What is “process bus”?
What is process bus?

**The technical concept...**

![Diagram of process bus system]

**...the definition**

A *technology concept* (distributed I/O for protection and control systems) that meets *business goals* (reducing time and skilled resource requirements for protection and control projects, enabling future power system operations).

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4 reasons for process bus

<table>
<thead>
<tr>
<th>Execute faster</th>
<th>• Reduce design, documentation, installation, and commissioning time. Modularize.</th>
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</thead>
<tbody>
<tr>
<td>Use less</td>
<td>• Reduce infrastructure for wiring. Use less cable trench, fewer panels, smaller building, smaller yards.</td>
</tr>
<tr>
<td>Operate better</td>
<td>• Better monitoring, asset management. Fewer maintenance trips, outages. Lifecycle management</td>
</tr>
<tr>
<td>Unlock value</td>
<td>• Digitally enabled substation. Adaptive line ratings, transformer loading, environmental considerations.</td>
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</table>
Copper Wiring

**Typical field wiring**

**And its limitations**

- Total engineered one-off design for each sub
- Focusing effort on wrong part of the value chain
- Limits future solutions: any change requires a rewire
  - Lifecycle management
  - Monitoring and diagnostics
  - Flexible system management

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**“Process bus”**

**Process bus**

**Definition**

Process bus interfaces:

- IF4: CT and VT instantaneous data exchange (especially samples) between process and bay level
- IF5: control-data exchange between process and bay level

Process bus definition:

- Sampled values published by devices at primary equipment, and subscribed to by bay level devices
- GOOSE messages between devices at primary equipment and bay level devices.
- MMS services in select circumstances
Process bus provides all data
All system needs included

Process bus data usages

Protection Data  Operations Data  Non-operational data

Right now  Trust, Verify  Accessible

Process bus data needs

• Protection information
  • Tripping, (re)-closing, blocking, permissive, status (anything that can be done with an output contact)
  • High reliability, low latency, deterministic

• Operations information
  • Reporting, control, interlocking (traditional SCADA)
  • Verified, trusted

• Non-operational information
  • Equipment monitoring, environmental
  • Availability to APM groups

How process bus supports business goals
One business goal

*Reducing time and skilled resources*

**Field wiring**
- Reduce the amount of field wiring required for protection and control systems: reduce costs, and skilled labor required

**Lifecycle Management**
- Simple replacement of process bus relays and devices makes for simple, low cost fleet management.

**Simplified Testing**
- Process bus can eliminate most routine testing of protection and control systems

**Simplified Expansion**
- Expanding a station simply means adding more I/O devices

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**Types of I/O devices**

- **Merging Unit (MU)**
  - Converts analog measurements to digital sampled values

- **Remote I/O (RIO)**
  - Contact I/O only for status and control of equipment

- **Process Interface Unit (PIU)**
  - Combination of an MU and RIO

- **DIT MUs**
  - Digital sampled values of proprietary measurement
Pick a wiring architecture

…wire every identical device the same…
...for every identical bay...

...including the network design.
Build around pre-tested sub-assemblies

- PIU boxes
  - PIUs pre-wired to terminal blocks / test switches

- Simple panels
  - Relay panel wiring limited to DC and ground

And pre-tested structures

- Simple outdoor structure for relays / relay panels.
  - "Plug-in" vs. "drop-in" control house

- Plug-in control house
Commission entire P&C system during FAT

**FAT Testing**

- I/O devices commissioned during manufacturing process
  - Identical wiring design for all I/O cabinets.
- Relay panels commissioned during manufacturing process
  - Using actual project I/O devices.

**Advantages**

Second business goal

*the digitally enabled substation*

**Digital substation architecture**

- Digitize all analog data at the source
- Make this data available to any application
- Examples:
  - Adaptive transformer loading
  - Dynamic line rating
  - Adaptive load flow
  - DA / DER integration
Basic concepts

Simplicity is the key

The goal is to move away from engineering protection and control installation. This means a simple architecture, with simple I/O devices, is required.

“Simple” means **modular design**

- Modules must be simplest building block for function/goal
- Modules must support open protocols and standards to ensure long term viability of solution
- Modules must be simple to configure / connect together to be repeatable, reusable
Protection system as modules

1:1 Connections

1:1 Connections

Connections between modules

1:1 connections

1:1 Connections

- 1 to 1 correlation between bay and IED
- Must support multiple connections if more than one connection to a module
- Allows point-to-point communications for simplicity.
- Supports dumb (configuration free) I/O devices
- I/O device must have point count to support application.
  - Every I/O device requires its own connection
  - May have multiple I/O devices in bay module
- Considers I/O device, not bay, as module
Connections between modules

1:many or many:1

1:many

- 1:many connections between modules
- Each I/O device shares path to/from module
- Every module can freely share with any module

1:many connection between bay and IED modules
- 1 connection to/from module contains all data
- Implies a LAN as communications network
- I/O devices require configuration
- Large point count inside bay module
- Can support multiple devices inside bay
- Considers bay as module

Communications Network

Communications module

Network adds challenges

- Bandwidth
- Traffic shaping
- Reliability
- Ownership
- Time synchronization
- Cyber security
- Number of devices

Do you need a “network”?

The Standard does not define a network architecture
Point-to-point architecture

- Perfect for 1:1 connections
- Simple, intuitive
- Supports dumb I/O
- No extra components (clocks, switches)
- Best MTBF for process bus
- Simplest cybersecurity requirements
- I/O devices, relays must support multiple connections
- More point count, more devices
- I/O device, not bay, is module

LAN architecture

- Ideal for 1:many connections
- Treats bay as module
- Can have multiple I/O devices per bay
- 1 communications interface per bay
- I/O devices require configuration
- Requires network (devices, configuration), clocks
- Introduces cyber security considerations
Typical Process Bus Solutions

Types of Process Bus I/O devices

<table>
<thead>
<tr>
<th>Process Interface Units (PIUs)</th>
<th>Remote I/O (RIO)</th>
<th>DI�s</th>
</tr>
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<tbody>
<tr>
<td>Outdoor/Indoor for 1:1 connections</td>
<td>Dedicated RIO</td>
<td>Optical CTs, including bushing versions</td>
</tr>
<tr>
<td>MU/PIU for 1:many connections</td>
<td>RIO</td>
<td>GIS CTs and VTs</td>
</tr>
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</table>
1:1 Process Bus System

Architecture

• Redundant PIU provide primary and stand-by sources of data for the IED
• Uniform IEDs-to-Interface panel layout, no variability
• Each PIU has 4 point-to-point connections
• Each IED has 8 point-to-point connections
• High-density connectors at the IED and the panel
• The system acts like today:
  • PIU are transparent
  • No extra devices in the system (LAN switches, master clocks)

Concept

Process bus IEDs

1:1 IEDs with PIUs

• IEDs Process Card installed
• Includes SV, digitals, time synchronization
• Must Work with 1:1 PIU

1:many IEDs

• IEDs with process bus option
• SV only on process bus port
• IEC 61850-9-2LE
• PRP, HSR support
• IEC 61869-9, GOOSE, IEEE1588 master, PRP, HSR
Process Bus Networking Solutions

**Ethernet Switches**
- Modular, ethernet switch with IEEE 1588 support
- Port options:
  - Ensure enough ports
  - Up to 24 1Gb ports (High-end Apps)
- 1588 TC and BC operation
- UltraRSTP for <5ms recovery

**Satellite Clocks**
- GNSS capable clocks for precision time synchronization
- Support for 1588, NTP, IRIG-B
- Electrical, optical, ethernet ports
- PRP support

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Process Bus in action
Case studies

Application based:
• Suncor: process bus allows for moving substations
• Arc flash mitigation through retrofit bus protection

Build faster:
• AEP: build substations faster, more repeatable, with fewer resources.
• Orion: Upgrade substations faster, more repeatable. Move relays from switchgear for safety. Multi-zone relays.
• Owen Sound: Build substations faster, more repeatable. Position substation design for future
• Transgrid: Modular design of substation protection and control for standard design, cost savings.

Drive future:
• PECO: Use of DITs for protection and control applications.
• RTE: fully digital substation to drive better power system operations (line rating, transformer loading, load flows)

Suncor Fort Hills
Greenfield oil sands extraction facility

The Project

Why process bus?

Execute faster
• Process bus supports moving substation with minimal design effort

Operate better
• Safety by design: no exposure to high energy signals
Suncor Fort Hills

Words

Substation

The results

- All mine shovel subs use 1:1 PIUs as data acquisition
- Sub moves with shovel, IEDs stay in substation
- Redesign/install is simply moving the fiber cables
- No exposure to high energy signals in substation

Arc flash mitigation

Using bus differential to reduce clearing time

The Project

Retrofit a low-impedance bus differential system to reduce fault clearing time

- Lowest cost, simplest project to add bus protection
- Process bus simplifies design / installation

Why process bus?

Execute faster

- Least impact / effort to add arc flash mitigation

Operate better

- Improve bus clearing times to limit arc flash hazards
Arc flash mitigation

**Substation**

Install a low-impedance bus differential
- Add slip-over CTs on feeder cables
- Use existing main and tie breaker CTs
- Use IEC-61850 Process Bus PIUs to gather CTs and control breakers

**The results**

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AEP Flag City Substation

*New Distribution Substation Standard*

**The Project**

Flag City is first digital distribution substation
- Now AEP design standard
- Goal is faster execution of protection and control projects

**Why process bus?**

**Execute faster**
- Faster construction. Use less skilled resources for design, installation, commissioning

**Use less**
- Copper wiring, infrastructure to support copper wiring
AEP Flag City Substation

*New Distribution Substation Standard*

**Substation**

**The results**

- Used 1:1 communications:
  - Learning curve / speed of execution
  - Mitigate cyber security concerns

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Orion Energy

*Rural Distribution Substation Upgrades*

**The Project**

- Refurbish rural distribution substations
  - Upgrade to microprocessor
  - Safety / arc flash mitigation
  - Typically 11 kV, in metal-clad switchgear

**Why process bus?**

**Execute faster**
- Faster construction

**Operate better**
- Safety (move relays from switchgear). Better lifecycle management and system reconfigurations
Orion Energy
*System Design*

**System layout**

**Installation**

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TransGrid
*Avon Digital Substation*

**The Project**
Upgrading 3 terminal 330 kV switching sub to digital
- Test of standard design for future substations
- Reduce copper cables to reduce cost
- Design for future DITs

**Why process bus?**
- Execute faster
  - Repeatable design for digital substation secondary systems
- Use less
  - Use conduit as opposed to cable trench, fewer panels, smaller building
TransGrid

Avon Network Design

- 1 m wide trench >> 0.1 m conduit
- 13 relay panels >> 2 relay panels
- 7.6 m² building >> 3.2 m²
- 10% total project saving

Results

PECO

230 kV Fully Digital Line Bays

Post substation

- 230 kV breaker-and-a-half line terminal using DITs
  - Retrofit installation of DITs to in-service circuit breaker
  - Add digital line protection and monitoring panel

Why process bus?

- Operate better
  - Meet application requirements in terms of installation, operating costs

- Drive the future
  - Future support for digital substations.
PESCO

Post design

Results

RTE Poste Intelligent

Fully Digital Substation

The Project

Refurbishment of 225 kV /90 kV

Goals:

• Reduce time / materials / cost to execute
• Improve safety / operations
• Use substation to improve power system operations

Why process bus?

Use Less

• Less wiring, less trench, fewer panels, smaller building, smaller footprint

Operate better

• Reduce maintenance trips by 80%

Drive the future

• Operate the system better through dynamic equipment loading
RTE Poste Intelligent

**Substation**

**The results**

Energized June 2016
Reduced:
- 260 km CU cables >> 4 km FO, 26 km CU
- 35 m² building >> 2.6 m² building
- Footprint 95 m² >> 26 m²
- Cap Ex by $380k

Reduce operating costs by $80k per year
Data to support advanced system operations

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**Design Considerations**

- **Cyber security**
  - Electronic security perimeter (physical security of MUs)
- **Protection reliability**
  - Provided by traditional physical segmentation and mission-based application design
- **Cost of network architecture**
  - Capital and O&M, particularly with redundant architectures
- **Change management**
  - Adopting a new solution: knowledge, training, roll out, risk
- **Firmware / software management**
  - More devices (MUs, LAN equipment), patches, cyber security concerns, complexity
Process Bus Solutions

- Use process bus to build faster, use less materials, operate better, and position for the future
- Use mature solutions for MUs/PIUs, RIOs, DITs
- Supports all process bus architectures
  - 1:1 when simple wiring replacement, learning curve, or cyber security are primary goals
  - 1:many when an overall view of system design, system operations, and meeting future requirements are the primary goal
- Long experience with process bus

Thank You

Questions?