DER Integration in the Electricity System

Progress in DG System integration and Research in Denmark

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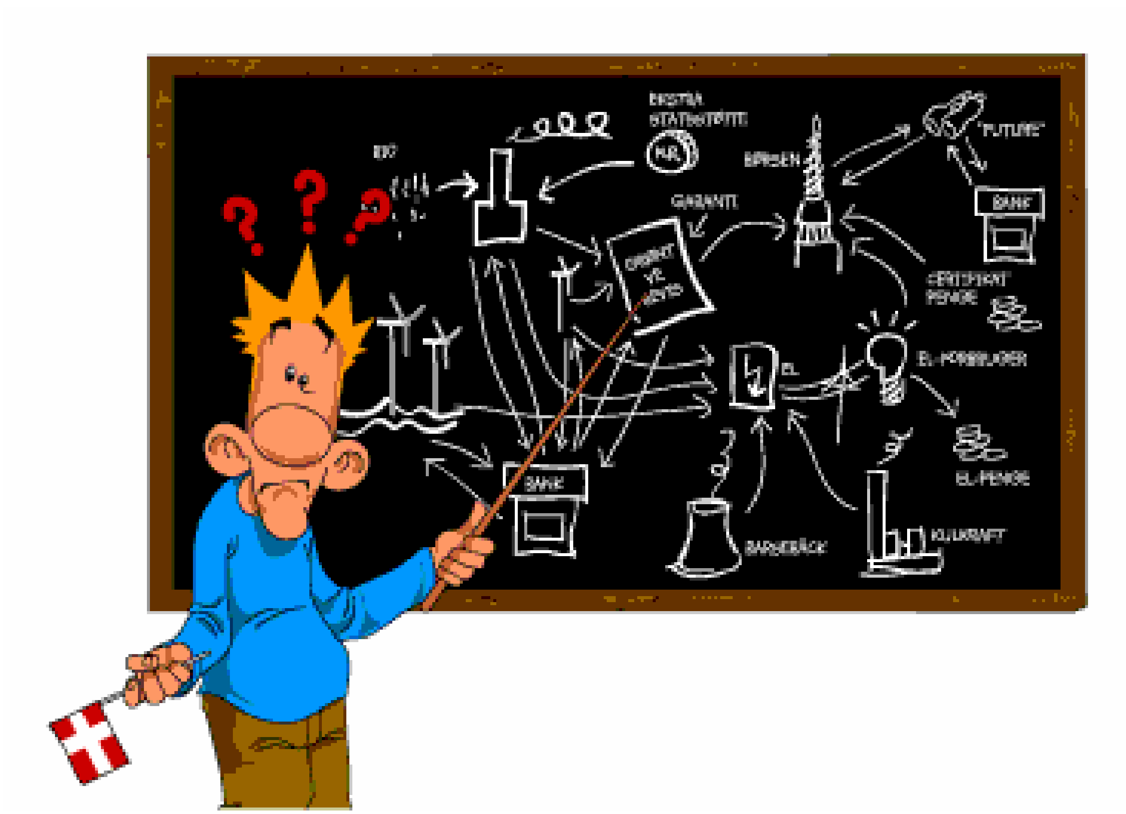
Agenda



- The history
- The system of today
- Trends
- Conclusion
- CET

Historical retrospect

Without el…

What is electricity?

"Electricity is for the modern civilization,

what rain is for the corn on the field,

and mothers milk for the little child"

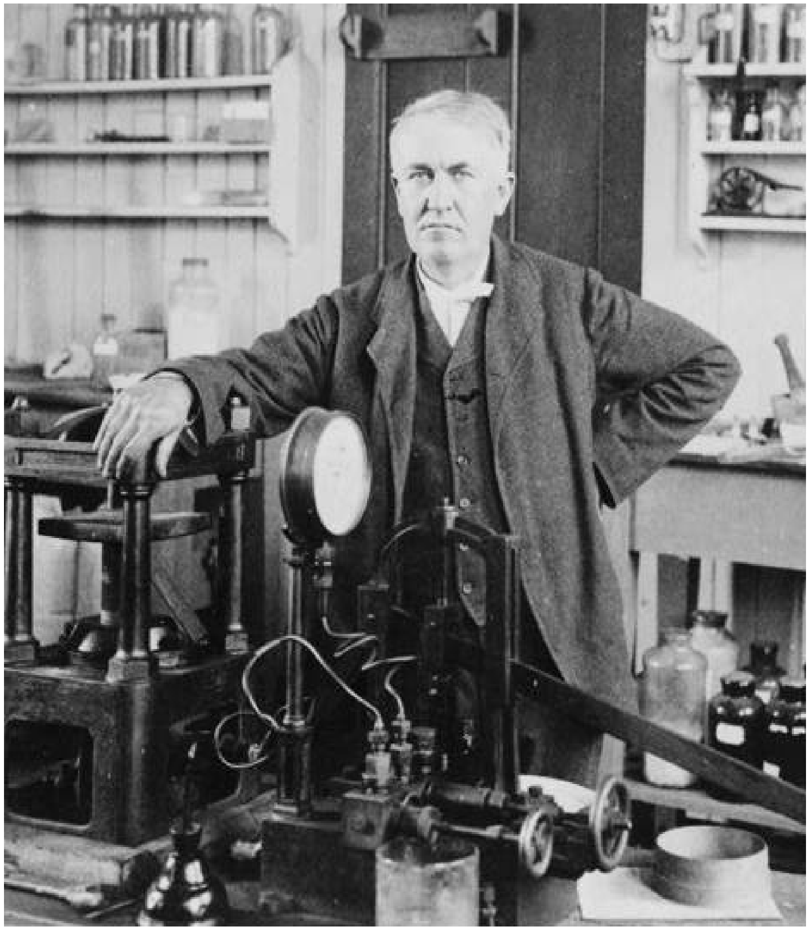
Source: Anders Lund Madsen, Urban, December, 2003

The great discoveries

- 1799 Volta discovers
  the galvanic element
- 1820 Ørsted discovers
  the elektromagnetism
- 1831 Faraday discovers
  the induction

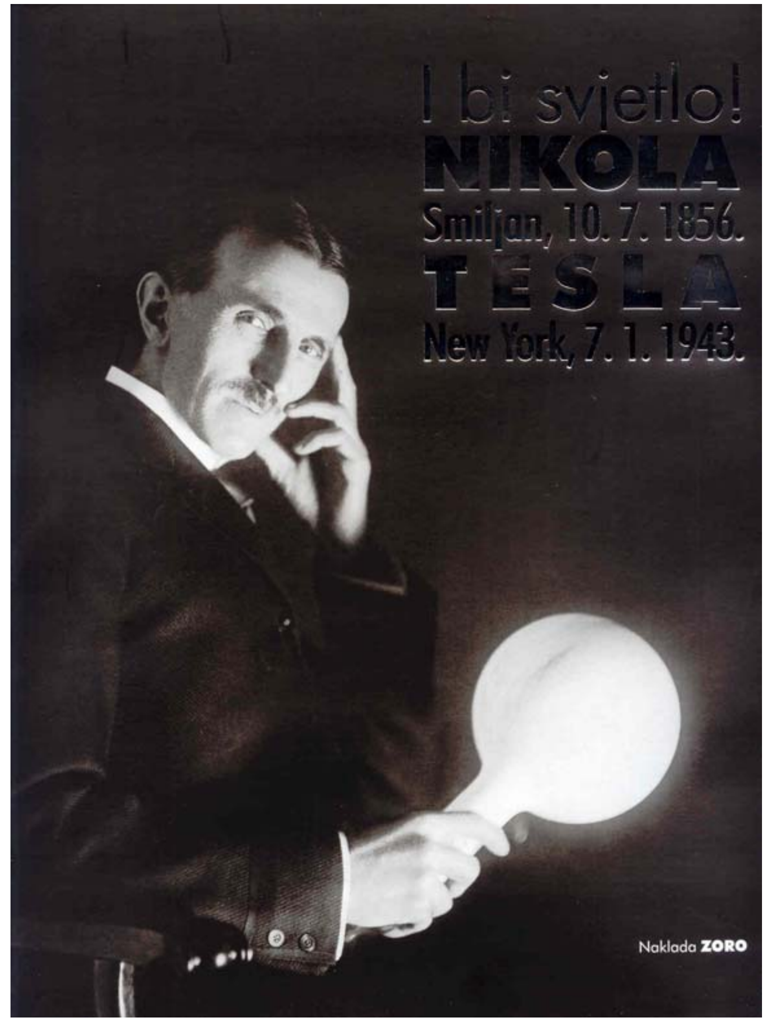
DC and Edison

- 1880: Edison invents the light bulb
- 1882: Edison builds the Pearl Street-station. The worlds first power station to supply of 400 light bulbs at 200 customers.
- The use of 110-220 V DC limits the service area to around 1 km



From DC to AC

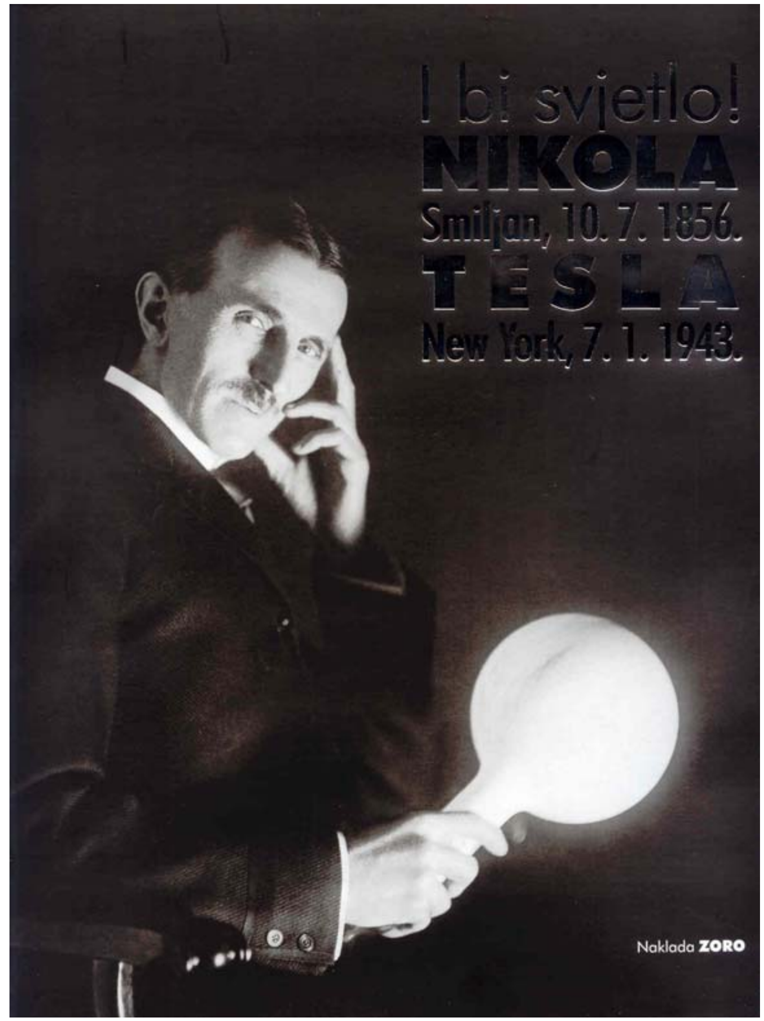
- AC makes it possible to **transform** electricity, and by that it is possible to service customers over long distances.
- **1891** 15 kV 175 km **AC transmission** is demonstrated at a exhibition in Frankfurt (AEG + BCC)
- **Tesla** invents the **AC generator**



From DC to AC

- **Westinghouse** is using Tesla's patents in the project at Niagara Falls **1895**

- Small local power plants is transformed into **a network of big central power plants,** with
  - Better reliability
  - Economy of scale
  - Possibility for planning the production



Do you know him ?

Fred Charles Schweppe

1974 Power Systems in 2000

Power

Power systems '2000': hierarchical control strategies

Multilevel controls and home minis will enable utilities to buy and sell power at 'real time' rates determined by supply and demand

Because more devices for customer generation and storage of energy will be in operation by the year 2000, the customer—residential, commercial, or industrial—will be considered a vital part of the electric power systems of the future. New types of central-station generation, storage, transmission, and distribution will be available, and there will be basic changes in the total energy picture as well.

Control systems adapt to changing technology and public needs. Capital and fuel costs will continue to rise rapidly, which will justify the expenditure of more and more money to improve the economics of power system operation. Other factors that will influence future changes will include the following:

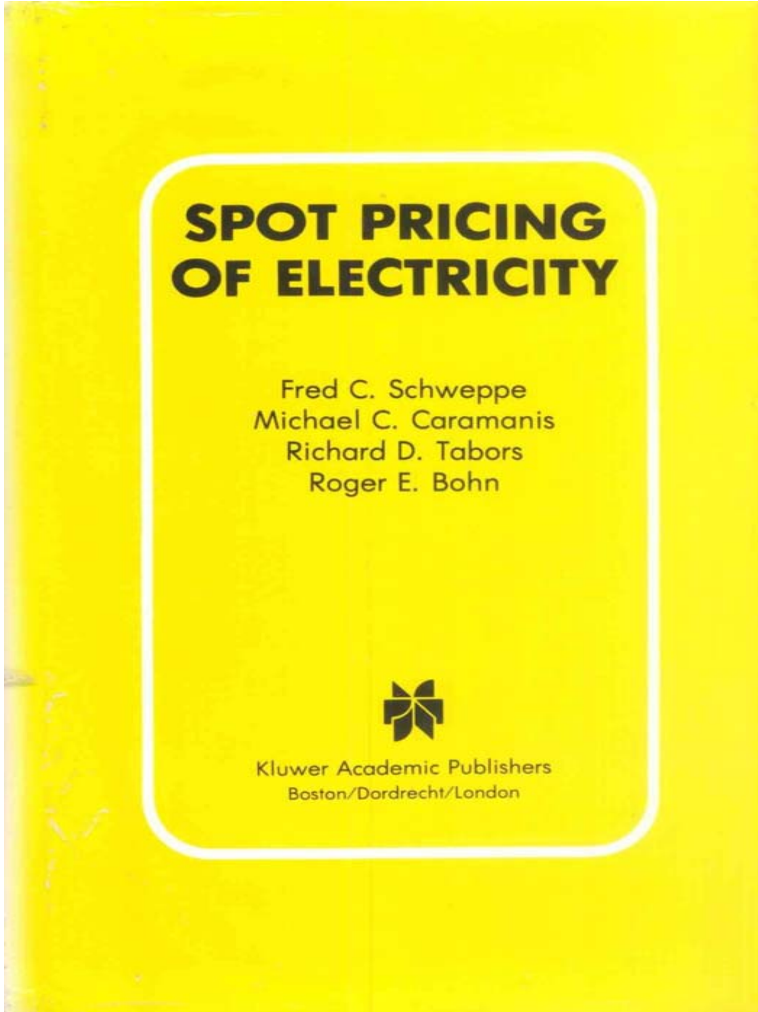
parallels the needs of electric power systems. Future control systems will exploit this technology extensively.

This writer's prediction of the control systems of 2000 is based on the foregoing predictions of influencing factors. The implications are that the future will see more sophisticated control systems involving many sensors and computers, all interconnected via extensive data networks. The need exists, the technology is available, and the dividends from its use will justify the expense.

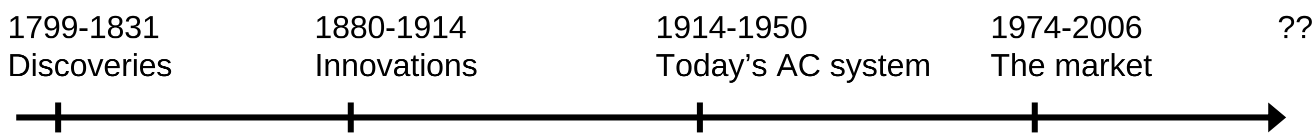
Already an electric power system is the largest physically interconnected system man has invented. The only way to control such a complex network is to break it down into levels defined by the issues of concern (Fig. 1). The elements at Level 0 are the direct-acting devices for

Source: IEEE Spectrum, July, 1974

1988 Spot Pricing of Electricity



What will happen in the future?

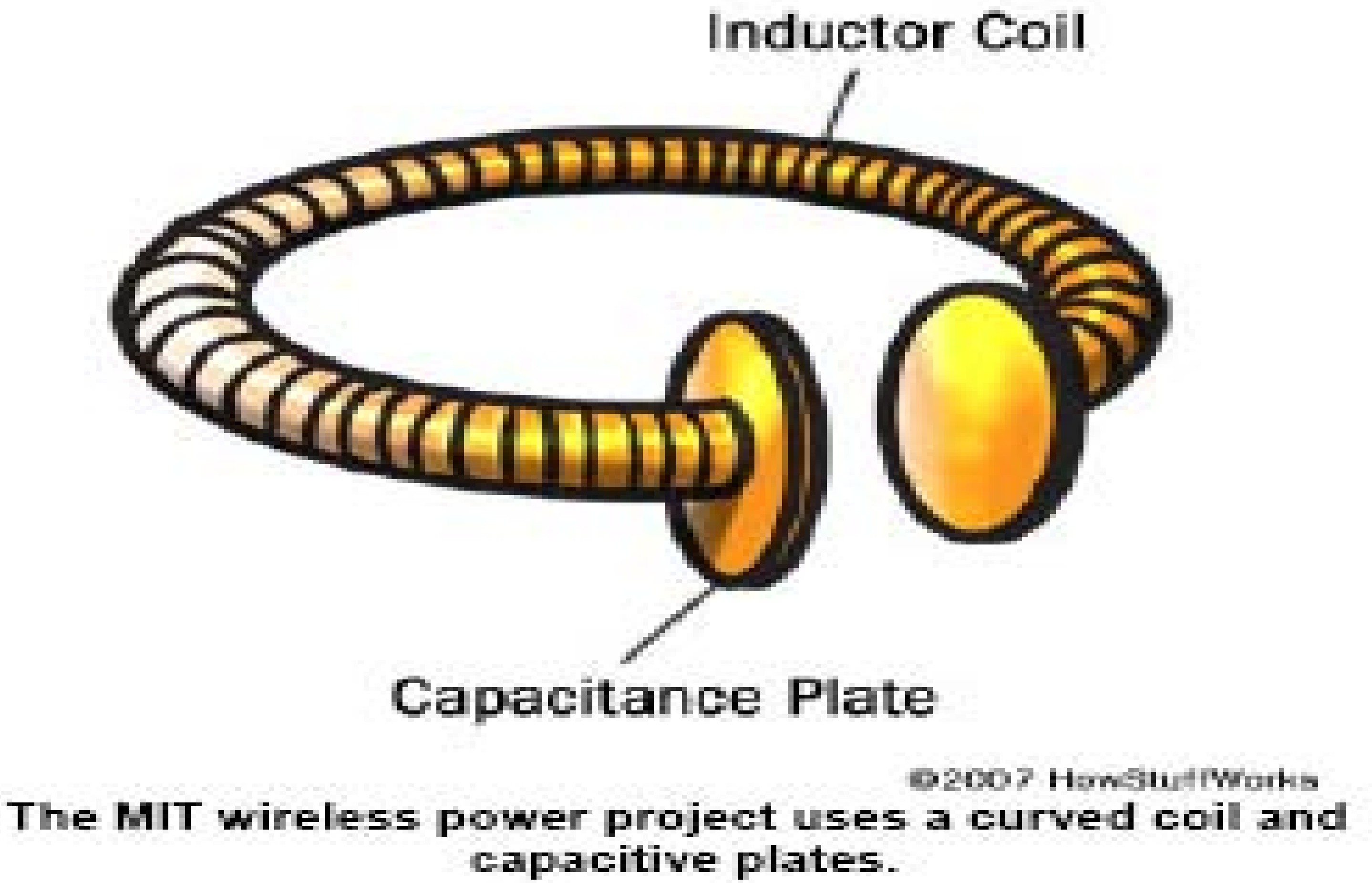


- **Optimize** todays technology **or** will we see a **new technology jump**?

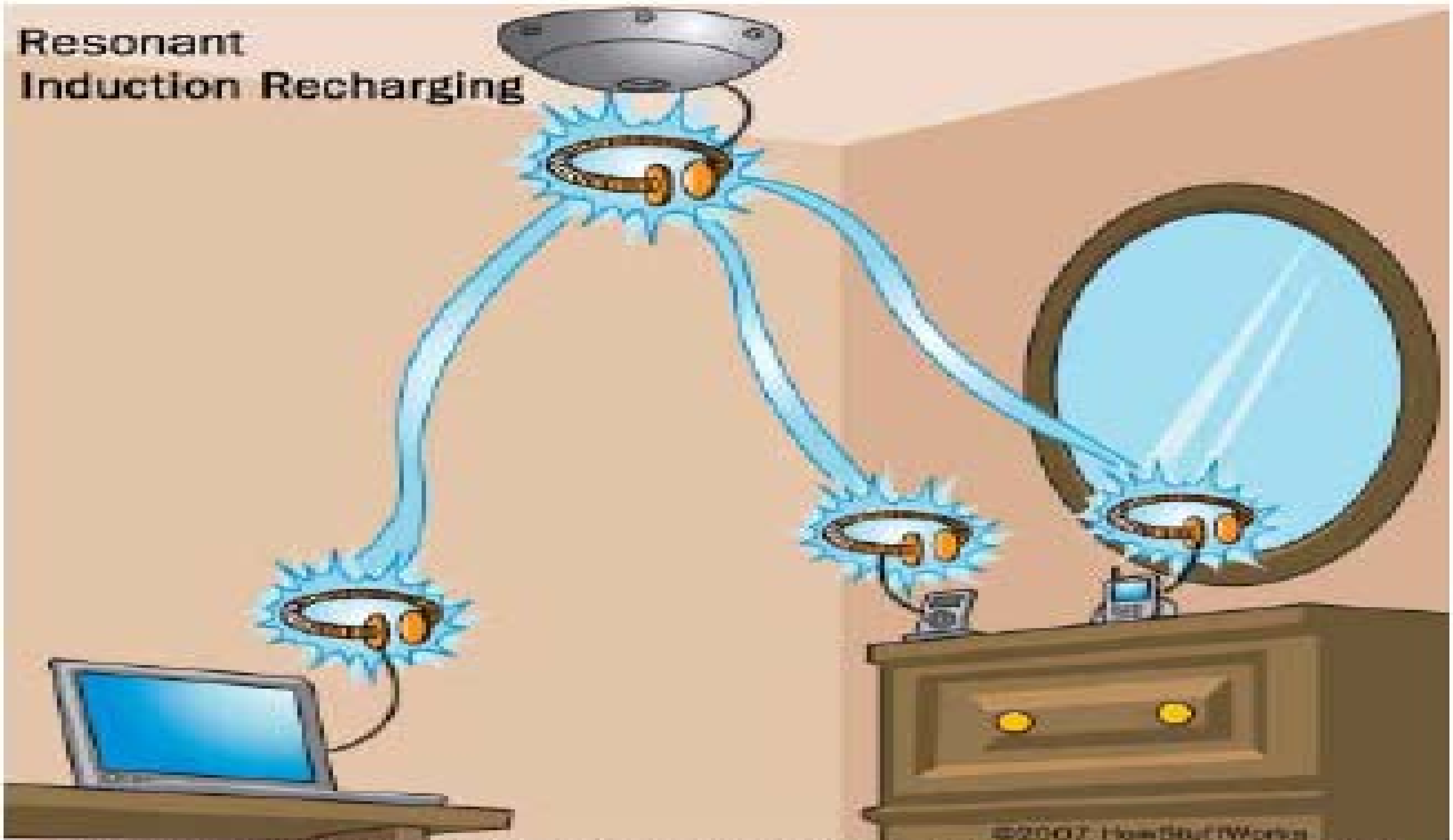
- What could generate such a development?
  - Weaknesses in todays technology?
  - Technology development (better, cheaper or more efficient)
  - Changing the political and economic framework

A trumpet

MIT's "Wireless Power Project"



Wireless Power



According to the theory, one coil can recharge any device that is in range, as long as the coils have the same resonant frequency.

www.TeslaMotors.com

www.Wrigthspeed.com

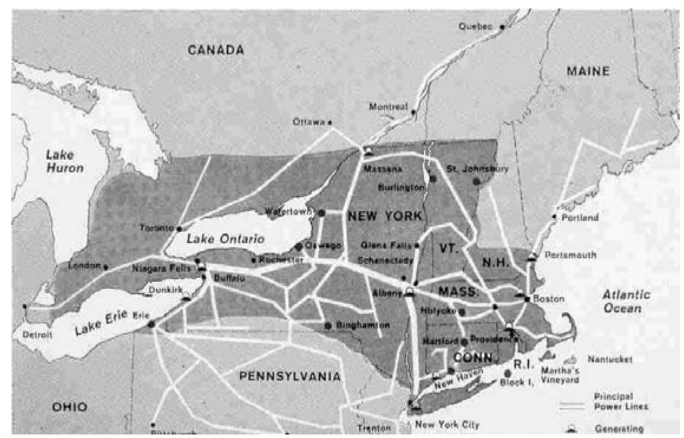
No problems ?

Why be interested in the Power System

– it works (for 100 years)

The great northeast Blackout in USA 1965

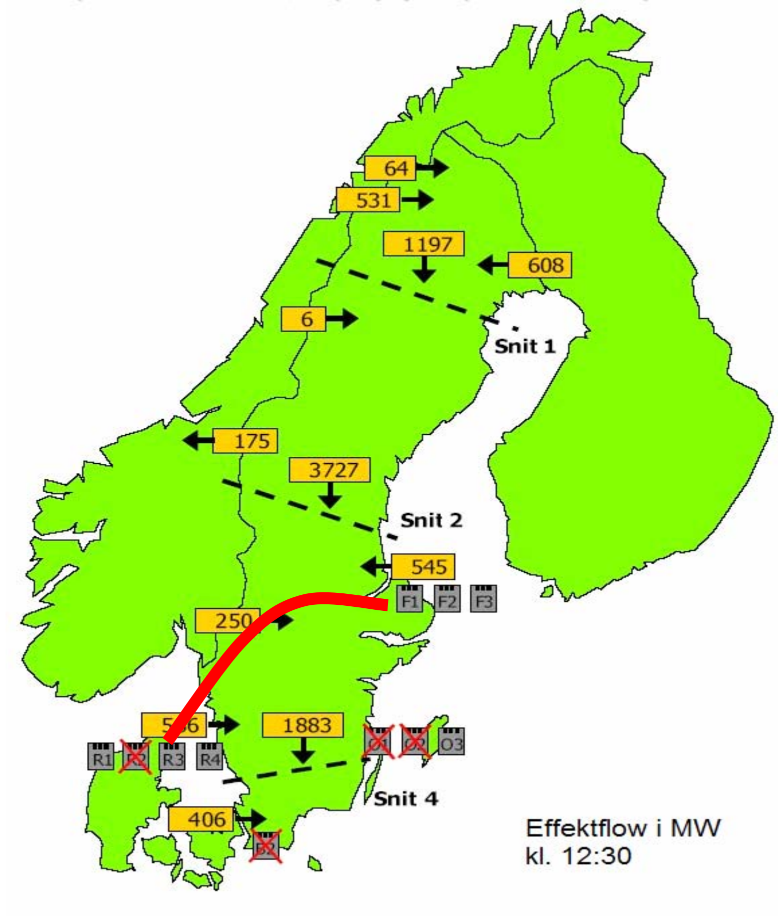
- A fault in a relay causes a line to drop out of service
- Other lines are overloaded and drops out too. The network splits up, and power station become overloaded and unstable. They drops out too.
- 30 million customers without power for up till 12 hours
- This was the first real blackout, and it attracted a lot of public awareness
- NERC is established
    - Central planning
    - Security standards



Source: "Prevention of power failures", U.S. Federal Power Commission, July 1967

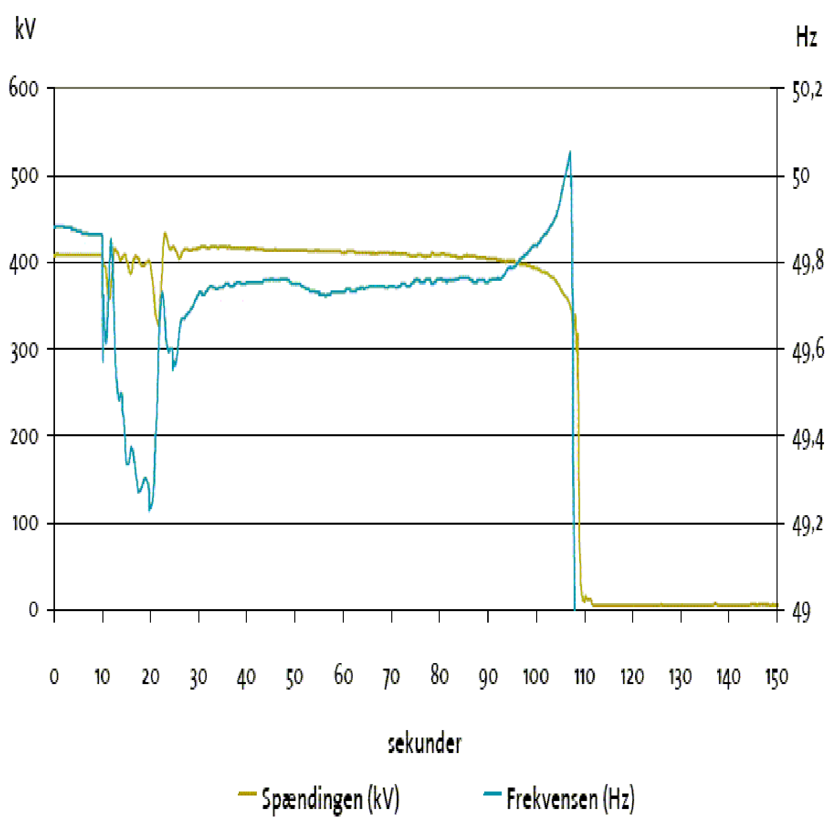
Blackout in Denmark, 23. september 2003

- A broken component in Sweden caused a cascade of outages and a voltage collaps
- All ”formalia” was in order
- The reserves in the southern part of Sweden was small



Sourfce: Svenska Kraftnät, ”Elavbrottet 23 september 2003 – händelser och åtgärder”, 2003

5 mill. Customers disconnected



Source: Elkraft, "Strømafbrydelse i Østdanmark og Sydsverige 23. september 2003 Endelig hændelsesrapport", november 2003

Why do Blackouts occur?

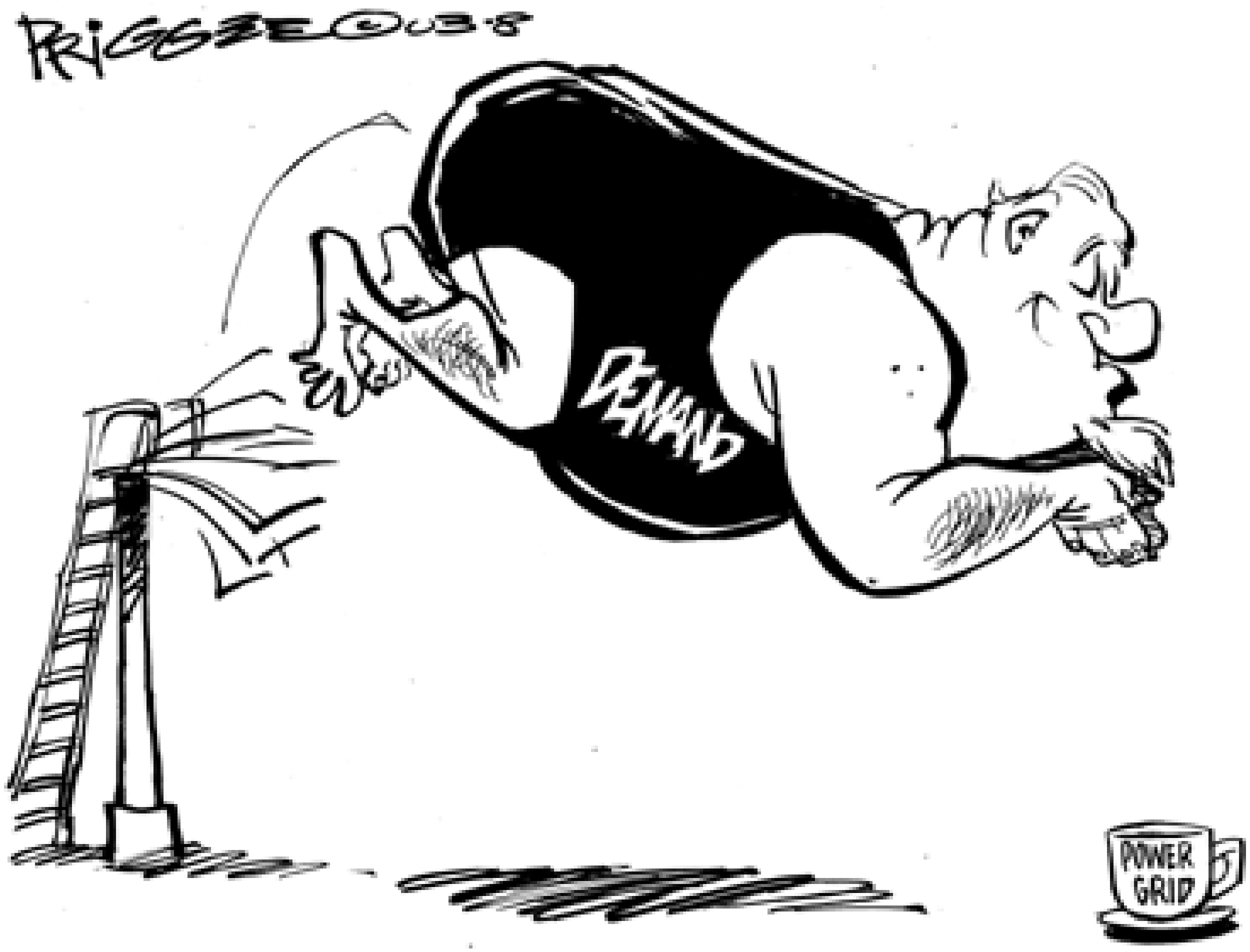
- A little error in the system makes it collaps

- After the the Blackout in 1965 the security standards (we use today) was formulated
  - Common resources in a meshed network
  - Components with faults should be removed quickly (~100ms)
  - Robustness (N-1 security)
  - Central control

- Why do Blackouts still?
  - Compelxity

- Others reasons
  - The ressources do not match the demand
  - The security strategies used

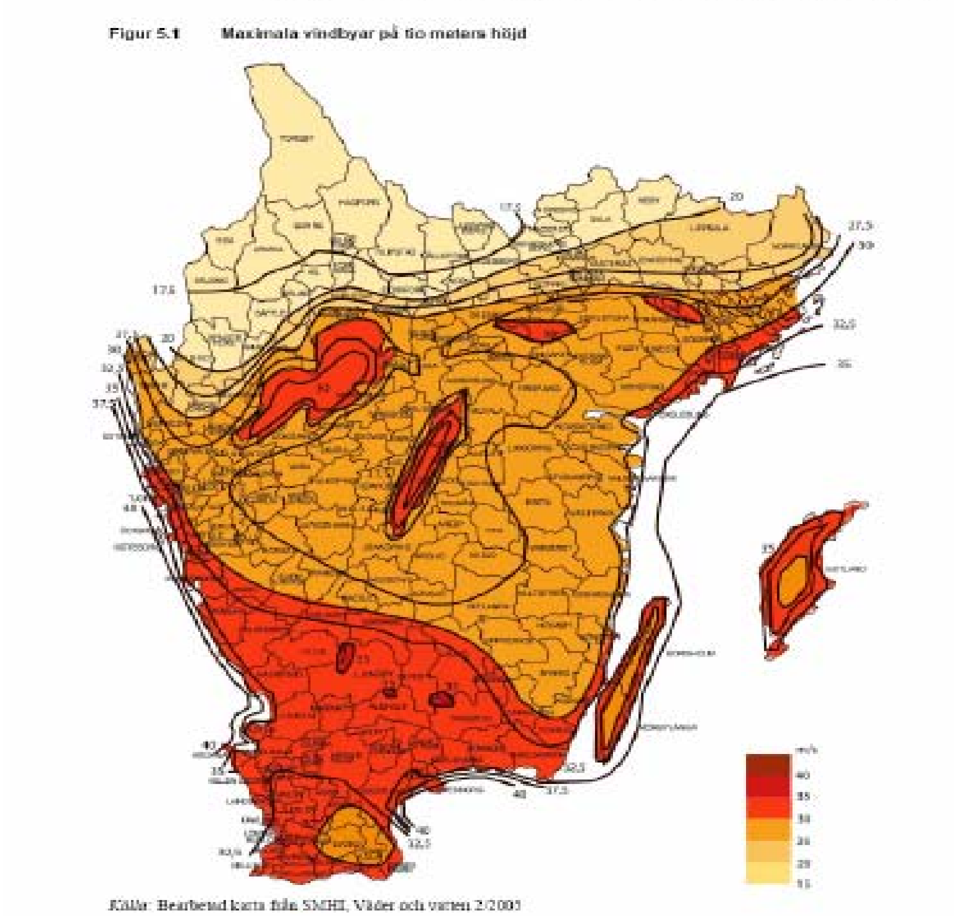
If resources and demand do not fit



The development in Sweden - Gudrun

The development in Sweden

Stormen Gudrun 2005-01-08



- Elavbrottets varaktighet: över 1 månad

The Blackout duration > 1 month

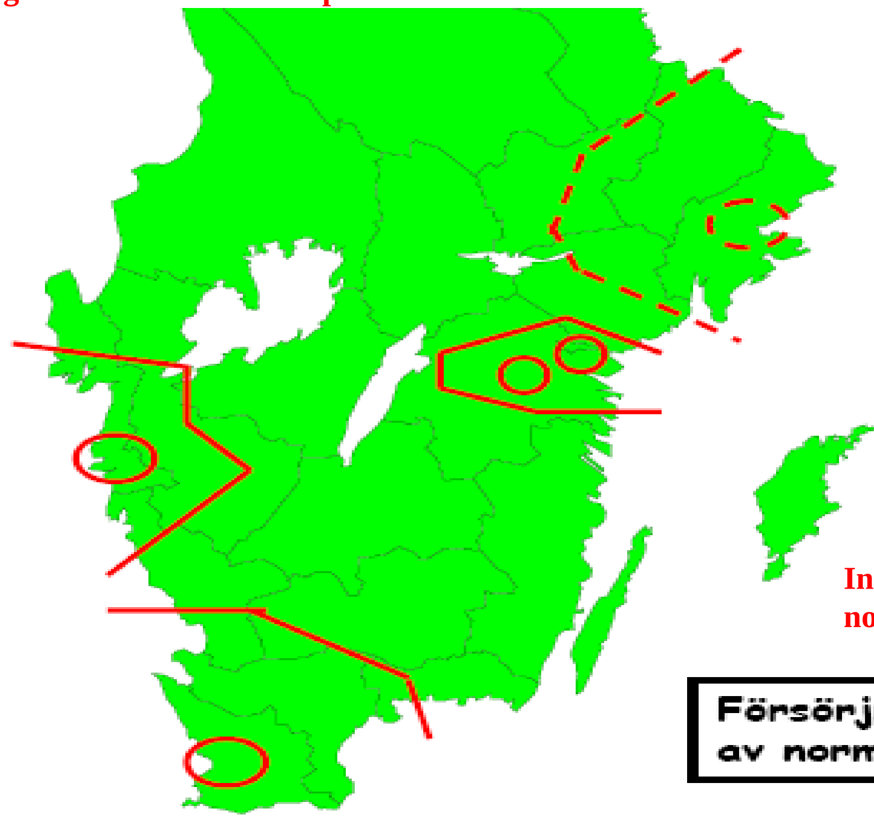
- Omfattning: 600 000 elkunder

Number of customers 600.000

The development in Sweden

Ödriftområden i södra Sverige

Islanding areas in the southern part of Sweden



In these areas only 25-50% of the normal load will be serviced

Försörjningsgrad 25-50% av normal förbrukning.

The development in Sweden

Svenska Kraftnäts målsättningen med ödrift

Genom försörjning av elsystemets lokalkraftanläggningar, vidmakthålls möjligheten till kommunikation och fjärr-manöver av stationerna
samt genom prioriterad försörjning i lokalnätet upprätthålls elförsörjningen samhällsviktiga funktioner.

Sammankoppling till ett nät med stor svängmassa ger större tålighet mot störningar och därför bättre förut-sättning till lyckad ödrift.

The development in Sweden

Svenska Kraftsnäts goal with the concept of islanding

By securing the power to the local power system devices, the ability to communicate and control the substations is secured.

Through prioritized supply in the local network, the continous supply is secured to loads who are important for a good function of the society.

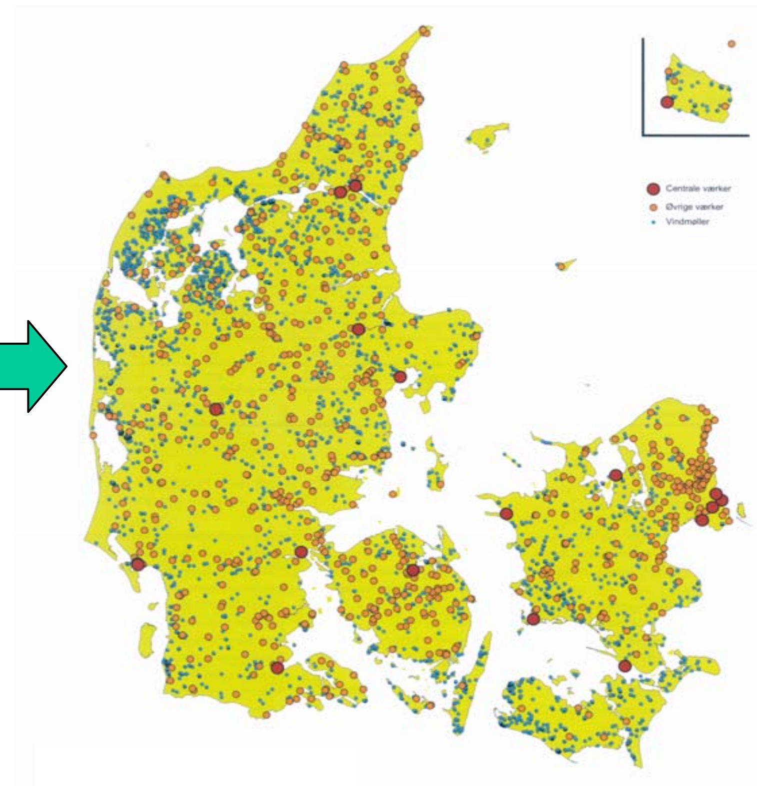
The connection of many power system devices into one network creates a big rotational energy and robustnes against disturbances and therefore a better chance for a succesfull islanding

The development in Denmark

<u>Central production</u>

16 central power plants

<u>Distributed production</u>



16 central + 1000 CHP + 6000 WT

Source: www.ens.dk

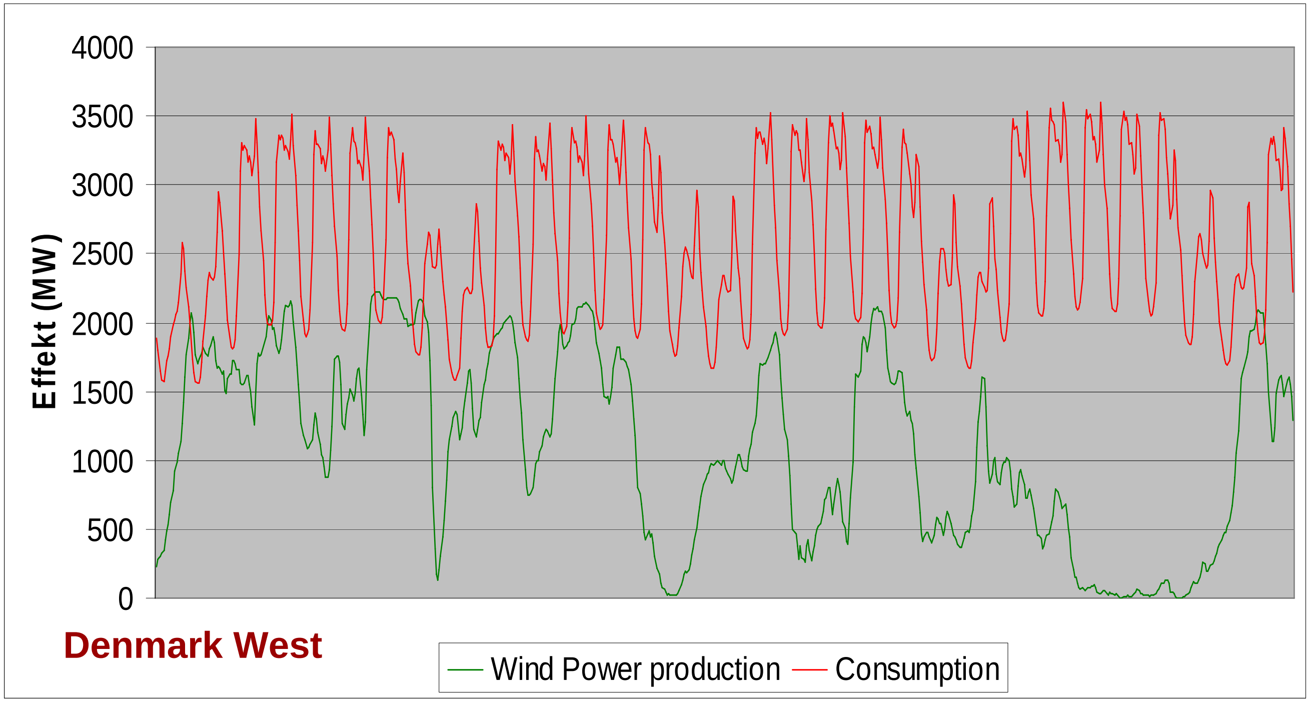
The infrastructure of the Power System

A massive decentralizing of the electricity production causes that the electrical energy to change direction

Even if it a AC system

The system is not normally not designed for this kind of operation

Wind power production/load, january 2005

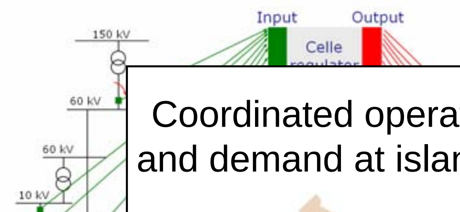


Denmark is a "real-life laboratory"

- High DG penetration in Western DK power system
  - Installed DG: 3,857 MW
  - Average load: 2,469 MW
  - Wind power covers 20% of the load
- Several research activities regarding network and control architectures in progress incl. real-life demonstration

Kul
Olie
Naturgas
Affald

Cell controller pilot project



Coordinated operation of wind and demand at island Bornholm

NextGen – future coherent electricity and information system with integrated DG

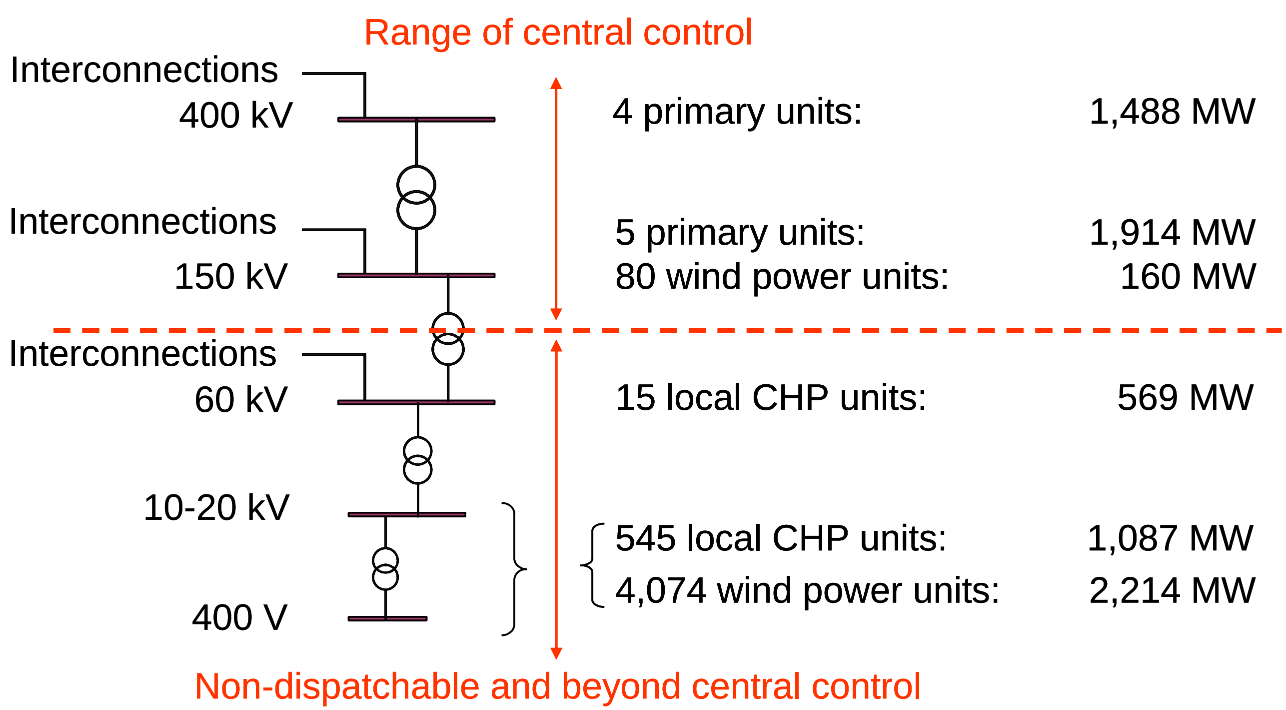
- Participation of local CHP in markets
- Ancillary services from DG/RES
- Development of IEC61850-standards

GINET/DK

Technical University of Denmark
Centre for Electric Technology (CET)

Why we look for new options

The impacts on power markets, system operation and security of supply are causing concern. Energinet.dk, the TSO of Denmark, is developing new solutions for optimal management of the large DG base at hand.



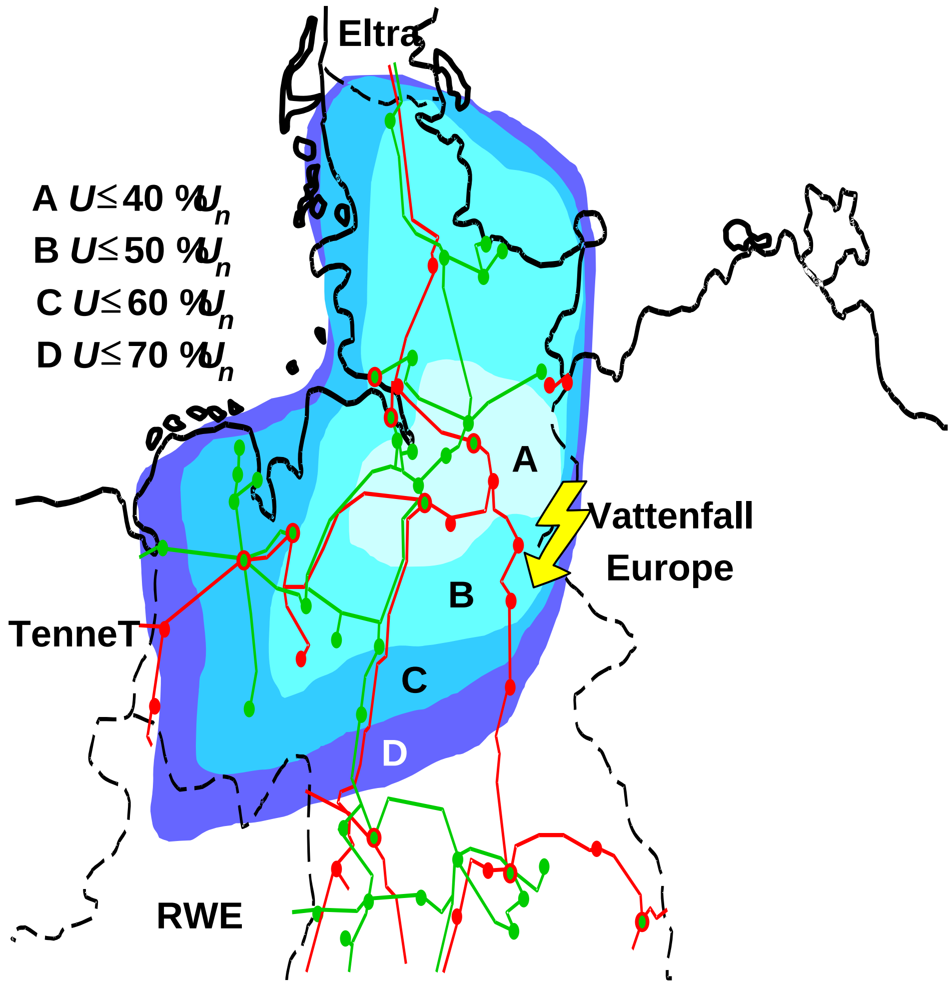
Production capacity per voltage level in western Denmark, 2005.

A new ambitious Danish energy policy

- The Danish government has proposed a new energy policy
- 30% RES in the overall energy system in 2025
- Wind power covers 50% of electricity demand in 2025
- Energinet.dk (Danish TSO) has responded with a research and development programme *EcoGrid.dk* with the goal to develop the new technologies and new market solutions

Distributed production and Blackouts

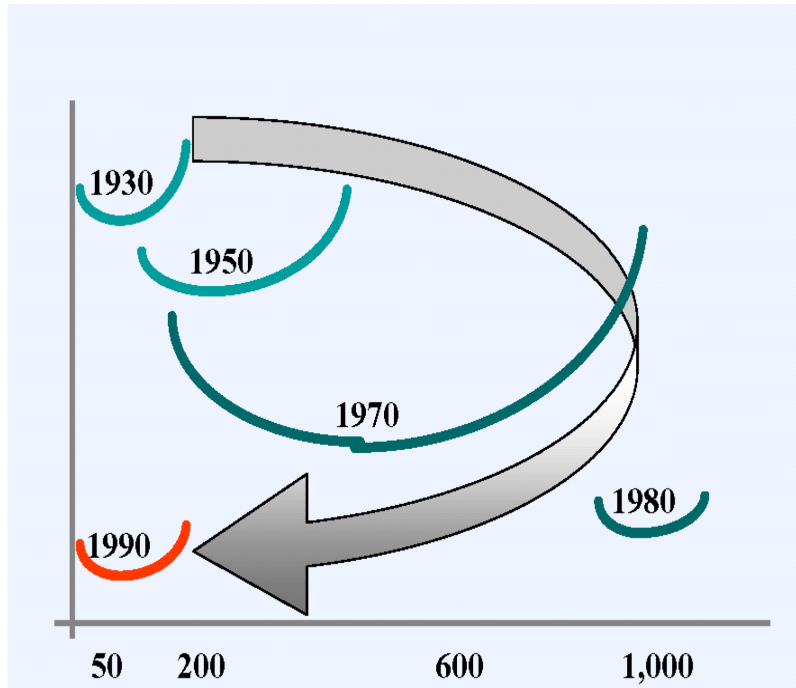
- By a short circuit a dip in the voltage will occur
- The DG will not (at the moment) support the voltage during a failure
- The DG will disconnect by a dip in the voltage, to avoid damage to the generator
- A critical situation is being even more critical
- Solution: A radical changed security strategy?



Source: Lange et al., Cigré session 2004, C6-201.

The trend towards smaller units continues

- The society wants
  - Kyoto 21% reduction i 2012
  - REN-tecnology
- New production technologies
  - Micro turbines
  - Fuel cells
- The central units and the services they provide is under pressure
- This underlines the nescessity for a revision of the security standards
- How can we manage thousends of production units?



Generator size [MW]

Source: C. E. Bayless: "Less is More: Why Gas Turbines Will Transform Electric Utilities", Public Utilities Fortnightly 12/1/94

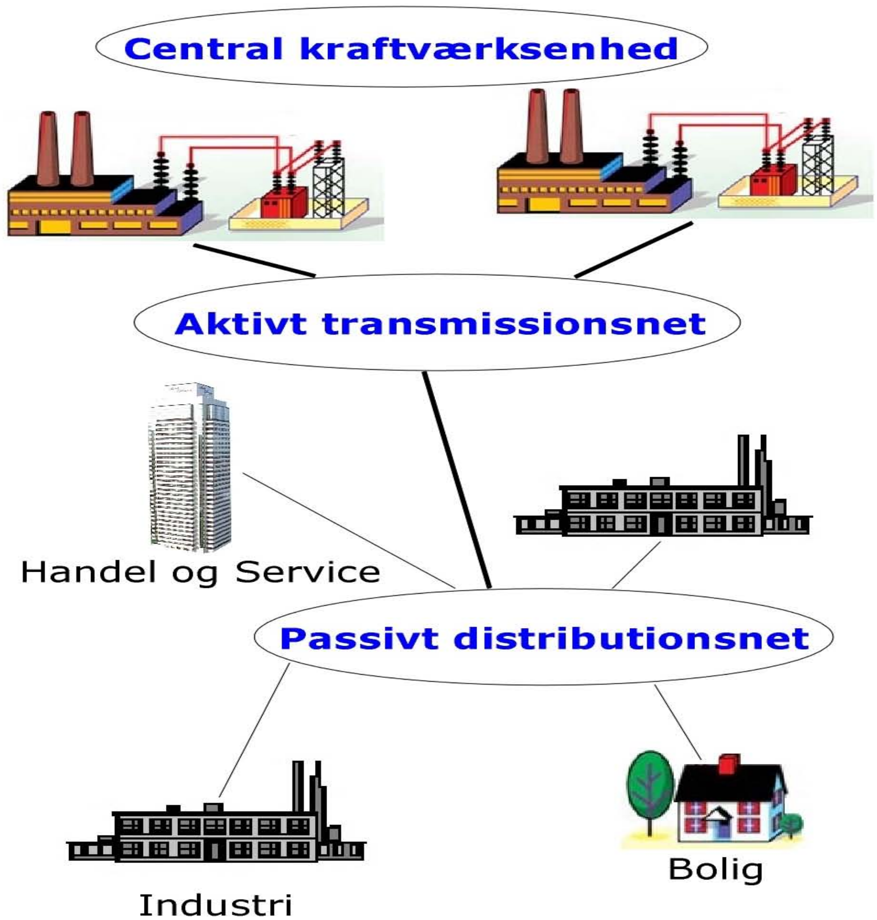
Decentralizing the control

- Todays' control strategy assumes that the control takes place by a limited number of central units, and that the distribuition system is managed passively

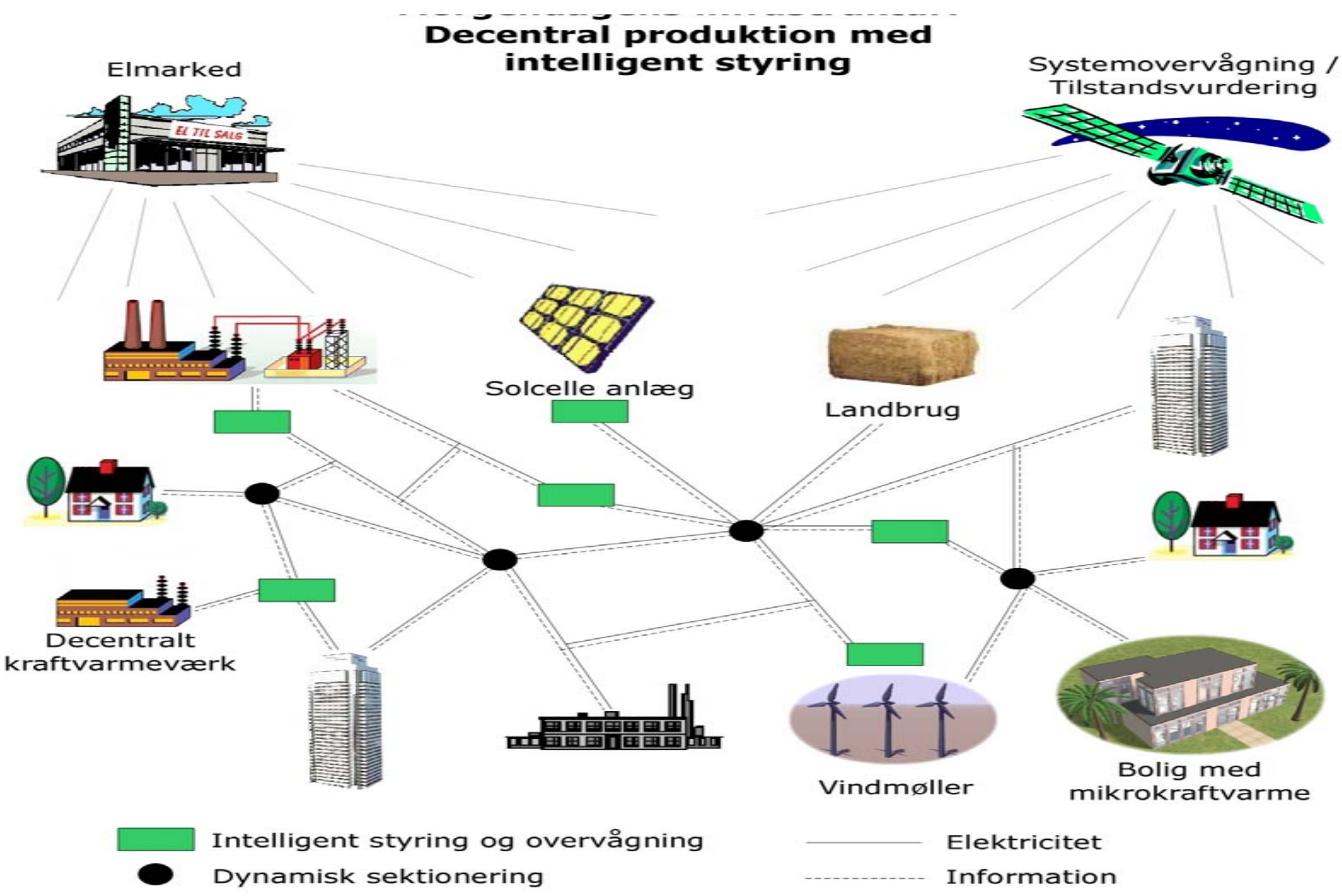
- By the introduction of a massive number of DG the control must also be decentralized

- At least the communication system must be redesigned

Yeasterdays infrastructure



Tiomorrow’s infrastructure

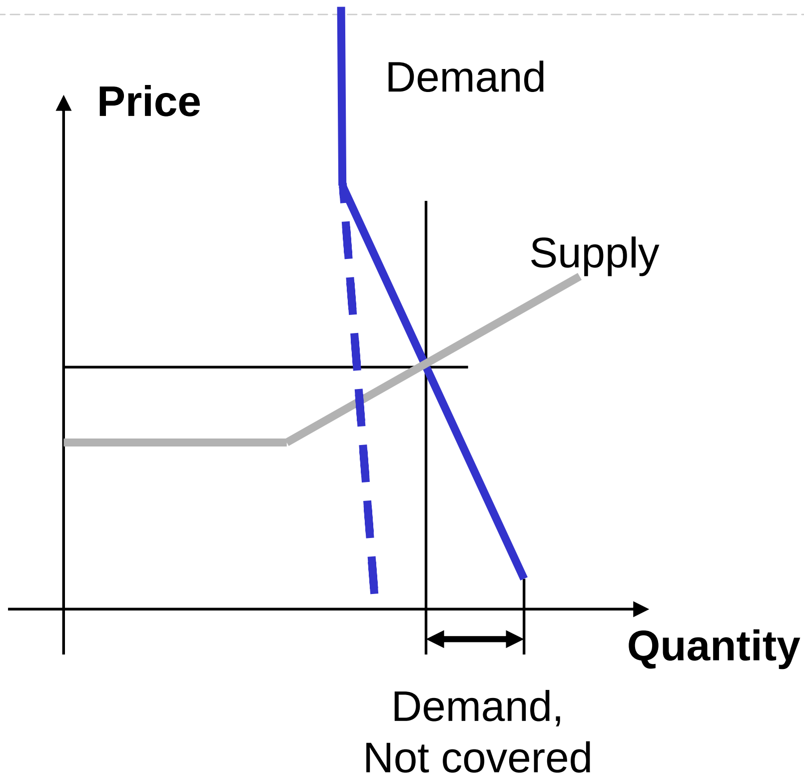


The Power balance

- The production must balance the load
- The balance is regulated by the market on an hourly basis
- Unbalances in forecasts and events are handled by reserves
  - Regulating power
  - Frequency regulation
- How can the balance be secured if there is a lot of production from the wind and the sun in the system?
- What about Storage? or flexibel load?
- What about Integrating the transport sector?
- What about integrating the heat production?

Flexibel loads

- Price dependent load
- ”Network friendly” appliances
- Frequency regulation, coming from the load
- What about unlinearity and stability?
- What about the market?



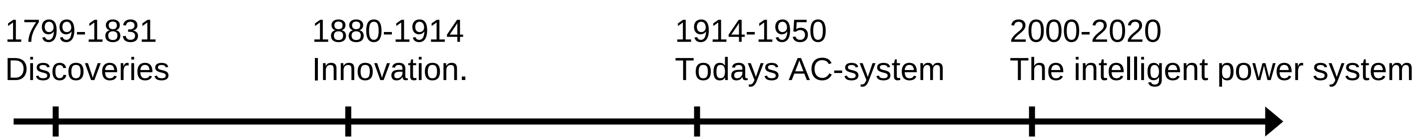
Conclusion

- Trends
  - Resources are changing (DG)
  - The framework is changing (Policy and economy)
- New strategy for security
  - New system design
  - New methods for control
- New technology
  - IT
  - Communication
  - Power Electronics

Conclusion

- The Intelligent Power System
  - Must be able to handle a distributed generation in a market framework by exploiting new technologies

- Technology jump



Conclusion

- Need for development of new market-based control concepts and the related network architectures
  - Totally new solutions for power systems with high penetration of DG/RES is needed
- The Danish situation
  - A “real-life laboratory” is available
  - Data and operational experiences exist
- Denmark can contribute to European research on active distribution networks

CET - Centre for Electrical Technology

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