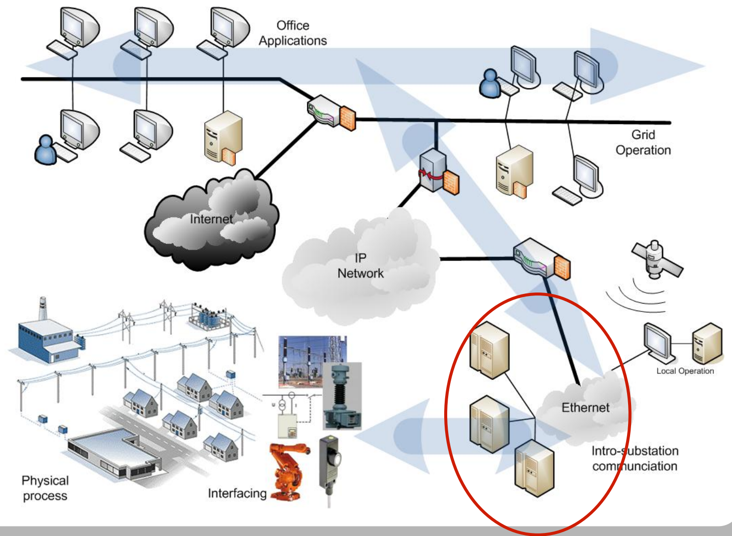
Lecture 5a
Substation Automation Systems

Course map



Contents of the Lecture

- Part 1 – Substation Automation
  - Substation Automation Development
  - Substation Automation Architectures
- Part 2 – IEC 61850 Standard
  - Purpose & Scope of IEC 61850
  - The Information Model in 61850
  - Substation Communication (intro)
  - Device Configuration & Example

Part 1
Substation Automation

Local systems

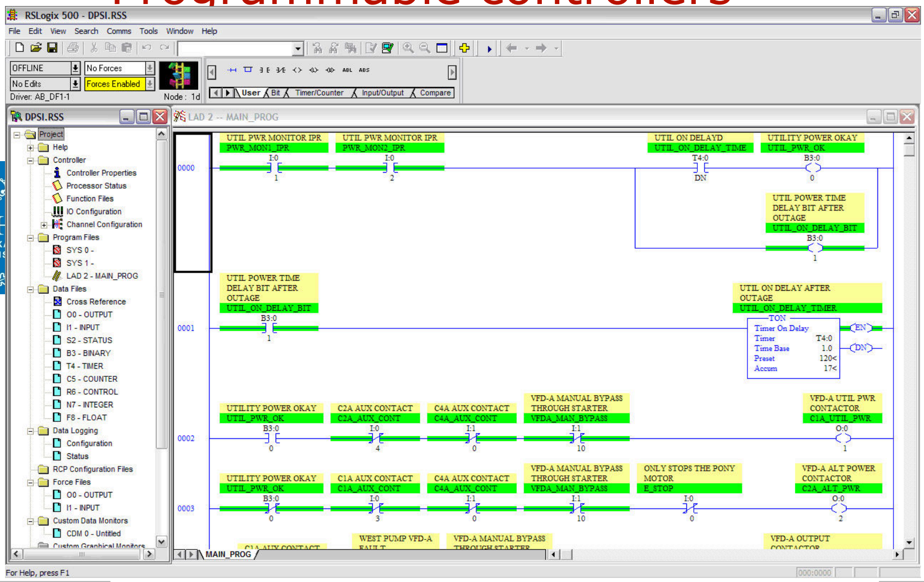
RTU - Remote Terminal Units
PLC – Programmable Logic Controllers
IED – Intelligent Electronic Devices
…

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



Substation automation

Common components

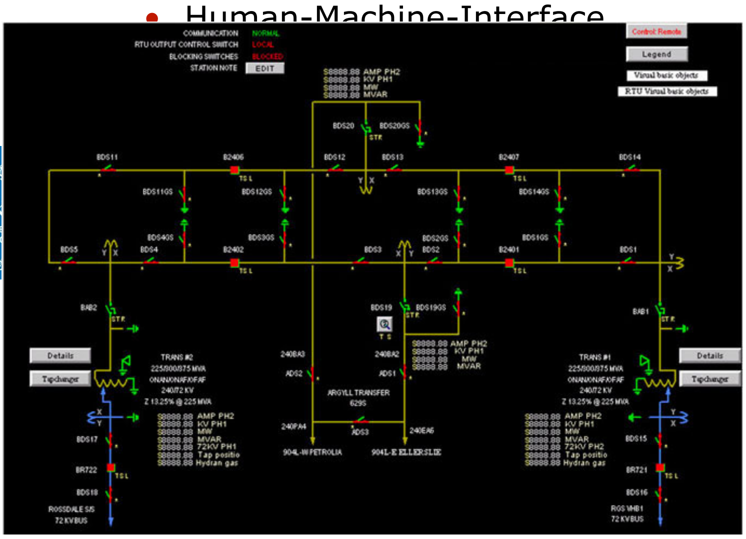
- Remote Terminal Unit (RTU)
  - For telemetry
  - Serial communication using
    - RS232
    - RS485
    - RS422
  - Standard protocols
    - Modbus
    - IEC 60870-5-101/104
    - DNP3
    - ICCP
  - Better suited to wide area telemetry than PLCs

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

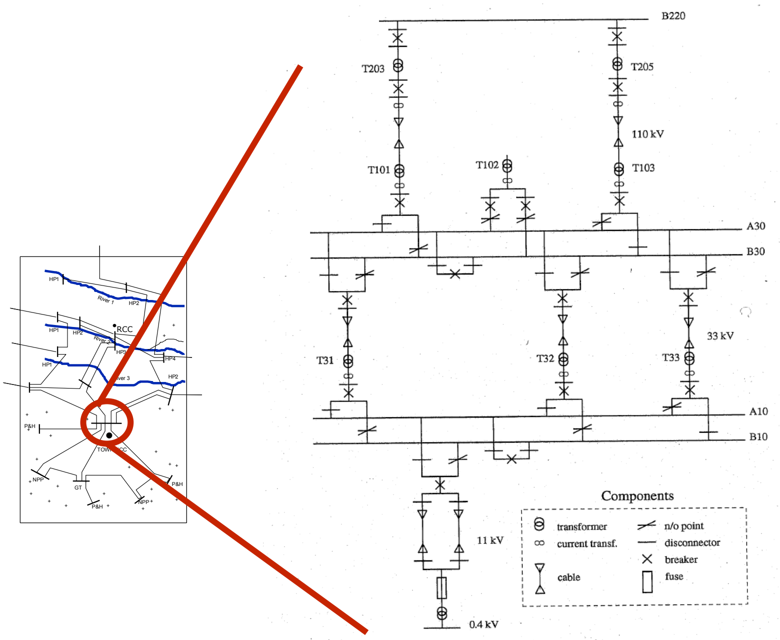
- Human-Machine-Interface

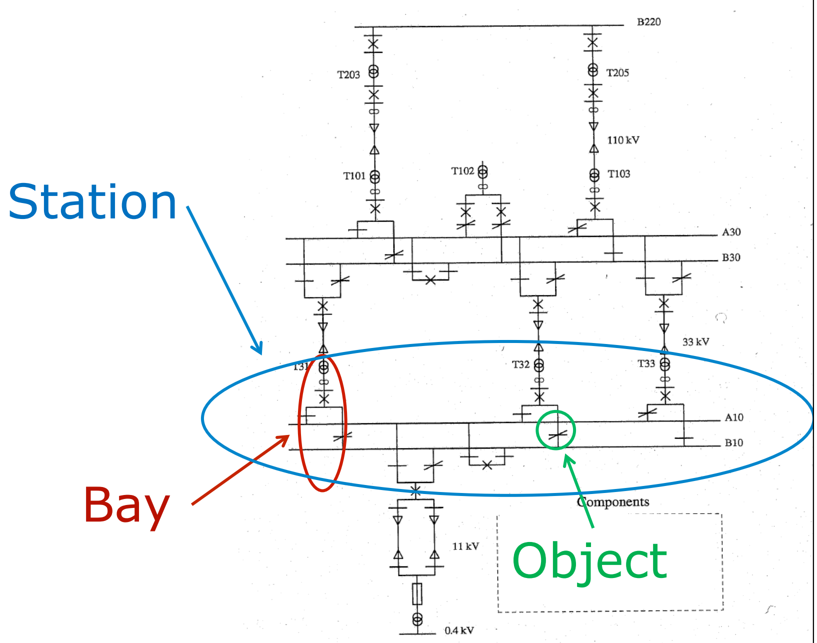


Terminology

- The terminology used for describing devices and Architectures varies significantly across vendors as well as with age and size of a particular substation
- For instance, see the difference between Strauss chapter 1 and NPAG chapter 24.

- Here we will use three different terms:
  - Station Controller, the top level controller in a substation
  - Bay controller, the unit controlling a bay in a substation
  - Relay, at the lowest level controlling a single object
- All of these controllers are implemented in IEDs – Intelligent Electronic Devices





What do 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

- Different areas of automation that can be built into a Substation Automation System

Interlocking

- To ensure that operation of Switchgear is safe and in accordance with standards
- For instance preventing of moving of a disconnector carrying load
- Implemented as functions in a bay Controller that controls the switchgear in the bay.

Switching Sequences

- To ensure that switching operations are performed in a correct sequence, and to automate manaul work
- For example, transfering a feeder from one bar to another. Restoration after a fault
- Implemented in station or bay controller depending on scope of the sequence

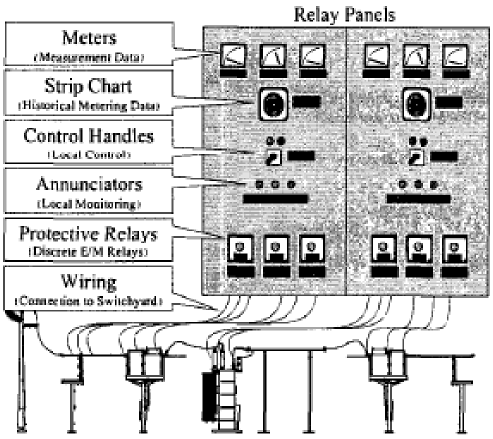
Load Management

- Automation shedding of load, and restoration of load.
- For example as a result of under frequence conditions, feeders are disconnected.
- Implemented at station level control

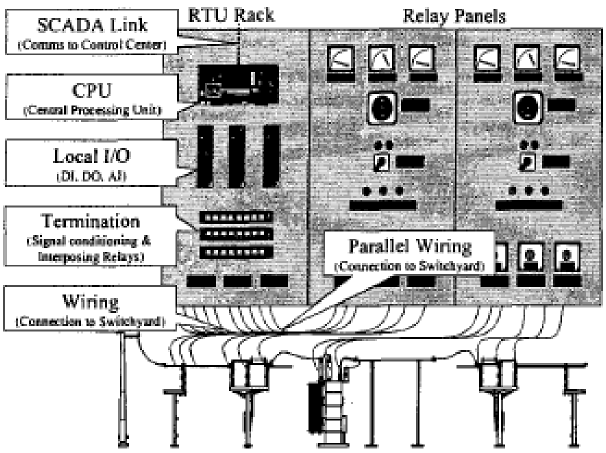
Equipment Status

- Monitoring of Equipment status for maintenance and safety purposes
- Generate Alarms and events in the case of deterioration or faults
- For example, monitoring of SF6 status, transformer temperatures etc.

Historical Substation design

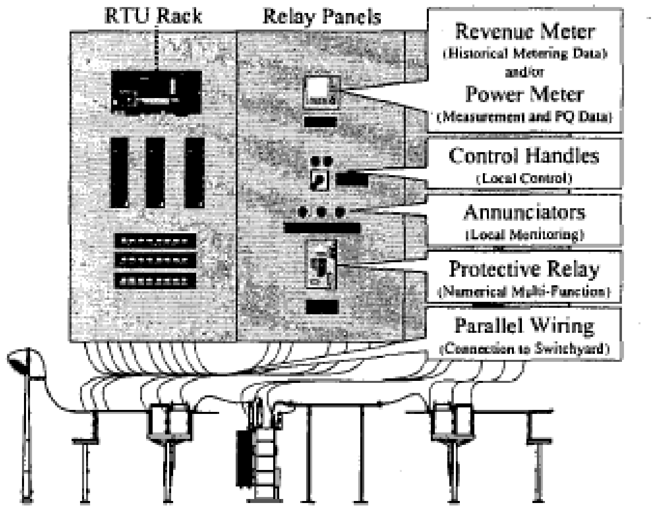


Enter SCADA & RTU

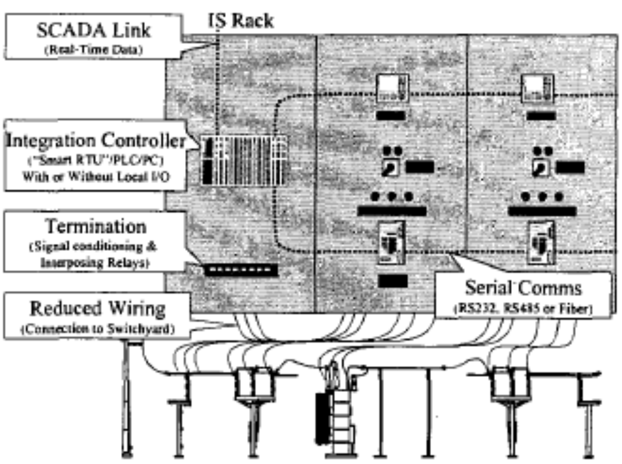


Mathias Ekstedt

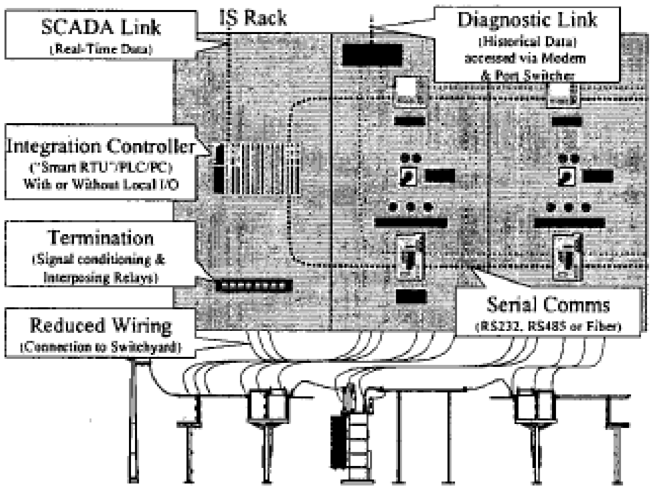
Enter the IED



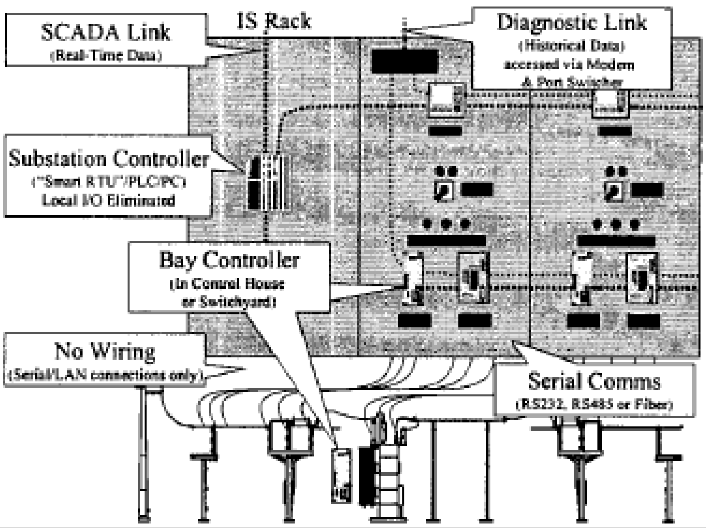
Integrating RTU with IED



Addressing Maintenance needs



The Bay controller concept



Components in a modern SAS

- 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 a industry 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.

Basic SAS Architectures - 1

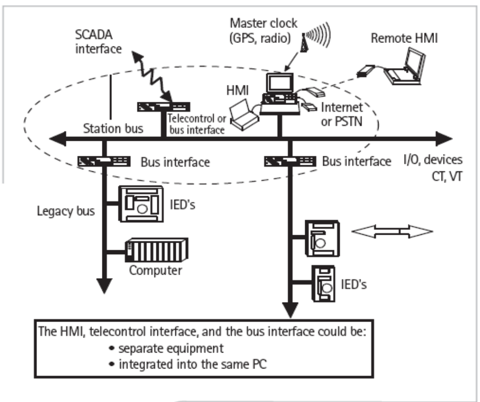


Figure 24.2: HMI-based hardware topology

- **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

Basic SAS Architectures - 2

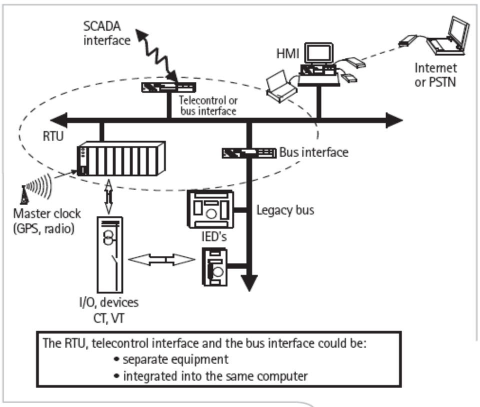


Figure 24.3: RTU-based topology

- 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*

Basic SAS Architectures - 3

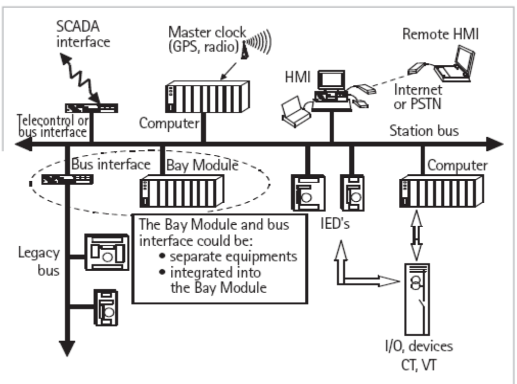
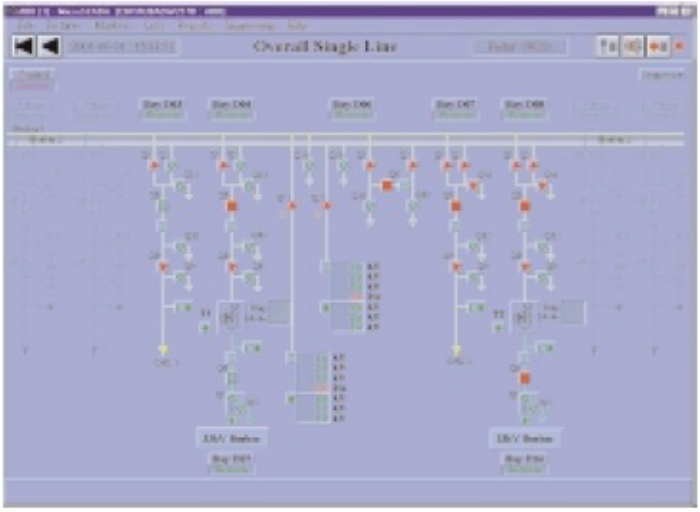


Figure 24.4: Decentralised topology

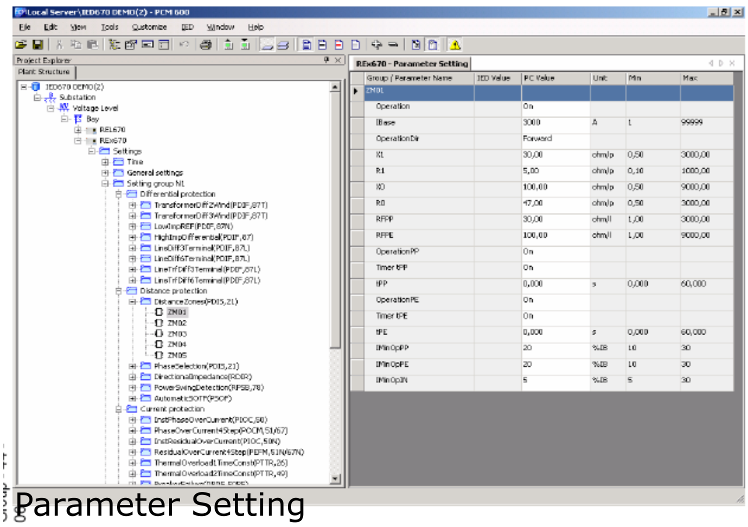
- **Distributed**
- Bay controllers implement interlocking and interface IEDs
- IEDs implement protection and switching
- HMI allows local control and system configuration
- Station controller manages station level control and communicates with SCADA.

Man Machine Interface



Local Control & monitoring

Man Machine Interface



Parameter Setting

System 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 an SAS is not driven by hardware but rather by configuration work!!

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Substation automation

Configuration

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- Consider also that systems from separate vendors often are used.
- Cost of a SAS is not driven by hardware but rather by configuration work!!

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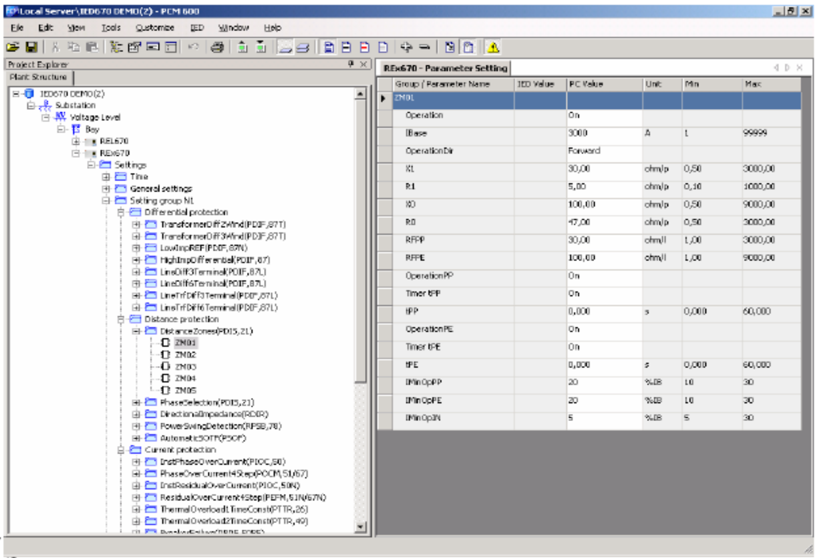
Substation automation



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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?

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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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SAS Discussion

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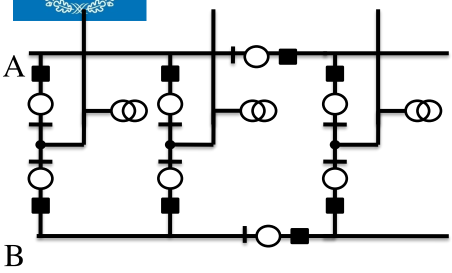
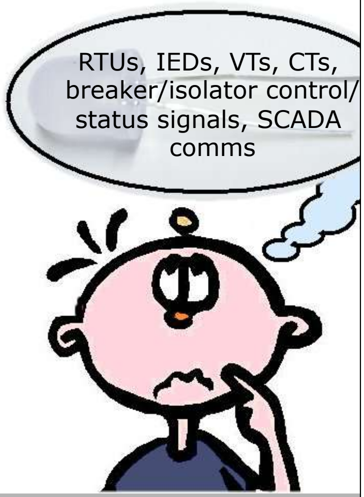
Substation automation

Exercise

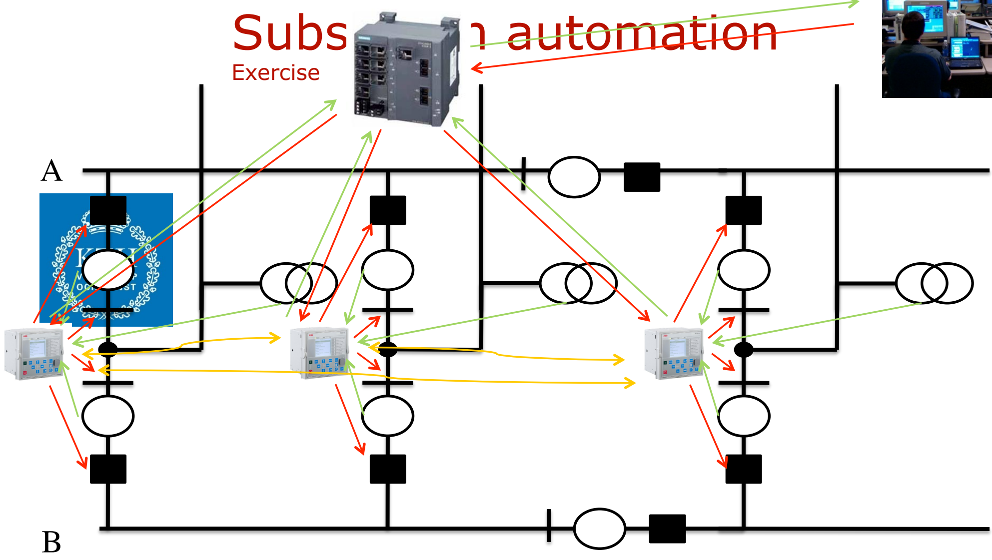
- Given a double breaker station
  - Choose an interesting function to implement eg. interlocking
  - What kind of automation equipme
  - What would need to be communi





Subs n automation

Exercise



End of Part 5a