Making Complex Protection and Control Systems Easy to Maintain

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What Does This Mean?

Using a technology solution to address business needs

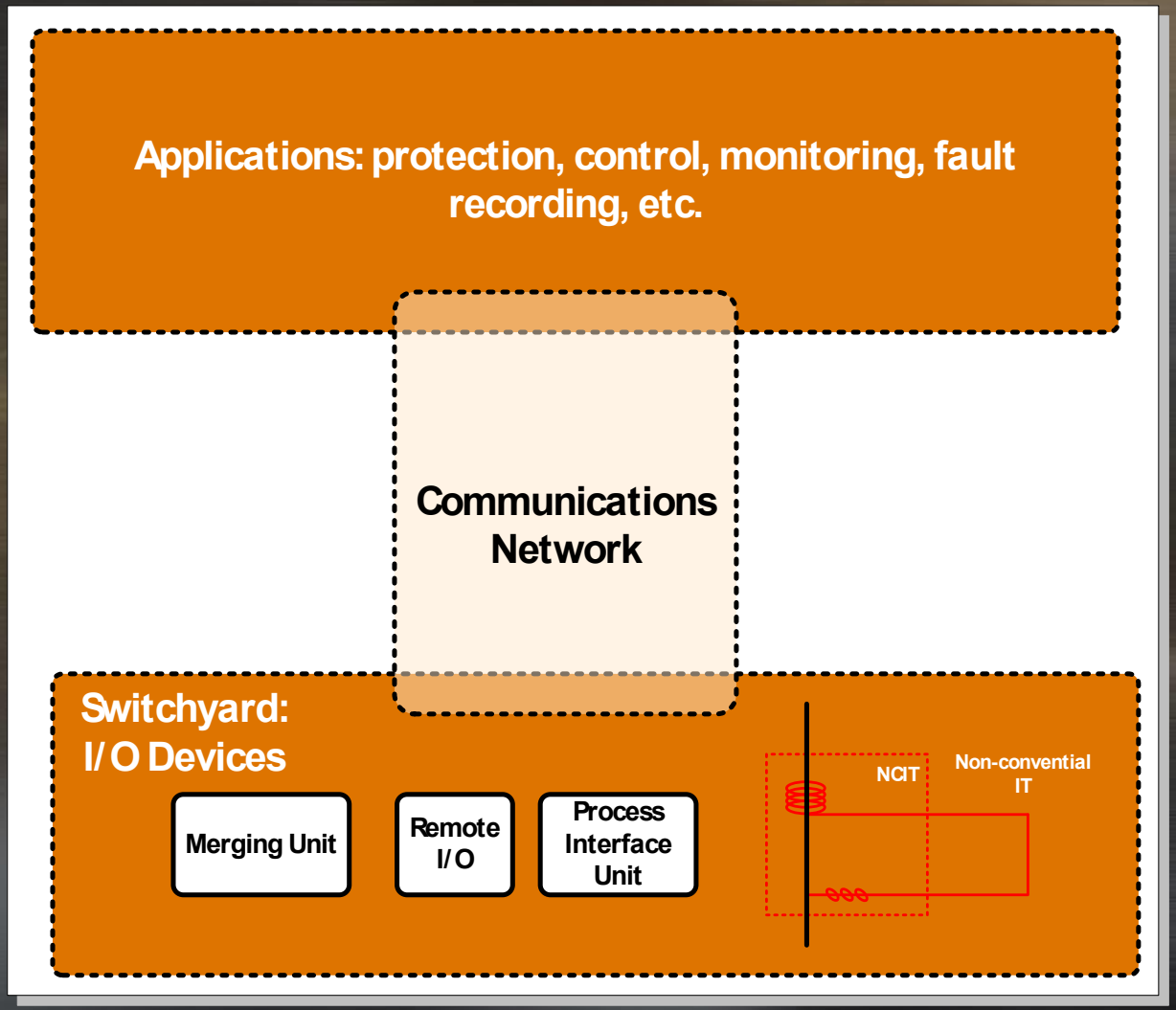
Business need

- Cost and effort to maintain protection and control systems

Technology solution

- Process bus

Process Bus


Applications: protection, control, monitoring, fault recording, etc.
Communications Network
Switchyard: I/O Devices
Merging Unit
Remote I/O
Process Interface Unit
NCIT
Non-convential IT

Process Bus Discussions To Date

Business case

- Project cost advantages unclear
- Less skilled resources is a strong case for adoption

Technical Issues

- Practical considerations for installation
- Network performance / concerns
- How to test
- Reducing the need for testing

Reliability

- Availability will be the same as conventional

The Big Questions

Long term system reliability	Long term costs
• More parts make up a system • Will process bus be as reliable	• More parts make up a system • What is the cost to maintain, with more possible device failures

To Answer These Questions:

Process bus is a possible solution

If the end result is that

PDT (Process Down Time) ---> 0

Which only works if

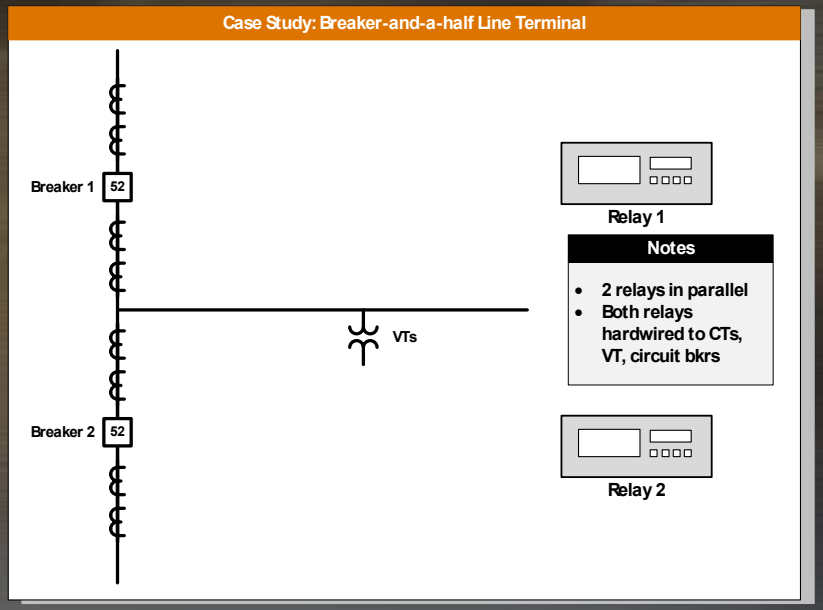
MTTR (Mean Time to Repair or Replace) ---> 0

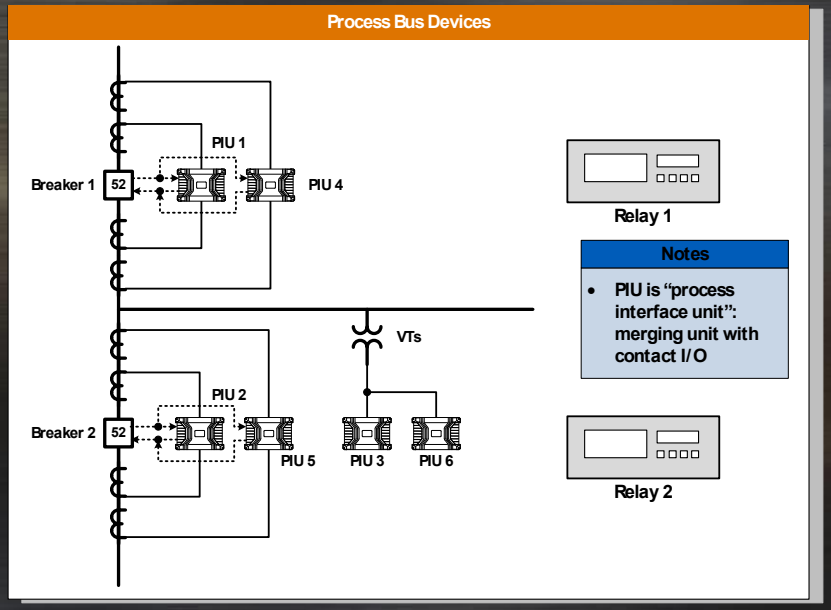
Devices can be quickly swapped out

Reliability Analysis

Case Study

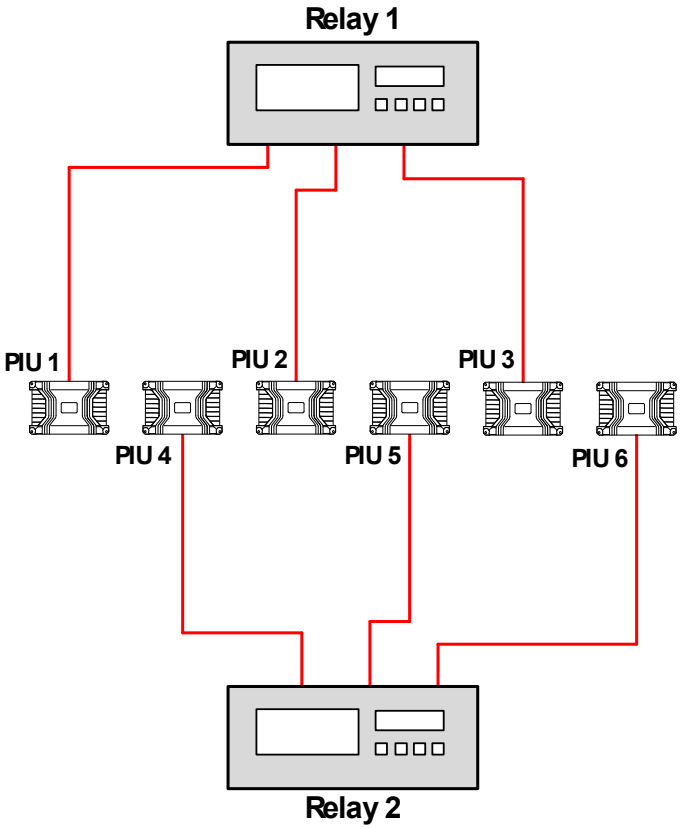
Breaker-and-a-half line terminal with process bus



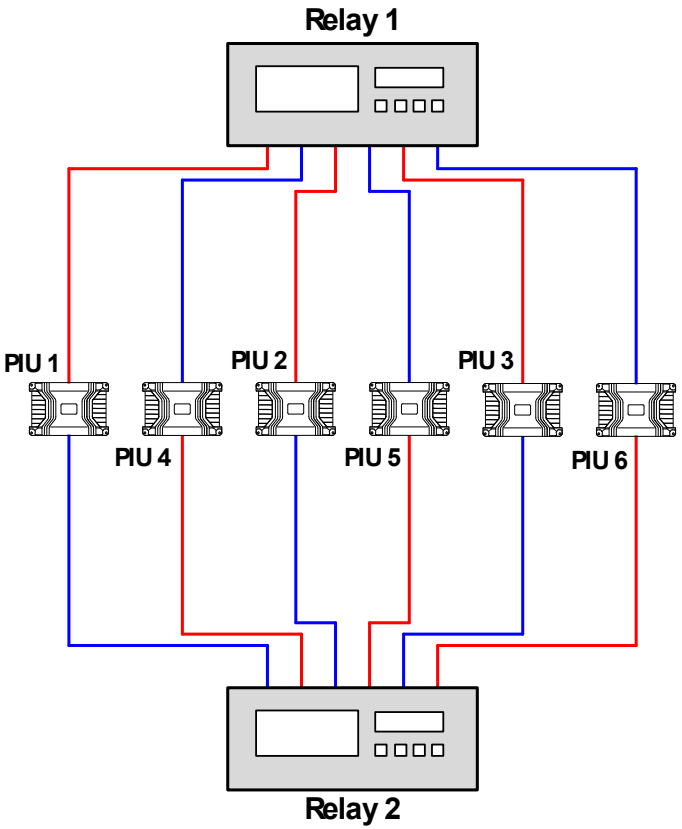


Architectures

Architecture 1: Independent Point-to-Point Process Bus



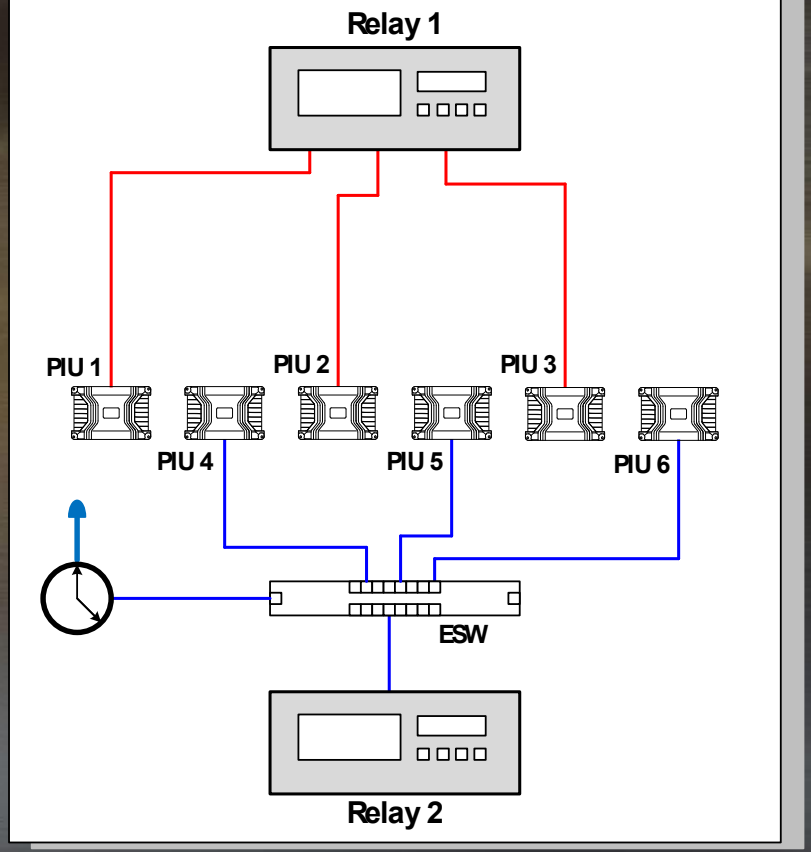
Architecture 2: Interoperable Point-to-Point Process Bus



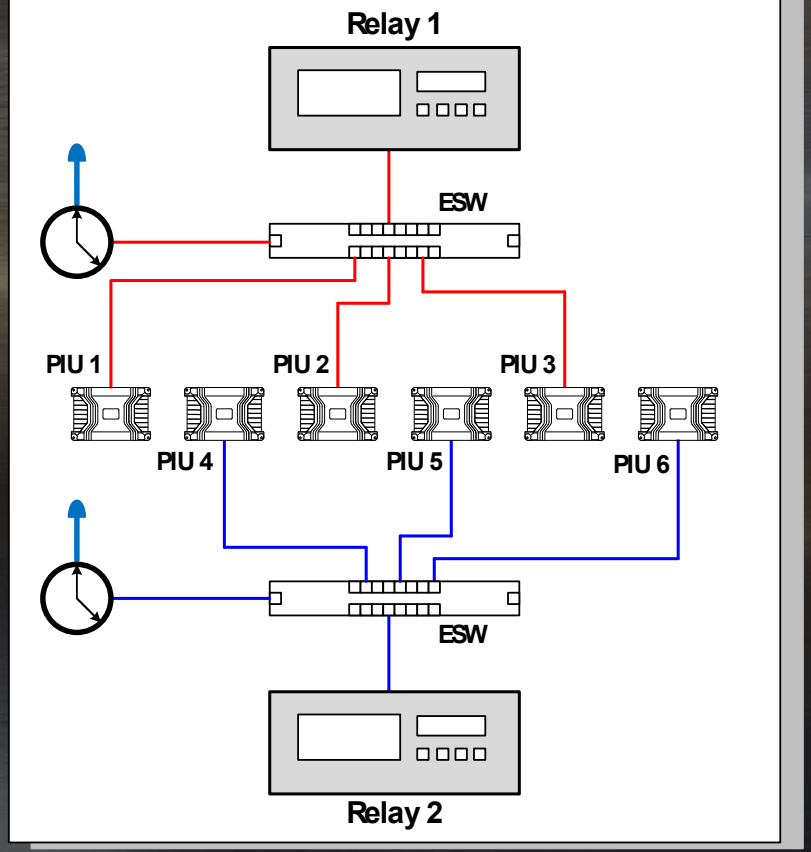
Architectures

- continued

Architecture 3: Point-to-Point / Network Process Bus



Architecture 4: Independent Network Process Bus



Architectures

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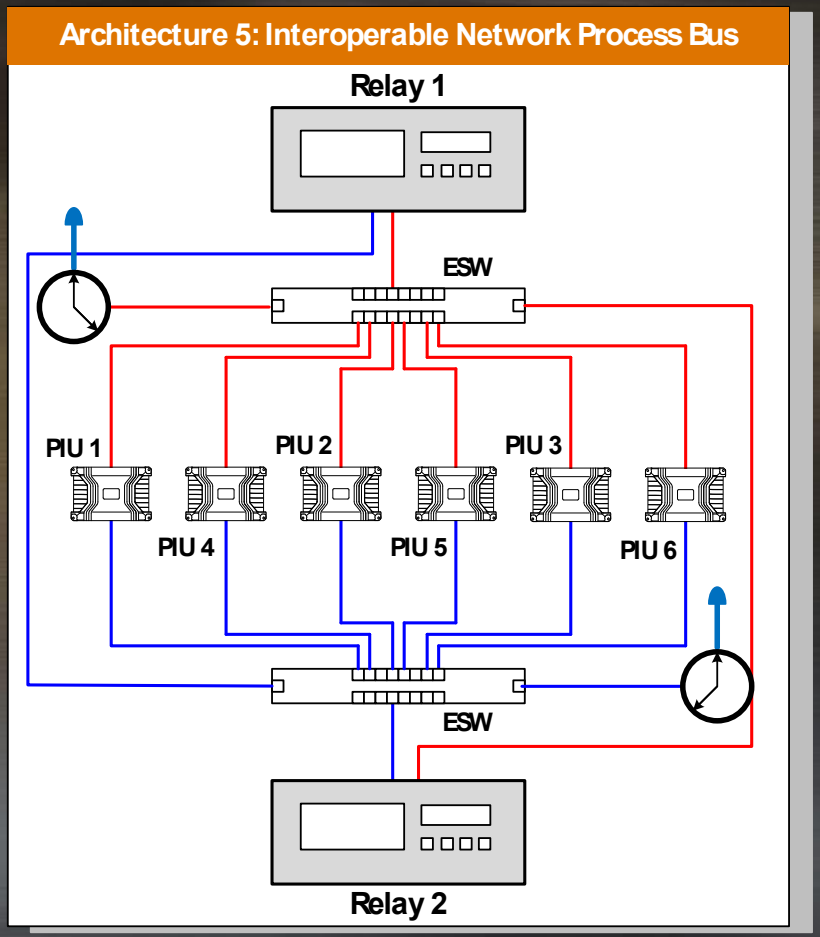
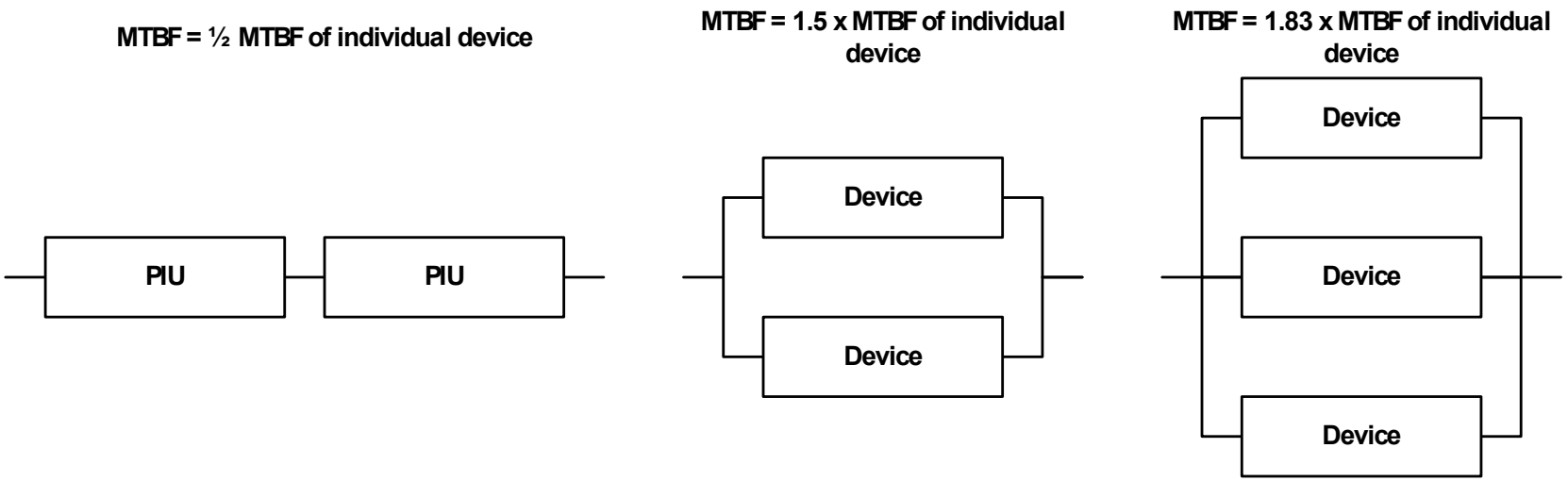


- All architectures are legitimate
- All have advantages / disadvantages in terms of cost, performance, reliability, usability
- Fault tree analysis shows any of these architectures will be as available as conventional protection

Reliability Analysis

Reliability is defined by $R(t) = e^{-\lambda t}$ where $\lambda = \frac{1}{MTTF}$

Reliability in concept (identical devices)



System Reliability Analysis

Actual device data

	General		At 1 year		At 10 years		At 20 years		At 30 years	
	Availability	MTBF	Reliability	Prob of Failure	Reliability	Prob of Failure	Reliability	Prob of Failure	Reliability	Prob of Failure
Conv.	1.00000	300	0.99998	0.0%	0.99762	0.2%	0.99094	0.9%	0.98060	1.9%
Option 1	1.00000	47	0.99903	0.1%	0.92659	7.3%	0.78053	21.9%	0.62486	37.5%
Option 2	1.00000	47	0.99974	0.0%	0.97646	2.4%	0.91522	8.5%	0.82995	17.0%
Option 3	1.00000	33	0.99586	0.4%	0.79411	20.6%	0.55853	44.1%	0.39599	60.4%
Option 4	1.00000	11	0.98232	1.8%	0.42253	57.7%	0.11196	88.8%	0.02749	97.3%
Option 5	1.00000	11	0.99183	0.8%	0.60797	39.2%	0.24339	75.7%	0.08357	91.6%

- Ethernet switches, clocks, clock antennas are the weak links

System Reliability Analysis

Ideal device data

	General		At 1 year		At 10 years		At 20 years		At 30 years	
	Availability	MTBF	Reliability	Prob of Failure	Reliability	Prob of Failure	Reliability	Prob of Failure	Reliability	Prob of Failure
Conv.	1.00000	300	0.99998	0.0%	0.99762	0.2%	0.99094	0.9%	0.98060	1.9%
Option 1	1.00000	69	0.99954	0.0%	0.96226	3.8%	0.87695	12.3%	0.77256	22.7%
Option 2	1.00000	69	0.99988	0.0%	0.98899	1.1%	0.95873	4.1%	0.91349	8.7%
Option 3	1.00000	59	0.99933	0.1%	0.94680	5.3%	0.83418	16.6%	0.70570	29.4%
Option 4	1.00000	47	0.99901	0.1%	0.92501	7.5%	0.77655	22.3%	0.61918	38.1%
Option 5	1.00000	47	0.99983	0.0%	0.98391	1.6%	0.94010	6.0%	0.87573	12.4%

- Assumes all devices have an identical MTBF of 200 years.

Comments on Reliability Analysis

Simplistic modeling

- Assumes failed devices aren't replaced
- Assumes replacement devices have same reliability, are same age as failed devices

In practice, reliability will be better than this

Obvious conclusions:

- Point-to-point is better than LAN (fewer devices in critical path)
- Redundant point-to-point is better (parallel paths)

Practical Considerations For Reliability

System Design

- Point-to-point: MTBF of 50 years, 95% reliability over 20 years
- Can we make LAN match this?
- Switches and clocks are the weak link
- Triple redundant networks, triple redundant clocks don't really improve MTBF, reliability
  - Clock ---> 11 years for 1, 17 years for 2, 20 years for 3
  - Not a practical solution anyway

Practical Considerations For Reliability

Device Design

- Make devices better
- To have a system MTBF of 50 years on LAN

$$MTBF = 50 = \frac{MTBF \ \ per\ device}{6\ devices}$$

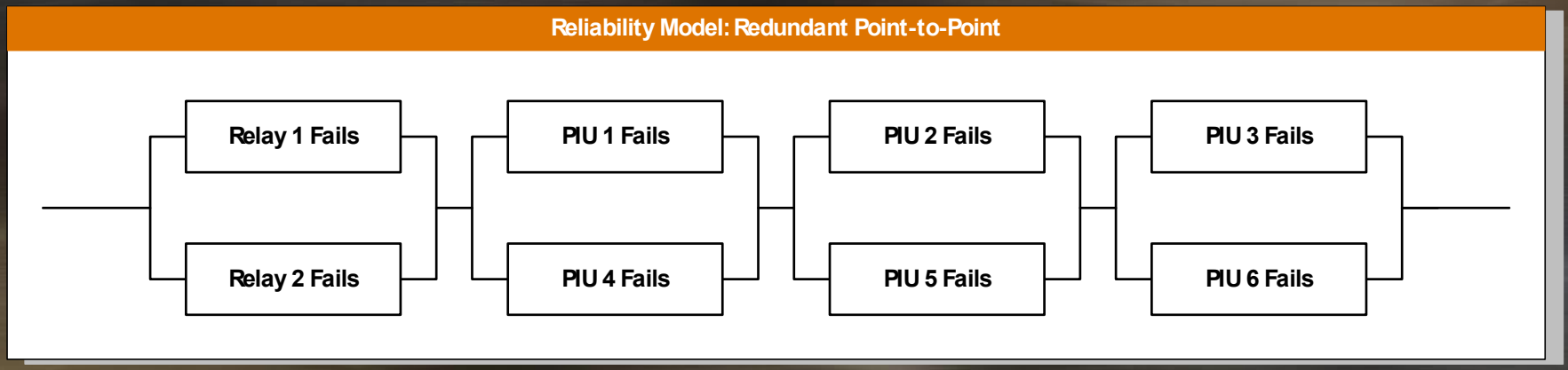
- Individual devices must have MTBF of 200 years
  - Relays there, possible for PIUs
  - Difficult for clocks (antennas, oscillators, transceivers)
  - Not really possible for switches (transceivers, power supplies). Already really optimized

Practical Considerations For Reliability

Make Repair Better

- Focus on MDT (Mean Down Time) or PDT (Process Down Time)
- PDT is total time down for problem diagnosis, device repair / replacement, testing
- Must focus on PDT for process bus
- Process bus PDT can (and should, and must) be lower than conventional PDT!

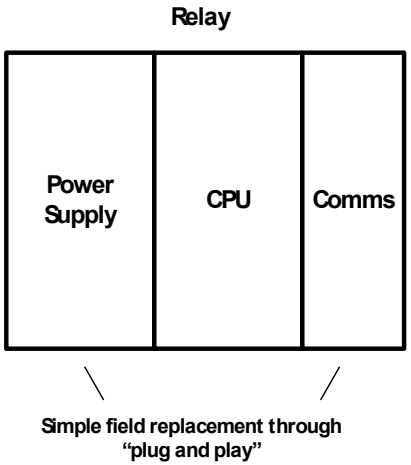
Making Protection And Control Systems Easier To Maintain



- System works with any individual device failure
- Treat devices as “black boxes”, or modules
  - Connectorized, defined functions
  - Simple swap out to replace failed unit
  - Don’t test, don’t analyze, just replace on alarms

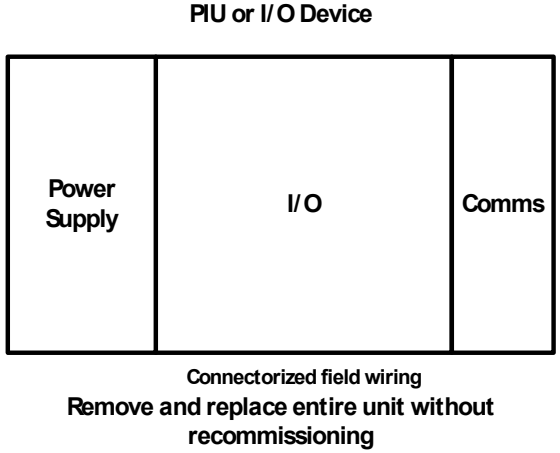
Reducing PDT

Process Bus: Ideal Devices to Reduce PDT



Relay

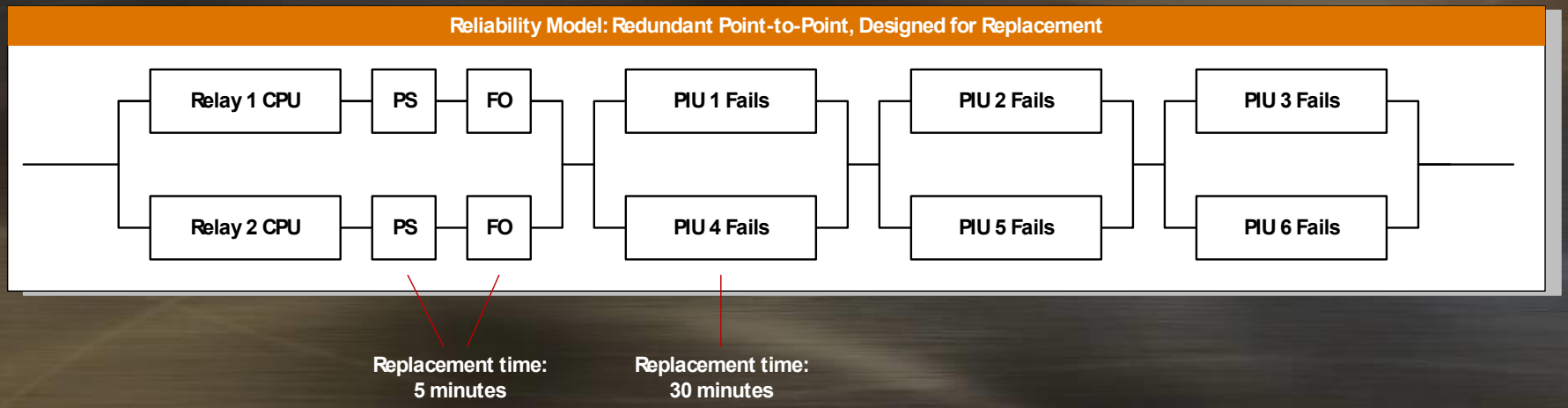
- Plug in power supply for simple field replacement
- Plug in communications module for simple replacement
- Reduces PDT for most common failure components towards 0



Distributed I/O

- Connectorized field wiring to support simple physical replacement
- Settings free device to support only simple physical replacement
- No recommissioning necessary on replacement reduces PDT towards 0

Reducing PDT



- Power supply and transceivers are plug-in modules
- PIUs can be easily designed as modules
- Even Relay CPU / application replacement is simpler

Conclusions

- The real concern with protection and control systems is PDT
- PDT is better with process bus
- Repair process is swap out failed devices
- Can implement “run to failure” modes, regular replacement cycles
- Makes device failure and repair a known, predictable quantity

Thank You

Questions?