Traditional NPP electric power systems and modern equipment - sensitivity to net disturbances
The original design and the introduction of modern equipment

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2017-05-04
Outline of presentation

• The historical development plant wise
• Representative single line diagrams
• Battery-backed AC- and DC-power systems
• The original design process
• Introduction of more sophisticated equipment (modern power electronics)
The historical development - Evolution

Oskarshamn 1
440 MW

Forsmark 1
900 MW

Forsmark 2
1050 MW

Oskarshamn 3
1050 MW

BWR 75

TVO 1
900 MW

Barsebäck 1
570 MW

Barsebäck 2
580 MW

TVO 2
660 MW

BWR 90

Oskarshamn 2
660 MW

Ringhals 1
760 MW

Forsmark 3
900 MW

R2
820 MW

R3
915 MW

R4
915 MW

BWR 90+

760 MW
Plant development

ASEA Atom/ABB Atom/Westinghouse
Forsmark 3 – Single line diagram for an one turbine plant

National grid

Westinghouse Non-Proprietary Class 3
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Forsmark 1 – Single line diagram for a two turbine plant
Oskarshamn 1 – Original uninterruptible 380 V AC power system

General requirement
This breaker had to be open unless the diesel-backed system was fed only from the diesel generator

Feeding motor-operated valves
Oskarshamn 1 - Original uninterruptible 220 V AC power system

Undisturbed uninterruptible power supply

Feeding instrumentation
Oskarshamn 1 – Original 110, 48 and 24 V DC power systems
Ringhals 1 – Original power system

- 110 V DC
- 220 V AC
- 440 V DC
- 500 V AC
- 400 V AC
- 220 V AC
- 24, 48, 24 V DC
Oskarshamn 2 - Original power system
Forsmark 1 - Original power system

24, ±24 V DC
48 V DC
110 V DC
440 V DC

500 V AC

220 V AC
380/220 V AC
Oskarshamn 3 - Original power system
The original Supplier (OEM)

- Mother company broad technical competence of plant construction
- The company-group manufactured a lot of equipment and components
- Thus the company-group covered and had experience from building including starting-up whole plants to equipment and components. There were a lot of “know-why” and “know-how” built up within the company-group.
The original Customer

- The original Customer was also a company with a lot of experience within its organization and also responsibilities. For instance “Statens Vattenfallsverk” had the following roles:
  - Purchaser of the reactor plant
  - Purchaser of the turbine plant
  - Responsible for some parts of the plant
  - Purchaser of some big components
  - Building contractor
  - Responsible for plant co-ordination
  - Responsible owner of the national grid
Co-ordination between the Supplier and the Purchaser

• The supplier of the plants was aware of both the conditions in the plant and its surrounding but also what used equipment and components could handle.

• The equipment and components were developed by a manufacturer who was familiar with the unique environmental condition existing in a power plant and the nearness to the main generator, the national grid and the high short circuit power.

• Consequently there was a very competent plant supplier who in a unique way coordinated technical issues with a very competent plant purchaser.
Summary – The original design

• The original configuration of the power systems (single line diagram) is not sensitive to electrical interference
• The connected objects determinate the sensitivity to electrical interference
• The original design was that the connected objects were motors, motor operated valves, electrical heaters, simple electrical rectifiers. These are not very sensitive to electrical interference
Summary – The original design

• A basic requirement was that the uninterruptible power supply systems belonging to different divisions (sub) have to be independent of each other. That means physically separated and functionally isolated. No connection to the external grid was allowed.

• In the case when the back-up power supply (by-pass) from the diesel-backed power system was connected, the diesel-backed power system had to be fed from its own diesel generator only.
Summary, cont.

• Harmonization of standards and protection of systems and components were made through a controlled design process. Much of the result of this work is not documented and therefore resulting in missing requirements when the plants are modified.

• Missing of overall picture leads to mistakes
Summary, cont.

- Uninterrupted AC supply not required in short time perspective
- Analyze internal component protections on system level
- Diversification
Coordination – Electrical meetings

For power and control systems there were three series of meetings between the Supplier and the Purchaser

- **KUL-meetings**
  KUL stands for design of control-room and layout

- **KUR-meetings**
  KUR stands for control equipment

- **HUR-meetings**
  HUR stands for power system equipment
Coordination – Electrical meetings, cont.

- **HUR-meetings**
  HUR stands for power system equipment

- At these meetings all aspects regarding power system equipment was handled

- For instance;
  - The Supplier presented the design basis documents for the power systems.

  - The design of the relay protections and the tripping points were agreed on. This coordination was special applied to relay protections or the national grid, main-, plant and start-up transformers and the main generator(s).

  - At the meetings the power consumption list between the Purchaser and the two Suppliers (Reactor and Turbine) was scrutinized
Introduction of more sophisticated power electronics

More conventional power equipment

More fault begun to occur

Introduction of more sophisticated power electronics

Introduction of more sophisticated power electronics, cont.

• New types of equipment implied that new aspects have to be taken into account in the design and during modification of the uninterruptible power supply systems

• The requirements for this new type of equipment with new properties outside the basic function of the equipment were not stated in any documentation