Digital Grid – the Future is Now

Dr. Alexander Apostolov

OMICRON electronics

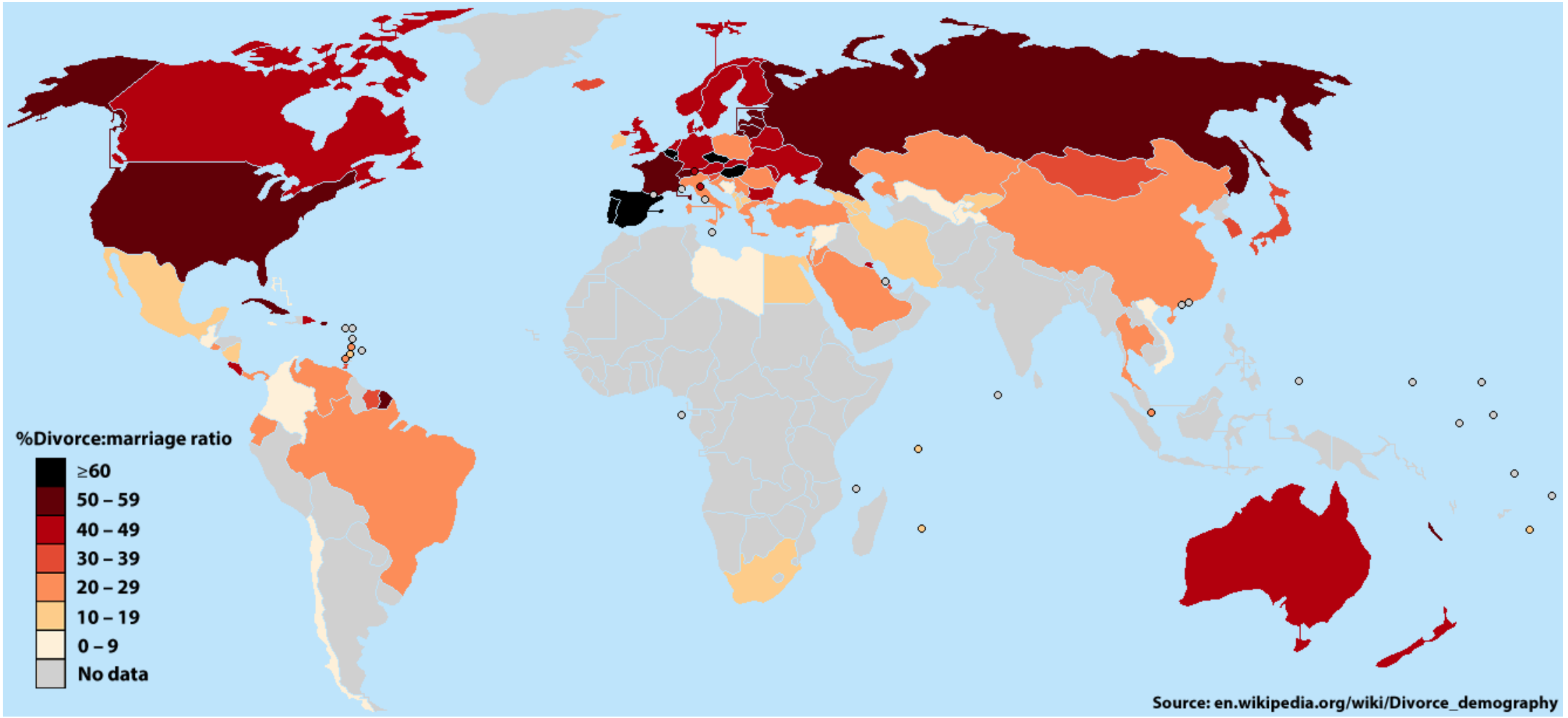
PAC World

Questions

- What are we doing?
- Why are we doing it?
- How are we doing it?

Questions

Questions


%Divorce:marriage ratio
≥60
50 – 59
40 – 49
30 – 39
20 – 29
10 – 19
0 – 9
No data
Source: en.wikipedia.org/wiki/Divorce_demography

What are we doing?

- Defining the electric power grid of the future

Future - Definition

- The indefinite time yet to come
- Undetermined events that will occur in that time
- A prospective or expected condition
- The condition of a person or thing at a later date

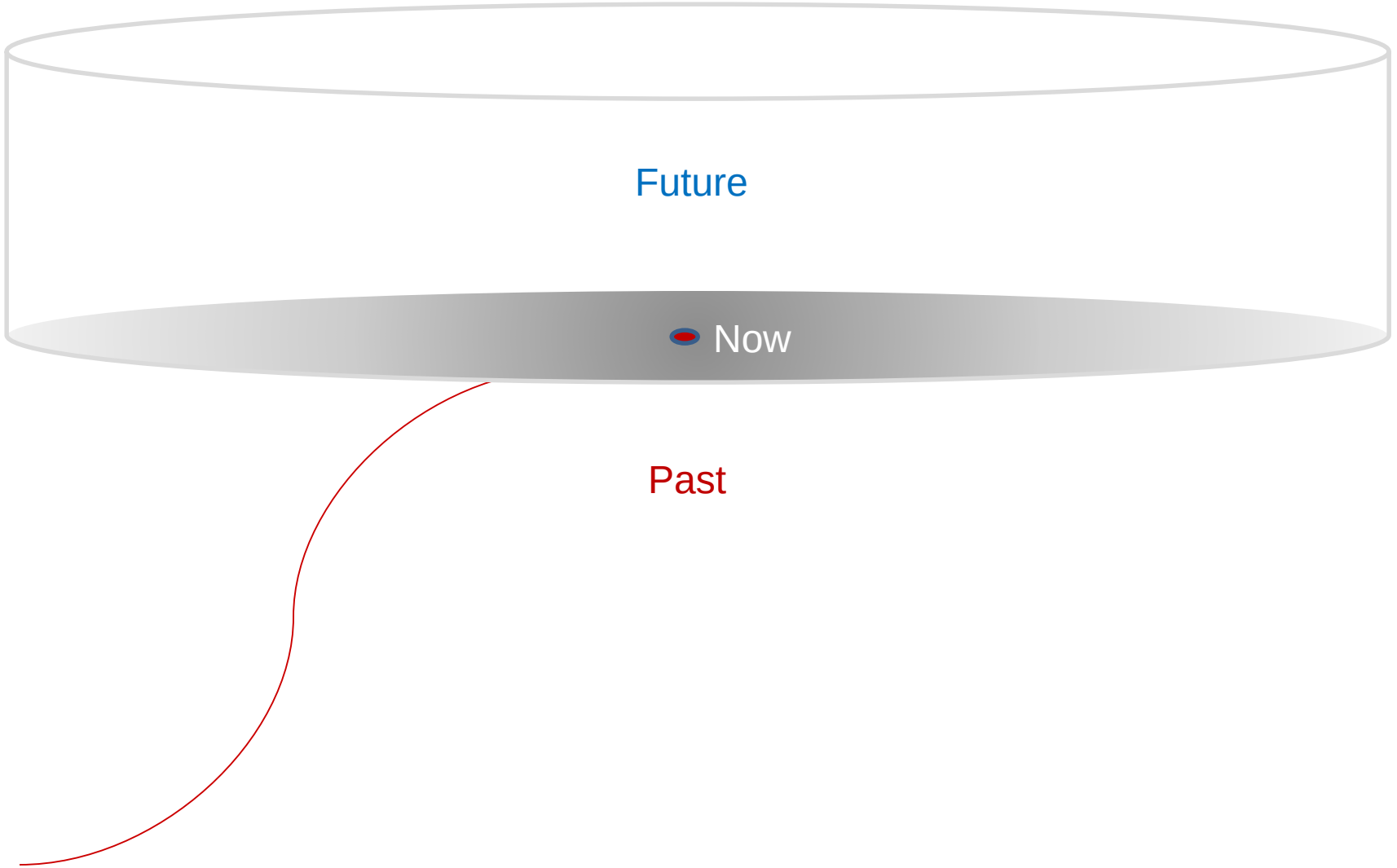
Future - Definition

- The future is a time period commonly understood to contain all events that have yet to occur.
- It is the opposite of the past, and is the time after the present.

Future in Philosophy

- Presentism – only the present exists. Past and future are logical constructions – fictions.
- Eternalism – past and future exist and are eternal.
- Growing Block theory – past and present exist.
- Tracism – only the present and traces of the past exist.

Life trajectory



Why are we doing it?

- We live in a changing world
- We cannot keep doing things as we always did

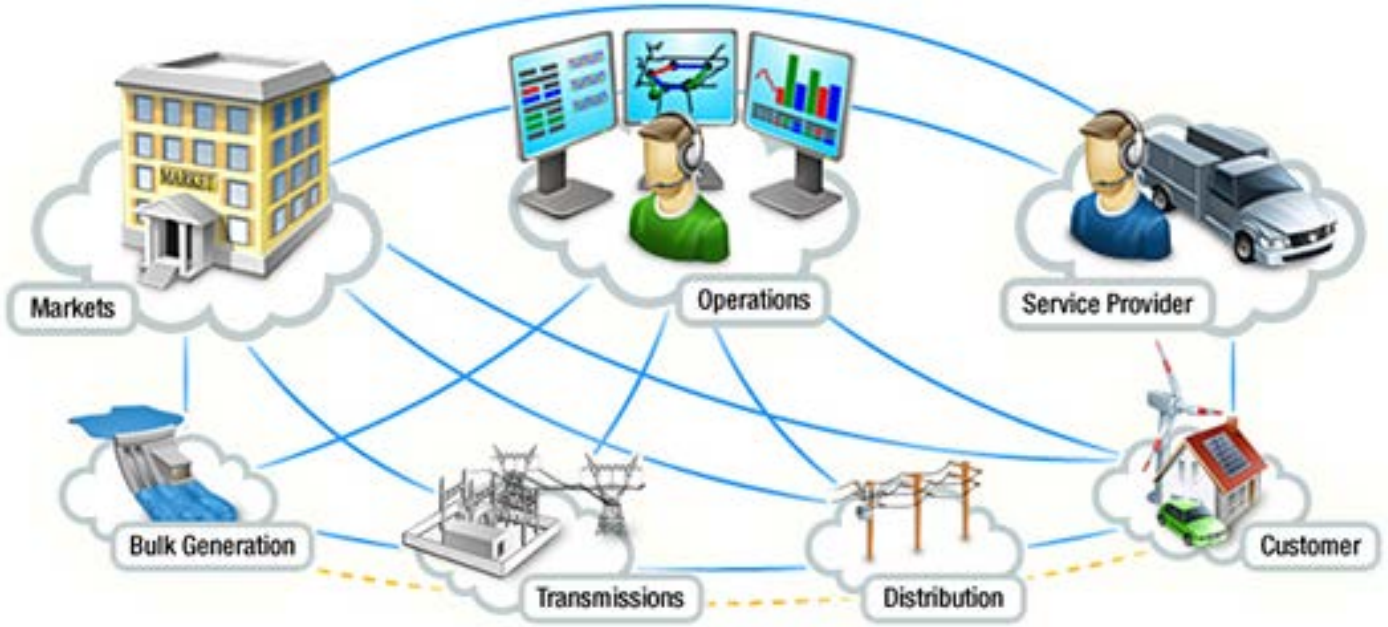
Smart Grid Definition

- Energy Independence and Security Act (2007):
- *It is the policy of the United States to support the modernization of the Nation's electricity transmission and distribution system to maintain a reliable and secure electricity infrastructure that can meet future demand growth and to achieve each of the following, which together characterize a Smart Grid:*

Smart Grid Definition

- Increased use of digital information and controls technology to improve reliability, security, and efficiency of the electric grid.
- Dynamic optimization of grid operations and resources, with full cyber-security.
- Deployment and integration of distributed resources and generation, including renewable resources.

Smart Grid Conceptual Model



Remember this equation

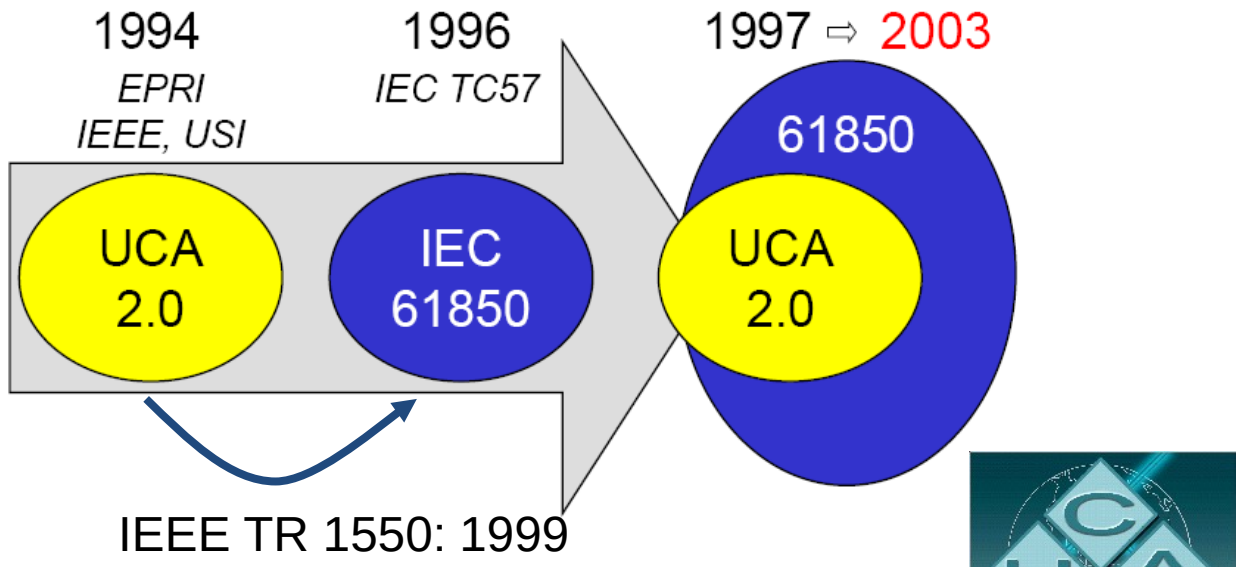
SG = DG

How are we doing it?

IEC 61850

History

1994 1994 1998 Present



"UCA & 61850 for Dummies." – Douglas Proudfoot

Working Groups at Work

What is IEC 61850?

IEC 61850

14 Parts

>1000 pages (English only !)

10 years of development

REAL SUBSTATION

Different vendors

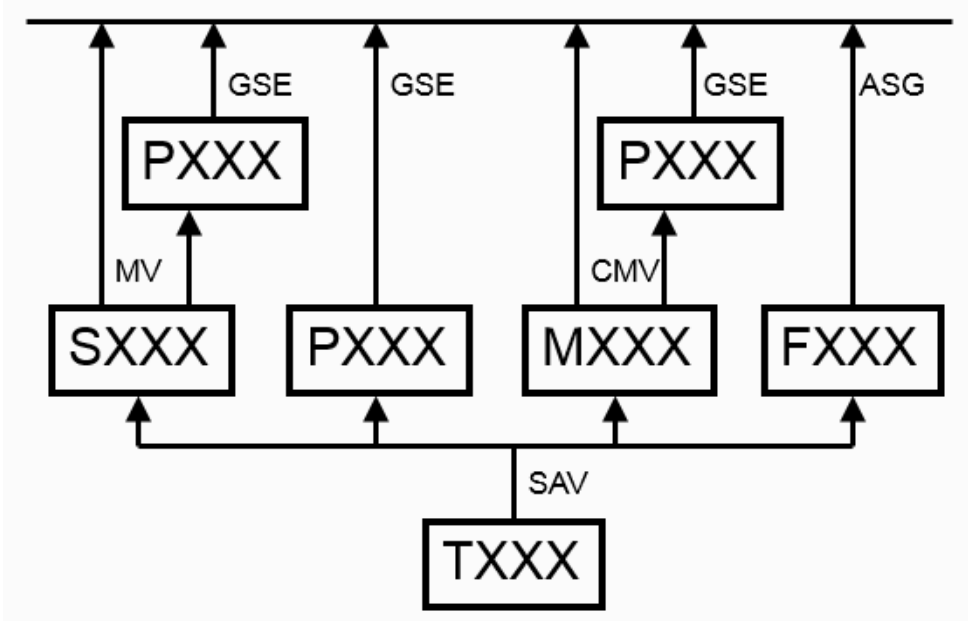
Interoperability

Easy specification

Digital twins

- A digital twin is a digital replica of a living or non-living physical entity.
- By bridging the physical and the virtual world, data is transmitted seamlessly allowing the virtual entity to exist simultaneously with the physical entity.
- Multiple applications in electric power

Functional Decomposition



IEC 61850 Standard Ed. 1

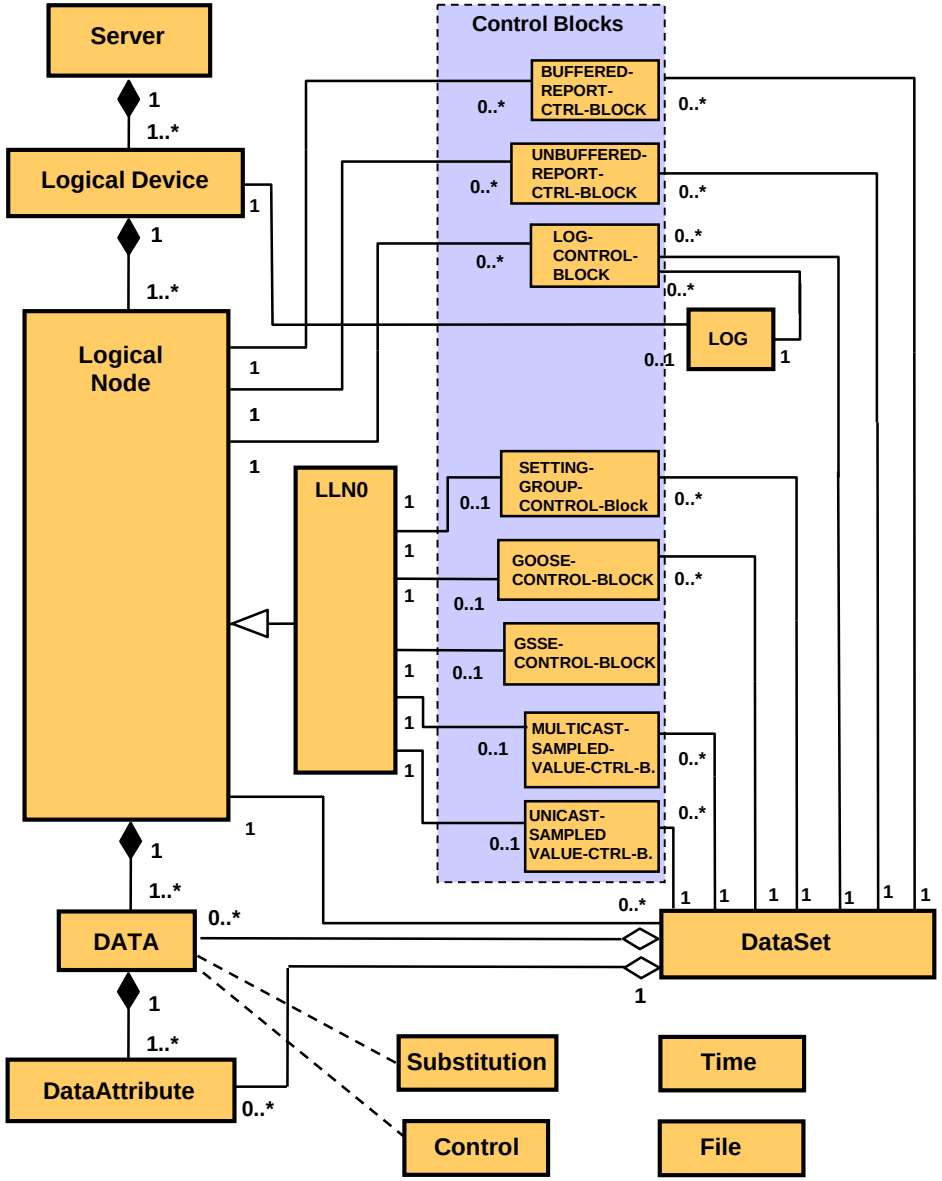
System Aspects
Part 1: Introduction and Overview
Part 2: Glossary
Part 3: General Requirements Part 4: System and Project Management
Part 5: Comm. Requirements for Functions and Device Models

Configuration
Part 6: Configuration Language for electrical Substation IEDs

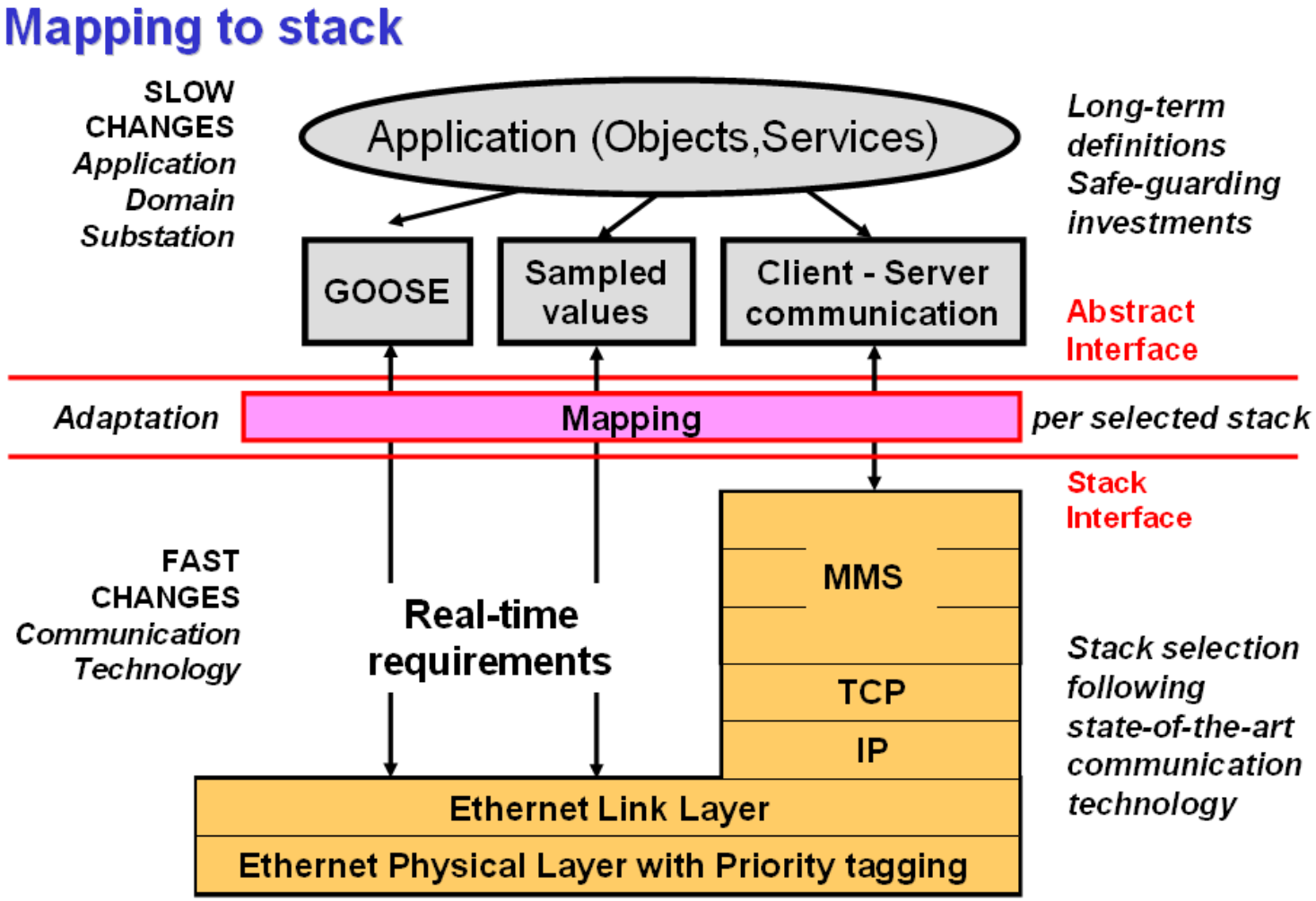
Data Models
Part 7-4: Compatible Logical Node Classes and Data Classes Part 7-3: Common Data Classes
Abstract Communication Services
Part 7-2: Abstract Communication Services (ACSI) Part 7-1: Principles and Models
Mapping to real Comm. Networks (SCSM)
Part 8-1: Mapping to MMS and to ISO/IEC 8802-3
Part 9-1: Sampled Values over Serial Unidirectional Multidrop Point-to-Point link
Part 9-2: Sampled values over ISO 8802-3

Testing
Part 10: Conformance Testing

IEC 61850 Services



IEC 61850 Standard - Station Bus Mapping



LN groups

Group indicator	Logical node groups
A	Automatic control
B	Reserved
C	Supervisory control
D	Distributed energy resources
E	Reserved
F	Functional blocks
G	Generic function references
H	Hydro power
I	Interfacing and archiving
J	Reserved
K[a]	Mechanical and non-electrical primary equipment
L	System logical nodes
M	Metering and measurement
N	Reserved
O	Reserved
P	Protection functions
Q	Power quality events detection related
R	Protection related functions
S	Supervision and monitoring
T[a]	Instrument transformer and sensors
U	Reserved
V	Reserved
W	Wind power
X[a]	Switchgear
Y[a]	Power transformer and related functions
Z[a]	Further (power system) equipment

New LNs in IEC 61850, 61400-25

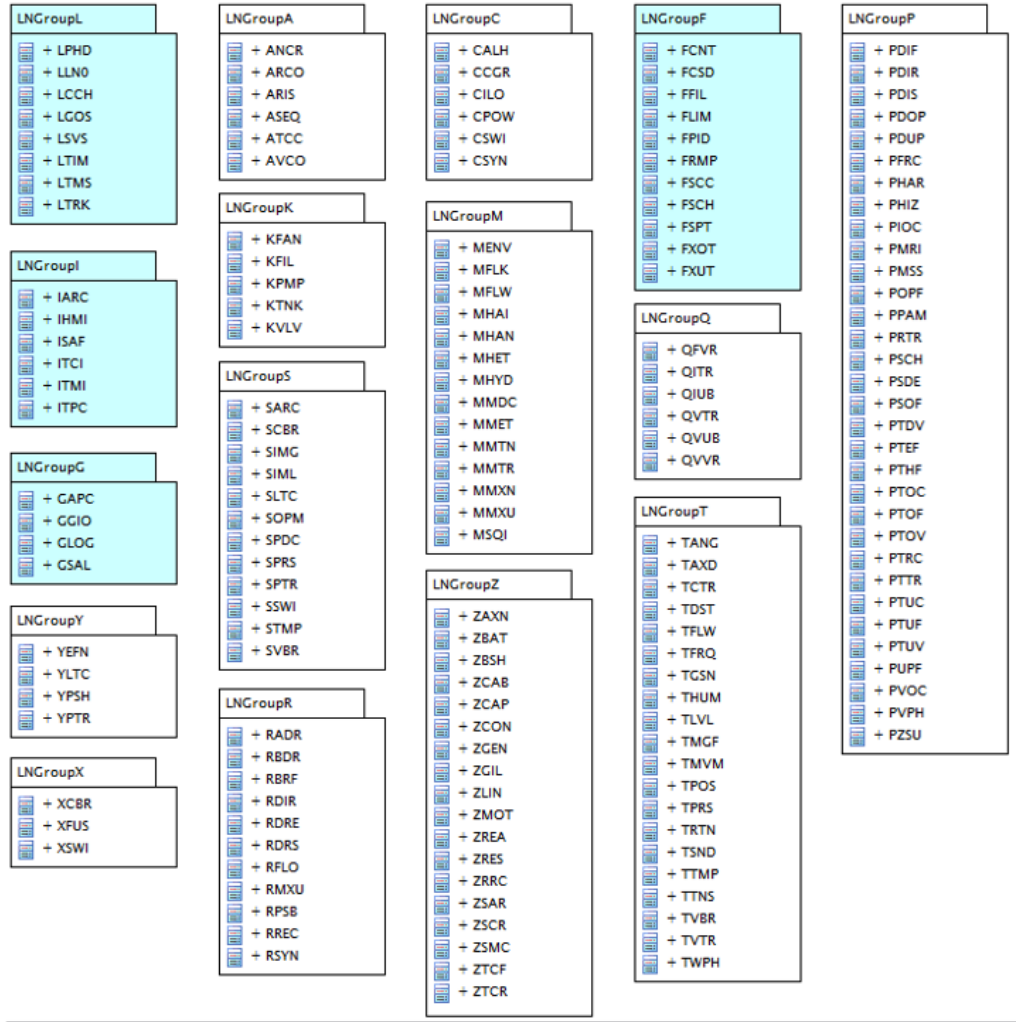
ANCR	MSQI	PTUV	YPSH
ARCO	MSTA	PUPF	YPTR
ATCC	PDIF	PVOC	ZAXN
AVCO	PDIR	PVPH	ZBAT
CALH	PDIS	PZSU	ZBSH
CCGR	PDOP	RADR	ZCAB
CILO	PDUP	RBDR	ZCAP
CLN	PFRC	RBRF	ZCON
CPOW	PHAR	RDIR	ZGEN
CSWI	PHIZ	RDRE	ZGIL
GAPC	PIOC	RDRS	ZLIN
GGIO	PM	[illegible]	ZMOT
GSAL	PM	RP[illegible]	ZREA
IARC	PO[illegible]	[illegible]	ZRRC
IHMI	PPAM	RSYN	ZSAR
ITCI	PSCH	SARC	ZTCF
ITMI	PSDE	SIMG	ZTCR
LLN0	PTEF	SIML	
LPHD	PTOC	SPDC	
MDIF	PTOF	TCTR	
MHAI	PTOV	TVTR	
MHAN	PTRC	XCBR	
MMTR	PTTR	XSWI	
MMXN	PTUC	YEFN	
MMXU	PTUF	YLTC	

92

ANCR	DPST	GAPC	ISAF	MMDC	PTEF	RDRS	TLEV	WTOW	ZREA
ARCO	DPVA	GGIO	ITCI	MMET	PTHF	RFLO	TLVL	WTRF	ZRES
ARIS	DPVC	GLOG	ITMI	MMTN	PTOC	RMXU	TMGF	WTRM	ZRRC
ATCC	DPVM	GSAL	ITPC	MMTR	PTOF	RPSB	TMVM	WTUR	ZSAR
AVCO	DRAT	HBRG	KFAN	MMXN	PTOV	RREC	TPOS	WYAW	ZSCR
CALH	DRAZ	HCOM	KFIL	MMXU	PTRC	RSYN	TPRS	XCBR	ZSMC
CCGR	DRCC	HDAM	KPMP	MPRS	PTTR	SARC	TRTN	XFUS	ZTCF
CILO	DRCS	HDLS	KTNK	MSQI	PTUC	SCBR	TSND	XSWI	ZTCR
CPOW	DRCT	HGPI	KVLV	MSTA	PTUF	SIMG	TTMP	YEFN	
CSWI	DREX	HGTE	LCCH	PDIF	PTUV	SIML	TTNS	YLTC	
CSYN	DSCC	HITG	LGOS	PDIR	PUPF	SLTC	TVBR	YPSH	
DCCT	DSCH	HJCL	LLN0	[illegible]	PV[illegible]	SOPM	TVTR	YPTR	
DCHB	DSFC	HLKG	LPHD	[illegible]OP	[illegible]VP[illegible]	SPDC	TWPH	ZAXN	
DCHC	DSTK	HLVL	LSVS	[illegible]	PZ[illegible]	SPTR	WALG	ZBAT	
DCIP	DTRC	HMBR	LTIM	PFRC	QFVR	SSWI	WALM	ZBSH	
DCRP	FCNT	HNDL	LTMS	PHAR	QITR	STMP	WAPC	ZBTC	
DCTS	FCSD	HNHD	LTRK	PHIZ	QIUB	SVBR	WCNV	ZCAB	
DEXC	FFIL	HOTP	MENV	PIOC	QVTR	TANG	WCON	ZCAP	
DFCL	FLIM	HRES	MFLK	PMRI	QVUB	TAXD	WGEN	ZCON	
DFLV	FPID	HSEQ	MFLW	PMSS	QVVR	TCTR	WMET	ZGEN	
DFPM	FRMP	HSPD	MFUL	POPF	RADR	TDST	WNAC	ZGIL	
DGEN	FSEQ	HUNT	MHAI	PPAM	RBDR	TFLW	WREP	ZINV	
DOPA	FSPT	HWCL	MHAN	PRTR	RBRF	TFRQ	WROT	ZLIN	
DOPM	FXOT	IARC	MHET	PSCH	RDIR	TGSN	WRPC	ZMOT	
DOPR	FXUT	IHMI	MHYD	PSDE	RDRE	THUM	WSLG	ZRCT	

233

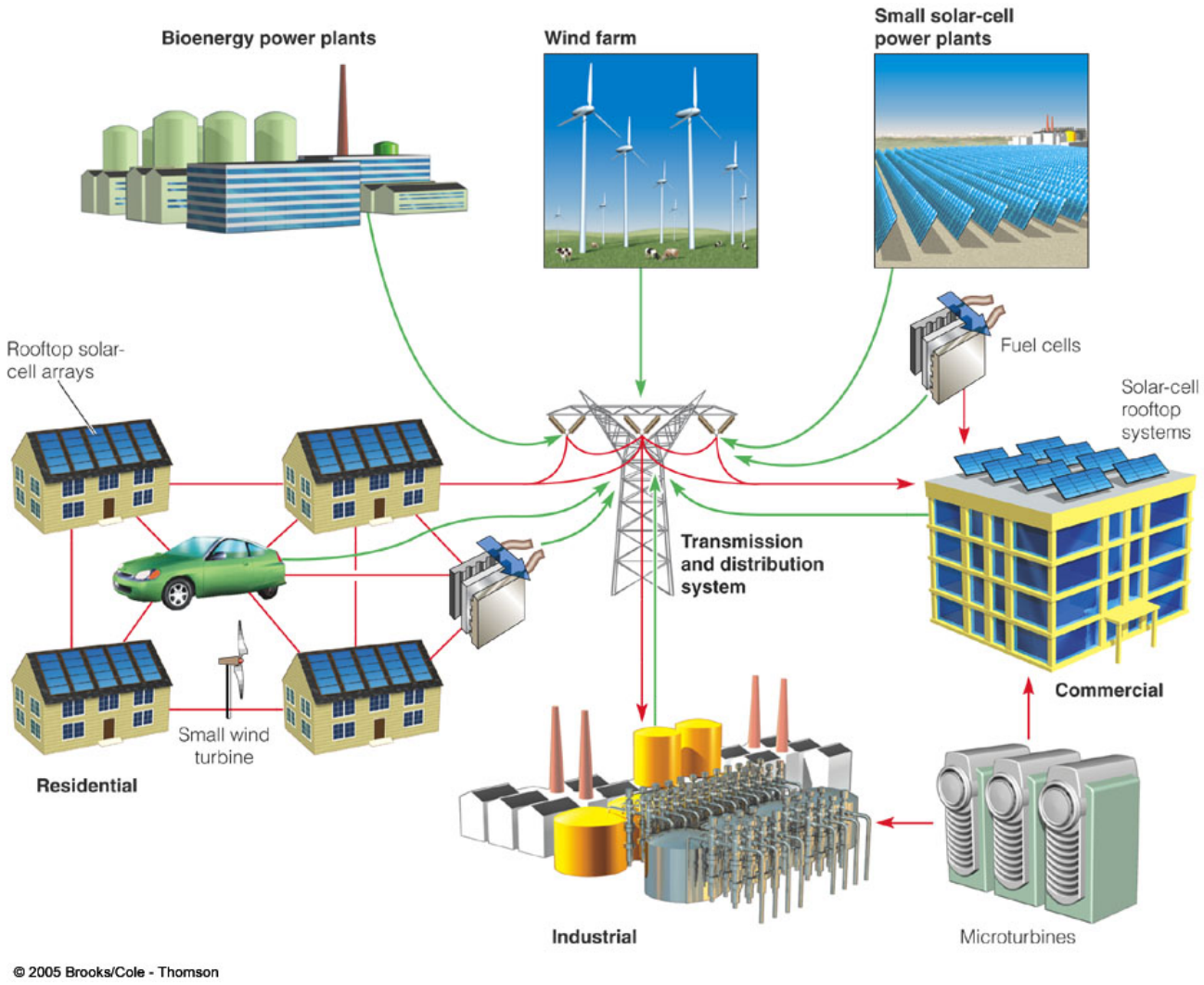
Class diagram LNs::LN Groups



Sensors LNs

- LN Angle TANG
- LN Axial displacement TAXD
- LN Current transformer TCTR
- LN Distance TDST
- LN Liquid flow TFLW
- LN Frequency TFRQ
- LN Generic sensor TGSN
- LN Humidity THUM
- LN Media level TLVL
- LN Magnetic field TMGF
- LN Movement sensor TMVM
- LN Position indicator TPOS
- LN Pressure sensor TPRS
- LN Rotation transmitter TRTN
- LN Sound pressure sensor TSND
- LN Temperature sensor TTMP
- LN Mechanical tension / stress TTNS
- LN Vibration sensor TVBR

DERs



IEC 61850 Development Status

WG	Title	Document	Ed
10	Introduction and overview	61850-1-1	2
10	Guideline for extending IEC 61850	61850-1-2	1
10	Glossary	61850-2	2
10	General requirements	61850-3	
10	System and project management	61850-4	2.1
10	Communication requirements for functions and device models	61850-5	2.1
10	Configuration description language for communication in electrical substations related to IEDs	61850-6	2.1
10	Configuration description language extensions for human machine interfaces	61850-6-2	1
10	Guideline for function modeling in SCL for substation automation	61850-6-100	1

IEC 61850 Development Status

WG	Title	Document	Ed
10	Basic communication structure – Principles and models	61850-7-1	2.1
10	Abstract communication service interface (ACSI)	61850-7-2	2.1
10	Common data classes	61850-7-3	2.1
10	Compatible logical node classes and data classes	61850-7-4	2.1
17	Communications systems for distributed energy resources (DER) - Logical nodes	61850-7-420	2
10	IEC 61850 modelling concepts	61850-7-5	1
10	Use of logical nodes to model functions of a substation automation system	61850-7-500	1
17	DER - Modelling concepts and guidelines	61850-7-520	1

IEC 61850 Development Status

WG	Title	Document	Ed
10	Guideline for Basic Application Profiles	61850-7-6	1
10	Specification of schema for namespace definition files	61850-7-7	1
10	Mappings to MMS (ISO/IEC 9506-1 and ISO/IEC 9506-2) and to ISO/IEC 8802-3	61850-8-1	2.1
17	Mapping to Webservices	61850-8-2	1
10	Sampled values over ISO/IEC 8802-3	61850-9-2	2.1
10	Precision time protocol profile for power utility automation	61850-9-3	1
10	Conformance testing	61850-10	
10	Functional testing of IEC 61850 based systems	61850-10-3	1

IEC 61850 Development Status

WG	Title	Document	Ed
10	Guideline to exchange information from a CDC based data model using IEC 60870-5-101/104	61850-80-1	
17	Mapping to Web Services – Requirement Analysis and Technology Assessment	61850-80-3	
10	Mapping between the DLMS/COSEM (IEC 62056) data models and the IEC 61850 data models	61850-80-4	
10	Mapping between Modbus and IEC 61850	61850-80-5	1

IEC 61850 Development Status

WG	Title	Document	Ed
10	Using IEC 61850 for the communication between substations	61850-90-1	
10	Using IEC 61850 for condition monitoring	61850-90-3	
10	Network engineering guidelines for substations	61850-90-4	2
10	Using IEC 61850 to transmit synchrophasor information according to IEEE C37.118	61850-90-5	
17	Using IEC 61850 for Distribution Automation	61850-90-6	1
17	Object models for photovoltaic, storage and other inverter based applications	61850-90-7	
17	Object models for electrical vehicles	61850-90-8	2
17	Object models for electrical energy storage	61850-90-9	1
17	Object models for schedules	61850-90-10	1

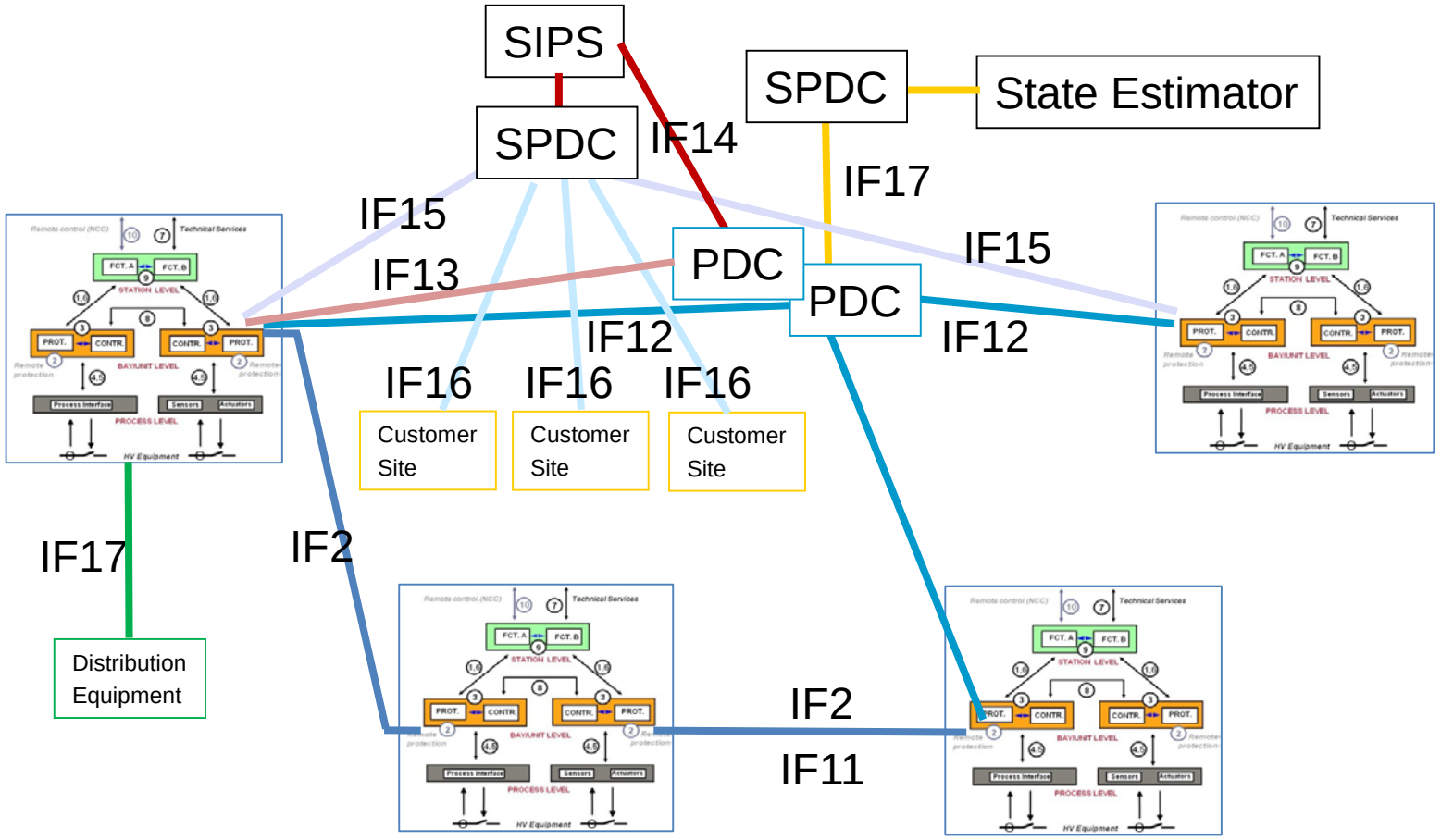
IEC 61850 Development Status

WG	Title	Document	Ed
10	Methodologies for modelling of logics for IEC 61850 based applications	61850-90-11	1
10	Wide area network engineering guidelines	61850-90-12	2
10	Deterministic network topologies	61850-90-13	1
10	Using IEC 61850 for FACTS and power conversion data modelling	61850-90-14	1
17	IEC 61850 based DER Grid Integration	61850-90-15	1
17	Requirements for System Management	61850-90-16	1

IEC 61850 Development Status

WG	Title	Document	Ed
10	Use of IEC 61850 to transmit Power Quality Data	61850-90-17	
10	Modeling Alarmhandling for IEC 61850	61850-90-18	1
10	Applying role based access to IEC 61850	61850-90-19	1
10	Guideline for redundant IEDs with IEC 61850	61850-90-20	1
10	Use of IEC 61850 for traveling wave fault location system	61850-90-21	1

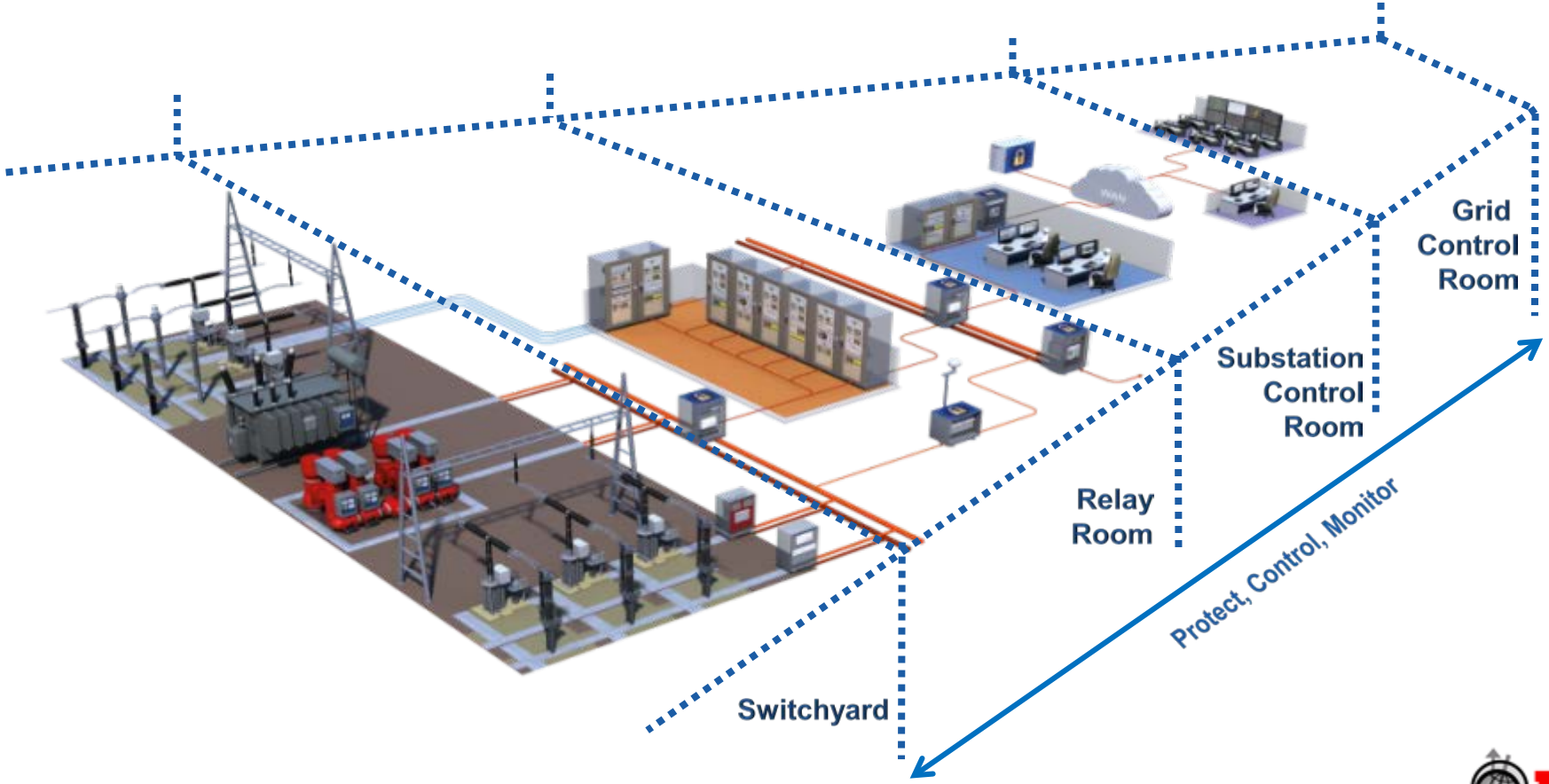
Communication Interfaces



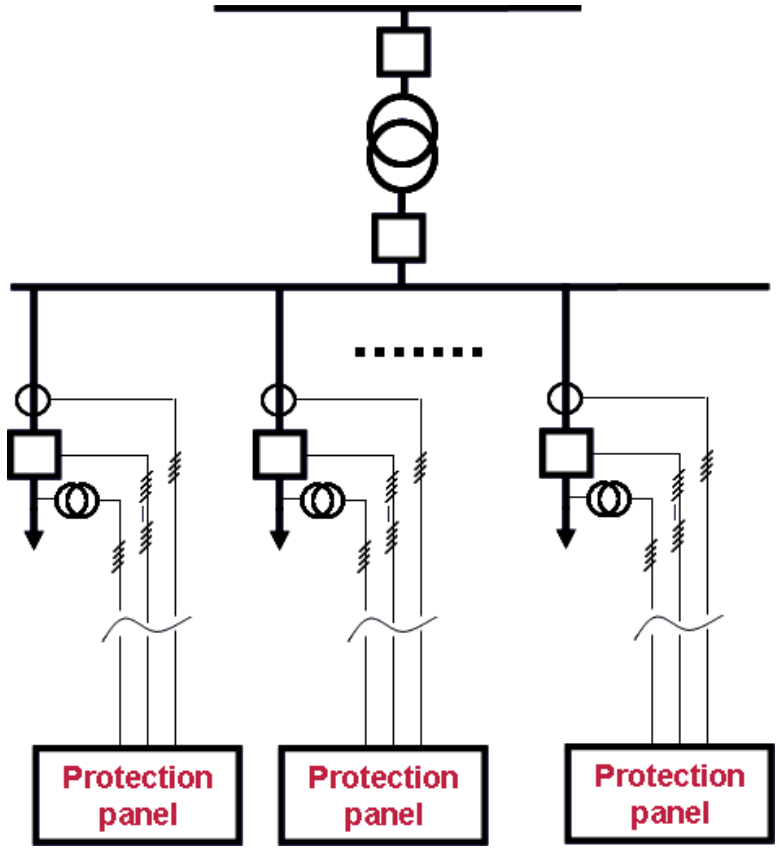
Digital Substation 2.0

For Air Insulated Switchgear

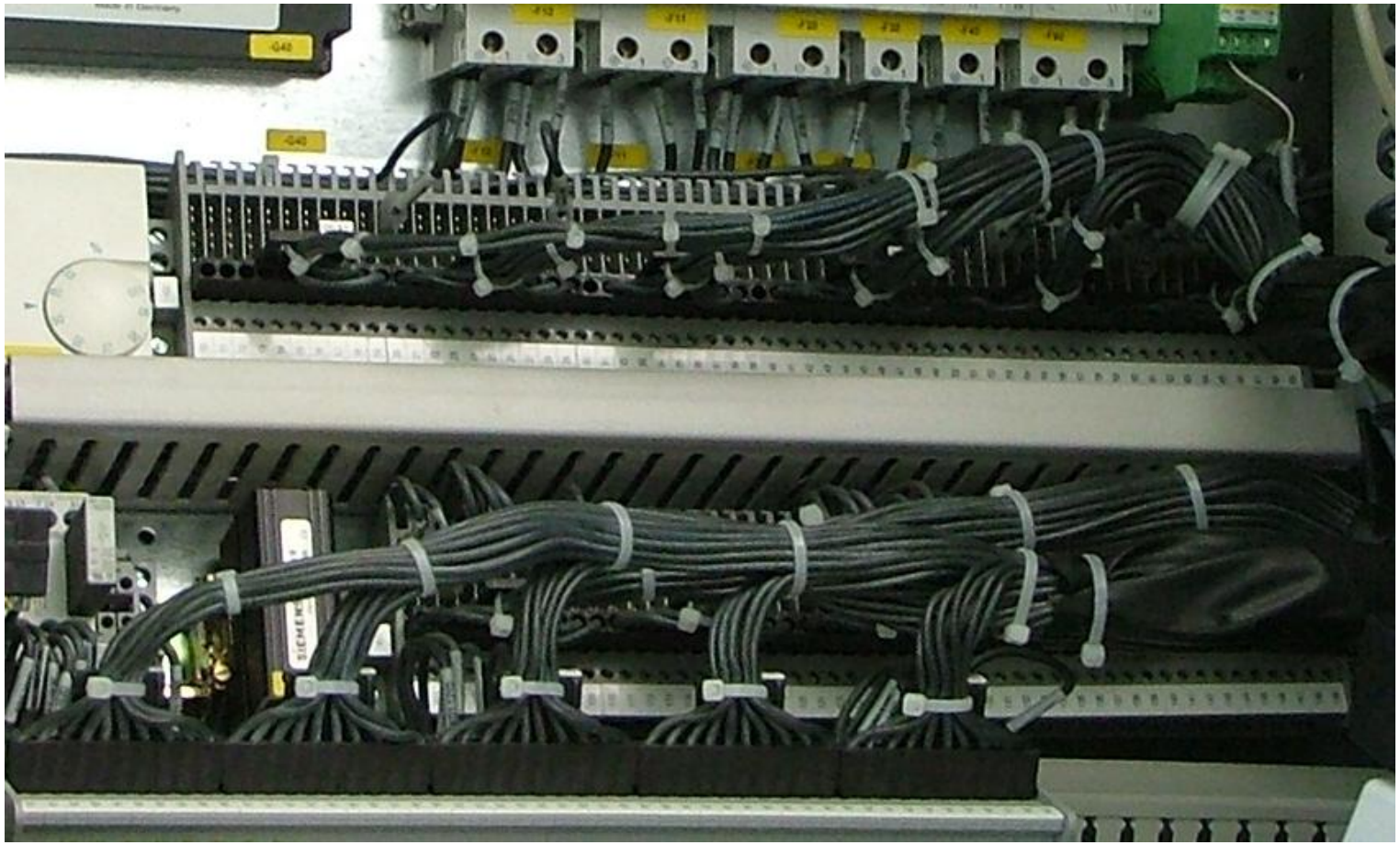
For Gas Insulated Switchgear



Conventional Substation



Conventional Substations

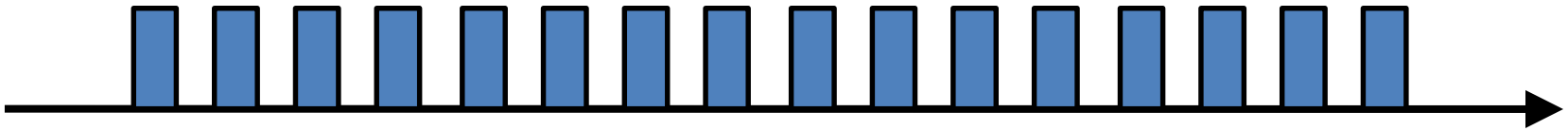


CT Explosion

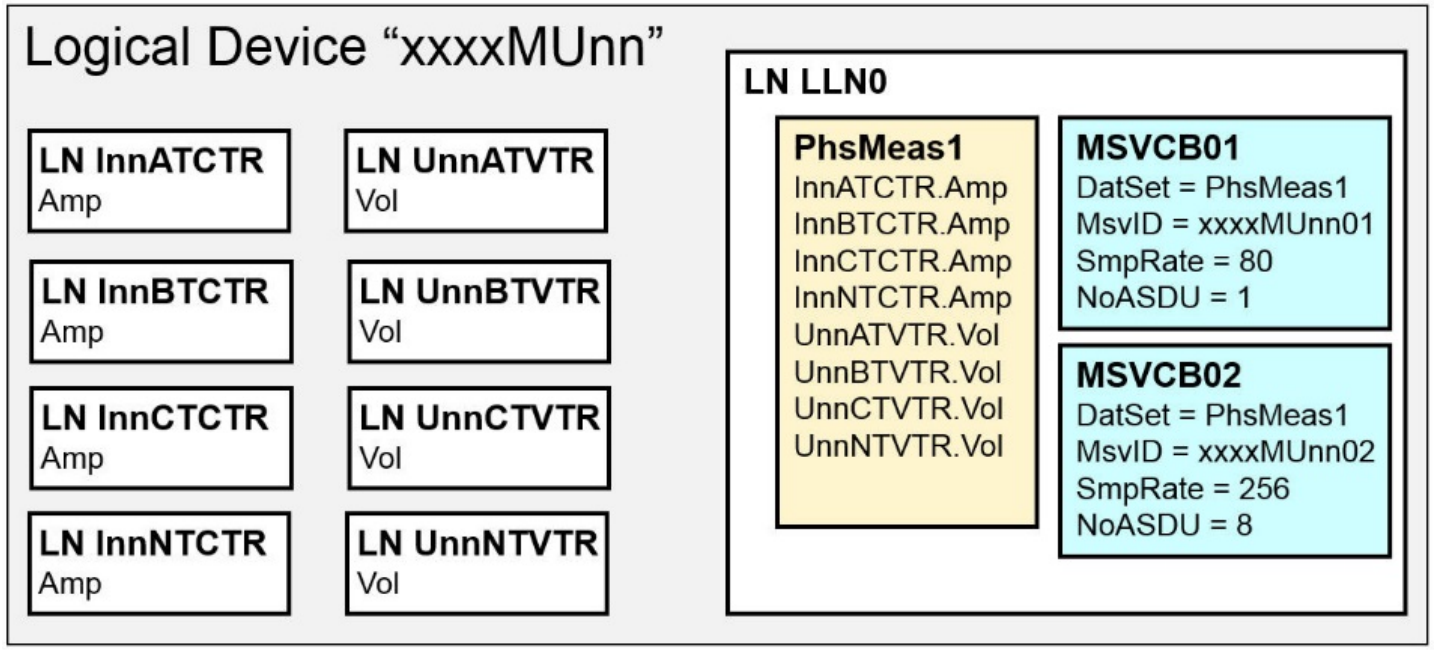
Wiring, wiring, wiring…

- **Safety issues** – equipment isolation, touch and step potentials, EMC
- **Copper** – raw material cost has increased 400% in 10 years
- **Material cost** – cubicle wiring and test costs, labour cost per wire end termination
- **Schematic design** - verification cost, excessive on-site work content
- **Civil work costs** – trays, troughing, cable access/egress…
- **Maintainability cost**

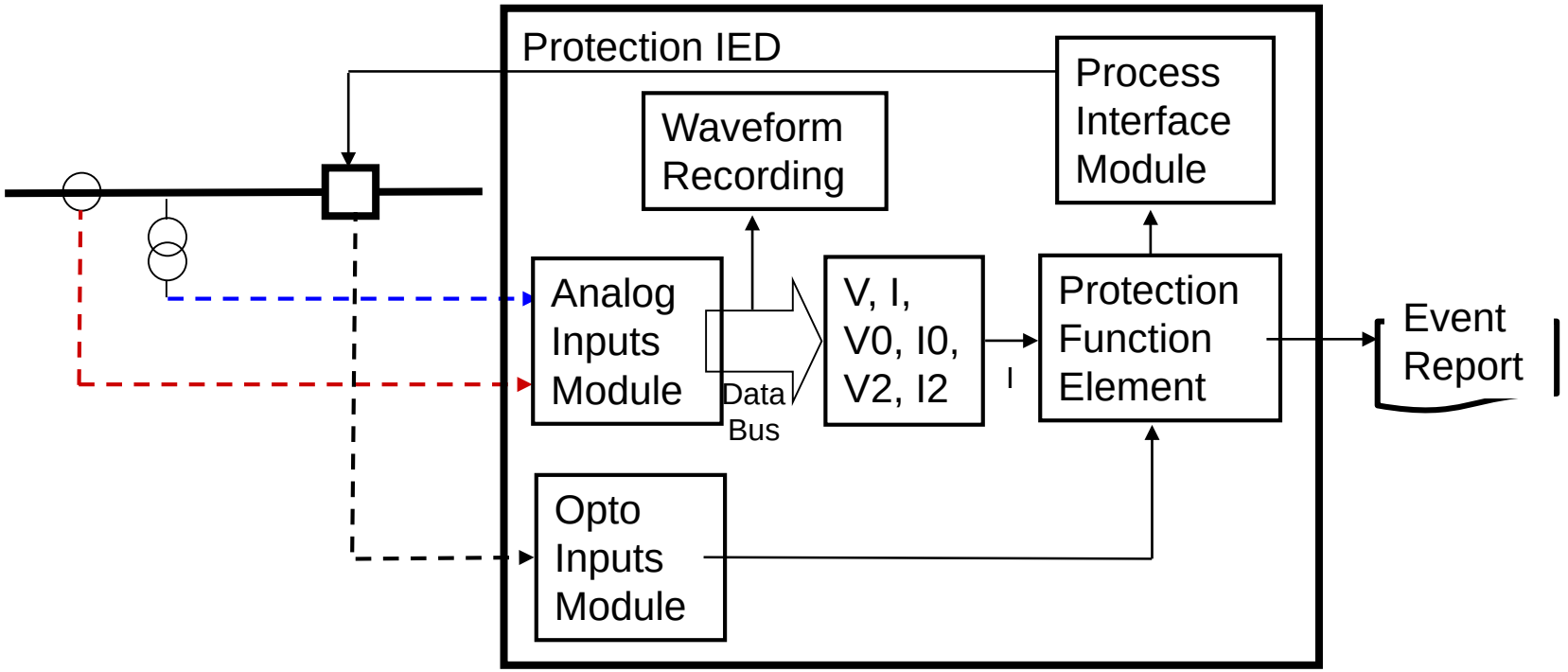
Sampled Values Communications



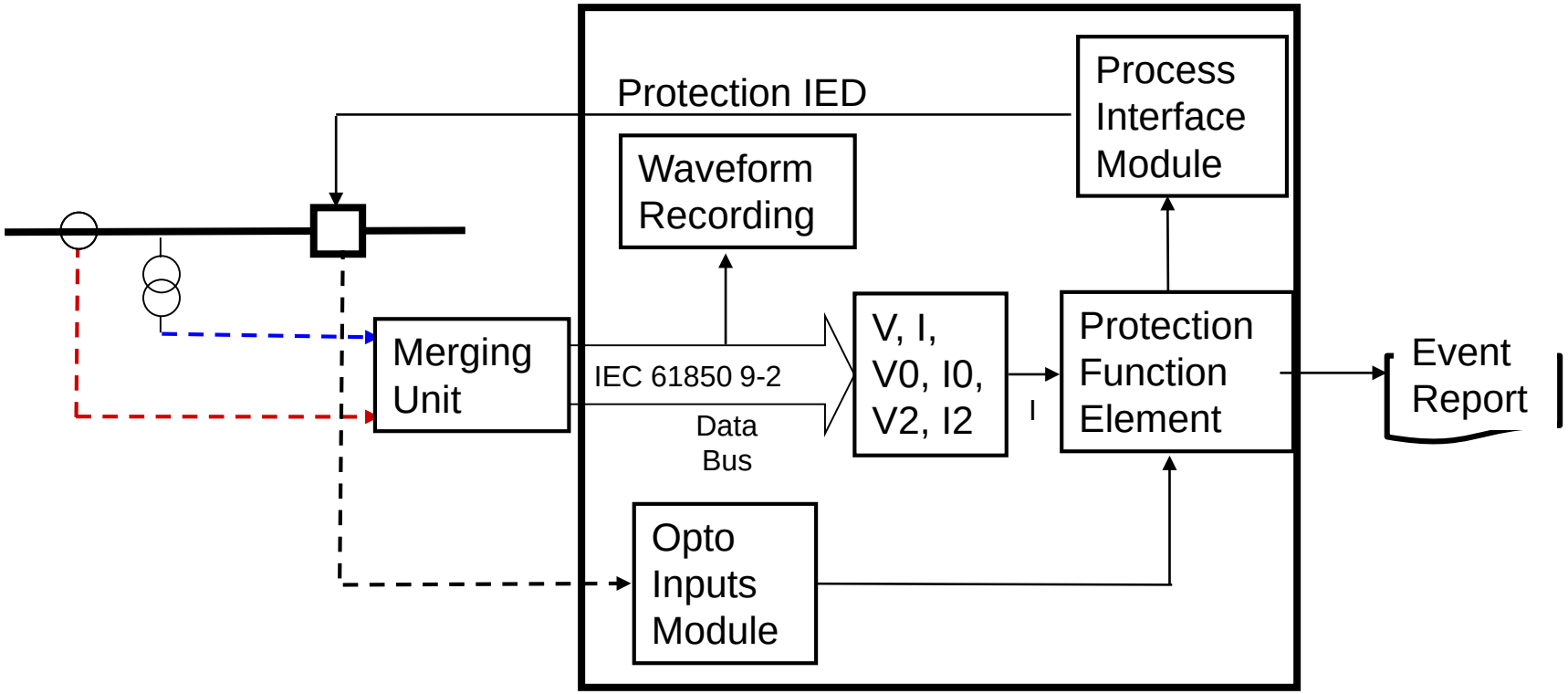
Merging Unit



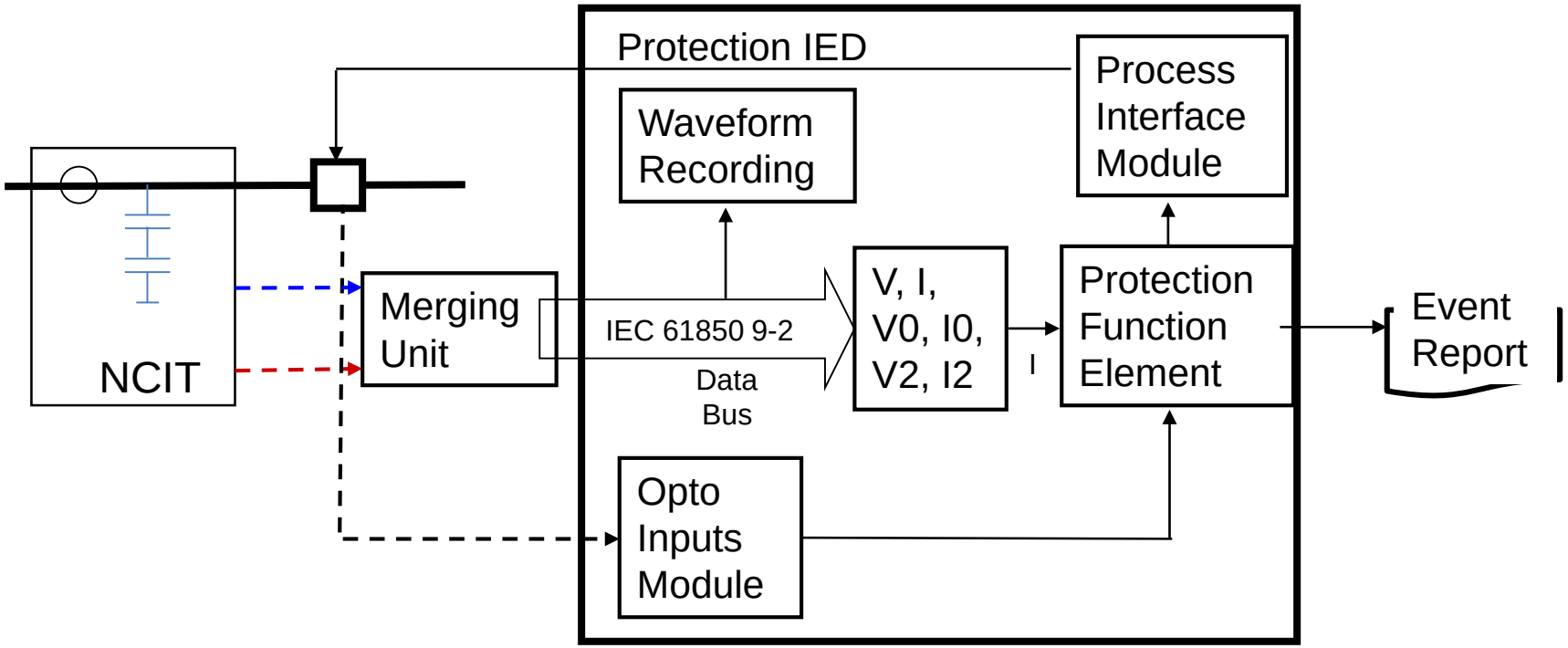
Conventional IED



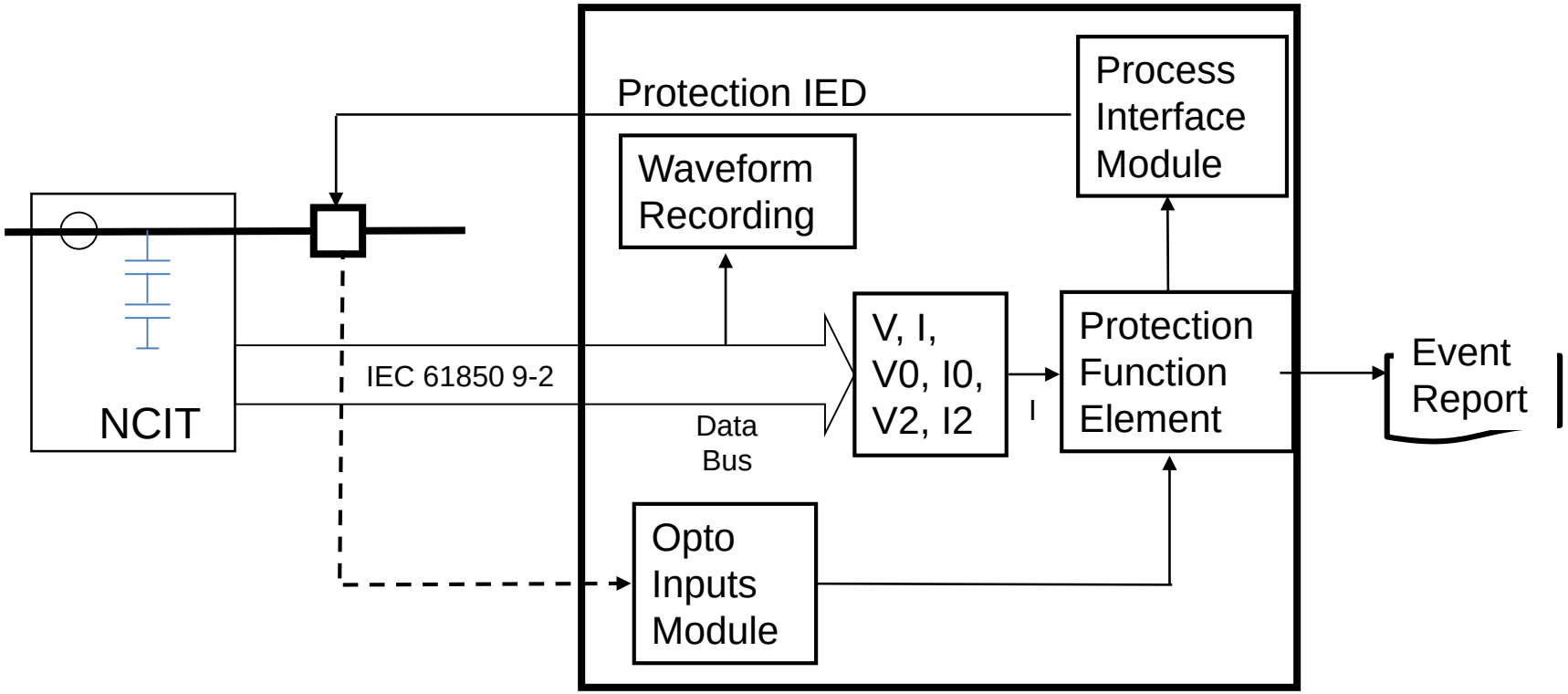
Stand Alone Merging Unit



NCIT with low level analog output



NCIT with embedded MU



Architecture Levels in a DS

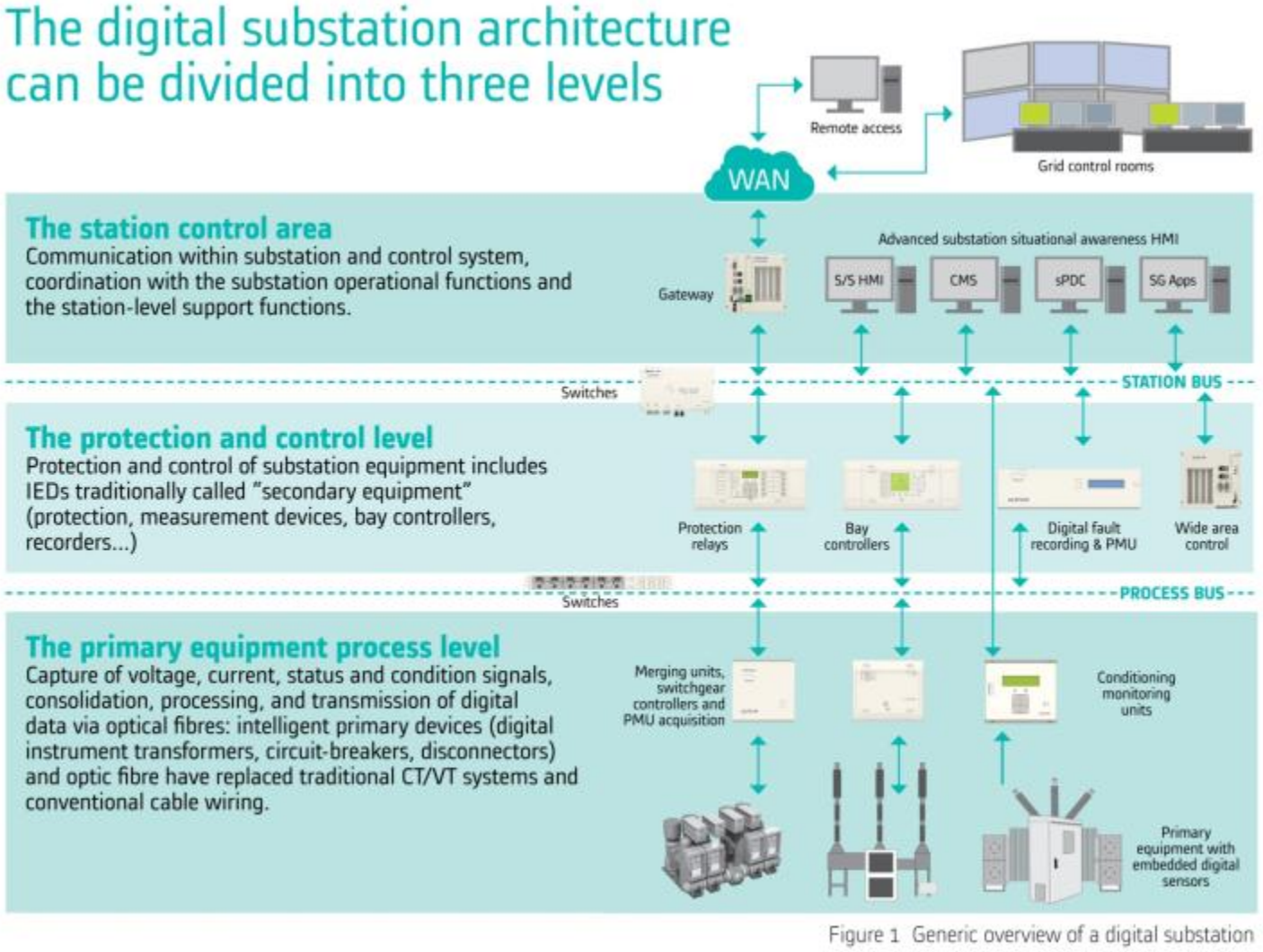
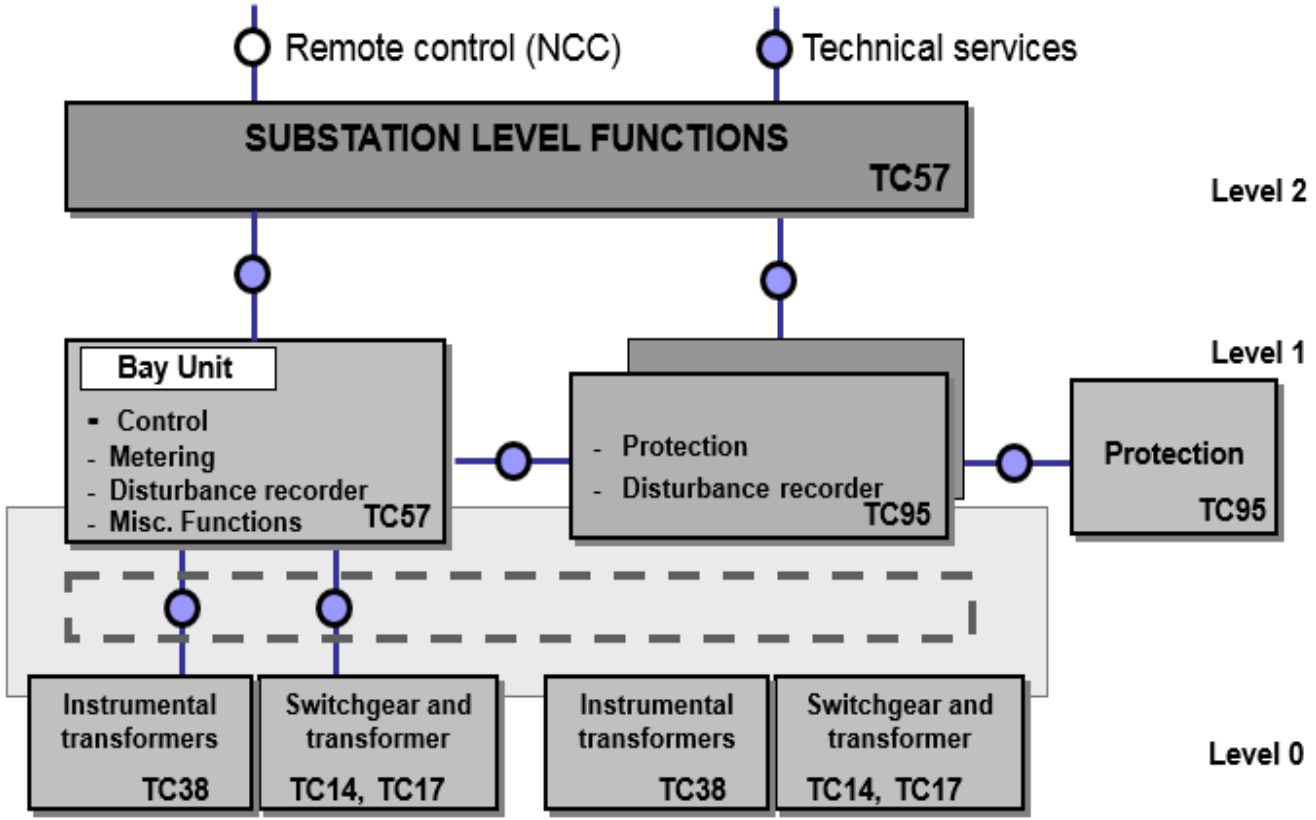


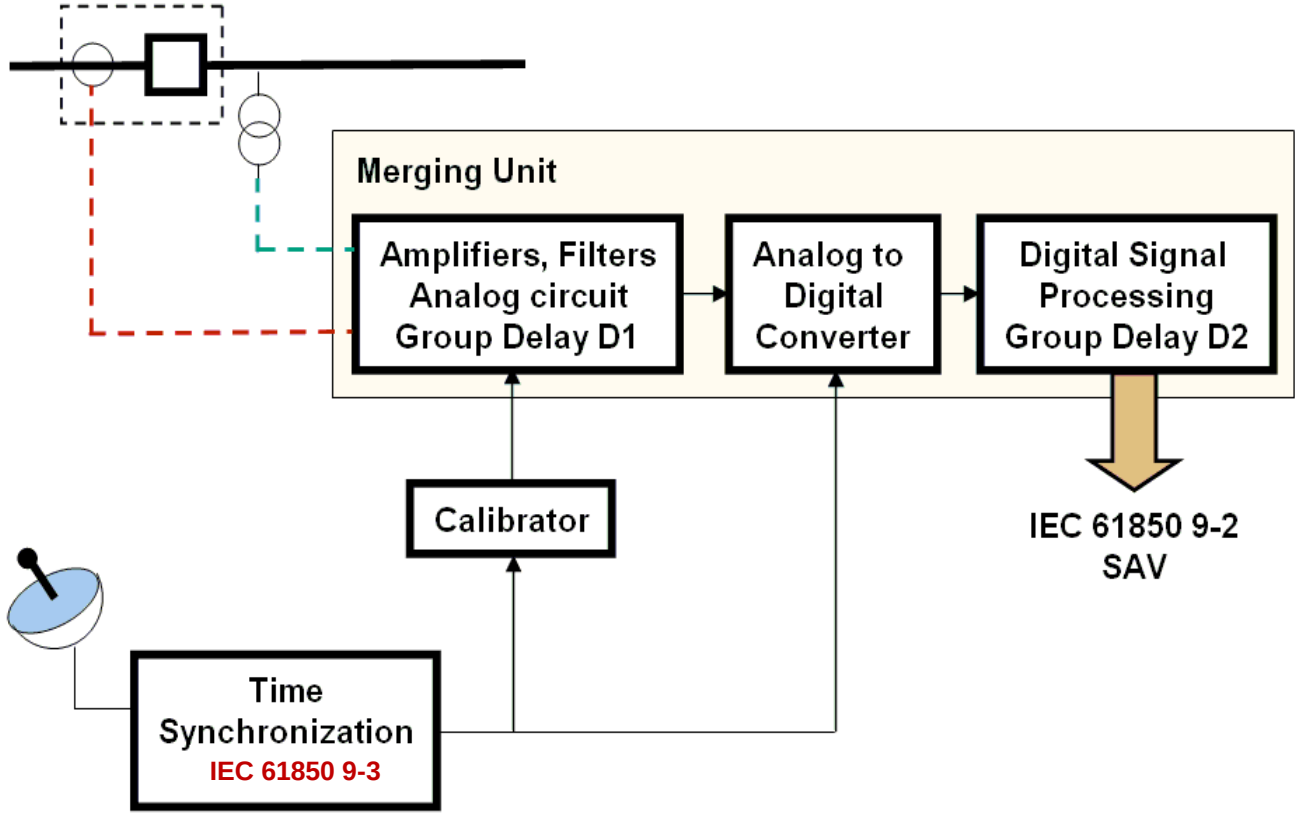
Figure 1 Generic overview of a digital substation

pacworld
PROTECTION, AUTOMATION & CONTROL WORLD

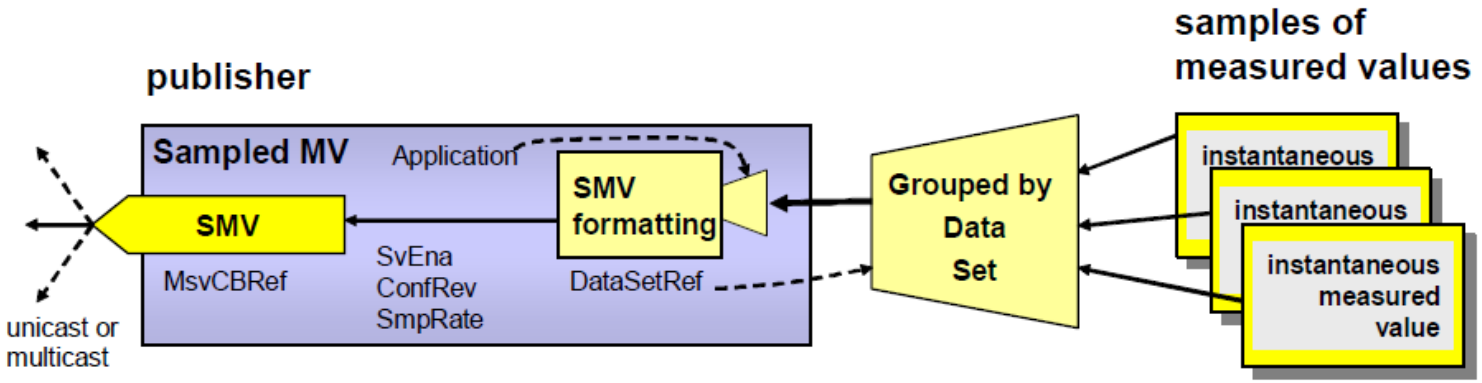
Process Bus Definition



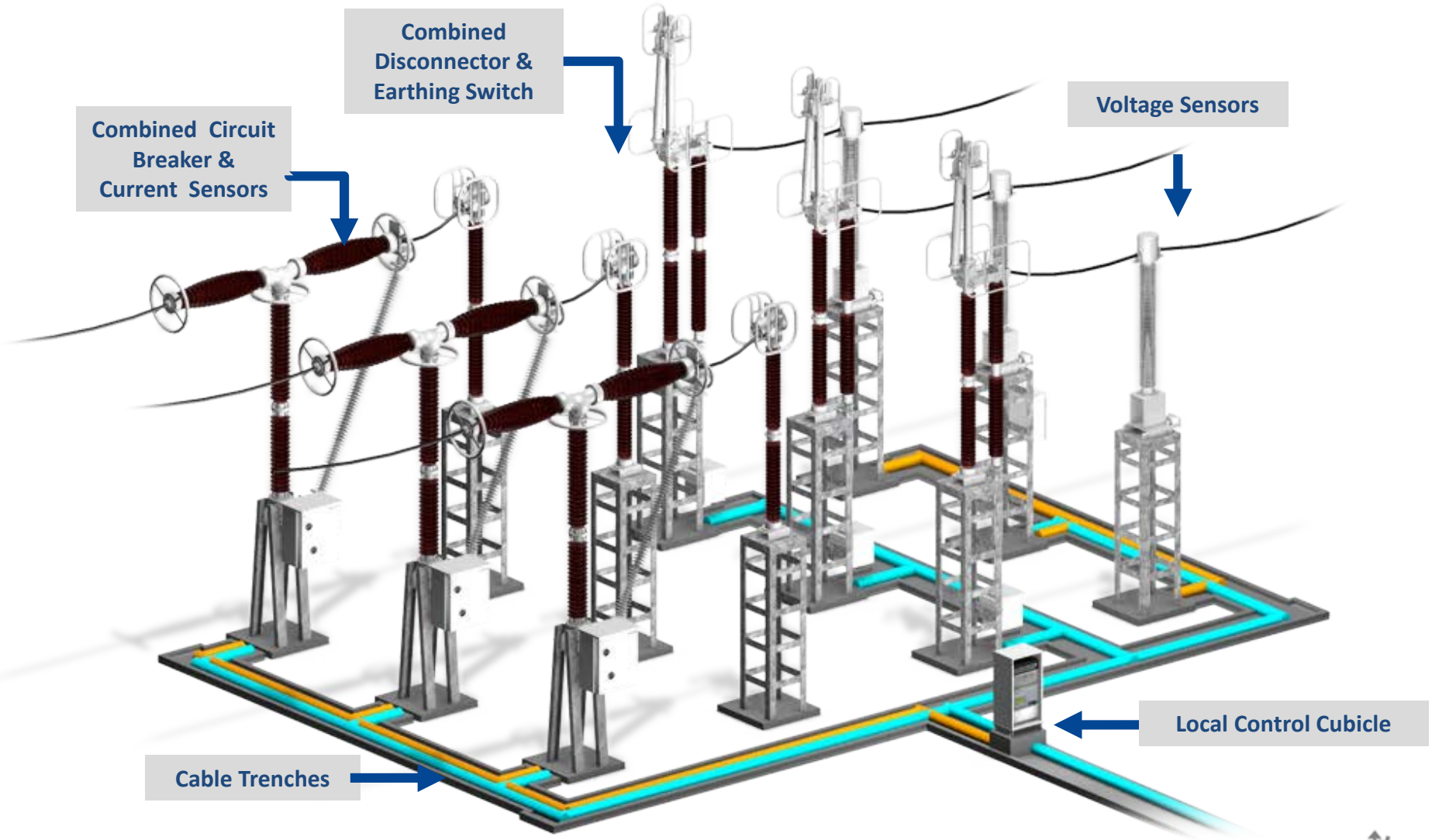
Merging Unit functionality



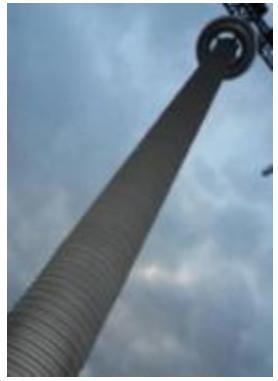
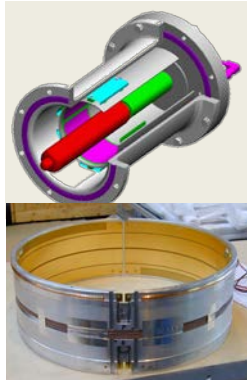
SMV Publishing



AIS Example - Footprint



NCITs for I & V

Application	AIS/GIS	AIS	GIS	GIS
Technology	Optical (Faraday)	Capacitive	Rogowski	Capacitive
	Current Measurement	Voltage Measurement	Current Measurement	Voltage Measurement
				


COSI-RECT


COSI-CEVT


COSI-CT-F3


COSI-CT

AIS Example: COSI-CT

Use the new options made possible by COSI-CT's light weight and absence of insulating fluids, to simplify your technical solution and re-invent your mounting arrangements.
Mount the COSI-CT directly on existing structures or associate it with other equipment.

COSI-CM 245kV
COSI-CT+ CVT

Significant savings:

- » Substation footprint,
- » Refurbishment works,
- » Foundations & supporting structures,
- » …

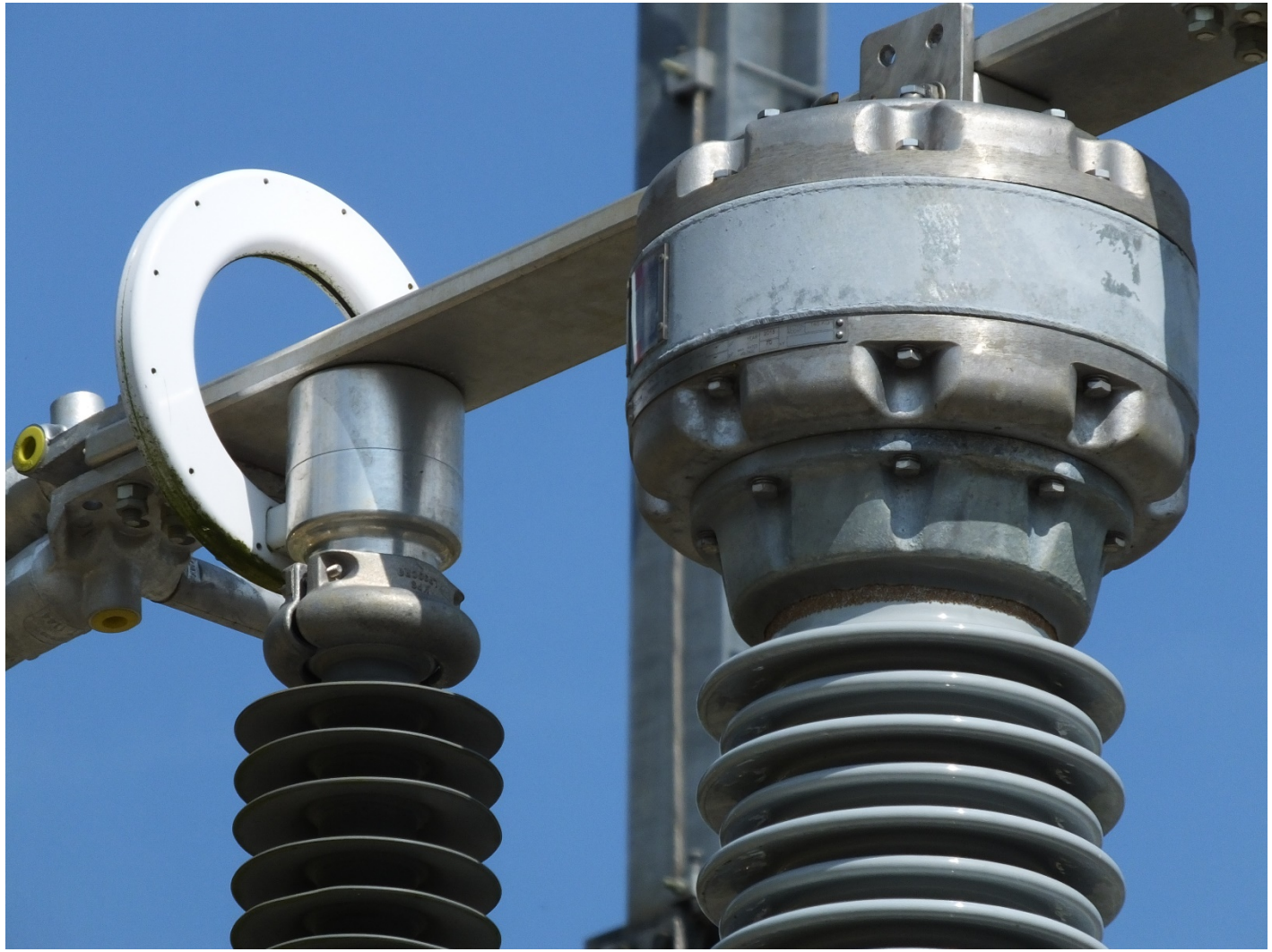
John Deer Wind Farm, USA
69 kV horizontal mounting

550kV CB-mounted COSI-CT

550kV CB
Alstom GL317

550kV
COSI-CT

Optical CT in France



Protection panel in France

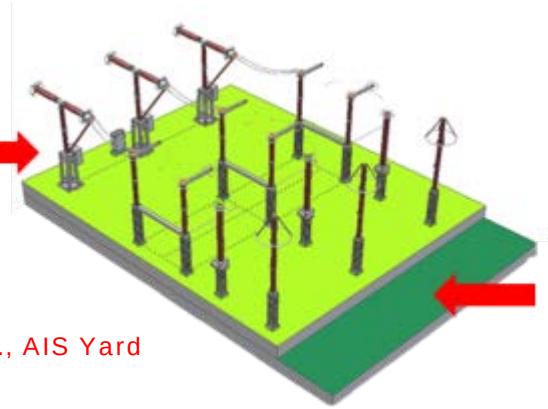
Merging Units in Peru

Digital Substation Drivers

1. Footprint Reduction

- **Primary equipment, AIS:** Sharing of steelwork and foundations
- **Primary equipment, GIS:** CT chamber size reduction with DIT, VT integration in bus-duct
- **Secondary equipment:** Panel size reduction: compact IEDs
- **Copper hardwiring replaced by fibre**

CB + CT



e.g., AIS Yard

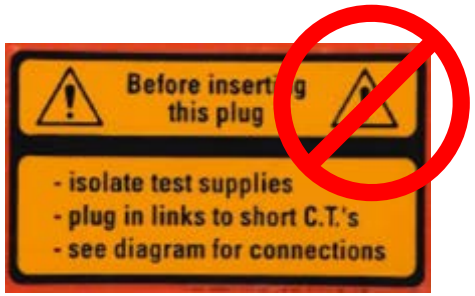
Panels

= Footprint reduction

up to 30%

2. Safety

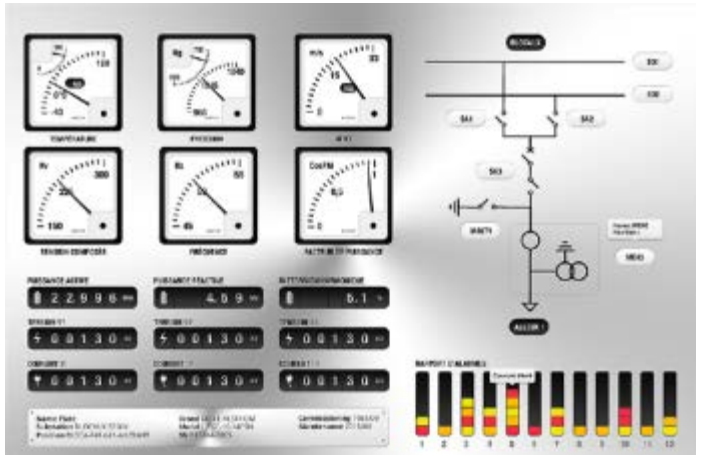
- **Primary equipment:** Oil-free instrument transformers
- **Secondary equipment:** Removal of CT secondary circuit, removal of need to change ratio taps



Care for employees and the public: No fatality risk

3. Situational Awareness Applications

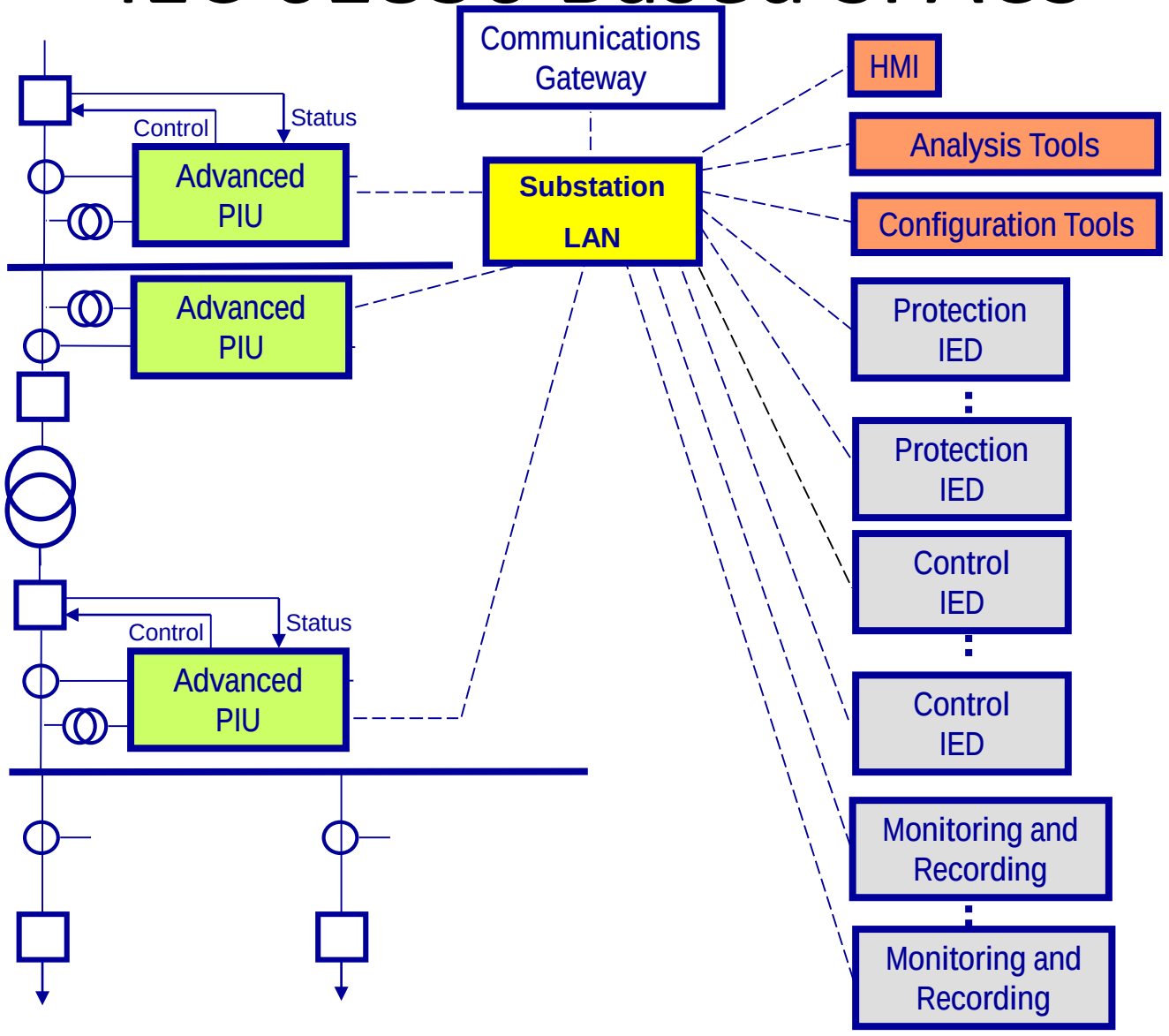
- Integrated condition monitoring, asset management and wide area control



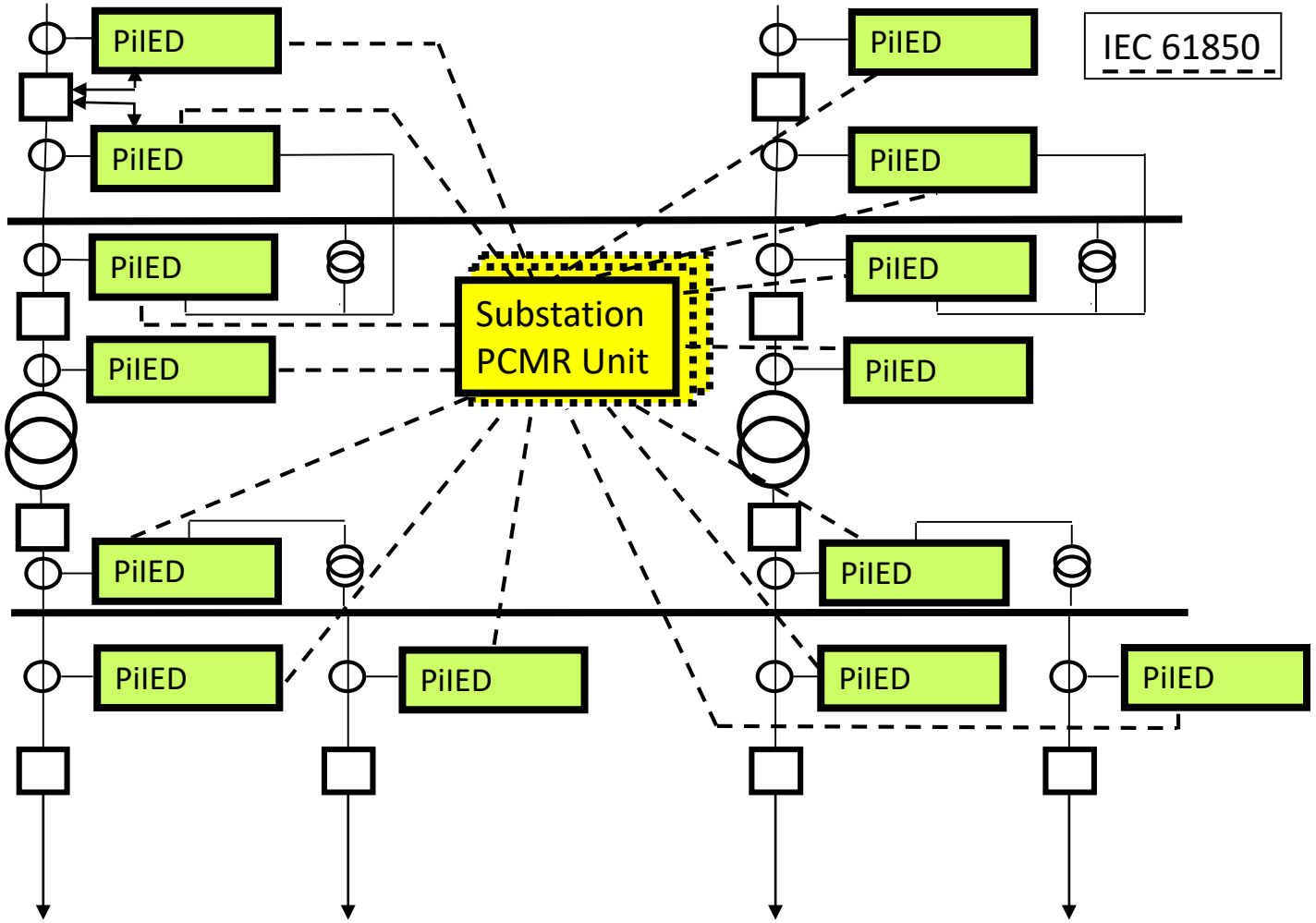
Clear alerts and dashboards

pacworld
PROTECTION, AUTOMATION & CONTROL WORLD

IEC 61850 Based SPACS

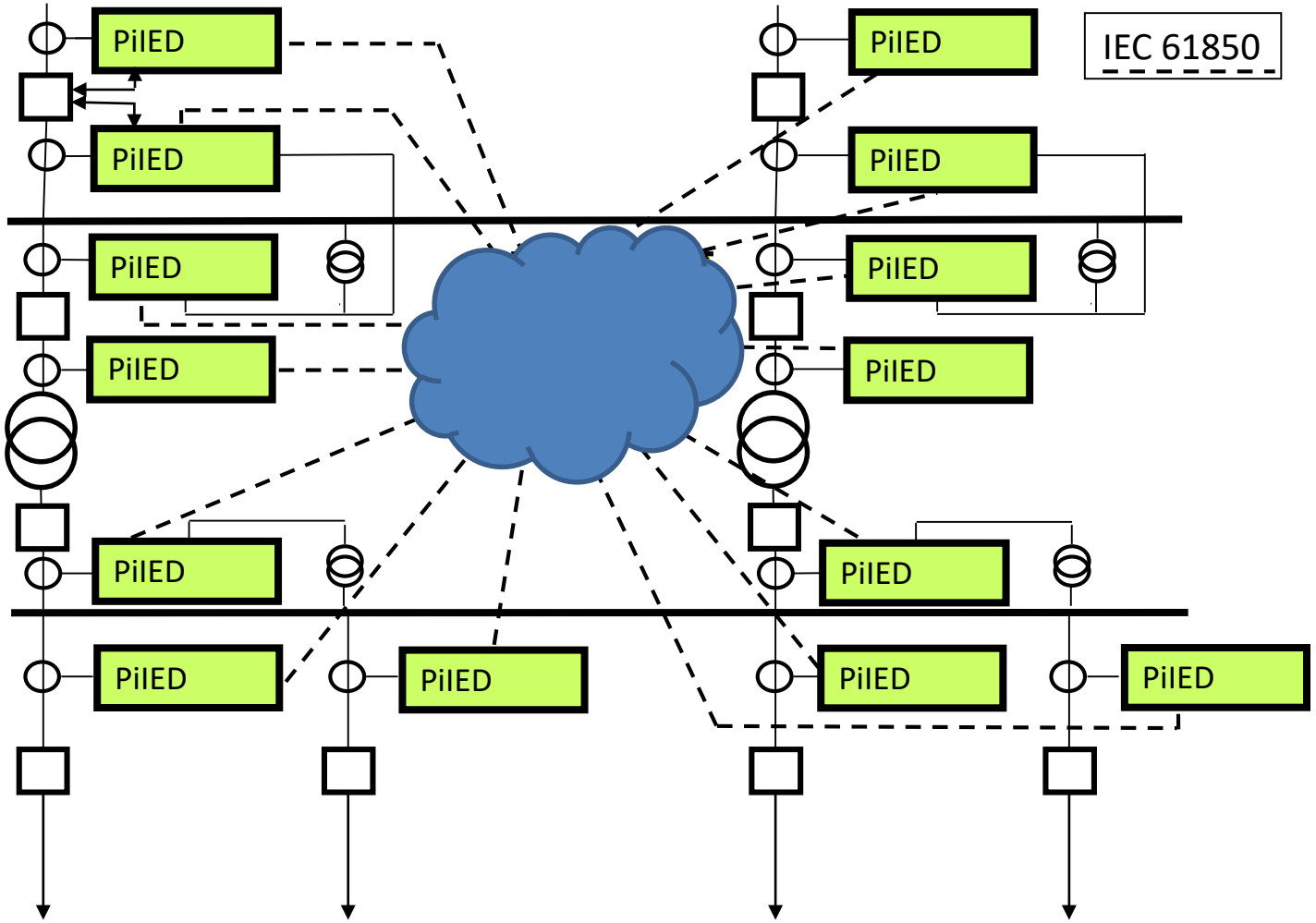


Centralized SPACS



Centralized Protection

Future SPACS

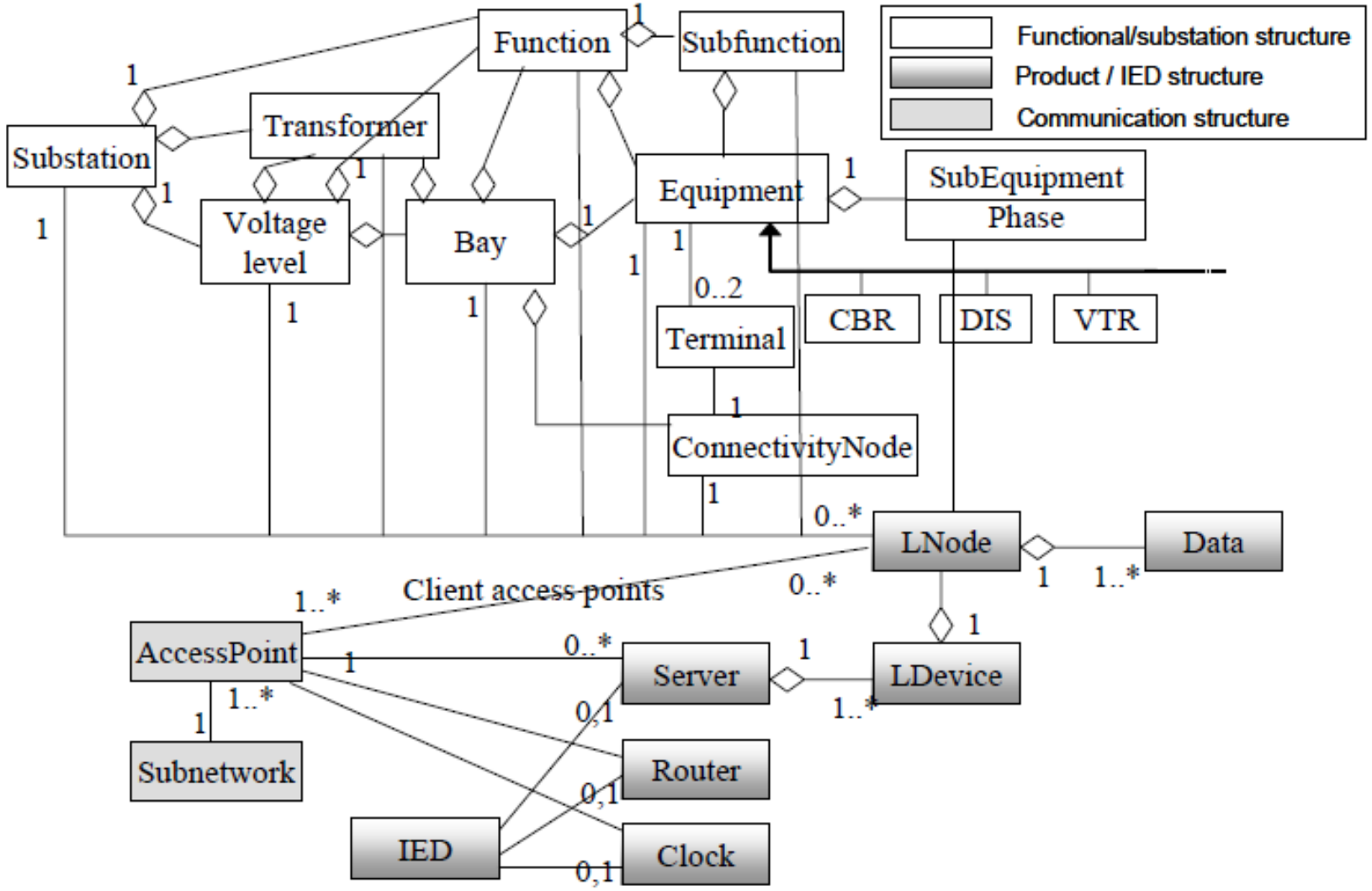


Future SPACS

SCL Files

- Substation Specification Description ***.SSD**
- IED Capability Description ***.ICD**
- Substation Configuration Description ***.SCD**
- Instantiated IED Description ***.IID**
- Configured IED Description ***.CID**
- System interface Exchange Description ***.SED**
- *IED Specification Description *.ISD*

SCL Object Model



Reduced Installation Costs

- Reduced costs due to the replacement of hundreds or even thousands control cables with a limited number of fiber optic cables
- Reduced costs due to the replacement of the wiring of hundreds of copper wires to the panels' terminal blocks and then from the terminal blocks to the relay terminals with the plugging in of a few pairs of fiber cables

Reduced Installation Costs

- Reduced costs due to the requirements for testing of all hard wired interfaces versus the testing of the GOOSE messages based on advanced software tools
- Reduced costs due to smaller foundation size
- Reduced costs due to smaller substation yard size
- Reduced transportation costs

Other Benefits (reduced costs)

- Improved safety
- Reduced probability for CT saturation or no CT saturation
- Improved flexibility
- Reduced maintenance
- Improved interoperability
- Improved reliability
- Remote testing

PAC World September 2018

Remote Testing

Remote Testing