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Lecture 14

Course wrap up & Smartgrid Architectures

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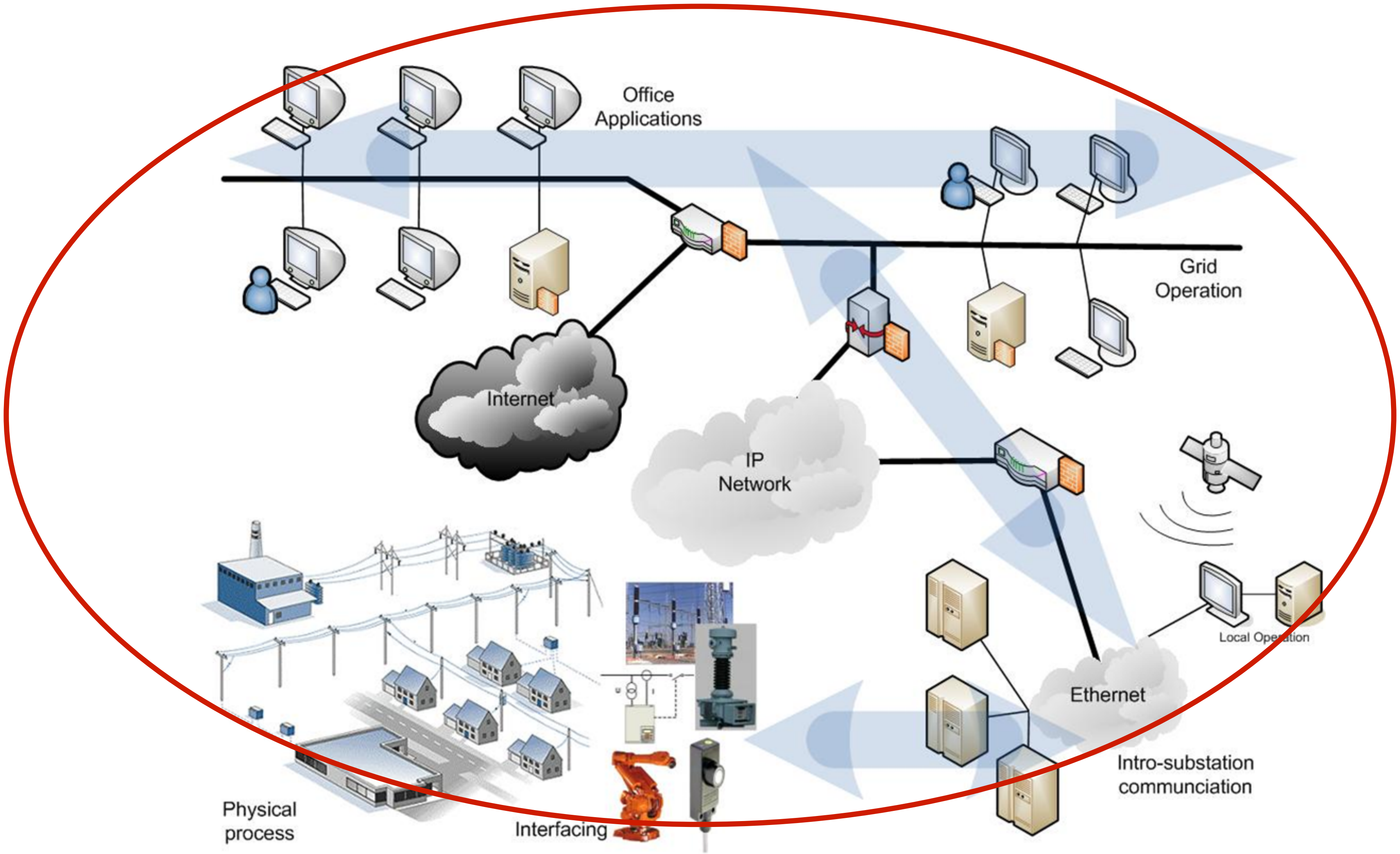
Course map


Office
Applications
Grid
Operation
Internet
IP
Network
Local Operation
Ethernet
Intro-substation
communciation
Physical
process
Interfacing

Outline of the lecture

- Course Wrap-up
  - Local systems
  - Communication
  - Control room applications
- System Architecture – introduction
  - Architecture Models – why?
  - Architecture Models – what?
  - SGAM - Smartgrid Reference Architecture Model
- Smartgrid Architecture Example

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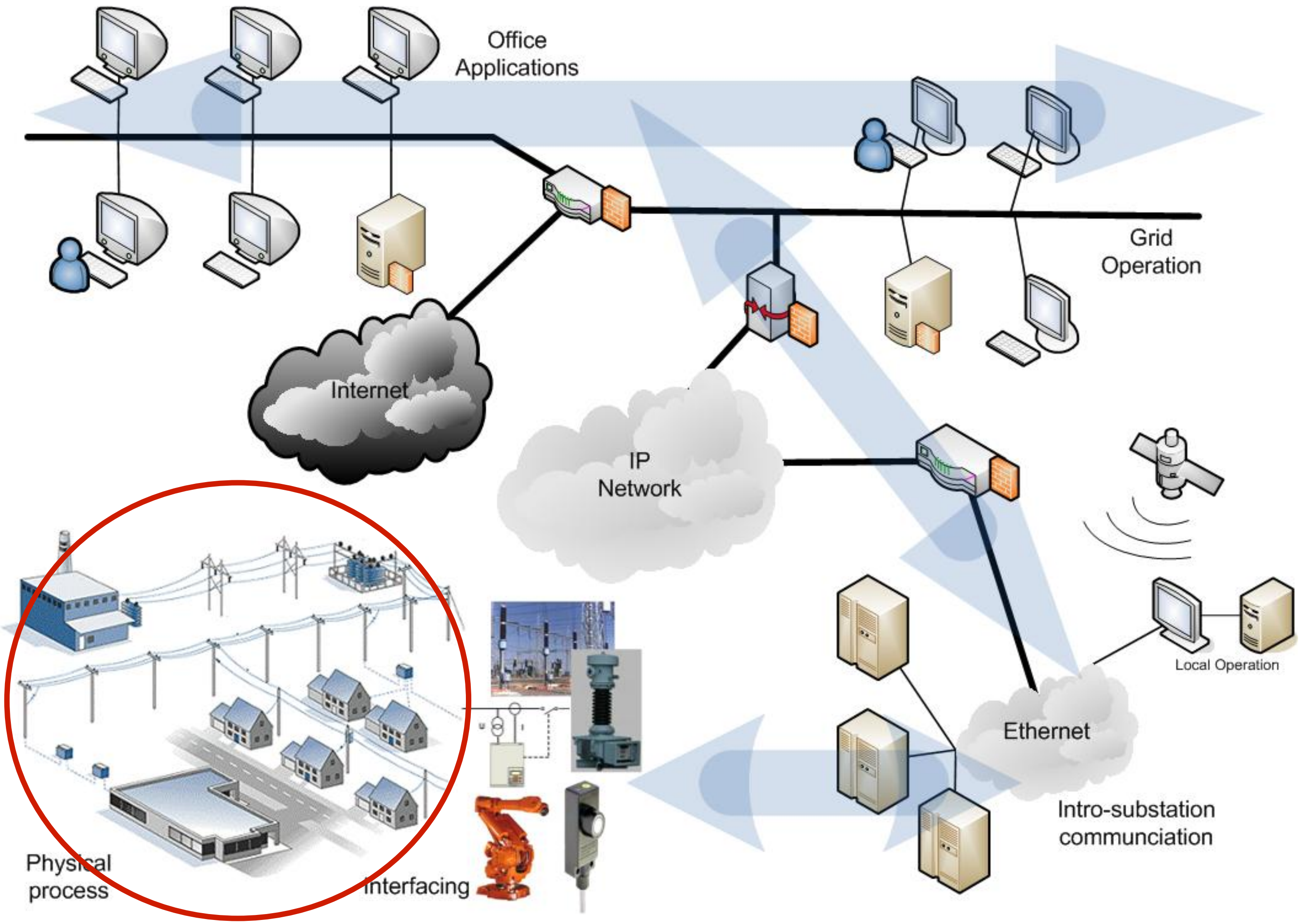
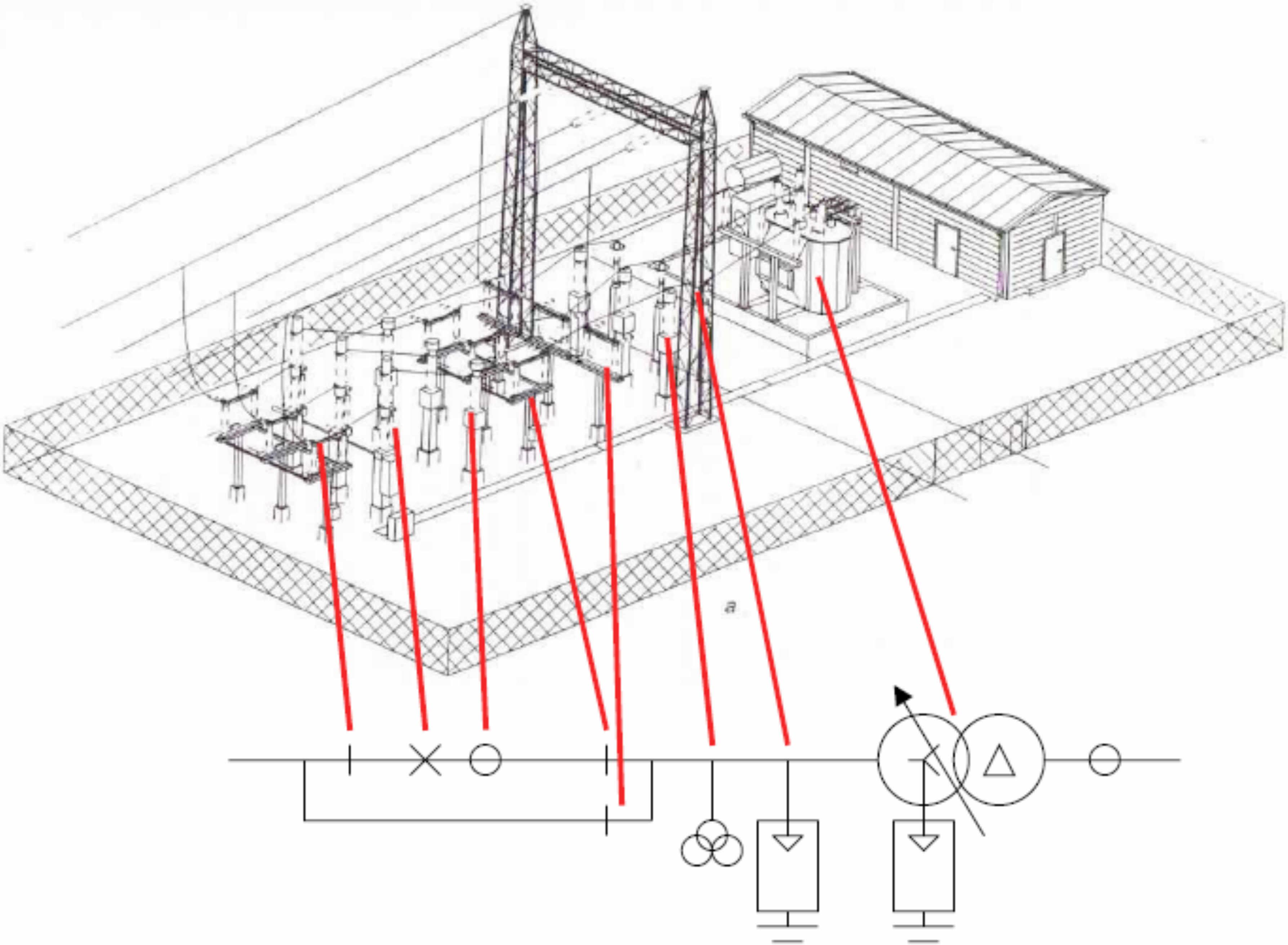
Course map





Source: Lakervi & Holmes

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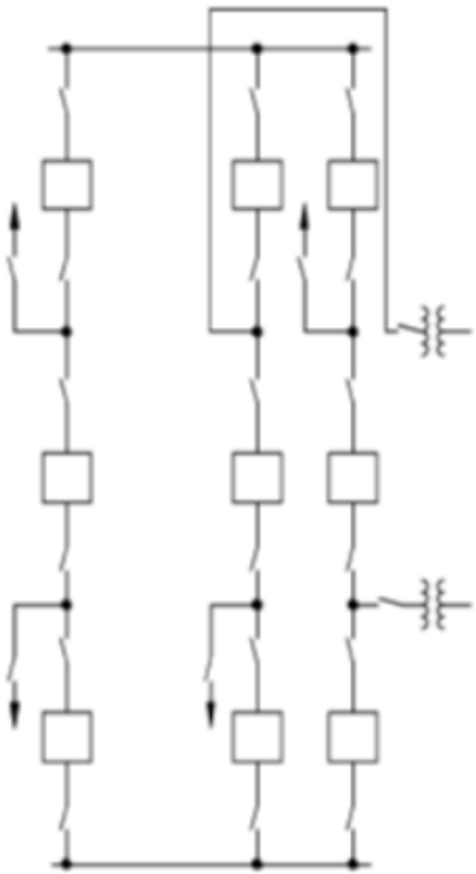
Breaker & a half configuration



Advantages:

• Flexible operation and high reliability

• Isolation of either bus without service disruption

• Isolation of any breaker for maintenance without service disruption

• Double feed to each circuit

• Bus fault does not interrupt service to any circuits

• All switching is done with circuit breakers

Disadvantages:

• One-and-a-half breakers needed for each circuit

• More complicated relaying as the center breaker has to act on faults for either of the 2 circuits it is associated with

• Each circuit should have its own potential source for relaying

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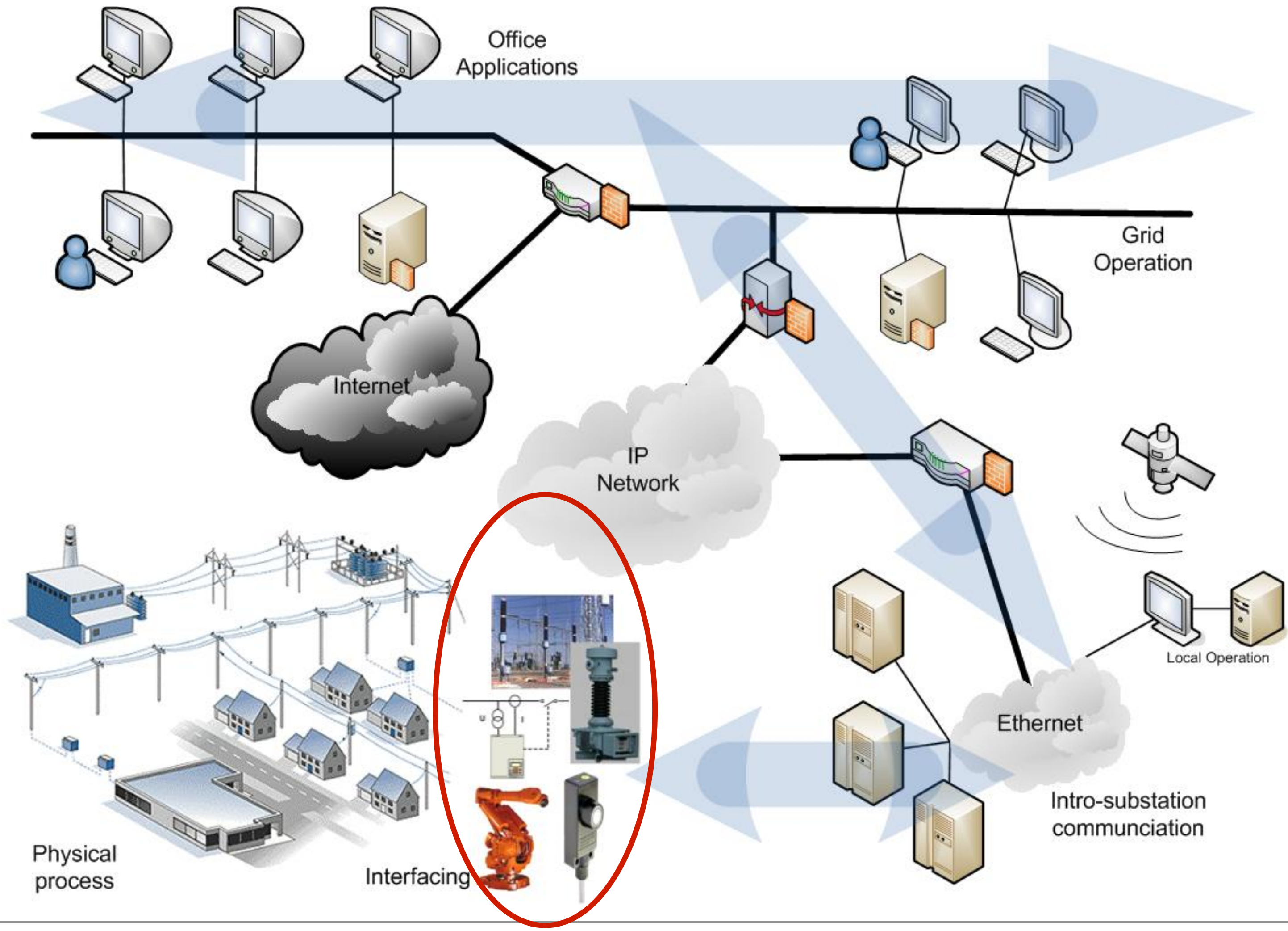
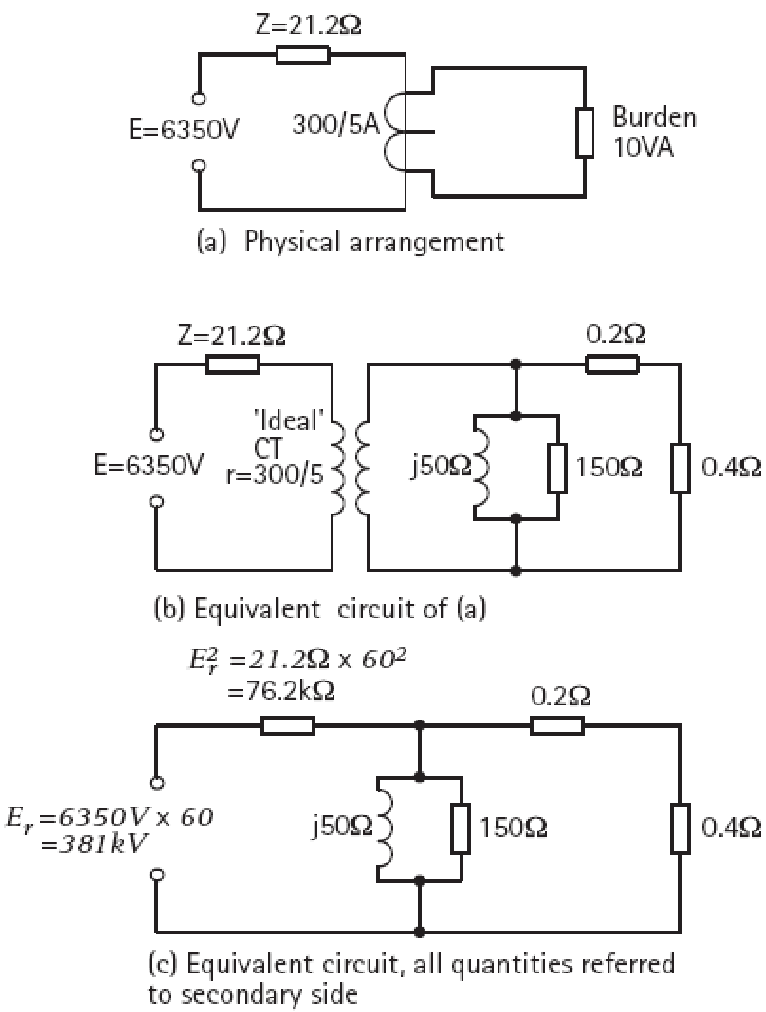
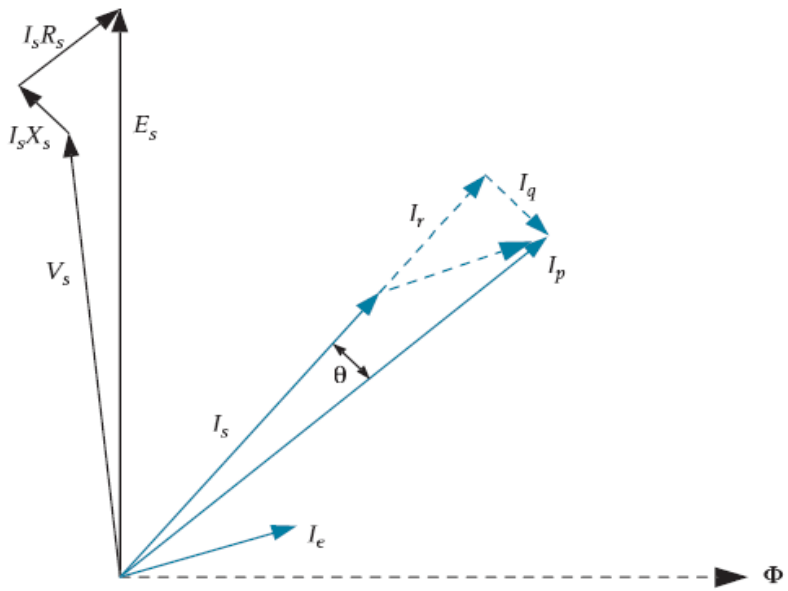


CT – Equivalent Model





E_s = Secondary induced e.m.f.
V_s = Secondary output voltage
I_p = Primary current
I_s = Secondary current
θ = Phase angle error
Φ = Flux
I_sR_s = Secondary resistance voltage drop
I_sX_s = Secondary reactance voltage drop
I_e = Exciting current
I_r = Component of I_e in phase with I_s
I_q = Component of I_e in quadrature with I_s

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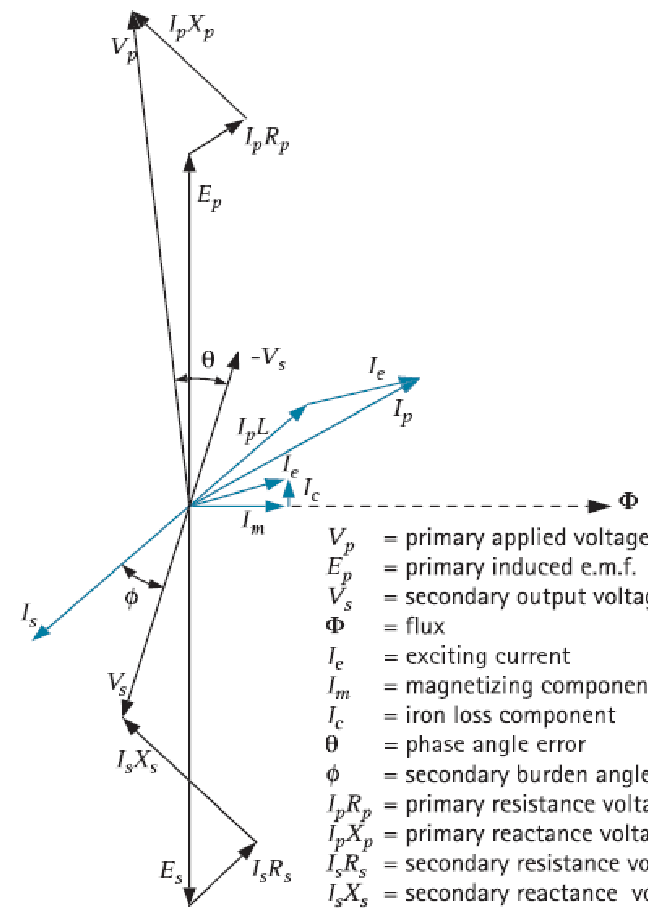
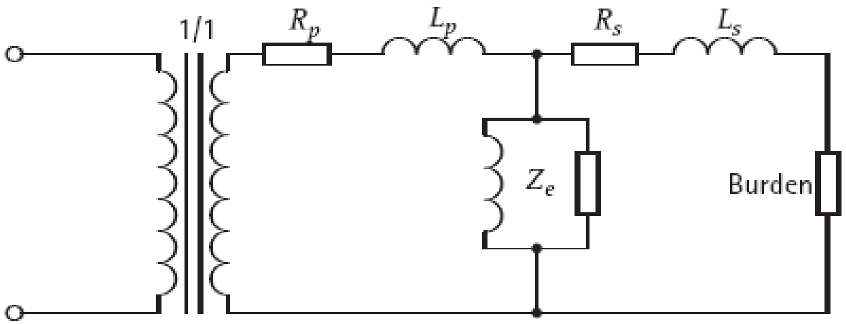
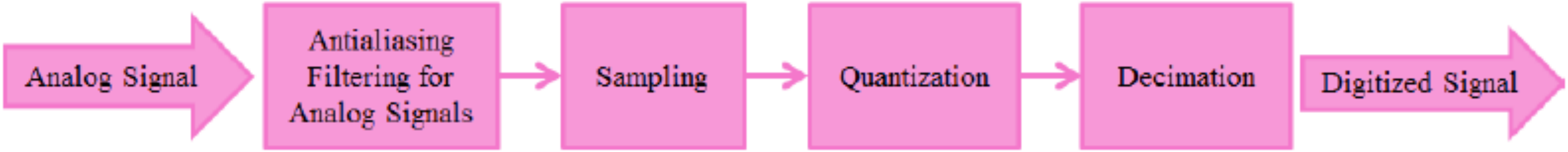
Equivalent Model



V_p = primary applied voltage
E_p = primary induced e.m.f.
V_s = secondary output voltage
Φ = flux
I_e = exciting current
I_m = magnetizing component
I_c = iron loss component
θ = phase angle error
ϕ = secondary burden angle
I_pR_p = primary resistance voltage drop
I_pX_p = primary reactance voltage drop
I_sR_s = secondary resistance voltage drop
I_sX_s = secondary reactance voltage drop
I_s = secondary current
I_pL = load component of primary current
I_p = primary current



A/D conversion



- Accuracy determined by
  - Bit resolution, Least Significant Bit
  - Non-linearity due to imperfections.
  - Sampling & Aliasing

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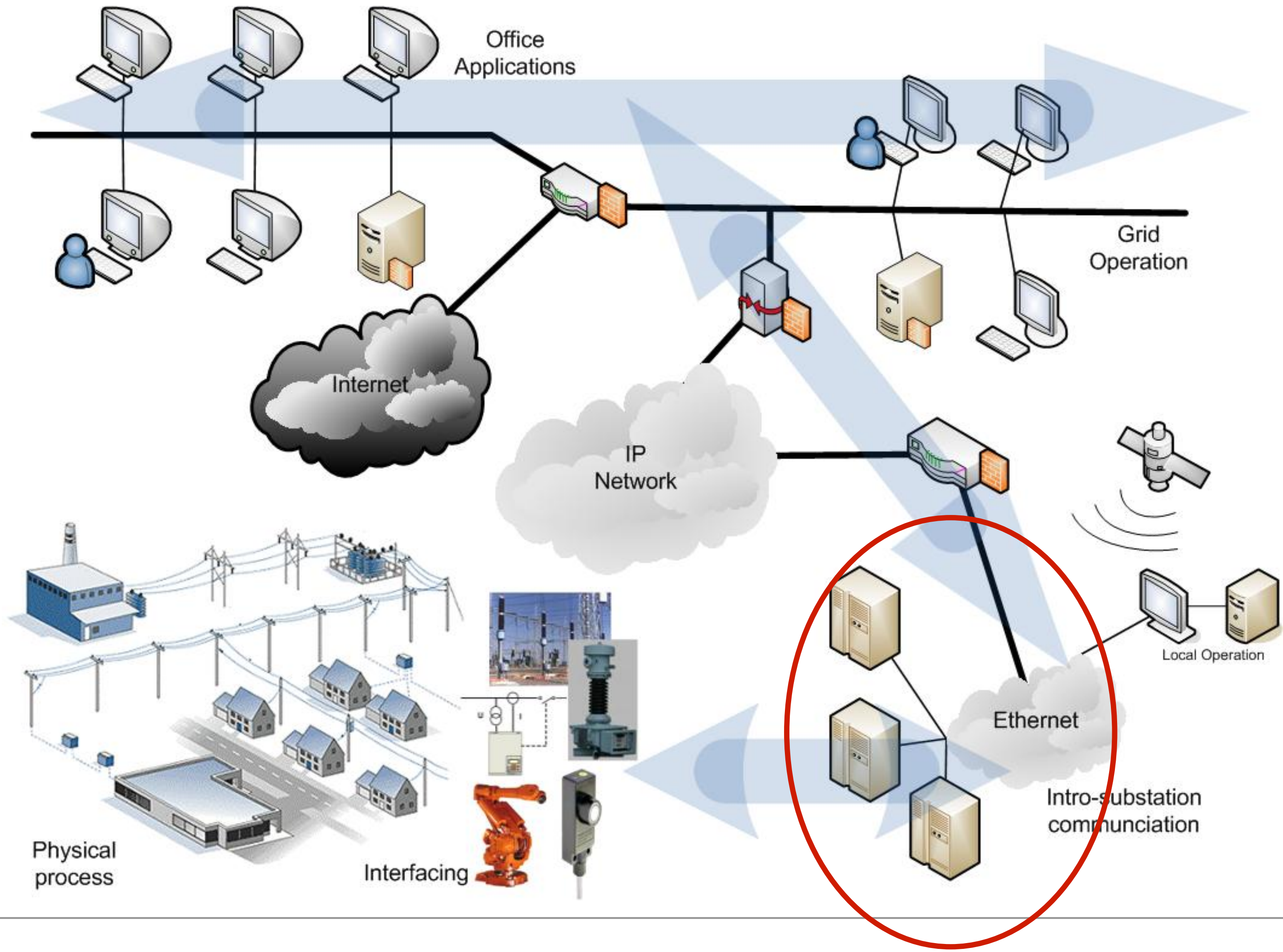
Course map



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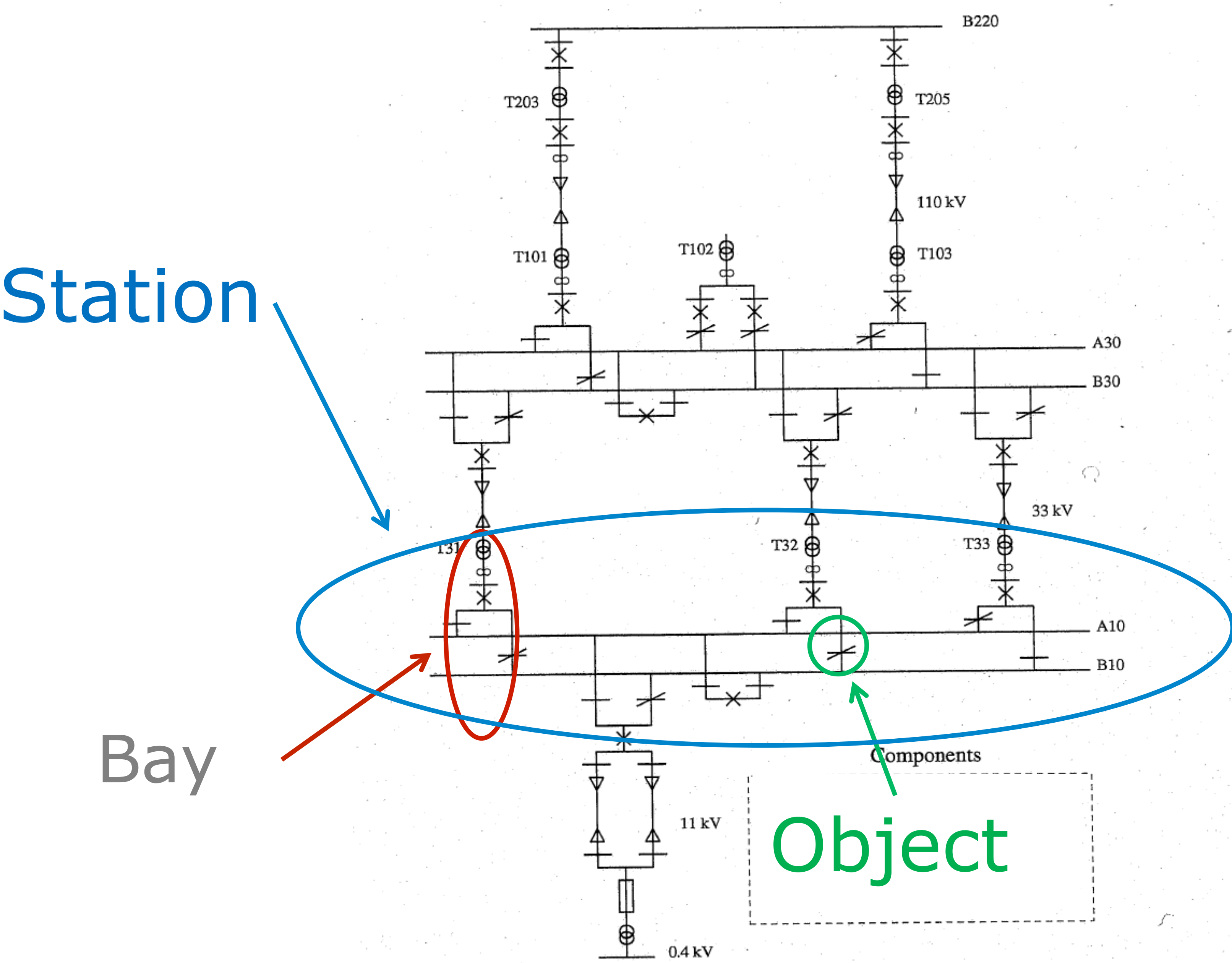


Basic SAS Architectures - 3

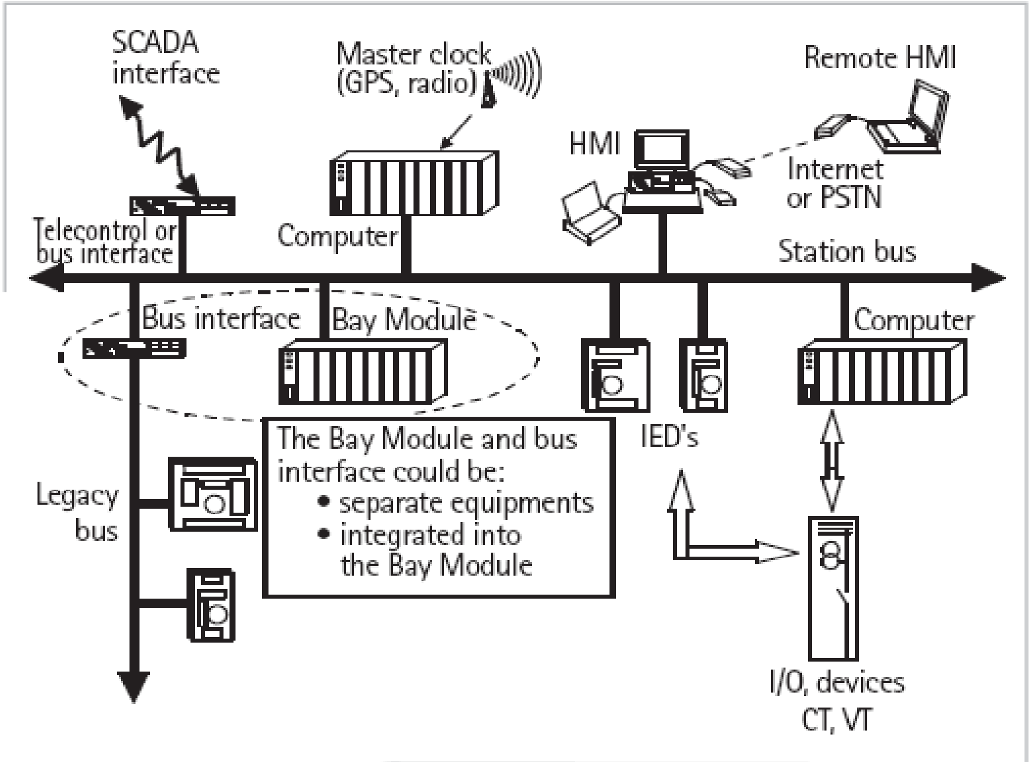
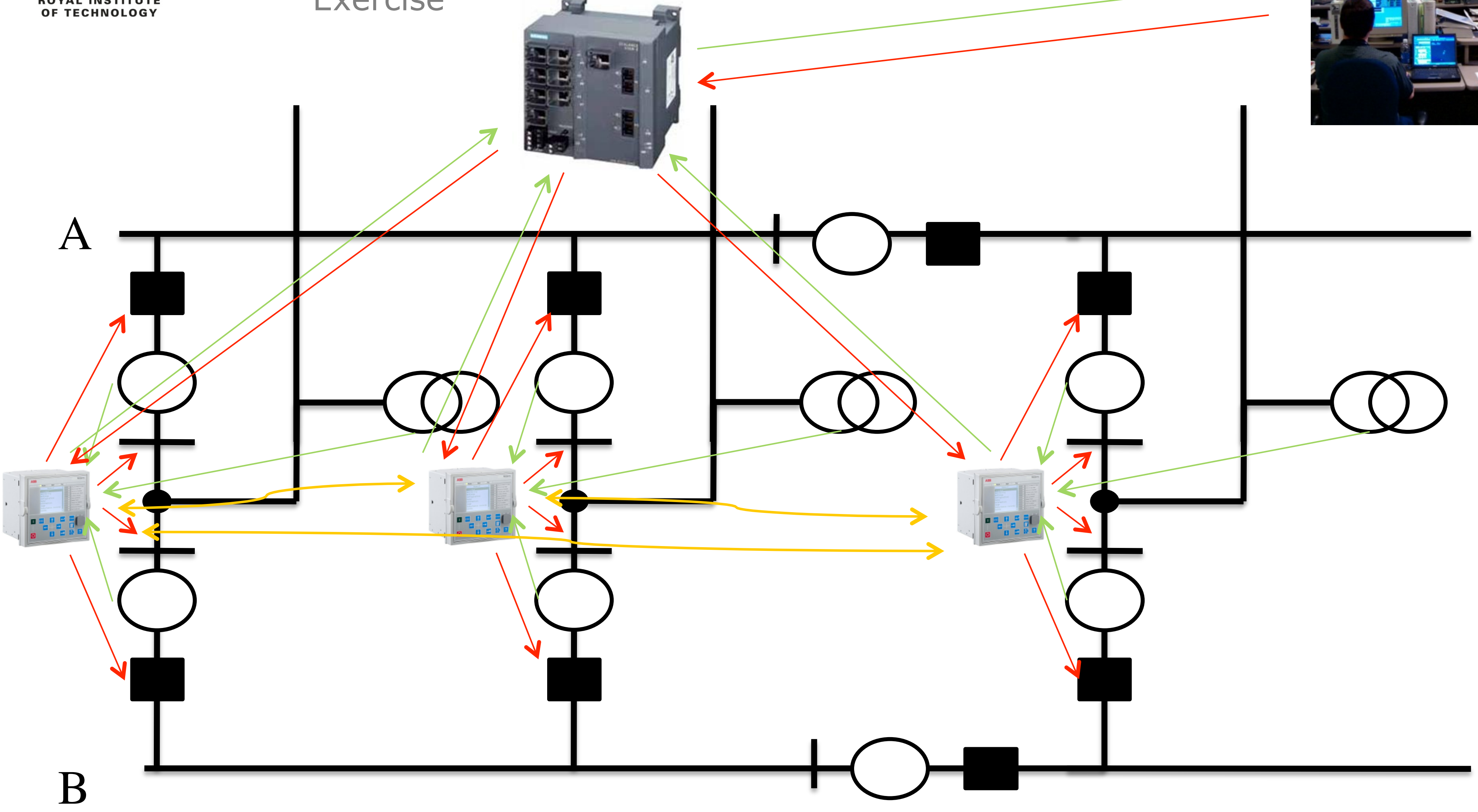


Figure 24.4: Decentralised topology

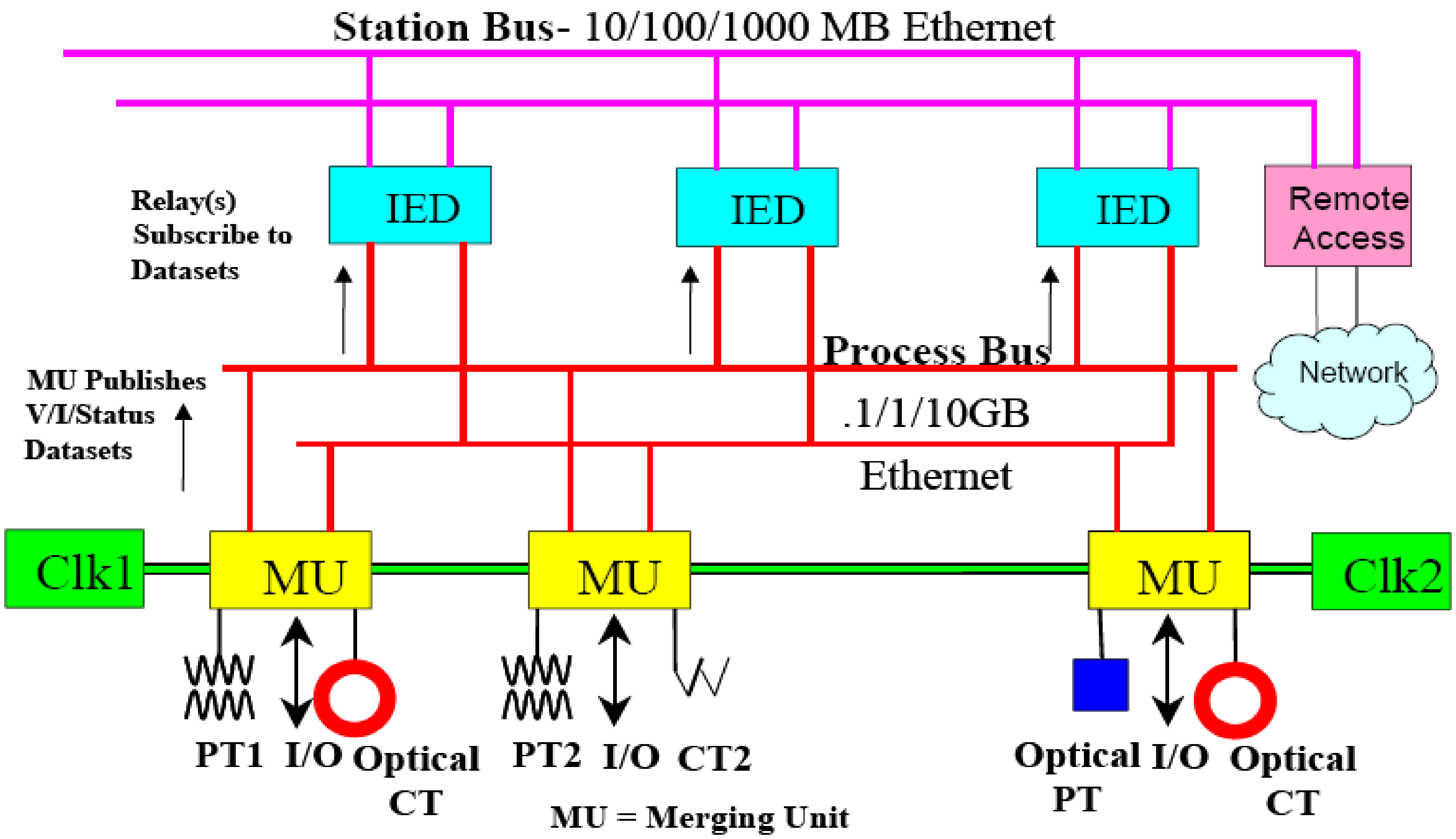
- **Distributed**
- Bay controllers implement interlocking and interface IEDs
- IEDs implement protection and switching
- HMI allows local control and system configuration
- Station controller manages station level control and communicates with SCADA.

Substation automation

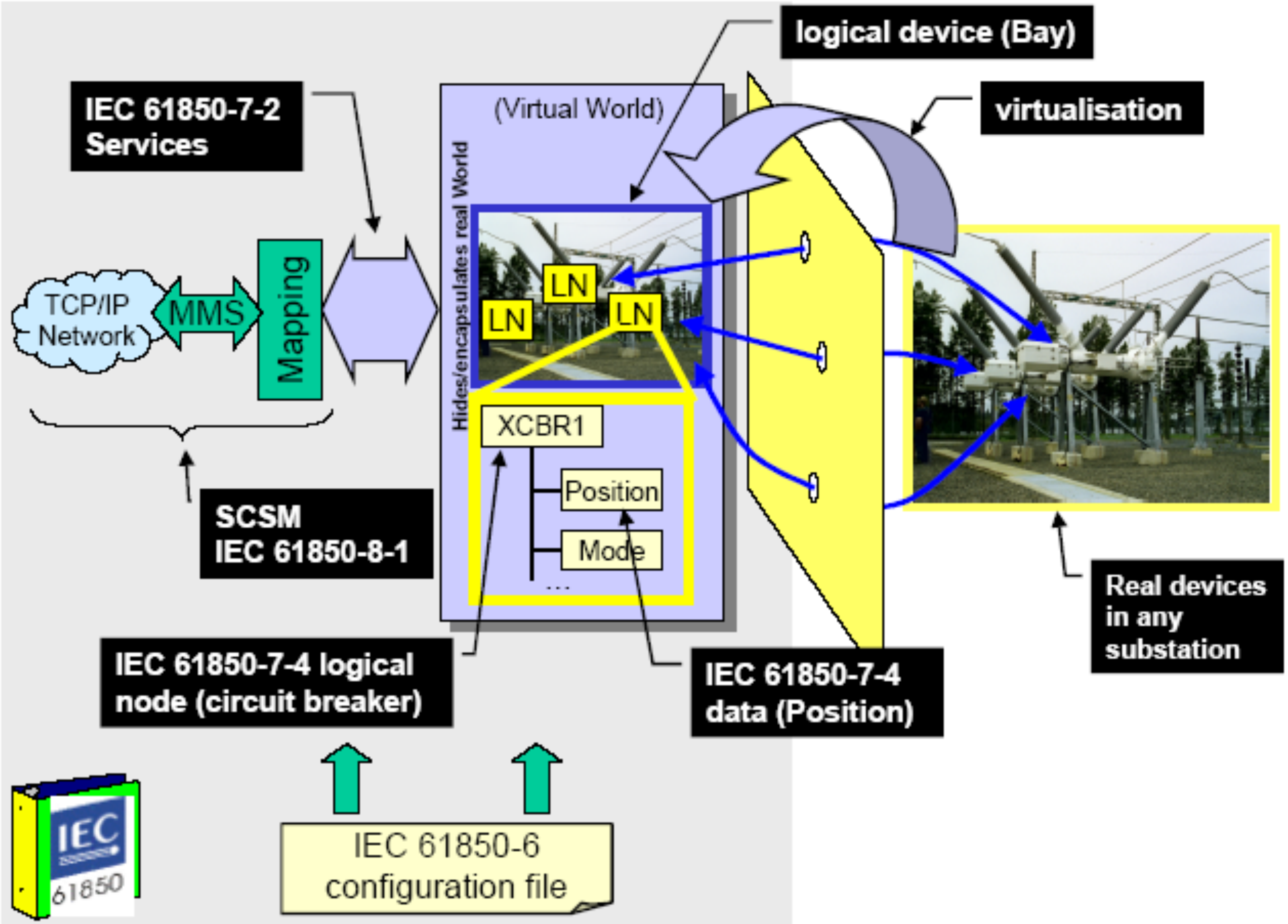
Exercise



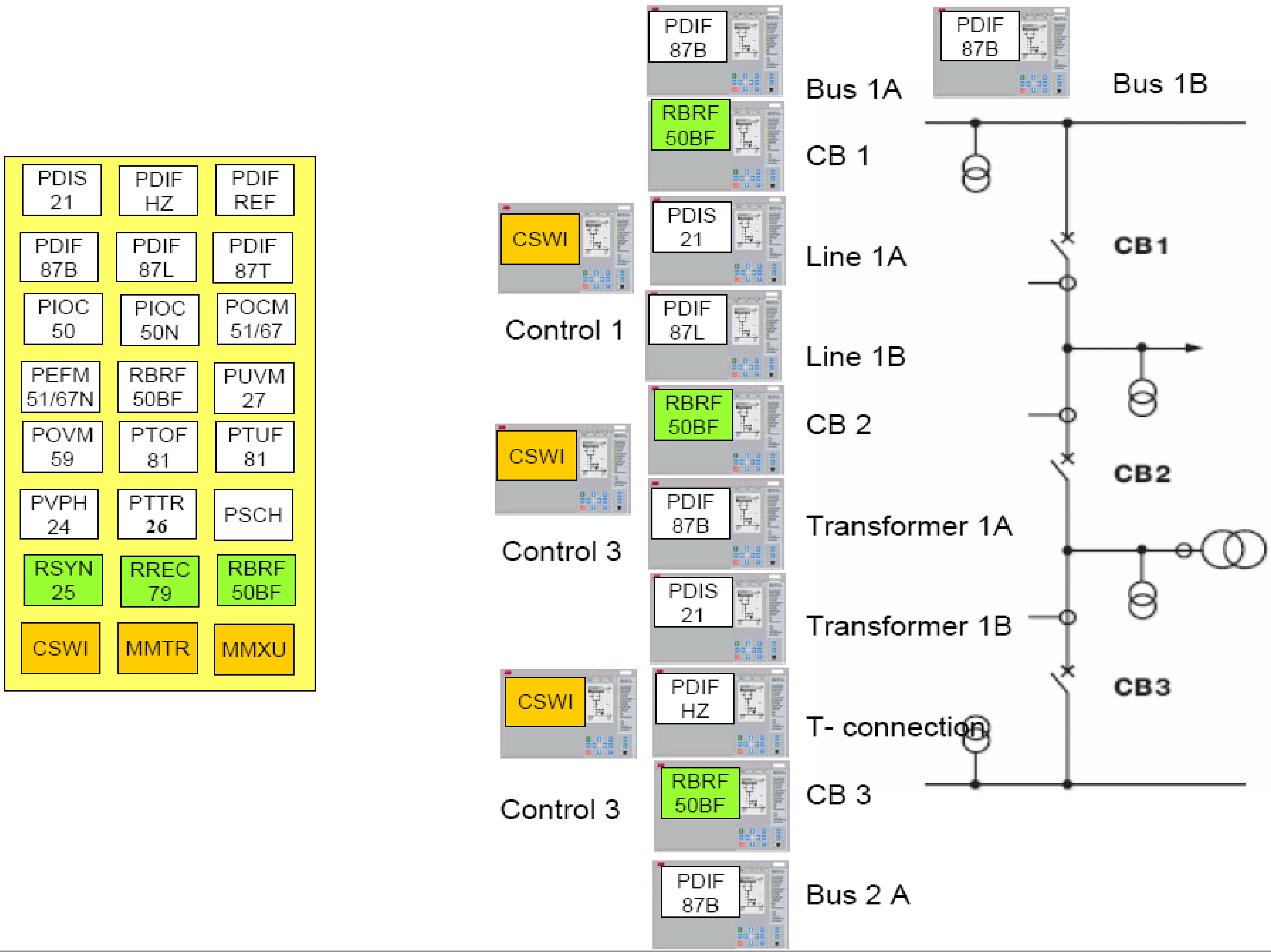
61850 Substation Architecture



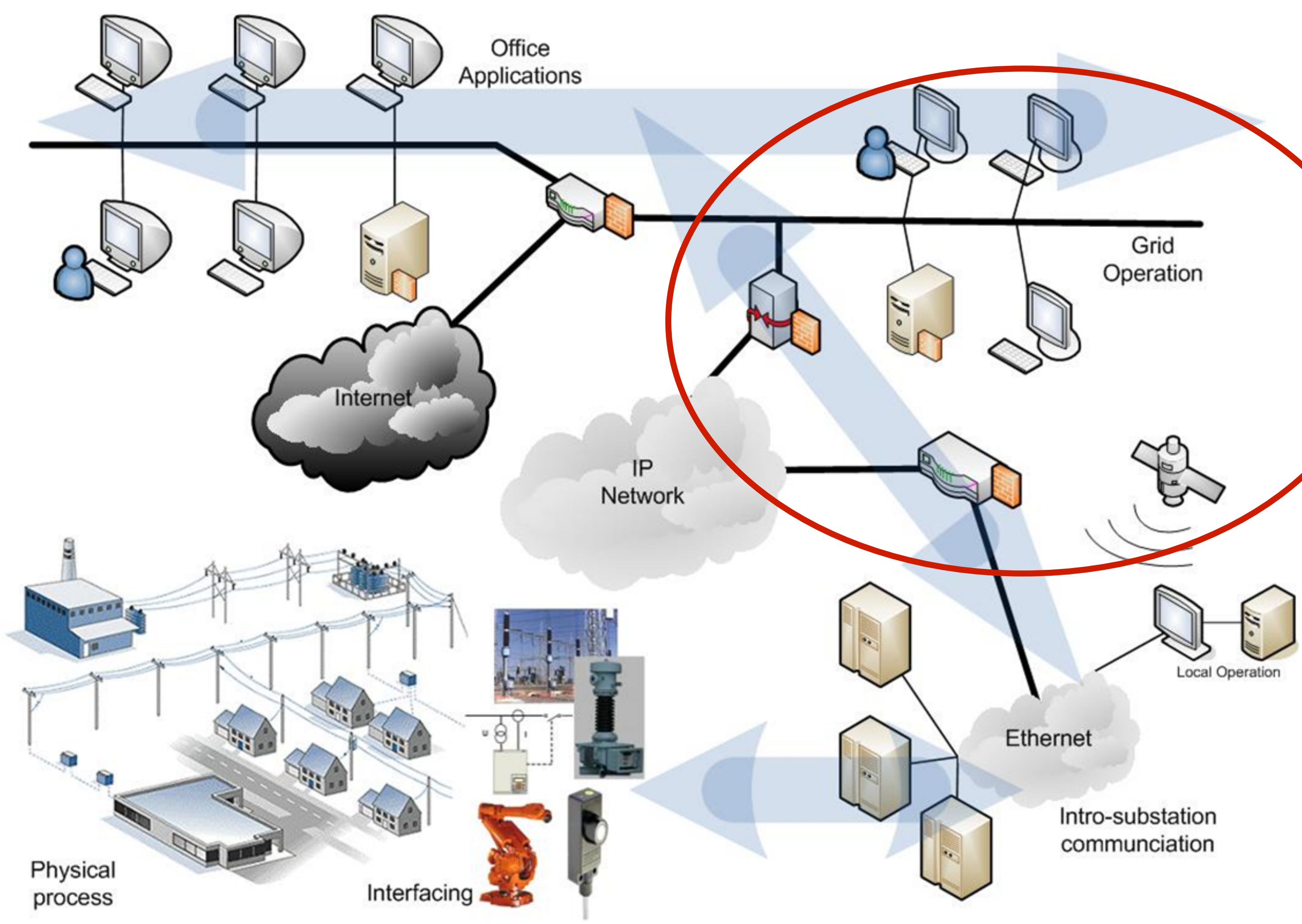
Modeling a substation



Allocate LNs to IEDs



Course map



Office
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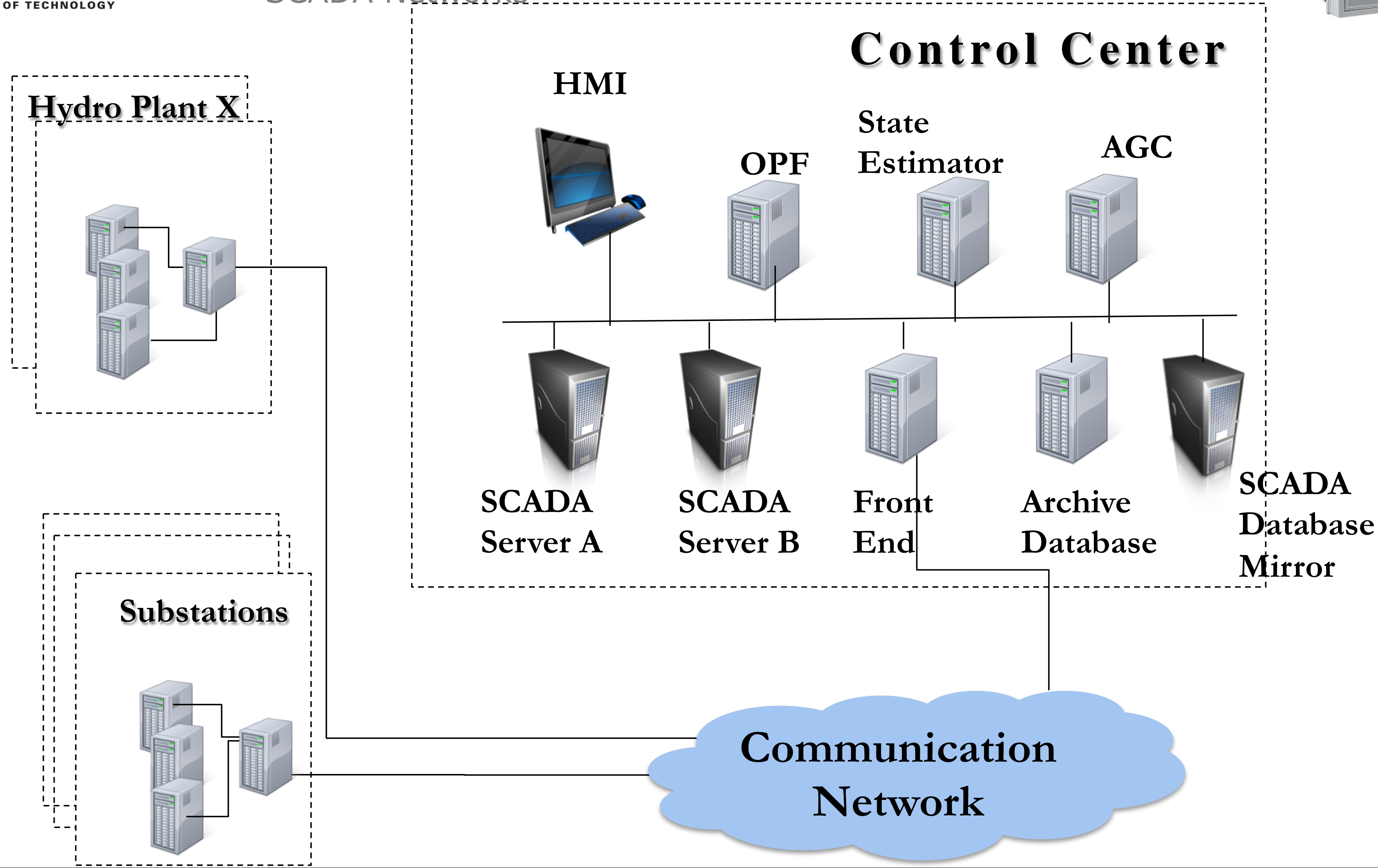
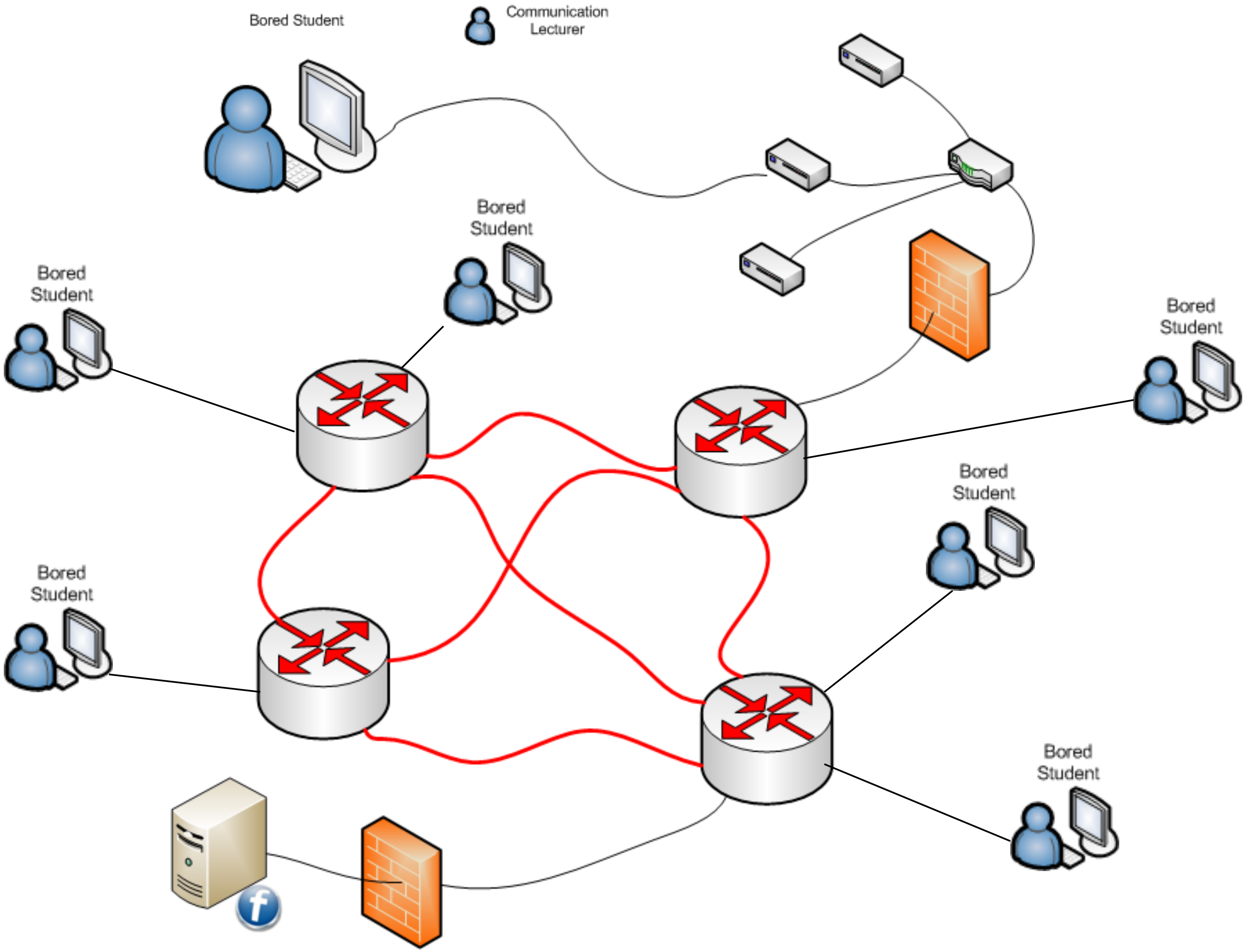
Recap

SCADA Networks



Protocol Basics

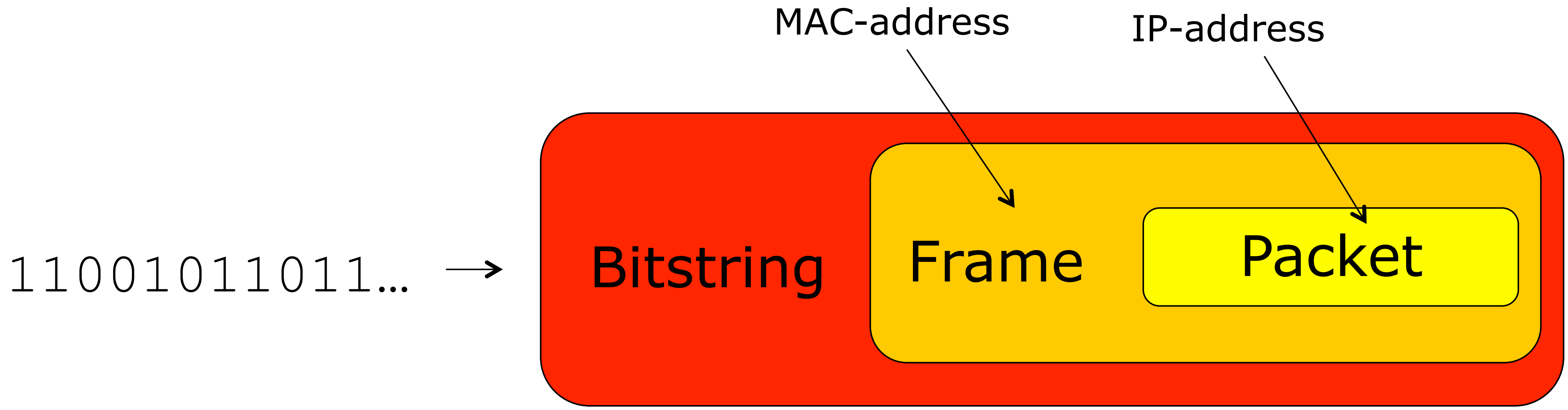
HTTP protocol



The OSI model

Layering

- Each layer encapsulates the container of the layer above
- Identification and addressing information for each layer



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The OSI model

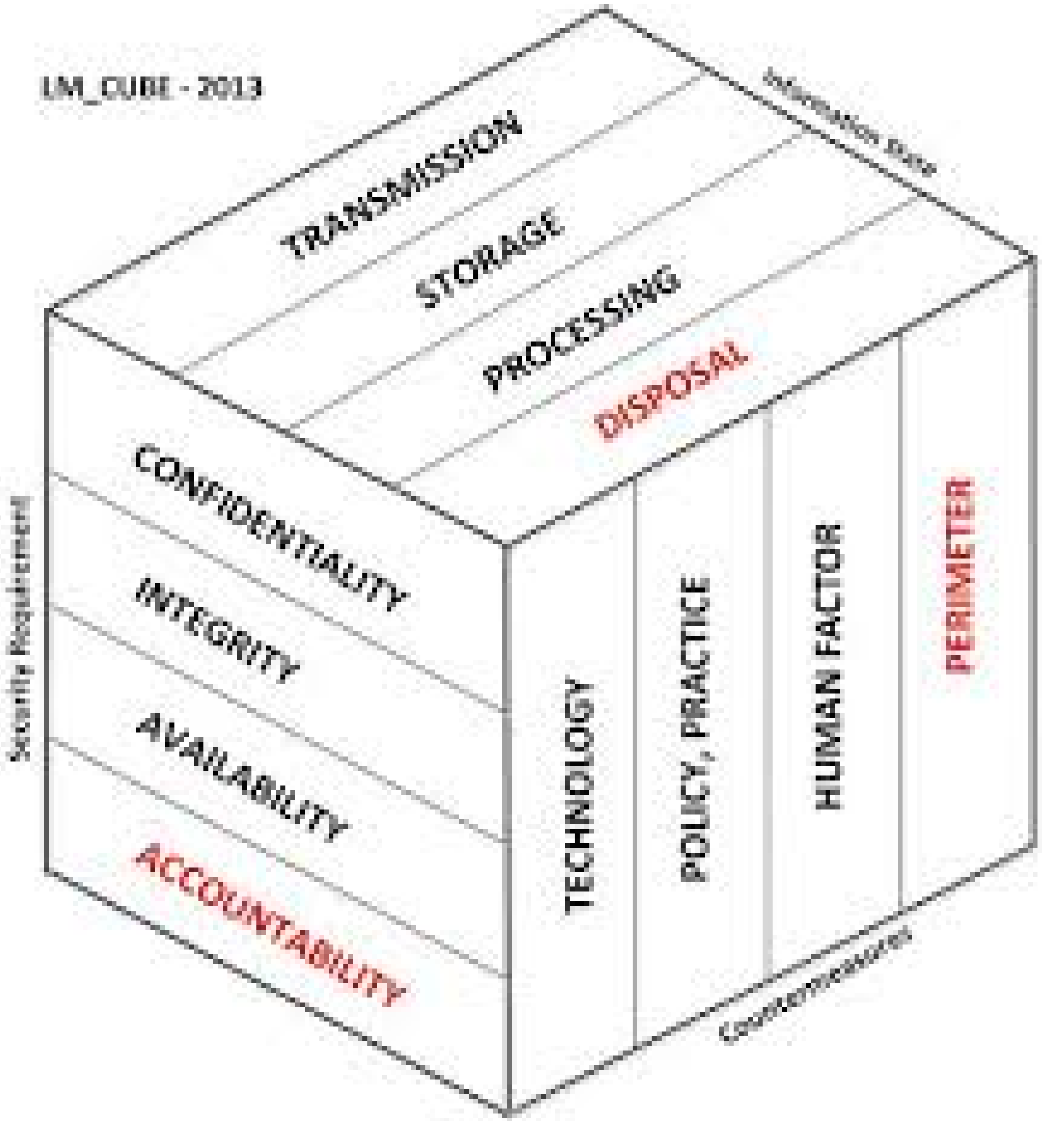
Layering

- Application
- Transport
- Network
- Data Link
- Physical

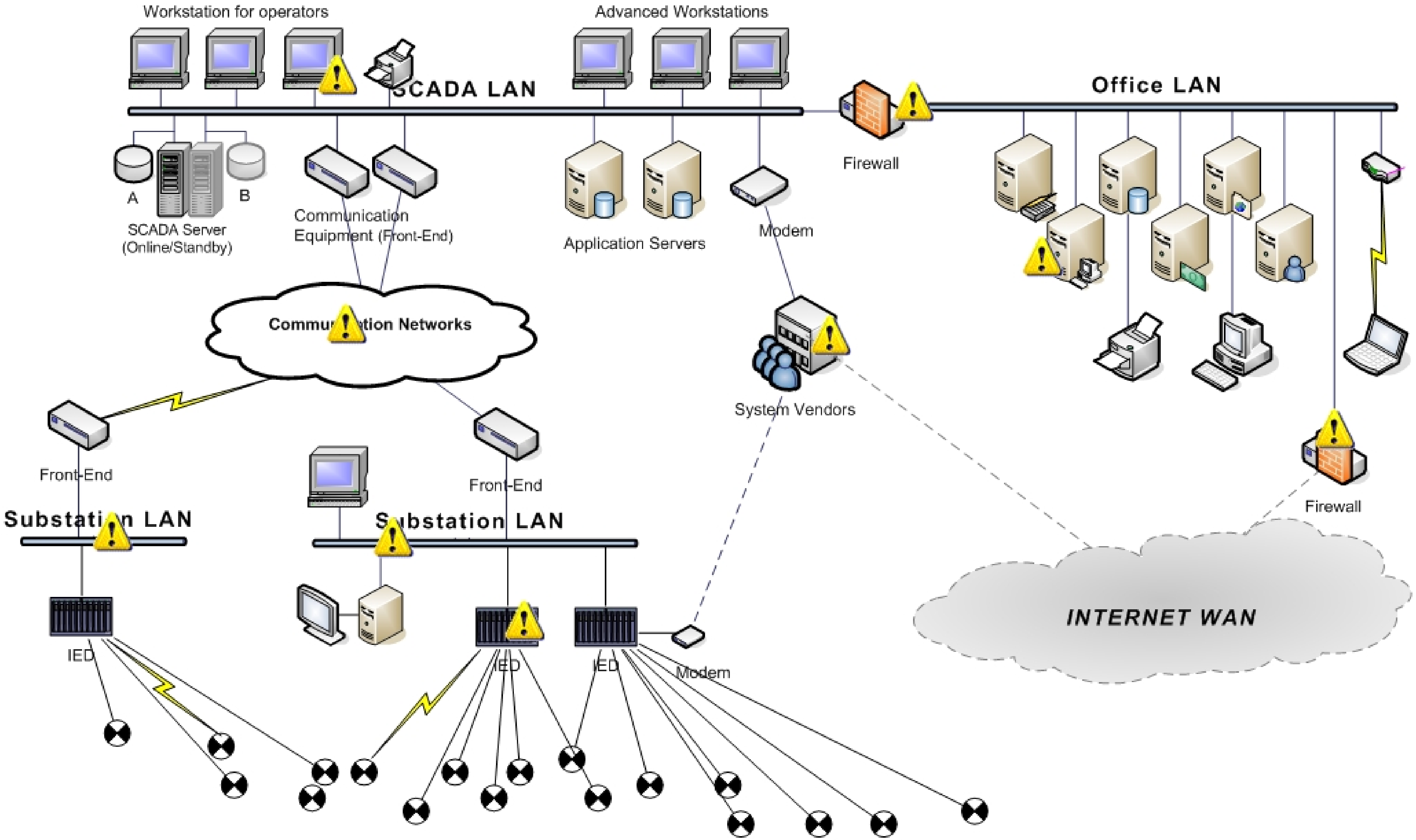
- Units of high-level **protocol data** eg. HTML
- Data is **segmented**, sometimes into streams (TCP) or “datagrams” (UDP)
- Each segment is **packaged** to be sent across a network.
- The package is enclosed in a **frame** to be sent on the **link** eg. Ethernet
- The frame is transmitted as a string of **binary bits** on the physical media eg. UTP

- Data
- Segments
- Packets
- Frames
- Bits

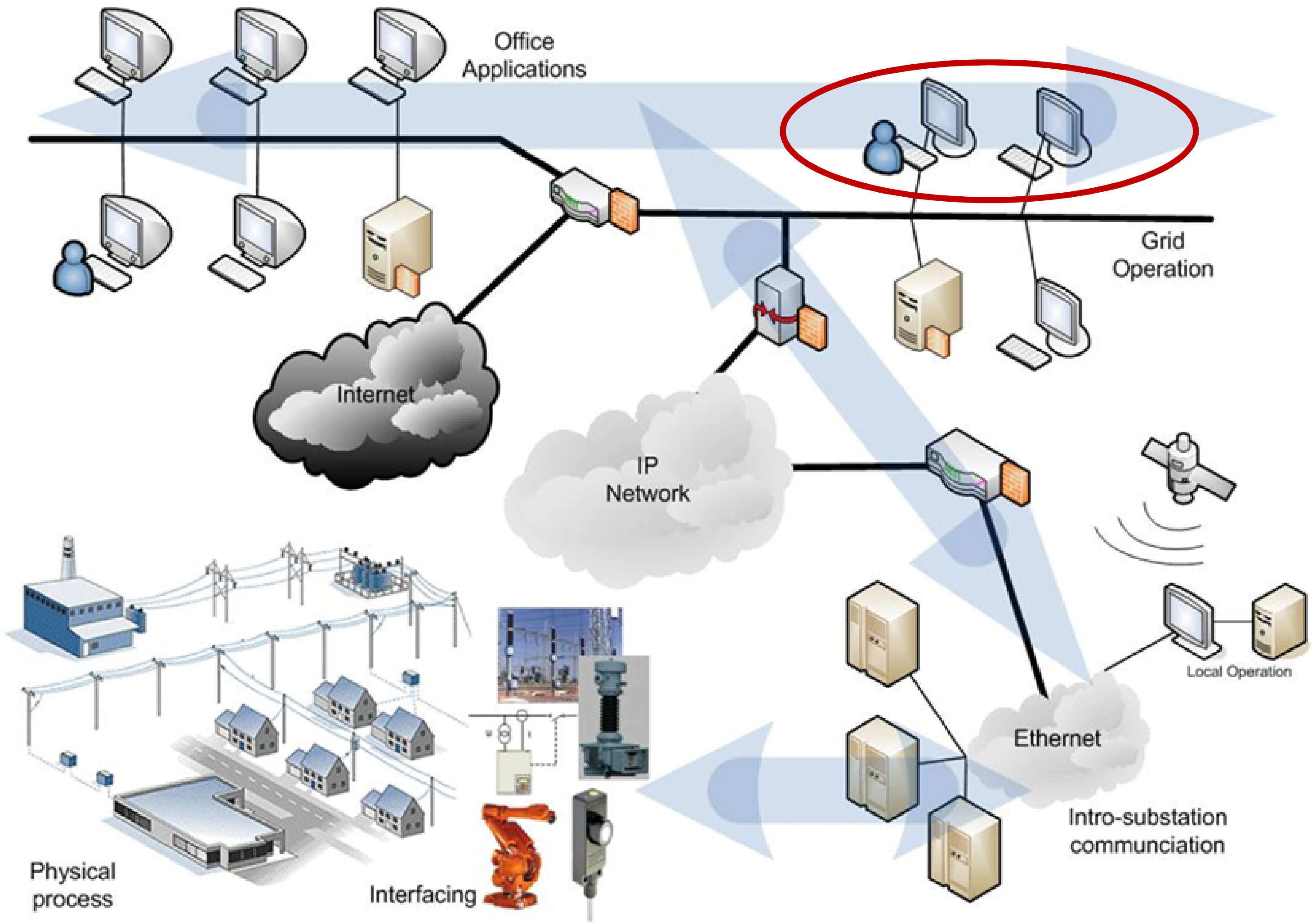
Information sec. – general IT (1)



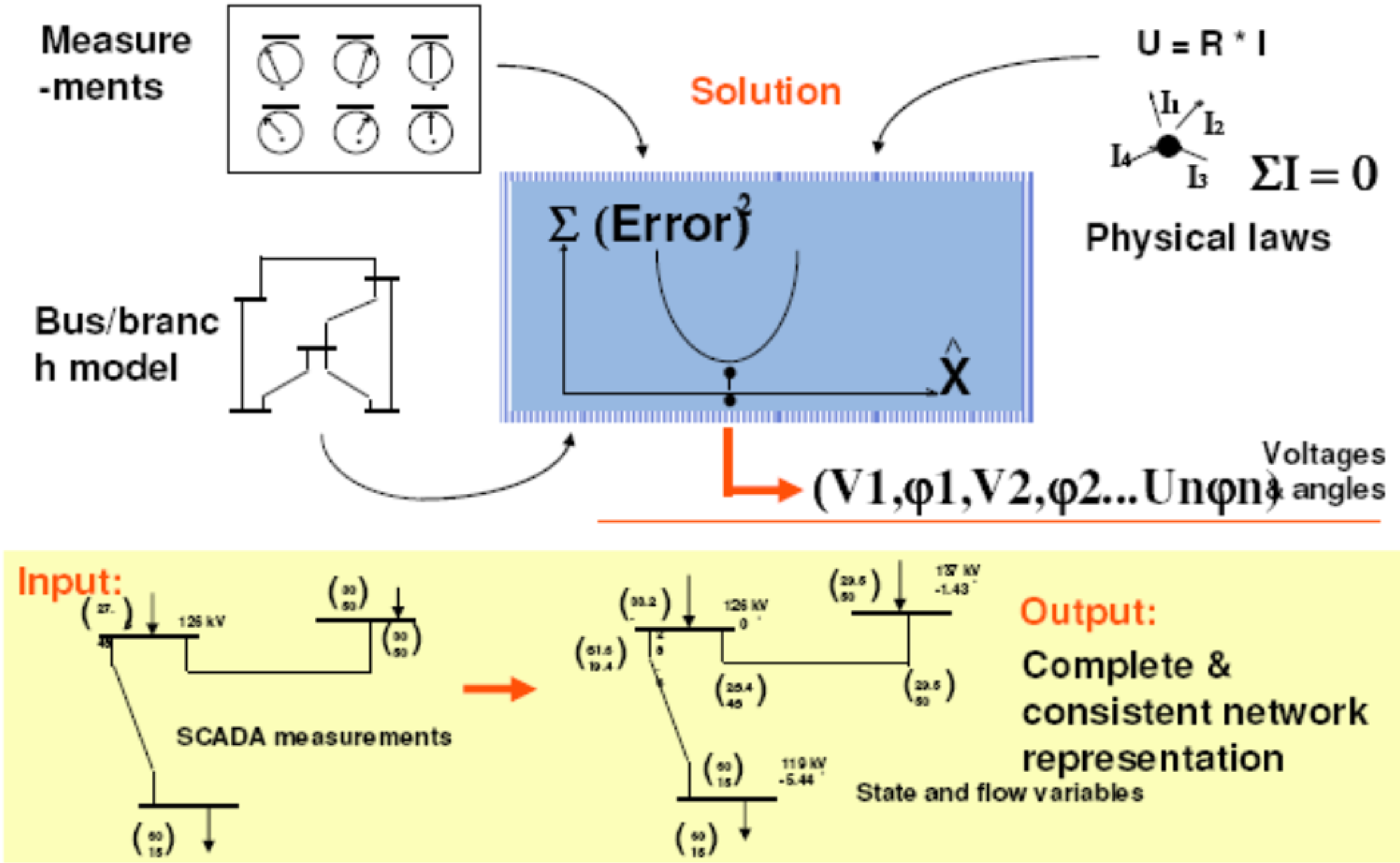
A simple ICS infrastructure…



Course road map



The truth is out here!



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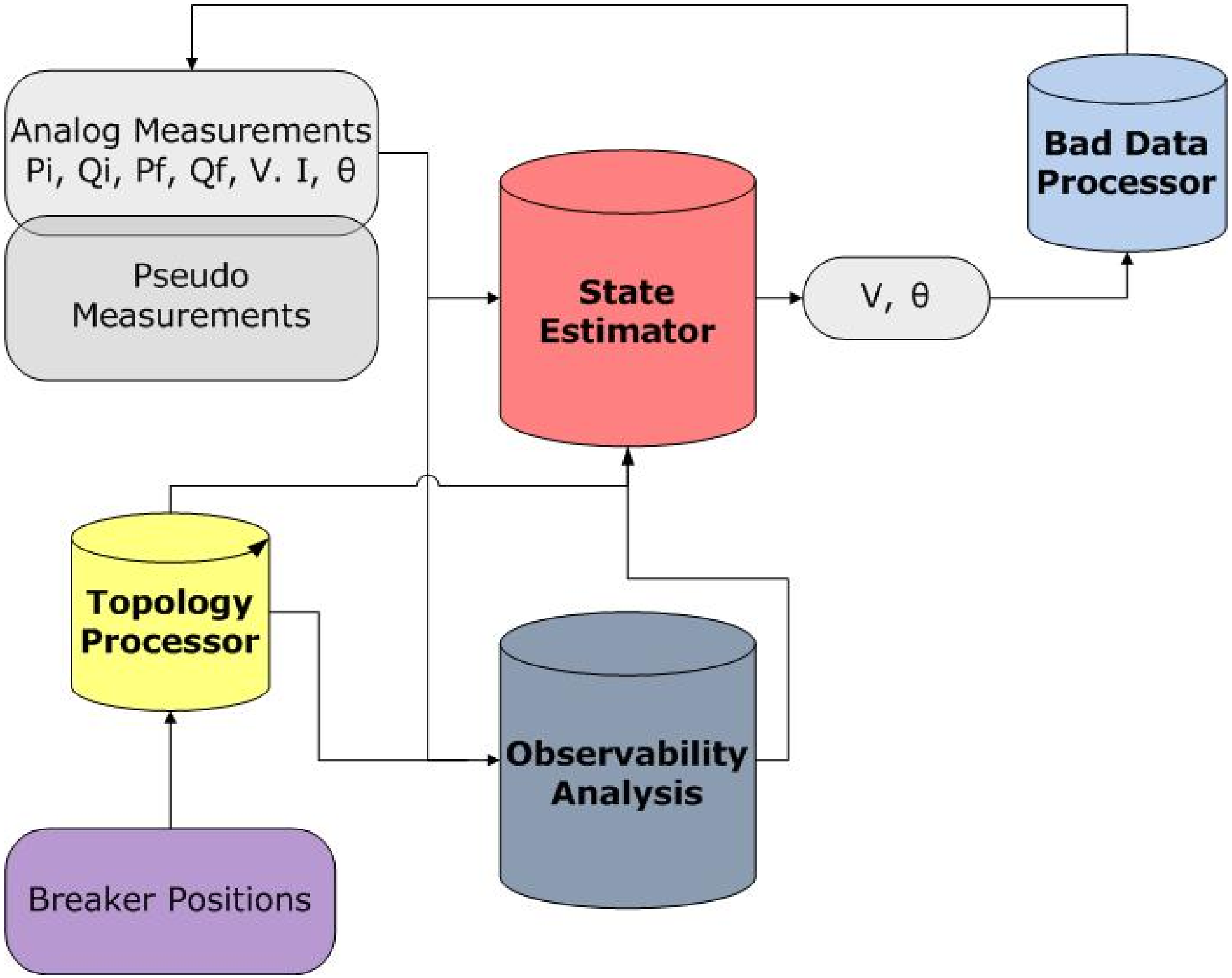
State estimation process



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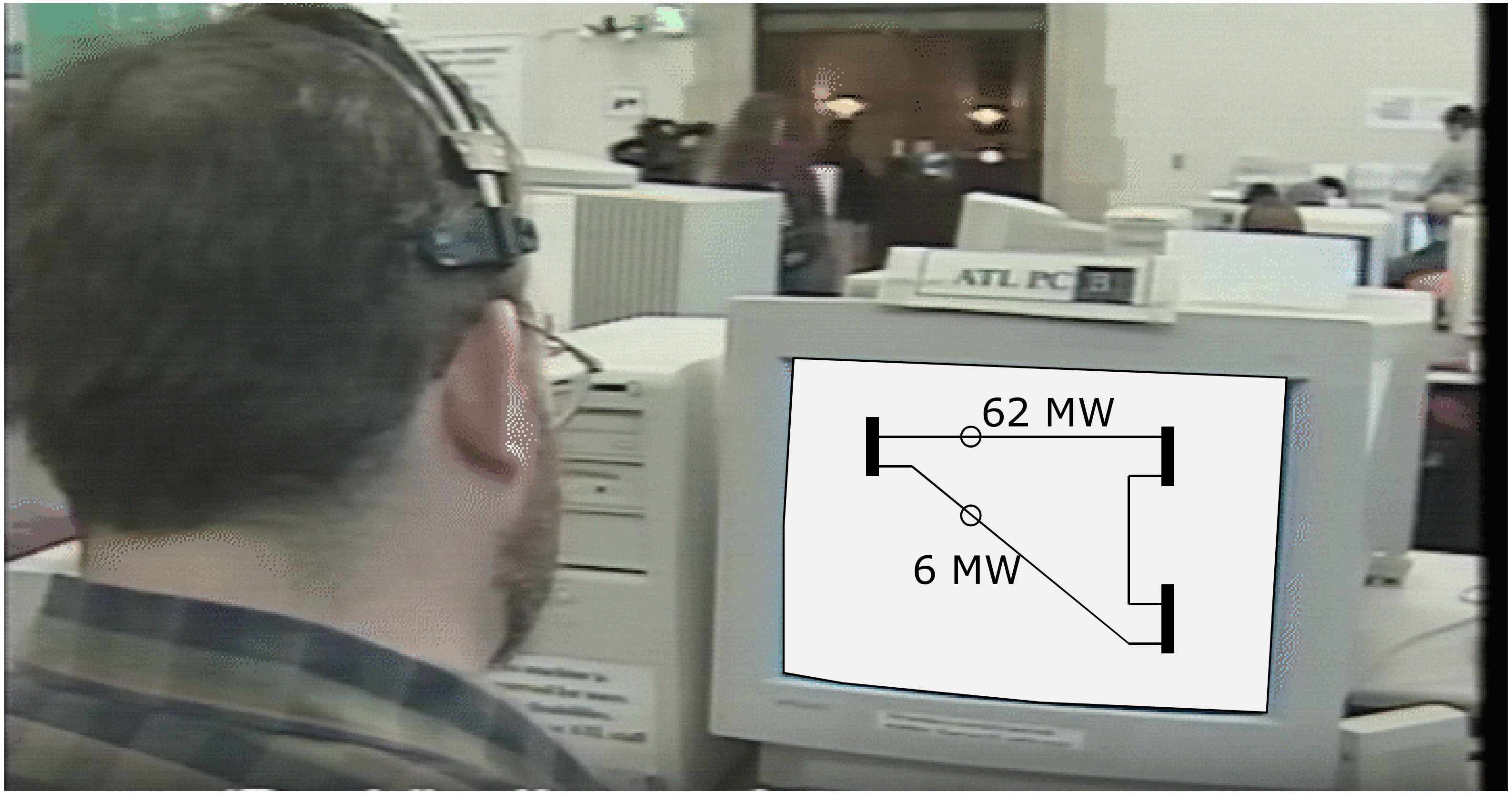
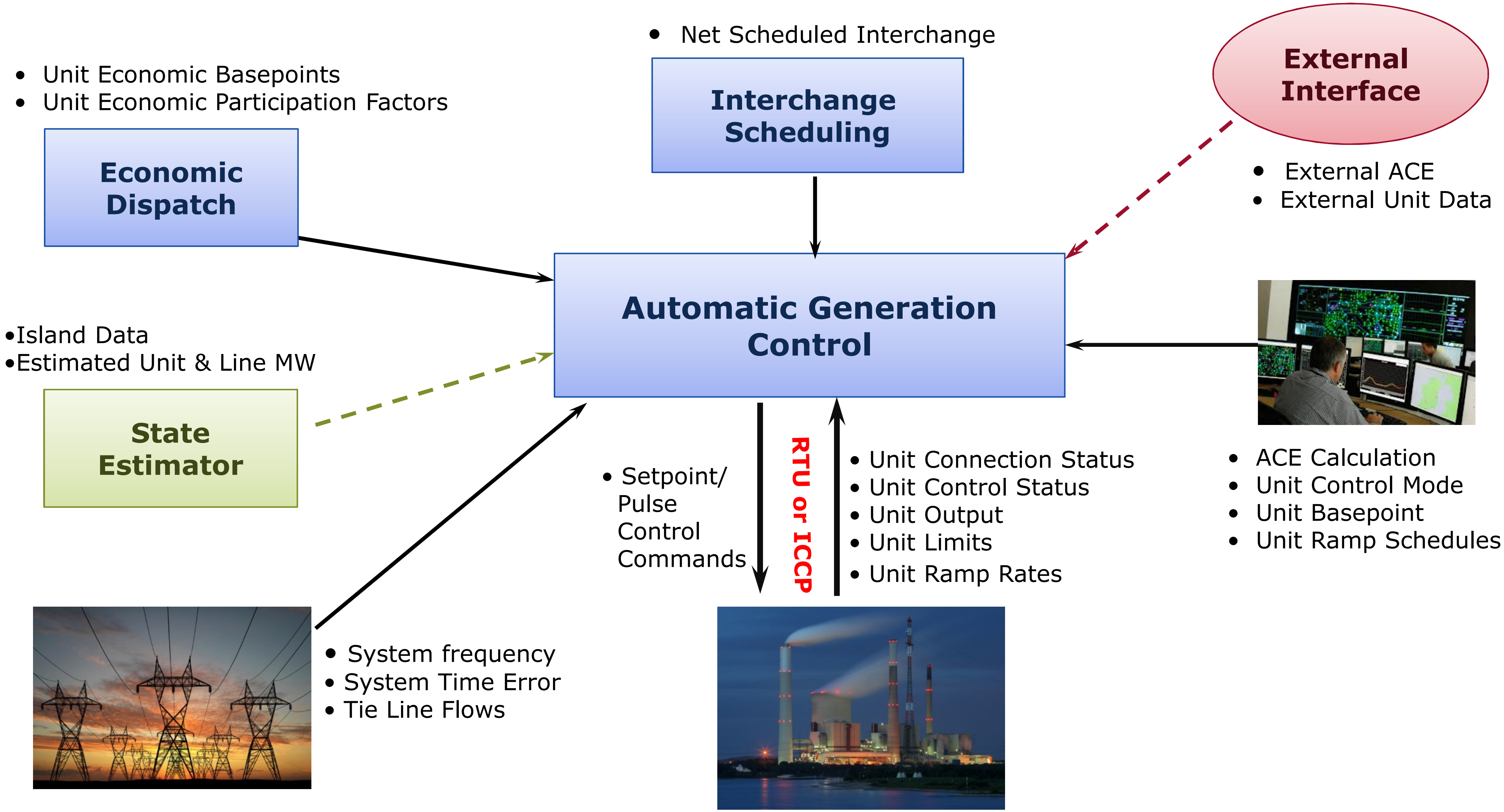
How could the operator know the system?



Automatic Generation Control Interfaces



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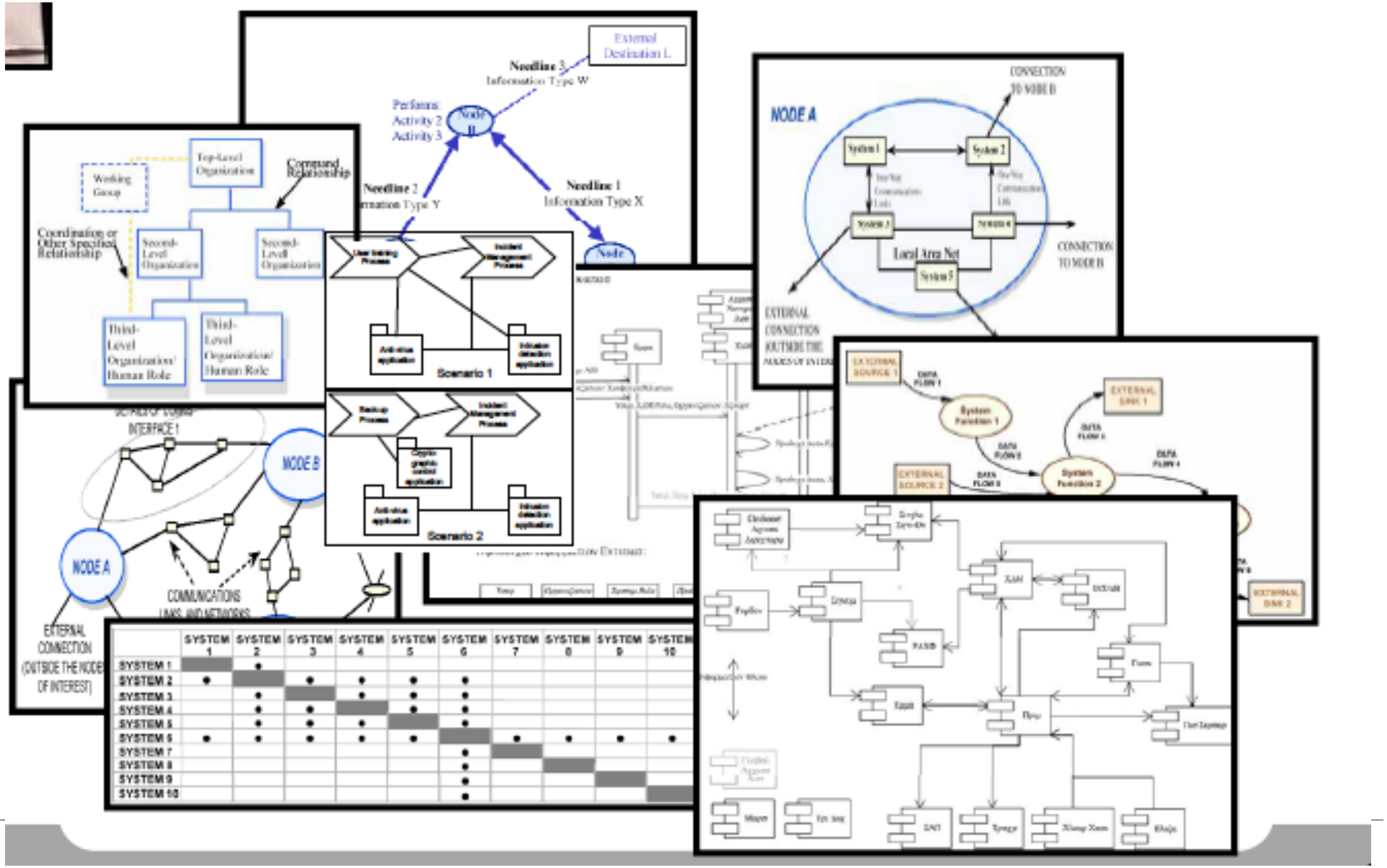
When and why to use which model?



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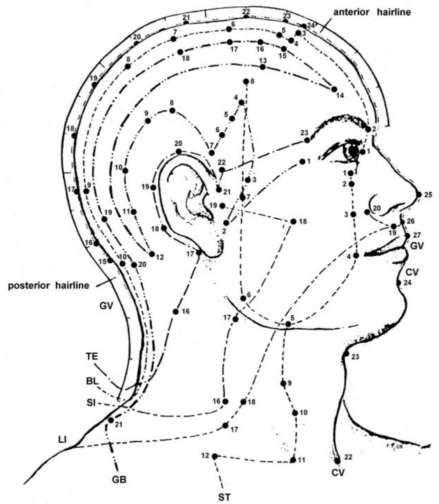
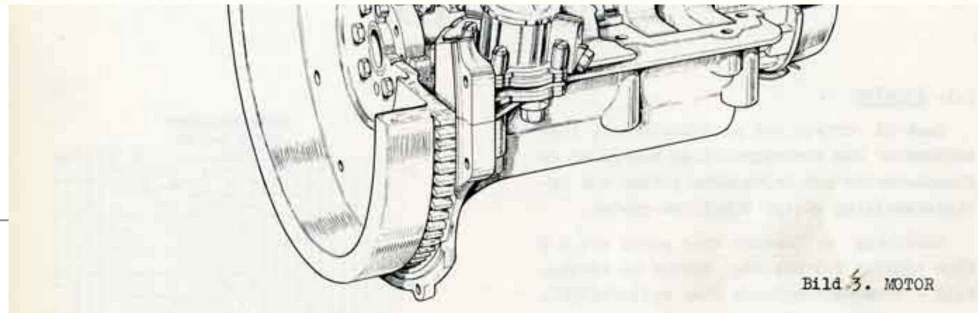
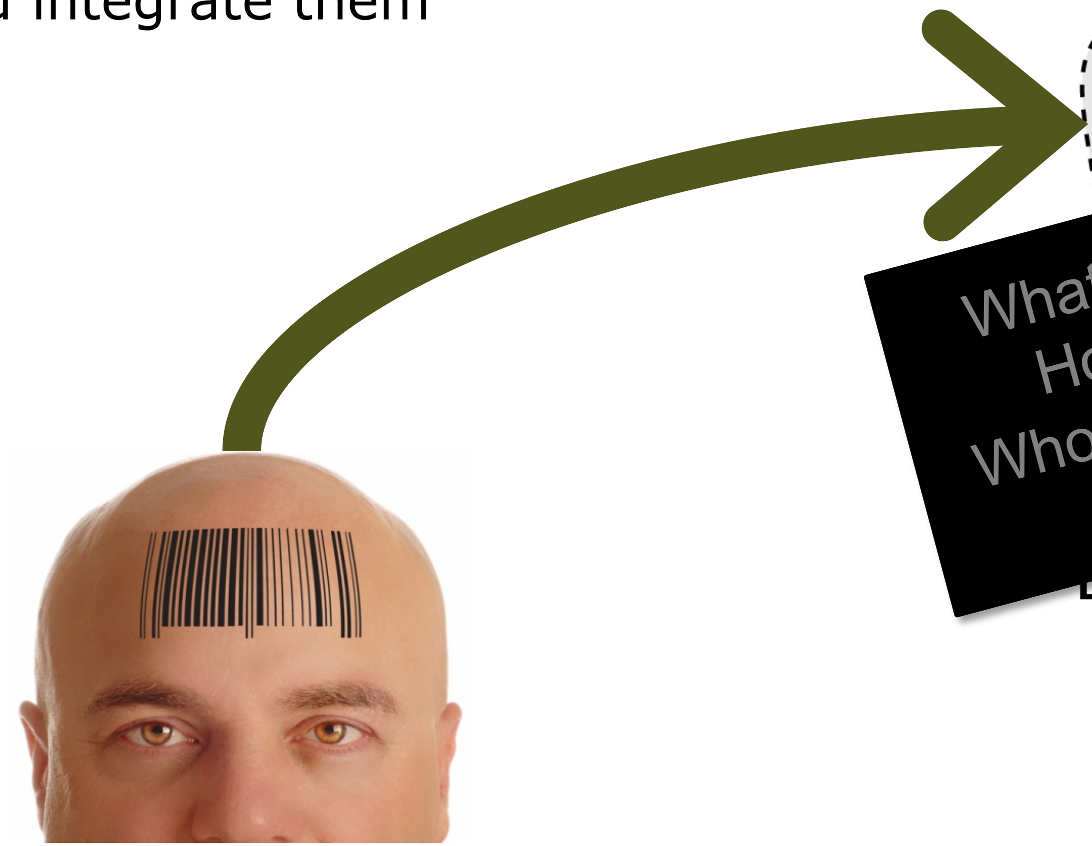
How to make things understandable

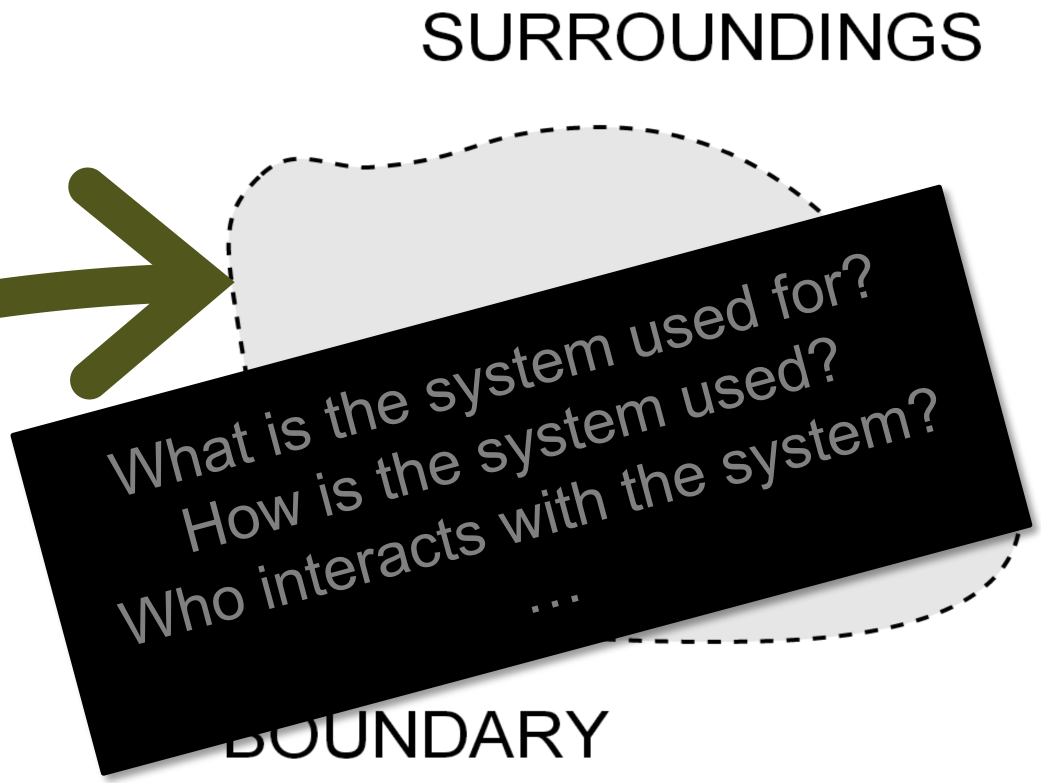




What is an architecture

- Approach: One bite at a time
  - Describe parts, build, deploy, and integrate them





Mandate 490
Task to European SDO

- The EC has issued a mandate (M/490) for the standardization of Smart grid functionalities to CEN, CENELEC and ETSI.
- The expected framework will consist of the following deliverables:
  - A technical reference architecture, which will represent the functional information data flows between the main domains and integrate many systems and subsystems architectures.
  - A set of consistent standards, which will support the information exchange (communication protocols and data models) and the integration of all users into the electric system operation.
  - Sustainable standardization processes and collaborative tools to enable stakeholder interactions, to improve the two above and adapt them to new requirements based on gap analysis, while ensuring the fit to high level system constraints such as interoperability, security, and privacy, etc.

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What is a reference architecture?

A Reference *Architecture* describes the *structure* of a system with its element types and their structures, as well as their *interaction* types, among each other and with their environment. Describing this, a Reference Architecture defines restrictions for an instantiation (concrete architecture). Through abstraction from individual details, a Reference Architecture is universally valid within a specific domain. Further architectures with the same functional requirements can be constructed based on the reference architecture. Along with *reference* architectures comes a *recommendation*, based on experiences from existing developments as well as from a wide acceptance and recognition by its users or per definition. [ISO/IEC42010]

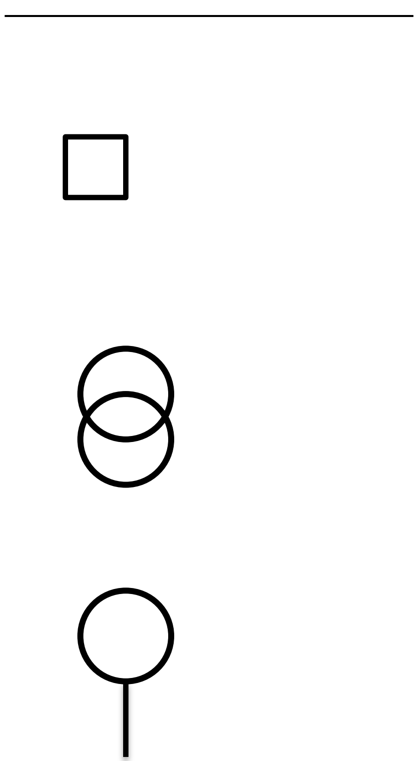
In short: it is the specification of which language you should use to describe the system you are describing.

Example:

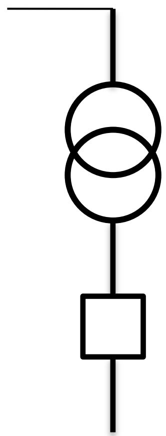
Reference architecture for for Power systems

One line diagram (just one possible form of description)

A set of symbols



Rules on how you can combine them



Sort of similar for ICT systems

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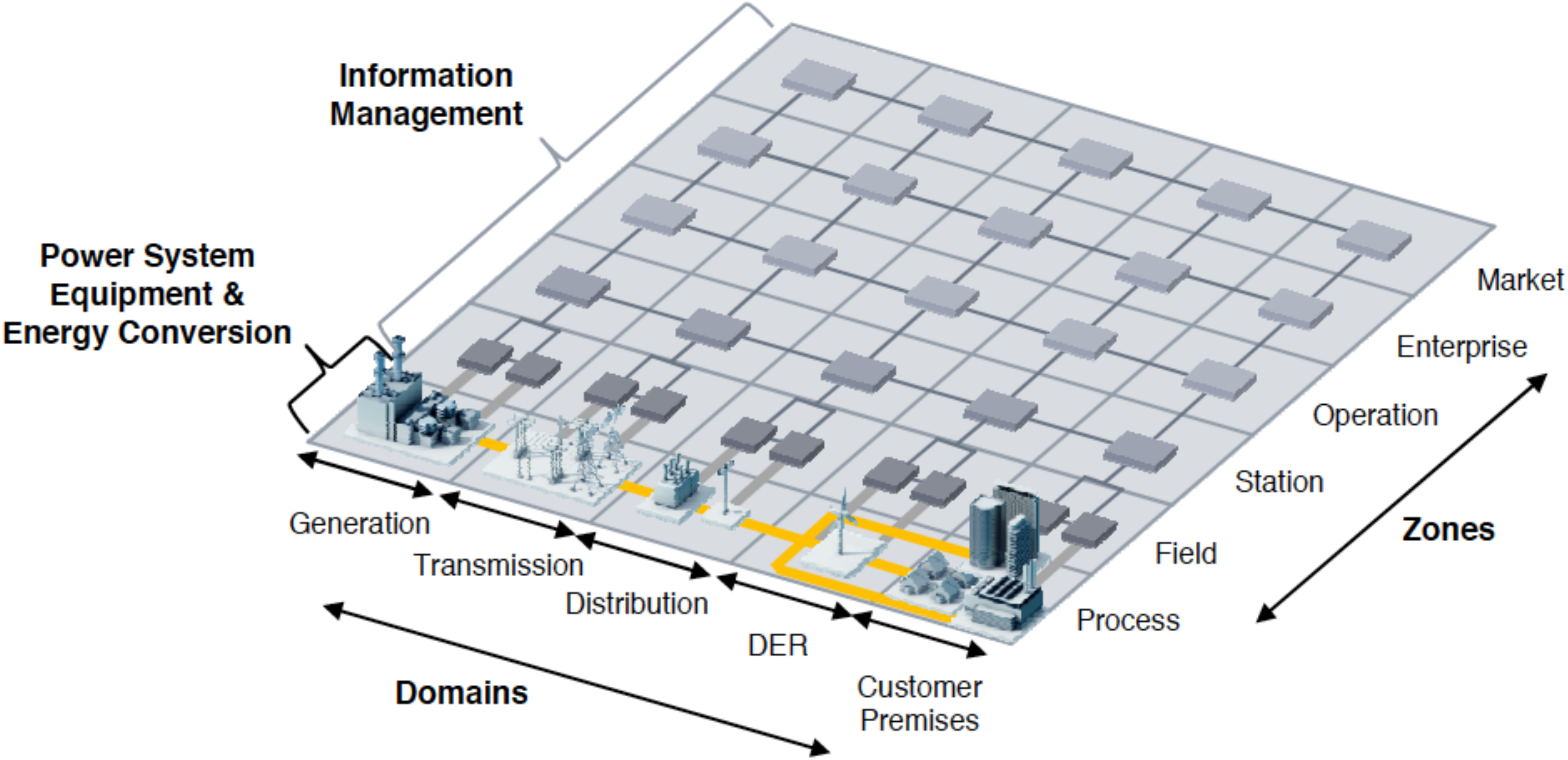
The context– the Smartgrid Plane



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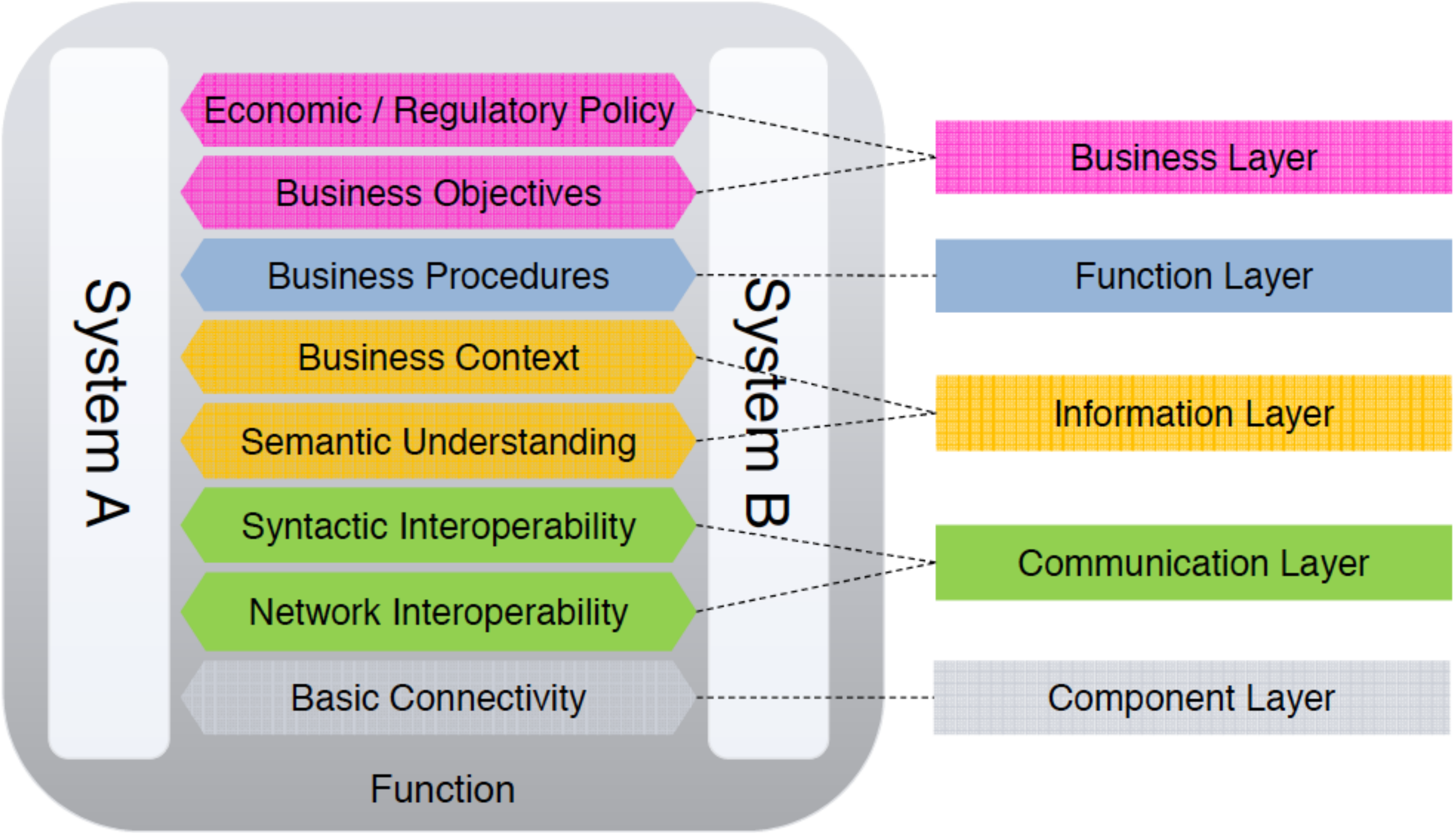
Architecture Domains

Domain	Description
Bulk Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale photovoltaic (PV) power– typically connected to the transmission system
Transmission	Representing the infrastructure and organization which transports electricity over long distances
Distribution	Representing the infrastructure and organization which distributes electricity to customers
DER	Representing distributed electrical resources, directly connected to the public distribution grid, applying small-scale power generation technologies (typically in the range of 3 kW to 10.000 kW). These distributed electrical resources can be directly controlled by DSO
Customer Premises	Hosting both - end users of electricity, also producers of electricity. The premises include industrial, commercial and home facilities (e.g. chemical plants, airports, harbors, shopping centers, homes). Also generation in form of e.g. photovoltaic generation, electric vehicles storage, batteries, micro turbines… are hosted

Architecture Zones

Zone	Description
Process	Including both - primary equipment of the power system (e.g. generators, transformers, circuit breakers, overhead lines, cables, electrical loads …) - as well as physical energy conversion (electricity, solar, heat, water, wind …).
Station	Representing the aggregation level for fields, e.g. for data concentration, substation automation…
Operation	Hosting power system control operation in the respective domain, e.g. distribution management systems (DMS), energy management systems (EMS) in generation and transmission systems, microgrid management systems, virtual power plant management systems (aggregating several DER), electric vehicle (EV) fleet charging management systems.
Enterprise	Includes commercial and organizational processes, services and infrastructures for enterprises (utilities, service providers, energy traders …), e.g. asset management, staff training, customer relation management, billing and procurement.
Market	Reflecting the market operations possible along the energy conversion chain, e.g. energy trading, mass market, retail market…

Condensed model in the SGAM



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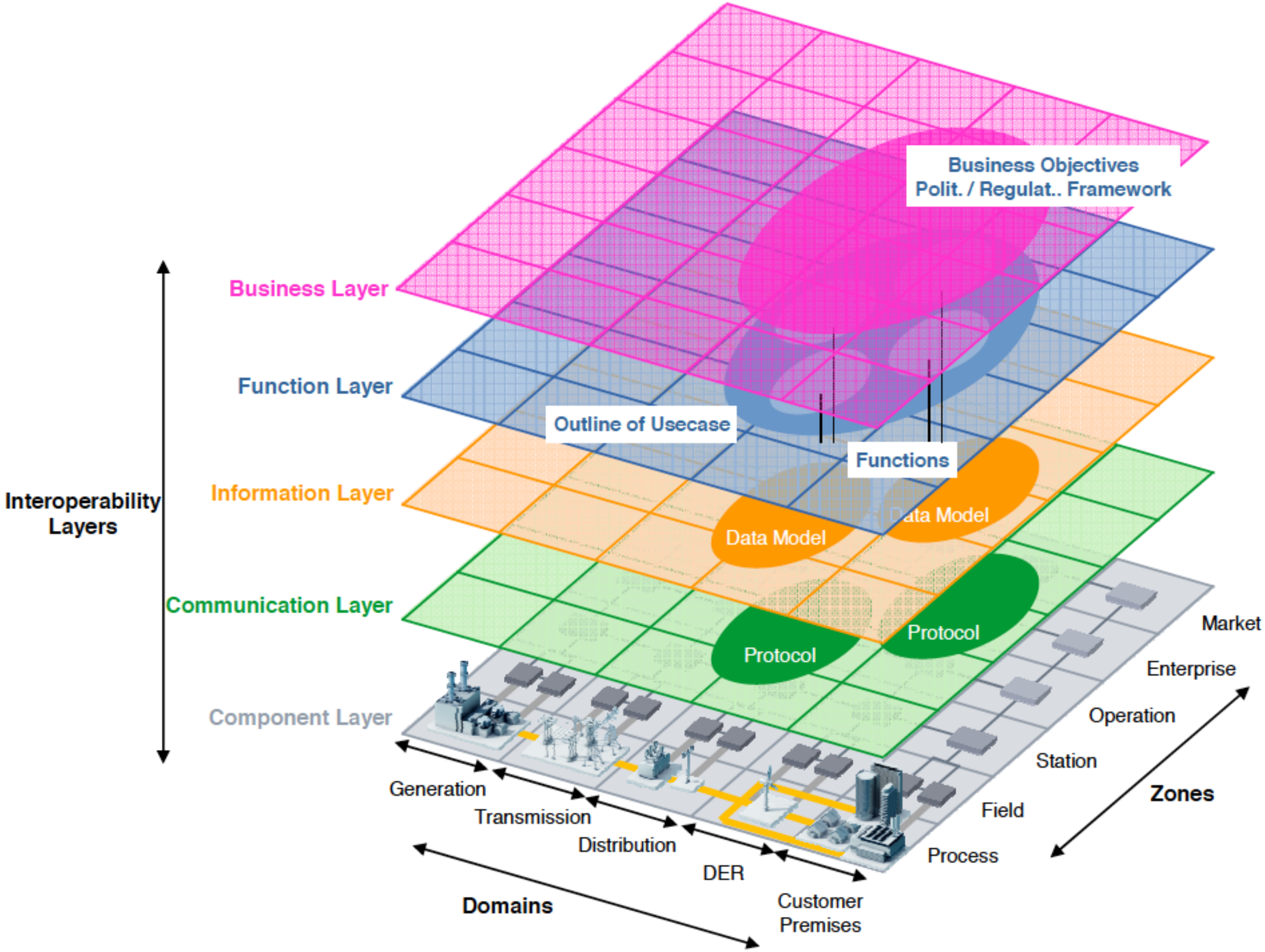
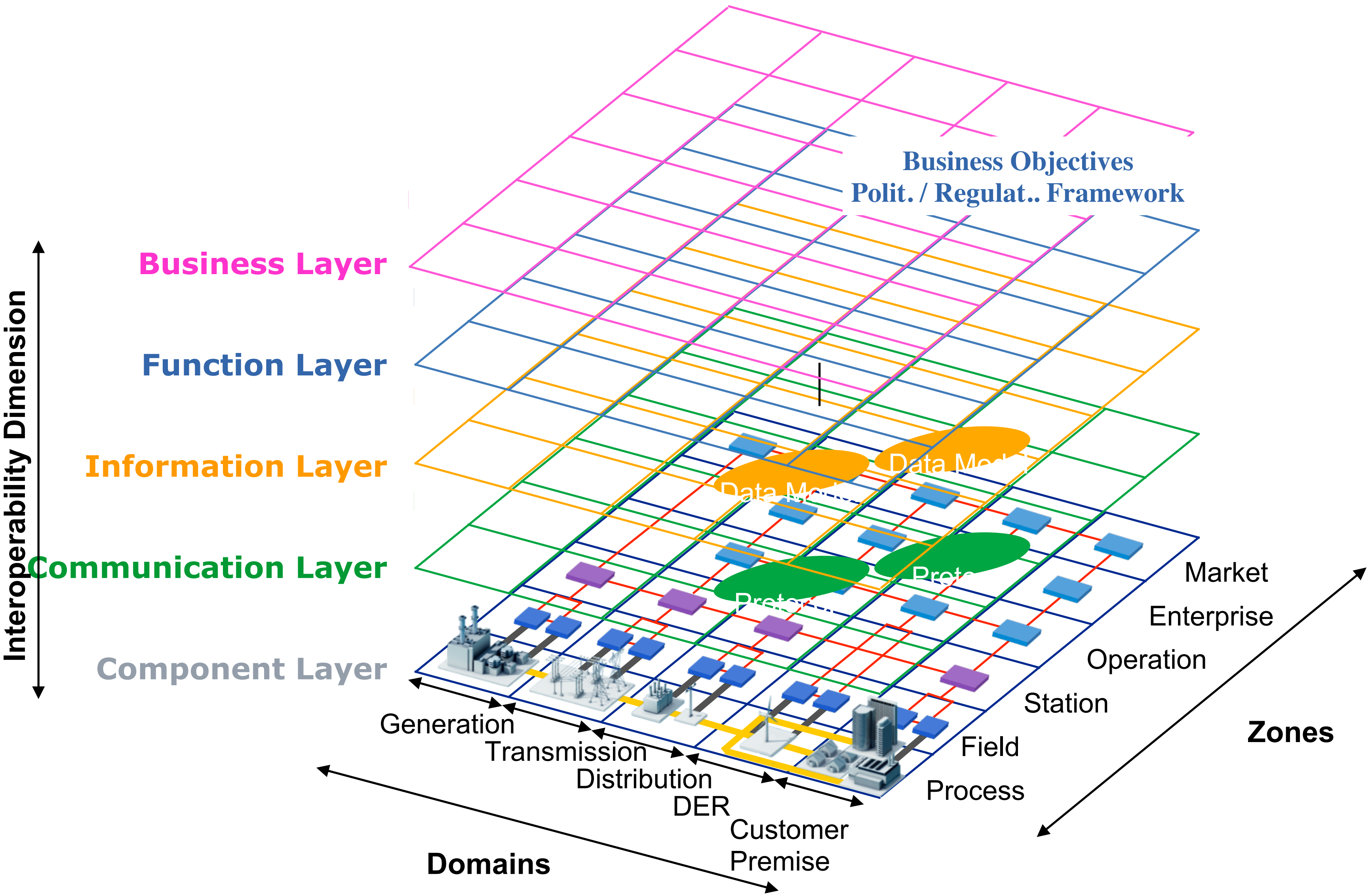
Complete Reference architecture

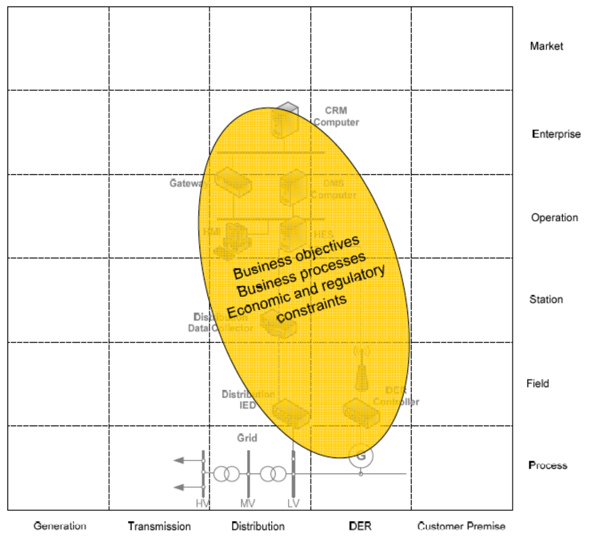


System Development



Business Layer

The business layer represents the business view on the information exchange related to smart grids. SGAM can be used to map regulatory and economic (market) structures and policies, business models, business portfolios (products & services) of market parties involved. Also business capabilities and business processes can be represented in this layer. In this way it supports business executives in decision making related to (new) business models and specific business projects (business case) as well as regulators in defining new market models. The Business layer is addressed in more detail in paragraph 6.1.



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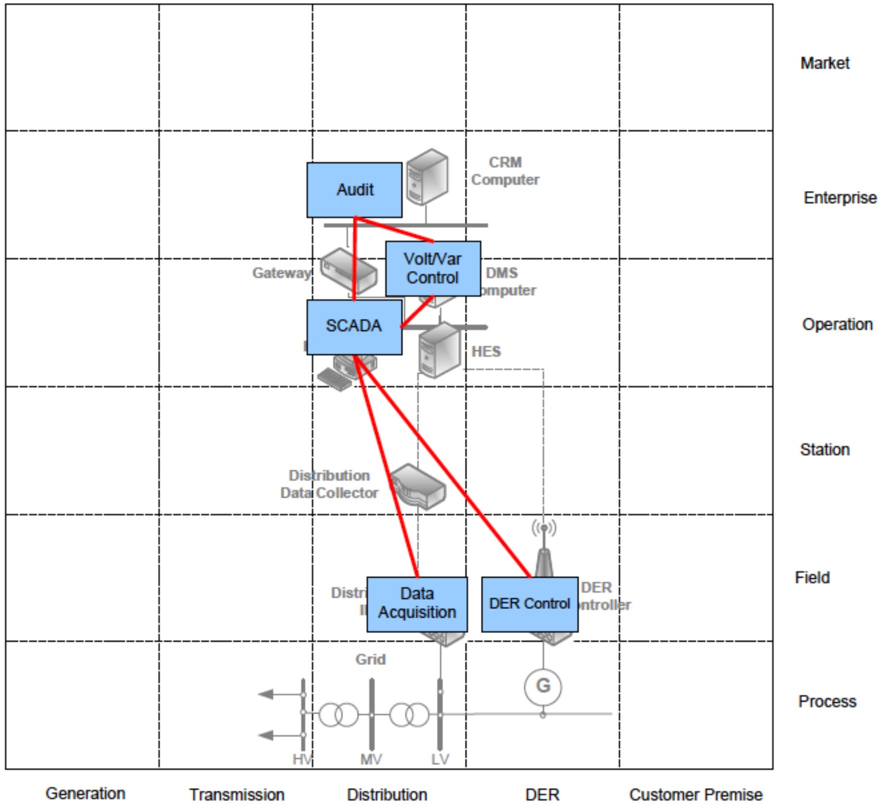
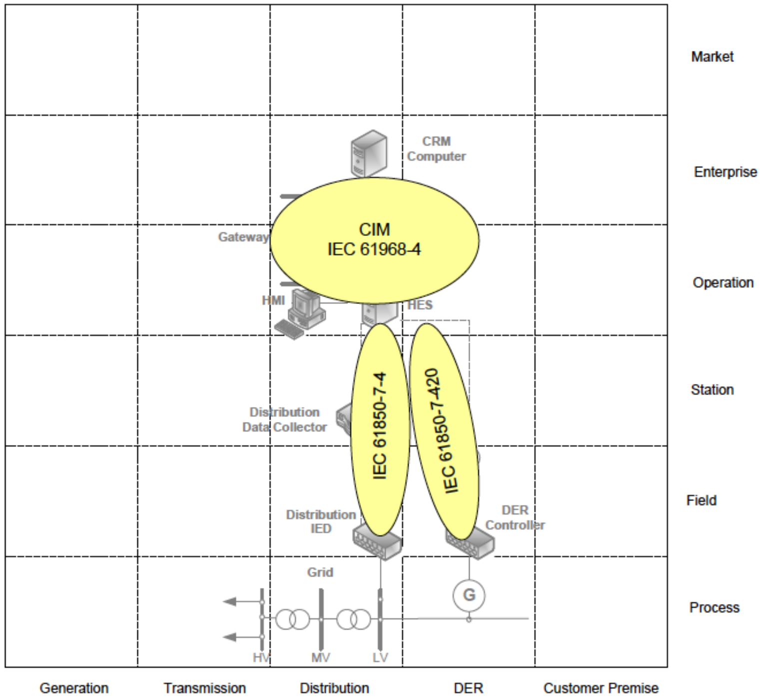
Function layer

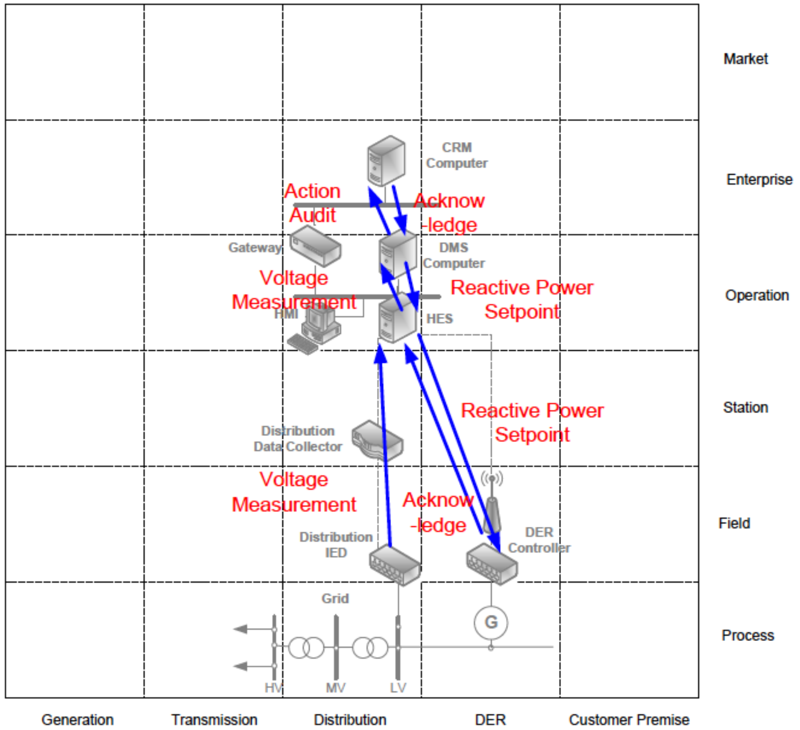
The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality which is independent from actors.

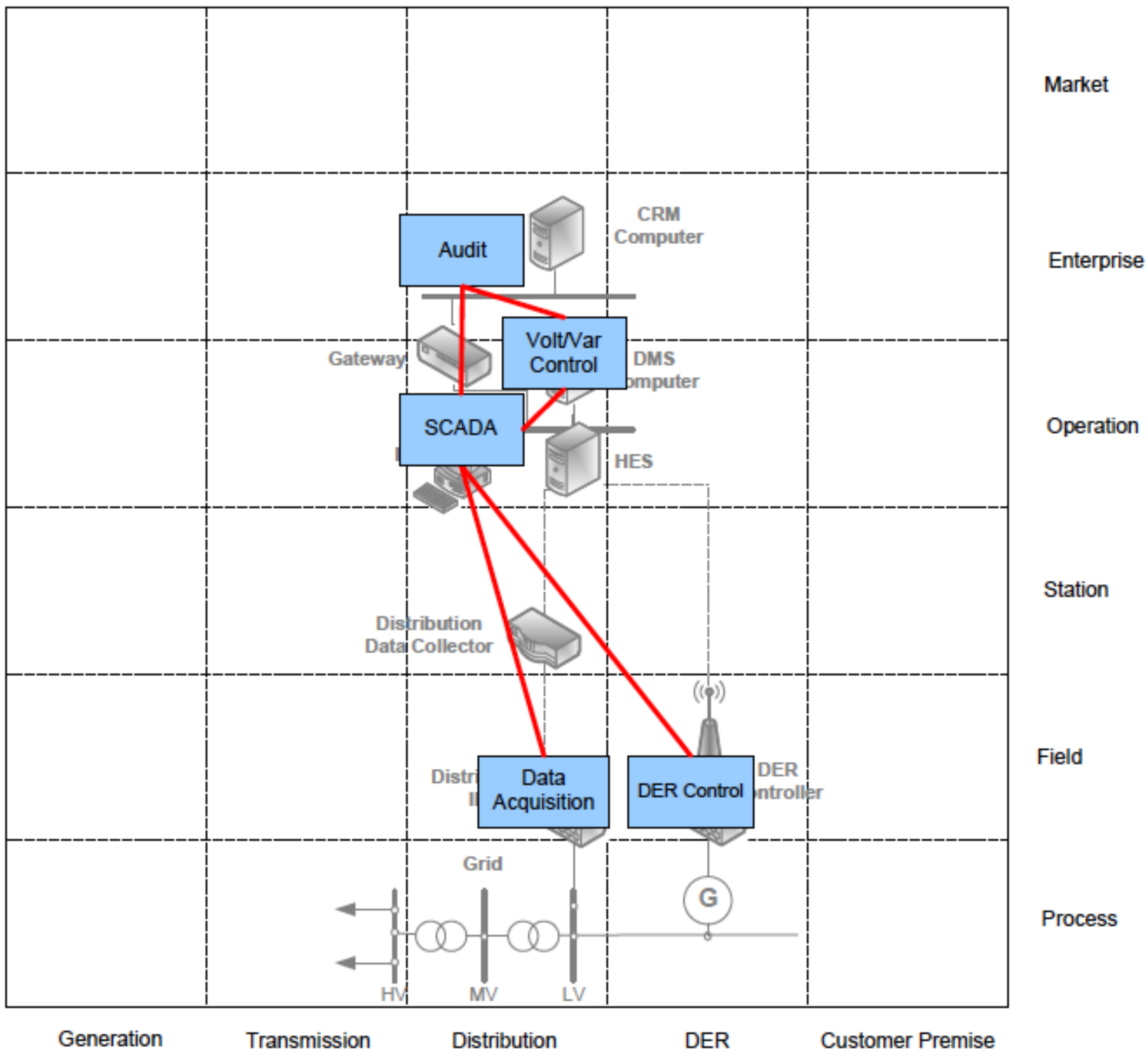


Information Layer

The information layer describes the information that is being used and exchanged between functions, services and components. It contains information objects and the underlying canonical data models. These information objects and canonical data models represent the common semantics for functions and services in order to allow an interoperable information exchange via communication means.






Market
Enterprise
Operation
Station
Field
Process
Audit
CRM
Computer
Volt/Var
Control
Gateway
DMS
SCADA
HES
Distribution
Data Collector
Data
Acquisition
DER Control
DER
Grid
G
HV
MV
LV
Generation
Transmission
Distribution
DER
Customer Premise

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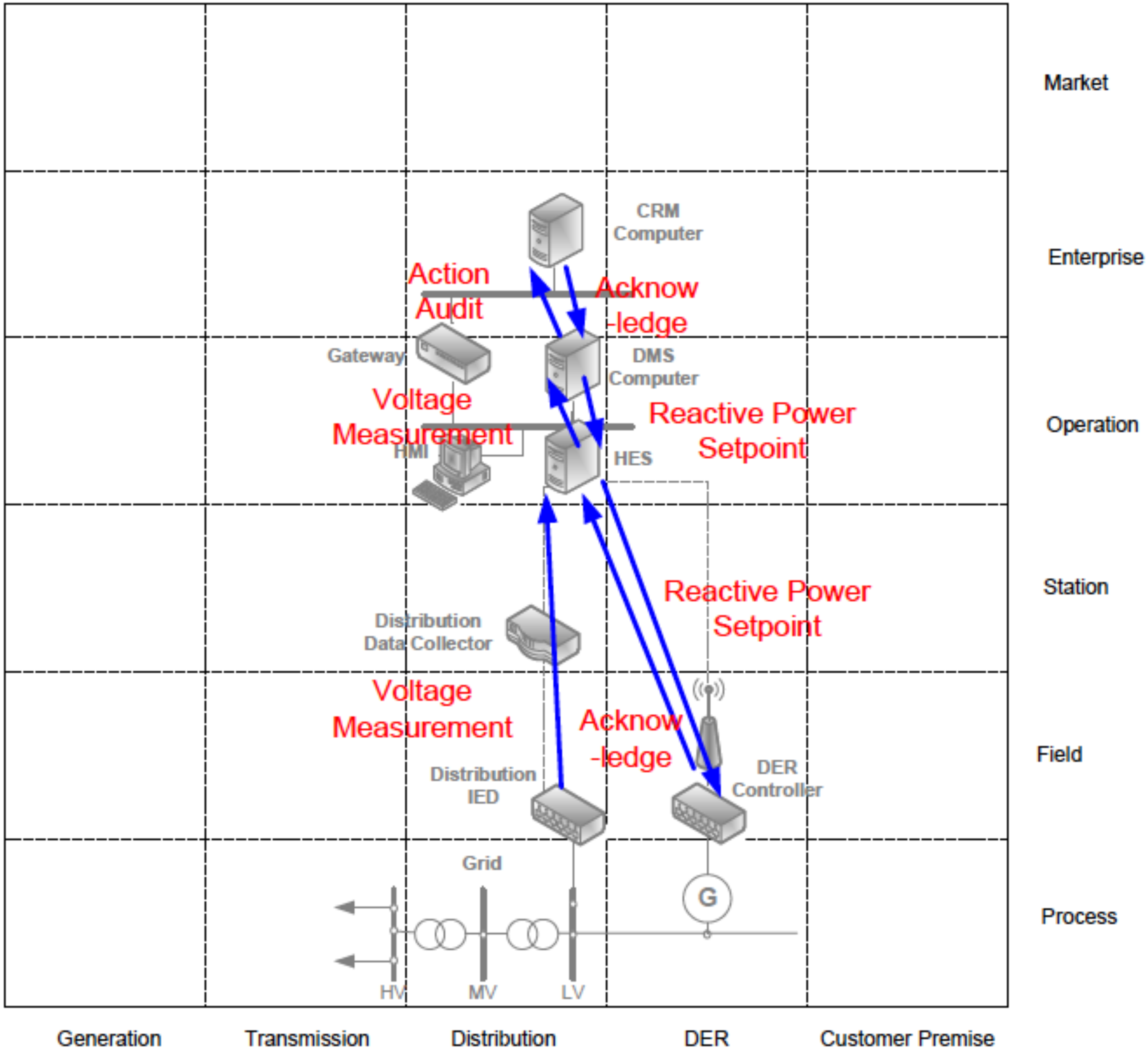
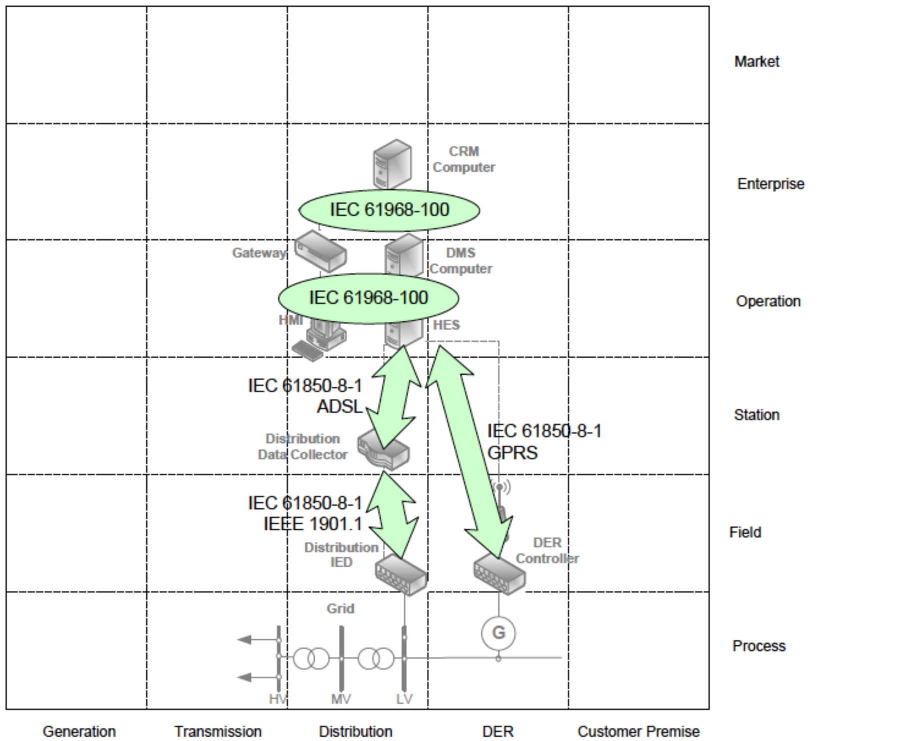


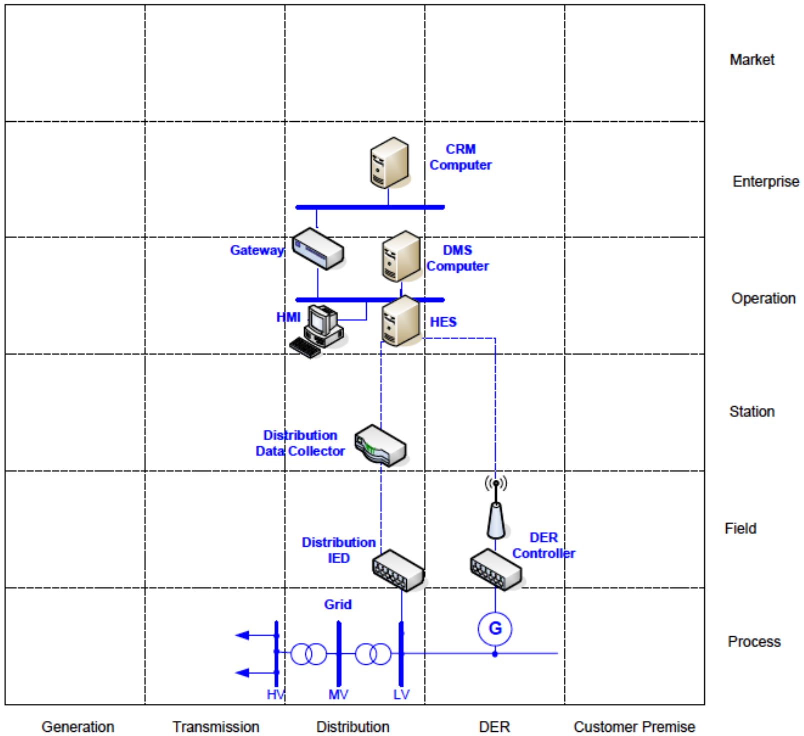
Communication Layer

The emphasis of the communication layer is to describe protocols and mechanisms for the interoperable exchange of information between components in the context of the underlying use case, function or service and related information objects or data models.



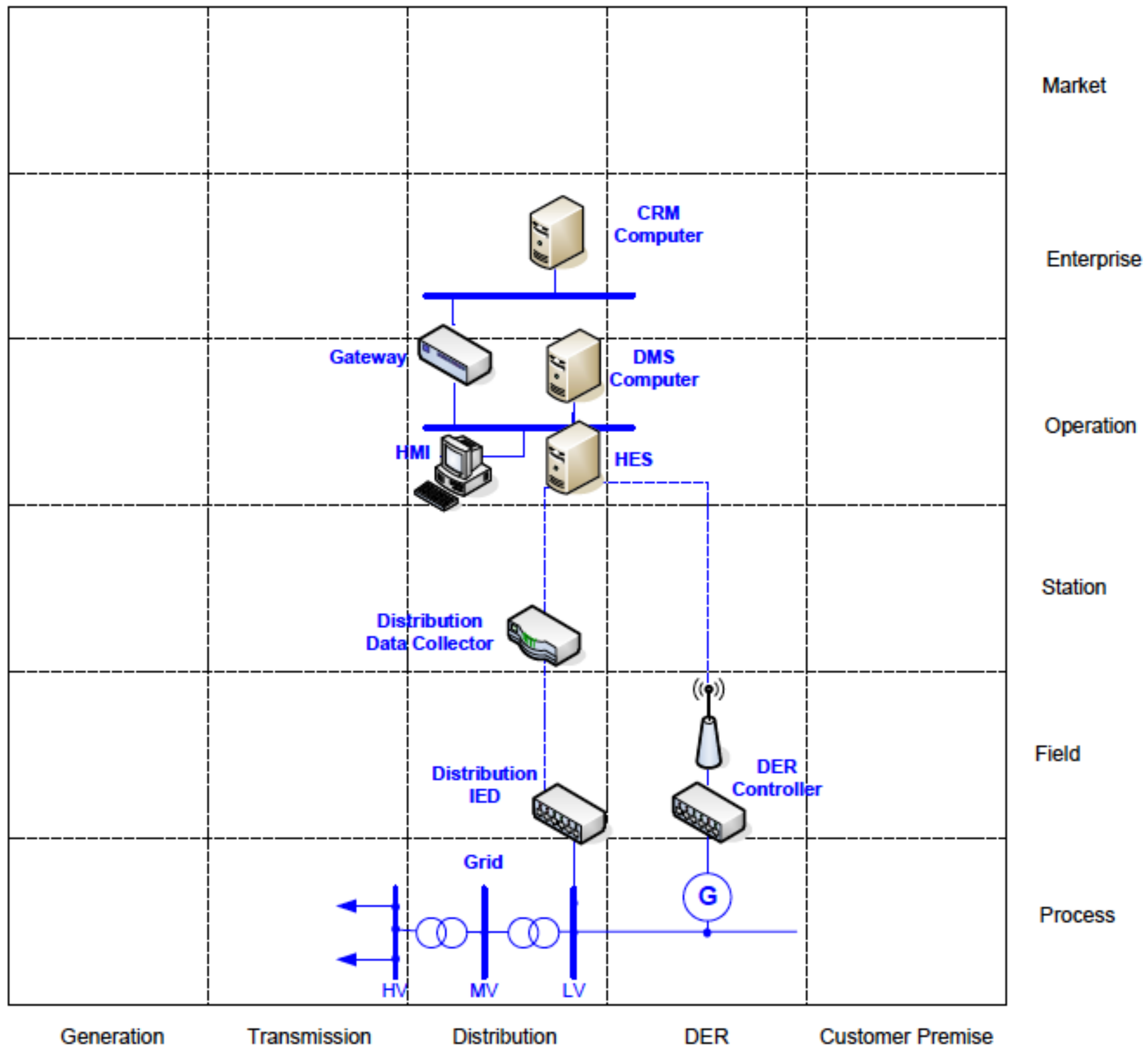
Component Layer

The emphasis of the component layer is the physical distribution of all participating components in the smart grid context. This includes actors, applications, power system equipment (typically located at process and field level), protection and tele-control devices, network infrastructure (wired / wireless communication connections, routers, switches, servers) and any kind of computers.



Step 1 – Develop Physical setup

Describe the components from the Use Case Diagram as tangible objects



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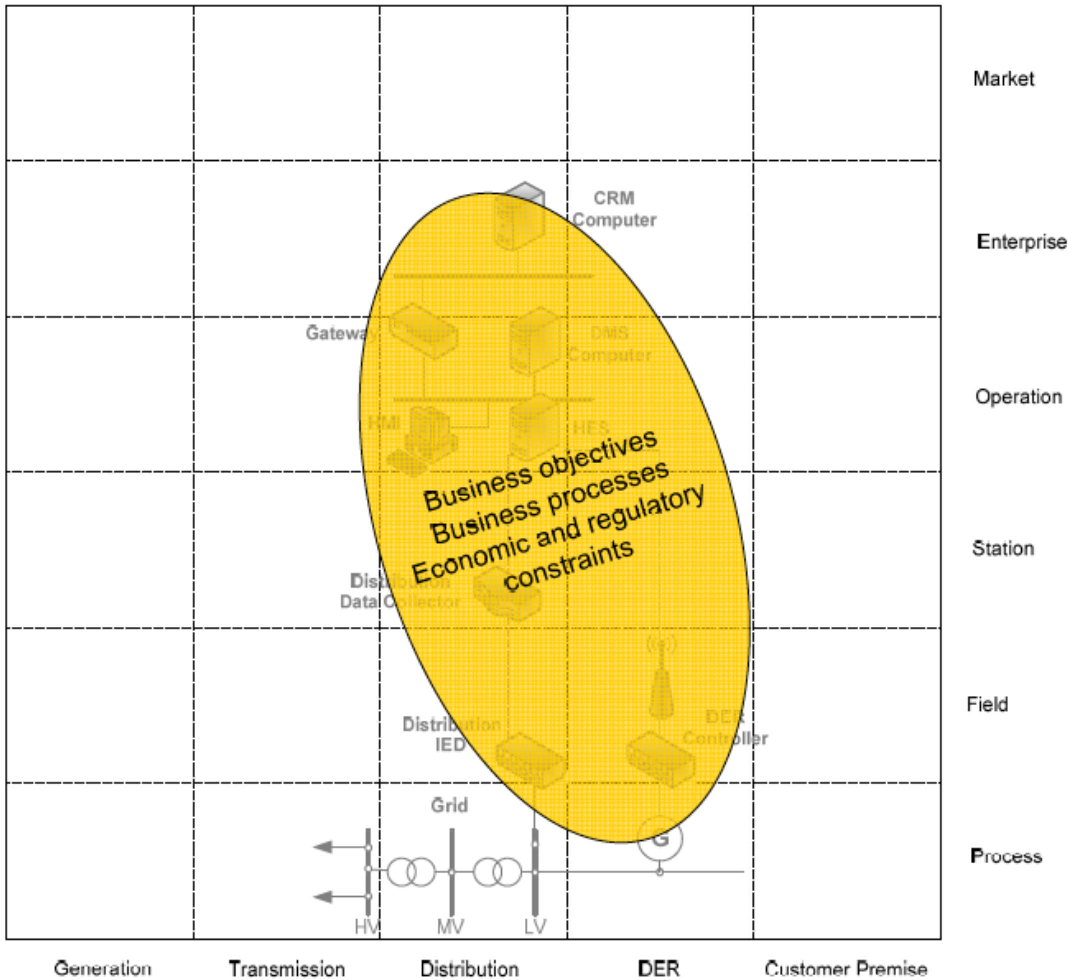
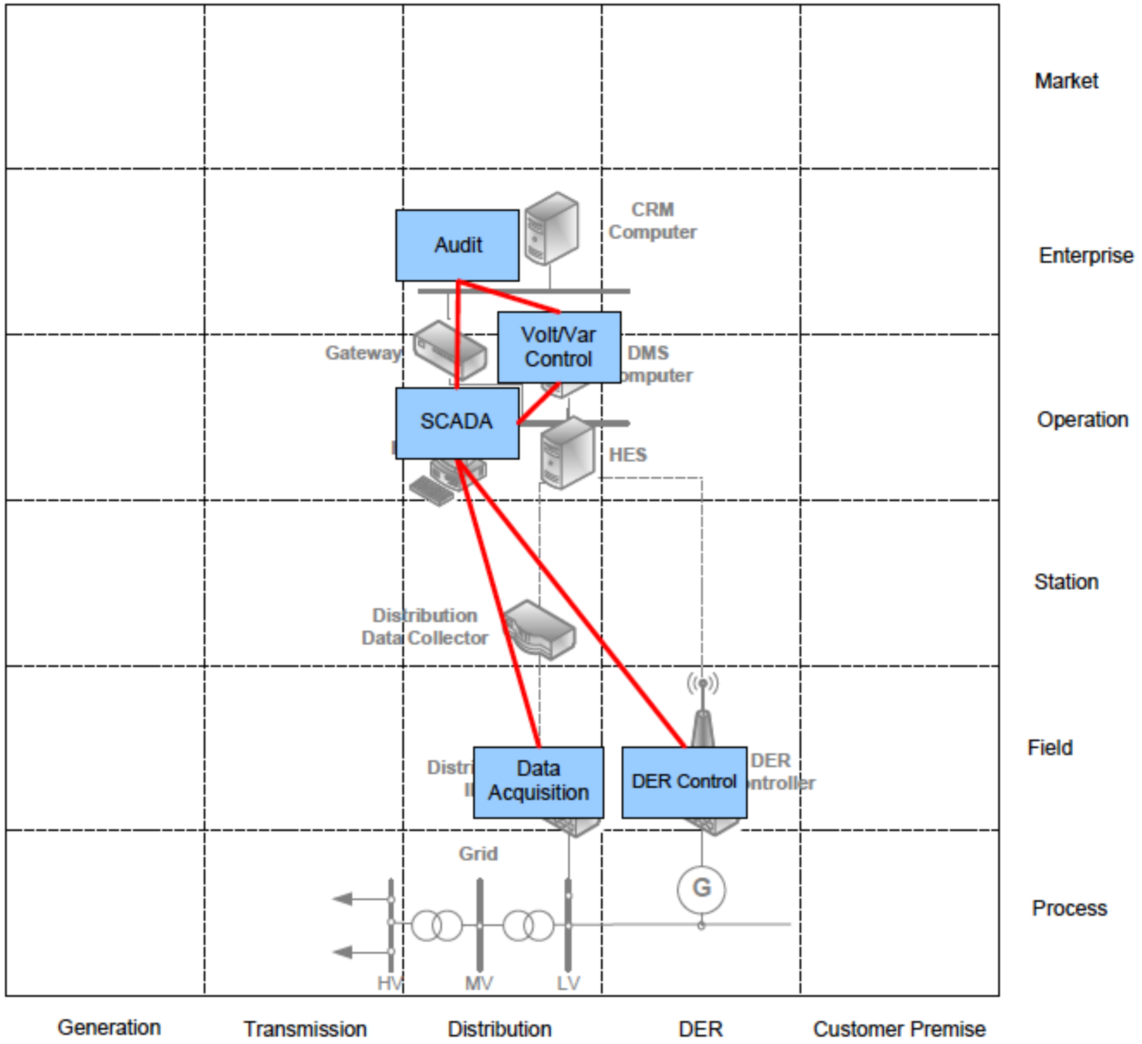
Step 2 – Develop Business layer

Useful to de-lineate the scope of the use case



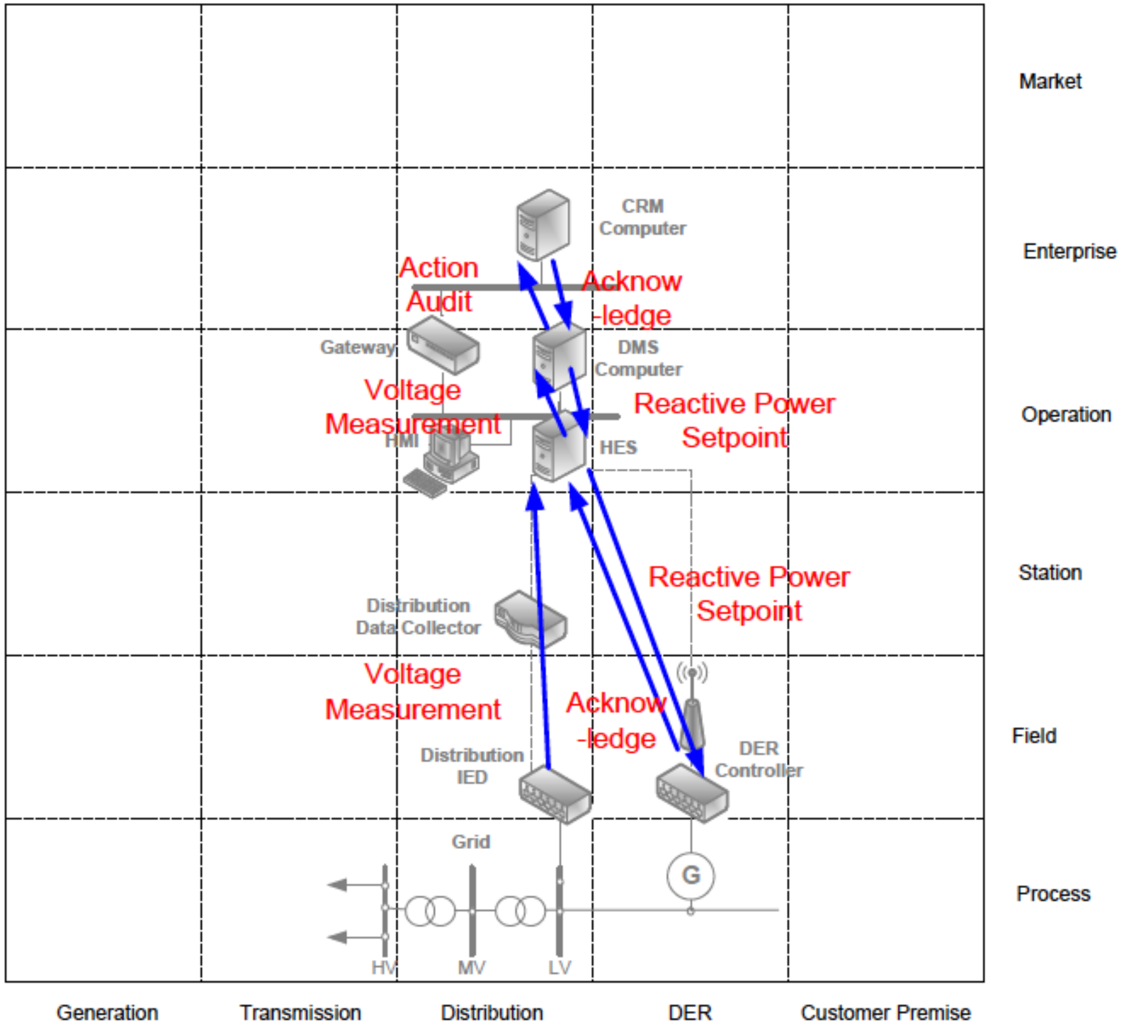
Step 3 – Develop the functional layer

Assign the functions to the components. Not necessarily one-to-one.



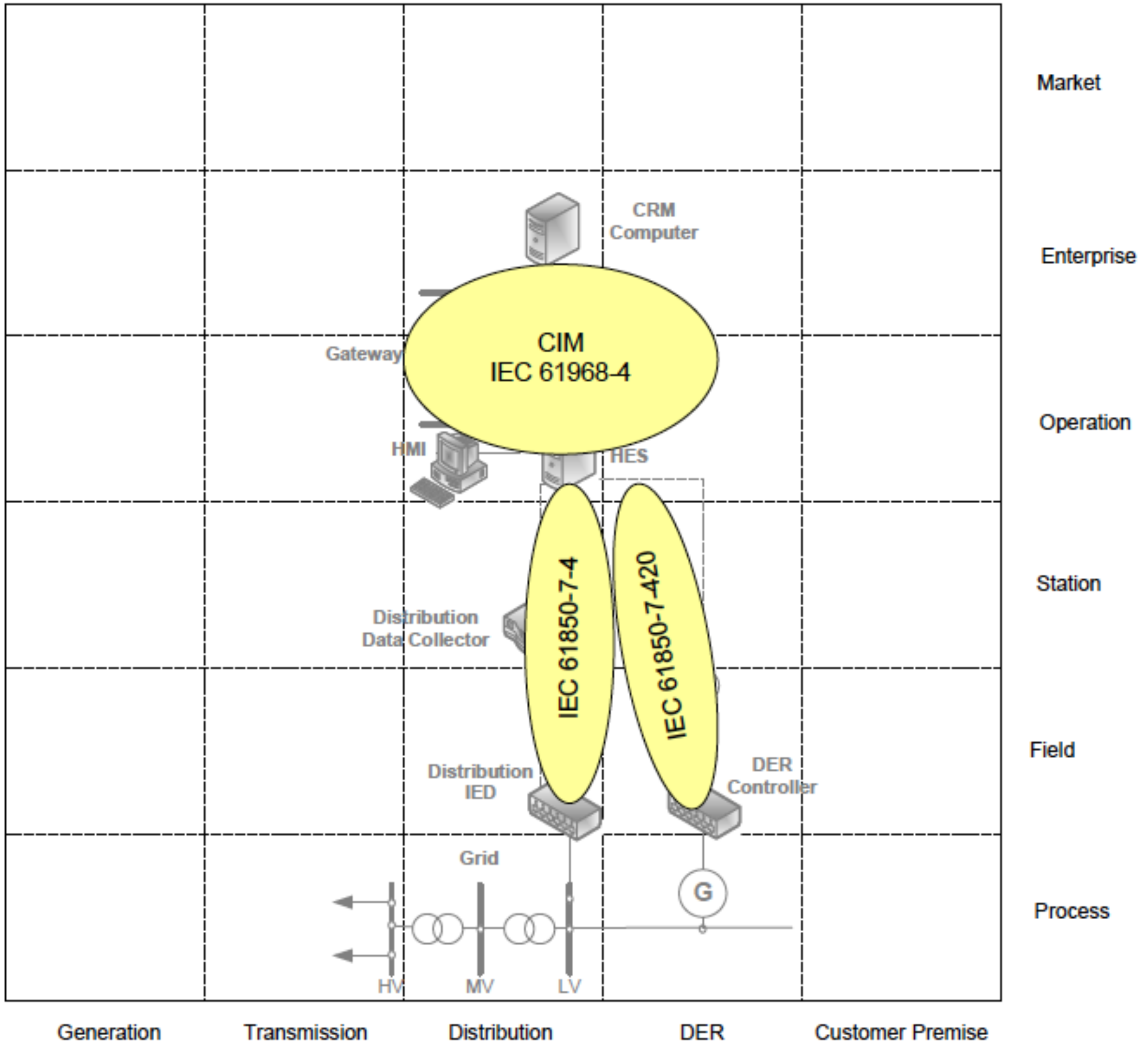
Step 4 – Develop the Information layer

Identify (from the Use case description) which data is to be exchanged between which components & function.



Step 5 – determine datamodels to use

Based on type of information exchanged, determine suitable standardised datamodel



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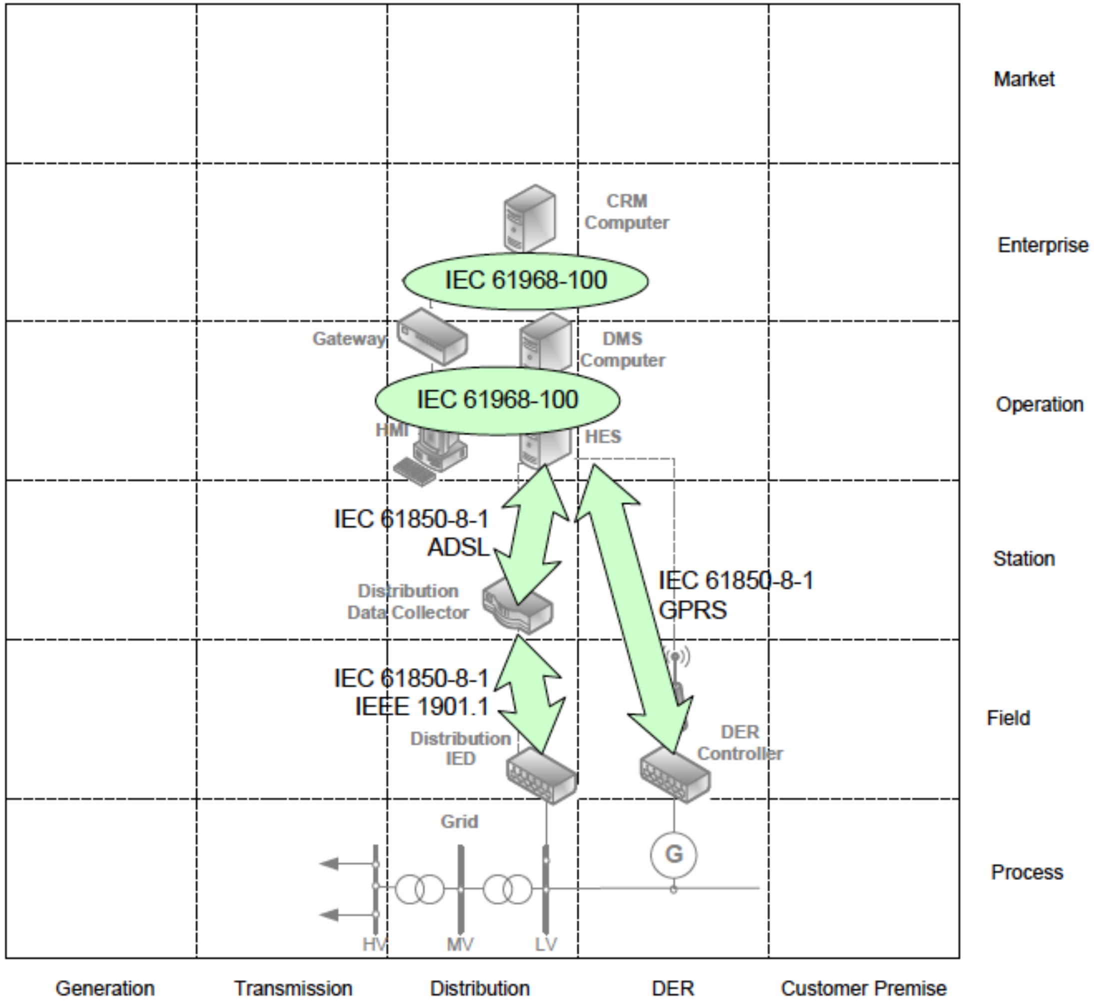
Step 6 – Determine communication protocols to use.

Define standard for communication protocol, including physical and link layer protocols to use



The end

- After following the process we should have:

  A total of 5 architecture ”drawings” that present different views of the System

Why all this?

The Smart Grid Architecture Model is being used in several European R&D projects to design the solutions being tested.

Outline of the lecture

- Course Wrap-up
  - Local systems
  - Communication
  - Control room applications

- System Architecture – introduction
  - Architecture Models – why?
  - Architecture Models – what?
  - SGAM - Smartgrid Reference Architecture Model

- Smartgrid Architecture Example