

Electric Cars

- Challenge or Opportunity for the Electricity Distribution Infrastructure?

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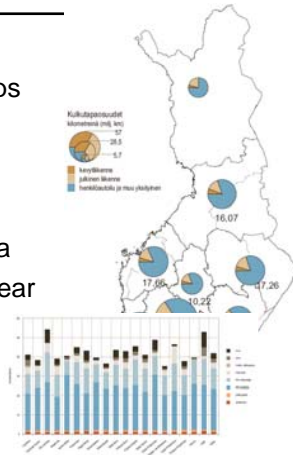
Target of the studies

- Define method to analyse network effects of electric vehicles
- Make network analyses using actual distribution network data and load flows (city area and rural area feeders)
- Define the best and the worst scenarios and define the needed network reinforcements
- Define network effects to the distribution fees paid by the end-customers

Input Parameters on Electric Car Network Simulation

National passenger transport survey

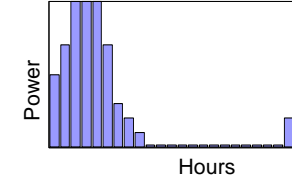
- Spatial and temporal variations in passenger trips
- Length of daily trips
- Annual length of driving (region dependent)
- Length of daily trips according to housing type
- Length of daily trips according to residential area
- Length of daily trips according to the month of year
- Length of trips according to the time of day
- Number of cars in households



Area-specific additional energy

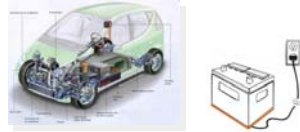
__ kWh/day
(working hours/
leisure time)

Charging profile



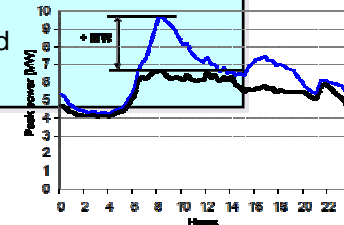
Properties of electric cars

- Energy consumption, kWh/km
- Capacity of the batteries, kWh
- Charging power, kW
- Required charging time, h/day (battery properties)



Network simulations and analysis results

- Load flow and loss calculations
- Estimation of reinforcements required



Town planning statistics

- Workplaces according to the area and time of day
- Residential areas (detached houses, terraced houses, apartment houses)



Penetration of electric cars

- Development of electric car markets



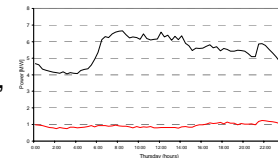
Tariffs and supplier

- Distribution fee

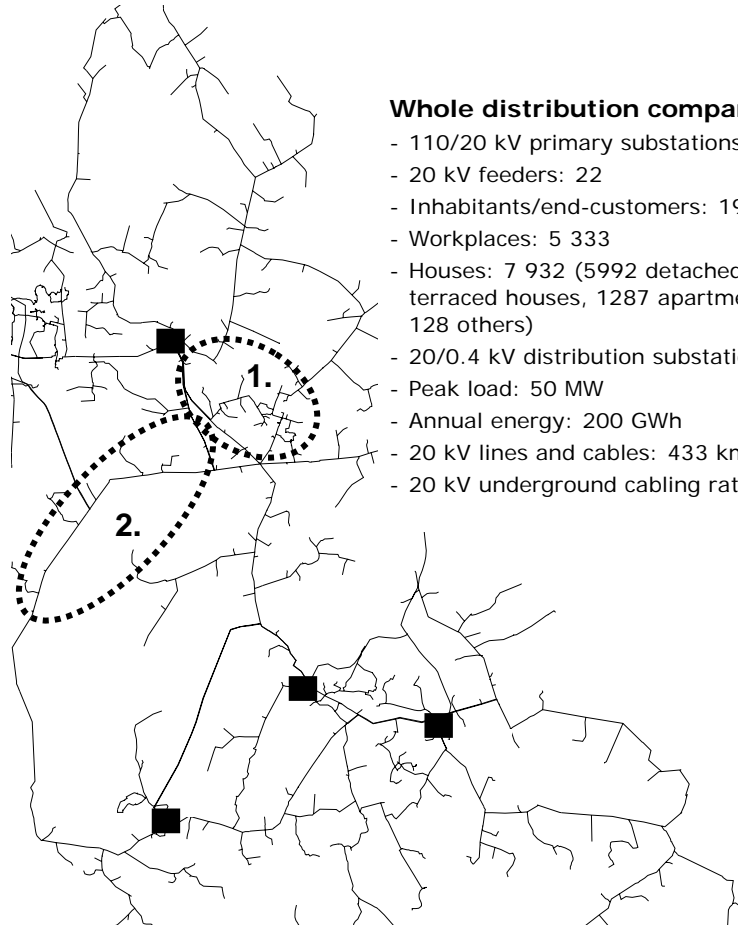


Electricity distribution network

- Network topology and customer information
- Feeder and hourly-specific actual load curves
- Network volume
- Replacement value
- Parameters: loss costs, load growth, lifetime, unit price of network components

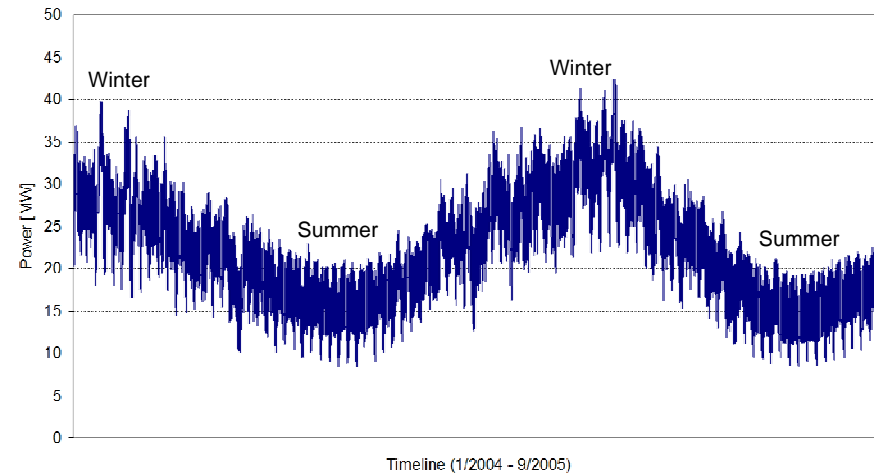


Case Network - Background data



Whole distribution company

- 110/20 kV primary substations: 4
- 20 kV feeders: 22
- Inhabitants/end-customers: 19 470 / 11 000
- Workplaces: 5 333
- Houses: 7 932 (5992 detached houses, 525 terraced houses, 1287 apartment houses, 128 others)
- 20/0.4 kV distribution substations: 470
- Peak load: 50 MW
- Annual energy: 200 GWh
- 20 kV lines and cables: 433 km
- 20 kV underground cabling rate: 16 %



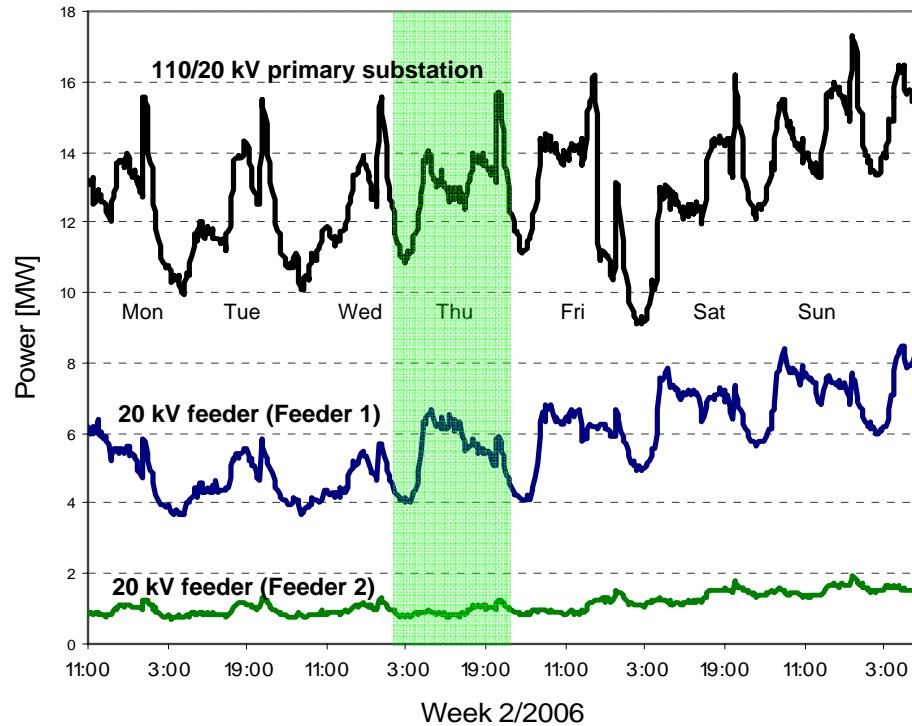
Feeder 1. (Densely populated area), 20 kV

- Peak load: 8 MW
- Annual energy: 36 GWh
 - Residential 58 %, industry 22 %, public 13 % and service 7 %
- Inhabitants/end-customers: 4171 / 2278
- Workplaces: 1 577
- Houses: 1 840 (659 detached houses, 266 terraced houses, 888 apartment houses)
- 20/0.4 kV distribution substations: 39
- 20 kV lines and cables: 21 km
- 20 kV underground cabling rate: 33 %

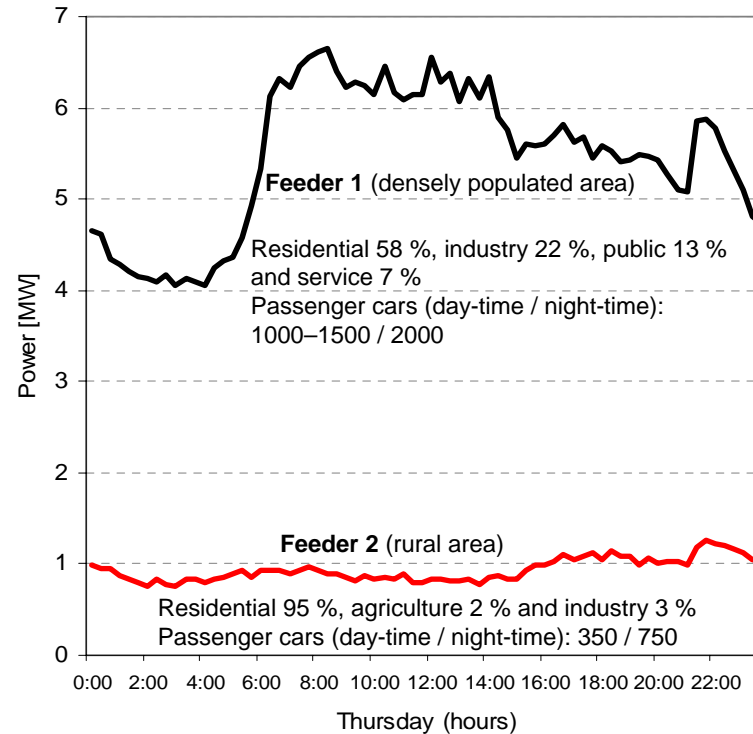
Feeder 2. (Rural area), 20 kV

- Peak load: 2 MW
- Annual energy: 6 GWh
 - Residential 95 %, agriculture 2 %, industry 3 %
- Inhabitants/end-customers: 1037 / 444
- Workplaces: 84
- Houses: 372 (all detached houses)
- 20/0.4 kV distribution substations: 27
- 20 kV lines and cables: 31 km
- 20 kV underground cabling rate: 6 %

Case Network - Load curves



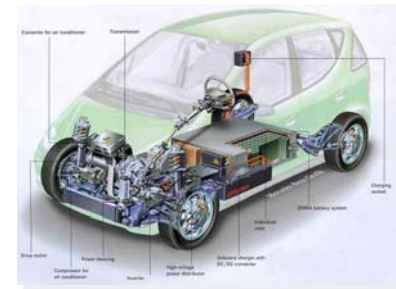
a)



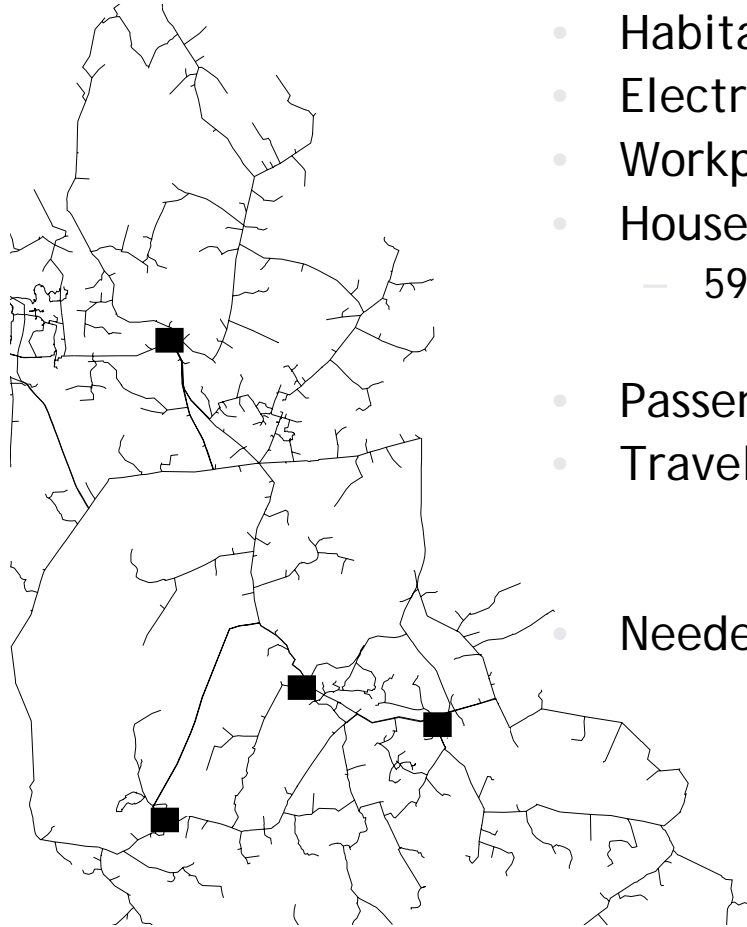
b)

Electric Vehicles - Properties

- Needed energy: 0.1 - 0.2 kWh/km
- Capacity: 30 kWh/car
- Charging power: 3.6 kW/car

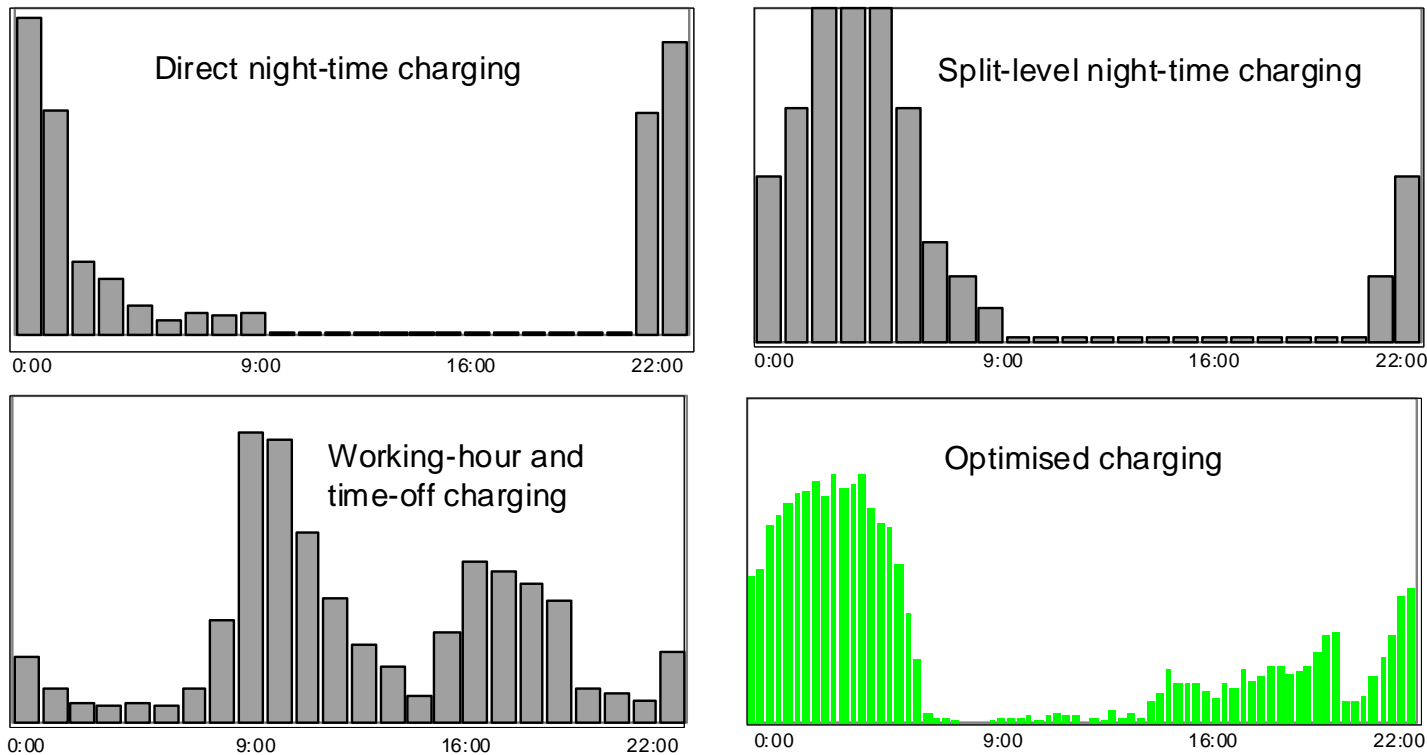


Case area



- Habitants: 19 470
- Electricity end-customers: 11 000
- Workplaces: 5 333
- Houses: 7 932
 - 5992 detached, 525 terraced, 1287 apartment, 128 others
- Passenger cars: 11 000
- Travelling distances: 20 900 km/car, a
= 57 km/car, day
- Needed charging energy: 11.5 kWh/car, day
46 GWh/a (all cars)

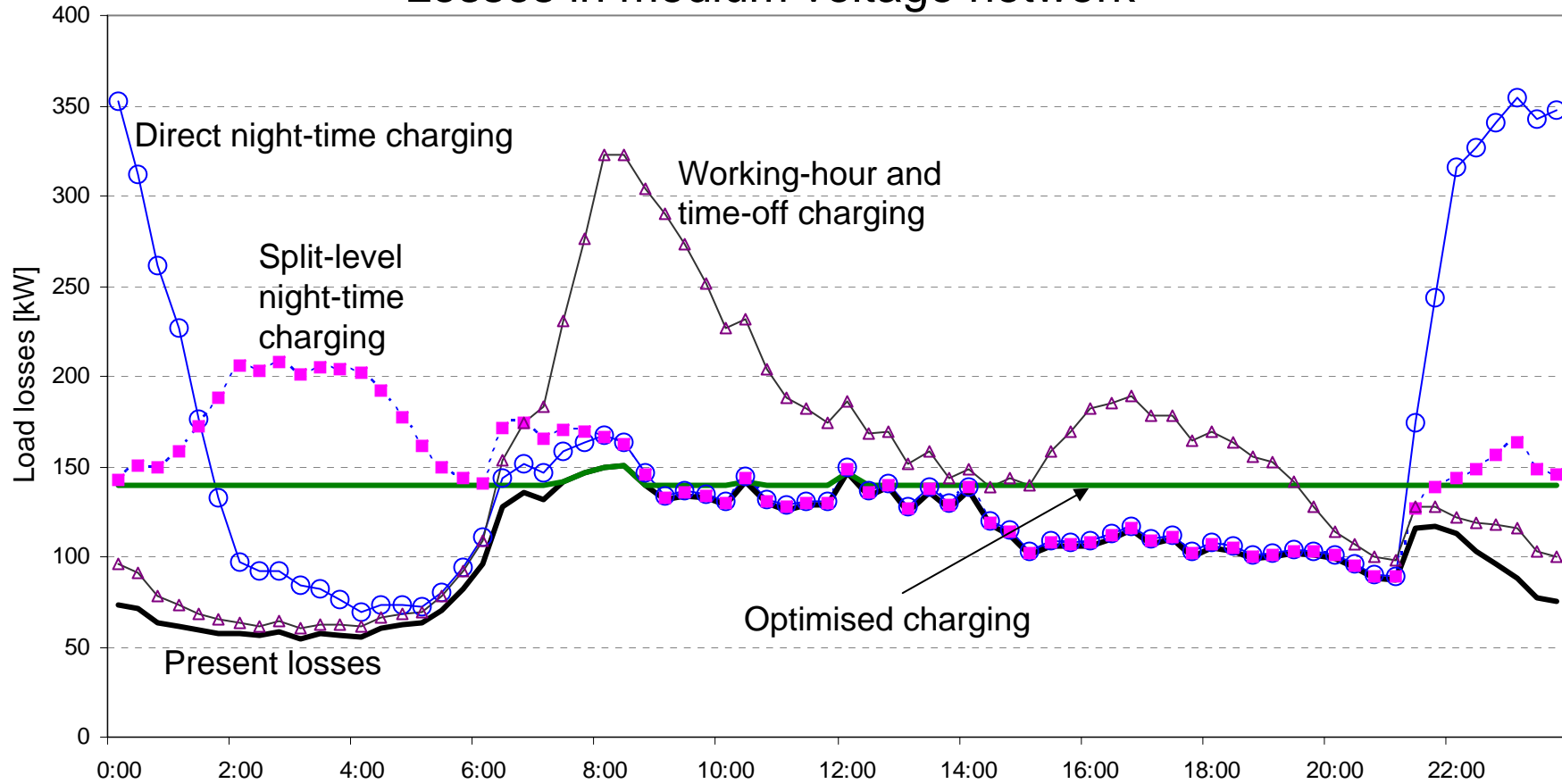
Case Network - Electric car charging profiles



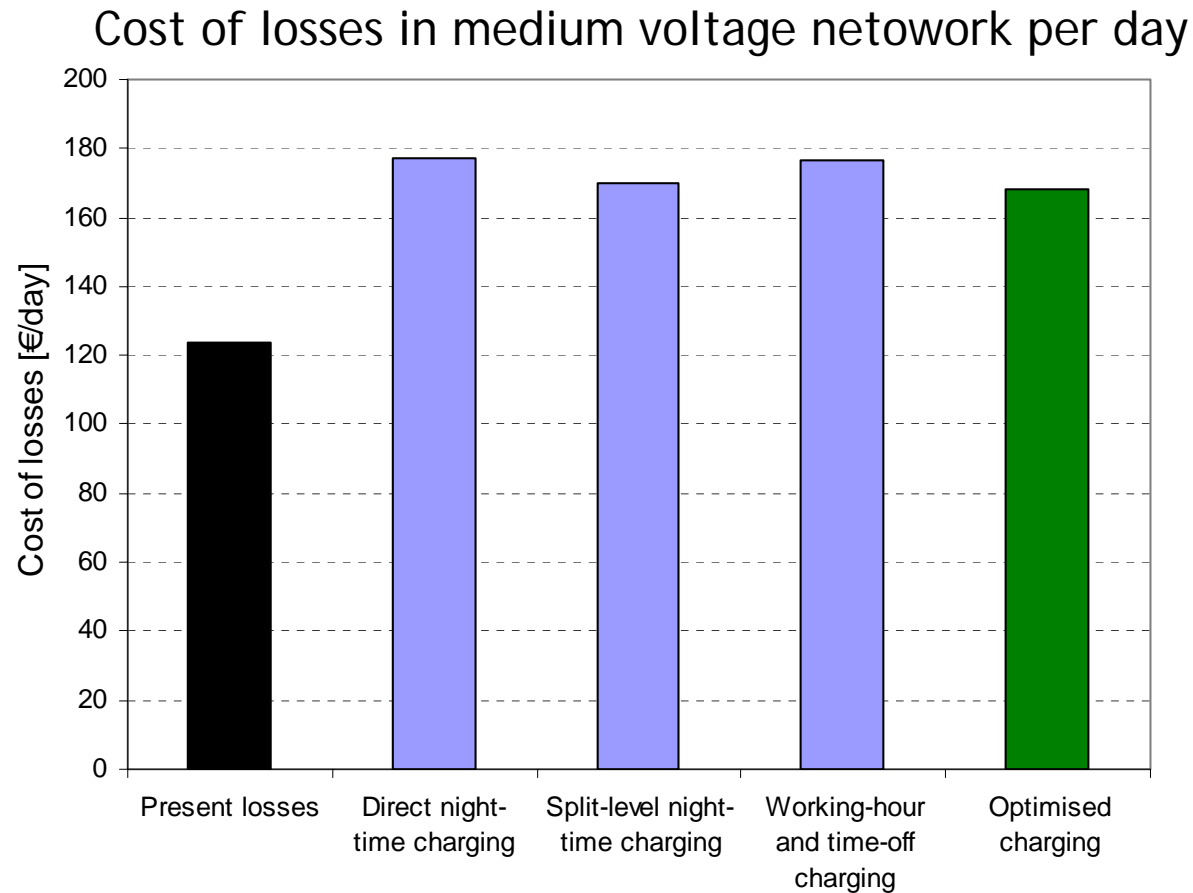
The same amount of charging energy in each profile!

- Transmission capacity in the network?
- Losses and loss costs?

Losses in medium voltage network

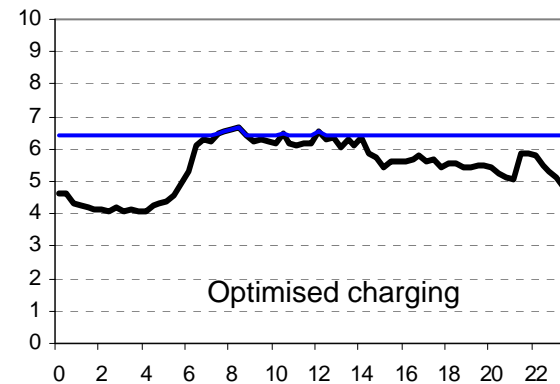
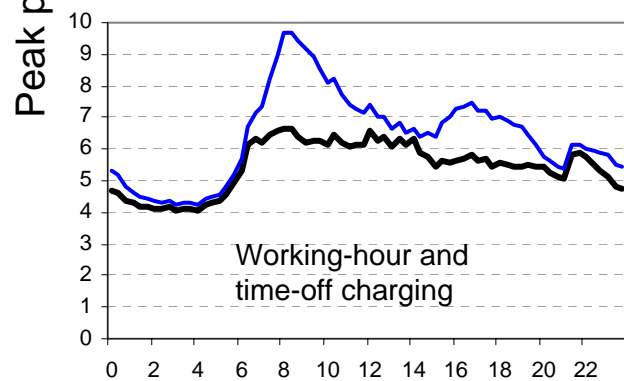
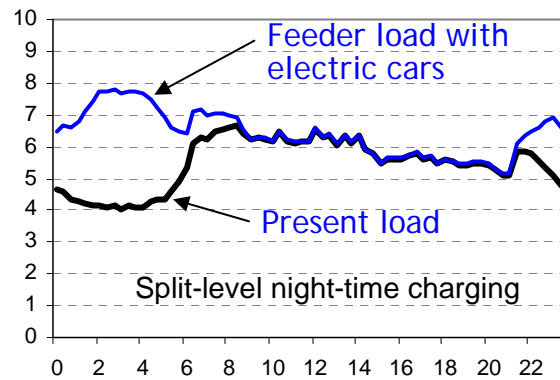
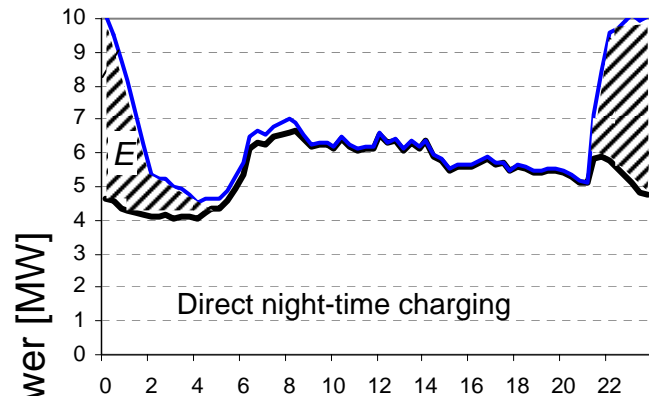


Case Network - Loss costs



→ No remarkable differences in charging profiles from loss costs point of view in medium voltage network!

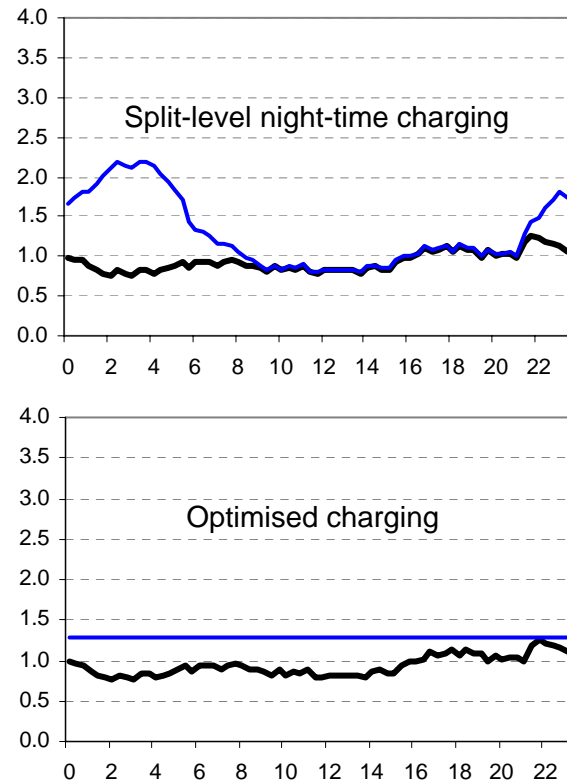
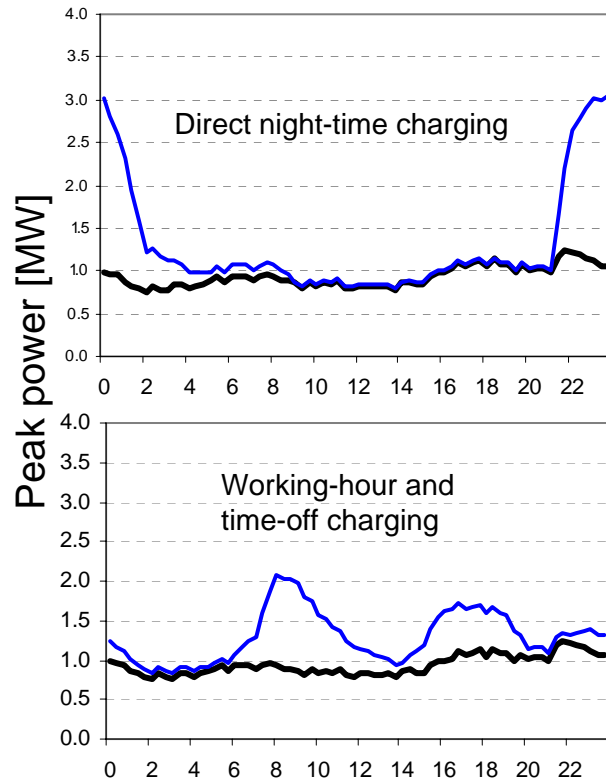
Case Network - Feeder 1 (city area)



City area feeder:

- Peak load of the day: 6.6 MW
- Minimum load of the day: 4.0 MW
- **Number of electric cars: 2000**
- Driving distance: 57 km/car, day
- Energy consumption: 0.2 kWh/km
- Charging energy: 11.5 kWh/car, day
→ **22.9 MWh/day for all cars**
- Charging power: 3.6 kW/car
- **Additional power: 0 – 3.5 MW**
(depending on charging method)
- Charging energy (E) is equal in each charging alternative

Case Network - Feeder 2 (rural area)

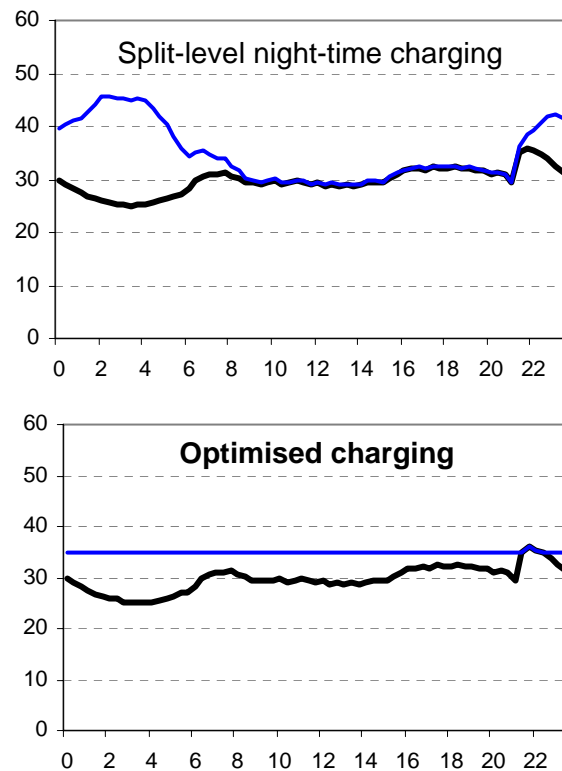
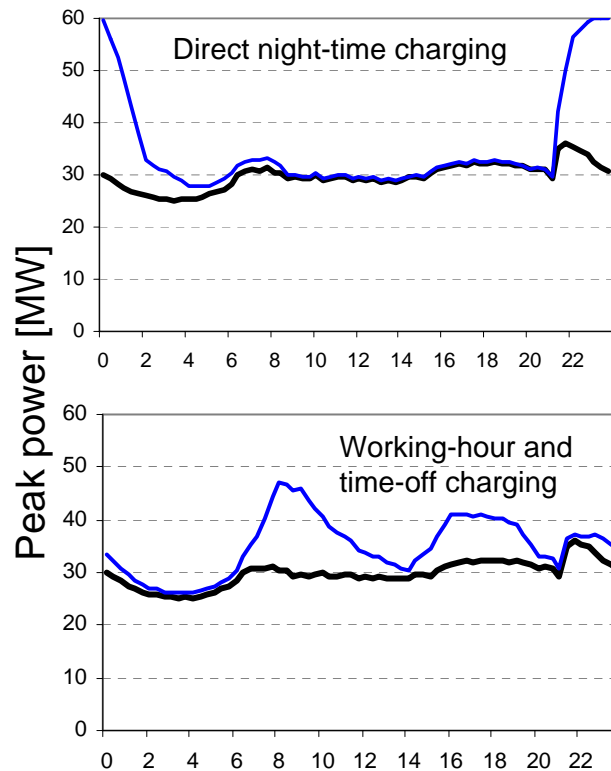


Rural area feeder:

- Peak load of the day: 1.25 MW
- Minimum load of the day: 0.75 MW
- **Number of electric cars: 750**
- Driving distance: 57 km/car, day
- Energy consumption: 0.2 kWh/km
- Charging energy: 11.5 kWh/car, day
→ **8.6 MWh/day for all cars**
- Charging power: 3.6 kW/car
- **Additional power: 0 – 1.75 MW**
(depending on charging method)

Charging energy is equal in each charging alternative

Case Network - Whole company



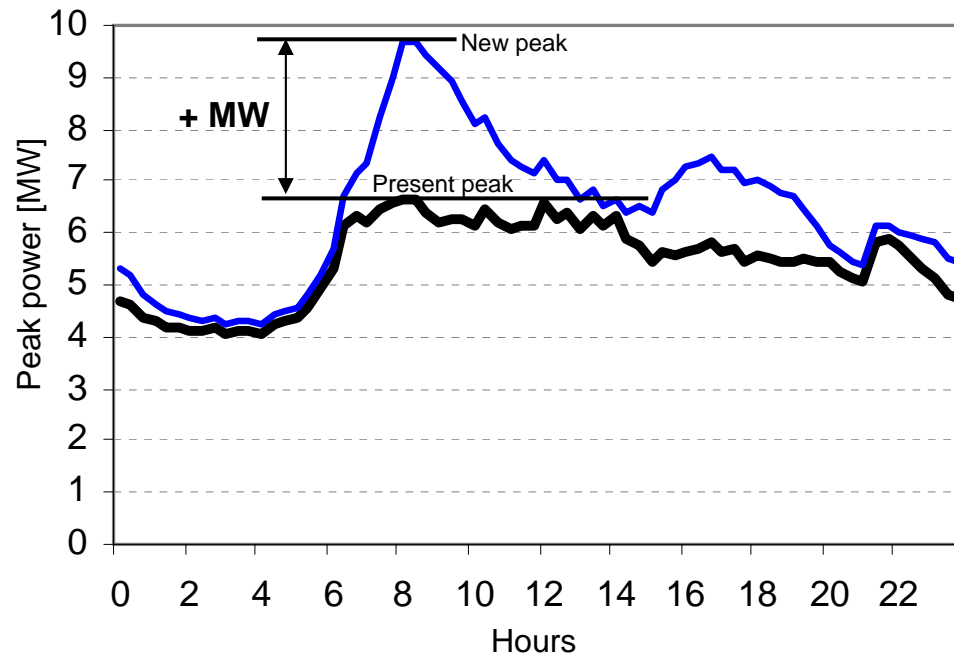
Whole company:

- Peak load of the day: 36 MW
- Minimum load of the day: 25 MW
- **Number of electric cars: 11 000**
- Driving distance: 57 km/car, day
- Energy consumption: 0.2 kWh/km
- Charging energy: 11.5 kWh/car, day
- **126 MWh/day for all cars**
- Charging power: 3.6 kW/car
- **Additional power: 0 – 24 MW**
(depending on charging method)

→ Using intelligent charging system (Optimised charging) charging can be adjusted fully into low-load moments

Case Network - Reinforcement costs

- Network value compared with the peak load in
 - low-voltage networks 320 €/kW
 - medium-voltage network 300 €/kW
 - primary substation level (110/20 kV) 100 €/kW



An example of defining required reinforcement investments on the medium voltage feeder

20 kV feeder 1. (densely populated area)

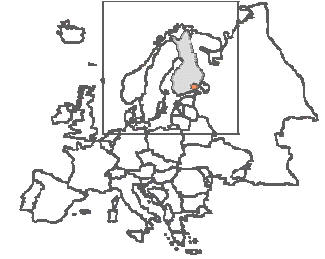
- Peak load of the day: 6.6 MW
- Additional power: + 3.0 MW

- Average marginal cost: 300 €/kW

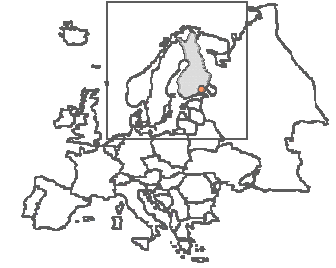
→ **Estimated need for reinforcement:**
 $300 \text{ €/kW} \times 3000 \text{ kW} = 900\,000 \text{ €}$

→ Using intelligent charging system (Optimised charging) charging can be adjusted fully into low-load moments

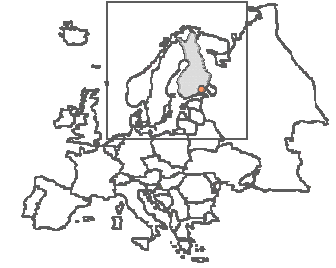
- Replacement value: 50 M€ (← 2.9 M€/a calculated by $p = 5\%$ and $t = 40$ a)
- Annual present delivered energy: 200 GWh/a
 - Network value per delivered energy 1.46 cnt/kWh
- Estimated additional annual charging energy required by electric cars: + 46 GWh/a (← 11 000 cars, 20 900 km/car,a and 0.2 kWh/km,car)
- Depending on charging method, estimation of the required investments in a new transformer and transmission capacity in the whole distribution network is 0 - 20 M€ (0 - 1 060 k€/a).
 - New distribution fee: 1.18 - 1.66 cnt/kWh after the network reinforcements



1. *Description of the overall methodology*; what background information is required and how it is used to determine the need for electric car charging energy and power and to analyse the network effects.
2. *Charging mode* has a significant impact on the peak load level on the feeder. Without any intelligence included in the system, charging of electric cars may increase the peak power even three times higher compared with the present load level on the medium-voltage feeder. With an intelligent charging system, charging can be adjusted to a low-load moment, thereby avoiding overlapping of the existing peak load and the additional charging load. This may reduce the distribution fees of the electricity end-users, because more energy is delivered through the same system without a need for reinforcement investments. This is possible especially on feeders where the load varies considerably.



3. It is possible to cut the transmission/distribution fees charged to electricity end-users during the large-scale adoption of electric cars, if the charging system is well-planned and enough intelligence is included in it. And opposite situation with charging system without intelligent control.
4. *Load variations of medium-voltage feeders* have to be taken into account in the analyses. The charging mode used on the city area feeder does not provide the desired end result on the rural area feeder. An intelligent charging system has to be able to take into account to which feeder each electric car is connected and where it is charged.



5. **Biggest challenges in low-voltage networks.** In the worst case the triple extra capacity has to be invested (home, work, cottage). However in Finland we have a lot of experience of transposition of loads (sauna oven, electric space heating, water heaters, block heaters).

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