IEC 61850 Standard for Power System Communications

Basics, Benefits, and Status

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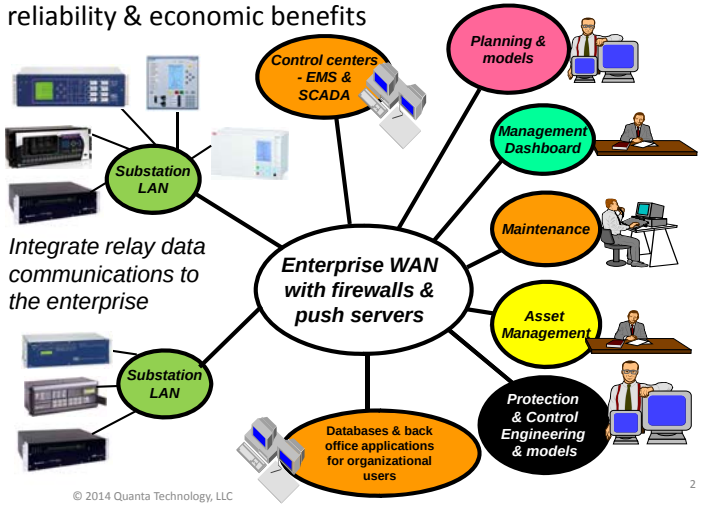
Substation communications for enterprise information – reliability & economic benefits



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Goals of substation data communications

Substation LAN (local area network)

- Lack of standard intervendor communications was a problem for decades.

- **Goal 1:** Gather up relay data for SCADA & local operators - phase out RTU & local discrete display/control devices.
- **Goal 2:** Access relay & IED operational & non-operational data for many business purposes.
- **Goal 3:** Replace wired control schemes with relays and data communications LANs.
- **Goal 4:** Replace switchyard wiring to primary apparatus and instrument transformers with optical fiber LANs.
- **Goal 5:** Collect and concentrate data for WAMPAC.

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Relay meas. & control over Ethernet LAN

Goal 3: Replace control wiring with messages on data networks.

- Substations & systems with IEC 61850 GOOSE messaging on redundant optical Ethernet LANs in service.
- Carry status & control, e.g. tripping & lockout.
- Logic in relays exchange messages to replace wires, control switches, lockout switches.
- Dramatic wiring reduction in the station.
- Can be *faster* than wiring.

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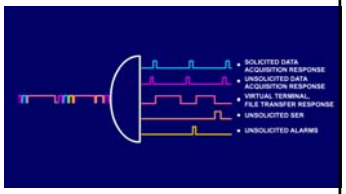
Why Ethernet?



- *Important* – Ethernet networks carry ***any combination*** of mixed traffic types, protocols, services…

Animation courtesy SEL

- Network tools to manage & prioritize mixed traffic.
- Modern Ethernet switches end old concerns about collisions and non-deterministic timing (but watch traffic volume!)
- New wide area transport with quality of service (QoS) prioritization.
- Extra network capacity always getting cheaper.
- Development of Ethernet based IT is crowding out other comms – serial now; TDM WAN will be next!

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IEC 61850 - *Communication networks and systems for power utility automation*

- Edition 1 comprised 10 Standard parts for substations, 1996-2003.
- Edition 2, 2012 and new parts – 36 in all and still growing…
- Server-client design for Ethernet networks.
- Application layers for utility system application.
- High speed protection, control, and data streaming services
- System-wide data and control services and methods.
- *Now the single* international standard for power system communications.
- Recognized by DOE, NIST as a Smart Grid communications backbone.

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What is IEC 61850?

- Ethernet based standard data communications <u>*application model ing & protocol structure*</u> with services and models aimed at utility protection and control requirements:
  - Relay/IED measurement, status, control exchanges with substation hosts – RTUs, concentrators, HMIs, enterprise – ***client-server objects***.
  - High-speed status & control over LAN to eliminate control wiring – ***GOOSE messaging***.
  - Switchyard/switchgear data acquisition and apparatus control – ***sampled values*** *(some* call it ***process bus****)*.
  - Services for reporting, configuration, file transfer, time synch.
  - Standardized configuration process for substation or system IEDs - ***system configuration language*** (SCL).
  - New ***wide-area*** GOOSE and sampled value/synchrophasor services.
- *Vision of a complete solution* to replace diverse protocols and communications systems.

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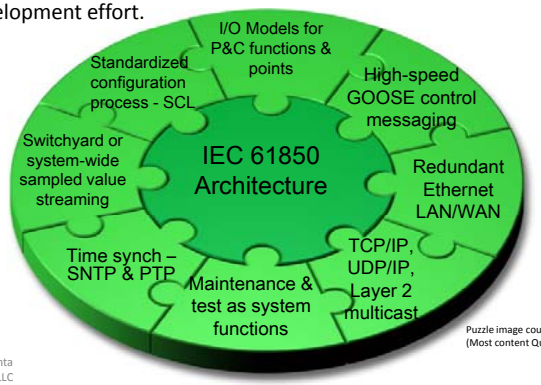
IEC 61850 is more than a protocol

- A power system P&C architecture.
- A modeling of applications and their exchanges.
- Multiple services, comply with many critical specifications – big development effort.



Puzzle image courtesy Siemens
(Most content Quanta Technology)

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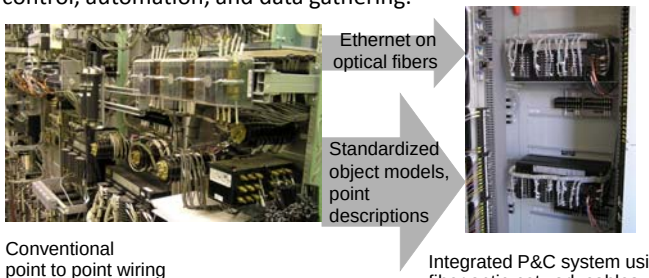
Wiring reduction

IEC 61850 aims to get rid of almost all wiring for protection, control, automation, and data gathering.



Conventional point to point wiring

Integrated P&C system using fiber optic network cables

- ***The wiring is gone, but what happened to the complex functionality?***
- ***Where are the test switches and maintenance check points?***

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IEC 61850 as multivendor standard

- Aims for integration of multiple vendors' devices.
- Each product has its own list of implemented services and features.
- Conformance – a product is tested to validate that ***claimed*** (not all) services conform to specs.
  - Vendor pays for DNV KEMA, TÜV SÜD, or similar approved-lab certificate.
- Interoperability – two or more products actually exchange information *(working on certification process).*
  - Vendor creative compliance, generic hand-map modeling shortcuts, standard interpretation. Will products actually interoperate? Plan to test and debug.
- Performance – a system of products performs the application properly *(no certification yet).*

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IEC 61850 server-client object services

- Much the standard (Parts 7-1, -2, -3, -4; new 7-5, new applications) describes power system object modeling structure and hierarchy.
- Defines objects for communications of measurements, status, control points, configuration services.
- Object modeling for substations is built on MMS application layer and Ethernet (Part 8-1).
- In general, relays and IEDs are *servers*; host computers and systems are *clients*.
- Products have 61850-specified data sharing function models –configuration easier than manual point maps (*System Configuration Language (SCL), Part 6*).

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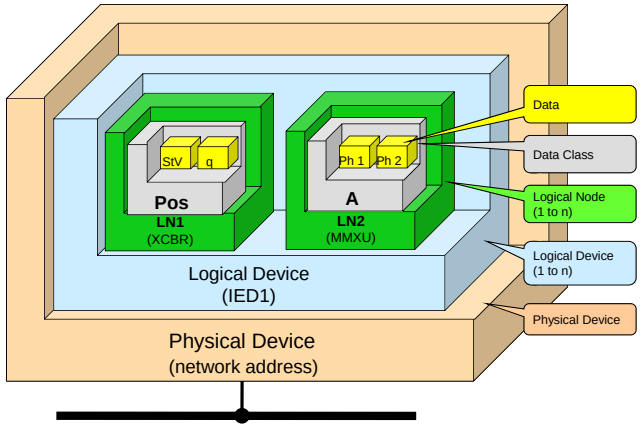
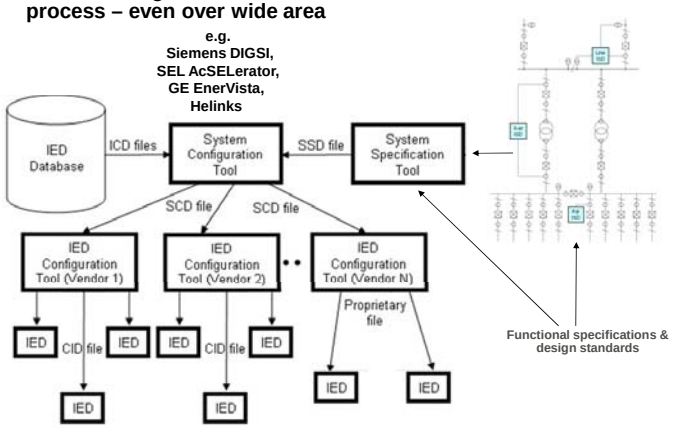
Object modeling hierarchy



Configuration with 61850-6 SCL tools

Unified configuration of entire facilities via XML file process – even over wide area



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IEC 61850 Edition 1 Documents

System Aspects	Data and Services Model
Part 1: Introduction and Overview	Part 7-4: Compatible Logical Node Classes and Data Classes Part 7-3: Common Data Classes
Part 2: Glossary	Part 7-2: Abstract Communication Services Interface (ACSI) Part 7-1: Principles and Models
Part 3: General Requirements Part 4: System & Project Management	Mapping to Ethernet
Part 5: Comms. Requirements for Functions and Device Models	Part 8-1: Mapping to MMS and ISO 8802-3 (Ethernet)
Configuration	Part 9-1: Sampled Values over Serial Unidirectional Point-to-Point link using ISO 8802-3 (defunct)
Part 6: Configuration Description Language for Communication in Electrical Substations	Part 9-2: Sampled Values over ISO 8802-3
Test	
Part 10: Conformance Testing	

International Standard (IS)
Technical Report / Specification

9-2 LE: UCA Implementation Agreement for merging units in switchyards (LE = Lite Edition)

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IEC 61850 is growing

- IEC 61850 Edition 1 – 1700 pages

IEC 61850 Edition 2

- International application – improved models
- Expanded structure
- Better clarity
- TISSUES (bugs) cleared
- New practical features
- New application domains
- *Products not out yet…*

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What is new in Edition 2 of existing parts?

- Clarifications and corrections (TISSUES)
- Modeling
  - Power Quality
  - Statistical evaluation of information
  - New models for mechanical equipment and measurements of non-electrical quantities
- New features for testing support
- Support for exchange of engineering information for configuration across projects and between facilities
- Redundancy – possibility to have IEDs with dual connections

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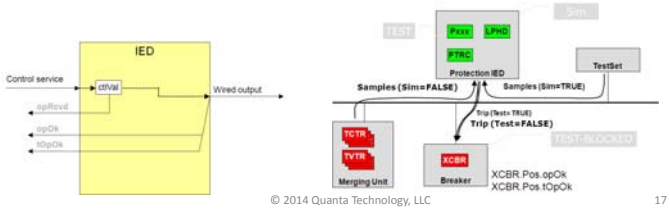
Testing improvements

- Edition 1 required expedient user construction of testing facilities!
- Mirroring/feeding back control information
- Isolation of functions in service
- Interlocking test methods



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IEC 61850 – new parts

- IEC 61850-7-410 – Hydroelectric power plants – Communication for monitoring and control
- IEC 61850-7-420 – Communication Systems for Distributed Energy Resources (DER)
- IEC 61850-7-500 /-7-510 (Technical Reports)
  - Explains how to use the concepts of IEC 61850 to model applications
- IEC 61400-25-x – Communications for monitoring and control of wind power plants.

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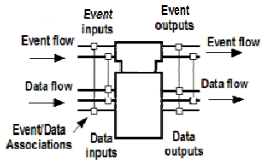
Further topics under development

- Part 100 - Methods for functional testing in IEC 61850 based systems
- Modeling of user-programmed logic within IEDs
  - Goal is to support design of distributed logic
  - Based on IEC 61499 function block language
- Part 7-10- web based IEC 61850 models
  - More consistent implementations than those from programmers reading paper documents.
- Configuration management of IEC 61850 based systems



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61850-90-1, 90-2, and 90-3

- 90-1: Interstation GOOSE communications – Chapter 5
- 90-2: Using IEC 61850 for the communication between substations and control centers – in development.
- 90-3: Condition monitoring of primary power apparatus – communications & asset management requirements:
  - Transformers, LTCs
  - GIS
  - Lines, UG cables
  - Sta. batteries

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90-4 Ethernet Network Engineering Guidelines

- Substation topology and physical locations of IEDs
- Protection and control application
- Logical data flows and traffic patterns
- Latency requirements for different types of traffic
- Redundancy and resiliency
- Reliability, availability, maintainability
- Time synchronization and accuracy
- Network management
- Configuration & addresses
- Environmental issues
- EMI immunity
- Form factor
- Physical media
- Remote connectivity
- Cyber security
- Upgradeability
- Testing
- Cost

Under development - 90-12 Wide Area (WAN) Network Engineering Guidelines

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Smart Grid integration with 61850

- 90-5: Synchrophasor transport according to IEEE C37.118 (*more later in presentation*)
- 90-6: Using IEC 61850 for distribution automation
- 90-7: IEC 61850 object models for photovoltaic, storage and other DER inverters
- 90-8: IEC 61850 object models for electrical vehicles
- 90-9: IEC 61850 object models for battery storage systems
- 90-10 – DER scheduling
- 90-11 – Electric vehicle integration
- 90-13 – Steam and gas turbines
- 90-14 – FACTS devices

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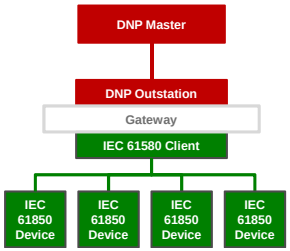
Mappings for gateways

- IEC 61850-80-2/IEEE 1815.1 – Exchanging Information between networks implementing IEC 61850 and IEEE 1815 (DNP3).
- IEC 61850-80-1 – same for IEC 60870-5-101 /-104, an IEC flavor of DNP3.



Next…stacks, GOOSE, Sampled Values…

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OSI 7-Layer Communications Stack

Layer	Name	Function
7	Application	Meaning of the data (utility user specifics)
6	Presentation	Building blocks of data and encryption for security
5	Session	Opening and closing specific communications paths
4	Transport	Error checking
3	Network	Determining the data paths within the network
2	Data Link	Data transmission, source and destination, checksum
1	Physical	Signal levels, connections, wires, fiber, wireless

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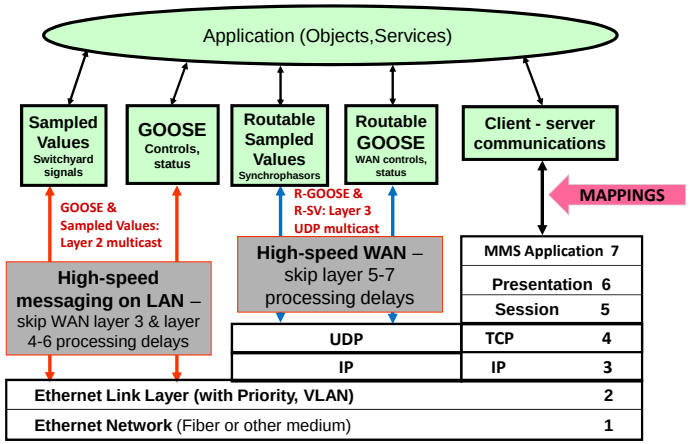
IEC 61850 communications stack mappings



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Role of IEC 61850 GOOSE messaging

Back to **Goal 3:** Replace control wiring with network messages.

- GOOSE messaging plus *programmable logic in relays* and IEDs replaces panel wiring and controls.
- *Benefits – panel and floor space reduction, less equipment overall, continuous monitoring and management of the system design ("wiring"), big potential wiring cost savings.*
- Works with other IEC 61850 services, or without them.

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61850 GOOSE messaging

- Generic Object Oriented Substation Event.
- A relay or IED can send a sequence of control or status points to replace individual signals on dedicated wires.

- Not just a single message to request remote action…
- A process to *continuously* send intended state from publishing (transmitting) IED – like a contact that picks up and drops out at critical moments.
- Even if a subscribing (receiving) relay is just powered up, it can get updated status it needs – *as wires would do*.

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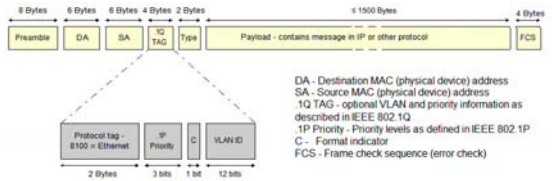
GOOSE Protocol in 61850-8-2

- Application layer directly accesses link layer for speed – same as Sampled Values messaging – no TCP/IP
- Uses Ethernet frame directly with priority/VLAN 802.1Q tag
- Use priority ≥4 for control messages; VLAN use is optional.
- Fields in GOOSE packet payload - source ID, time stamp, quality (good/bad), test mode, sequence number, configuration revision (ConfRev), time-to-live (TAL), application payload status bytes and analog values with description.



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Publisher-subscriber exchange

- Each relay *publishes* a continuous stream of GOOSE packets with status/control points that other IEDs *might* need.
- Any other relay or IED can *subscribe* to (view contents from) the streams it needs.
- Publisher just talks – *does not know* who subscribers are, or whether they got the messages in the stream.
- GOOSE works naturally only within a LAN (multicast; no destination address)

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Did GOOSE arrive at destination?

Publisher-subscriber exchange is unconfirmed service, backed up by:

- Constant repetition.
- Real-time updating of contents.
- Redundancy in LAN and relaying architecture.
- Monitoring and alarming by subscriber IEDs that fail to receive publisher's GOOSE.

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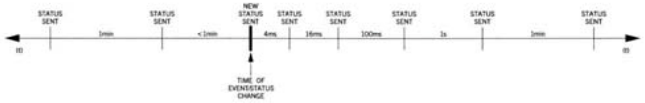
Overview of GOOSE messaging

Adaptive rate of GOOSE message transmission:



- Time values are *examples* in standard – manufacturers vary.
- Heartbeat reports values during quiescent times:
  - Communications monitoring by all *subscribing* relays.
  - Update of latest status for any subscribing IED that was just turned on.
- Modern LAN with Ethernet switches & proper traffic design handles the message burst even for a worst-case power system fault event.

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GOOSE packet rates

- SEL example, set 1 s heartbeat:

Message number	Interval from previous, ms	Time mark, ms
1	N/A	0
2	4	4
3	8	12
4	16	28
5	32	60
6	64	124
7	128	252
8	256	508
9	512	1 s

- GE UR example:

Scheme	Sq Number	Time from last Tx (ms)
Aggressive	0	0
	1	4
	2	4
	3	8
	4	Heartbeat
	5	Heartbeat
Medium	0	0
	1	16
	2	16
	3	32
	4	Heartbeat
	5	Heartbeat
Relaxed	0	0
	1	100
	2	100
	3	300
	4	Heartbeat
	5	Heartbeat
Heartbeat	0	0
	1	Heartbeat
	2	Heartbeat
	3	Heartbeat
	4	Heartbeat
	5	Heartbeat

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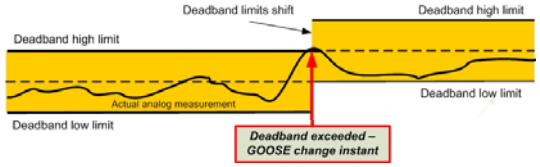
Analog GOOSE messaging

- *Concept* - send analog values with same millisecond exchanges as for status or control points.
- Accelerating change-events defined by settable measurement deadband.



- Multiple analog values in one GOOSE packet; can also combine with binaries in same packet.
- Any analog or binary change accelerates GOOSE.

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Analog GOOSE messaging

Products today:

- Send analog values at a fixed slower rate – 100 ms or 250 ms – not that useful for relaying.
- Some will send values at rate driven by status points in message, but analogs are just repeated – values actually updated only every 100 to 500 ms.
- Some can publish *synchrophasor values*, but only at a rate of 2 to 4 per second (GE and SEL) - synchrophasor time tags in packets.
- GOOSE time tag – *not the same* as synchrophasor time tag, which is another analog value in the packet.
- This GOOSE is too slow for most WAMPAC – use 90-5.

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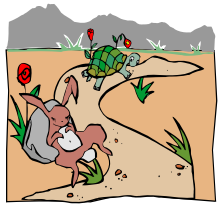
Speed of GOOSE messaging



GOOSE message control can be ***faster than a wired connection!*** Save 1-4 ms. *How?*

- A wired trip signal goes through:
  - The relay processor output program loop delay.
  - Output delay of hardware interface to wires.
  - Input debounce filter delay of receiving relay.
  - Signal waits milliseconds for the input processing program logic loop to notice it and react.
- GOOSE message bits are sent and read directly between relay processors with microsecond Ethernet delays.
- Products vary – ask manufacturer, or test.

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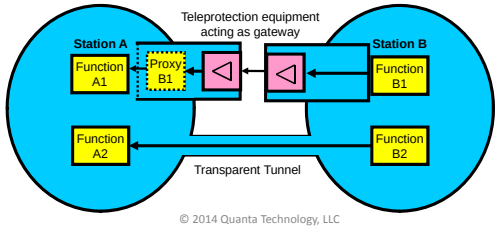
61850-90-1 on interstation GOOSE

- 61850 modeling/semantics & system engineering *across stations.*
- Ethernet LAN/WAN configuration advice in 90-5.

GOOSE works only on LAN, or *equivalent*…

- Ethernet between stations:
  - Wideband direct connection of LANs (e.g. via Ethernet card in TDM).
  - Router-configured Tunnel filters and transfers GOOSE packets over WAN.
- Non-Ethernet gateway proxy – e.g. teleprotection device.



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Electromechanical lockout switch drawbacks

- Adds 1 cycle operating time.
- Funnels wiring from bus full of breakers into one panel location.
- A lot of wiring.
- Wiring reflects and must adapt to changes in substation topology or relaying philosophy.
- Rarely operates in normal service – some jam and don't trip.
- Dangerous testing challenge - NERC PRC-005-2 says test it every 6 years.
- Cost added to scheme – deters differential relay use.

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Distributed lockout with GOOSE

- Each relay with breaker control keeps track of lockouts in effect, by logic programming.
- Relay lockout states are set by GOOSE from the relay that initiates lockout .
- Then lockouts coordinated/managed by a station computer or centralized lockout monitor & control function.
- Each relay has nonvolatile memory of lockout state
  - Some use mechanically latched output relays.
- No extra wiring or cost.
- Self monitoring feature eliminates periodic testing.
- As fast as direct tripping.
- *See 2009 NETAWorld article by Myrda, Donahoe, Udren for design example.*

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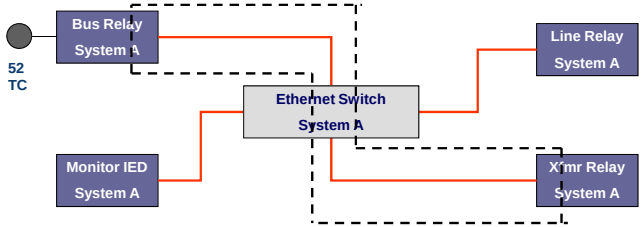
Continuous end-to-end monitoring

End-to-end check of GOOSE communications:

- The transformer relay publishes a GOOSE message including a bus breaker trip bit
- Normal-state message (do not trip) is generated every second by DSP in transformer relay.
- Passed to the communications processor.



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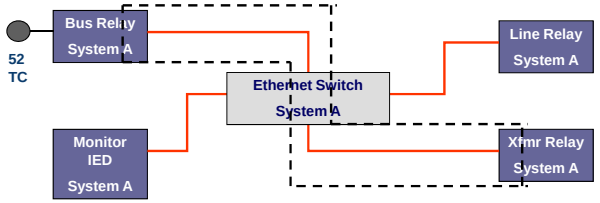
Ability to trip is monitored

- Passed through Ethernet controller to fiber, then to switch.
- Switch passes message to subscriber bus relay port.
- Communications processor of bus relay passes no-action message to bus relay DSP.
- Bus relay alarms if no-action subscribed GOOSE disappears.
- Wires cannot check themselves this completely!
- Alarms for configuration errors.



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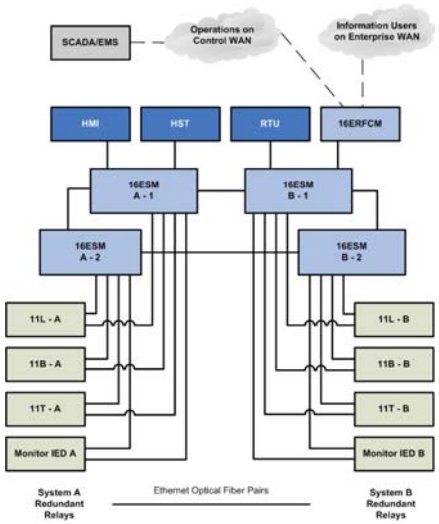
Redundant station bus for IEC 61850 GOOSE messaging

- No single point of failure within each of dual redundant LANs.
- Use relay primary and failover optical Ethernet ports.
- Dual switches and paths for GOOSE messages.



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Ethernet switches for substation LAN

- Use optical fibers everywhere for reliable high-speed data flow during faults or switching in substation environment.
- Ethernet switches carry protection traffic and become *relaying components* –
  - Protection engineers will become more familiar with their design and use.
  - Switches will isolate zones and redundant systems.
  - Substation-hardened switches have been available – conform to IEEE 1613 class 2.
- Relaying and IT experts must learn more about each other's needs and problems.
- Wide area GOOSE – use hardened routers and cyber security implementations (e.g., VPN).

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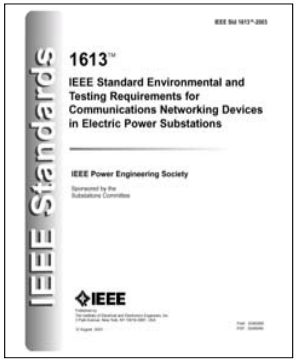
Standards for hardening network equipment in substations


NORME INTERNATIONALE
CEI IEC 61850-3
INTERNATIONAL STANDARD
Réseaux et systèmes de communication dans les postes –
Partie 3:
Prescriptions générales
Communication networks and systems in substations –
Part 3:
General requirements


IEEE Standards
1613™
IEEE Standard Environmental and Testing Requirements for Communications Networking Devices in Electric Power Substations
IEEE Power Engineering Society
IEEE

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Management of LAN based control systems

Settings management is critical

- Microprocessor relays *already* had lots of settings to configure functions & replace old relay panel wiring.
- With LAN control, inter-relay control and signaling wired connections are replaced by *more settings*.
  - Tripping, lockout, and tagging tables.
  - Inter-relay high-speed relaying and control messaging.
  - Application logic for GOOSE packet processing – protection, control, monitoring and alarming.
- Uncontrolled setting changes = unknown "moving wires".
- The untold issue with wiring reduction – *manage this complexity!*

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Settings management

- Need a *closed-loop business process* that initiates and tracks all installation and updating of setting records.
- Communicates with the IEDs themselves (over WAN is future method) to check consistency between the data base and the installed settings and firmware.
- Need a convenient way of installing settings *within* the management system in every use case.
  - Firmware update, maintenance check, operating emergency, relay replacement, etc.
- New software data base tools can connect with tested devices, test equipment, and enforce management processes – OMICRON, EnoServ, IPS, others.

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GOOSE conclusions

- Many practical installations of IEC 61850 GOOSE for high speed control.
- Also used for RAS/SPS communications over large areas.
- *Relay selection question* – is the installation all-61850, or GOOSE with DNP3/Modbus to host? Can *relay* support both on Ethernet network?
- Biggest design questions:
  - Logic design has control isolation for testing?
  - Are setting templates well protected in a version control system?
  - This is your new wiring…

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Sampled Values service for process bus

Goal 4: Replace switchyard wires with a few optical fibers.

- Eliminate conventional cables and surge/EMI pickup.
- Just a few wires left - we still have to get dc & station service power out to the yard.

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Process bus

- Voltages, currents, and status sampled near the source and converted directly to Ethernet packet stream.
  - Multiple sample sets per packet for data transmission efficiency.
- Supports trend towards intelligent power apparatus - data gathering & control IEDs installed directly in the power apparatus, even in the factory.
- Reduce field wiring cost.
- Cut wiring losses and burdens.
- Add field signals without new wiring to control house.
- *Reduce hazards of CT circuit work in control building.*

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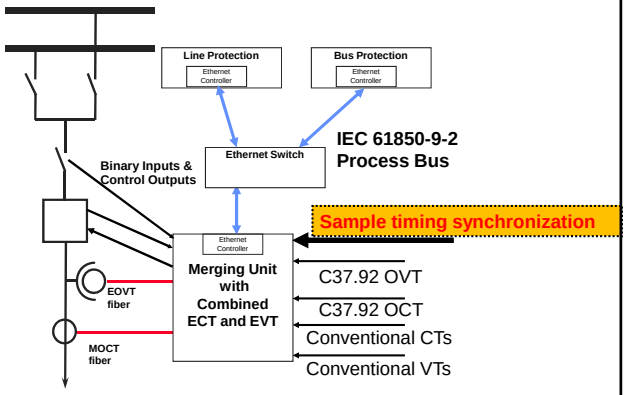
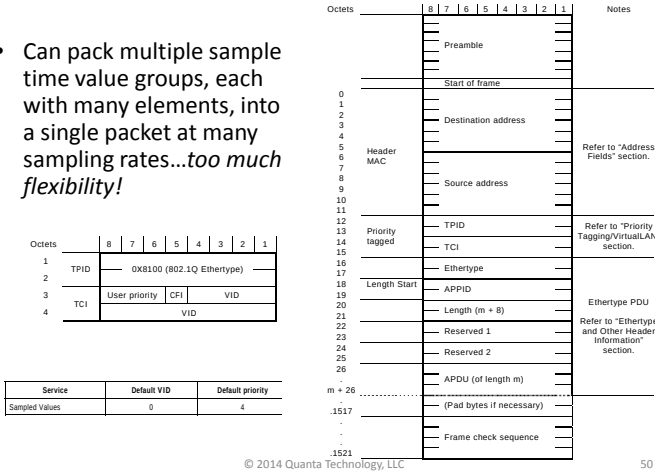
Switchyard Merging Unit (MU)



IEC 61850-9-2 Frame – generic and flexible

- Can pack multiple sample time value groups, each with many elements, into a single packet at many sampling rates…*too much flexibility!*



Service	Default VID	Default priority
Sampled Values	0	4

9-2 LE (Lite Edition) Implementation Guideline

UCA International Users Group
10604 Candler Falls Court
Raleigh, NC 27614
Tel: +919-847-2241, Fax: +919-847-2939
http://www.ucainternational.org

IMPLEMENTATION GUIDELINE FOR DIGITAL INTERFACE TO INSTRUMENT TRANSFORMERS USING IEC 61850-9-2

IEC 61850-9-2 LE Data Set

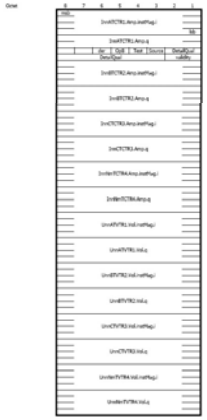
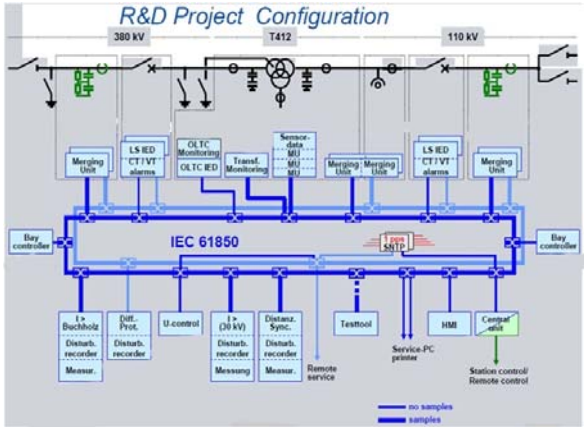


Figure 5 – Encoding of the dataset

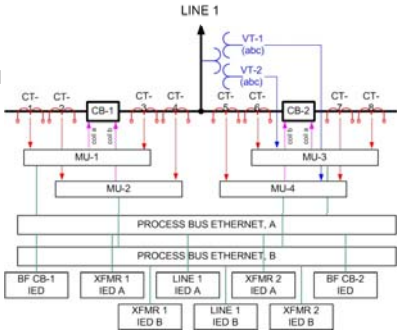
- Fixed sampling rates of 80 or 256 samples per power cycle at 50 or 60 Hz.
- Fixed data frame format.
- Merging unit must be time synchronized with a separate1pps fiber signal piped around the station.
  - o Shared timing signal is a point of station-wide vulnerability.

Unified substation-wide LAN using 9-2 LE



Chopping up the ring for redundancy

- 9-2 LE zones of protective relaying share merging units & LANs.
- Relay engineers are used to separating zones of protection for reliability & limiting single point failure effects.
- Another way to apply MUs:
- Dedicated MU function for each zone, each location, and System A or System B – full redundancy and isolation.
- This takes more MUs equipment but separates zones.
- Can we make a low cost robust MU?



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Another direction – 61850-9-2, but not 9-2 LE

- GE Multilin introduced HardFiber® process bus system.
- Uses 61850-9-2 sampled values format for process data flow to relays.
- Uses 61850-8-1 GOOSE messaging downward from relay for sampling synchronization and control – instead of shared fiber with 1 pps running around to all MUs as in 9-2 LE.
- Low-cost MU function implementation.
- Technically helpful (*author's opinion*) architecture solution that addresses unified process bus application concerns:
  - Isolation of protection zones.
  - Isolation of redundant systems.
  - Works with today's GE UR relays.
  - Each relay drives its own data sampling, as it does conventionally.
  - Tracks system frequency and avoids distance relay polarizing problems.
  - Design includes solutions to installation efficiency and testing issues.

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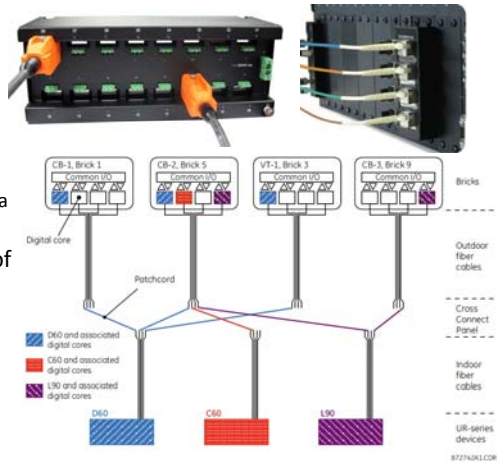
GE HardFiber® process bus system

- Weatherproof Brick® mounts on apparatus; has four mini merging units inside – GE calls them *cores*.
- Connect to relays in control house via factory fiber assemblies and weatherproof connectors.

GE HardFiber ® components

- Indoors:
  - Cross connect panel.
  - Fibers to/from relays.
  - Power from panel to remote Brick via HardFiber cable.
- Flexible patching of Brick MU to multiple GE UR relays.



HardFiber interoperability with other vendors?

- ABB, Siemens, Alstom Grid, SEL used 9-2 LE.
- 9-2 LE is an *implementation guideline*, not part of 61850 standard, but GE signed it with the others.
- Brick cannot work in a 9-2 LE system & vice versa.
- What about multiple vendors and interoperability of 61850?
- Friction and confusion in the marketplace – setback!

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Coming - a way out of the impasse!

- Merging unit standards project in IEC TC 38 (Instrument Transformers) – **IEC 61869-9 Merging Unit Standard.**
- IEC 61869-9 uses 61850-9-2 and chooses specific options – tonly wo sampling rates, standard frames, etc.
  - More limited than 9-2 LE – fewer vendor options.
- *Eliminates 1 pps fiber time synchronization.*
- Uses IEEE 1588 precision timing protocol (PTP) on existing Ethernet connection to synchronize sampling.
- Every vendor can adapt products they have - GE and others are adapting.
- MUs and relays interoperate, with flexible architecture choices – from isolated zones to station/process bus.

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Ngrid UK 400 kV process bus demo

- Switchbox for MU replacement.



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Switchyard maintenance solution!

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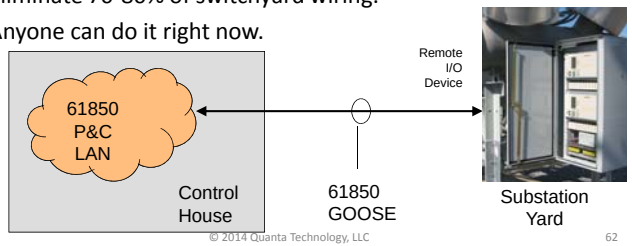
Get much of the benefit now

- A cost effective interim solution – extend the *station bus* into the switchyard for status and control I/O.
- Put a remote binary I/O relay (e.g. SEL 451, GE UR C90) in the switchyard for all status and control via GOOSE.
- Wire only the CTs and CVTs back to the control house as we do today.
- Eliminate 70-80% of switchyard wiring.
- Anyone can do it right now.



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New cyber secure synchrophasor streaming – TR 61850-90-5

Goal 5: Collect and concentrate data for WAMPAC.

Wide area network (WAN) services use 61850 principles

- Sampled Value or GOOSE publish/subscribe *across the Ethernet WAN – Routable SV (R-SV) and Routable GOOSE (R-GOOSE).*
- Adds layer 3 transport – UDP/IP unicast/multicast (*unconfirmed* efficient stream of data packets – not TCP/IP)
- Subscribers can search for publishers, & manage WAN routes dynamically using Internet Group Management Protocol (IGMP) V.3, *a standard IT router service*.

New cyber secure synchrophasor streaming – TR 61850-90-5

- New - *a big deal* – end-to-end authentication in the packet!
  - *IT standard* SHA-2 authentication hash code - computed in real time.
  - Needs new PMU or relay processors to compute authentication hash code for every packet, authenticate incoming packets.
  - *IT standard* Group Domain of Interpretation (GDOI) security key distribution/management.
- Packet encryption specification (can be done in router or in PMU/relay).
- Valuable for *all* control functions.

Using 61850 services on the LAN

Understand design impact of specific 61850 services.

- Client-server exchanges of standard defined objects for metering, status, control, and IED configuration.
  - Metering and status via polling or report-by-exception.
  - *No visible impact on installation* – benefit is drive to easy engineering and maintenance.
  - DNP3 or 60870-5 can perform similar role with familiar polling & manual point configuration lists.
- GOOSE messaging gets rid of conventional control wiring among relays and IEDs – *design commitment; visible change*.
- LAN can carry mixed traffic – e.g. DNP3 metering and status, plus GOOSE for wiring elimination.

Many potential users don't realize this.

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Advice to new 61850 users

- Develop a new standard in laboratory facility:
  - Get bugs out.
  - Get maintenance & user buy-in & training.
  - Have platform for testing firmware/hardware versions.
  - Facility for post-mortem analysis & field event debugging.
  - Showplace for sponsoring managers and the industry

- Get SCL tool and hardware/software product vendors to take responsibility for successful integration
  - Training with your products in your lab
  - They stay with you to fix problems and bugs

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Advice to new 61850 users

- Include functional monitoring of communications in your applications programming
  - Latency, lost packet counts & path outage statistics
  - Applications alarm if they stop exchanging critical data – as with current differential line protection.
  - Condition monitoring for NERC PRC-005-2/3
- Design I/O facilities specifically for testing and troubleshooting
  - Test switches to engage test modes.
  - Alarms for test modes left by technicians
  - Functional test of critical functions built in (as for RAS annual test) until 61850 Ed. 2 testing is more proven.

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Questions?

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