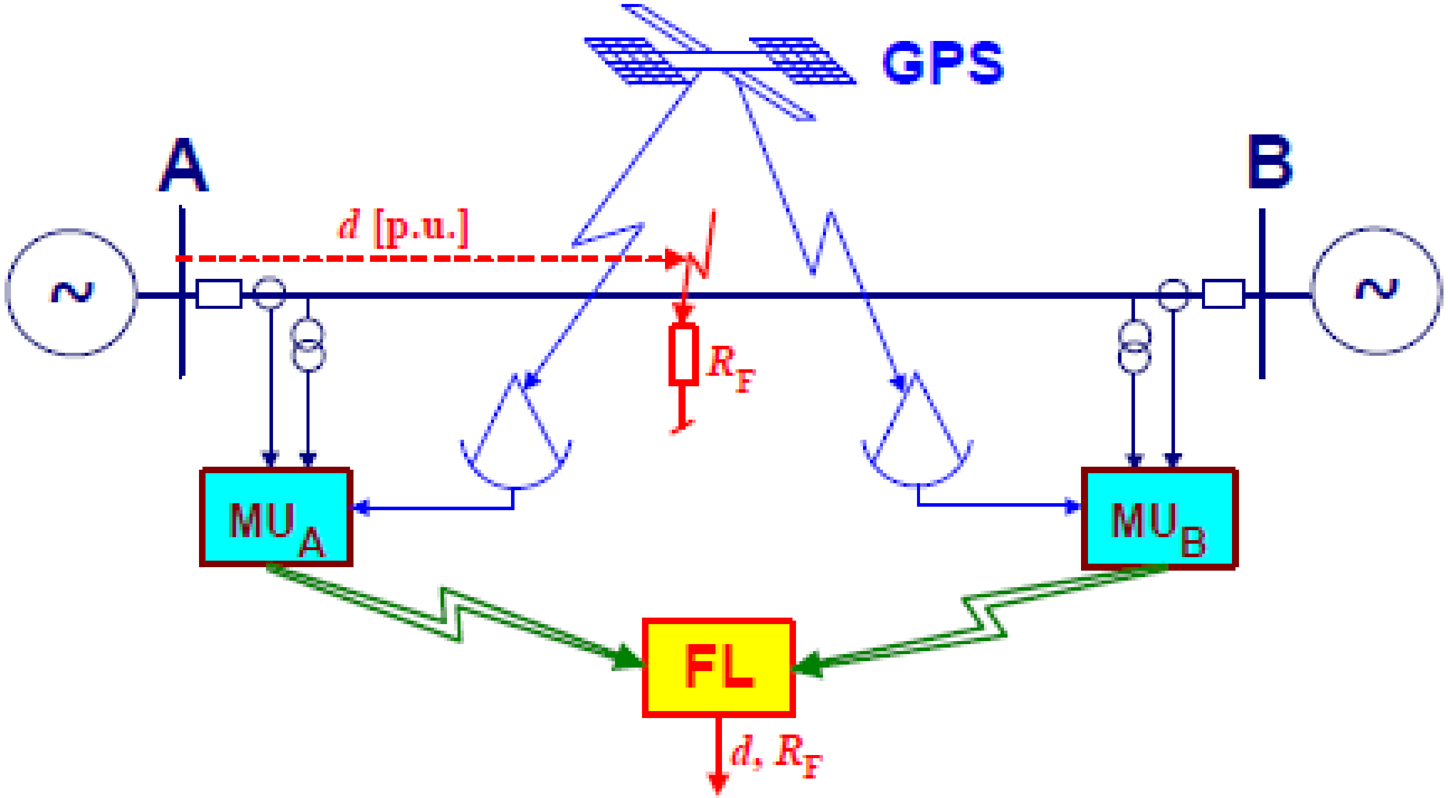
Substation Automation Systems

Nicholas Honeth (nicholash@ics.kth.se)

Contents of the series

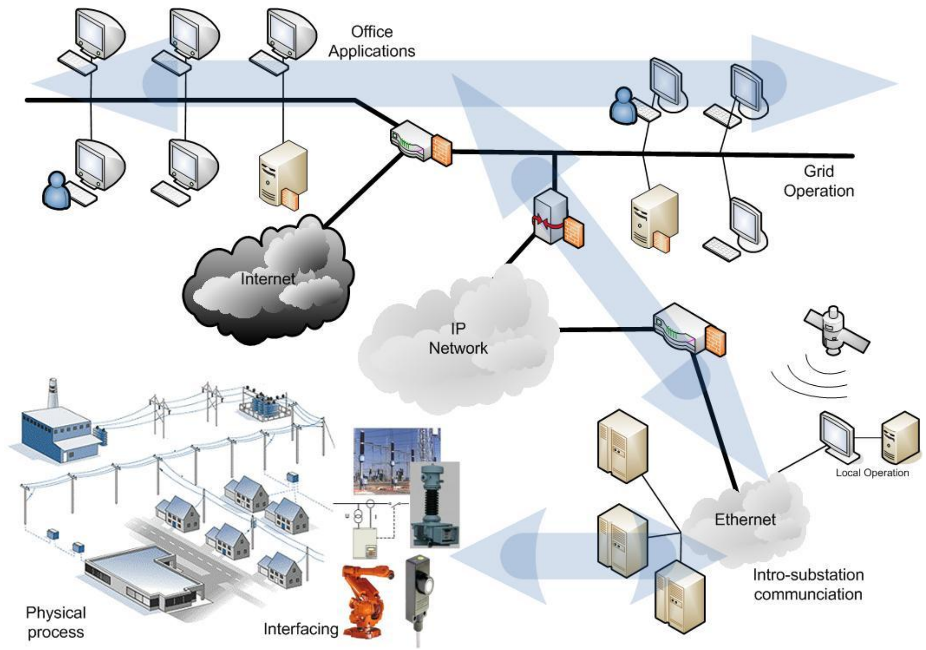
- Lecture 5
  - Introduction to SAS
  - Nice creative exercise
- Lecture 6
  - A bit about information modelling
  - Data types and structures
  - Infomation modelling in the power industry
- Lecture 7
  - Modern substation architectures
  - The IEC 61850 standard

Boxes and lines…



Contents of lecture 5

- Automation systems
- Programmable controllers
- Sensors/actuators
- Networking and Communication
- Substation automation



Some terms and acronyms…

HMI

ADC

IED

LAN

PLC

SAS

OO

PC

TCP/IP

SCADA

Ethernet

PAC

CT/VT

RS232

UTP

RTU

GPS

WAN

RTOS

RAM

Bus

ROM

I/O

Automation systems

- Production line
- Integration of process control

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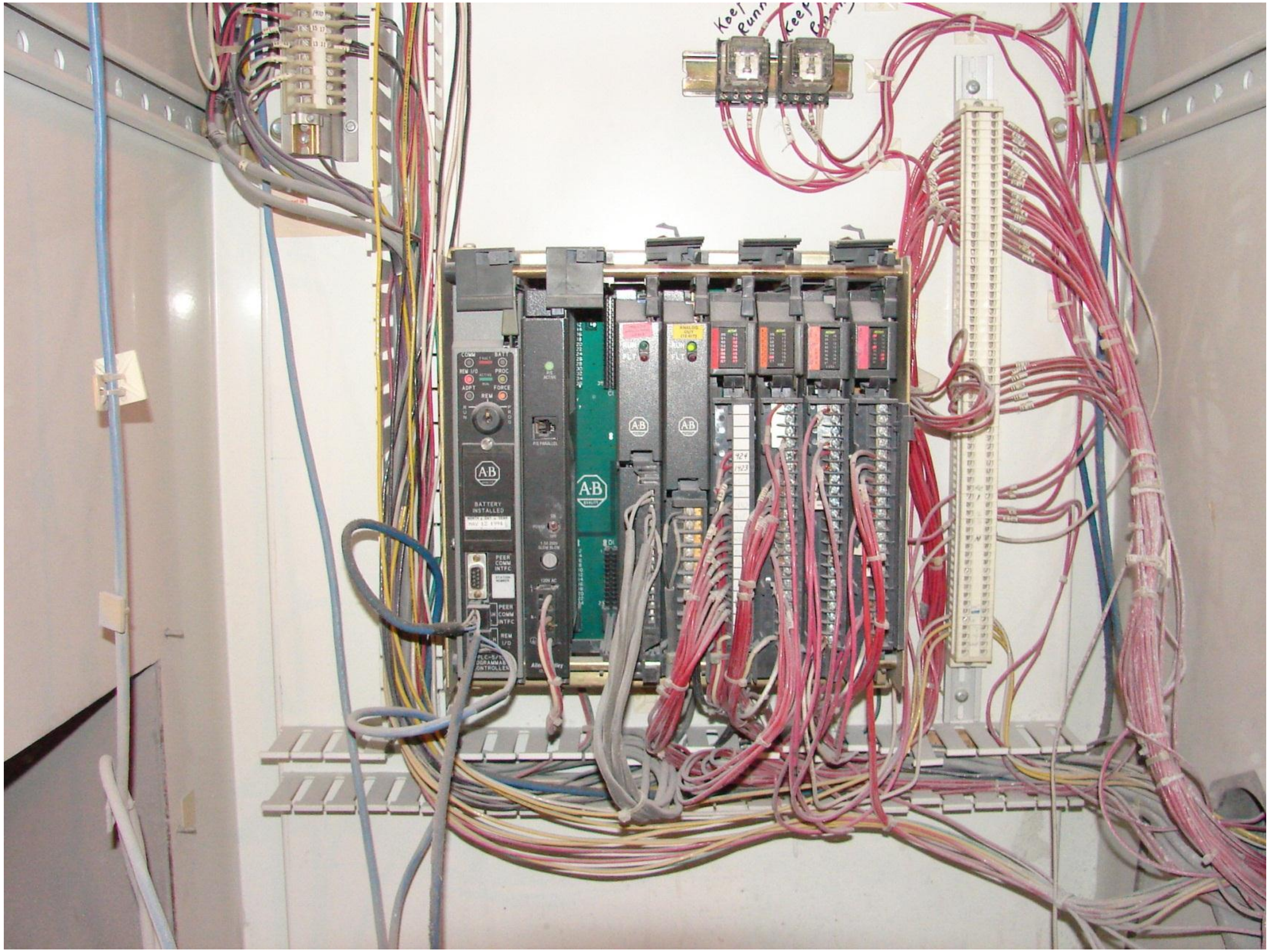
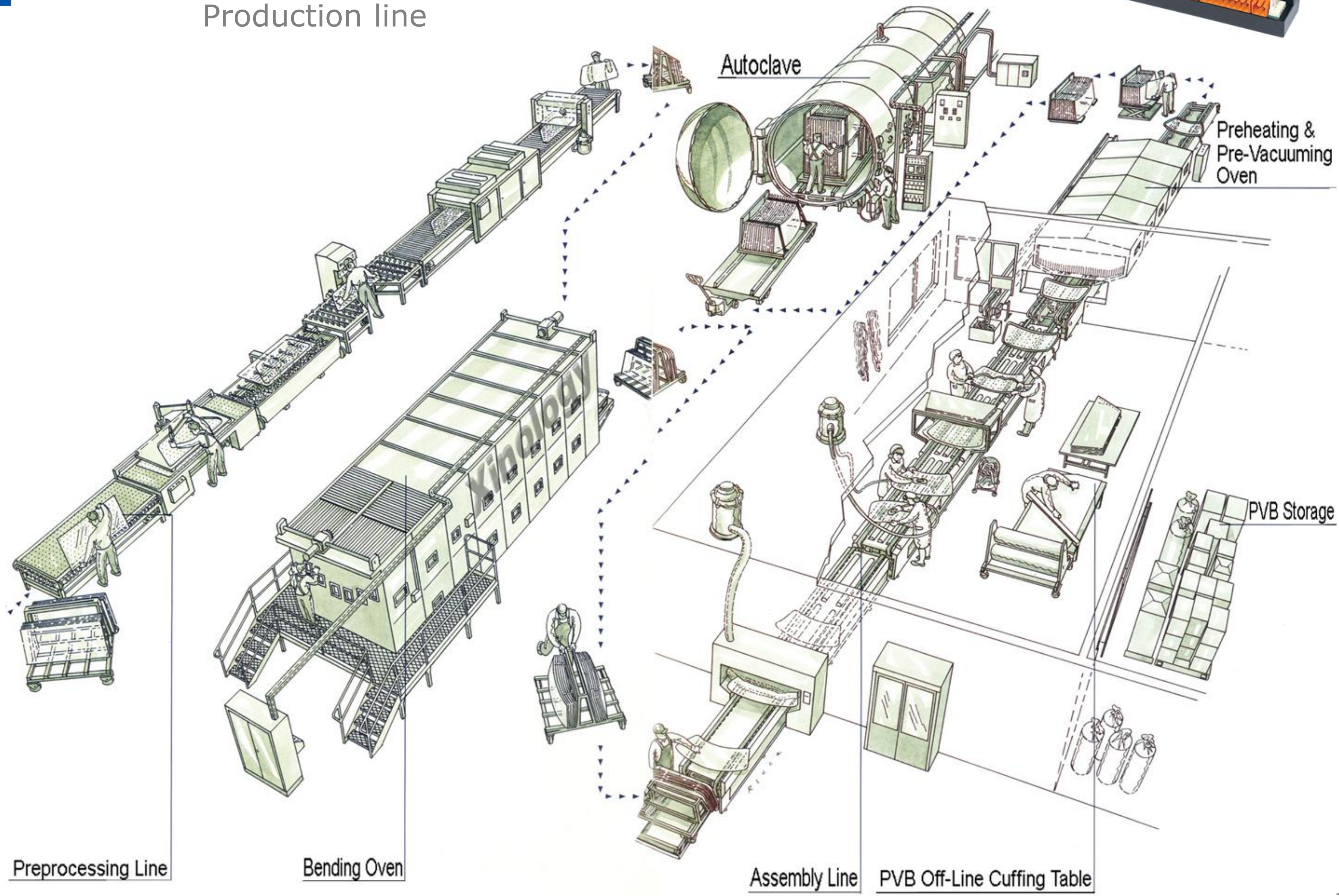
Automation systems

Production line



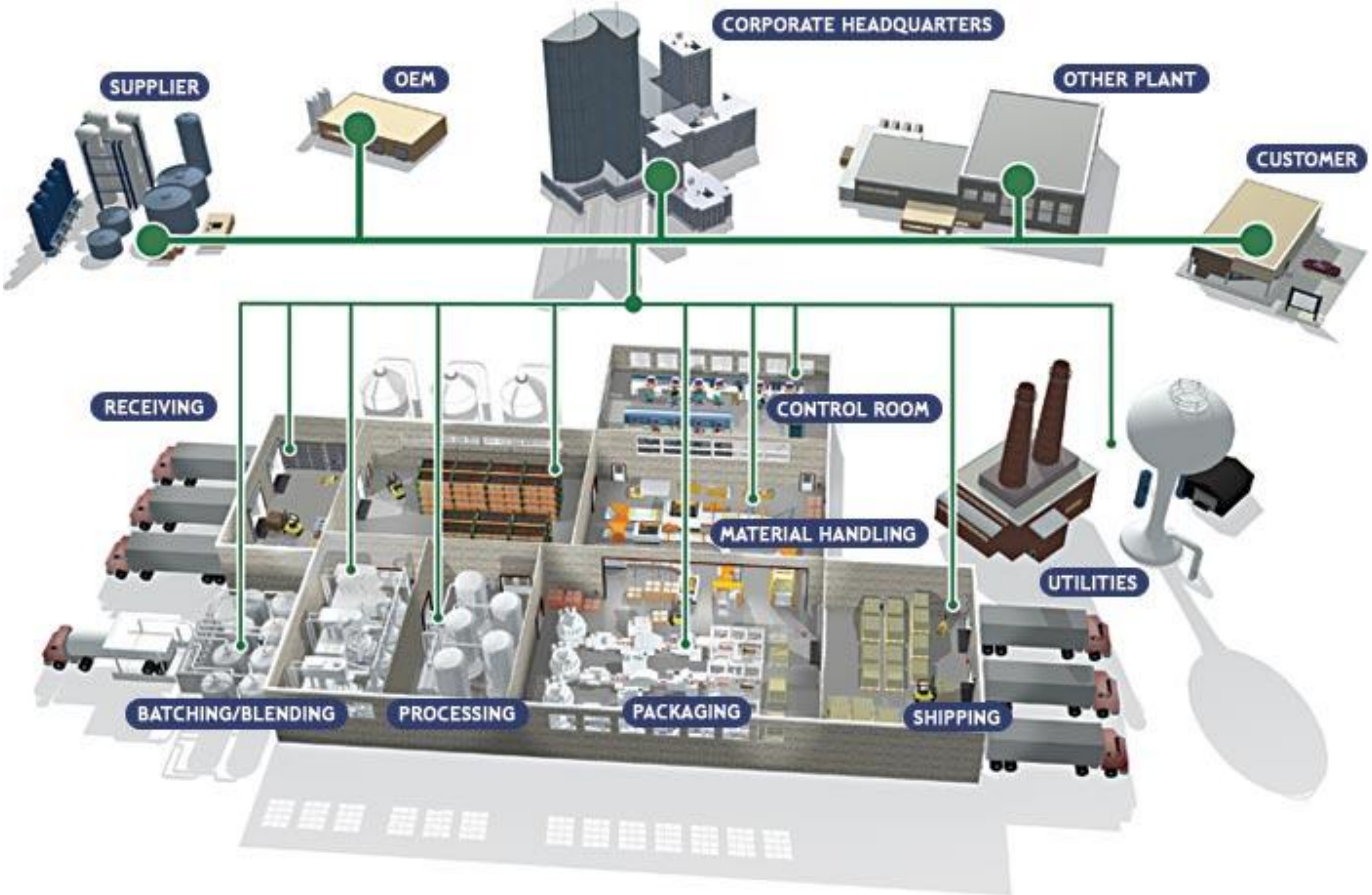
Automation systems

Production line



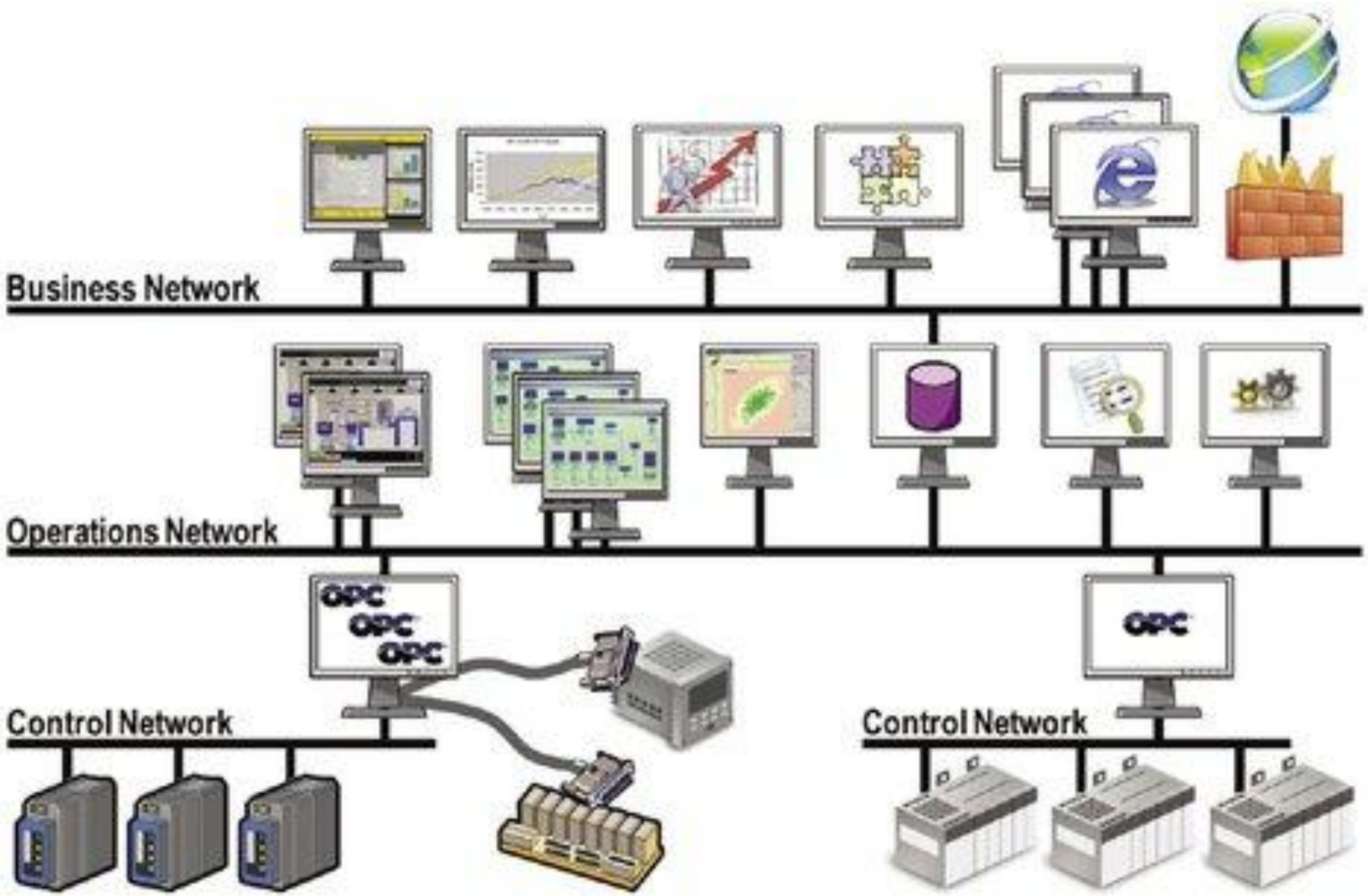
Automation Systems

Integration of process control

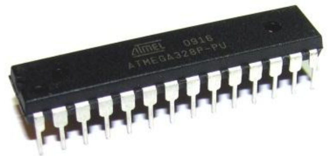


Automation systems

Process control



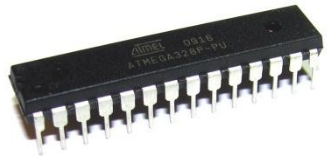
Programmable controllers



- Connect the blocks (PLC programming)
- Microcontroller programming
- Embedded systems

Programmable controllers

PLC programming



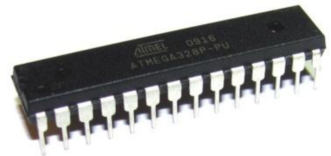
Programmable controllers

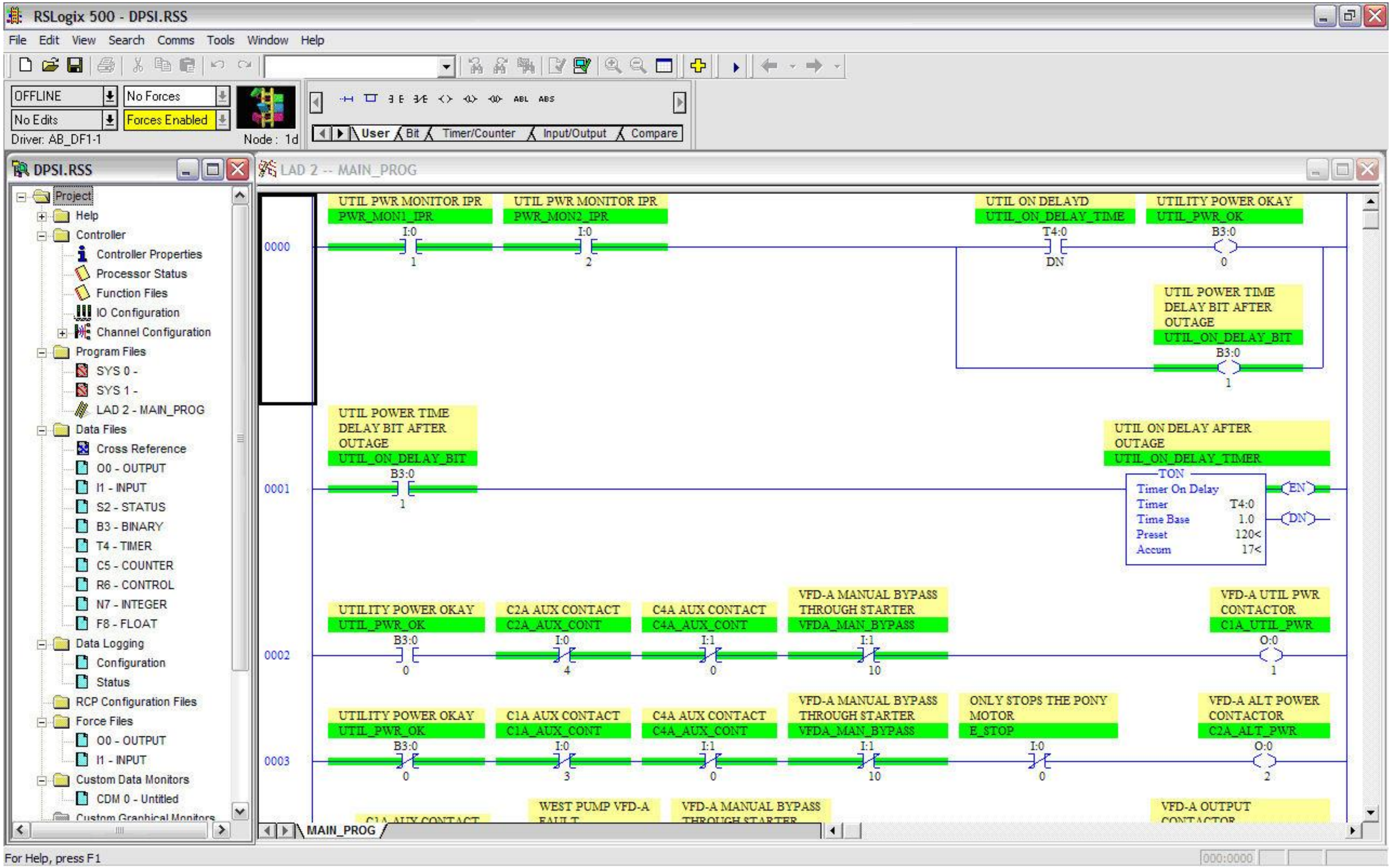
PLC programming

- Automation of electromechanical processes
- Built for tough environments
- Hard real-time system – outputs in bounded time
- Fairly simple and cheap devices.

Programmable controllers

PLC programming



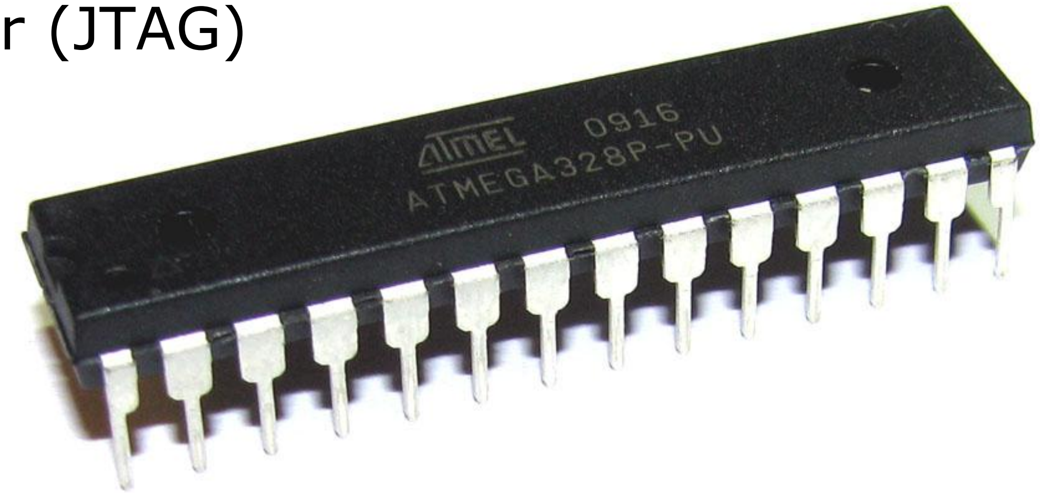


Programmable controllers

Microcontroller programming

- Very cheap but surprisingly powerful
  - ROM holds lots of program code
- Very small Random Access Memory (RAM)

- Programmed in C/C++/Assembler
- Need a programmer (JTAG)



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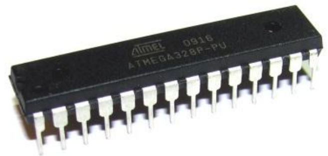
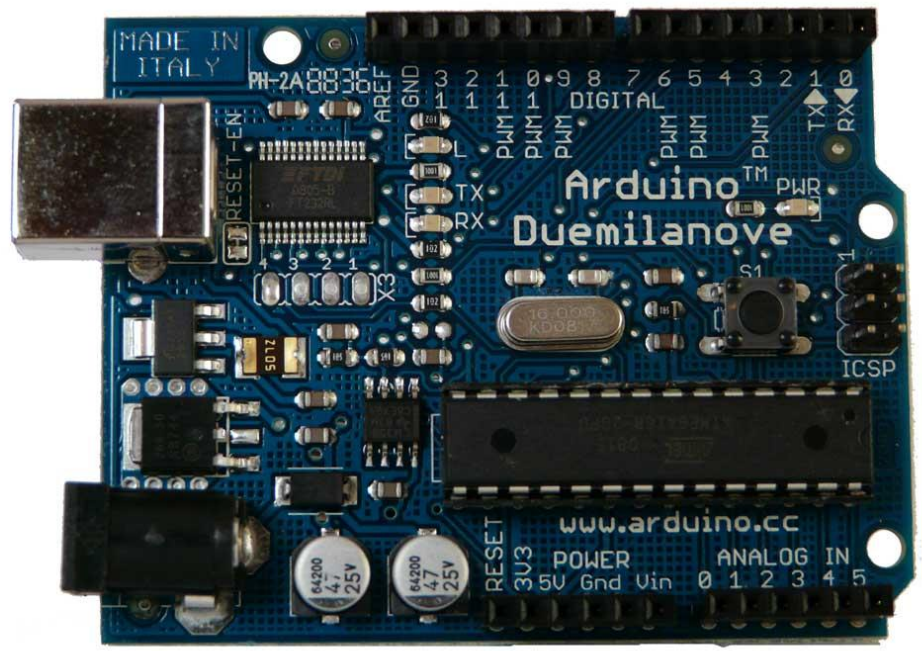
Programmable controllers

Microcontroller programming



- Packaged as development boards
  - Give access to some of the facilities (usually pins)
- Will later be built into the controlled device.



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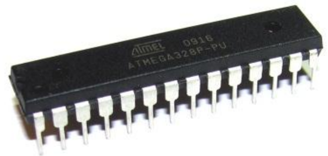
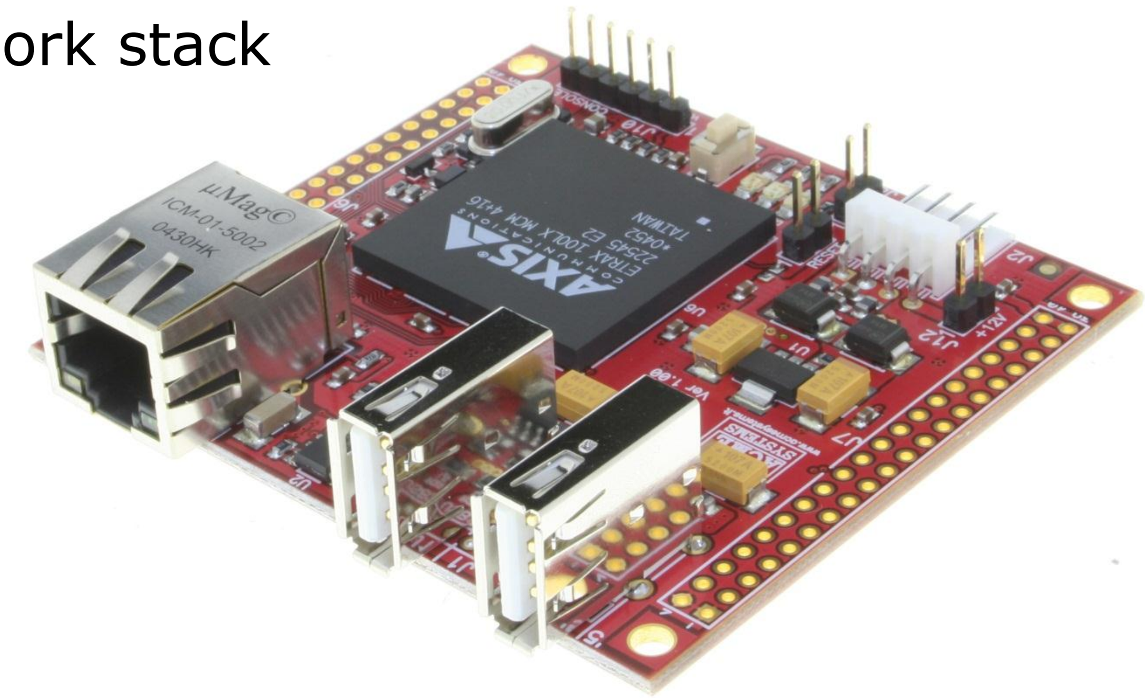
Programmable controllers

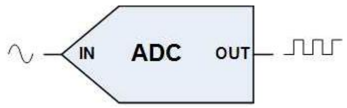
Embedded systems



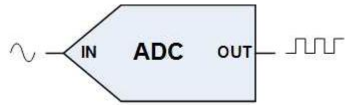
- Larger, more powerful systems
- Usually run an operating system - RTOS
- Programmed in C/C++
- Need a programmer (JTAG)
- Often have full network stack



Sensors/actuators



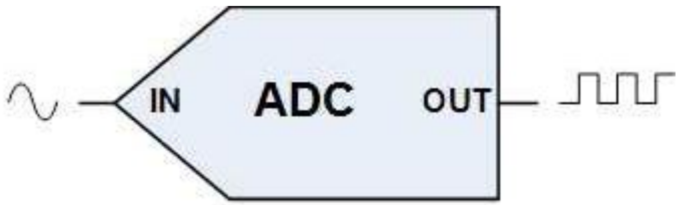
- Analog to digital conversion
- Actuators

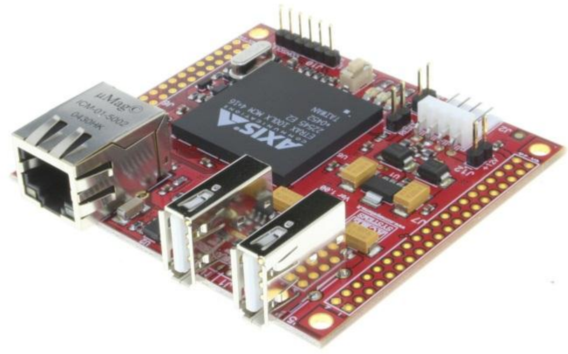


Sensors/actuators

Analogue-to-Digital Conversion

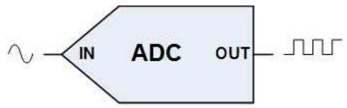
- Convert a continuous analog signal into digital samples





Sensors/actuators

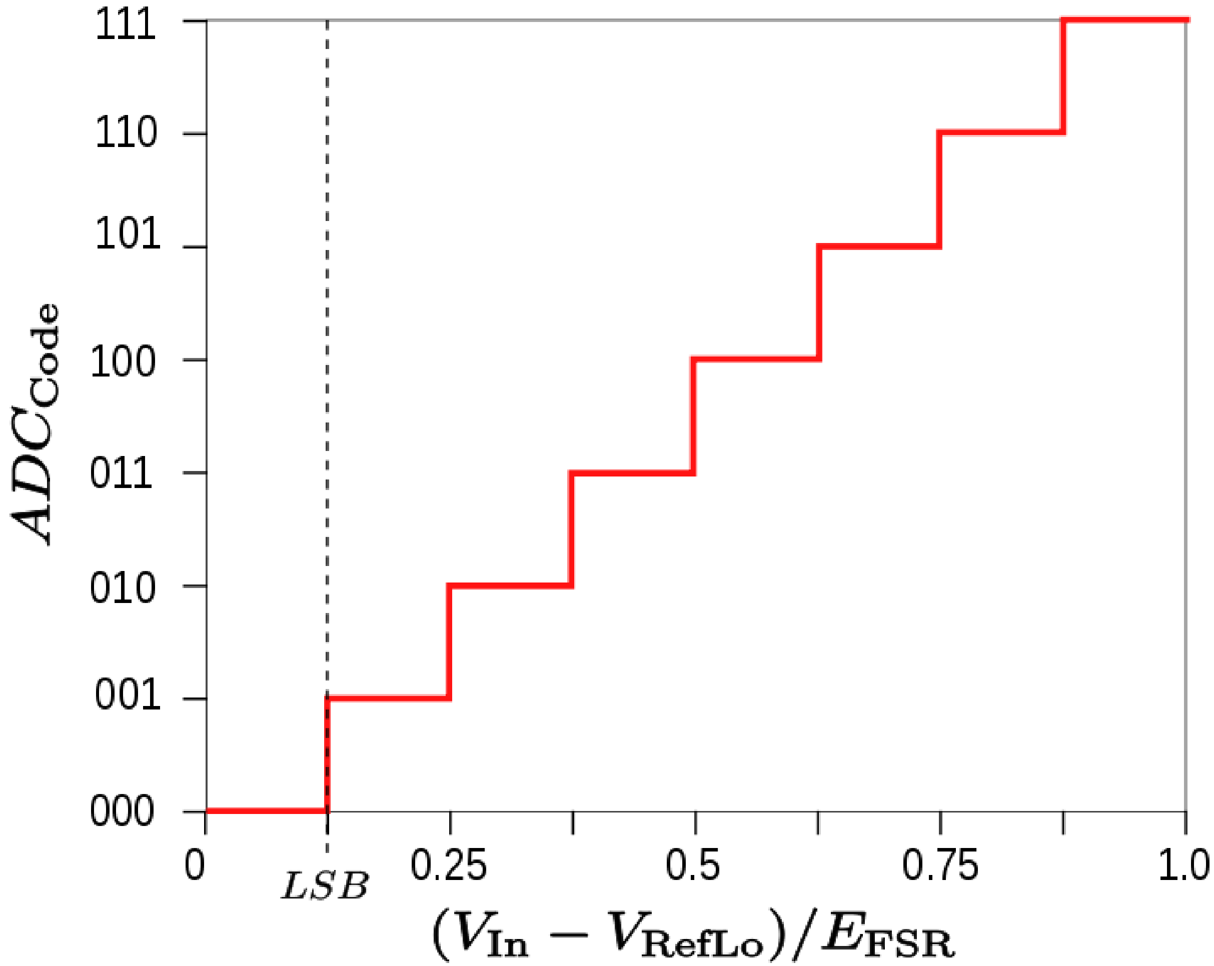
Analogue-to-Digital Conversion

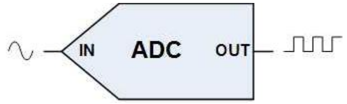


- Resolution
- Sampling rate

- 8-step (3-bit) ADC

- Encoding
  - Two's compliment
  - BCD
  - Gray code

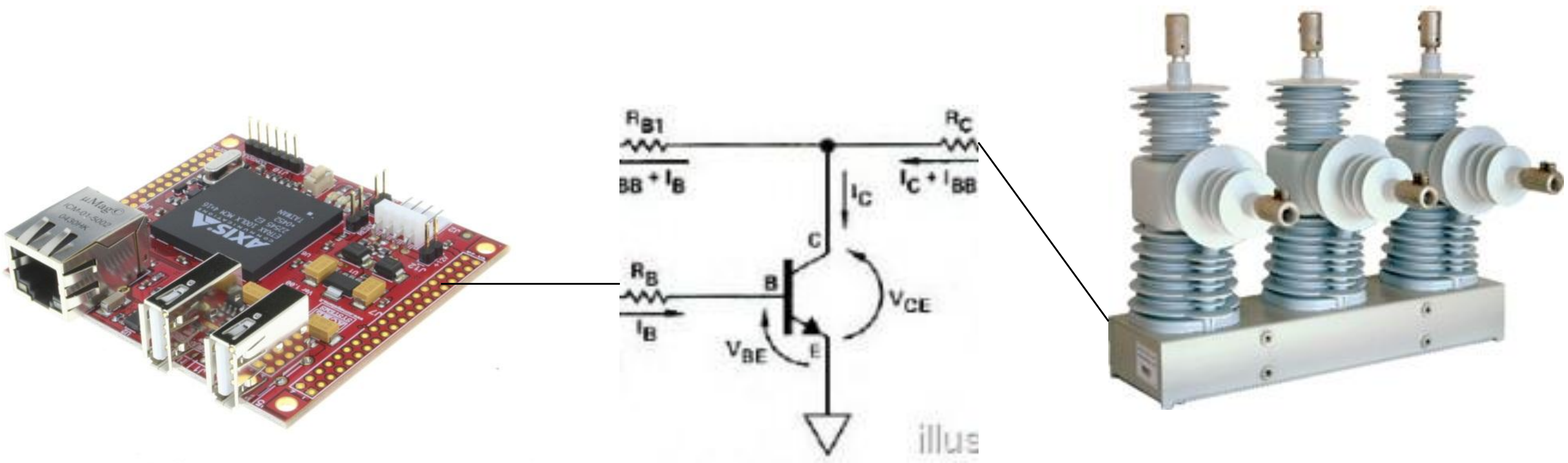




Sensors/actuators

Actuators

- Convert weak microelectronic signal to a breaker/isolator/tap change manuver



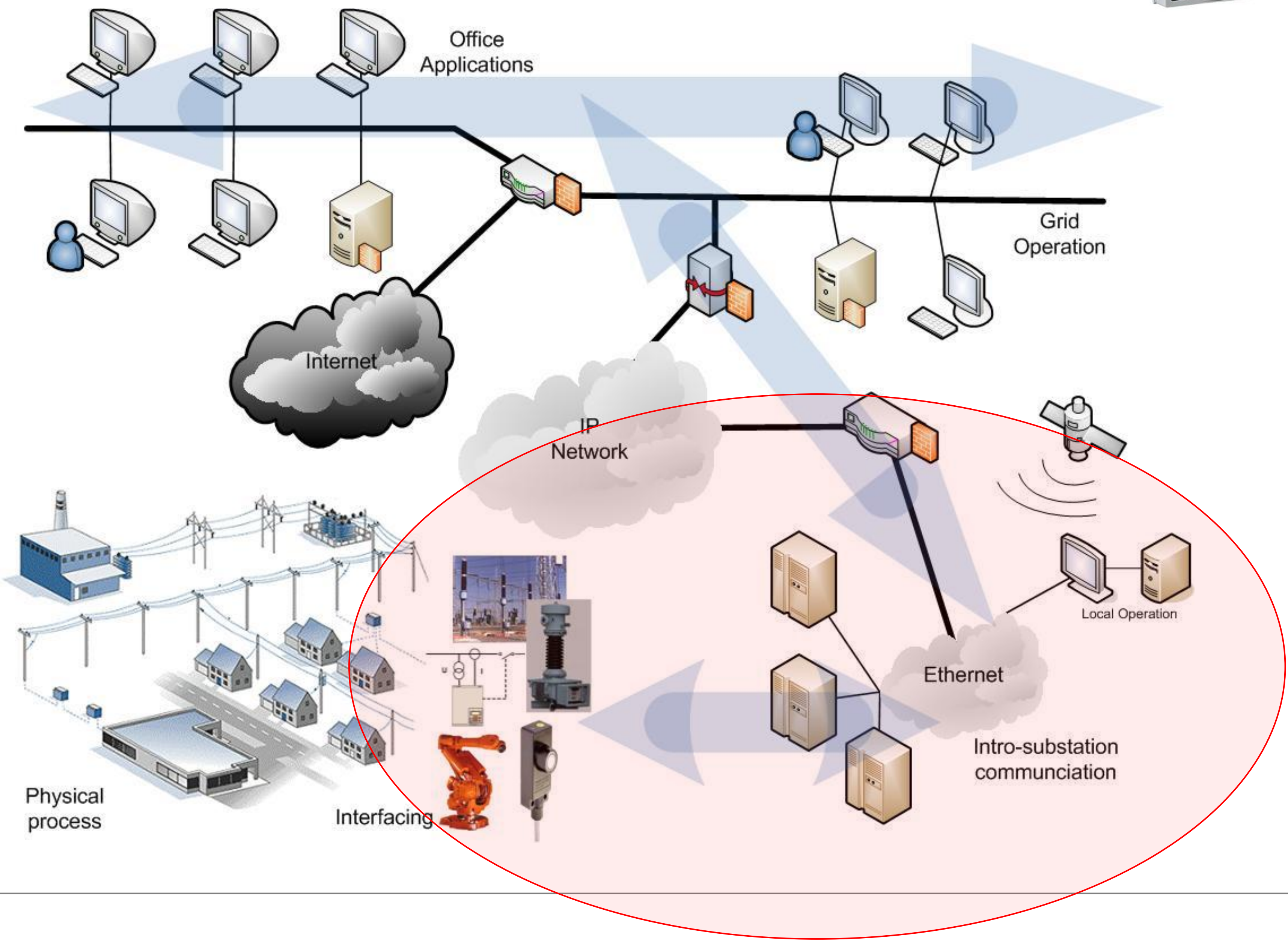
Networking and Communication

- Why do we need to communicate?
- What do we want to send/receive?
- How do we accomplish this?
- How long does it take?
- How is it done in the real world?

Substation automation

- What would we want to automate?
- Common components
- Substation architectures

Substation automation



Substation automation

What would we want to automate?

Functional area	Functionality			
Interlocking	CB's	Isolators	Contactors	
Tripping sequences	CB failure	Intertripping		Simultaneous trips
Switching sequences	Automatic transformer changeover	Automatic busbar changeover	Restoration of supply following fault	Network re-configuration
Load management	Load shedding	Load restoration	Generator despatch	
Transformer supervision	OLTC control	Load management		
Energy monitoring	Import/export control	Energy management	Power factor control	
Switchgear monitoring	AIS monitoring	GIS monitoring		
Equipment status	Relay status	CB status	Isolator status	
Parameter setting	Relays	Transformers	Switching sequences	IED configuration
HMI functionality	Access control Trend curves Interface to SCADA	One-line views Harmonic analysis Alarm processing	System views Remote access 512	Event logging Disturbance analysis

Table 24.6: Typical substation automation functionality

Substation automation

Common components

- **Remote Terminal Unit**
  - Telemetry and remote control device
- **Intelligent Electronic Device(s)**
  - Device that implements functions in a substation, such as a protection relay
- **Bay controller**
  - A device that controls all devices related to a single bay (transformer, feeder,..) and communicates with relays for functionality
- **Human Machine Interface**
  - Typically an industrial PC with operator console for local control and system configuration
- **Communication bus(es)**
  - Connection between devices
- **Upwards communication interface.**
  - Implemented in the HMI, the Bay controller or in an IED.

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Substation automation

Common components

- Remote Terminal Unit (RTU)
  - For telemetry
  - Serial communication using
    - RS232
    - RS485
    - RS422
  - Standard protocols
    - Modbus
    - IEC 60870-5-101/104
    - DNP3
    - ICCP
  - Better suited to wide area telemetry than PLCs

Substation automation

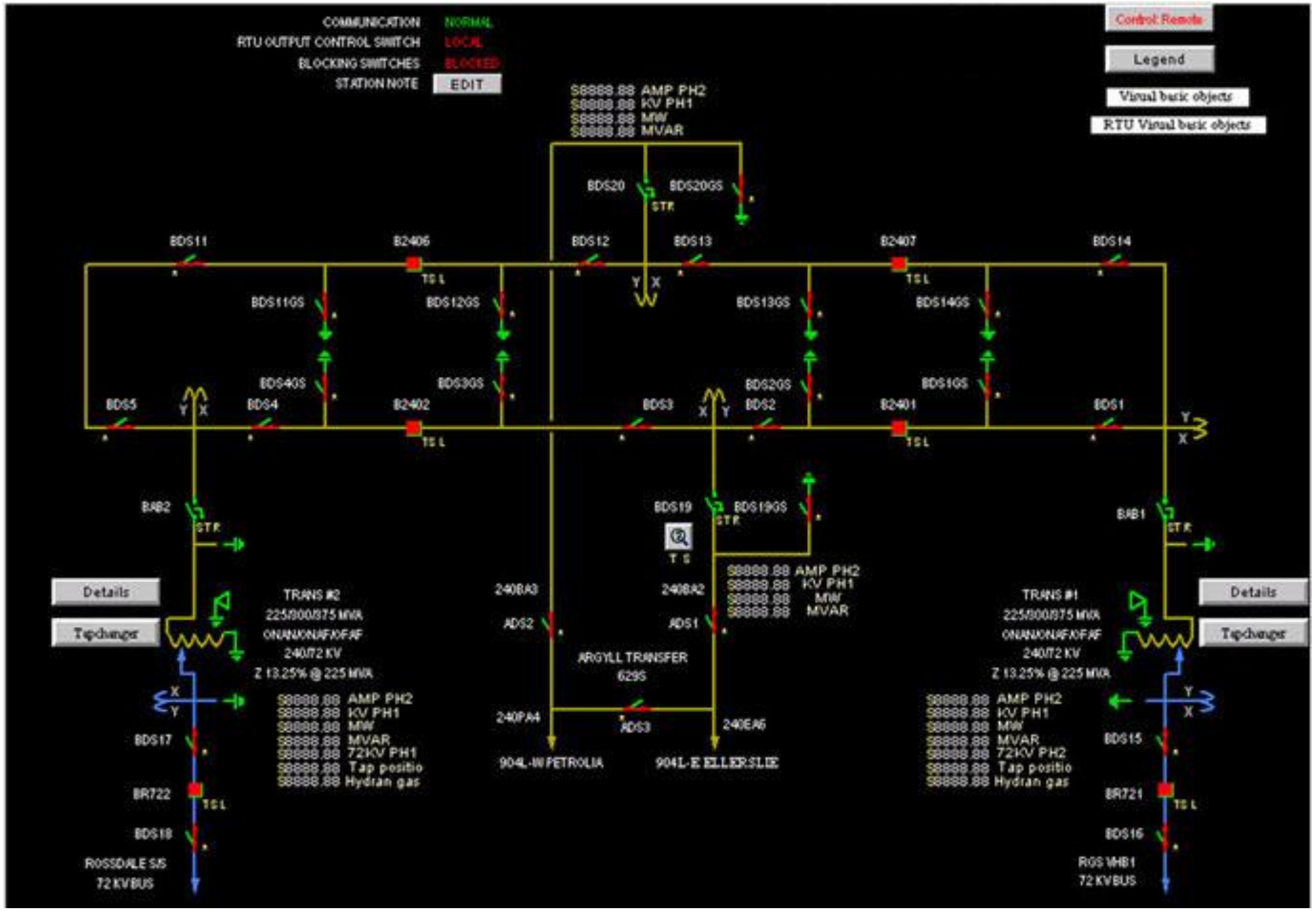
Common components

- Intelligent Electronic Device (IED)
  - Digital protective relay with added functionality
  - Can usually interface with RTU
    - Report events and measurement data
    - Receive commands from RTU/SCADA
  - Advanced functions need IEDs to communicate with each other
    - Horizontal communication
  - Control functions can include
    - Load tap changer controller
    - CB controller
    - Capacitor bank switches
    - Recloser controllers
    - Voltage regulators

Substation automation

Common components

- Human-Machine-Interface



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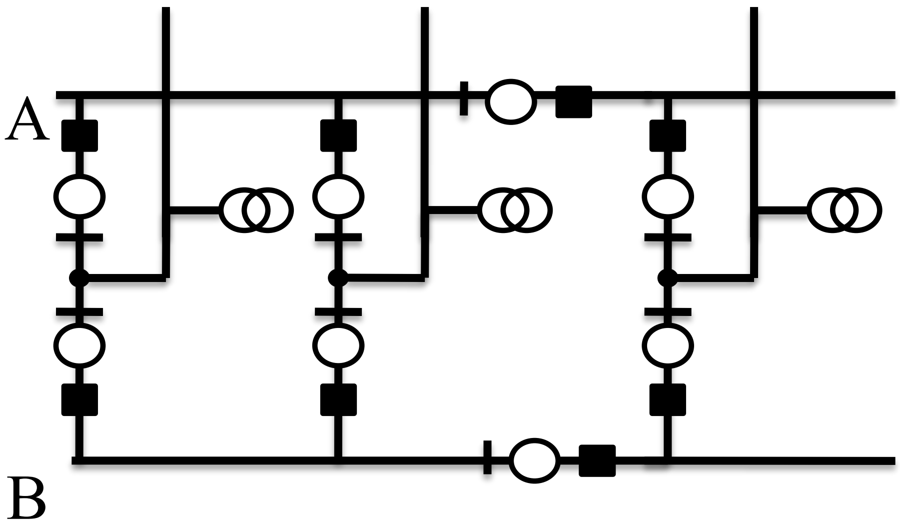
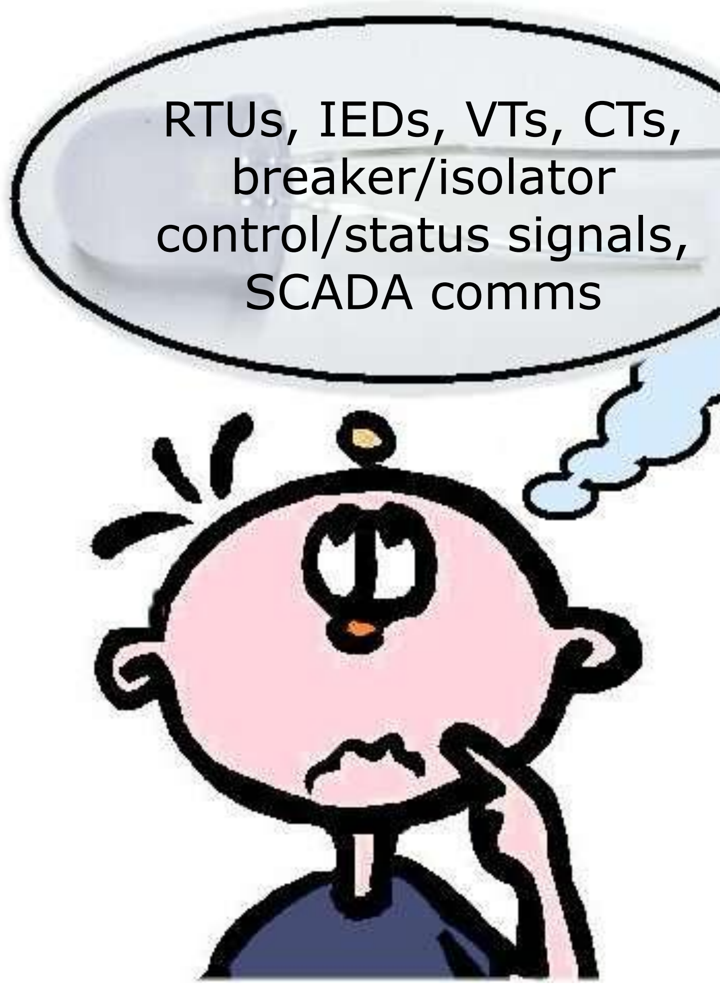
Substation automation

Exercise

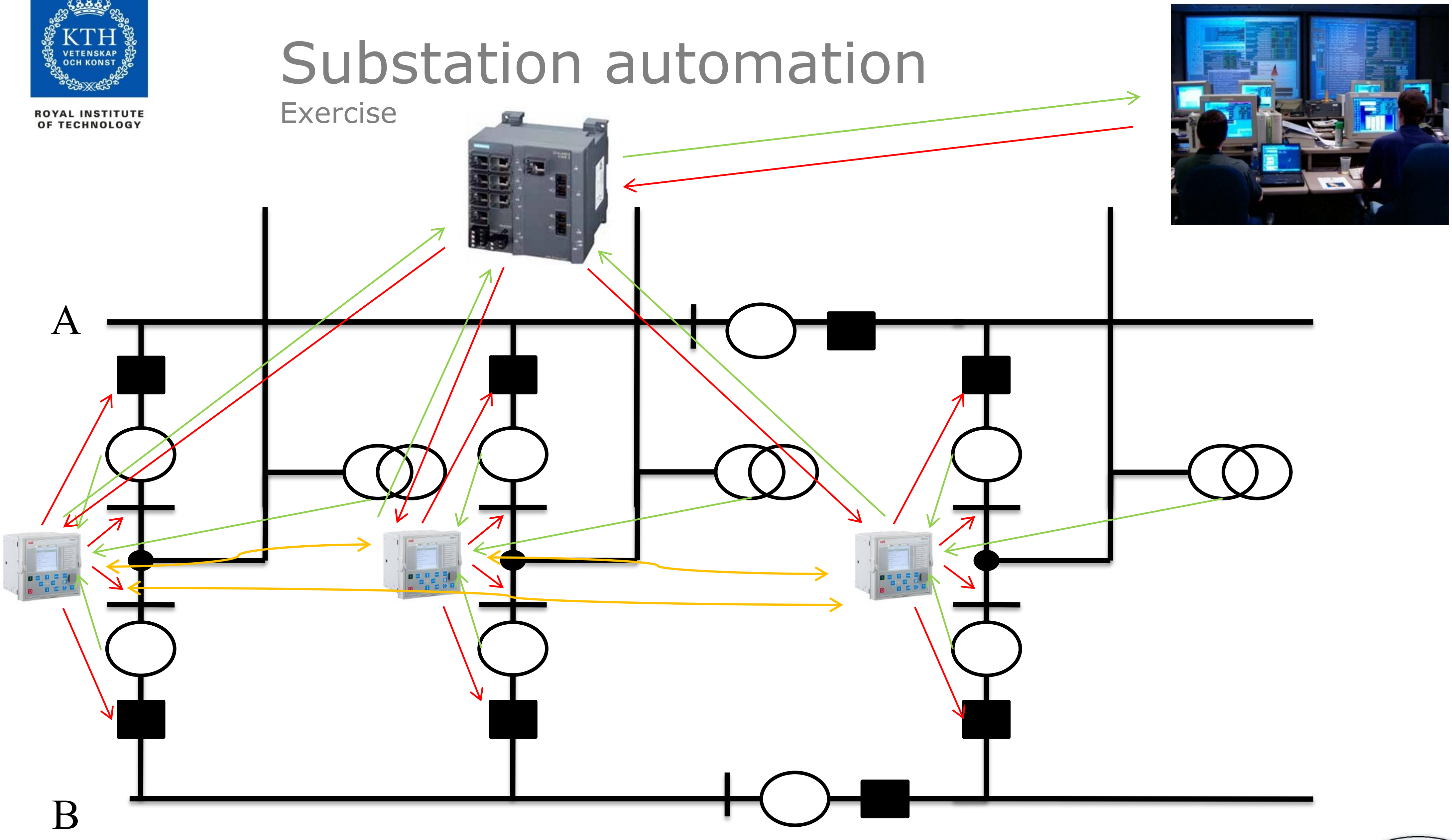
- Given a double breaker station
  - Choose an interesting function to implement eg. interlocking
  - What kind of automation equipment would we use?
  - What would need to be communicated?





Substation automation

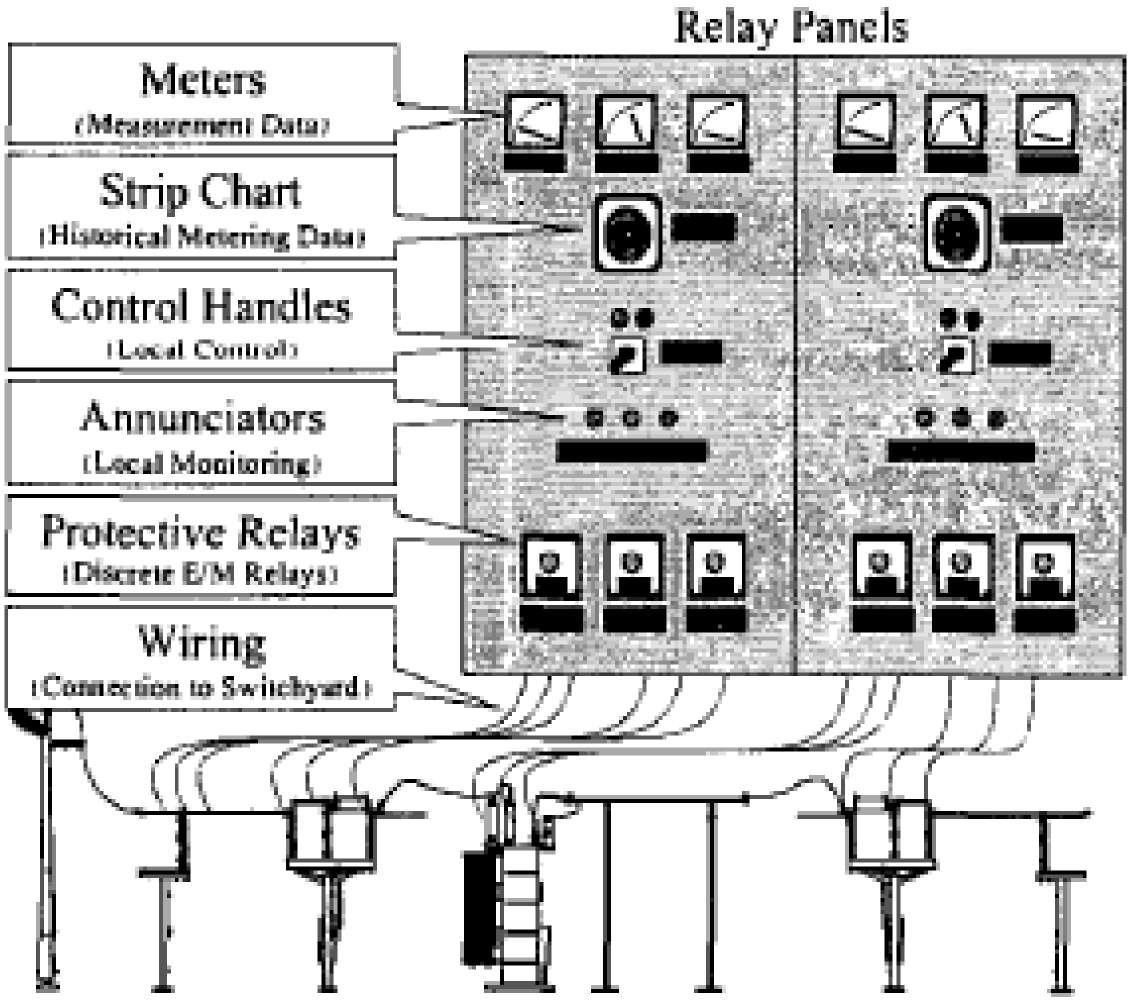
Exercise



Substation automation

Architectures

- Some history…



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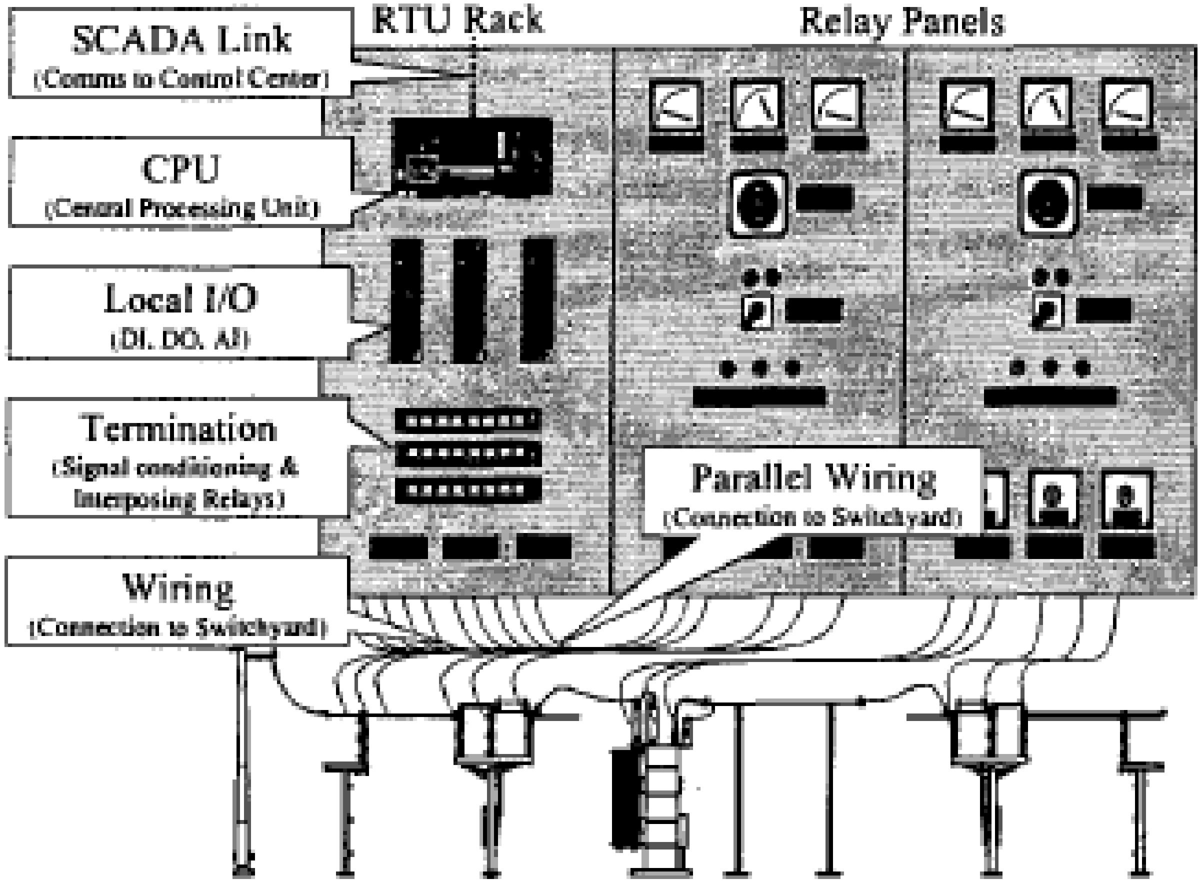
Substation automation

Architectures

- Some history with SCADA and RTU…



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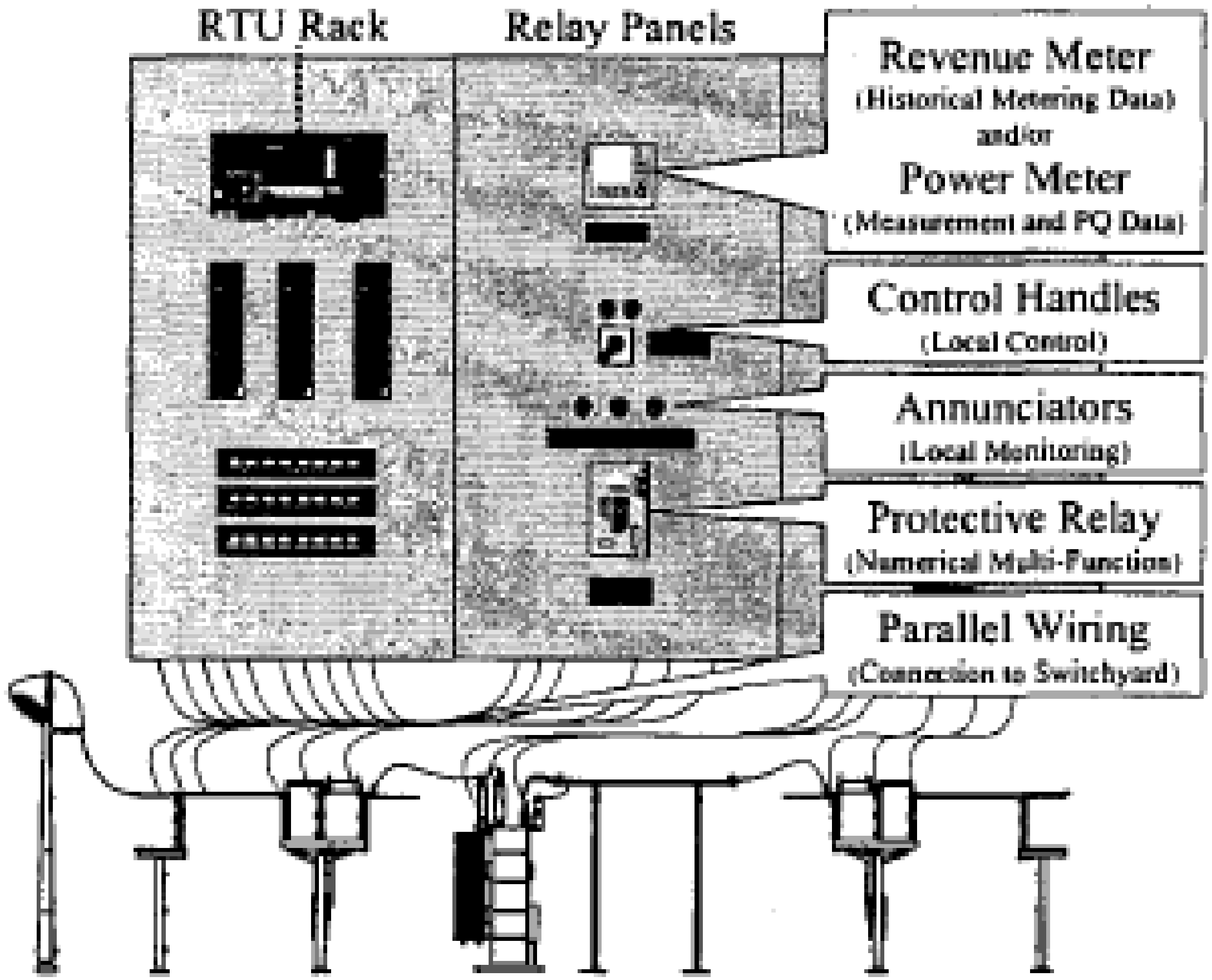
Substation automation

Architectures

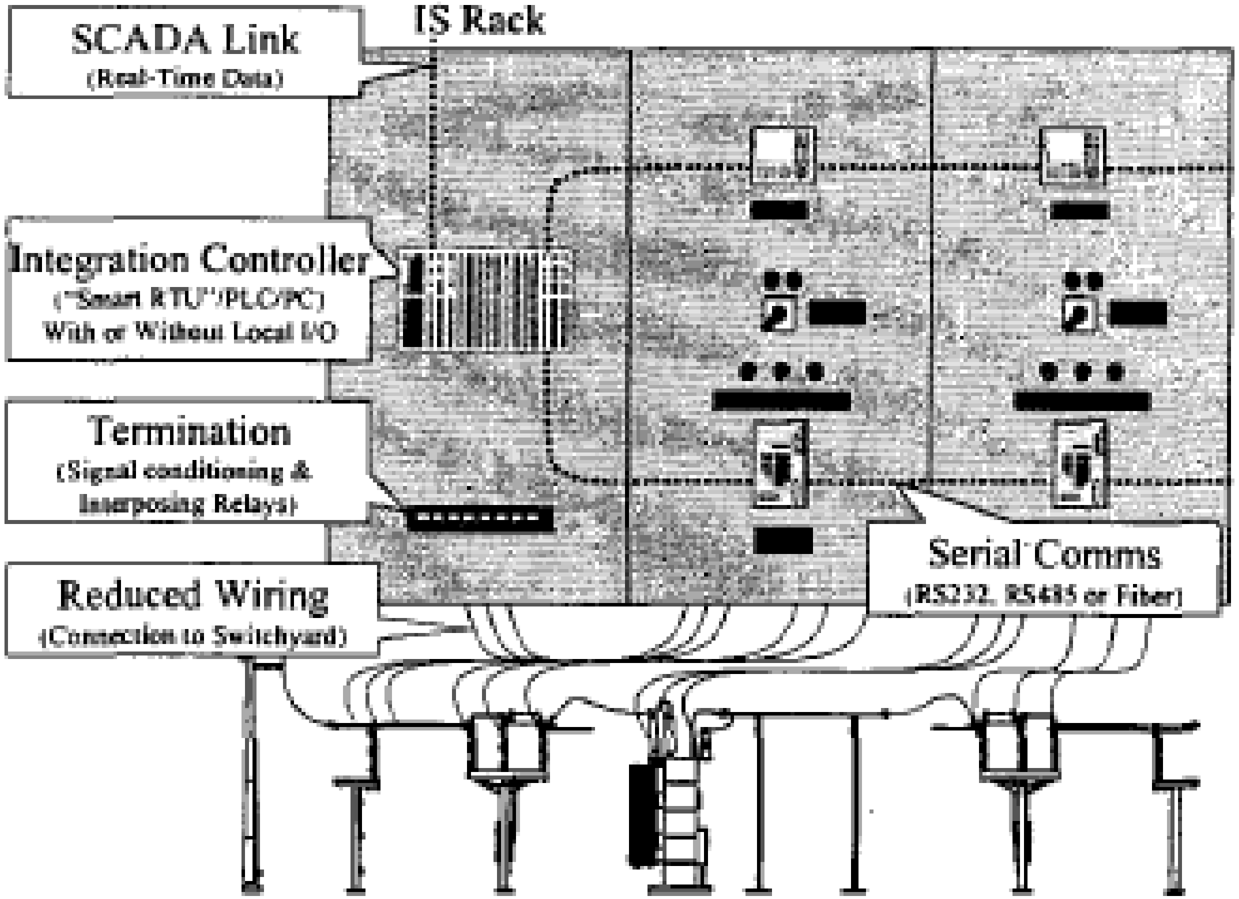
- Some history with SCADA and RTU and IED…



Substation automation

Architectures

- Some history with SCADA and RTU with integrated IED…



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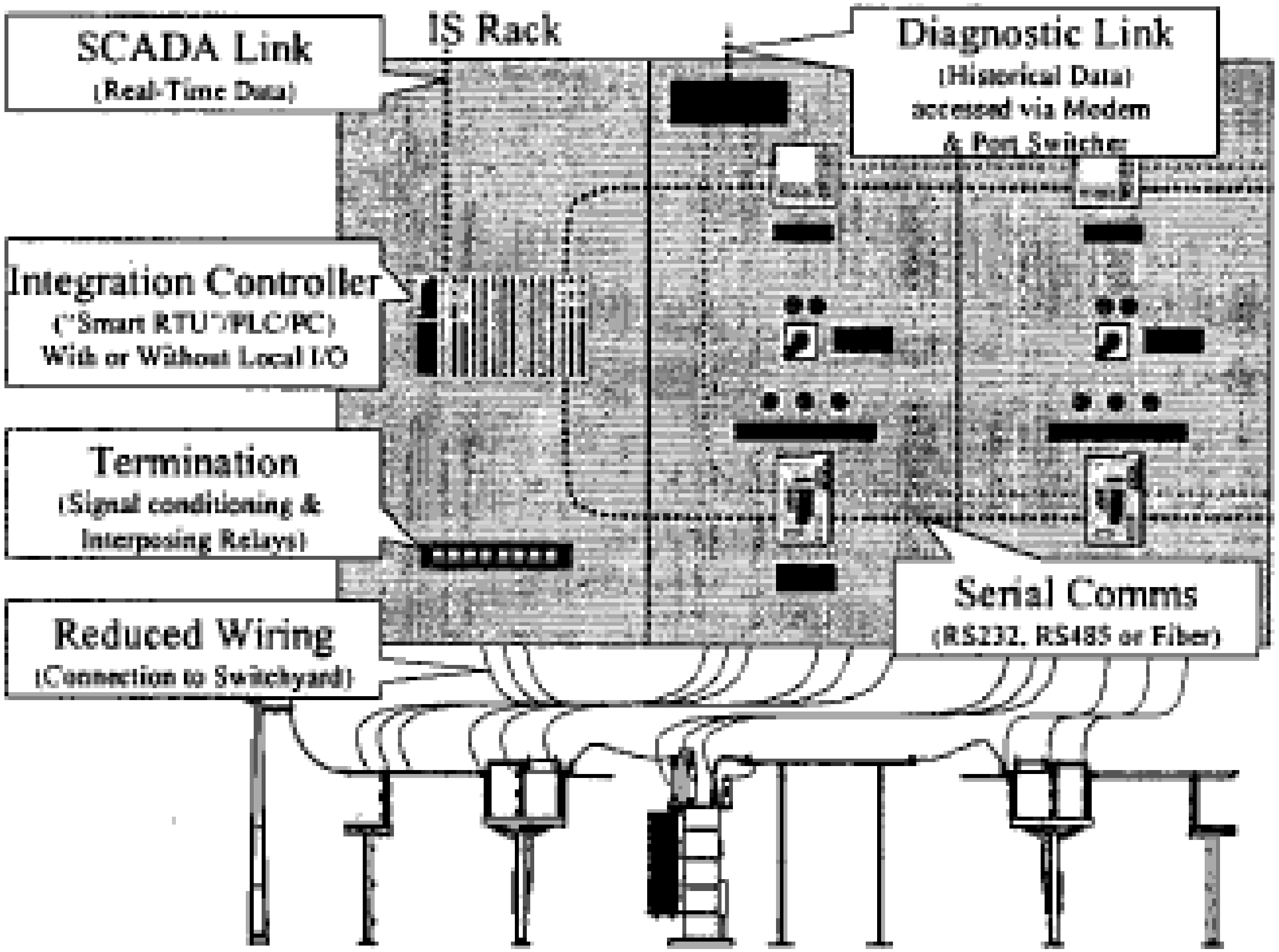
Substation automation

Architectures

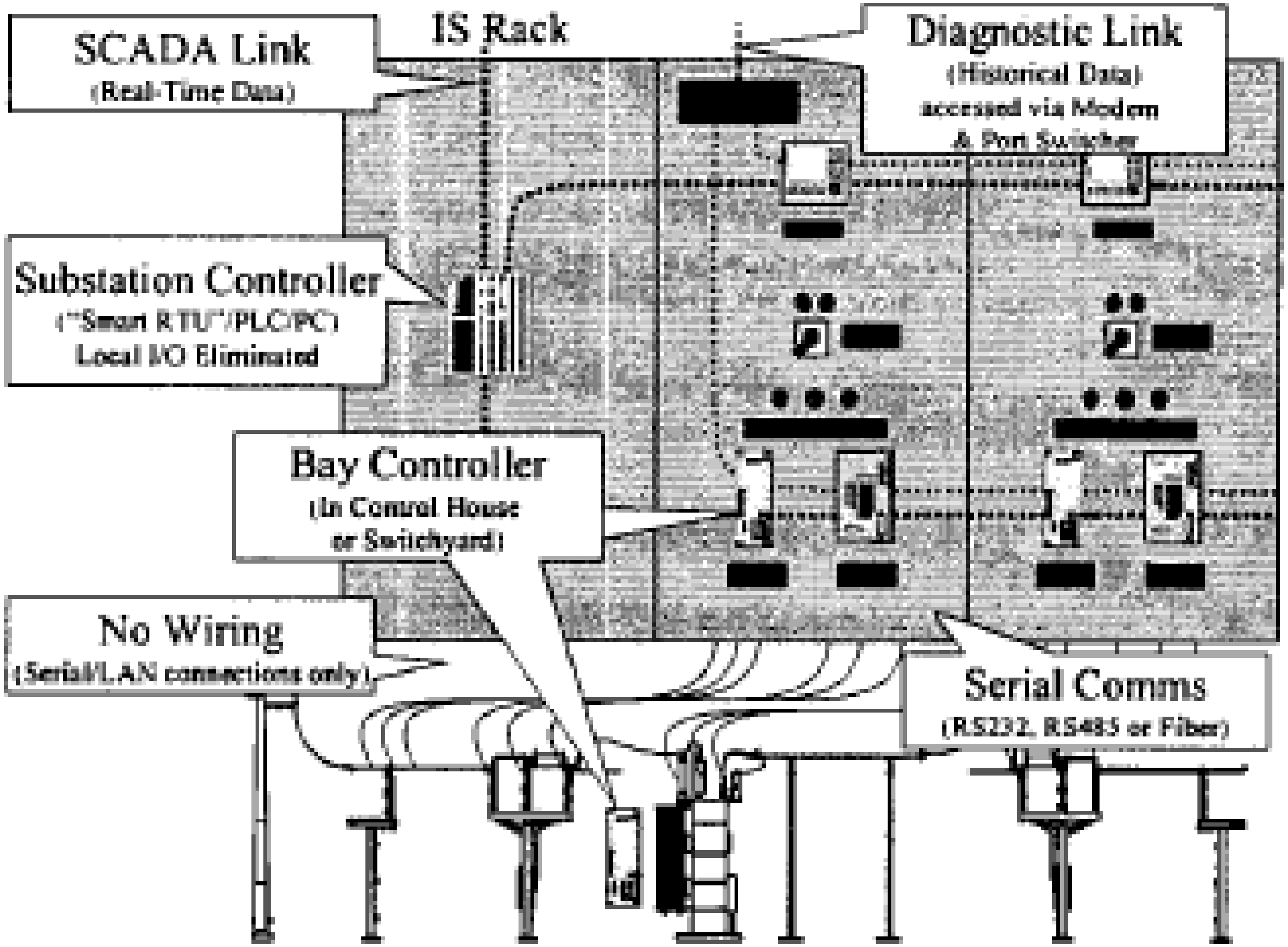
- Addressing maintenance needs



Substation automation

Architectures

- Bay Controller



Substation automation

Architectures

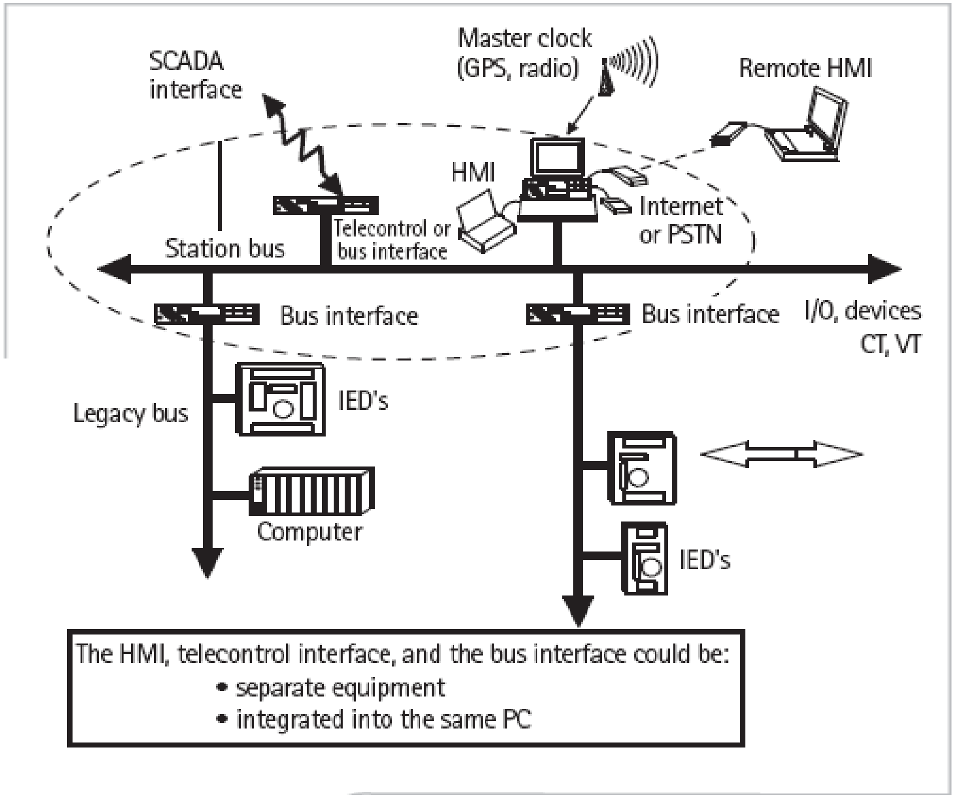


Figure 24.2: HMI-based hardware topology

HMI based

- The Man machine interface (rugged PC) implements all control and communication functionality
- IEDs implement protection & switching functionality
- Simplest solution
- Reliability of HMI computer a risk

Substation automation

Architectures

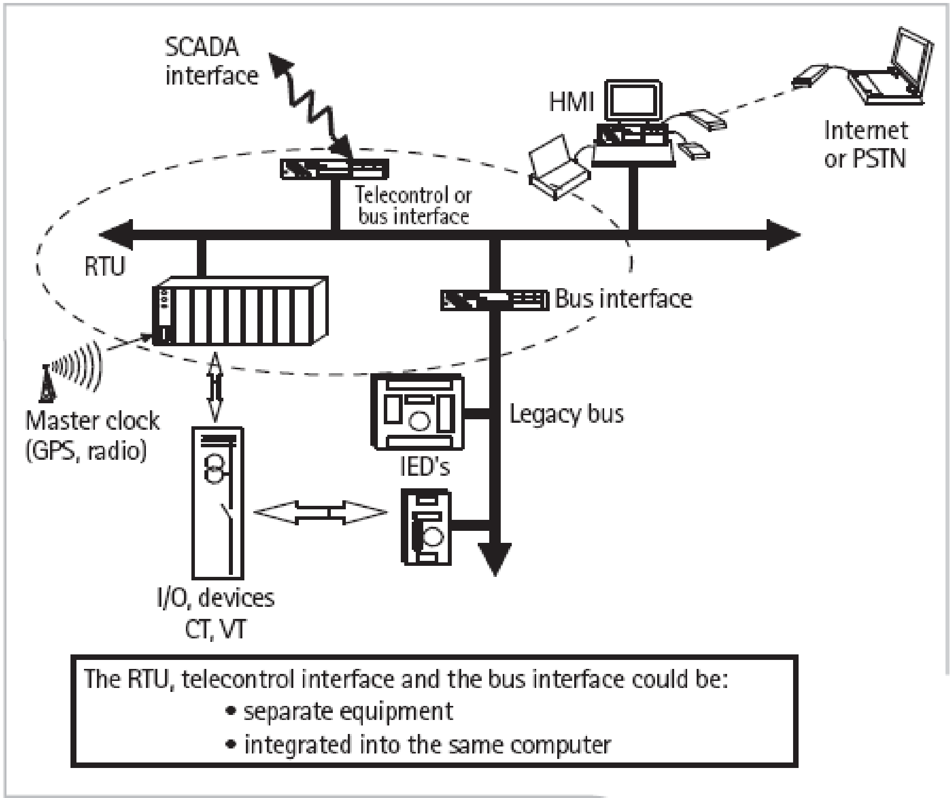


Figure 24.3: RTU-based topology

RTU based

- HMI separated from control & communication
- RTU implements the SCADA interface and substation control
- IEDs implement control & switching functionality

Strauss Type 3 & 4, with telecontrol equipment separate or not

Substation automation

Architectures

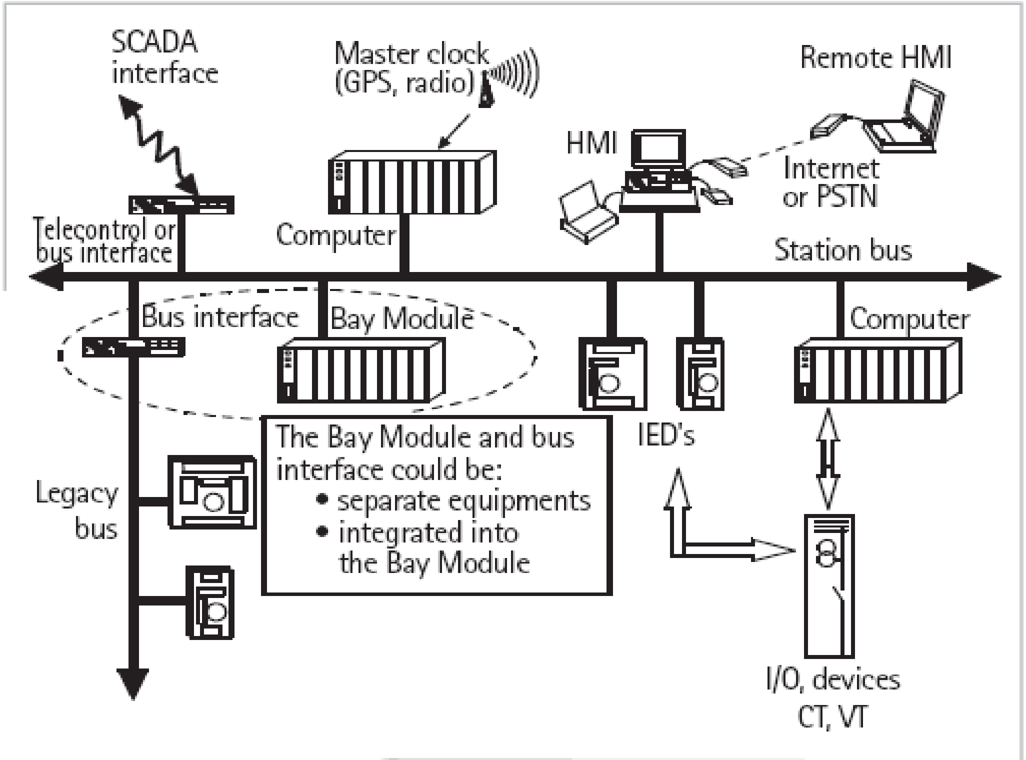


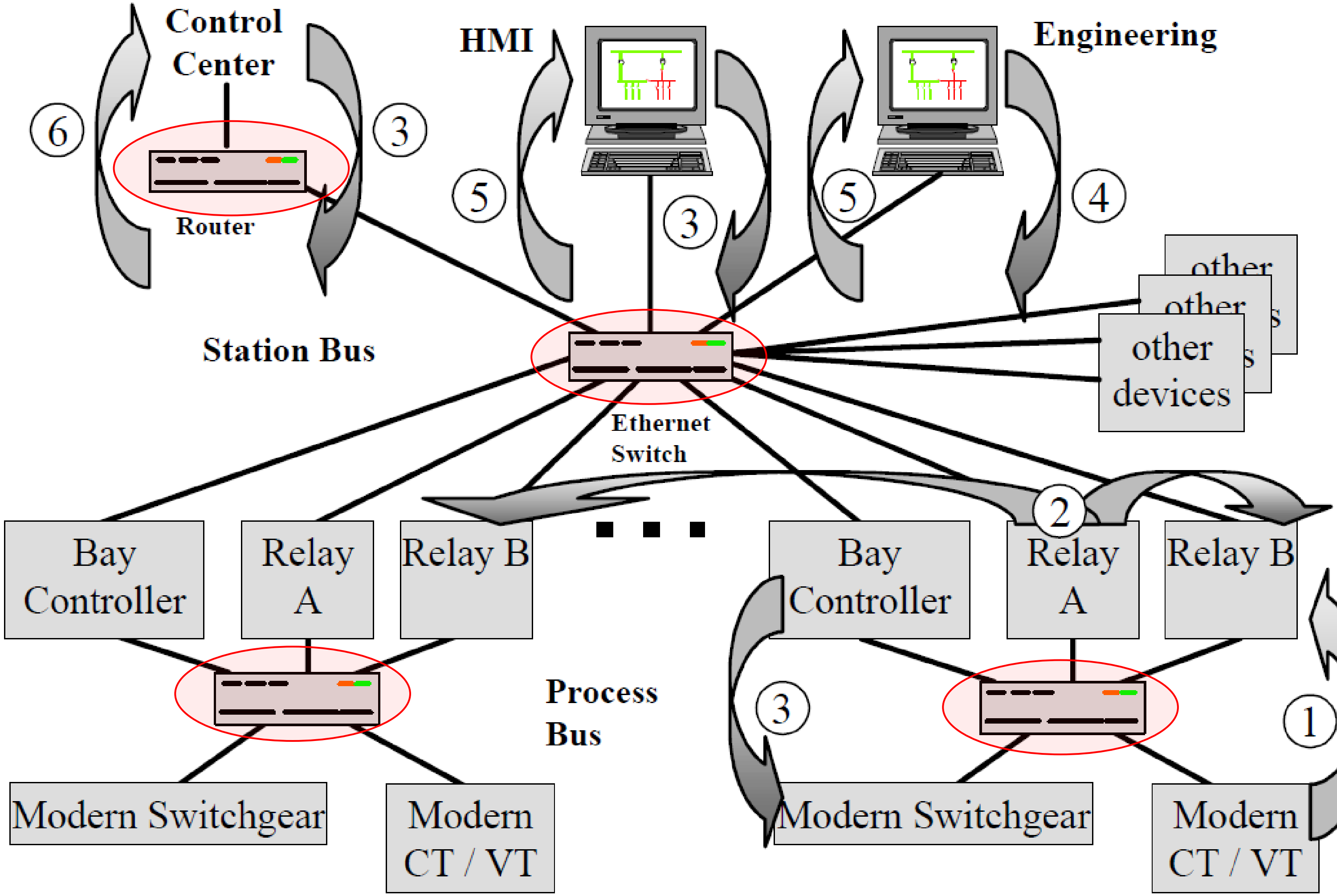
Figure 24.4: Decentralised topology

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

Architectures

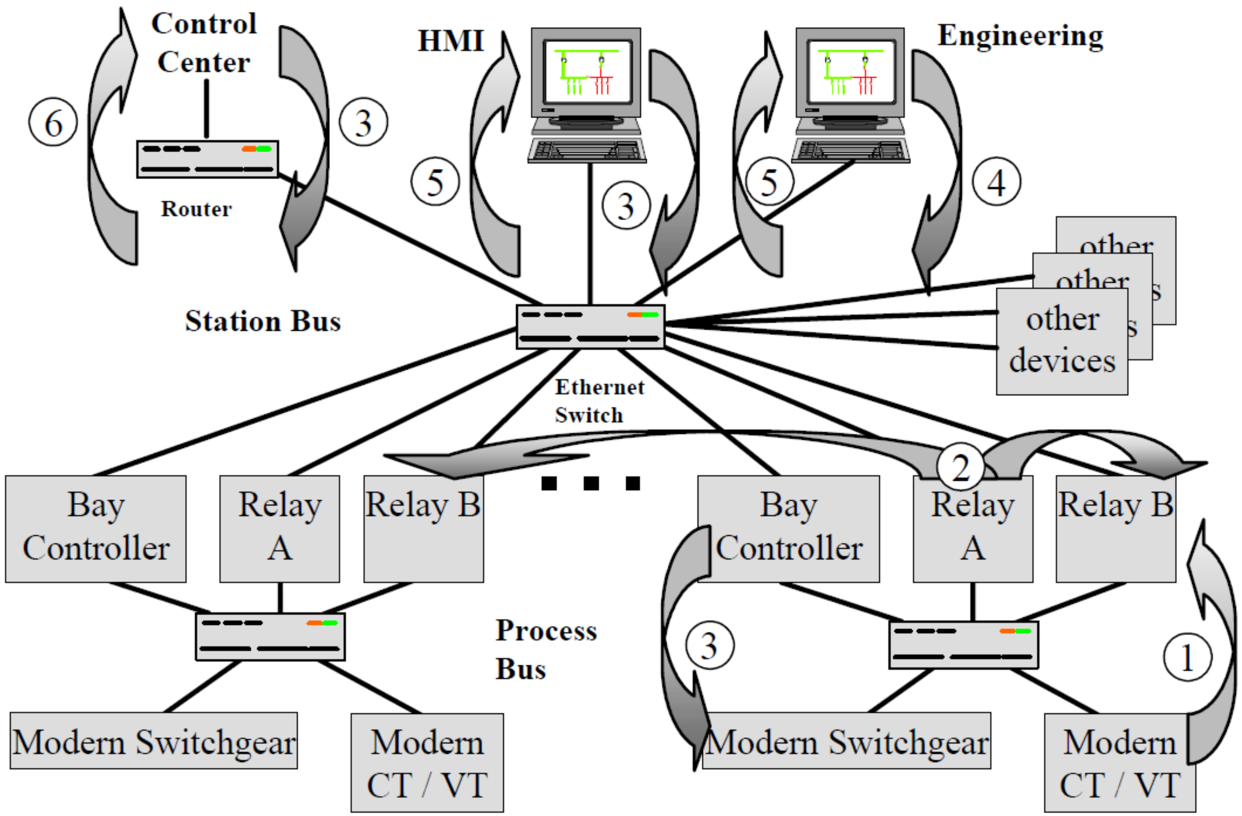


Substation automation

Architectures

Modern substation architecture:

1. Sampled values for current and voltage
2. I/O for protection and control
3. Control signals
4. Engineering and configuration
5. Monitoring and supervision
6. Control Center communication
7. Time synchronization



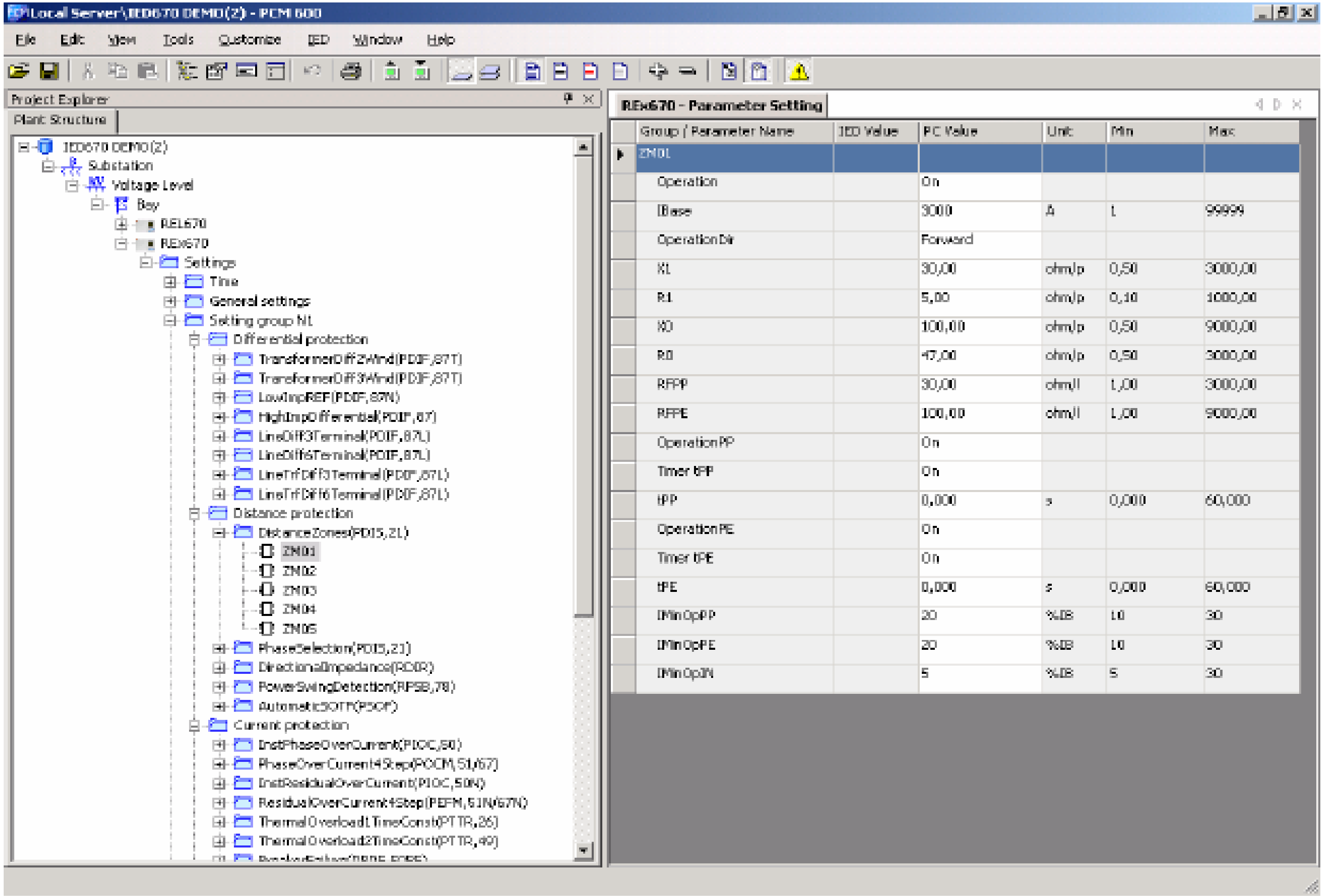
Substation automation

Configuration

- Substation Automation Systems can have several *10s to 100* different programmable devices.
- Managing functionality & data spread over several platforms becomes a challenging task.
- Consider also that systems from separate vendors often are used.
- Cost of a SAS is not driven by hardware but rather by configuration work!!

Substation automation

Configuration



Conclusions

Many questions to try and answer…

- How do we organize/label/handle/process the data and commands?
- How are automation and protection applications implemented in these devices?
- What semantics and protocols do devices like IEDs and RTUs use to communicate?
- What standards are used in industry and how do they work?

Conclusions

- SAS is one of many types of automation systems
- They can be implemented using:
  - Microcontrollers
  - Embedded systems
  - Industrial PCs
- We've looked at some SAS architectures
  - They can vary considerably
- The volume of process data and commands quickly becomes large, this makes management and configuration a complex task

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Some terms and acronyms…

HMI

ADC

IED

LAN

PLC

SAS

OO

PC

TCP/IP

SCADA

Ethernet

PAC

CT/VT

RS232

UTP

RTU

GPS

WAN

RTOS

RAM

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