Welcome!
EH2741
Communications & Control in Power Systems

Lars Nordström
larsno@kth.se

Outline

- Administration
  - Few words about the department
  - Walk through of course syllabus
- Demonstration of KTH-social course platform
- CAPS course introduction
  - Power system control & operation

General Information

- Teachers
  - Examiner & Lecturer
    - Prof.Lars Nordström
  - Course Assistants
    - Yiming Wu yiming.wu@ics.kth.se
    - Davood Babazadeh, davoodb@ics.kth.se
- Industrial Information and Control System
  - Architectural analysis for ICT system in general
  - Particular focus with power industry

PSMIX group

Group lead: Nordström
APost-Doc: Saleem
7 PhD students + 2 IndPhD
8 MSc Students

Educational Activities:

- Communication & Control for Power Systems
- Computer Applications in Power Systems
- Circa 20 Masters & Bachelor projects annual

Research Areas:

- Reliable and High-performing ICT infrastructures
- Distributed Control of Power Systems
- Novel Market Models for Active Power Systems

Funding:
1,2 MEUR Annual
58% External
Main sources:
FP7, Swedish Energy Agency ABB, SvK.

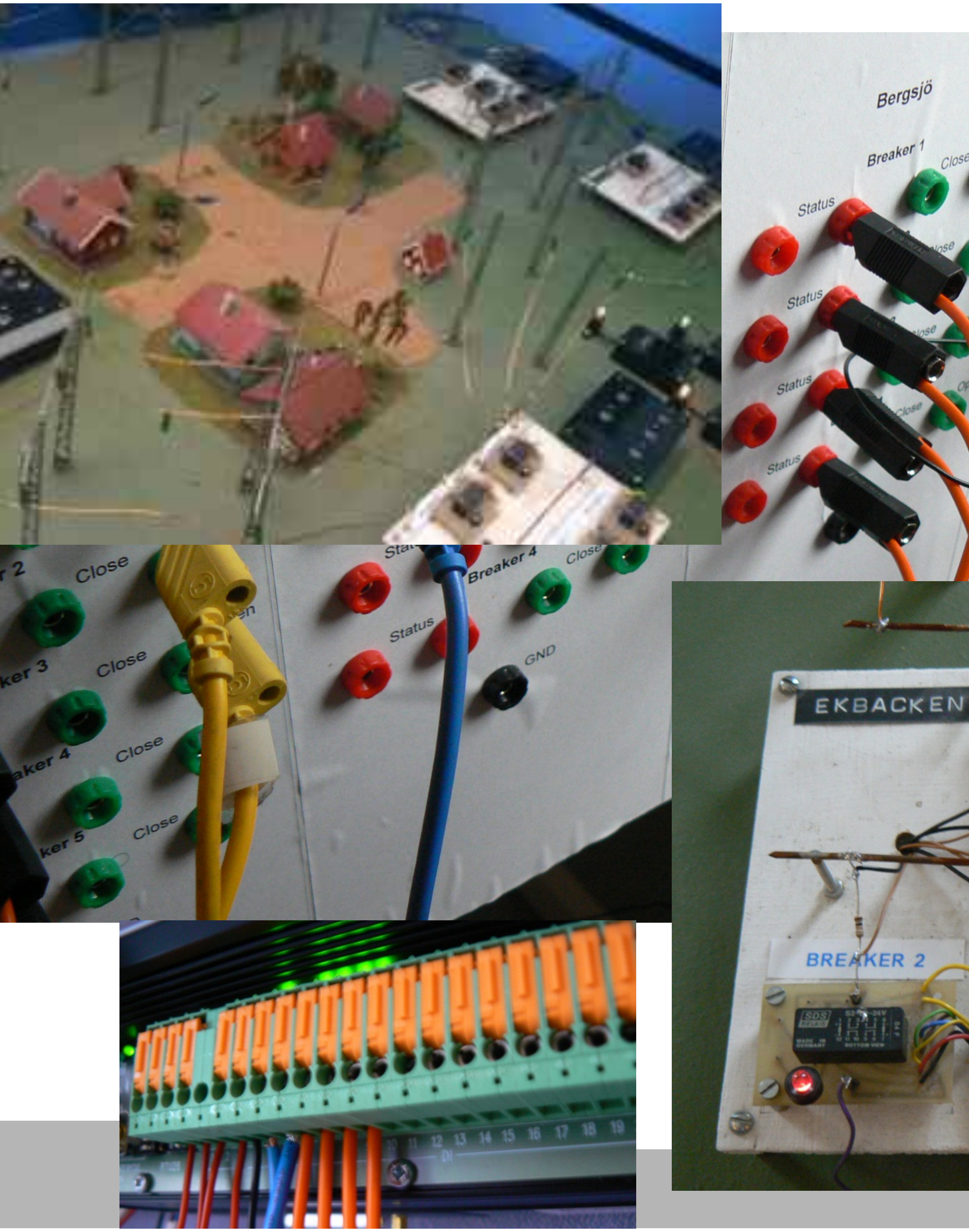
Education – Power Systems track

EH2741
Communications & Control in Power Systems

EH 2745
Computer Applications in Power Systems

EH2751
Communications & Control in Power Systems
Project course

Connecting things



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CommLink	-	System	CommLink
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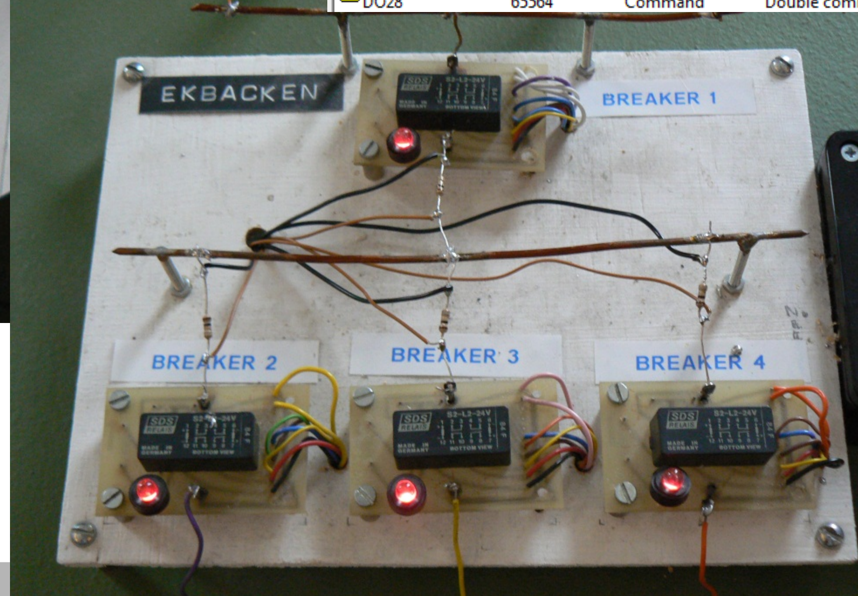
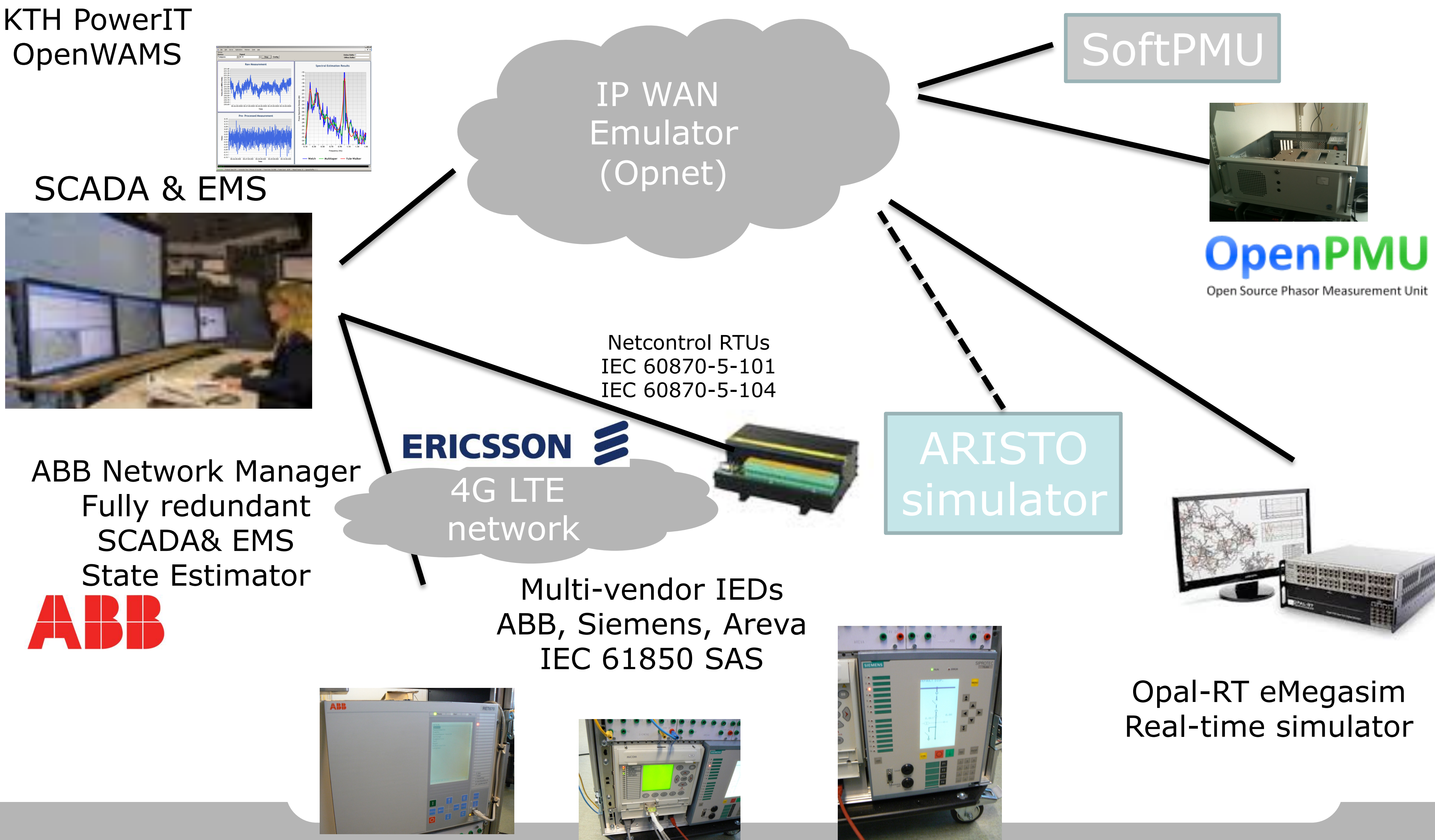
DI19	65555	Acquisition	Boolean
DI20	65556	Acquisition	Boolean
DO21	65557	Command	Double command
DO22	65558	Command	Double command
DO23	65559	Command	Double command
DO24	65560	Command	Double command
DO25	65561	Command	Double command
DO26	65562	Command	Double command
DO27	65563	Command	Double command
DO28	65564	Command	Double command



Control System Laboratory



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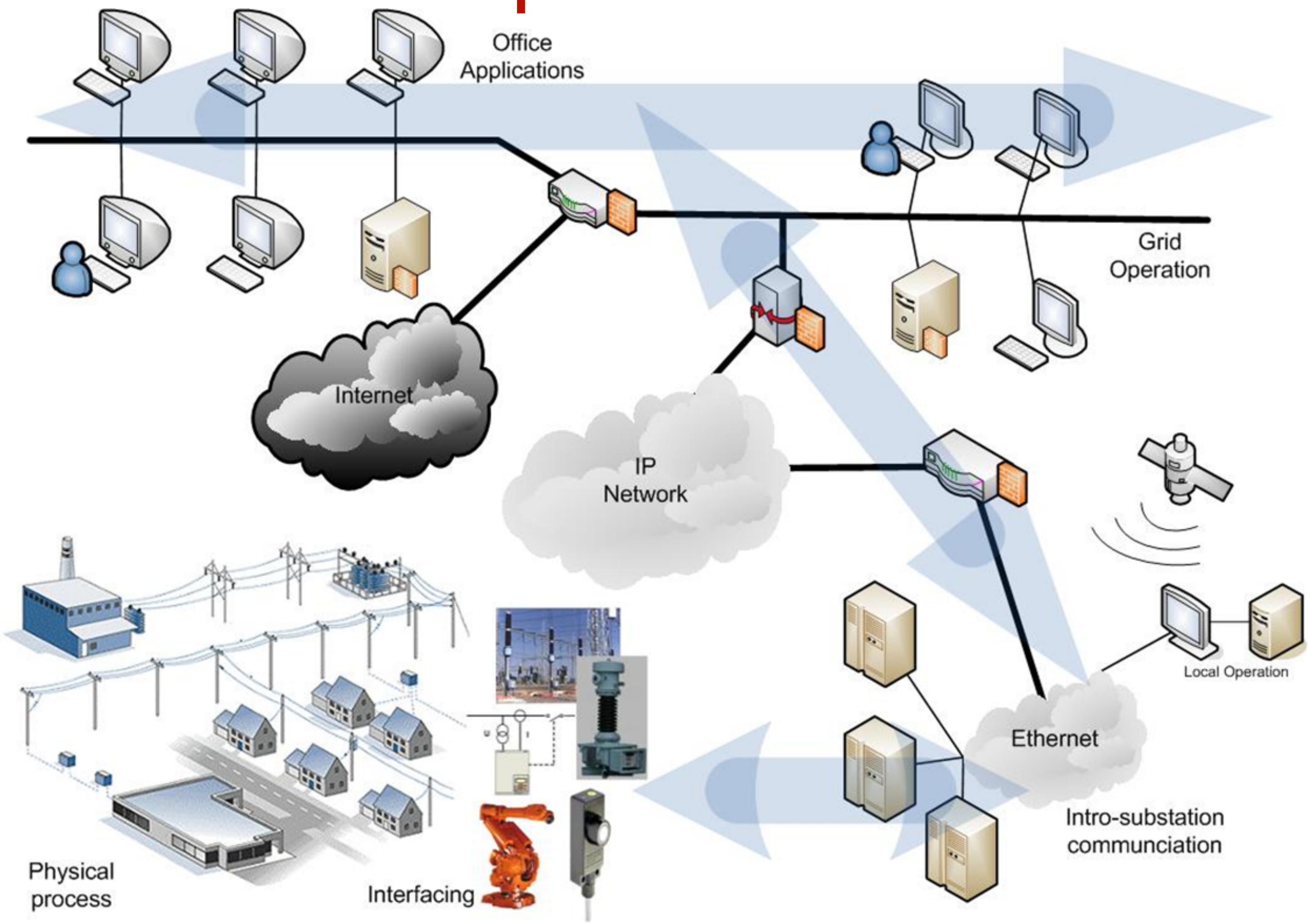
Course content

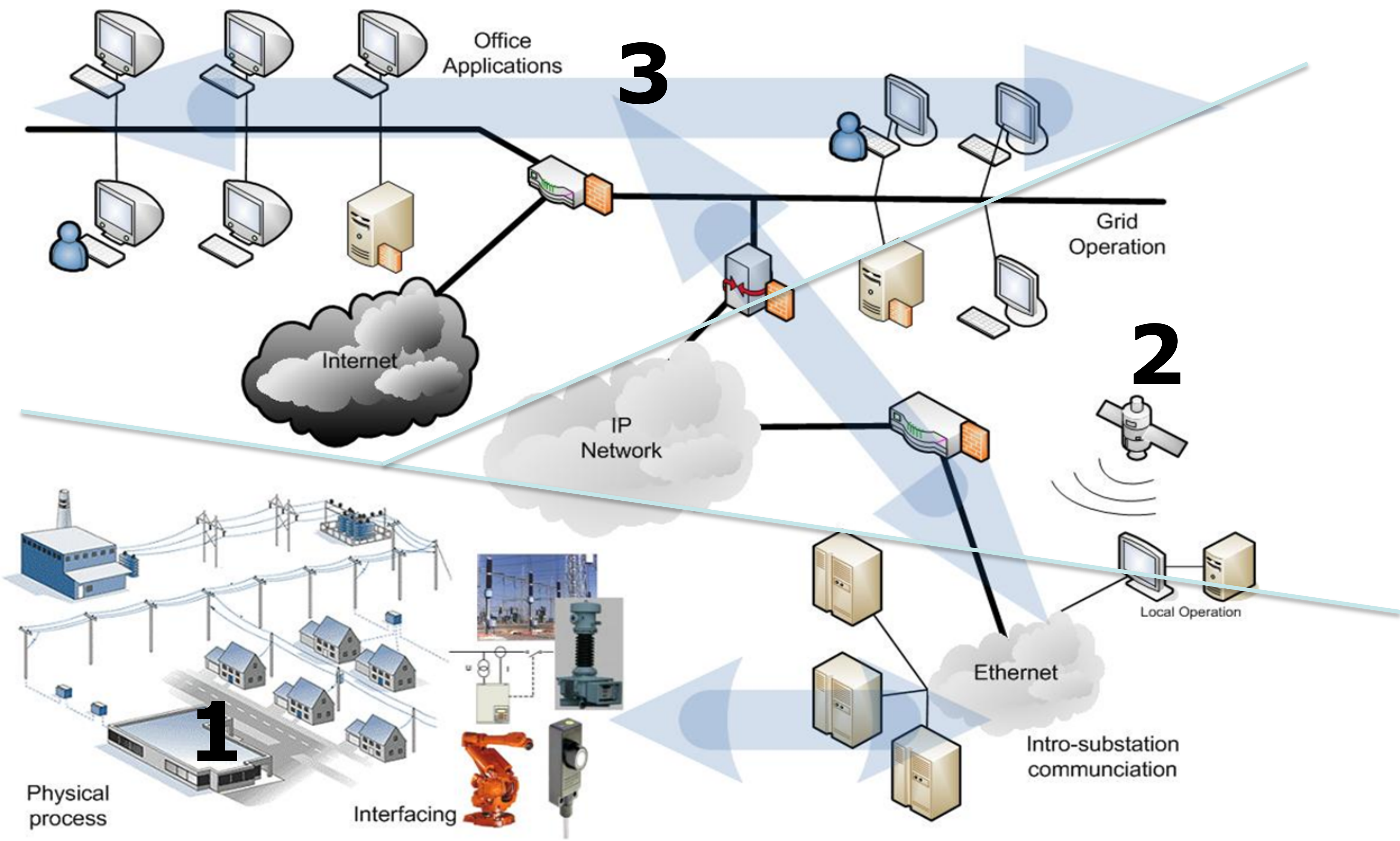
EH 2741 Communications & Control in Power Systems

- Power System Analysis
- Power System Protection
- Power System Instrumentation
- Power System Operation/Control
- Power Communication Systems
- Information System Architecture
- Information Modeling

Course map


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

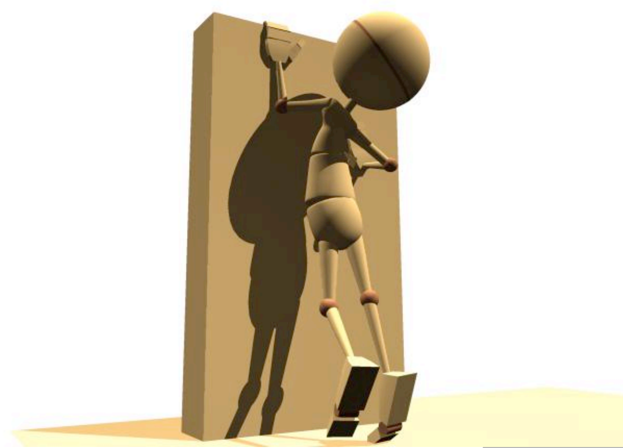
Course Map



Office
Applications
3
Grid
Operation
Internet
IP
Network
2
Local Operation
Ethernet
Intro-substation
communciation
1
Physical
process
Interfacing

Course philosophy

- Open the door to future study
  - EH2745/EH2751 advanced & project courses
  - Degree projects
- Systems engineering approach
- Complement to Power Systems
- Applying theory and methods from several fields to real-world problems
- Engineering skills
- State of the Art technologies
- Industry involvement



Course syllabus

- Course objectives
- Prerequisites
- Course administration
- Course Schedule
- Literature
- Assessment & Grades
- Course Staff

Course Objectives

- Describe the functions of the primary equipment in the power system that is relevant for protection, automation and control
- Analyze substations and simple power systems in terms of reliability protection, automation and control needs.
- Describe the function and architecture of information and control systems used for protection, automation and control of power systems.
- Describe the function and architecture of communication systems used for information & control systems for power system control.
- Describe the importance of information & control systems for the ability to connect large amounts of renewable power sources.
- Analyze and develop basic systems for substation automation and protection.
- Analyze and develop basic information & control systems for system-wide control from control rooms, e.g. SCADA systems and EMS applications.
- Construct a state estimator for power systems.
- Describe relevant interoperability standards in the field, such as IEC 61850
- Describe the threats and risks associated with the use of information & control system for controlling the electric power system, known as Cyber Security.

Course Components - I

- 14 Lectures +5 Exercises
- Project Assignment 1,2 and 3
  - Project hours
- Individual Tests and 2 (voluntary)
- Lab 1 and 2
- Study visit
- Guest Lectures

Course Components - II

- Project Assignment 1 2 ECTS
  - *Designing a Substation and its protection and automation functions*
- Project Assignment 2 2 ECTS
  - *Designing a SCADA and wide area communication architecture*
- Project Assignment 3 2 ECTS
  - *Design a power system state estimator*

Literature

- Course Book
  - *"Power System SCADA and Smartgrids"*
    Mini Thomas & John D McDonald

- Additional reading provided as hand-outs.

Assessment and Grade

- No final exam
- Project Assignment 1, 2 and 3: fail, pass 6 course points
  - pass with bonus 7- 10 course points
- Test 1 & 2 - 0 - 15 course points
- Lab 1 and 2 : fail, pass

Grade

Grade	Course Points
E	18-24
D	25-31
C	32-39
B	40-46
A	47-60

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KTH social

- All course related information is available on the KTH social platform
- You get access to the platform once you are registered to the course

https://www.kth.se/social/course/EH2741/

Team up!!!

Project Assignment
Power System Control Lab
SCADA & Wide Area Communications

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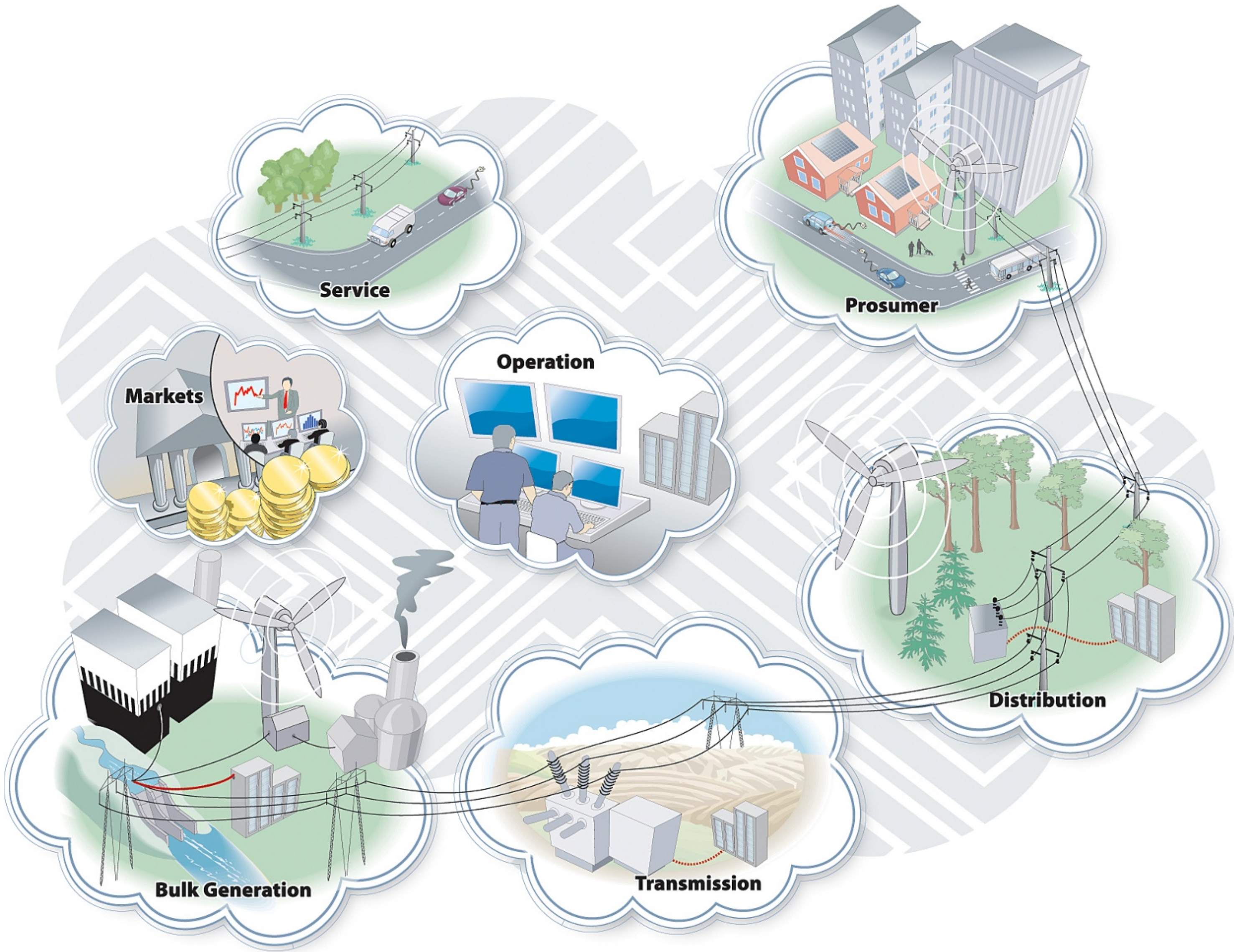
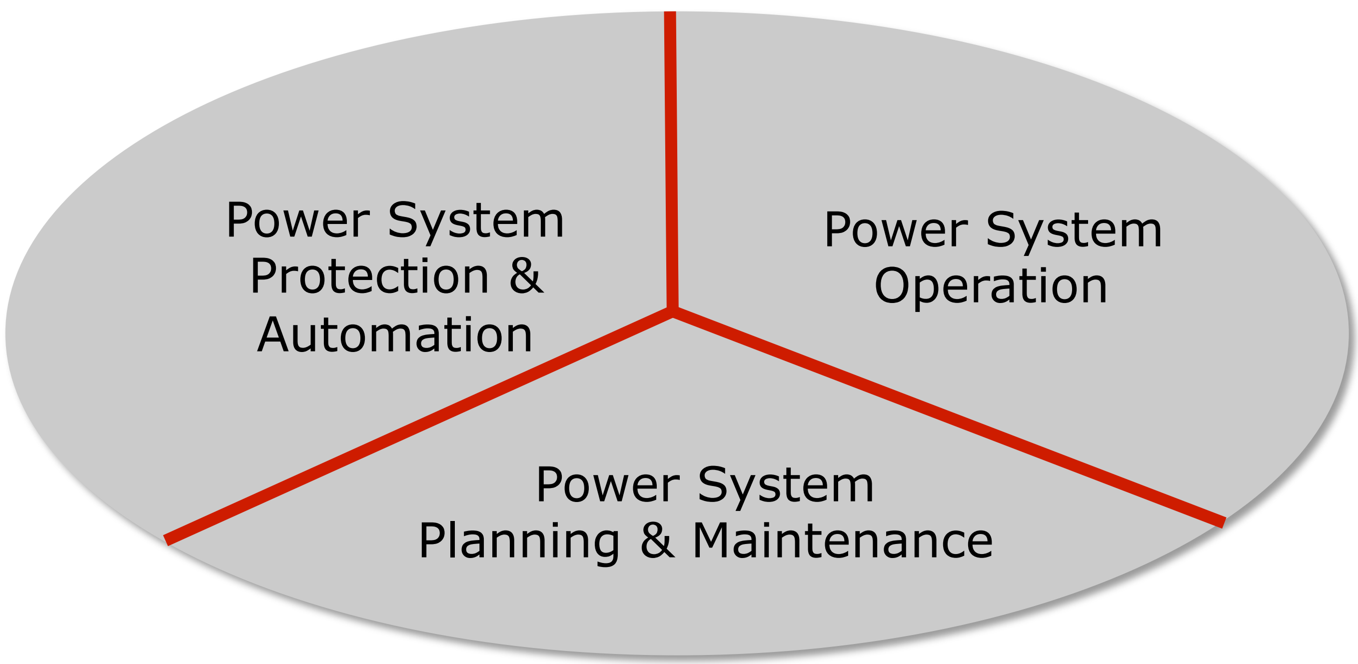
Communication & Control in Power Systems



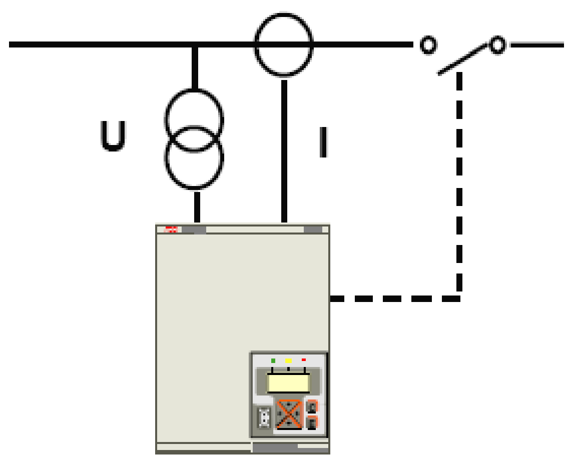
Integration of topics & timescales

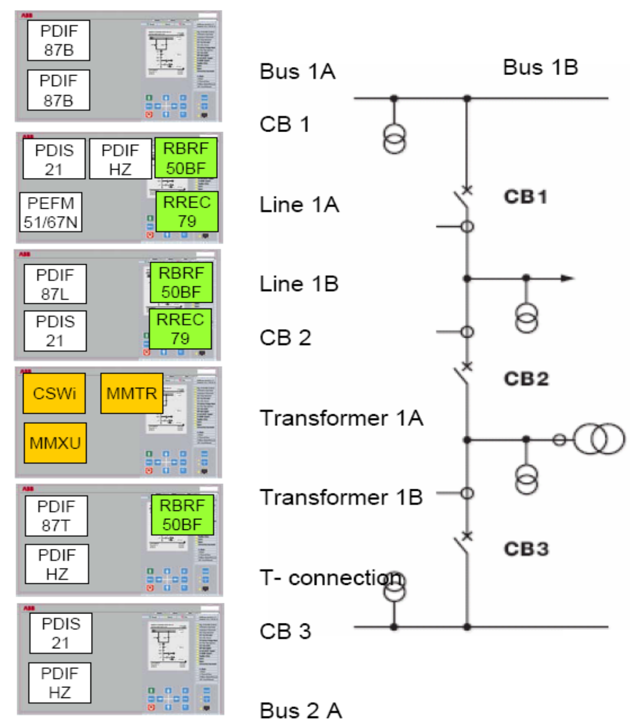
- Meeting the challenges of the future power system requires integration of previously separated areas with ICT as the enabler



Power System Protection & Automation

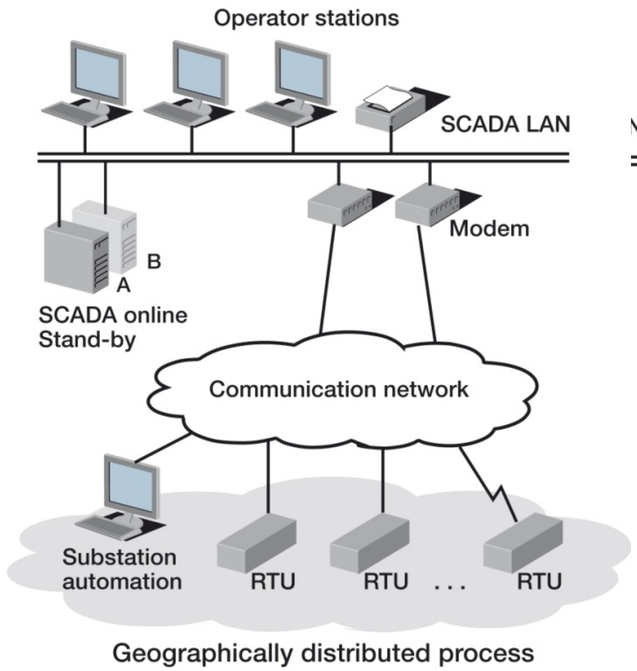
- Protect Equipment
- Protect People & Property
- Separate faulty section from power system
- Restore normal operation
- Local control

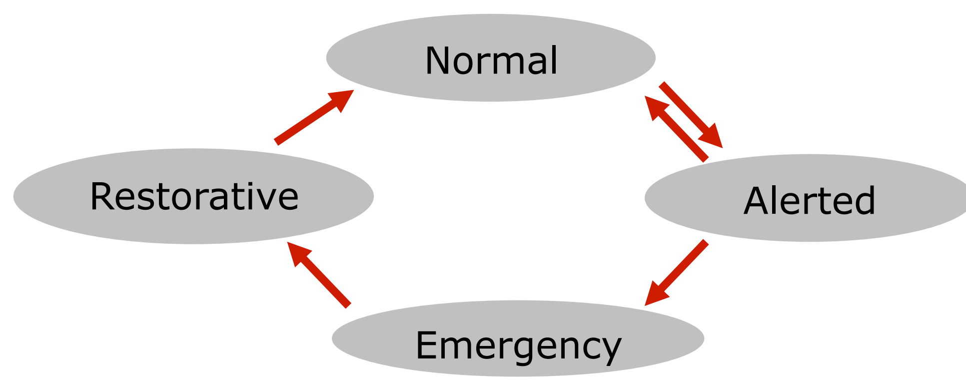




Power System Operation

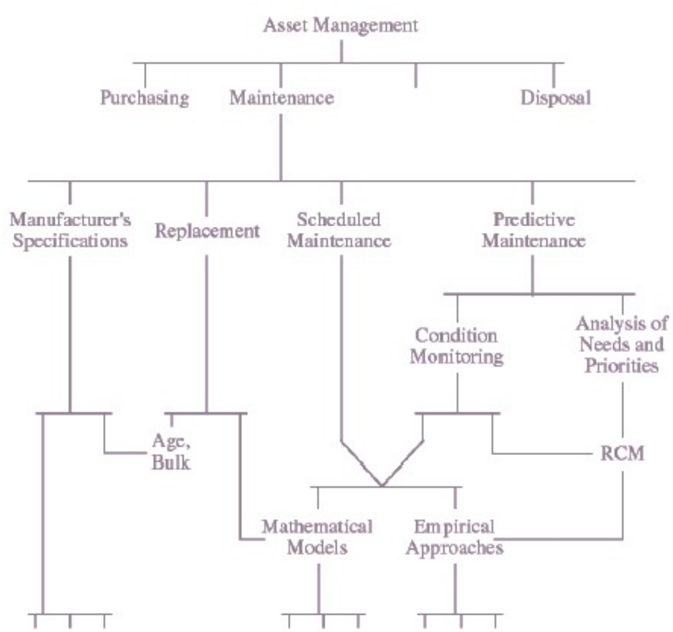
- System-wide monitoring, planning & optimisation for reliable and cost efficient operation of the power system

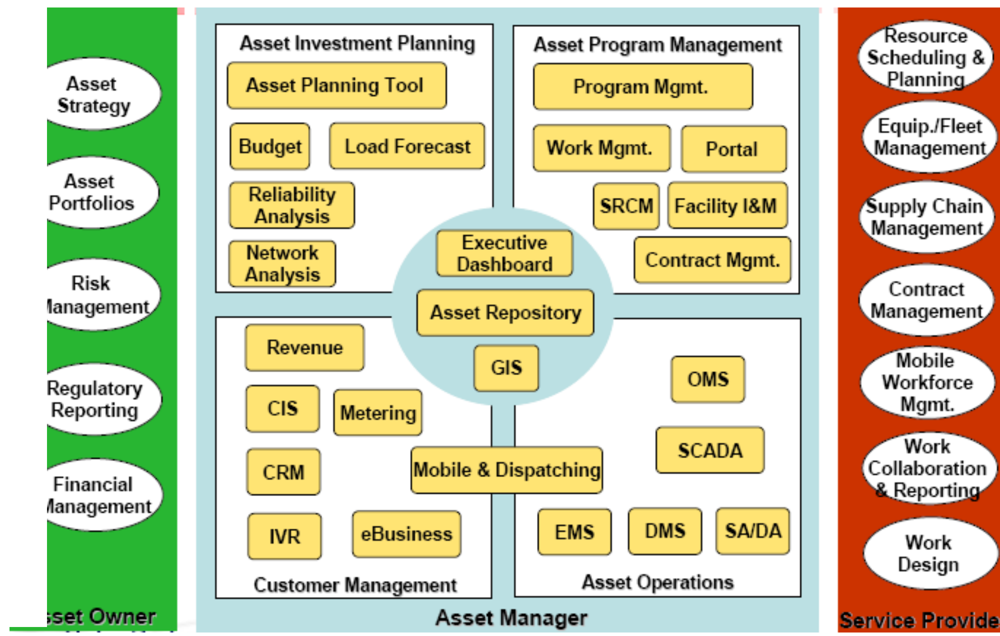




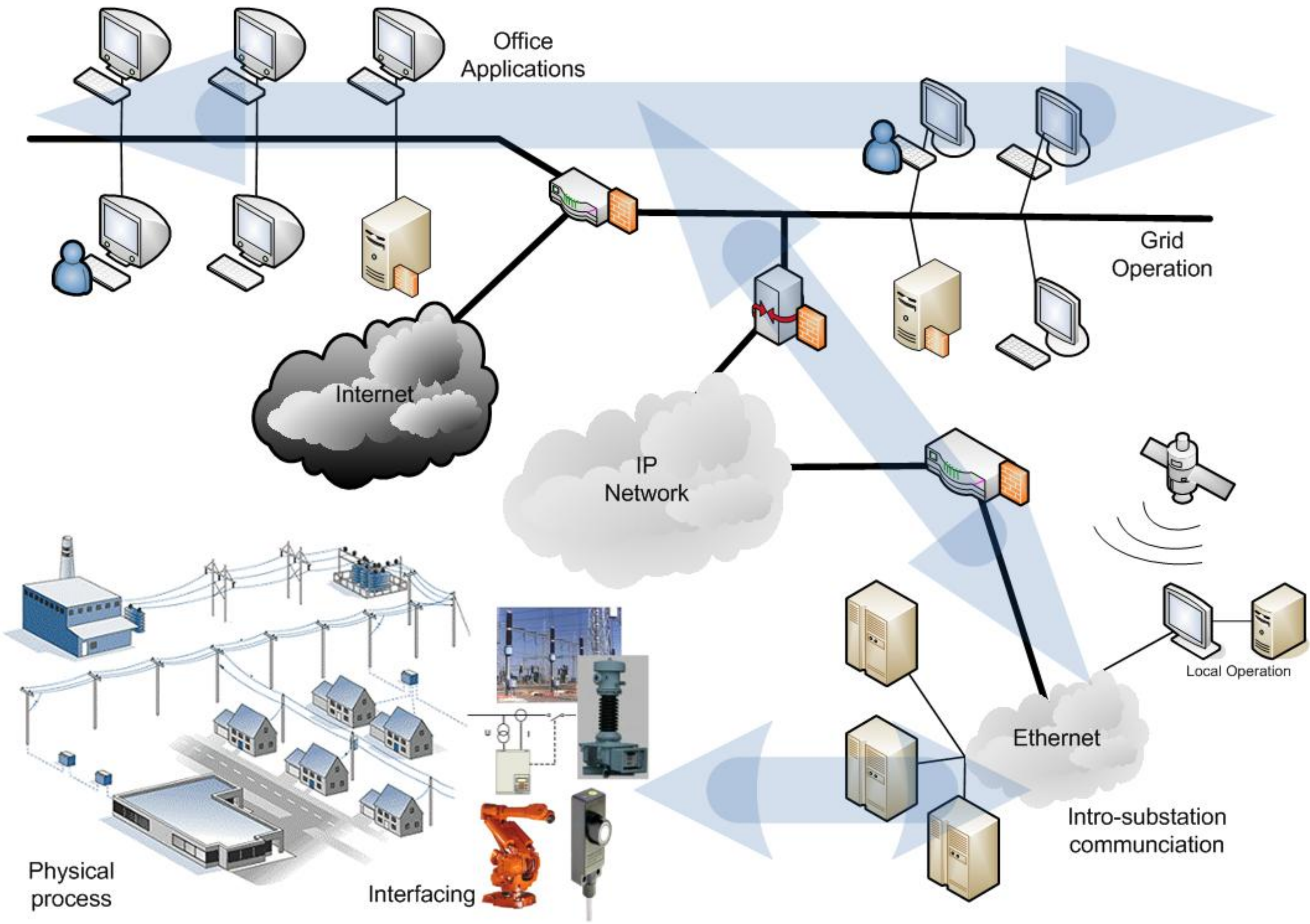
Power System Maintenance & Planning

- Cost efficient maintenance, replacement and commissioning of primary equipment in the power system to achieve required reliability

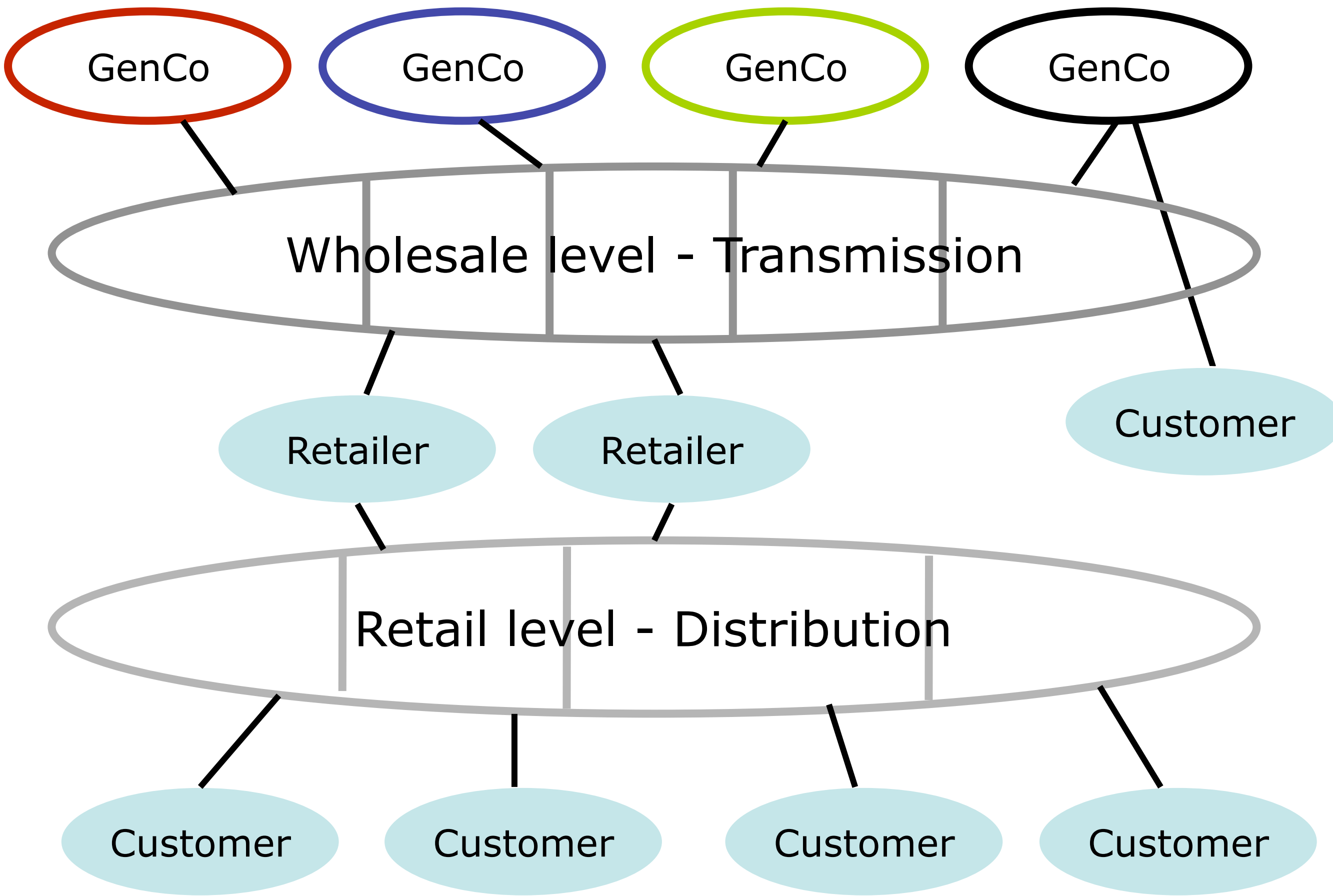




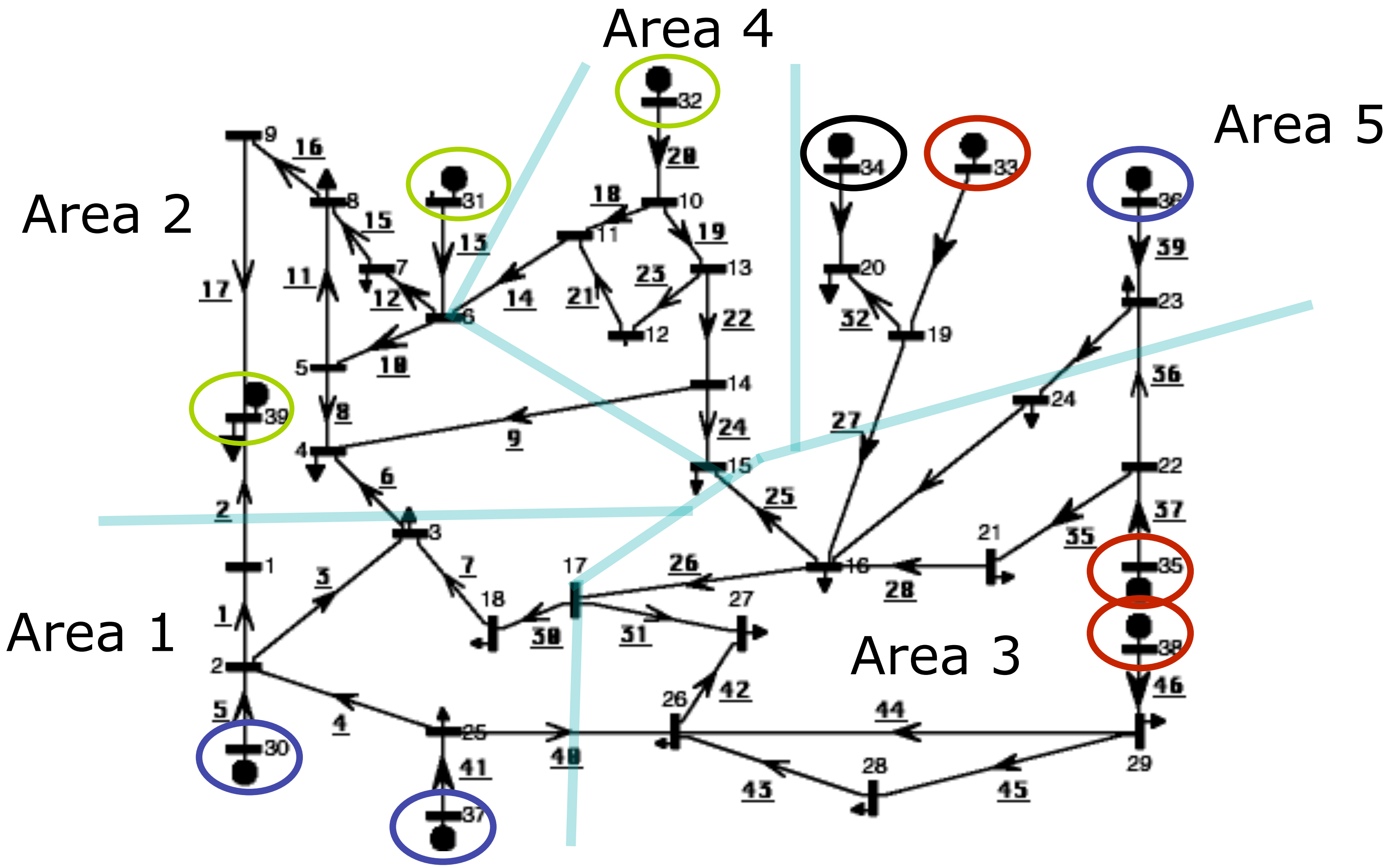
Integrated systems for Smart grids



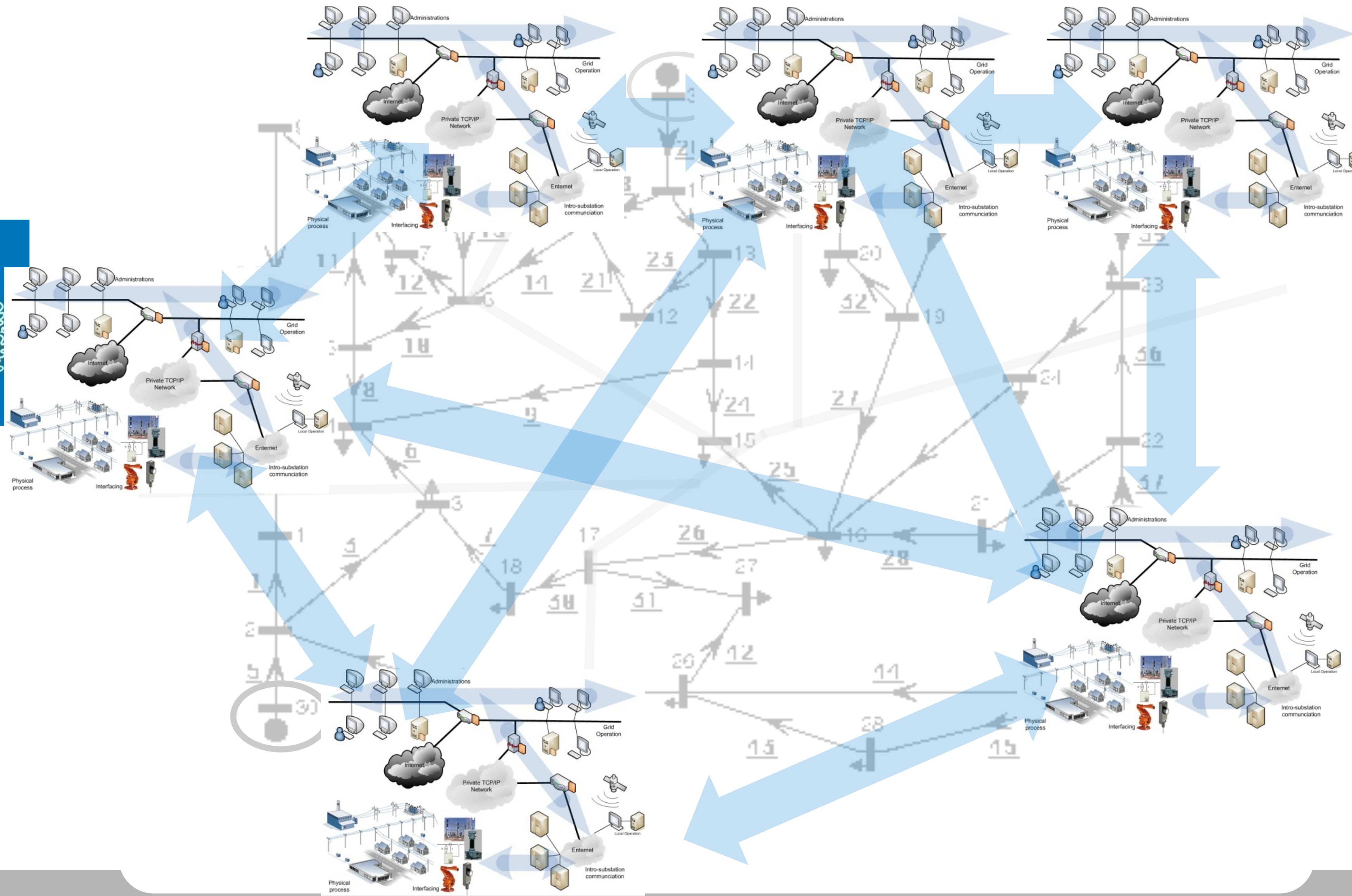
Deregulation– in theory



Deregulation – in practice



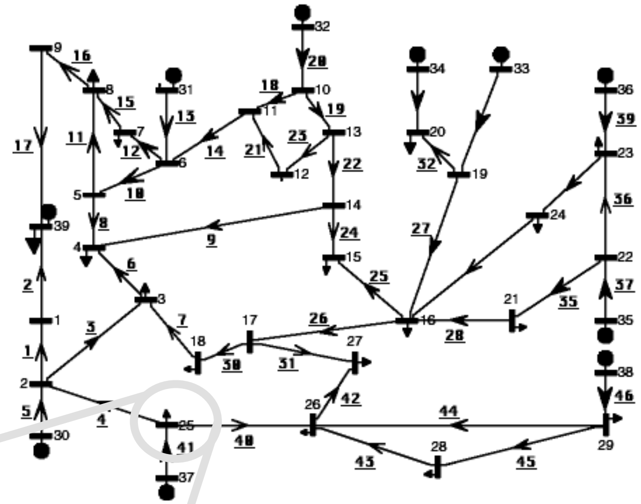
Integration of Systems

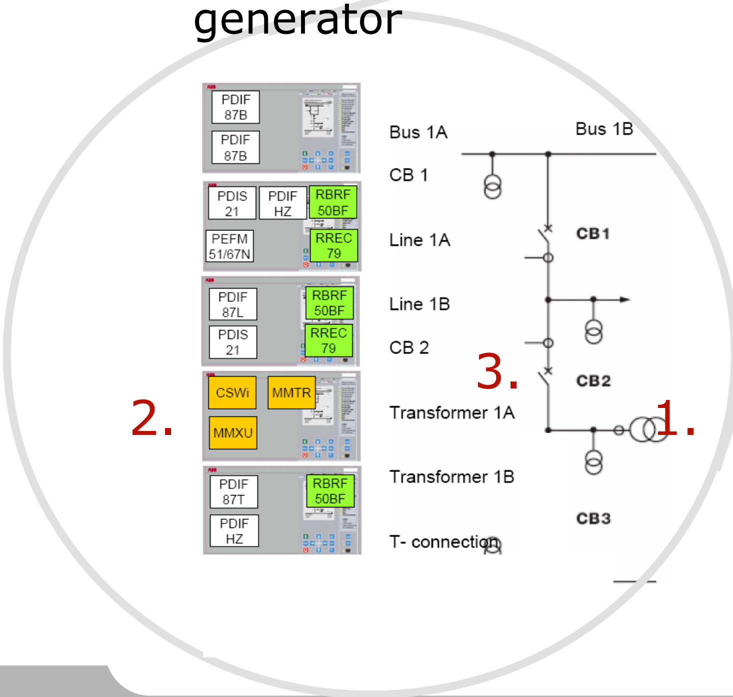


Information Exchange
– a simple example

Example – root event

1. Step-up transformer insulation fault
2. Fault is detected by protection system
3. Trip signal sent to breaker to disconnect generator

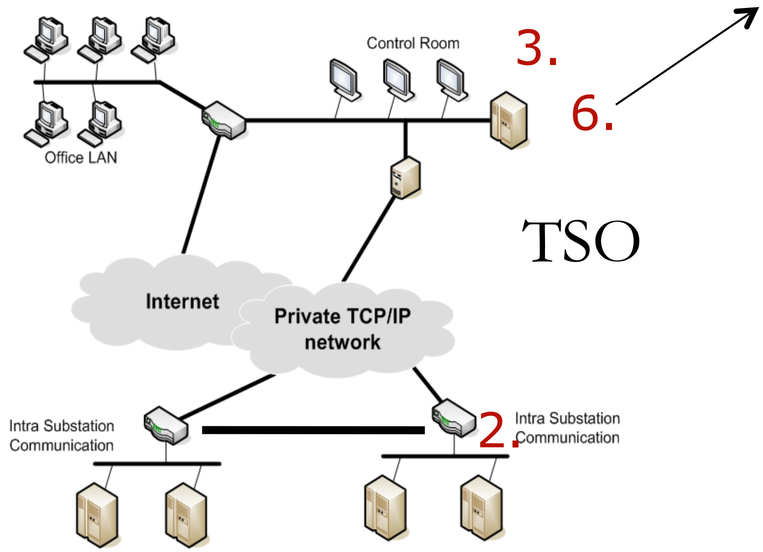


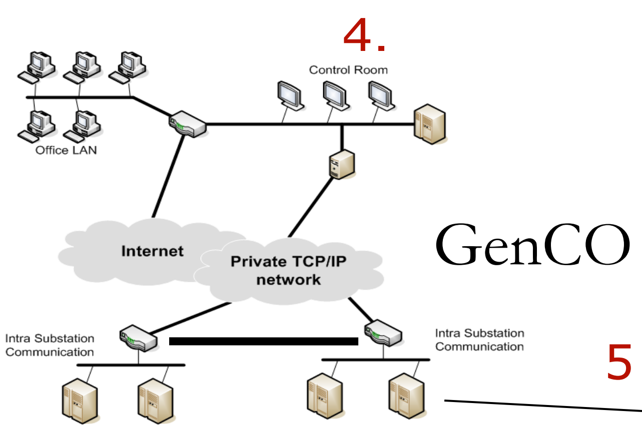


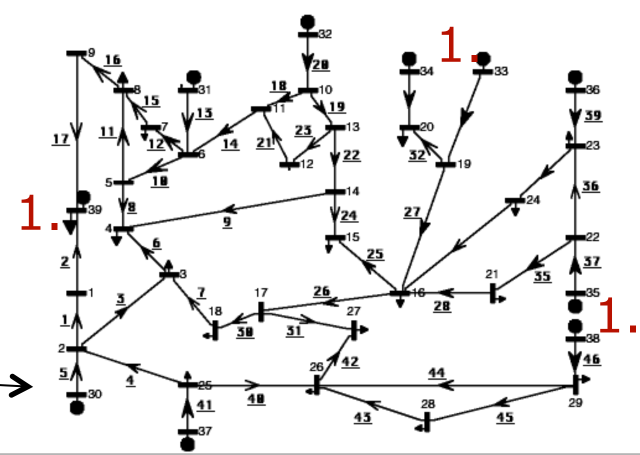
TSO – Frequency control

TSO – Maintenence

TSO - Frequency Control

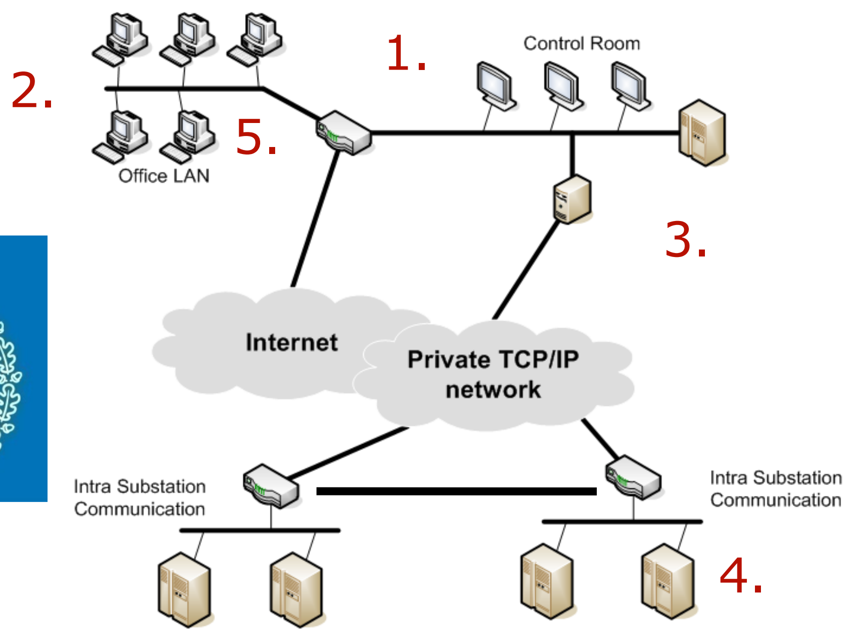


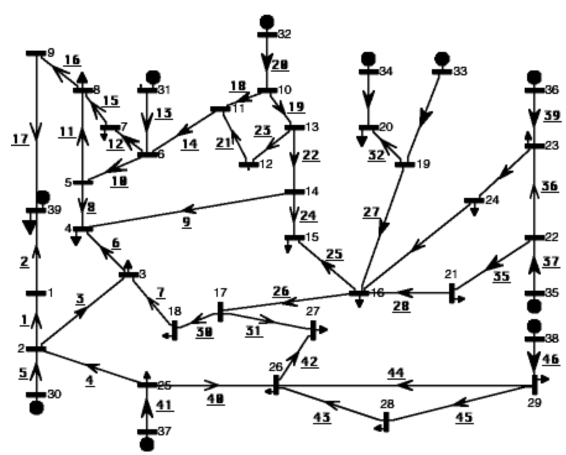




1. Frequency dip detected at generators committed to Load Frequency Control leads to automatic increase of output
2. Continuous under-frequency measured are sent to SCADA system using IEC 60870-5-101
3. Control room operator activates secondary reserve by issuing order to GenCo via phone.
4. GenCo orders production increase in secondary reserve.
5. Order for production increase sent to plant from GenCo CC.
6. New measurements sent to neighbouring Grid Utility using ICCP.

TSO- Repair & Maintenance





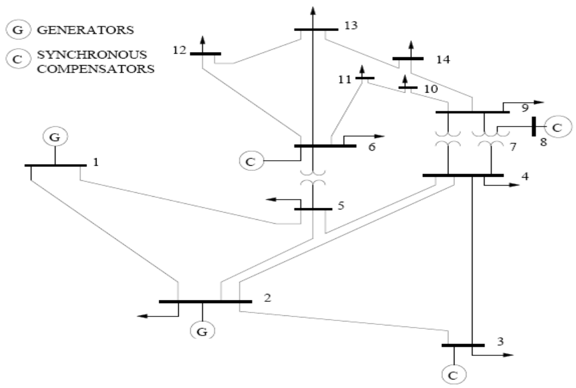
1. Fault in transformer sent from SCADA system to work management system using e.g. IEC 61968-4
2. Repair crew sent to site from work dispatch
3. At site, work crew reports to control centre to initiate safe switching sequences
4. Station set to manual control, fault repaired (!) or report initiated for major overhaul.
5. After completed assignment, info on failure stored in maintenance database.

Power System Decisionmaking

- Power system analysis, control and operation is dependent on models
- Using the models, analytical and numerical analysis provides decision support for e.g.
  - Security
  - Stability
  - Optimal power flow
  - Contingency analysis
  - Expansion planning
  - Market clearing

$$0 = -P_i + \sum_{k=1}^{N} |V_i||V_k|(G_{ik}\cos\theta_{ik} + B_{ik}\sin\theta_{ik})$$

$$0 = -Q_i + \sum_{k=1}^{N} |V_i||V_k|(G_{ik}\sin\theta_{ik} - B_{ik}\cos\theta_{ik})$$

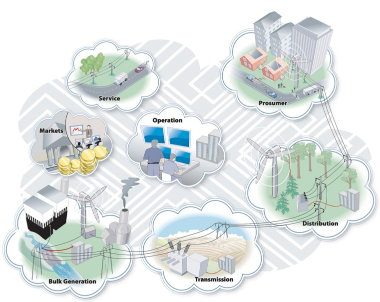


Smartgrids Decisionmaking

- Smart grids are power systems integrated with ICT systems
- Decisionmakers want to take informed decisions about:
  - Functionality
  - Security
  - Stability
  - Reliability
  - Performance
  - Interoperability
  - Usability

Analysis tools?

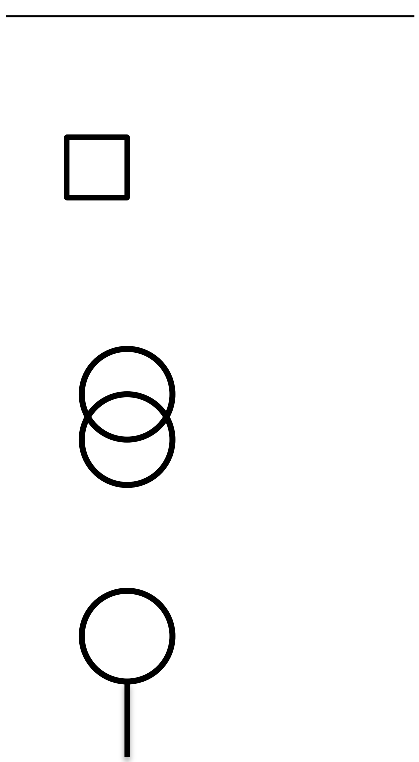
Models?



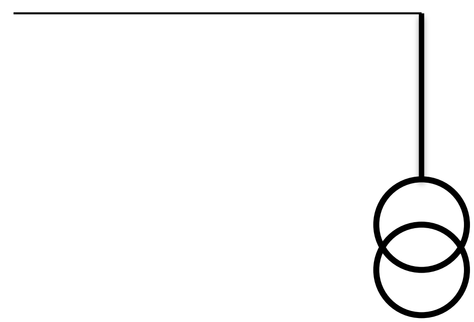
Example:
Reference architecture for for Power systems

One line diagram (just one possible form of description)

A set of symbols

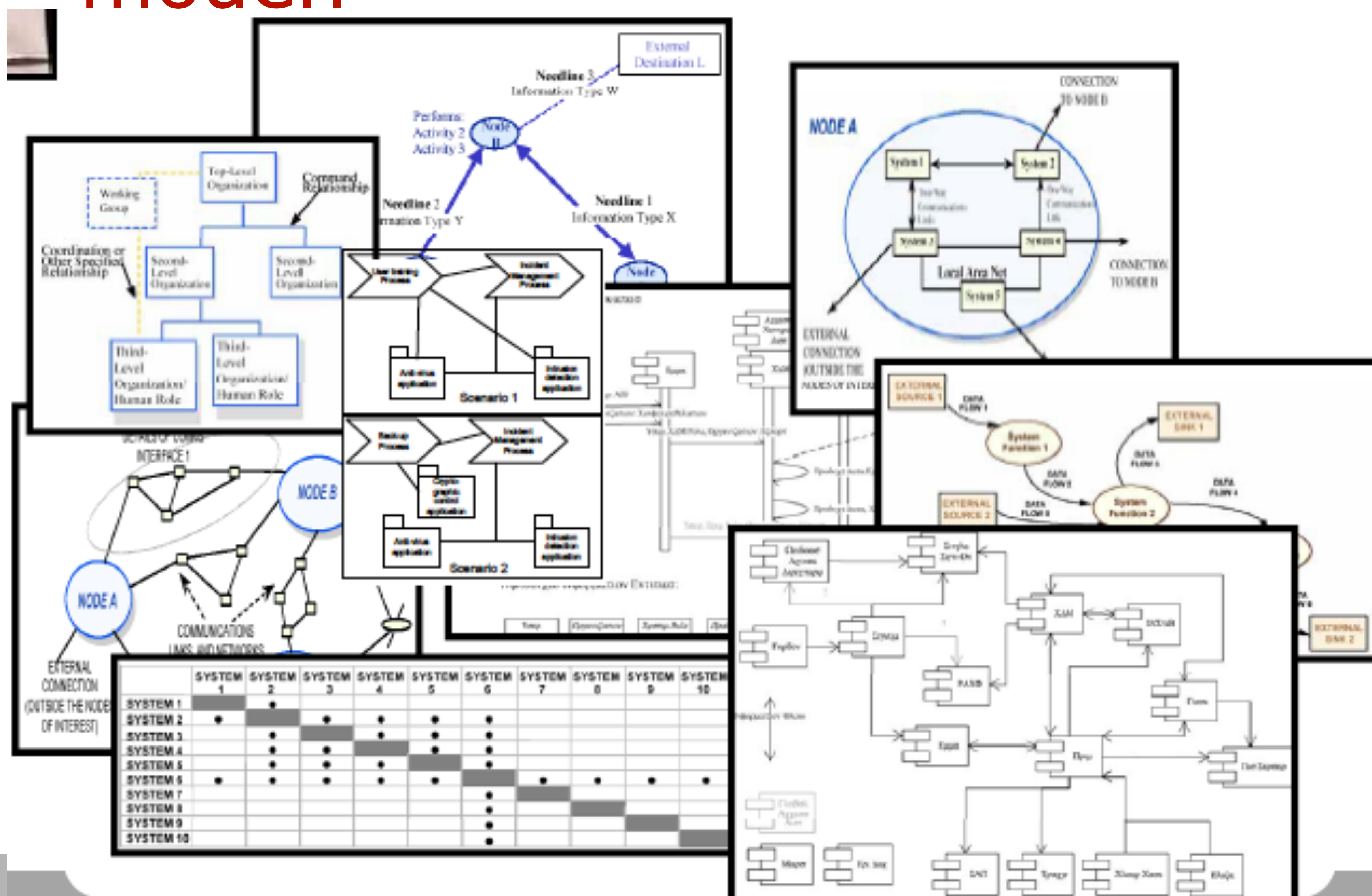


Rules on how you can combine them

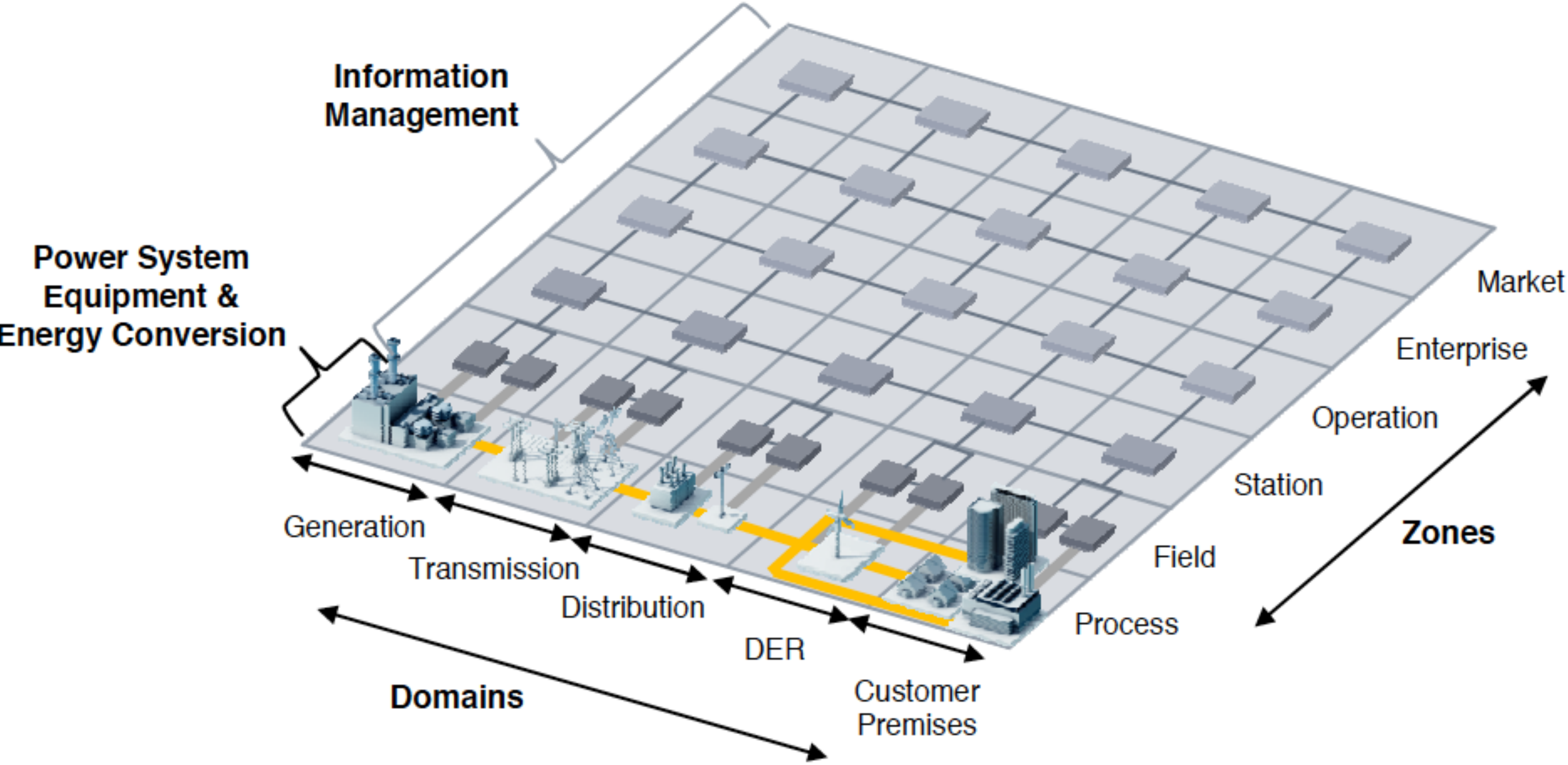


Sort of similar for ICT systems

When and why to use which model?



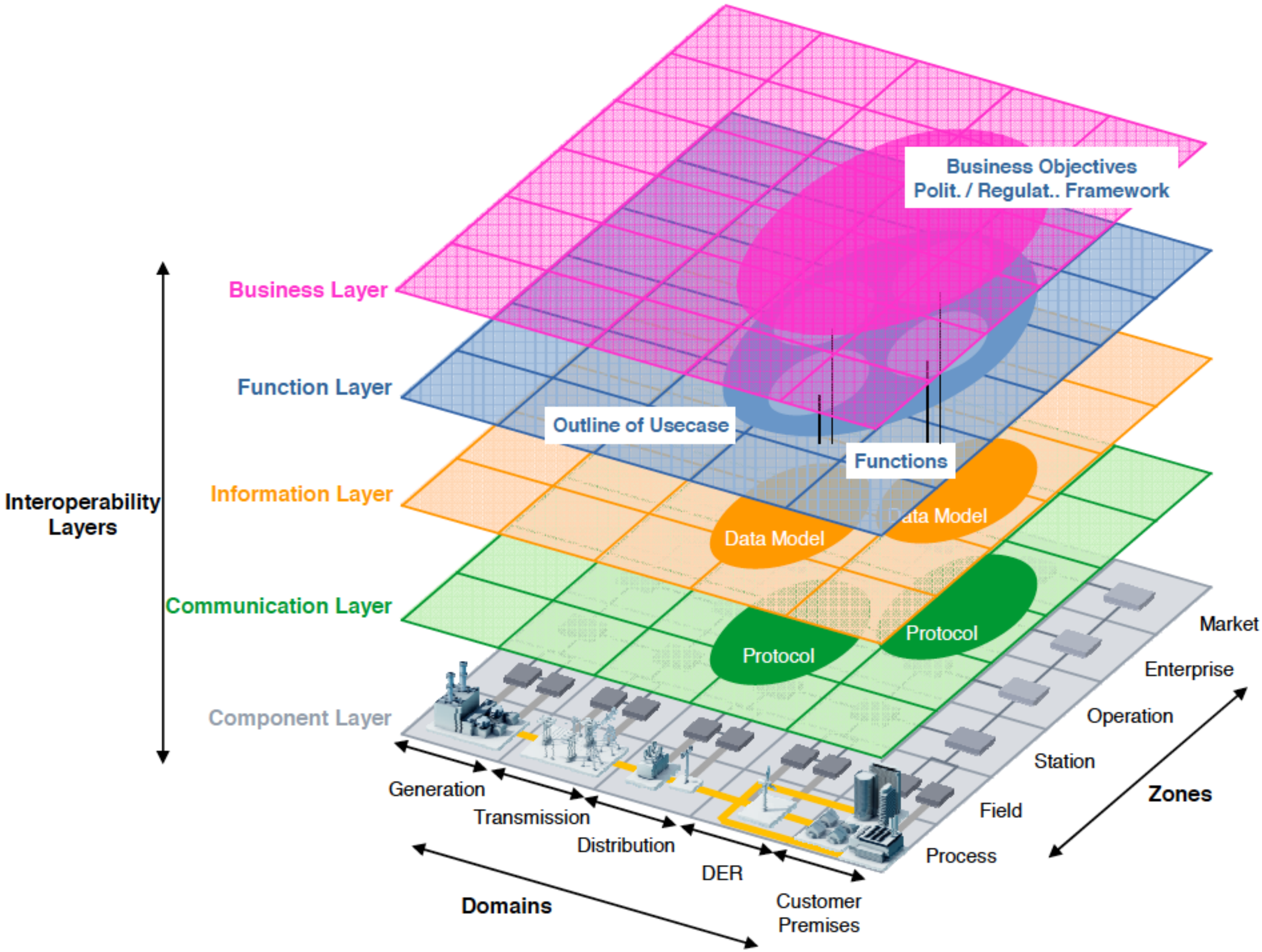
The context– the Smartgrid



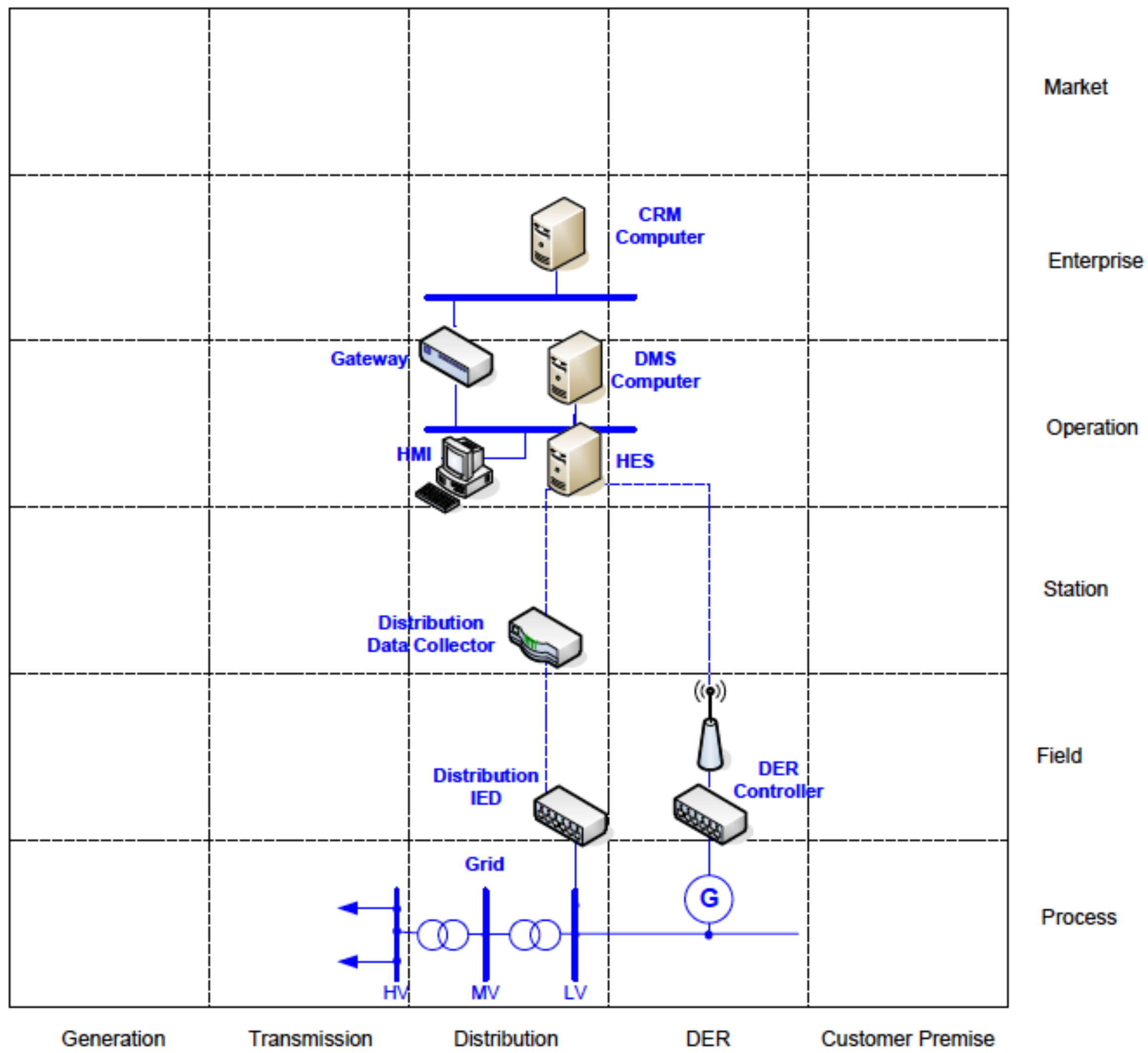
Domain	Description
Bulk Generation	Representing generation of electrical energy in bulk quantities, such as by fossil, nuclear and hydro power plants, off-shore wind farms, large scale photovoltaic (PV) power– typically connected to the transmission system
Transmission	Representing the infrastructure 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...

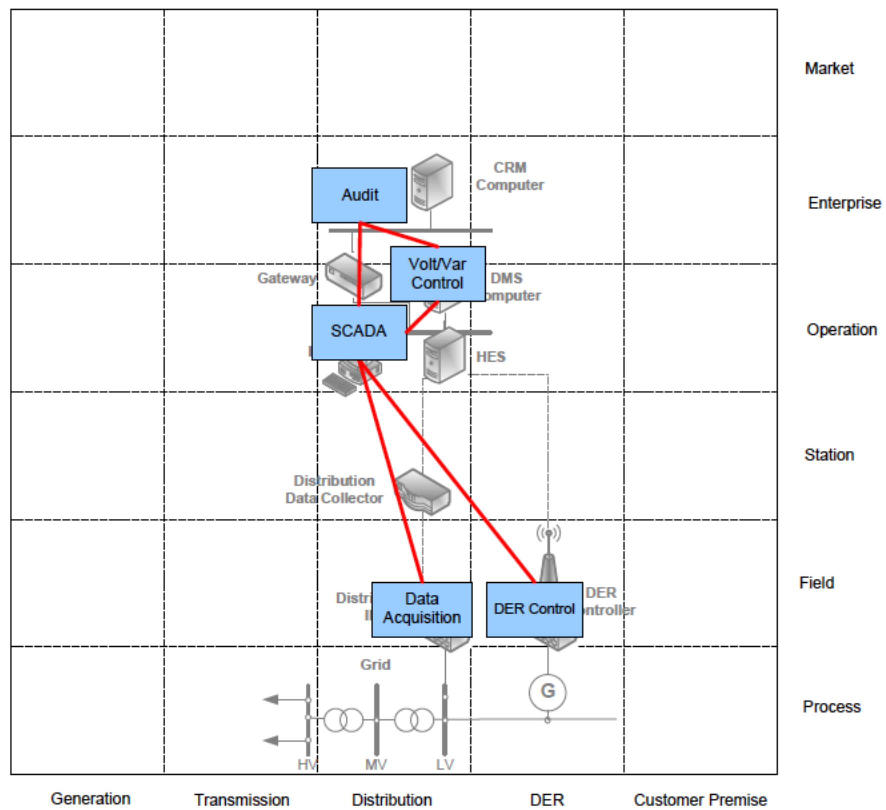

Business Objectives
Polit. / Regulat.. Framework
Business Layer
Function Layer
Outline of Usecase
Functions
Interoperability Layers
Information Layer
Data Model
Data Model
Communication Layer
Protocol
Protocol
Component Layer
Market
Enterprise
Operation
Station
Field
Process
Zones
Generation
Transmission
Distribution
DER
Customer Premises
Domains

Component Layer



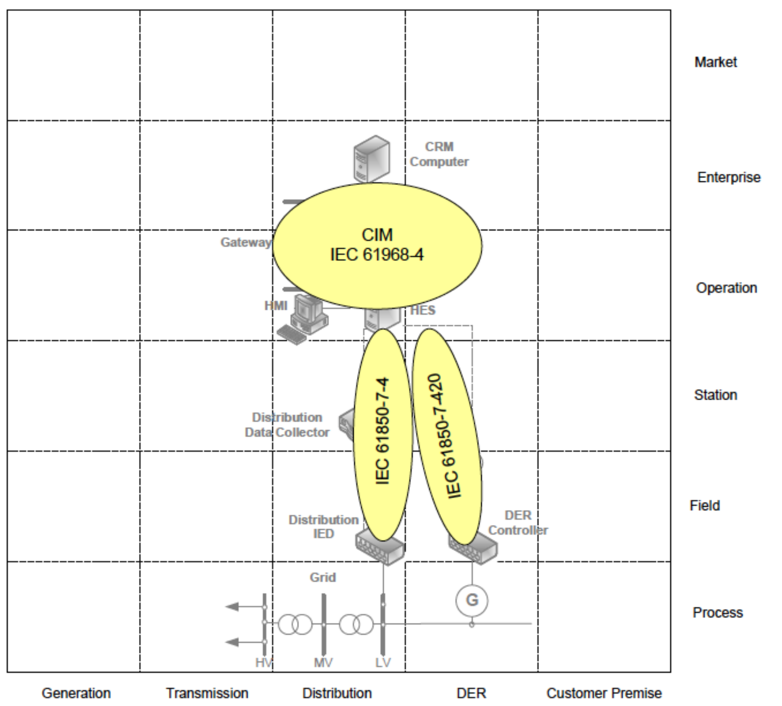
Function layer

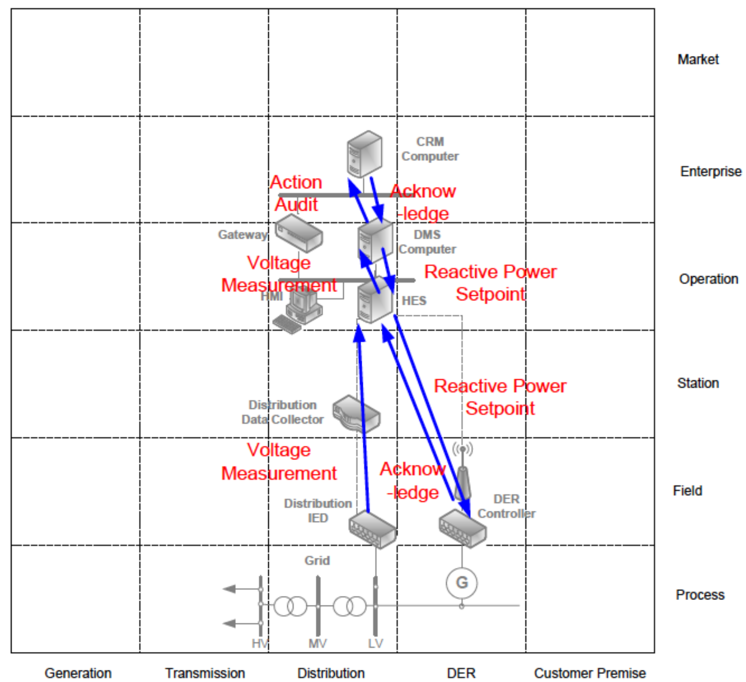
The function layer describes functions and services including their relationships from an architectural viewpoint. The functions are represented independent from actors and physical implementations in applications, systems and components. The functions are derived by extracting the use case functionality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



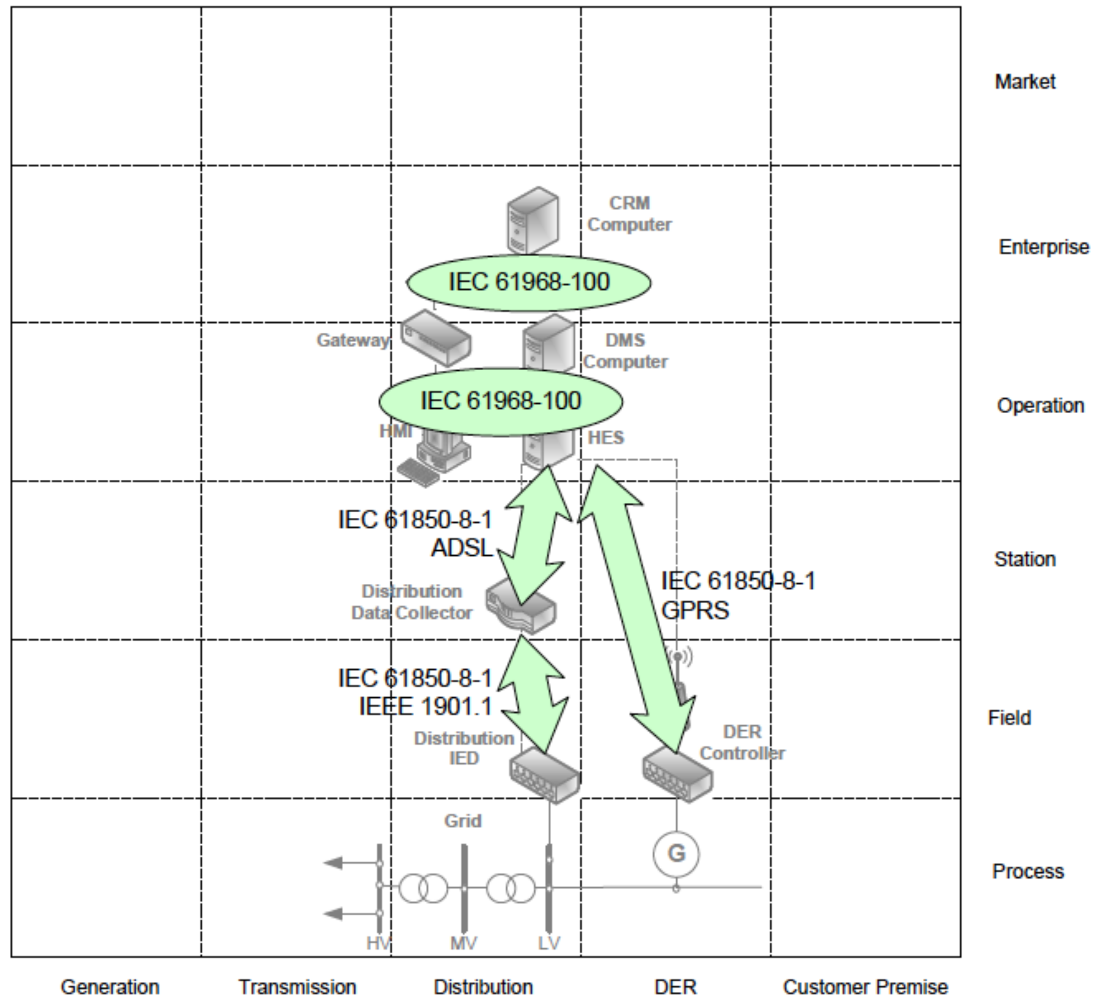
Information Layer

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.





Communication Layer



Business Layer