Substation Automation Systems

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Contents of the series

• Lecture 5
  - Introduction to SAS
  - Nice creative exercise
• Lecture 6
  - A bit about information modelling
  - Data types and structures
  - Information 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...

- SCADA
- PLC
- RTU
- IED
- UTP
- Ethernet
- WAN
- LAN
- SAS
- PC
- OO
- ADC
- HMI
- TCP/IP
- PAC
- CT/VT
- I/O
- RAM
- ROM
- PC
- RS232
- Bus
- WAN
- SAS
- SCADA
Automation systems

- Production line
- Integration of process control
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)
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.
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
- 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?

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<th>Isolators</th>
<th>Contactors</th>
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<td>Alarm processing</td>
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<td>Disturbance analysis</td>
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*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.
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
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?

RTUs, IEDs, VTs, CTs, breaker/isolator control/status signals, SCADA comms
Substation automation
Exercise
Substation automation
Architectures

• Some history...
Substation automation
Architectures

- Some history with SCADA and RTU...
Substation automation
Architectures

• Some history with SCADA and RTU and IED...
Substation automation
Architectures

• Some history with SCADA and RTU with integrated IED...
Substation automation
Architectures

• Addressing maintenance needs
Substation automation Architectures

• Bay Controller
Substation automation
Architectures

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

*Figure 24.2: HMI-based hardware topology*
Substation automation
Architectures

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

*Figure 24.3: RTU-based topology*

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

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.

Figure 24.4: Decentralised topology
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
Some terms and acronyms...

LAN, SAS, SCADA, RS232, WAN, Bus, IED, ADC, PC, Ethernet, CT/VT, RTU, RTOS, ROM, RAM, I/O, PLC, TCP/IP, PAC, HMI, UTP, GPS, RAM, I/O