Welcome!
EH2741
Communications & Control in Power Systems

Lars Nordström
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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

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

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

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

Education – Power Systems track

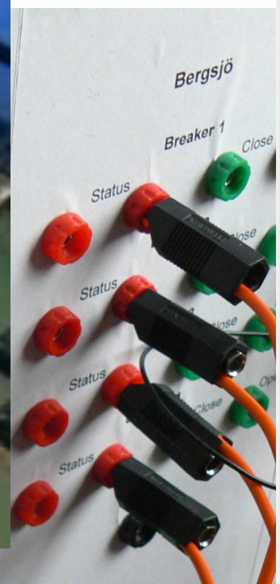
EH2741
Communications & Control in Power Systems

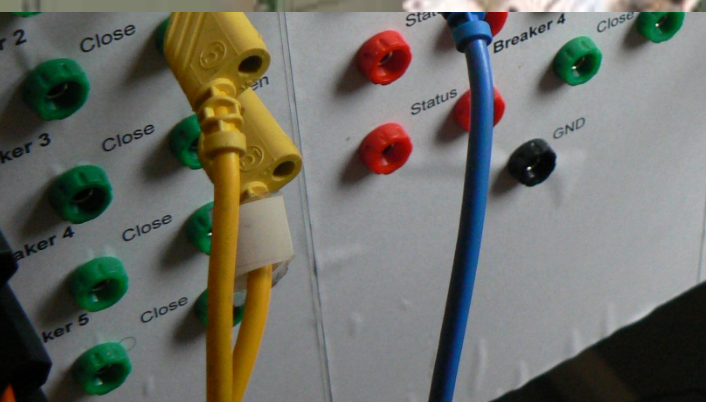
EH2790
Requirements Engineering

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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DI6	65542	Acquisition	Boolean
DI7	65543	Acquisition	Boolean
DI8	65544	Acquisition	Boolean
DI9	65545	Acquisition	Boolean
DI10	65546	Acquisition	Boolean
DI11	65547	Acquisition	Boolean
DI12	65548	Acquisition	Boolean
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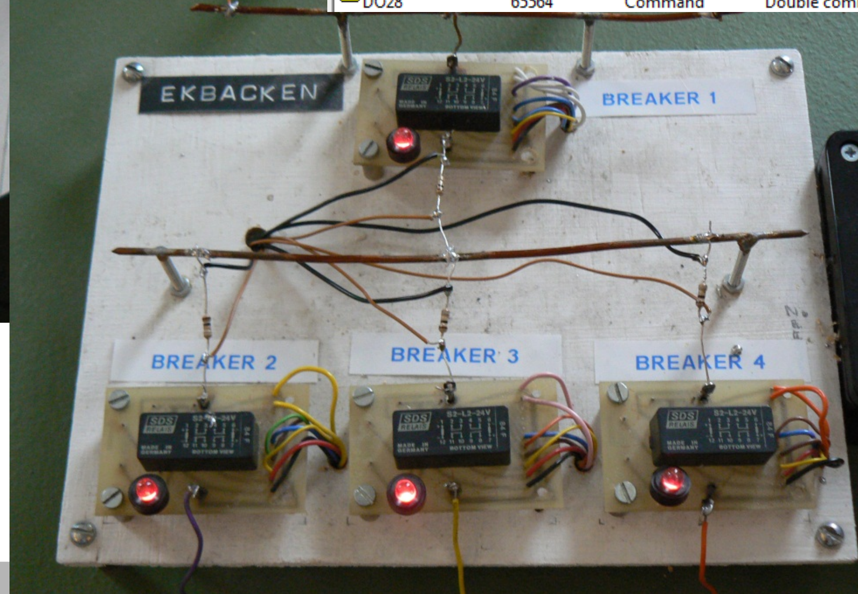
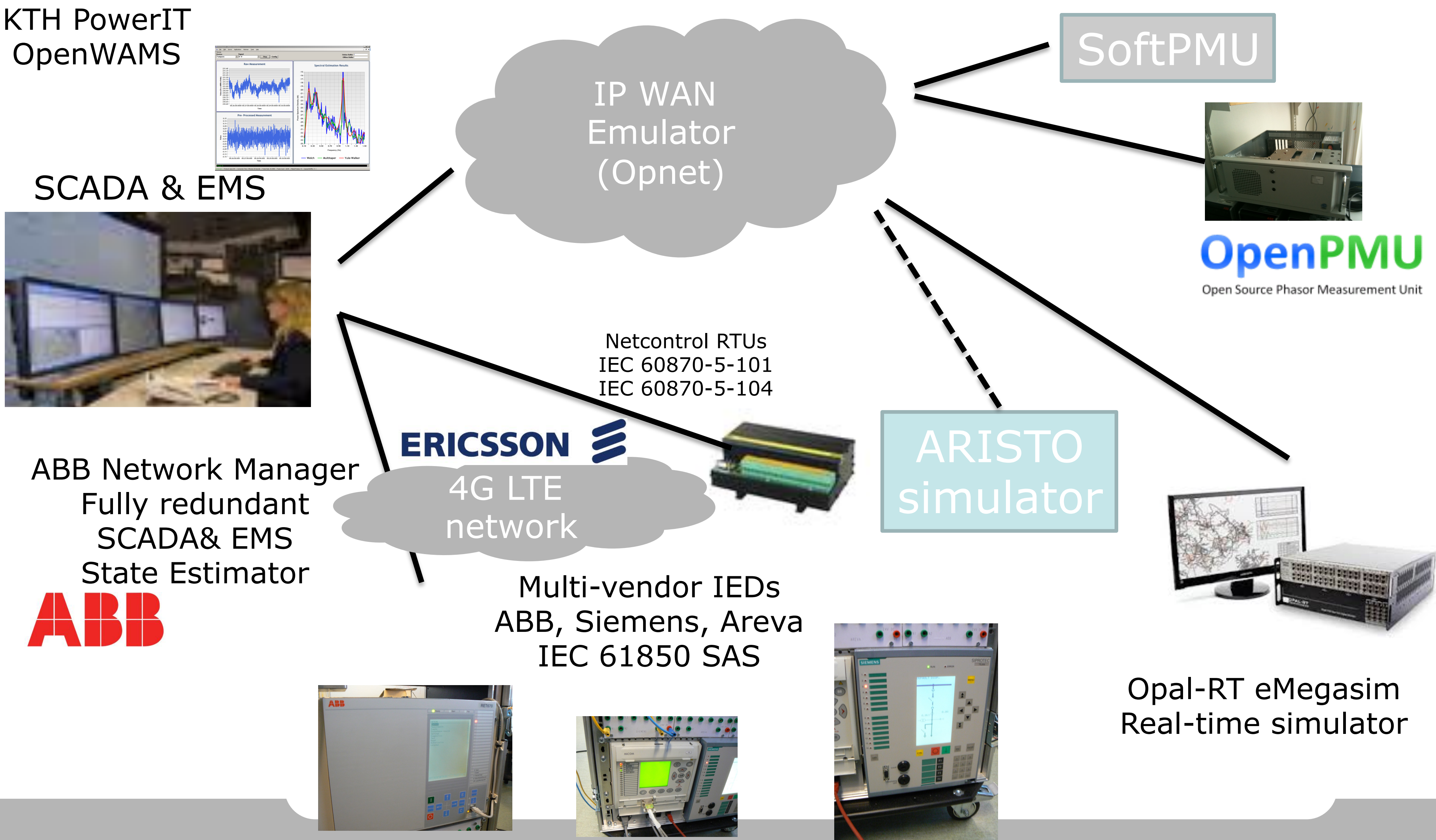
DI14	65550	Acquisition	Boolean
DI15	65551	Acquisition	Boolean
DI16	65552	Acquisition	Boolean
DI17	65553	Acquisition	Boolean
DI18	65554	Acquisition	Boolean
DI19	65555	Acquisition	Boolean
DI20	65556	Acquisition	Boolean
DO21	65557	Command	Double command
DO22	65558	Command	Double command
DO23	65559	Command	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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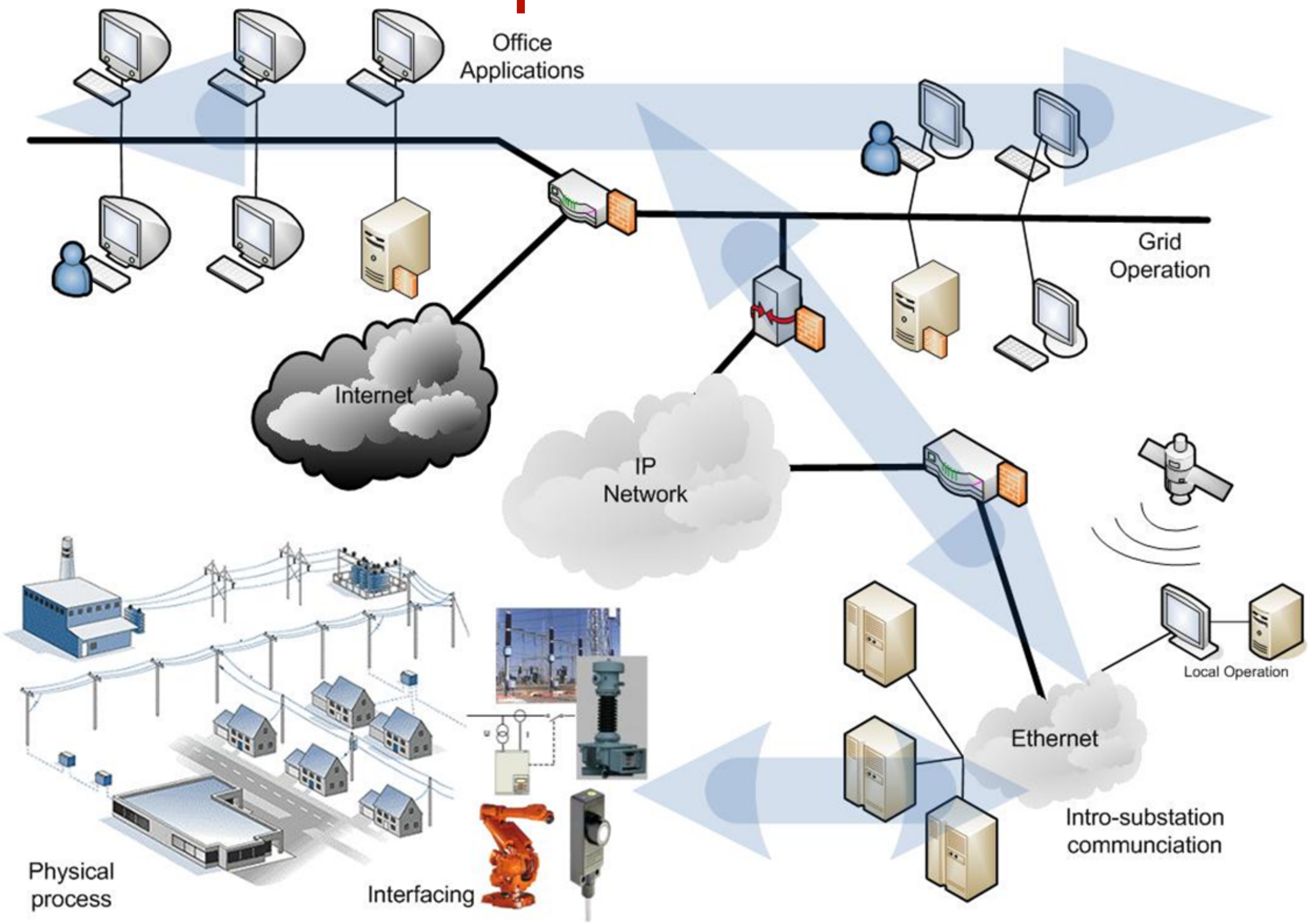
Course content

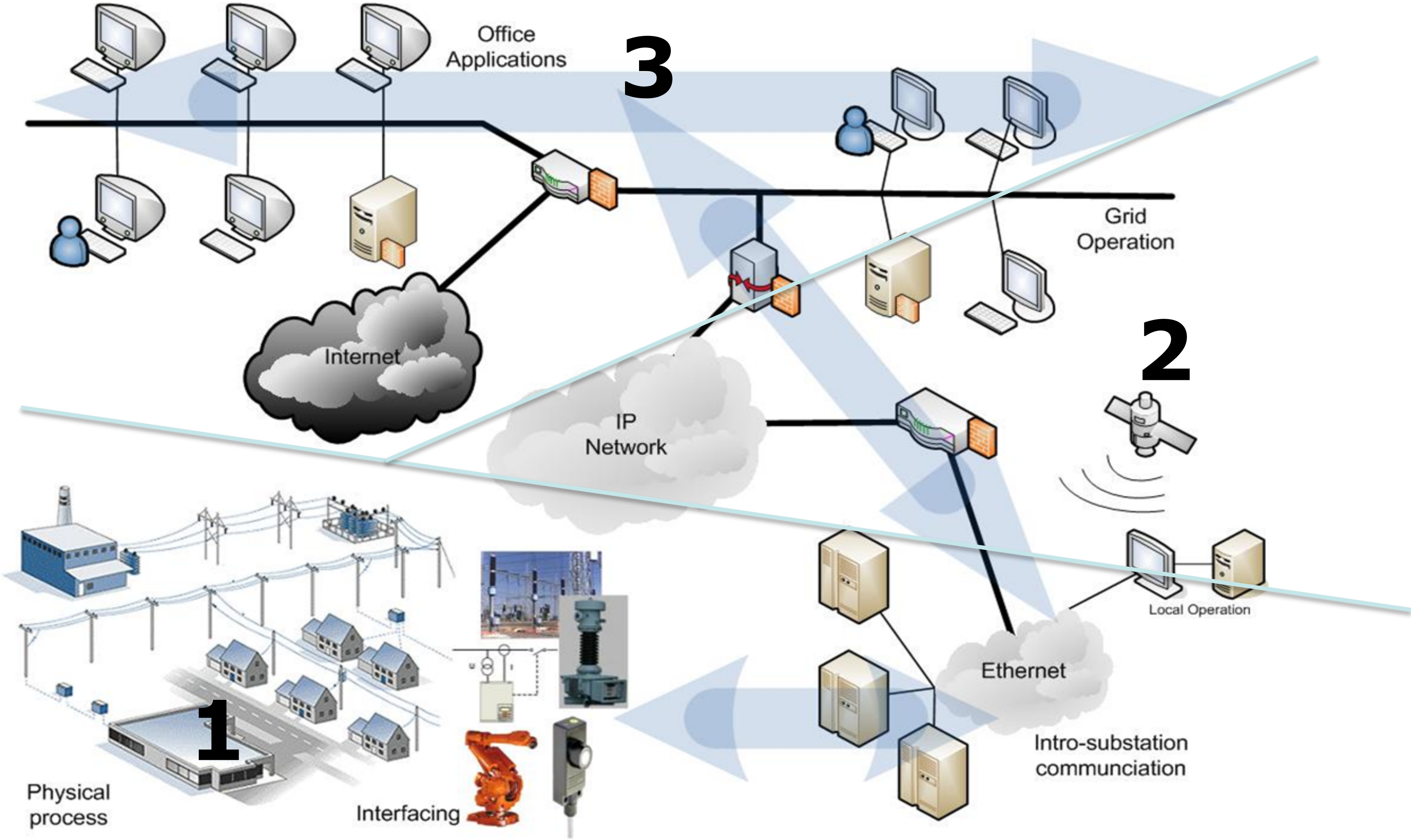
EH 2741 Communications & Control in Power Systems

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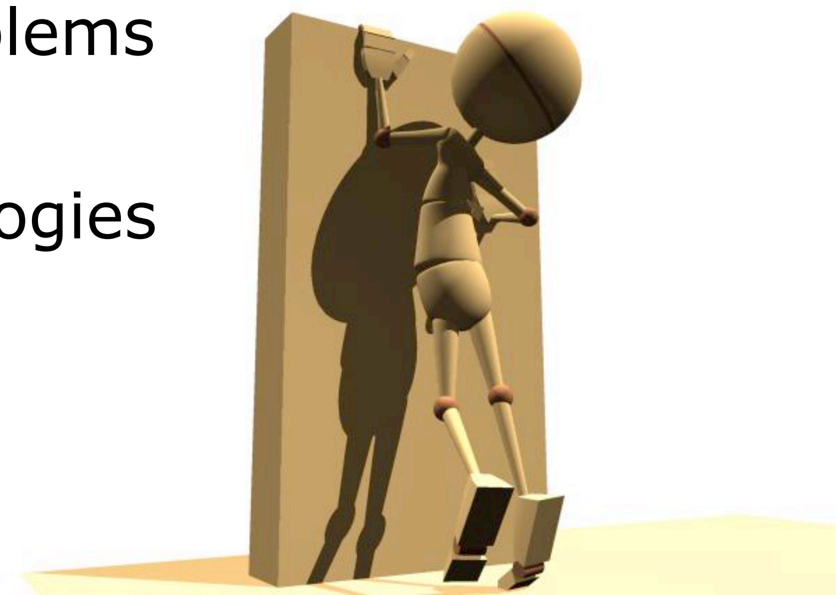
Grid
Operation
Internet
IP
Network
2
Local Operation
Ethernet
Intro-substation
communciation
1
Physical
process
Interfacing

Course philosophy

- Open the door to future study
  - EH2745/EH2751 advanced & project courses
  - Degree projects
- Systems engineering approach
- 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 1,2 and 3 (voluntary)
- Lab 1 and 2
- Study visit
- Guest Lectures

Course Components - II

- Project Assignment 1 2 ECTS
- Project Assignment 2 2 ECTS
- Project Assignment 3 2 ECTS

Literature

- Course Books

  Electrial Network Automation and Communication Systems, 2003 by Cobus Strauss

- Additional reading provided as hand-outs on lecture 2.

Assessment and Grade

- No final exam
- Test 1, 2 and 3: 0-10 course points
- Project Assignment 1, 2 and 3: fail, pass (6 course points)
  pass with bonus (7-10 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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Lecture philosophy

- This lecture is intended to provide some insights into how Information & Communication Technologies enables control & operation of power systems.

- I have deliberately focused on the clear advantages of ICT, staying away from the ”visionary” aspects.

Definitions of Smartgrids

"Smart Grid is an electricity network that can intelligently integrate the behaviour and actions of all users connected to it – generators, consumers and those that do both – in order to ensure economically efficient, sustainable power system with low losses and high levels of quality and security of supply and safety."

European Technology Platform

"The integration of kW and kBit"

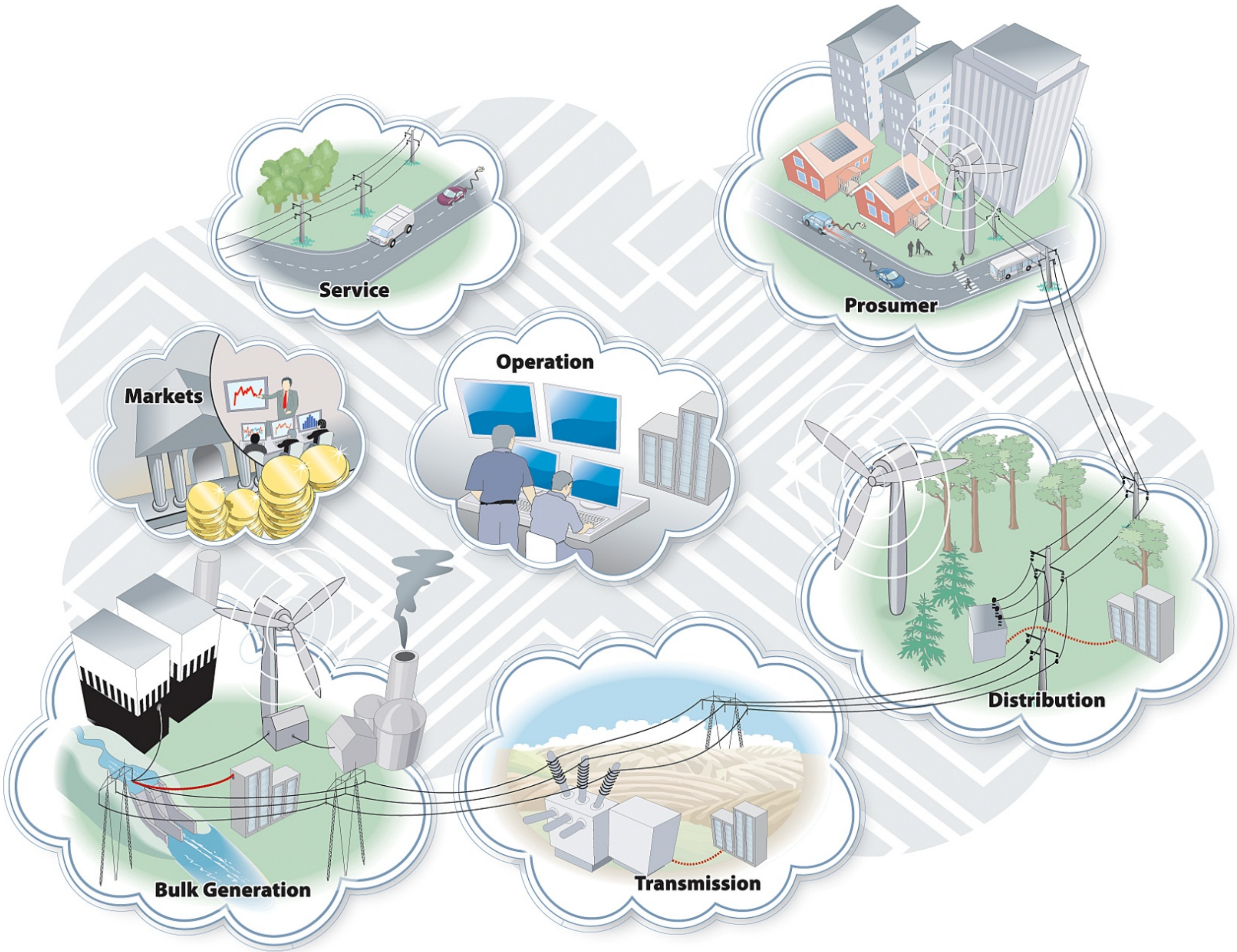
M. Jimenez-Sanchez, DG ENERGY

Wit n. intellect; reason; cleverness; sharpness; one who is sharp

kWit

L. Nordström, KTH

Communication & Control in Power Systems

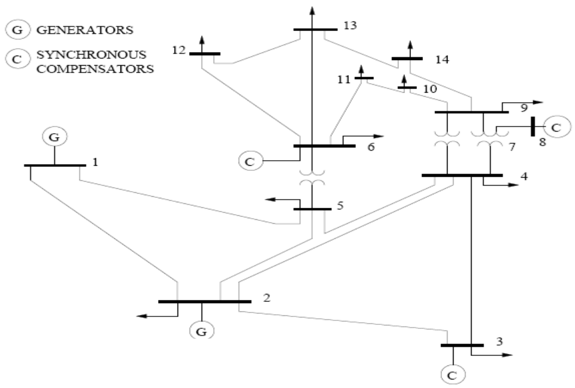


KTH
VETENSKAP
OCH KONST

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

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



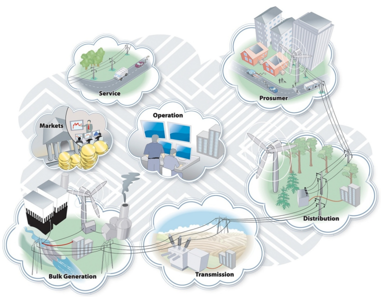
Smartgrids Decisionmaking

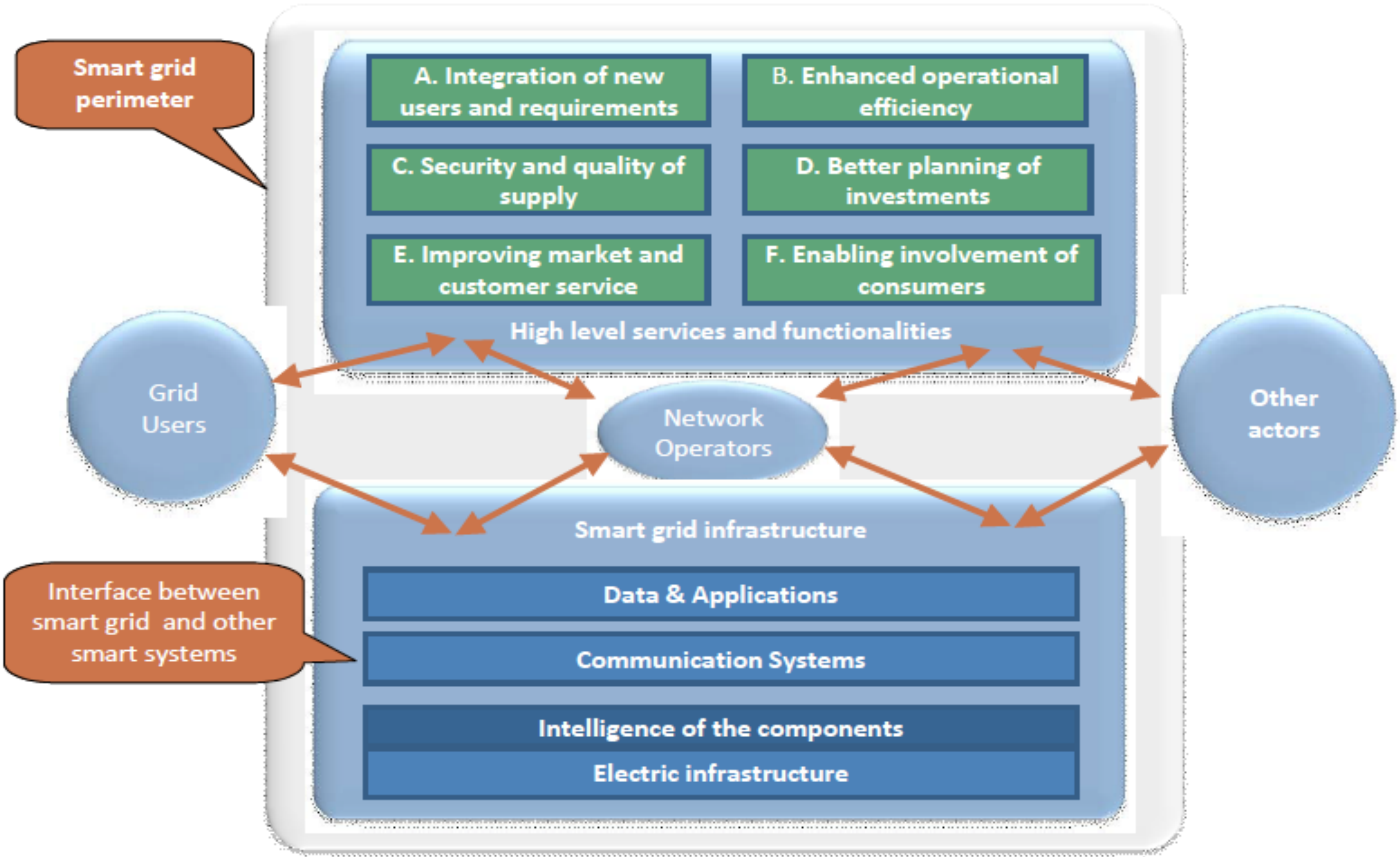
- Smart grids are power systems integrated with ICT systems

- Decisionmakers want to take informed decisions about:
  - Functionality
  - Security
  - Stability
  - Reliability
  - Performance
  - Interoperability
  - Usability

Analysis tools?

Models?





Source: EU Commission Task Force for Smart Grid, Expert Group 1: Functionalities of smart grids and smart meters

Smartgrids functionalities

A. Enabling the network to integrate users with new requirements
B. Enhancing efficiency in day-to-day grid operation
C. Ensuring network security, system control and quality of supply
D. Enabling better planning of future network investment
E. Improving market functioning and customer service
F. Enabling and encouraging stronger and more direct involvement of consumers in their energy usage and management

Source: EU Commission Task Force for Smart Grid, Expert Group 1: Functionalities of smart grids and smart meters

Where can ICT help?

1. To develop new customer services – enabling the active consumer

2. Enable control of grids that are changing into active grids due to introduction of new generation

3. Make Grid Operators more efficient in their daily operation offering lower costs and improved customer quality

Focus of the course

Where can ICT help?

1. To develop new customer services – making the enabling the active consumer

2. Enable control of grids that are becoming into active grids due to introduction of new generation

3. Make Distribution companies more efficient in their daily operation offering lower costs and improved customer quality

ICT – area #1

Consumer possibilities in Smartgrids

- Direct communication of
  signals between
  umer and producer
  ibility to shift load
  time
  rconnection of
  igent appliances in
  Smart Household
  le the producing
  umer – the Prosumer
  microgeneration
  gy savings
  er cost of electricity
  e Automation

Possible is not Sufficient

BEA Systems, Inc. (Nasdaq: BEAS), the E-Commerce Transactions Company(TM), announced that [redacted] one of the largest energy companies in Europe, is using BEA's WebLogic product family of industry --leading e-commerce transaction servers, along with BEA components, to build an integrated network A network that supports both data and voice and/or different networking protocols for providing 'smart building' subscription services throughout Sweden. The services let customers remotely monitor their refrigerators, ovens, electricity consumption and power mains status, and control their burglar alarms and heating and air conditioning air conditioning, mechanical process for controlling the humidity, temperature, cleanliness, and circulation of air in buildings and rooms. [redacted] estimates that, before the end of next year, 150,000 Swedish households will be using the new services, and hopes to add 200,000 new customers a year en route to a customer base of one million households within five years.

United States Patent [19]

Bateman et al.

[11] **4,240,030**

[45] **Dec. 16, 1980**

[54] **INTELLIGENT ELECTRIC UTILITY METER**

[76] Inventors: **Jess R. Bateman,** 1516 Esplanade Ave., Redondo Beach, Calif. 90277; **Robert L. Carpenter,** 12,032 Freeman Ave.; **Ross K. Smith,** 5435 W. 124th St., both of Hawthorne, Calif. 90250

[21] Appl. No.: **969,303**

[22] Filed: **Dec. 14, 1978**

[51] **Int. Cl.**^{3} **G01R 1/00**

[52] **U.S. Cl.** .... **324/110;** 346/14 MR; 235/449

[58] **Field of Search** .... 324/51, 110, 113, 157; 364/483; 235/449, 493; 346/14 MR; 307/140

[56] **References Cited**

U.S. PATENT DOCUMENTS

2,019,866	11/1935	Morton	324/110
3,001,846	9/1961	Franceschini	346/14 MR
3,380,064	4/1968	Norris et al.	346/14 MR
3,778,637	12/1973	Arita	307/140
3,835,301	9/1974	Barney	235/61.11
4,019,135	4/1977	Lofdahl	324/110

Primary Examiner—Michael J. Tokar

Attorney, Agent, or Firm—Poms, Smith, Lande & Rose

[57] **ABSTRACT**

A conventional electric utility meter is equipped with special circuitry and components which work in conjunction with an inserted magnetic card to regulate the supply of electricity to the structure to which the unit is attached. In addition to including the conventional dials which indicate overall kilowatt hours, the exterior of the unit includes a receptacle for the card and additional displays which show the kilowatt hours, and corresponding dollar value thereof, for the current payment period. The special circuitry includes a microprocessor, a set of magnetic read/write/erase heads, and a power relay. The circuitry interfaces with the conventional meter components by means of a photocell positioned above apertures or notches in the rotating disk of the meter. In the primary mode of operation, a prepayment card is inserted containing a predetermined kilowatt hour credit. The special circuitry senses this amount and adds it to the amount of power the customer is entitled to receive. Also, the circuitry warns the customer when only a small electricity credit remains. In an alternative mode, a blank postpayment card is inserted into the unit and the amount of the electricity utilized during the current payment period is encoded on the card. The card is then sent to the utility company as the basis of a future billing. Finally, the unlocking of the meter unit case is controlled by a special card code.

15 Claims, 6 Drawing Figures

United States Patent [19]
Whyte

[11] **3,980,954**
[45] **Sept. 14, 1976**

[54] **BIDIRECTIONAL COMMUNICATION SYSTEM FOR ELECTRICAL POWER NETWORKS**

[75] Inventor: **Ian A. Whyte,** Churchill Borough, Pa.

[73] Assignee: **Westinghouse Electric Corporation,** Pittsburgh, Pa.

[22] Filed: **Sept. 25, 1975**

[21] Appl. No.: **616,711**

[52] **U.S. Cl.** .... **325/48;** 325/64; 340/310 A; 340/310 R
[51] **Int. Cl.²** **H04M 11/02**
[58] **Field of Search** .... 325/36, 47, 48, 55, 325/64; 179/2 E, 2.5 B, 41 A; 340/310 R, 310 A, 311, 312

[56] **References Cited**

UNITED STATES PATENTS

3,376,506	4/1968	Sontag	325/64
3,714,375	1/1973	Stover	179/2 E

Primary Examiner—Benedict V. Safourek
Attorney, Agent, or Firm—D. R. Lackey

[57] **ABSTRACT**

An arrangement of communication components to provide communications between a central control center and various customer load locations in an electrical power distribution system. Control or interrogation signals are originated at the control center and transmitted over a suitable facility, such as a telephone line, to an FM broadcast station. The control signals frequency modulate an ultrasonic subcarrier which modulates the FM broadcast transmitter simultaneously with the normal broadcast program material. Radio receivers at the customer load locations receive, filter, and decode the broadcast signals which are used to activate the control or logic circuits associated with the customer location. A reply signal is generated at the customer location and applied to the power lines by carrier techniques. The power line carrier reply signal is remotely detected by a suitable receiver and transferred over a suitable wire line facility which terminates at the control center.

8 Claims, 3 Drawing Figures

an electrical power distribution system. One type of communication system of growing importance is a system which transfers information between a central control station and the customer load location. Such a system can be used to selectively control the power consumption at the customer location, interrogate the customer's metering facility to produce signals which are responsive to the energy used, or for any other purpose requiring two-way communication facilities.

ICT Area #1

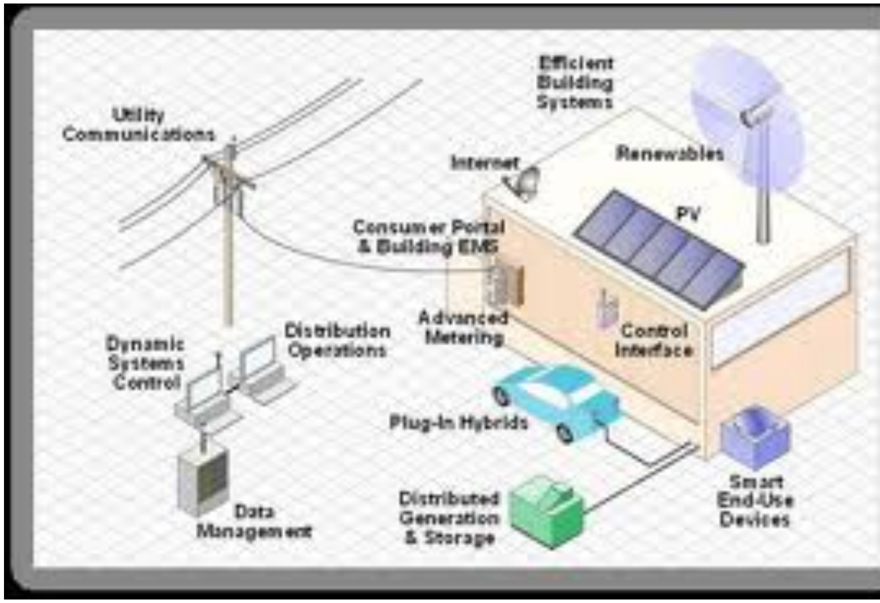
Important Lessons from history

- Technology-wise, many of the smartgrids concepts appear to have been invented and tested already
- It seems, that although something is possible from a technical perspective it is not realised at full scale because it is not needed.

ICT Area #1

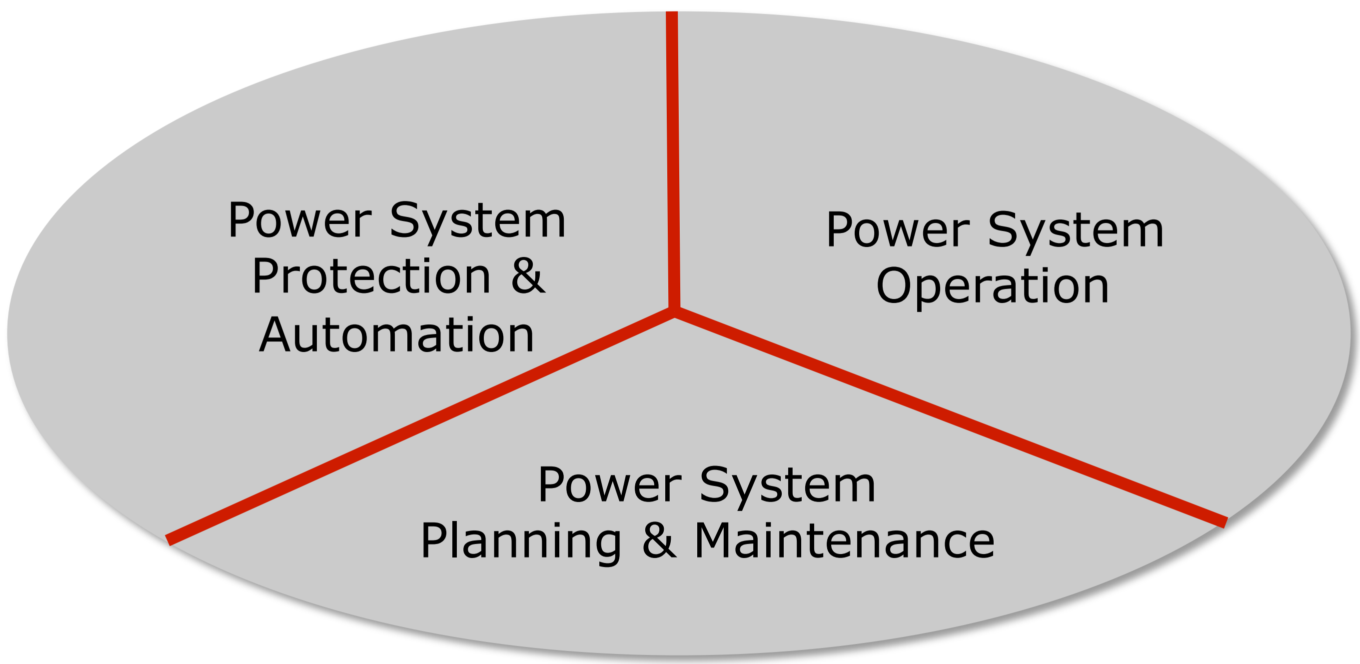
Going forward

- Several demonstration projects are rolling out all over Europe & the World testing technologies and business models.
- AMR metering is being rolled out across europe mandated by law (less focused on business cases) opens possibilities
- Integration with business models for consumer appliances critical for success



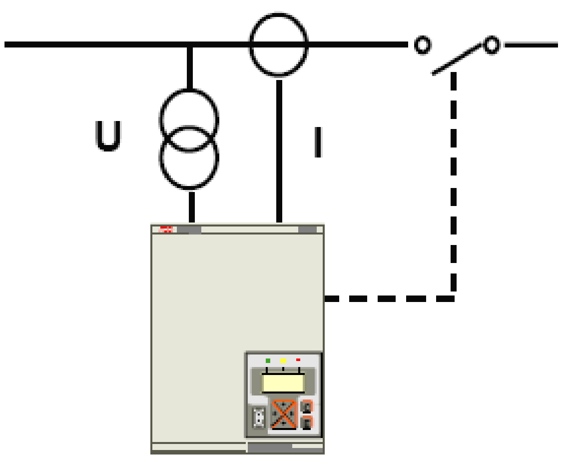
ICT Areas #2 & #3

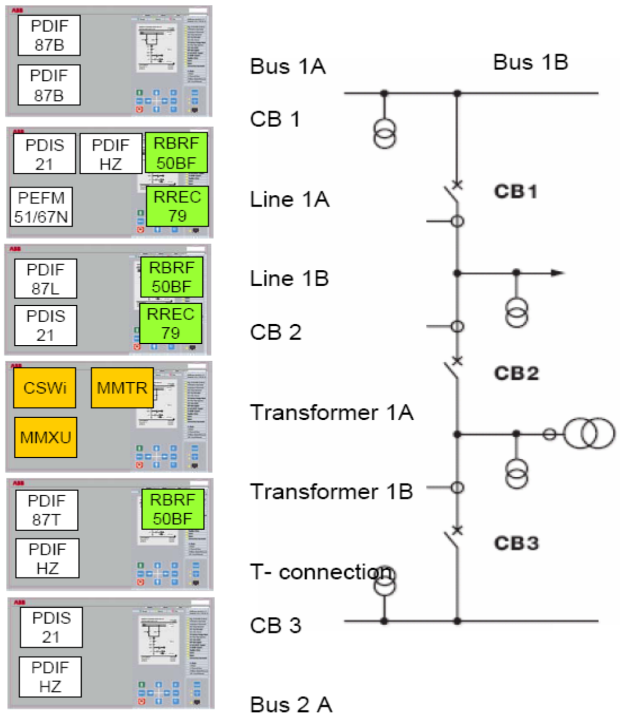
- Meeting the challenges of the future power system requires integration of previously separated areas with ICT as the enabler



Power System Protection & Automation

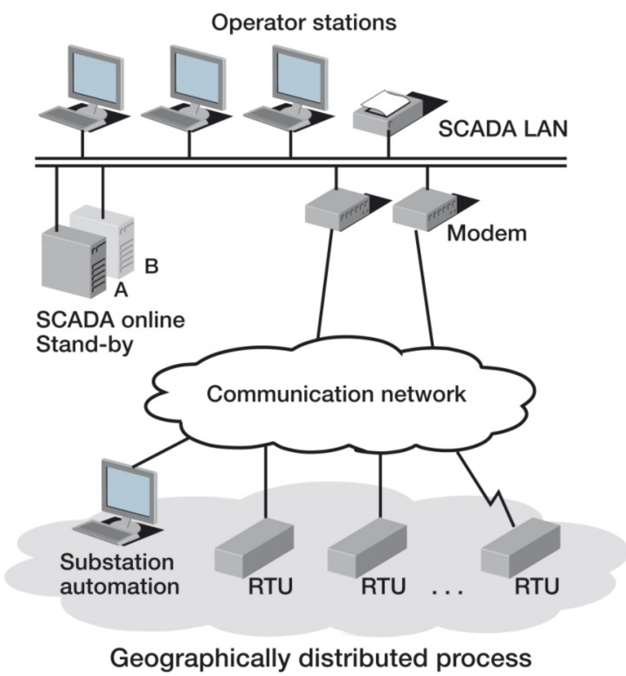
- Protect Equipment
- Protect People & Property
- Separate faulty section from power system
- Restore normal operation
- Local control

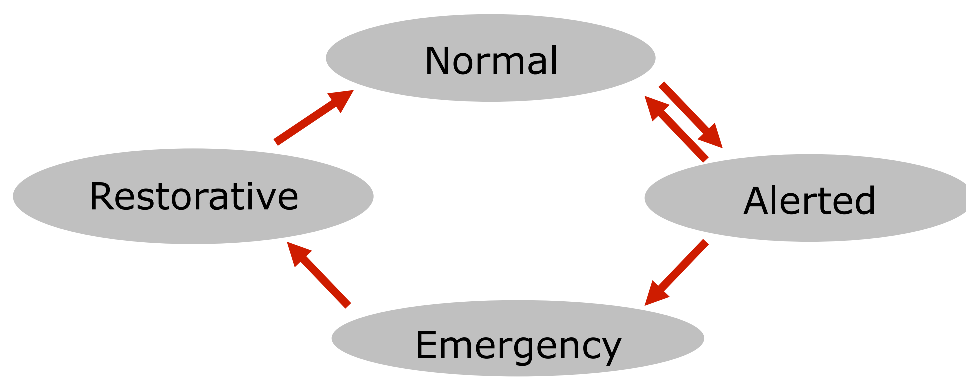




Power System Operation

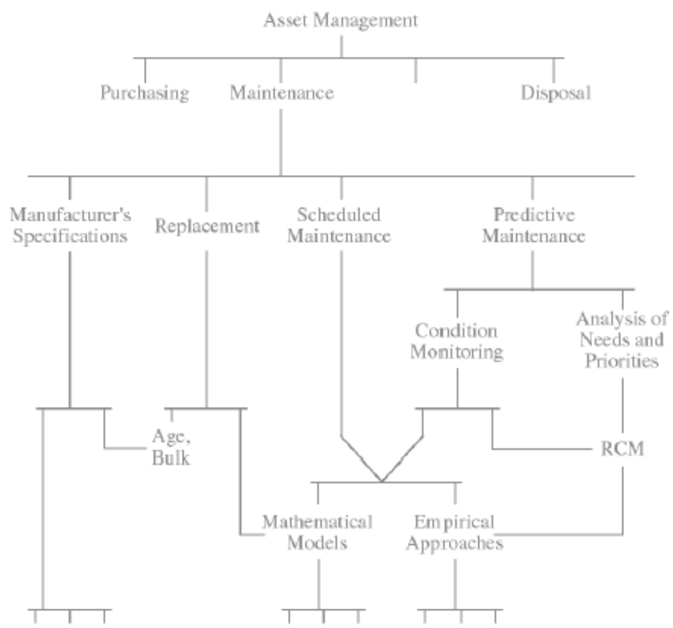
- System-wide monitoring, planning & optimisation for reliable and cost efficient operation of the power system

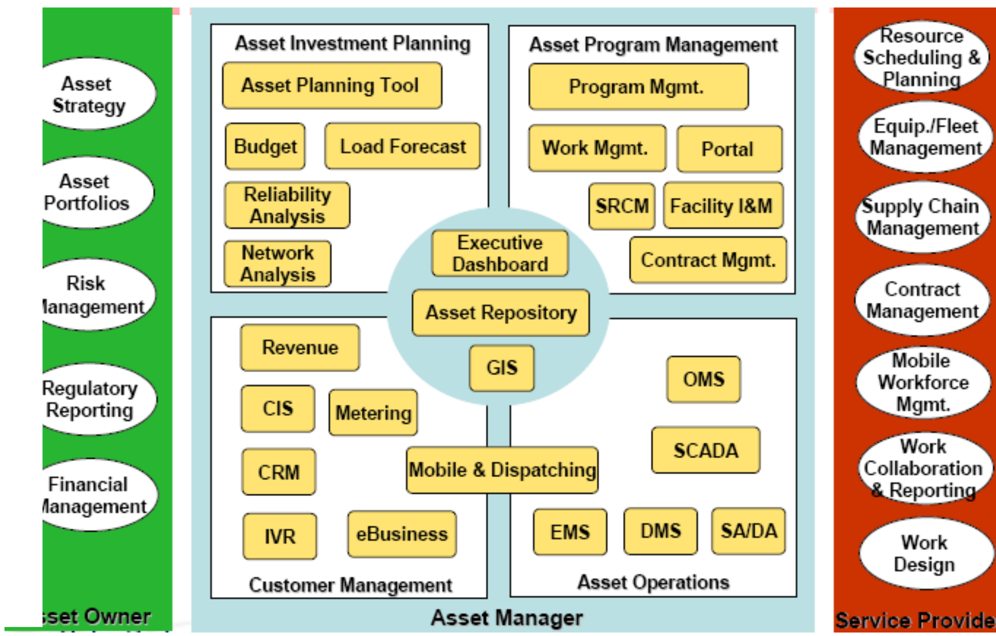




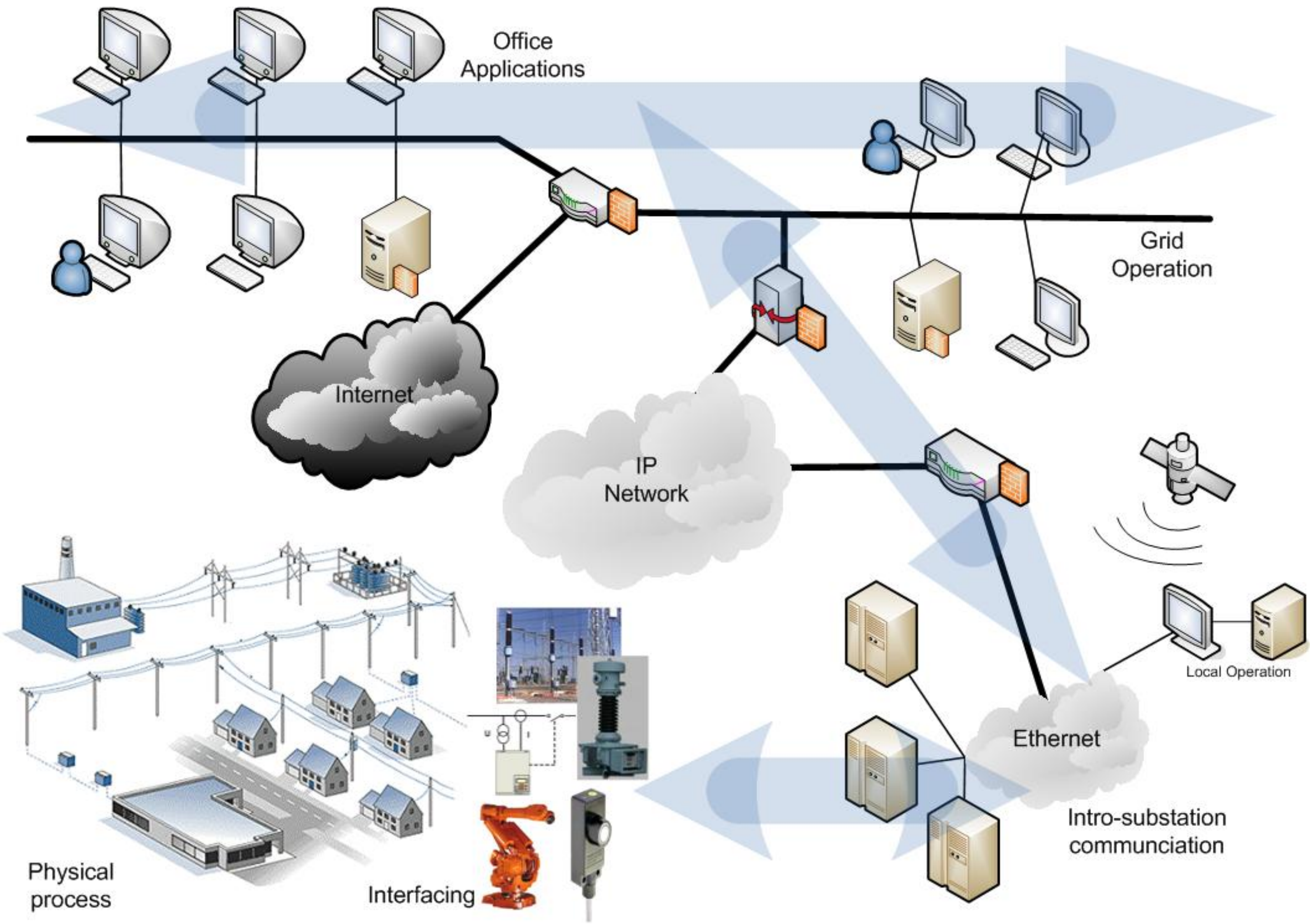
Power System Maintenance & Planning

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

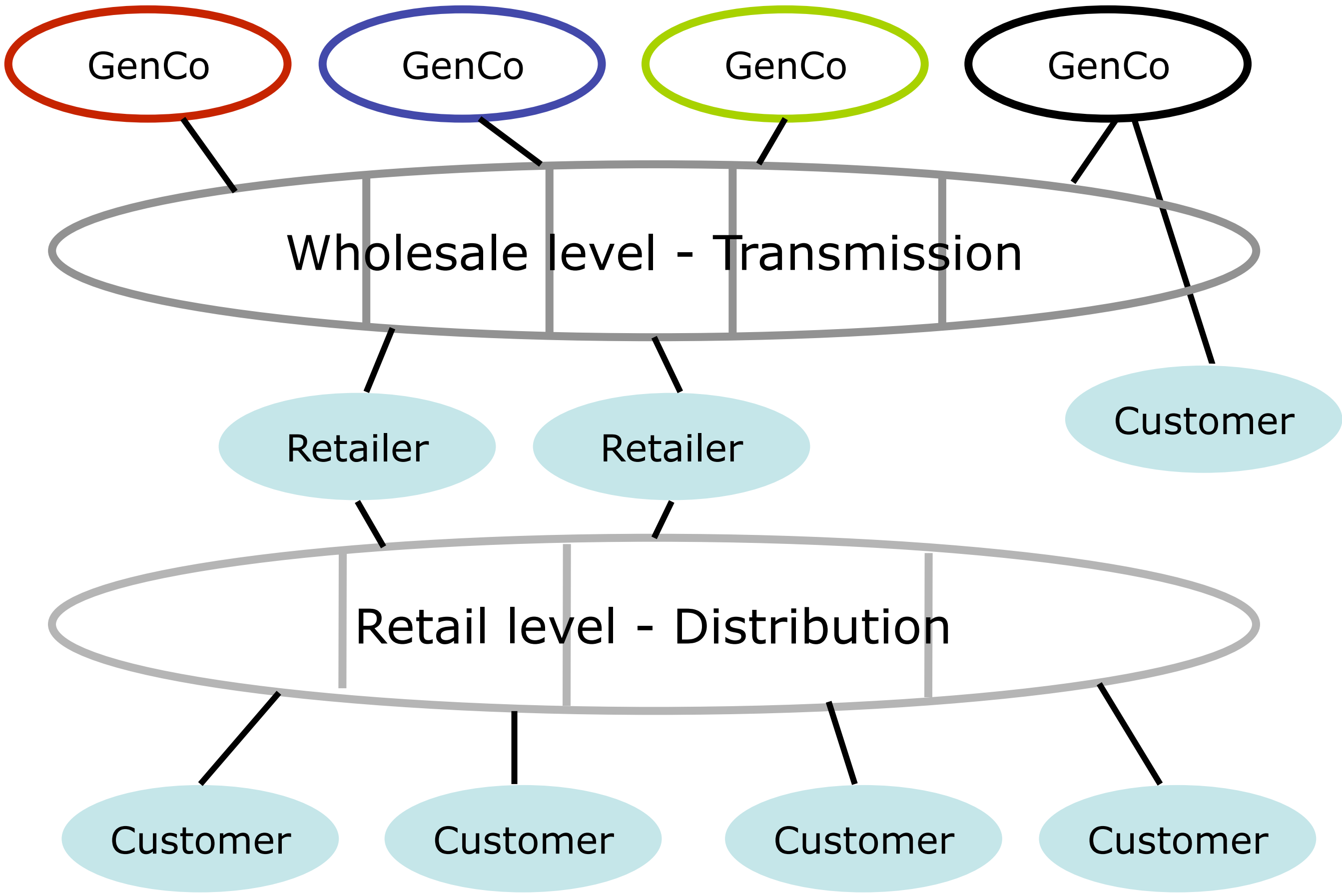




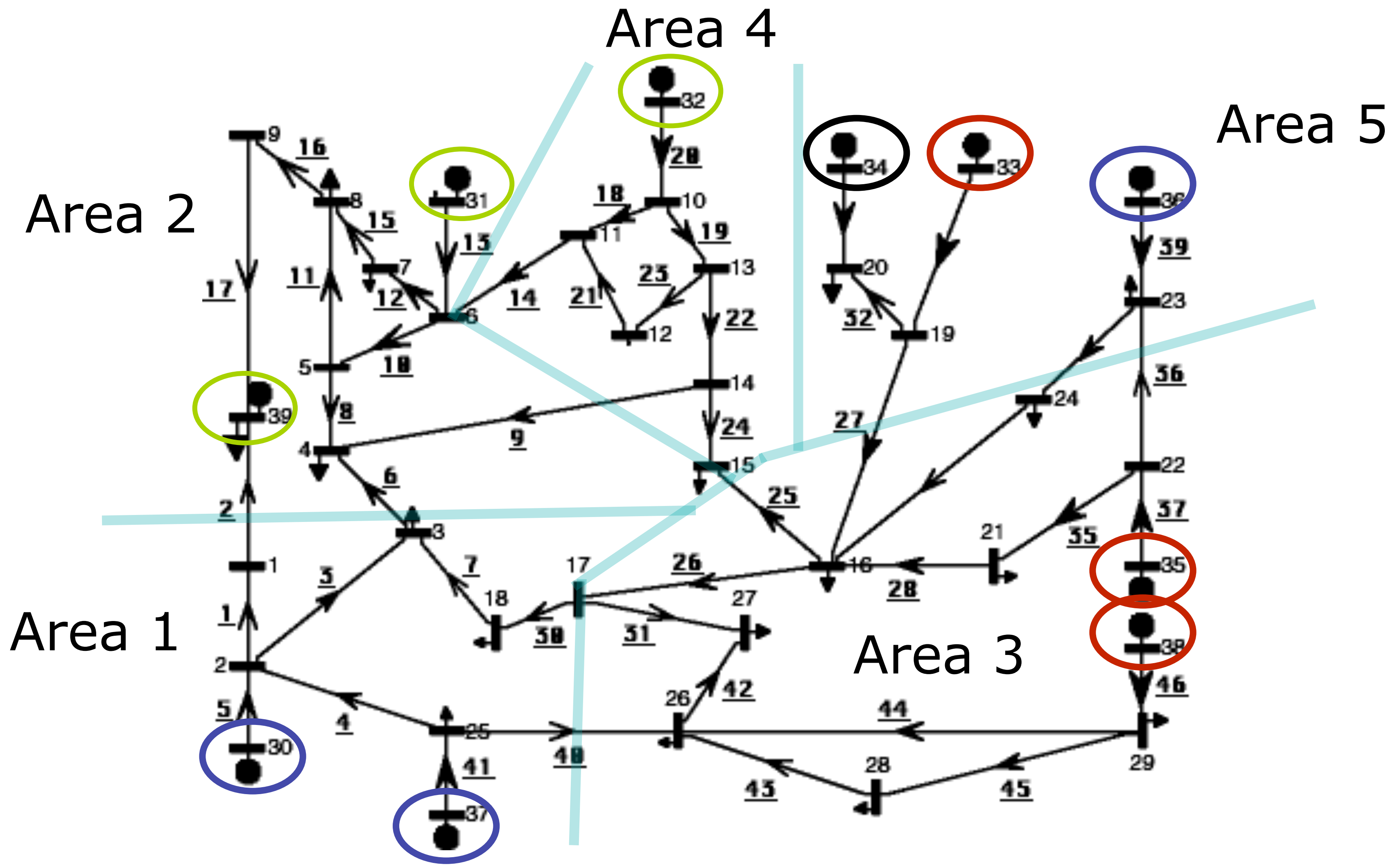
Integrated systems for Smart grids



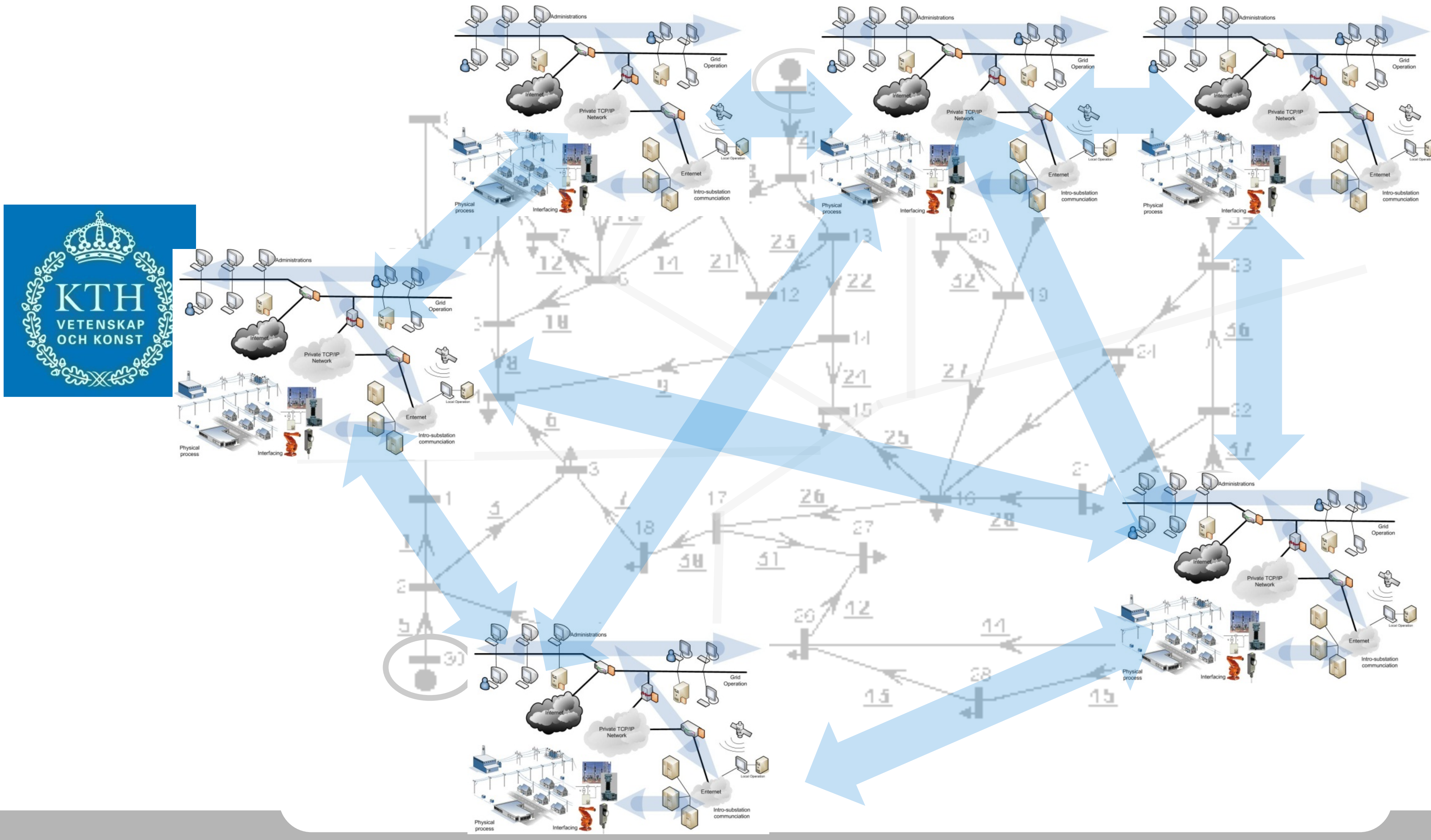
Deregulation– in theory



Deregulation – in practice



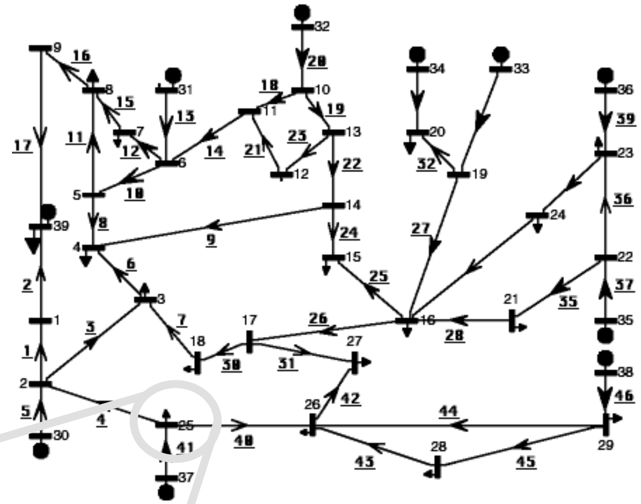
Integration of Systems

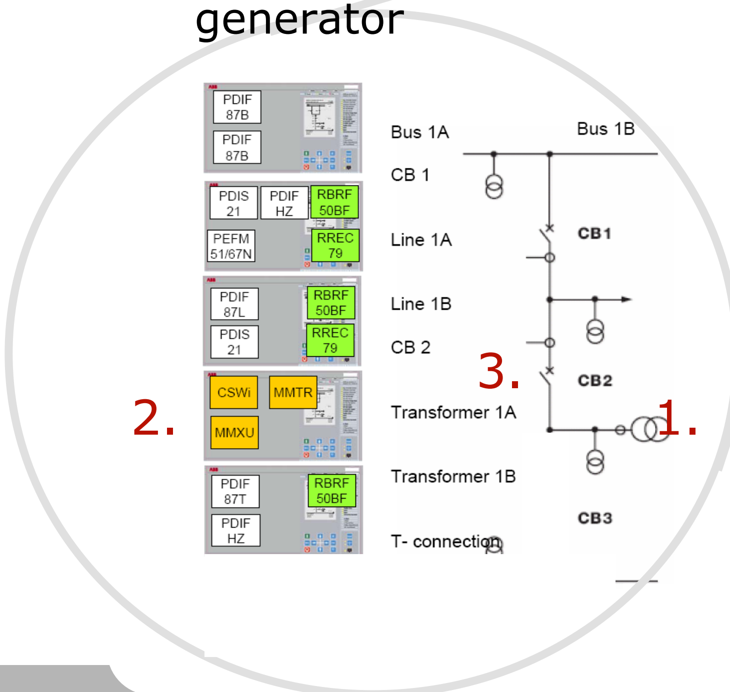


Information Exchange
– a simple example

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

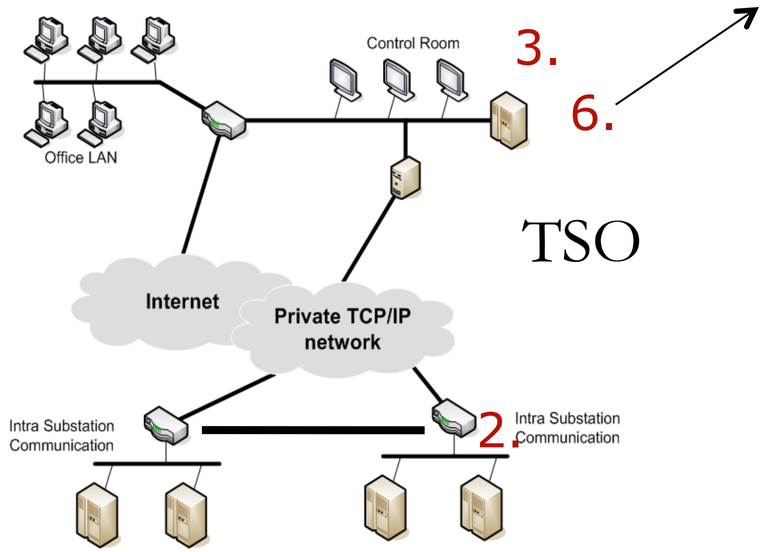


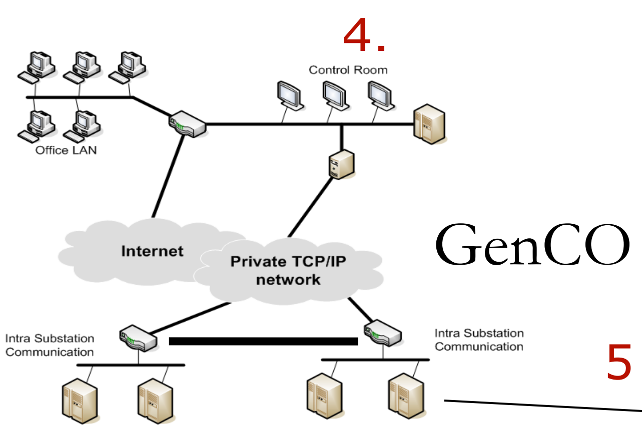


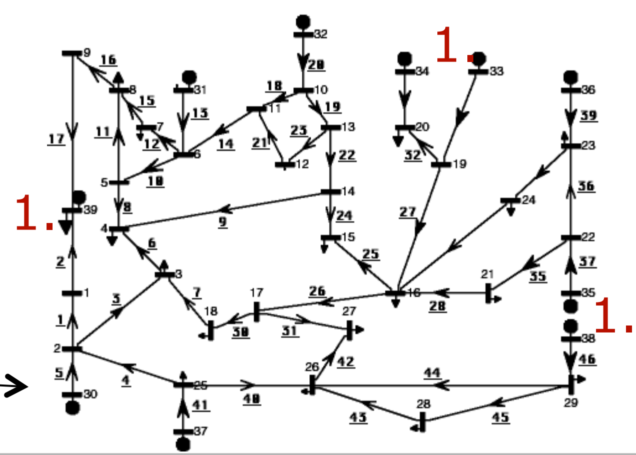
TSO – Frequency control

TSO – Maintenence

TSO - Frequency Control

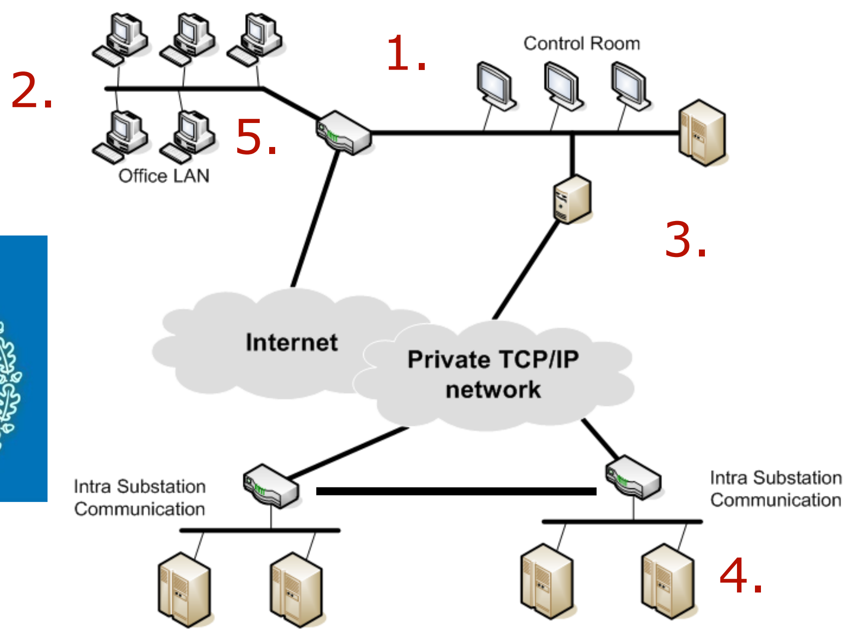


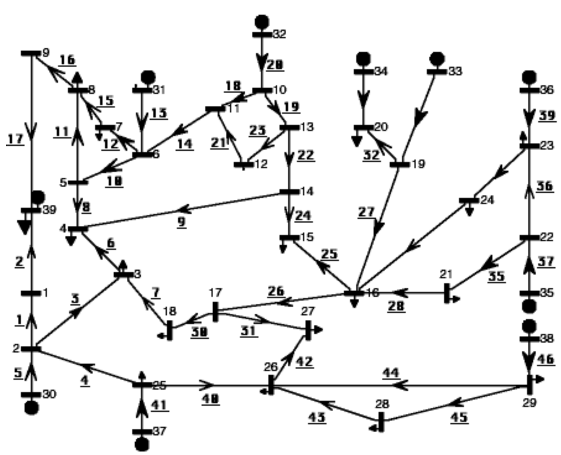




1. Frequency dip detected at generators committed to Load Frequency Control leads to automatic increase of output
2. Continuous under-frequency measured are sent to SCADA system using IEC 60870-5-101
3. Control room operator activates secondary reserve by issuing order to GenCo via phone.
4. GenCo orders 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.

Points for discussion

- What drives the development in
  - ICT area #1? – ”Consumer services”
  - ICT Area #2? – ”New production”
  - ICT Area #3? – ”Grid operation”

- Which parties are involved in information exchange required
  - For frequency control?
  - For voltage control in a distribution grid?
  - For optimal dispatch of production?

Questions or comments?