ROLE OF MICROGRIDS IN ENSURING SECURE ELECTRIC SUPPLY IN NORDIC RURAL AREA DISTRIBUTION NETWORKS

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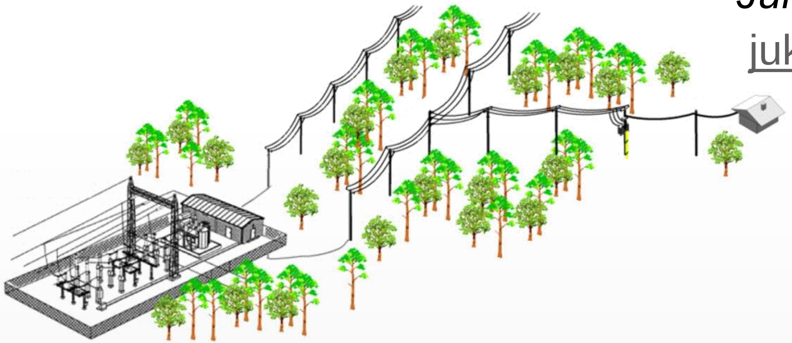

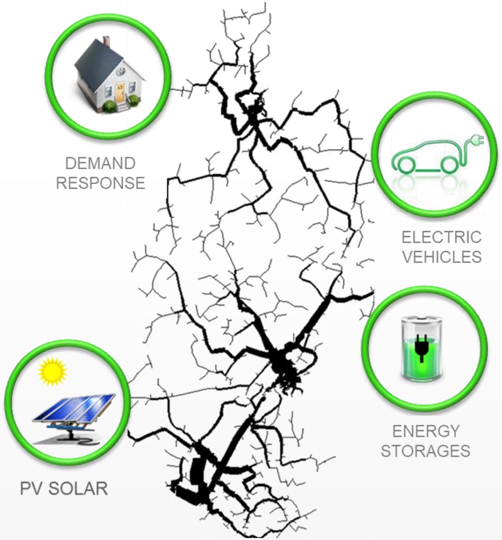

Singapore 2022 Symposium on Microgrids
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Role of microgrids in ensuring secure electric supply in Nordic rural area distribution networks

1. Trends and motivation
2. Operating environment in Nordic countries
3. Smartgrids and flexibility
4. LVDC microgrid technology
5. Conclusions

Electricity distribution
Trends related to electricity distribution

- The role and the **need of electricity** grows (degreasing emissions)
- **Distributed generation** and **electric cars** grows strongly
- **Flexibility** in the energy system emphasized
- **Distribution networks** have significant role in electrification of society and in the harnessing and integrating of (distributed) flexibility to the electricity markets
- **Reliability of supply** in the key role (for instance electrification of transportation and remote working)
- **Technological development** (for instance microgrids, storages, flexible loads)

Trends in electricity distribution
Deregulation

Electric utility
- Generation
- Transmission
- Distribution
- Sale

→

Power generation company | Transmission (grid) company | **Distribution company** | Sales company

Distribution company:

Network ownership
- Financing arrangements
- Target setting
- Network management agreements

Asset management
- Setting principles of operation **(= strategy)**
- Management of service agreements

Service providers
- Equipment supplier
- System supplier
- Network operation
- Construction
- Measurement

Micrograds part of network development strategy?

20 kV overhead line

20/0.4 kV distribution substation

400 V aerial bundled cable (AMKA)

Planning of electricity distribution networks

Fundamentals of network design and operation

Long-term target: **minimization of life-time costs**

$$C_{\text{total}} = \min \int_0^T \left(C_{\text{investment}}(t) + C_{\text{opex}}(t) + C_{\text{outage}}(t) \right) dt$$

Investment costs

- Building
- Materials
- Capital costs
- Planning, research and development
- Storages, transportation

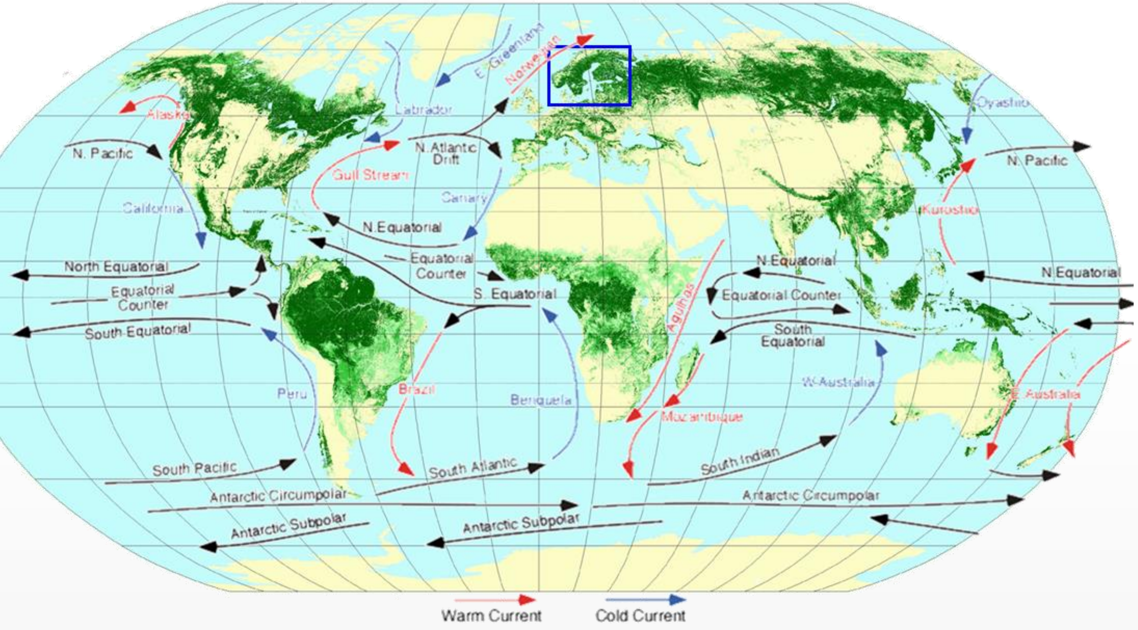
Operational costs

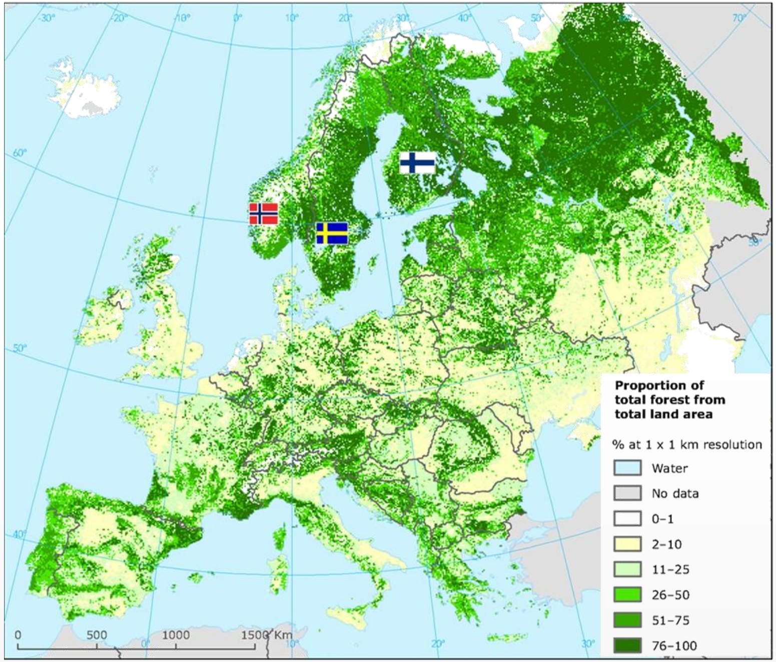
- Network operation
- Network maintenance
- Network losses
- Fault repairing

Outage costs

- Economic harm for end-user because of outage

Trends in electricity distribution
Operating environment – Reliability



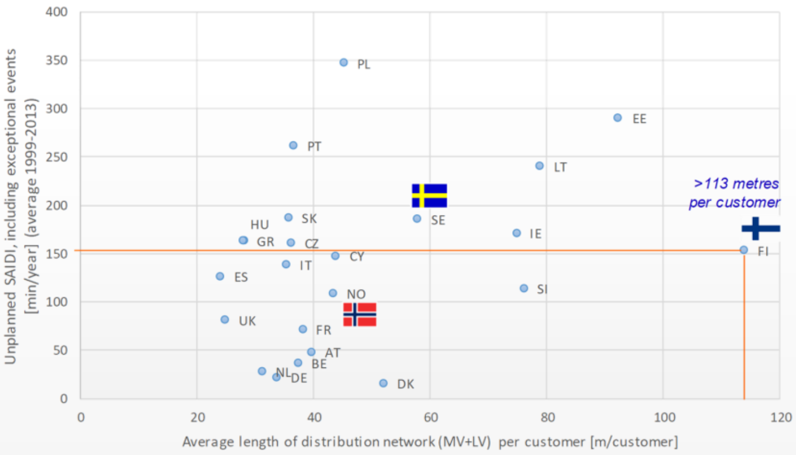


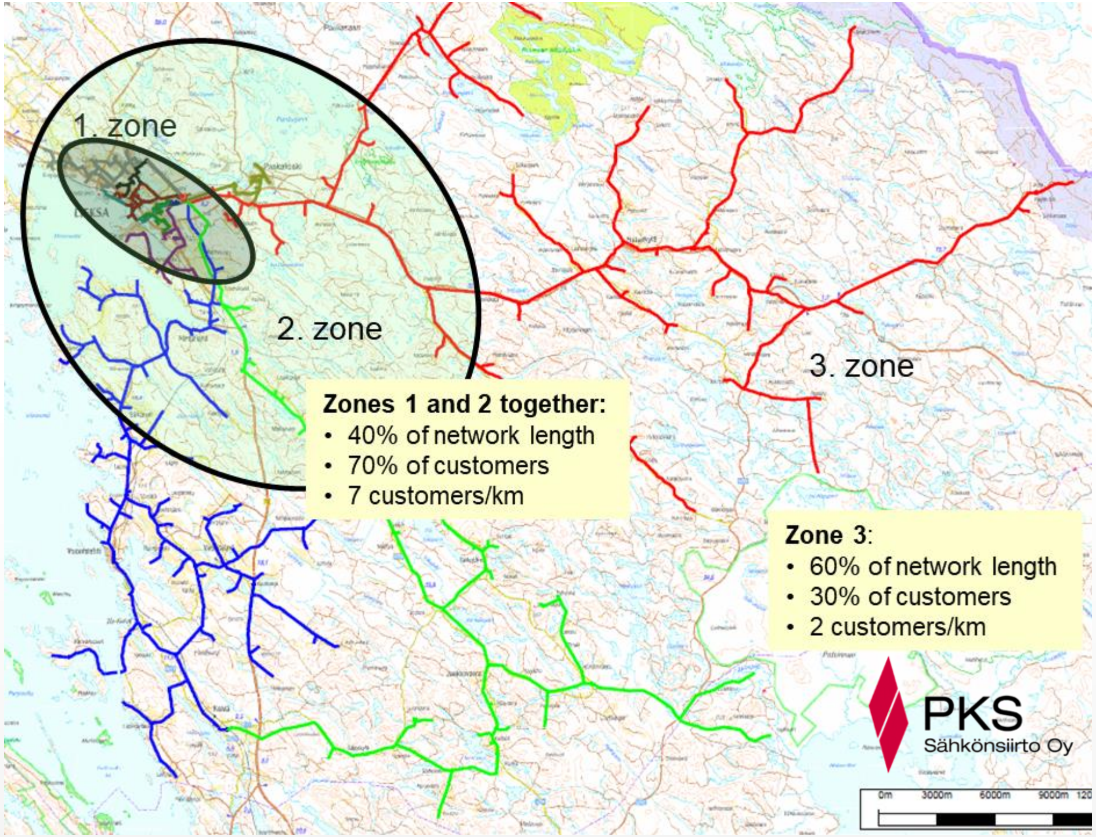
Source: Cired 2019, Effects of the Future Trends in Distribution Networks (Paper 1681)

Trends in electricity distribution
Operating environment

LUT University

Challenge of rural area electricity distribution companies: long distances and lines in sparsely populated areas together with decreasing number of population





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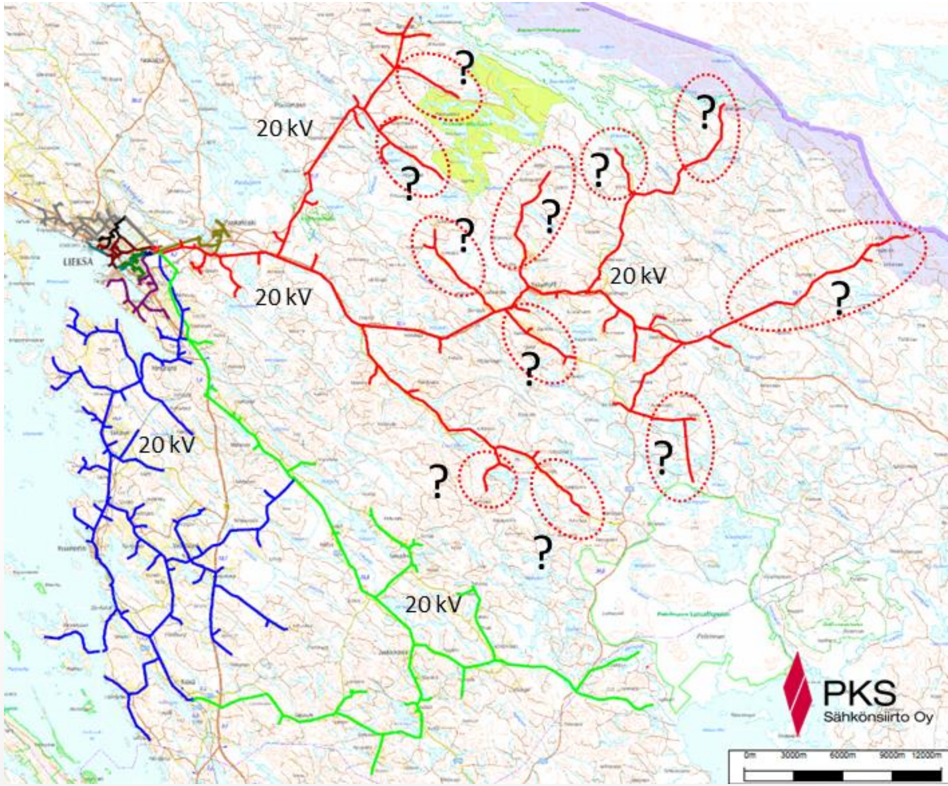
Electricity distribution in rural areas
Flexibility regarding reliability of supply?

Target: Define the techno-economic feasibility and potential of different (network) solutions to provide flexibility for reliability of supply

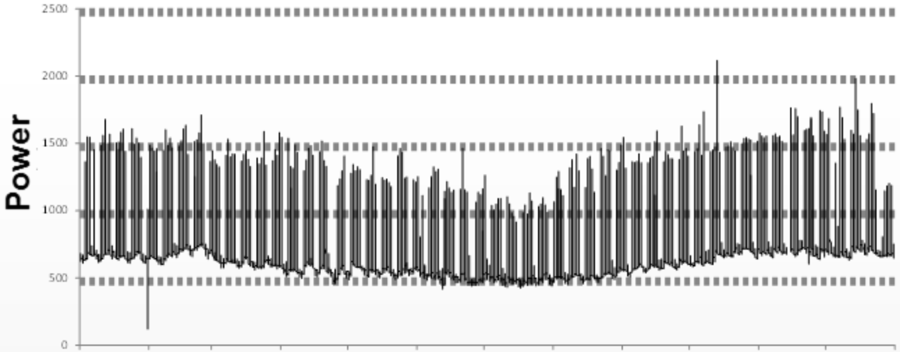
Benefit: Distribution system operator (DSO) can manage investment risks in the sparsely populated areas where customer lost is high (depopulation from rural area to cities)

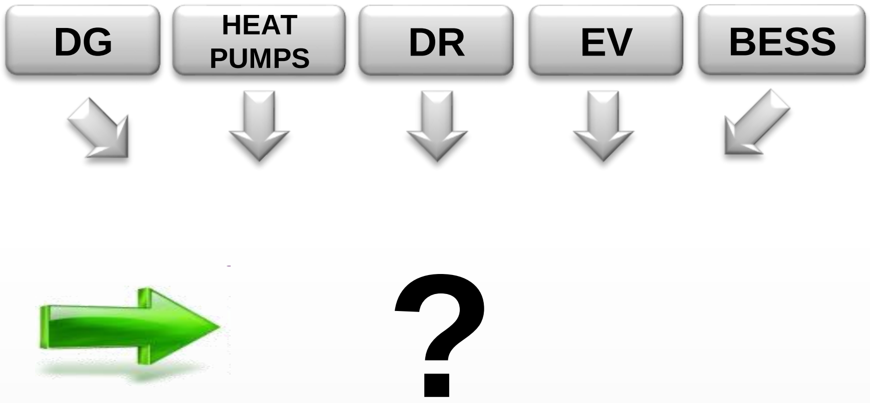


Trends in electricity distribution
Demand curve in 2030?

Challenge of the future profile; How different trends affect on profile?

LOAD CURVE TODAY



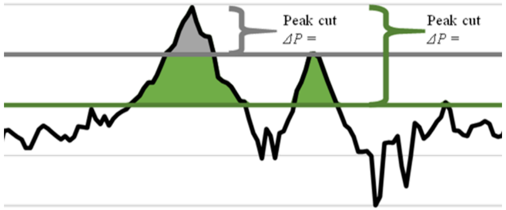


DG – distributed generation
DR – demand response
EV – electric vehicle
BESS – battery energy storage system

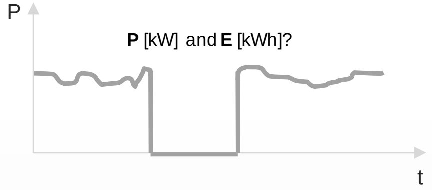
Trends in electricity distribution
Key facts of rural operation environment

- **Long network lengths** - Sparsely populated country (low customer density)
- **Challenges regarding reliability** - High forest rate and vulnerable network technologies for weather originated storms (overhead line networks in forests), 56% of the outages experienced by end-customers are caused by trees falling on the lines
- **Use of electricity and load profiles well known** - 100% of customers have AMR-meter (customer –specific hourly based numbers from several years)
- **Uncertainty regarding continuity and future demand** – depopulation from rural areas to cities and change of load profile due to electric vehicles, distributed generation and heating system renovations

Flexibility needs in electricity distribution
Main targets and important viewpoints



- **Management of network powers (peak powers)**
  - Efficient use of existing network capacity (lines and transformers)
  - Management of increase in peak powers without network renovations and reinforcements of the network capacity
  - Possibility of reasonable dimensioning of network components
  - Controlled charging of electric vehicles, dimensioning of distributed generation and demand response, energy storages and implementation of residential heating system renovations
- **Supply of reliability and outage management (major storm risk and outage costs)**
  - Meeting the expectations of electricity market rules (city and village areas, rural areas)
  - Deacreasing of outage costs
  - Energy storages and demand response (for instace priorization of load in buildings)
  - Flexibility aggreements with customers



- **Voltage quality**
  - Ensuring voltage quality (especially customer points with low voltage rigidity and low short circuit currents)
  - Delaying or avoiding of network renovation investments
  - Voltage control of main transformers (110/20 kV), microgrids, secondary substation automation (20/0.4 kV), power electronics with DG, demand response
- **Management of reactive power**
  - Avoiding reactive power payments for national transmission grid company and avoiding unnecessary network investments
  - power electronics with DG and BESS

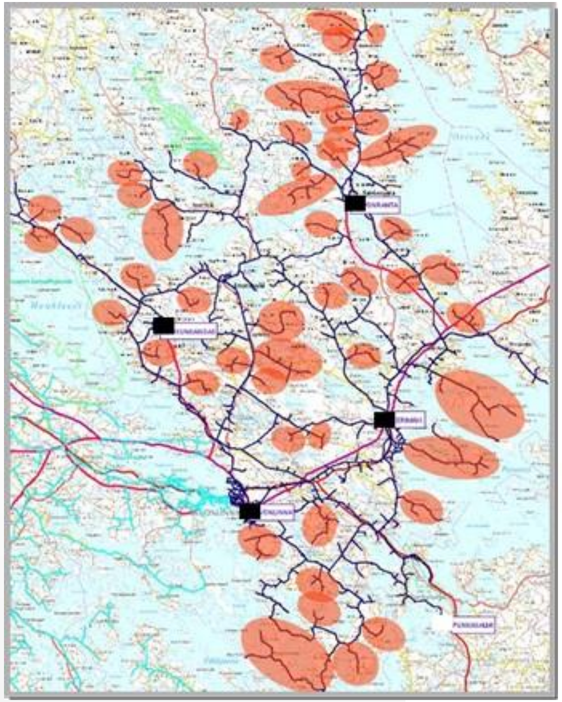
DG – distributed generation
BESS – battery energy storage system

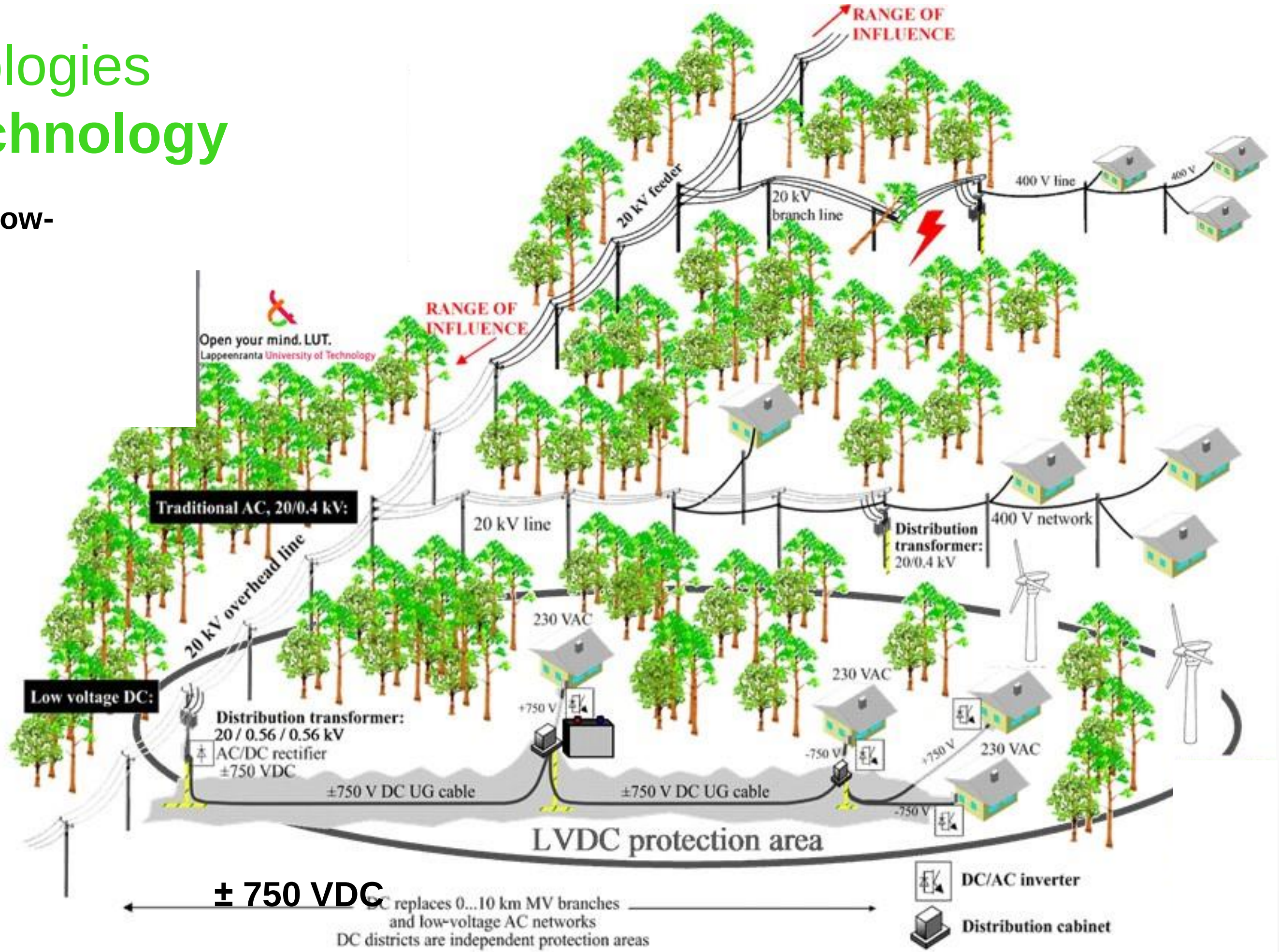
Development technologies
LVDC microgrid technology

- Application of power electronics in electricity distribution – Feasible replacement of medium voltage (MV) distribution branches (20 kV) and low voltage (LV) distribution networks (400 VAC)
- Higher transmission capacity: up to 16 times power transfer capability that of a traditional 400 VAC system (the bipolar ±750 VDC system)
- Longer transmission distance
- Usage of traditional low voltage components (cables and protection devices) with higher voltage
- Independent, individual protection zones and improved power quality
- Efficient integration of renewables and energy storages
- Permits advanced control over loads, power generation and energy storages
- Increases the controllability and flexibility of the distribution network

Development technologies
LVDC microgrid technology

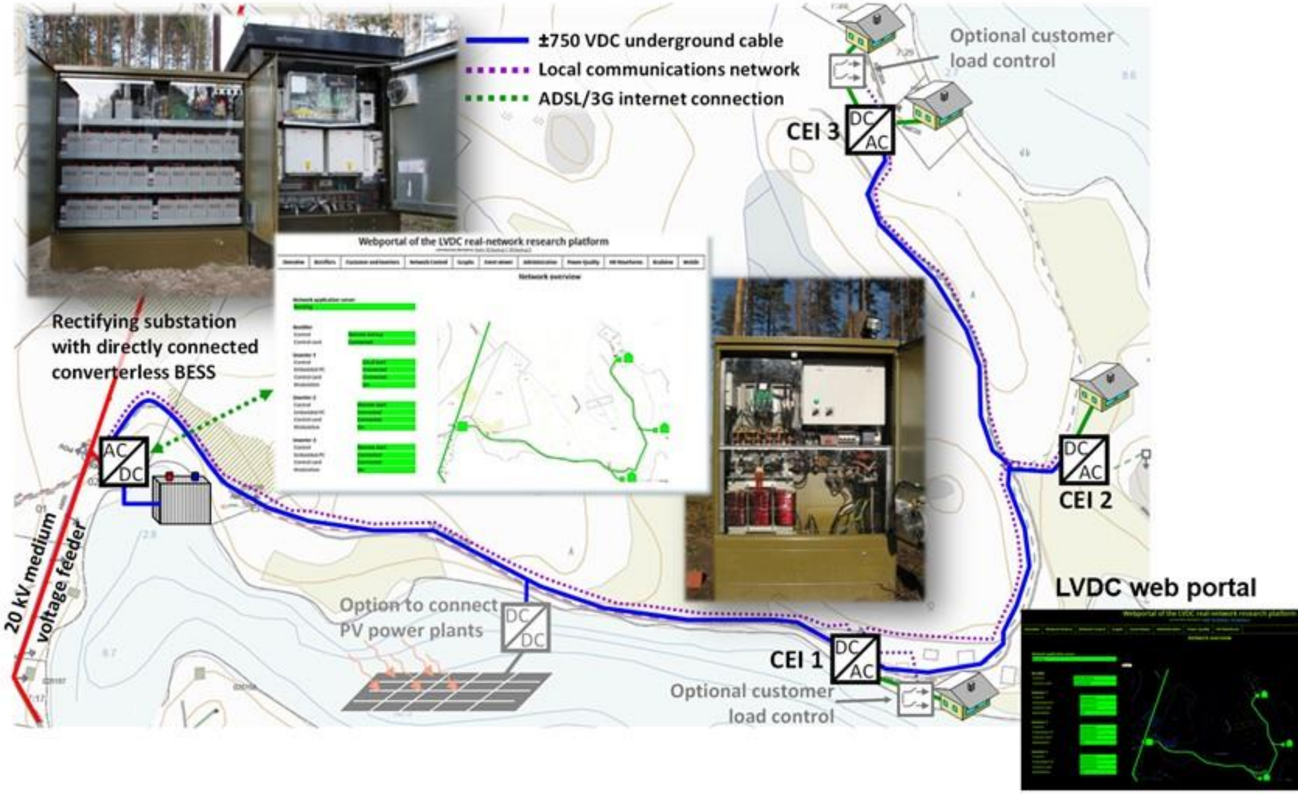
Technoeconomic potential of LVDC (low-voltage DC) in distribution network



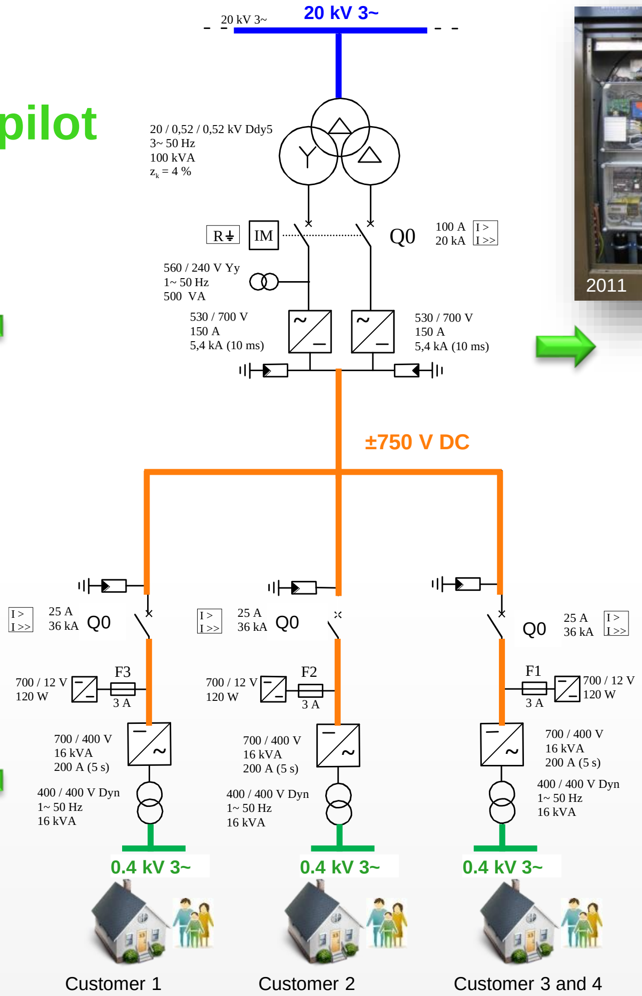


Development technologies
LVDC microgrid technology

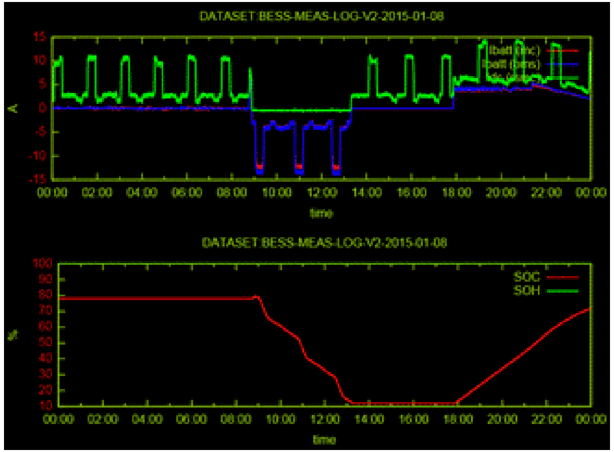
Microgrid technology offering at the same time **local services** (reliability of supply, voltage quality) as well as **power system level services** (for instance frequency reserve)



Development technologies
Concept of rural LVDC distribution, pilot

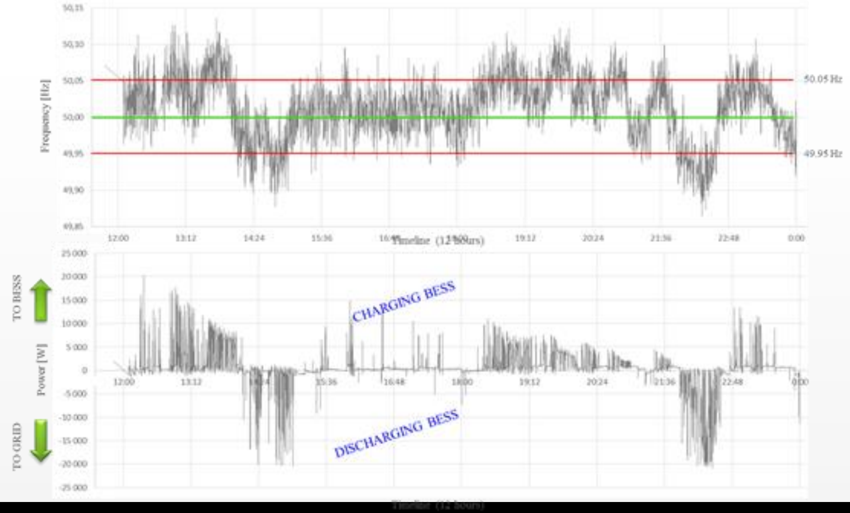


Development technologies
LVDC microgrid technology



Background information

- Actual DSO operating LVDC microgrid
- Operated since 2011
- BESS installation 2014



Flexibility supporting functionalities of LVDC microgrid tested with BESS

- Island operation of microgrid with BESS
- Power grid reserve; frequency control
- Power band operation

LVDC distribution
Active resource as a part of flexible energy system

Whole power system | Local distribution system | Microgrid

Role of microgrids in ensuring secure electric supply
Conclusions

- Several global and local trends are changing the role and expectations of electricity distribution (networks)
- Load profile is changing due to trends → Need and value of demand side flexibility in energy system is growing
- Technological development (Microgrids, DG, EV, BESS, DR) makes possible for cost efficient development of electricity distribution with managing risks related to operating environment
- LVDC microgrids technologically cababible and economically feasible to provide local and system level services
- Succesfull development and desing of future energy system requires strong knowledge of whole energy chain
- The management of background (Big)data is emphasized – possibilities for instance for new services

References

- **LVDC-microgrid related doctoral theses in LUT**
  - LVDC power distribution system: computational modelling http://urn.fi/URN:ISBN:978-952-265-619-3
  - Power-line-communication-based data transmission concept for an LVDC electricity distribution network – Analysis and implementation http://urn.fi/URN:ISBN:978-952-265-531-8
  - Power Electronic Converters in Low-Voltage Direct Current Distribution – Analysis and Implementation http://urn.fi/URN:ISBN:978-952-265-891-3
  - Phase voltage control and filtering in a converter-fed single-phase customer-end system of the LVDC distribution network http://urn.fi/URN:ISBN:978-952-214-994-7
  - Design of Customer-End Converter Systems for Low Voltage DC Distribution from a Life Cycle Cost Perspective http://urn.fi/URN:ISBN:978-952-335-240-7
  - Assessing the applicability of low voltage direct current in electricity distribution : key factors and design aspects https://urn.fi/URN:ISBN:978-952-335-577-4

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