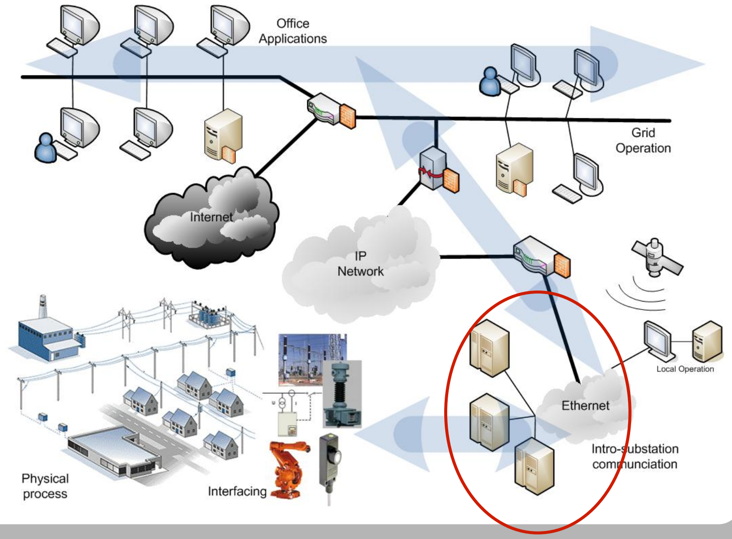
Lecture 5
Substation Automation Systems

Course map

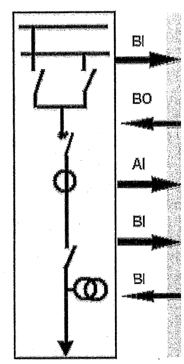


Contents of the Lecture

- Part 1 – Substation Automation
  - Components & Architectures
  - Substation Automation Functions
  - Communication within the Substation (Intro)
- Part 2 – Intro to Helinks

Part 1
Components & Architectures

Process Interface



BI Binary Input
BO Binary Output
AI Analog Input
FI Filter
AD Analog/Digital Converter

Intelligent electronic device (IED) for protection and control

Figure 6-3 Process connection to a typical IED

The interfaces

- Analog Input
  - CT & VT for Current & Voltage measurments
  - Ranges 1-5A, 100-200 V AC
  - Temperature
- Binary Input
  - Breaker status, Normally using two indicators to indicate intermediate status
  - Tap changer positions
- Binary outputs
  - Controlling the operation of circuit breakers/switches
  - Two BO in series for normal switching
  - One single BO for circuit breaker tripping
- Analog outputs

Measurement accuracy

Function/Device	Accuracy	Comments
Instrument transformer: transforms kV to range of +/-200 V	Relative accuracy at nominal value 0.5 %	An accuracy of 0.5 % in average, is normally used for plausibility check of measurands - more details see in chapter 5.
Interposing transformer from 200 V to 10 V	Relative accuracy at nominal value 0.1 %	Acts as barrier against disturbances as well
Filter	Influences frequency range only; no influence on the RMS value.	
A/D converter 16 bit	Conversion inaccuracy can normally be neglected. The inaccuracy depends on the bit range that is used for the measurand range (e.g full 16 bit signed used for needed range => accuracy is 2^{-14} = 0.006 %)	An 8 bit measurand (either for transmission, or from A/D conversion), leads to an accuracy of 2.5 %, a 12 bit measurand (11 bit + sign) to 0.25 %
Scaling	Can be neglected, if the result is a 32 bit floating point (accuracy better than 16 bit integer)	32 bit floating point has a mantissa of 24 bits
Communication oscillation suppression delta	Depending on the delta: to get a sufficient communication load reduction, often around 0.1 % of the measurand normal/nominal value is needed	The inaccuracy of cyclic sending is zero at the moment of sending. If the maximum change rate of the measurand is not known, no accuracy can be estimated in between.

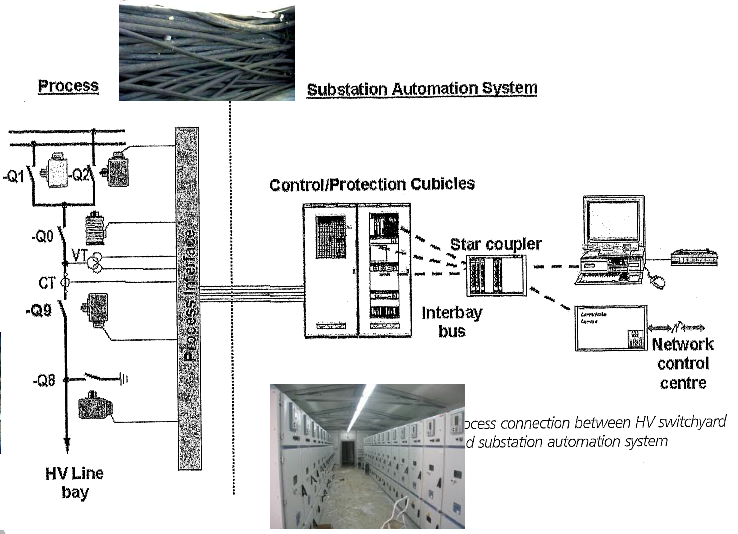
7

Local systems

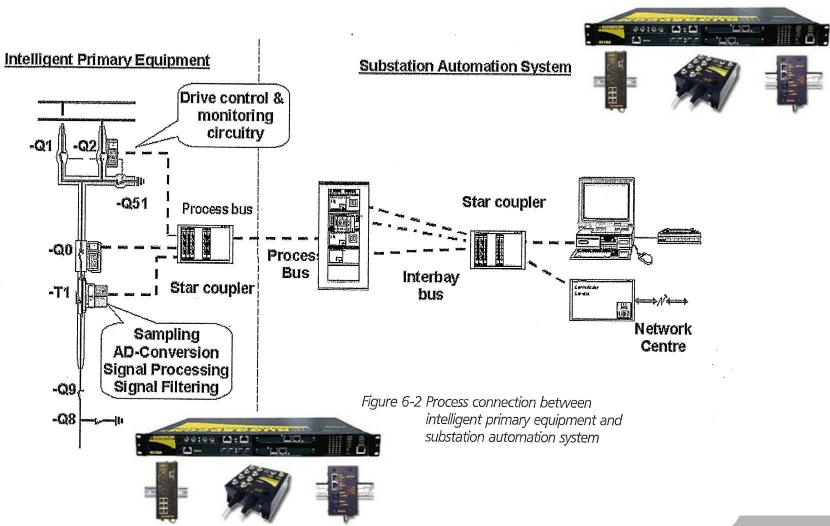
RTU - Remote Terminal Units
PLC – Programmable Logic Controllers
IED – Intelligent Electronic Devices
…

8

Traditional SAS architecture



Architecture with "Intelligent" primary equipment



Local systems

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

Substation automation

Common components

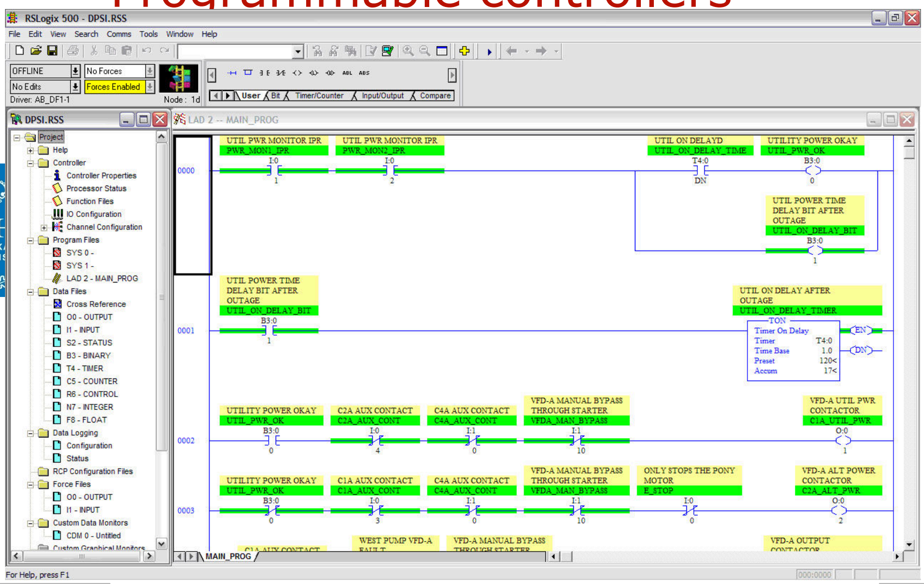
- Intelligent Electronic Device (IED)
  - Digital protective relay with added functionality
  - Can usually interface with RTU
    - Report events and measurement data
    - Receive commands from RTU/SCADA
  - Advanced functions need IEDs to communicate with each other
    - Horizontal communication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

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

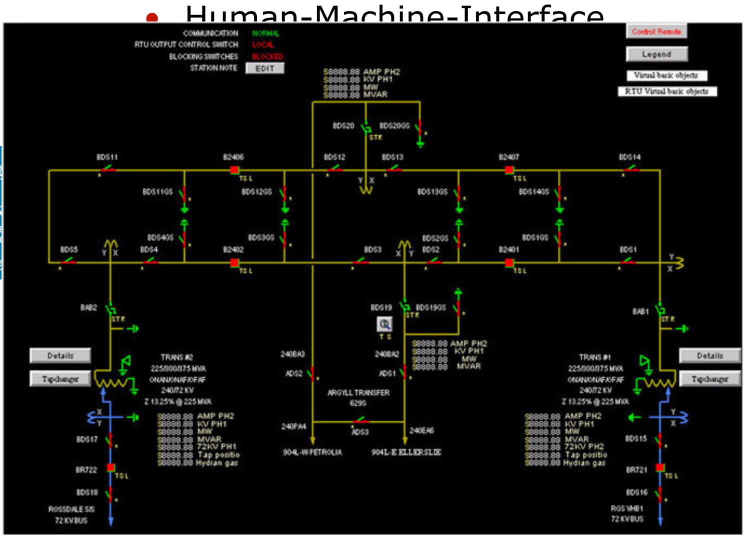
Common components

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

Substation automation

Common components

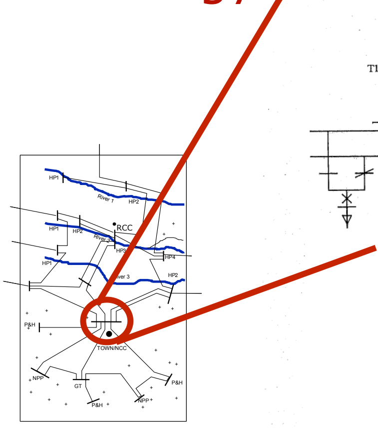
- Human-Machine-Interface

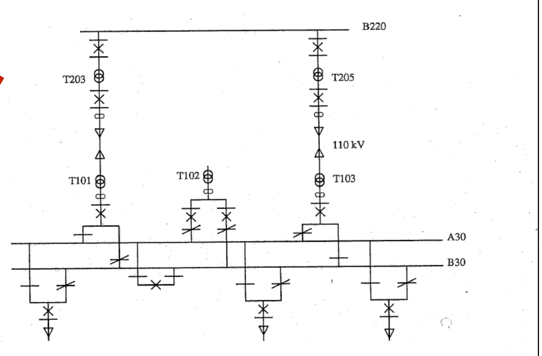


Terminology

- The terminology used for describing devices and Architectures varies significantly across vendors as well as with age and size of a particular substation
- In this course 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
- *Relays and Bay controllers* are implemented in IEDs – Intelligent Electronic Devices
- The station controller is a Industrial PC/server

Terminology



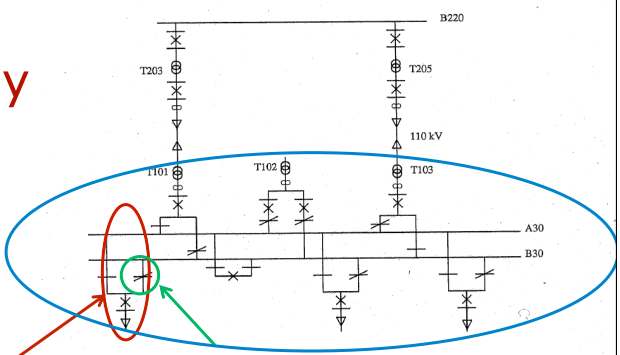


Terminology

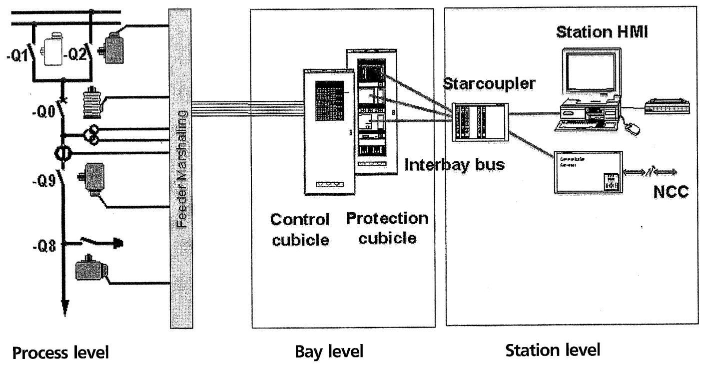
Station

Bay

Object

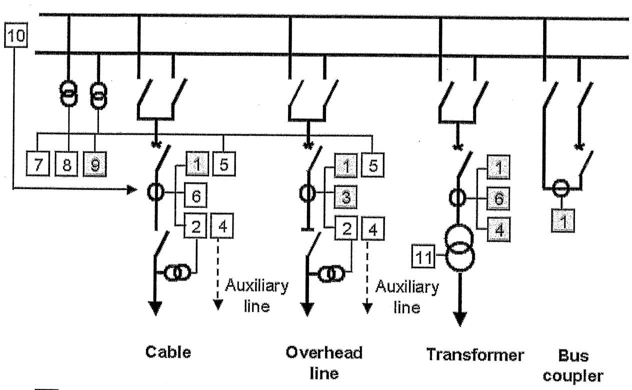


Terminology



Part 1
Substation Automation Functions

Protection!



Recommended basic protection

Optional protection

Figure 6-18 Protection concept for a substation

1. Overcurrent protection
2. Distance protection
3. Autoreclosure relay
4. Differential protection
5. Directional earth fault protection
6. Overload protection
7. Frequency relay
8. Voltage relay
9. Earth fault indication relay
10. Busbar protection system
11. Buchholz protection, thermal monitoring

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.

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See SAS Handbook, 6.3.3.3 & 6.3.4.3

Switching Sequences

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

See SAS Handbook, 6.3.5.1

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

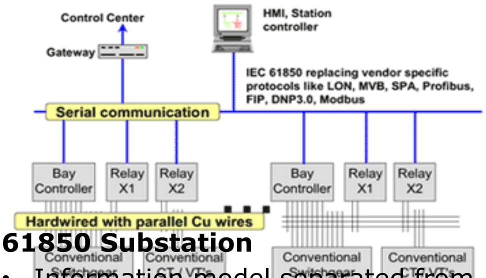
See SAS Handbook, 6.3.5.5

Communication in the Substation (Intro)

What to Communicate?

Data type	Maximum allowed age	Data integrity	Exchange method	Remarks
Alarm	1 s	Medium	Spontaneous	Alarms are urgent process changes that must be brought to the attention of an operator, to perform corrective actions
Commands	1 s	High	Spontaneous	Commands directly act on the process
Process state data	2 s (binary), 5-10 s (measurands)	Medium	Spontaneous	Gives the operator an overview on the process state
Time stamped events	10 s	Low	On request	Sequence of event data is used for later analysis of a problem
Interlocking data	5 ms (fast block)	High (directly influ-ences the process via commands)	Spontaneous	Used to prevent dangerous commands
Interlocking data (state information), other Automatics	100 ms	High (directly influ-ences the process via commands)	On request (upon a command)	Used for Interlocking to prevent dangerous commands; or for automatics like load-shedding
Trip from protection	3 ms	High (directly influ-ences the process via trips)	Spontaneous by fault in the power system or in the switch-gear	Used to clear dangerous situations

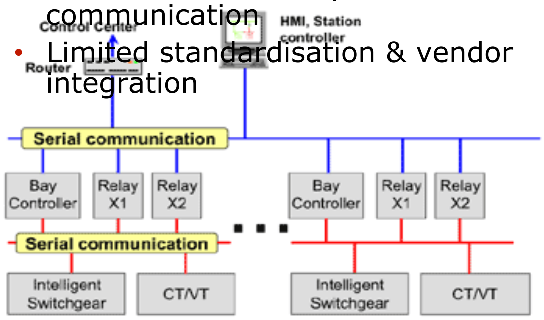
Substation Automation Development



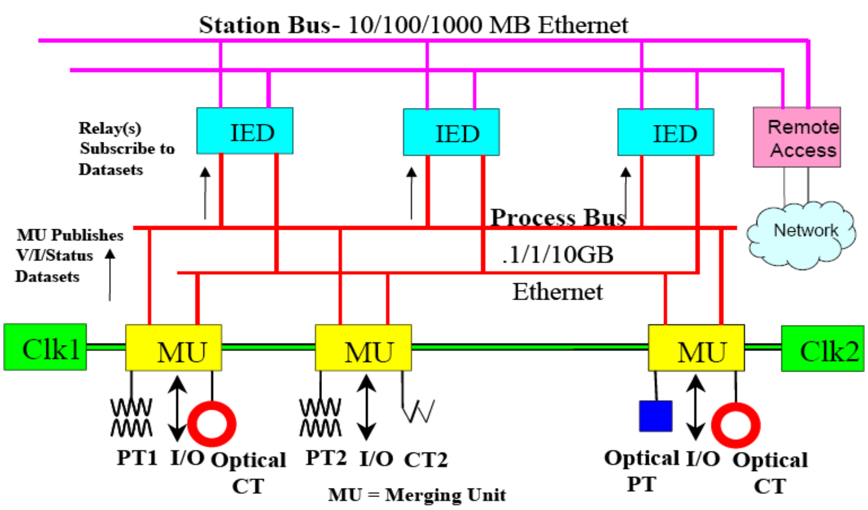
61850 Substation

- Information model separated from protocol implementation
- Improved vendor interoperability
- Point to multipoint Measurement access via sampled values (-9-2)
- "Free" allocation of functions to devices.

- **Traditional Substation**
- Functions tied to physical device
- Measurement connection based on point to point links (Copper wires)
- Some buses for relay communication
- Limited standardisation & vendor integration



Substation Communication Systems



Part 1
System Configuration

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!!

Substation automation

Configuration

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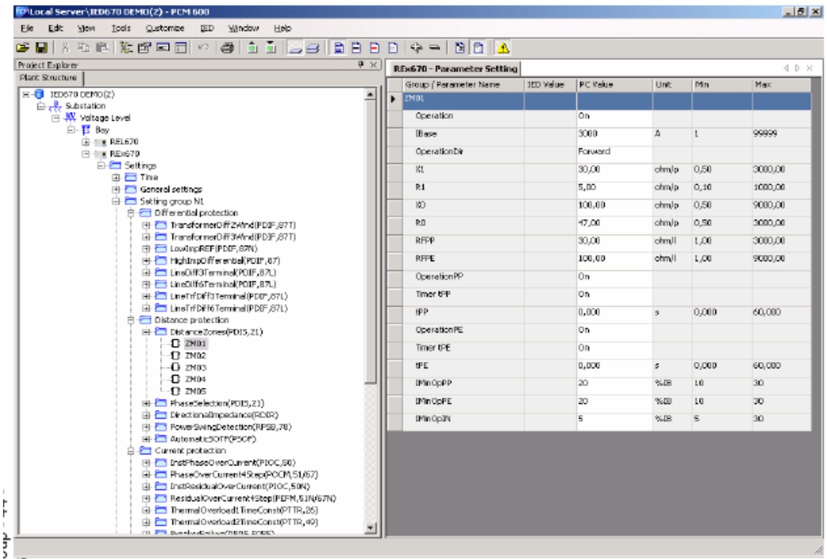
Substation automation



Conclusions

Many questions to try and answer…

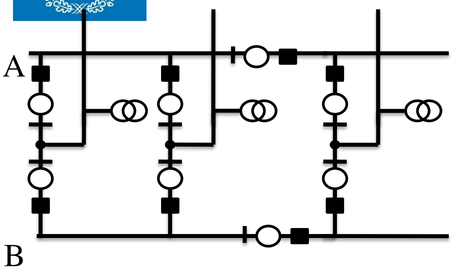
- How do we organize/label/handle/process the data and commands?
- How are automation and protection applications implemented in these devices?
- What semantics and protocols do devices like IEDs and RTUs use to communicate?
- What standards are used in industry and how do they work?

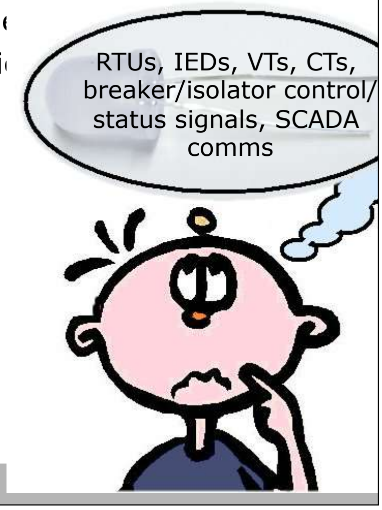
SAS Discussion

Substation automation

Exercise

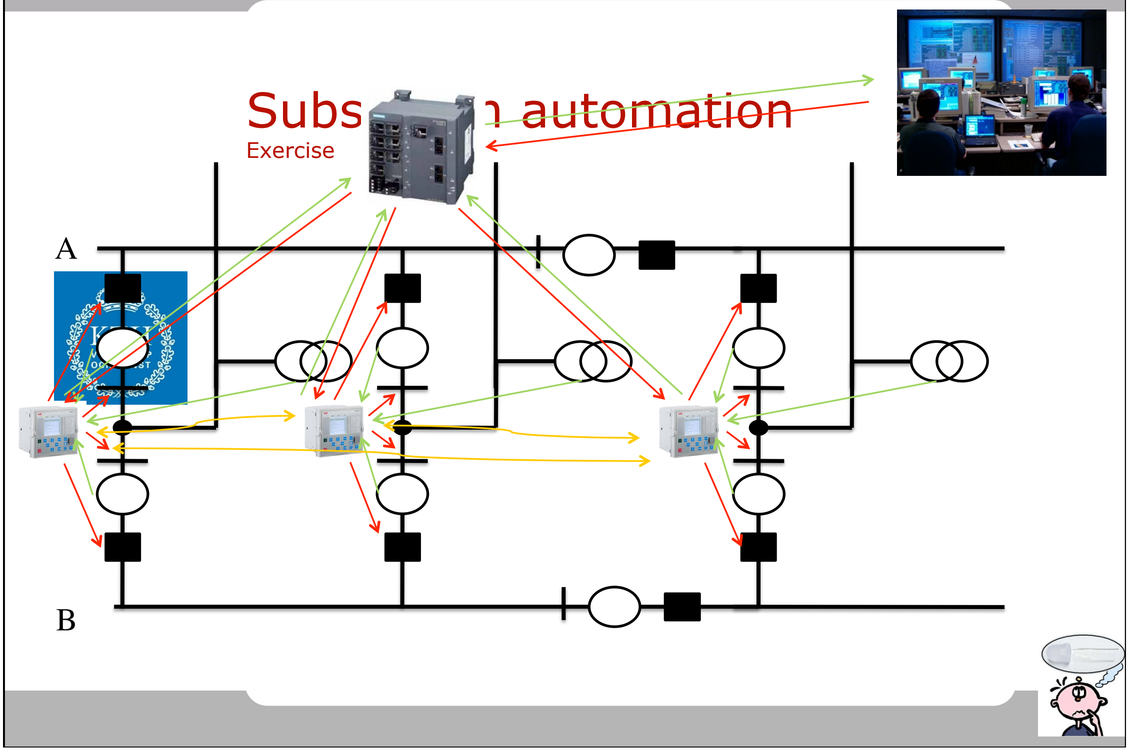
- Given a double breaker station
  - Choose an interesting function to implement eg. interlocking
  - What kind of automation equipm
  - What would need to be communi





Subs n automation

Exercise



Substation automation

Exercise