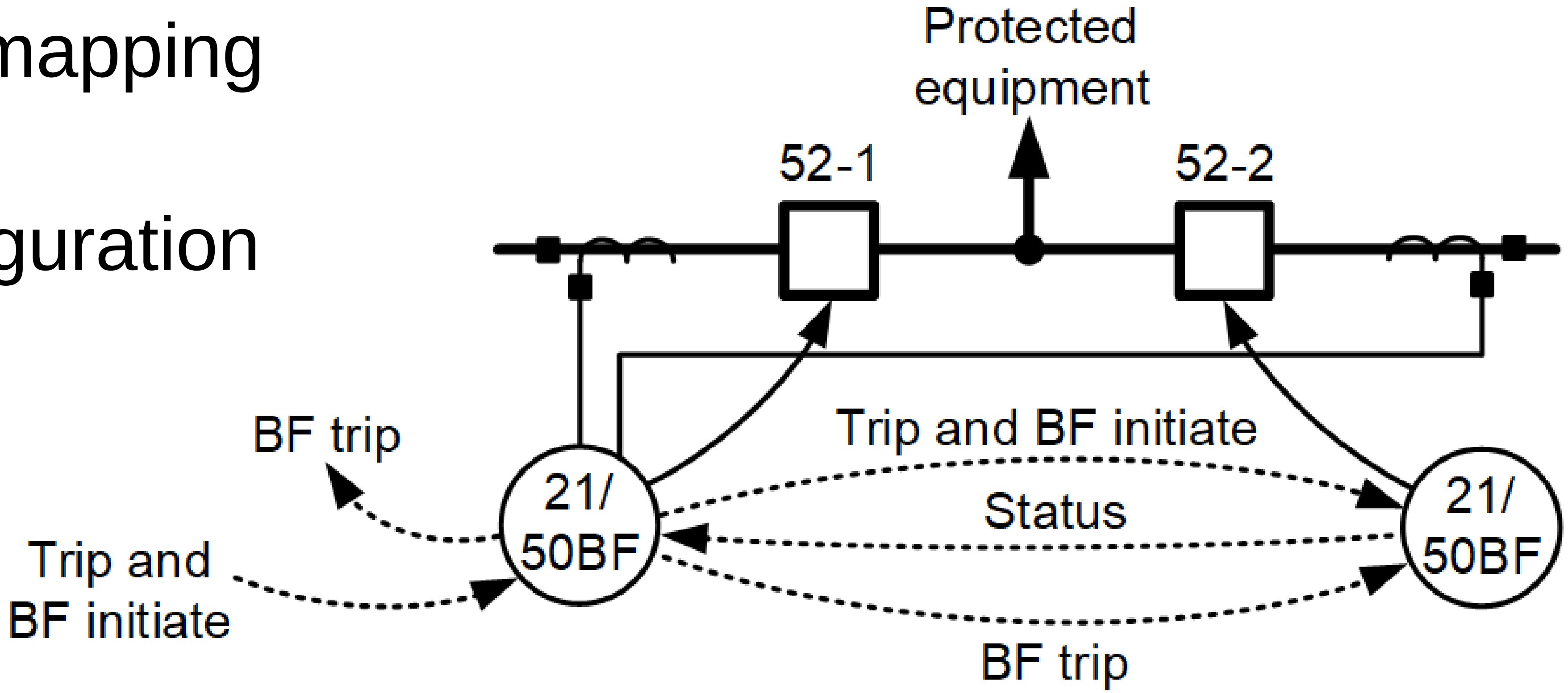
Complexity – IMU example

- Highest point-mapping requirements
- Point mapping identical between identical devices



Complexity – relay-in-the-yard example

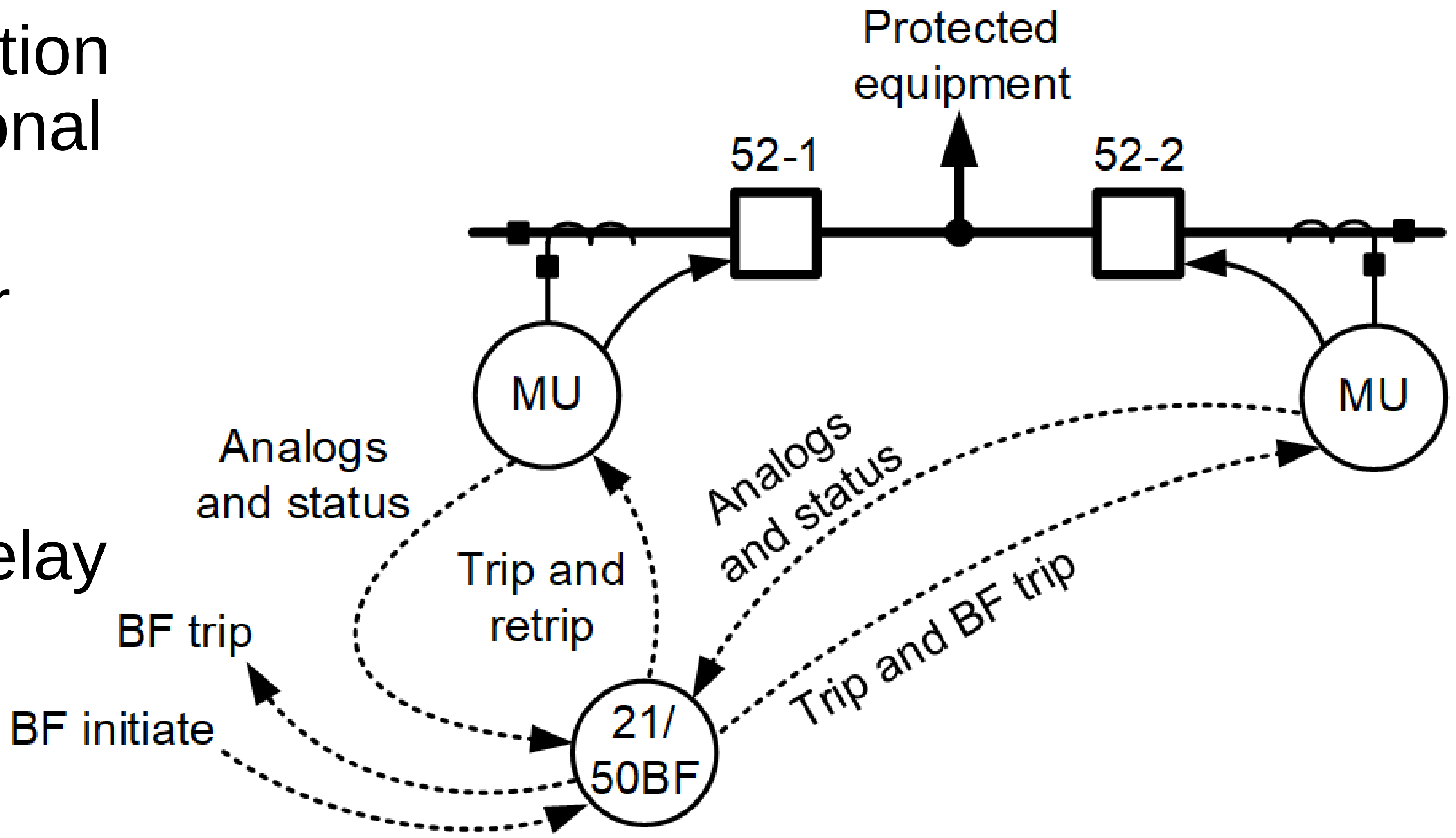
- Lowest point-mapping requirement
- Identical configuration across bays



Speed – SV system example

Networked solution will have additional delays

- SV subscriber buffer delay
- GOOSE operational delay

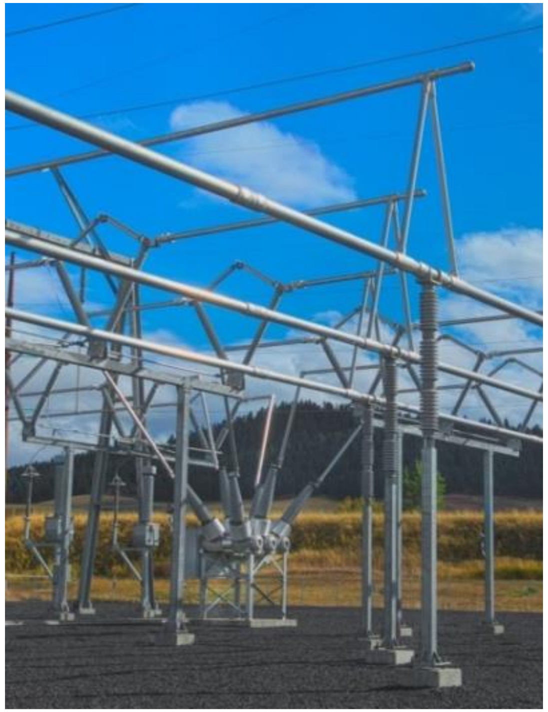


Modern power systems require high resolution

Accurate fault location

Protection with heavy IBR penetration

Better power system stability



Improved power quality

Resolution requires bandwidth

Example

- Networked protection solutions require determinism
- Packet must be received within publication interval
- Message size is small, but publication rate is high

$$BW = \frac{F_S \bullet S_{rate}}{ASDU}$$

where:

F_S = frame size

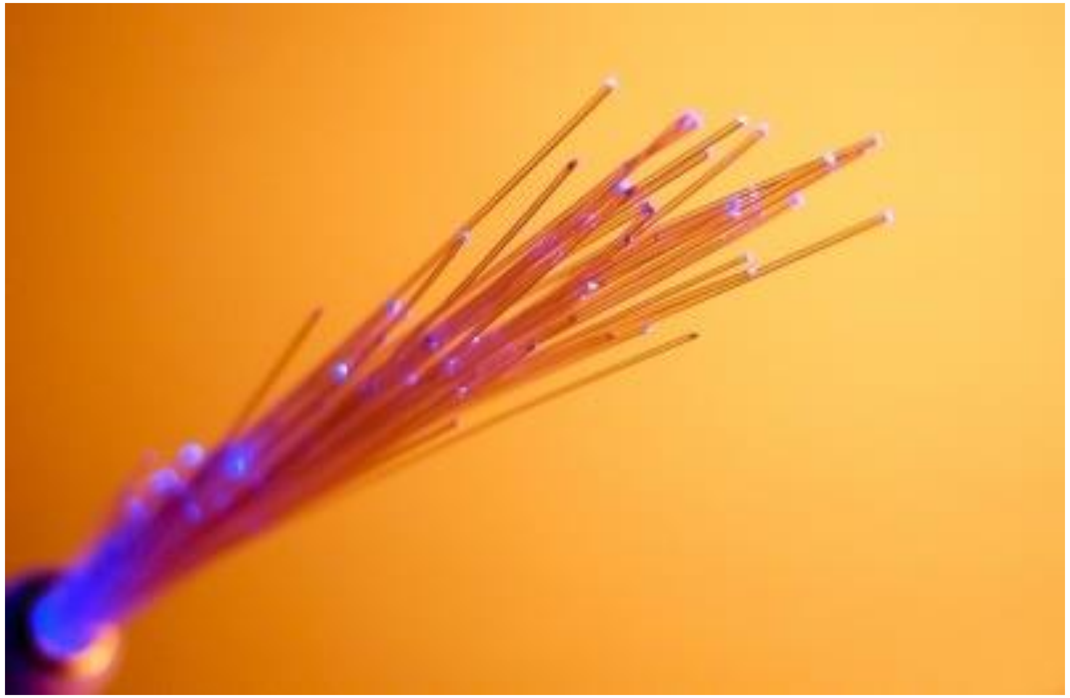
S_{rate} = analog quantity sampling rate

ASDU = analog quantity samples per frame

Bandwidth and TWs

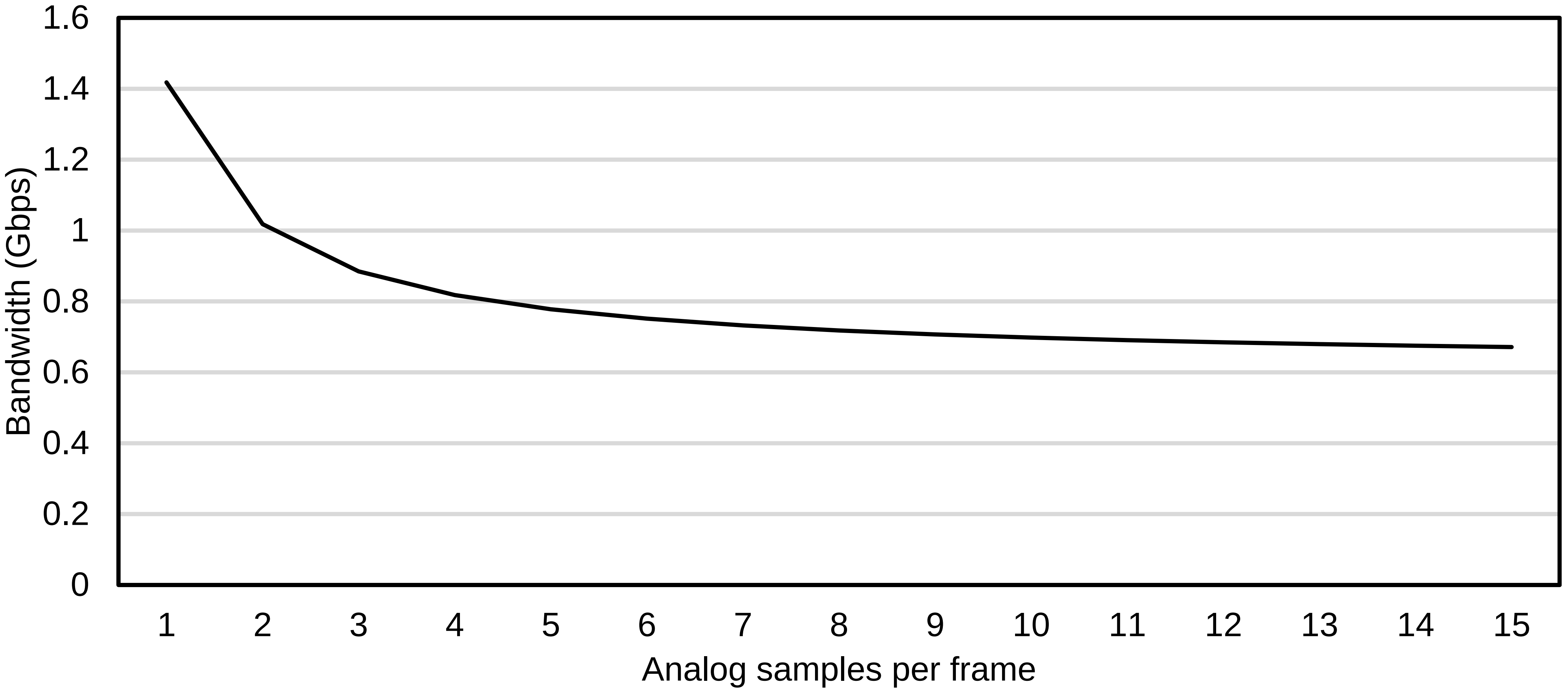
Example

- Sampled values maximum frame size (1,624 bits)
- Sampling or publication rate (1 MHz)
- Single sample per frame



Single stream requires 1.63 Gbps

Bandwidth savings decrease as more samples are added to a frame



High-resolution solutions

Install relay in the yard

- TW functions are applied like conventional control house installation
- Nonpacketized, direct links reduce bandwidth requirements

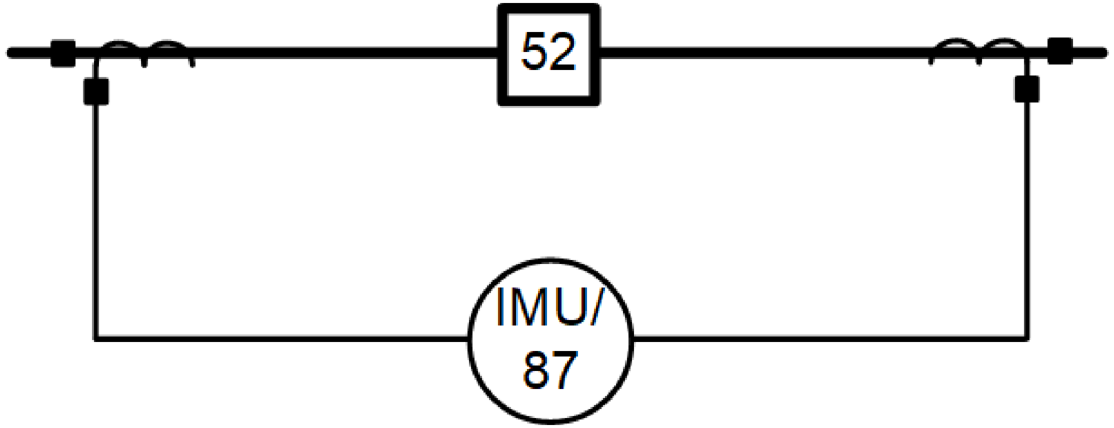
Install MU with intelligence

- TW functions could be hosted in IMU
- IMU supports future innovations

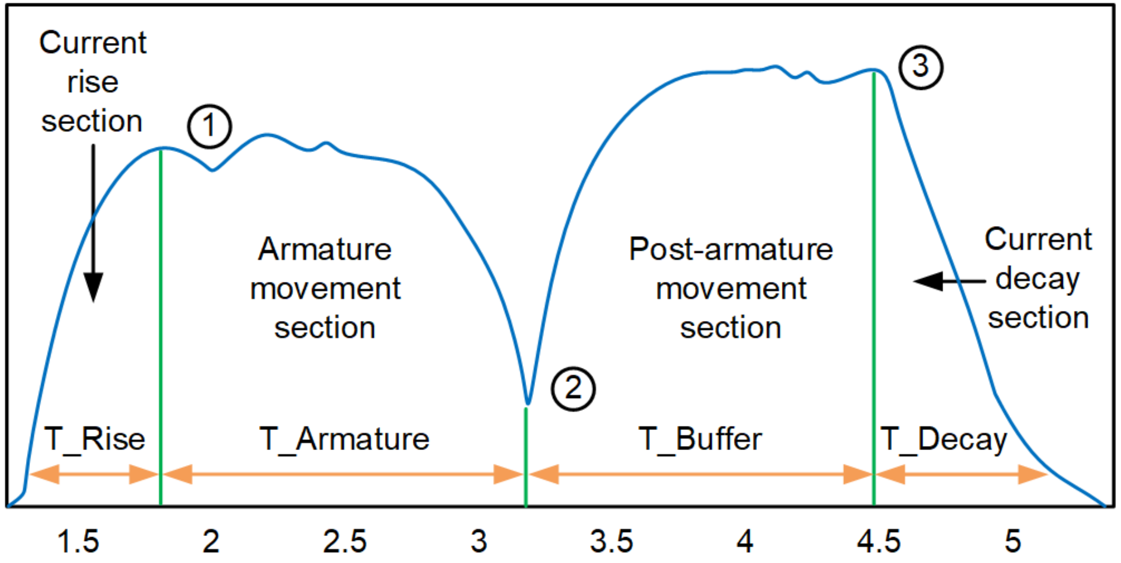
Future power system developments

Yard intelligence leads to future development

Breaker differential



Breaker TC current signature



Conclusion

Yard intelligence

- Aids system event analysis
- Is more likely to uncover root cause with maintenance troubleshooting
- Supports advanced functions
- Encourages future advancements

Yard-hosted protection

- Increases system availability
- Reduces complexity
- Speeds up fault isolation

Questions?