CLEEN
Cluster for Energy and Environment

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Task 5.2.1: **Behaviour of customer activities and interactions**

sgem
Smart Grids and Energy Markets

Lappeenranta University of Technology

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8.2.2011 Espoo

Research objectives of the task:

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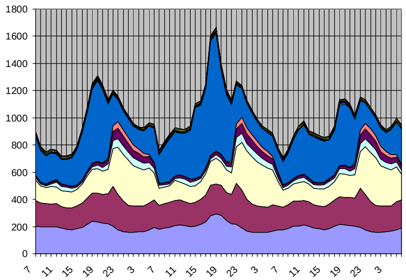
1) Analyze, how customers behave when they get incentives to adjust their consumption

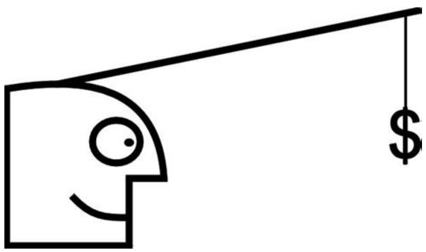
2) Determine the impacts of the customers behavioural change for DSOs

Outline of presentation

1. Customer load modelling



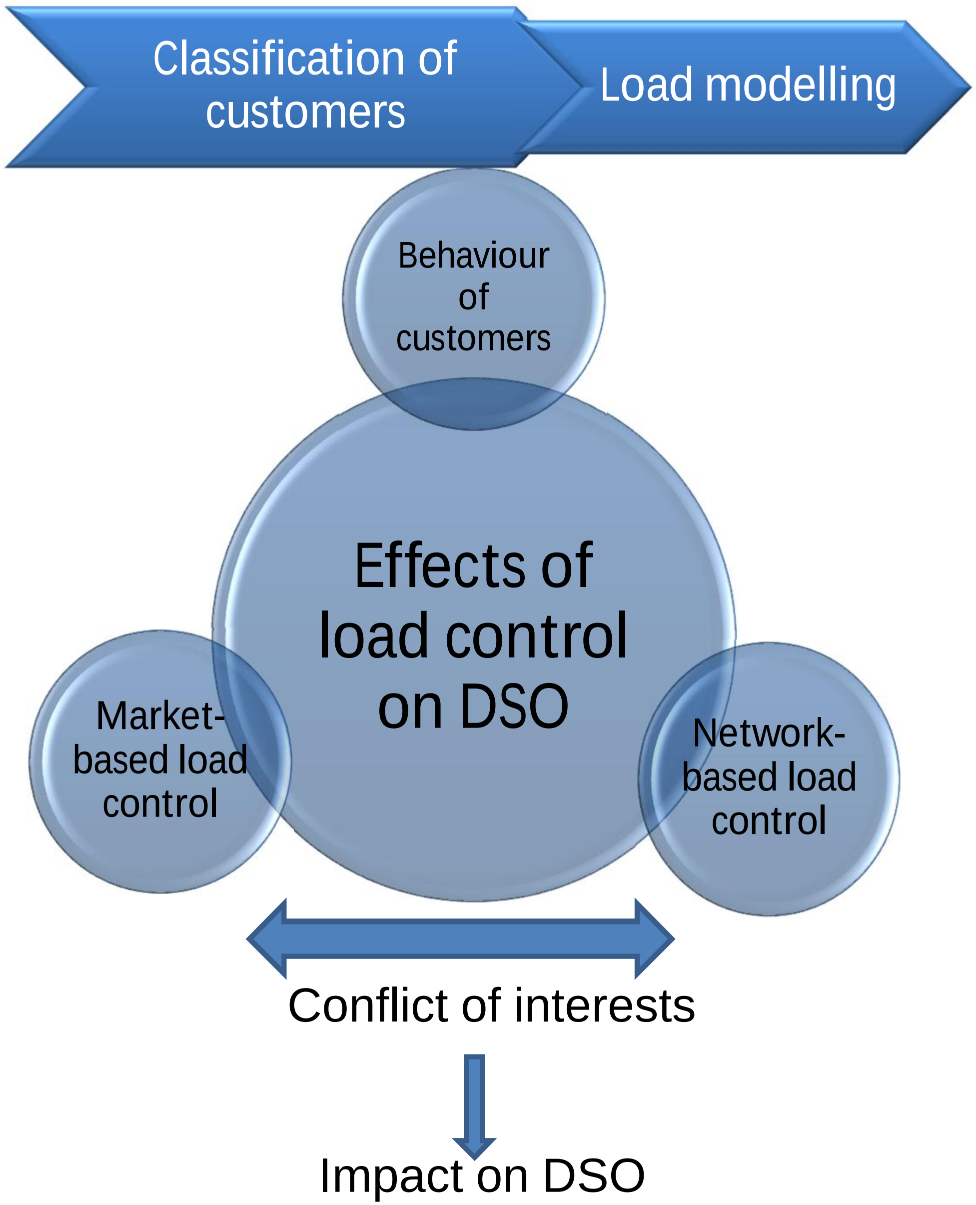
2. Incentives for customers to control load



3. Load control possibilities

4. Impact on DSOs

Structure of research question



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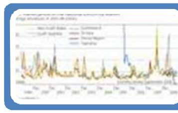
Customer load modelling

1. Classification of customers


Customer's appliances types and sizes

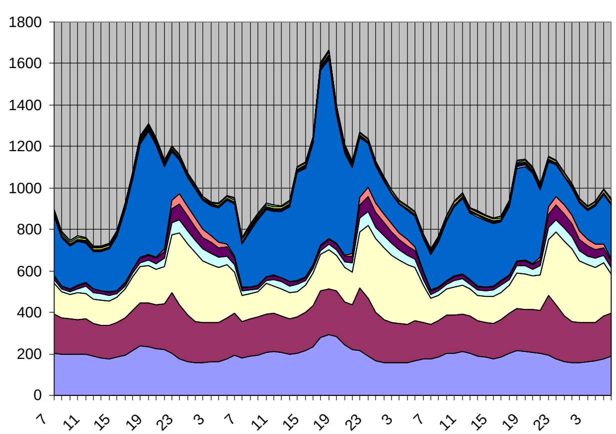

Load control based on own customer's decisions


Load control based on network signals

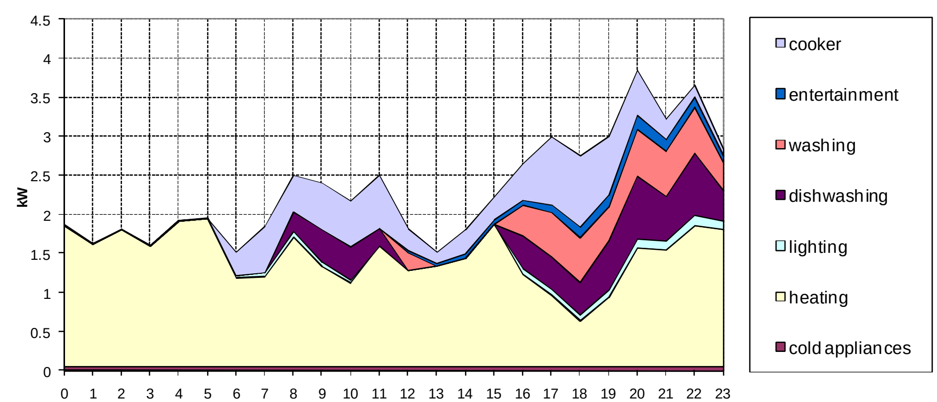

Load control based on market signals

2. Load modelling

Simulated feeder load curve with customer type classification



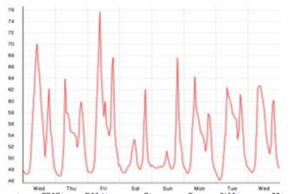
7 customers with direct electric heating.
Modelling carried out by Monte-Carlo simulations



Incentives for customers: savings in money!

Electricity markets

supplier



1201	2004	1	1	9:00	158
1201	2004	1	1	10:00	315
1201	2004	1	1	11:00	380
1201	2004	1	1	12:00	301
1201	2004	1	1	13:00	146

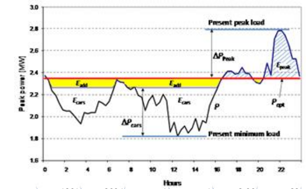
Data: hourly price, price forecasts

Price signals

Grid

DSO

Power signals



1201	2004	1	1	8:00	33
1201	2004	1	1	9:00	158
1201	2004	1	1	10:00	315
1201	2004	1	1	11:00	380
1201	2004	1	1	12:00	301
1201	2004	1	1	13:00	146

Data: feeder load curve, peak powers, load forecast, distribution fee

Enabling technologies: Interactive Customer Gateway

Active customer

Load control possibilities

Loads

Electric heating... | Heat pumps | Electric vehicles (G2V)

Data: hourly use of electric heating and home devices; heat pump penetration rate, coefficient of performance

Data: number of EVs, driving schedule, properties of batteries, charging powers

Storages

Electric vehicles (V2G) | Battery

Data: number of EVs and batteries, driving schedule, properties of batteries, dicharging (V2G) powers

Generation

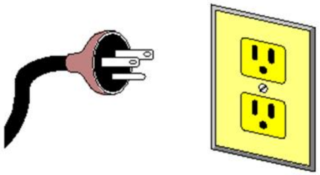
Wind power | Solar power

Data: Wind speed, turbines, production

Data: radiation, panel properties, production

Types of Demand response

- Demand Response
  - Market - based
    - Follow → Bill savings
    - Override → no savings, no losses
  - Network-based
    - Follow → Payment
    - Override → Penalty



Methodology to evaluate load control possibilities

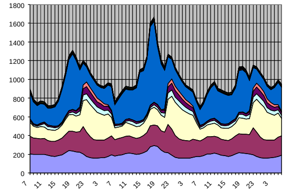
Direct load control (network-based)

NIS
(Network Information System)

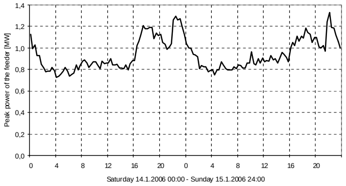
CIS
(Customer Information System)

SCADA
(Source of measurement data)

Simulated feeder load curve



Measured feeder load curve



Impact on DSO
ΔP

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Market-based load control

Classification of customers according to elasticity

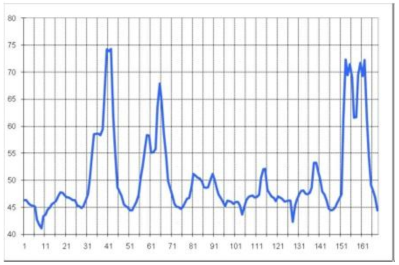
$$e = \frac{\Delta P_{ij} / P_i}{\Delta C_{ij} / C_i}$$

Cottage house

e1

Row house

e2



e3

Summer house

e4

Apartments

Inelastic:

Loads are almost not affected by changes in price, e = 0.2
Wa < 10 000 kWh

Impact on DSO

$$\Delta P_{ij} = e \cdot \frac{\Delta C_{ij}}{Ci} \cdot P_i$$

Elastic:

Loads are sensitive to price changes, e = 1.2
Wa > 10 000 kWh

Impact of load control on DSO business profit

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Savings require continuous success of load control

!

Permanent savings

Temporary savings

Distribution fees ⇐ DSO ⇒ Delay in investments

$$\Delta P_{DSO} = \sum_{i=1}^{N} \Delta P_i$$

ΔP_1 ΔP_2 ΔP_N

Feeder 1 Feeder 2 .... Feeder N

ΔP - peak power change on a feeder

DR effects on a case distribution company

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Scenario		Peak power reduction %	Peak power reduction kW	Annual savings, k€/a	Distribution fee cut, cent/kWh	Delay in investments
Incentive-based demand response						
No energy storages	I, 20 %	3	60	7.7	0.14	2 a
	II, 80 %	10	180	22.8	0.4	7 a
Energy storages, 5 %	I, 20 %	5	90	11.7	0.2	3.5 a
	II, 80 %	11	208	26.9	0.47	8.4 a
Energy storages, 30 %	I, 20 %	13	250	32.4	0.57	10.1 a
	II, 80 %	19	345	44.7	0.78	14.5 a
Price-based demand response						
Low elasticity	1.2 + 0.2	1.7	30	3.9	0.07	1 a
High elasticity	2.0+0.6	2.98	60	7.7	0.14	2 a
Incentive-based and price-based DR						
No energy storages + low elasticity	I, 20 %	3	60	7.7	0.14	2 a
	II, 80 %	11,9	210	27.2	0.48	8.4 a

Optimizing retailer's energy purchases and sellings

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Approach: optimize energy costs for energy purchases and sellings for retailer

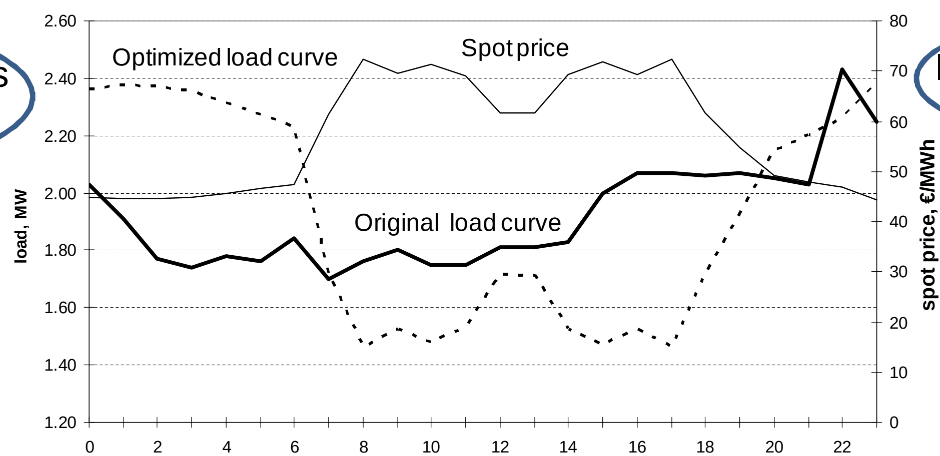
Assuming that hourly energy costs are equal to each other during a day, we get optimized load curve.

$$E_{procured} = \int_1^{24} \mathrm{Price}(t) * \mathrm{Load}(t)dt = \sum_1^{24} \mathrm{Price}(t) * \mathrm{Load}(t) = \sum_1^{24} E_{const} \Rightarrow E_{const} \cdot \left(\frac{1}{\mathrm{Price}(1)} + \frac{1}{\mathrm{Price}(2)} + \dots + \frac{1}{\mathrm{Price}(24)}\right) = \sum_{t=1}^{24} \mathrm{Load}(t)$$

$$E_{const} = \frac{\sum_{t=1}^{24} \mathrm{Load}(t)}{\left(1/\mathrm{Price}(1) + 1/\mathrm{Price}(2) + \dots + 1/\mathrm{Price}(24) \right)} \Rightarrow$$

Optimized load curve $\mathrm{Load}(t) = \frac{E_{const}}{\mathrm{Price}(t)}$

Optimized load curve is theoretically possible!

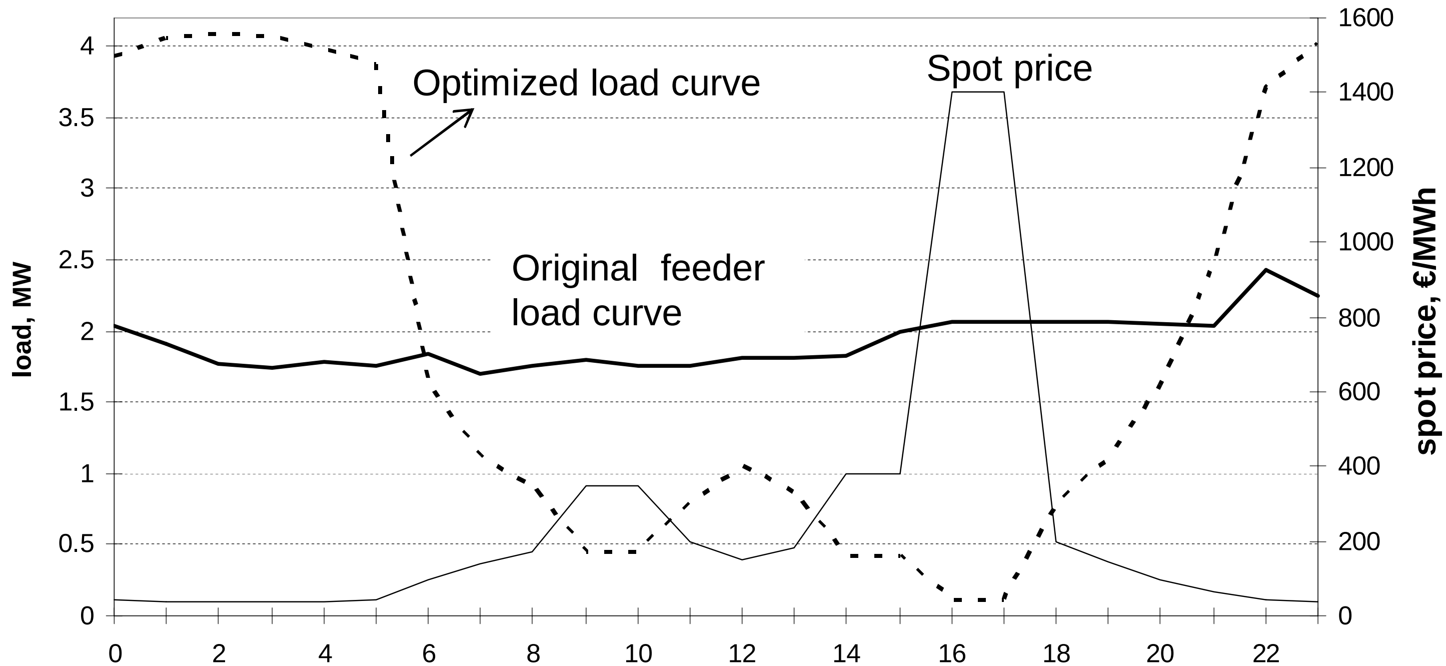


It is inversely proportional to spot price curve

Conflict of interests: retailer's load control

Optimization target: the optimized load curve follows the spot market prices so that consumption decreases when price increases and vice versa. That way retailer's daily energy costs are minimized.

Critical peak price winter day



Savings for retailer

68% savings in energy costs after price-based load control

Conflict of interests between retailer and DSO

Disadvantage for DSO

Increased peak power and power losses => increased investment costs

Conflict of interests: customer's load control

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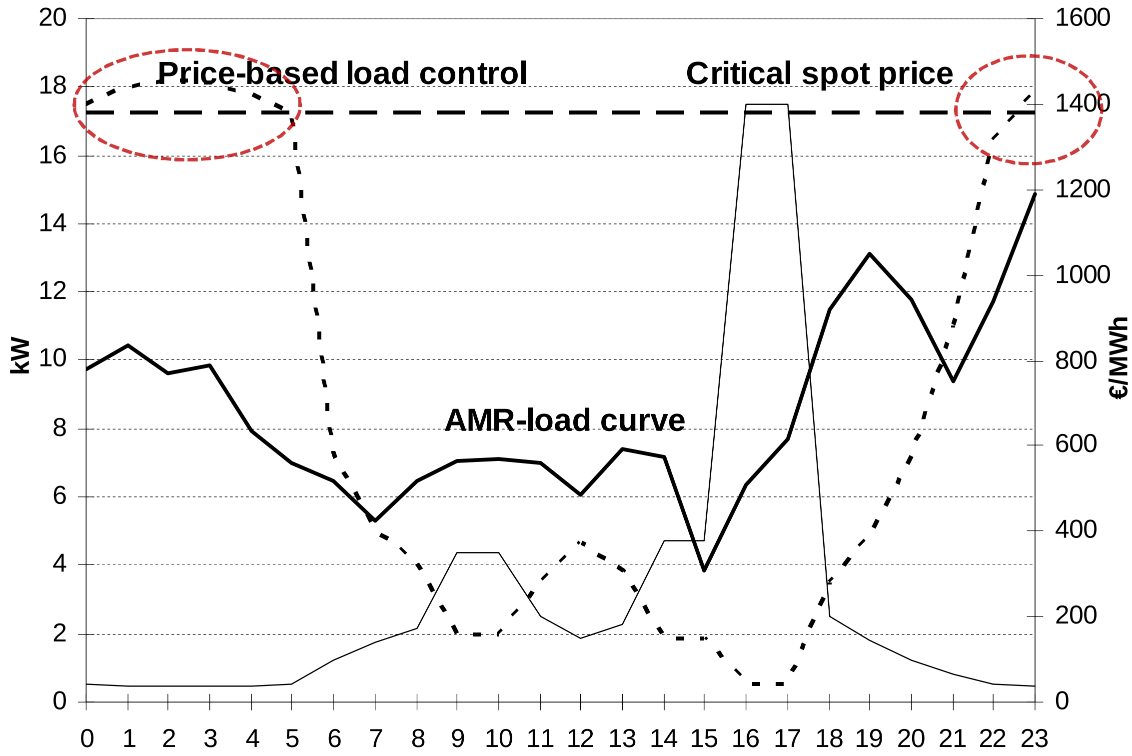
Example

As a result of price-based load control (critical spot price day) a customer has exceeded the allowed contractual power limit 17.2 kW (fuse 3x25A, 230V)



This illustrates conflict of interests between DSO and customer

Conflict of interests part II

One way to solve the conflict is to set a dynamic network tariff

Now: flat rate or two-time tariff between DSO and customers

Suggestion: dynamic tariff between DSO and customers, cost-reflective for the network and satisfying comfort requirements for customers

Scenarios:

1. Energy-based component variable, power-based component fixed

2. Power-based component variable, energy-based component fixed

3. Both energy- and power-based components are variable

Dynamic network tariff : energy-based component variable

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Assumption: energy-based component increases by 50% (3.4 cent/kWh -> 5 cent/kWh) during the hours when power limit is exceeded and for those powers which are above the limit

Energy payments from a customer to retailer and DSO on a critical peak price day

	Payments to retailer	Payments to DSO	Total payments for customer
Without load control	44 €	7 €	51 €
Price-based load control	16.8 €	9 €	25.8 €
Price-and network-based load control	17.3 €	7 €	24.3 €

Change in savings is small !

Conclusion: customer may not have enough incentives for dynamic network tariff with energy-based component variable, because the difference in savings is very small. This kind of tariff poses network company at risk that customer will exceed the limit.

Dynamic network tariff: power-based component variable

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Target: calculate, how much more and how a customer has to pay to DSO?

Assumption: a customer exceeded his contractual current limit X times per year

Approach: the estimated increase in power-based component can be found by calculating the following coefficients:

$$k_1 = \frac{P_{\text{max, customer, hour i}}}{P_{\text{feeder, hour i}}}$$

- shows, what is the contribution of customer's peak load to the feeder load at the hour of exceeding customer's power limit

$$k_2 = \frac{P_{\text{feeder, hour i}}}{P_{\text{max, feeder}}}$$

- shows, what is the contribution of the feeder power value at the hour i to the set power limit of the network company

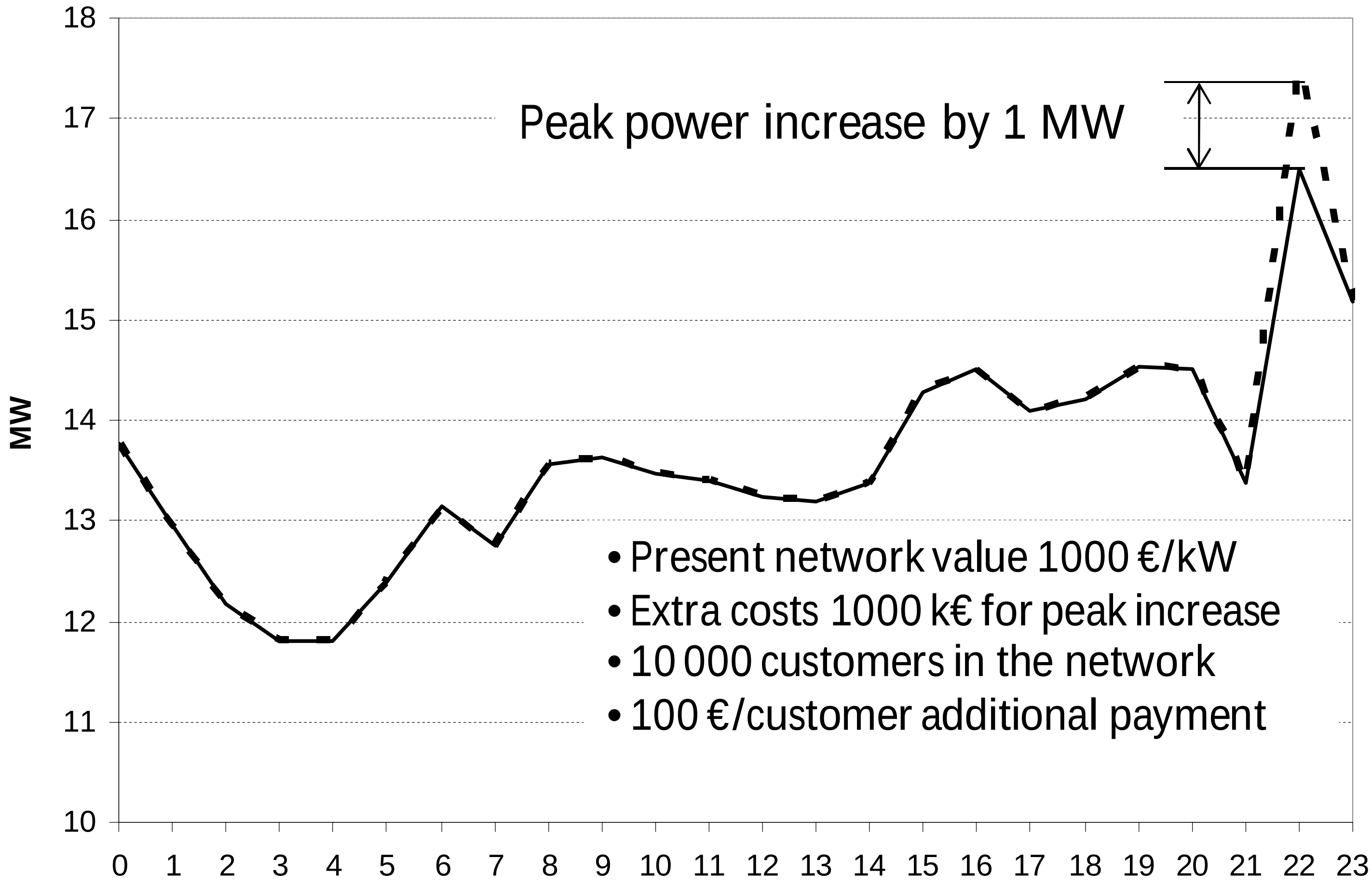
$$\text{Payment} = \text{Contractual power payment}(1 + k_1 * k_2 * \beta)$$

where ß - customer's specific coefficient, which depends on customer's heating type, consumption level…

Simplified approach:

Dynamic network tariff: power-based component variable

Simplified approach: calculate average cost of growing capacity (€/kW) for a distribution network customer



Conlcusions

1. The presented methodology requires accurate information about consumption patterns of customers, such as AMR data, in order to make quantitative results trustworthy

2. For a case feeder, the peak power can be reduced by 10 % due to direct load control of el.heating loads. As a result, end-user distribution fee (energy-based) can be cut by 0.4 cents/kWh, or investments delayed by 7years. The cut in peak power in long-term requires permanent customers' response!

3. A dynamic tariff structure for customer groups depends on their consumption level, load groups and technical possibilities for load control.

Further questions:

1. Important question is, what is the cost of exceeding one ampere for an average LV-network customer, so that the customer has incentives to keep his power under the limit during the year?

2. What will be the effect of dynamic tariff on the network load curve in long term. How it would affect the network company profit, and finally change the end-customer distribution fee?