CLEEN
Cluster for Energy and Environment

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Theme 1 - Smart Grids architectures

sgem
Smart Grids and Energy Markets

WP1.1: Significance of electricity and Smart Grids

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Underground Cabling

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Energy Technology | Electrical Engineering | Environment Technology

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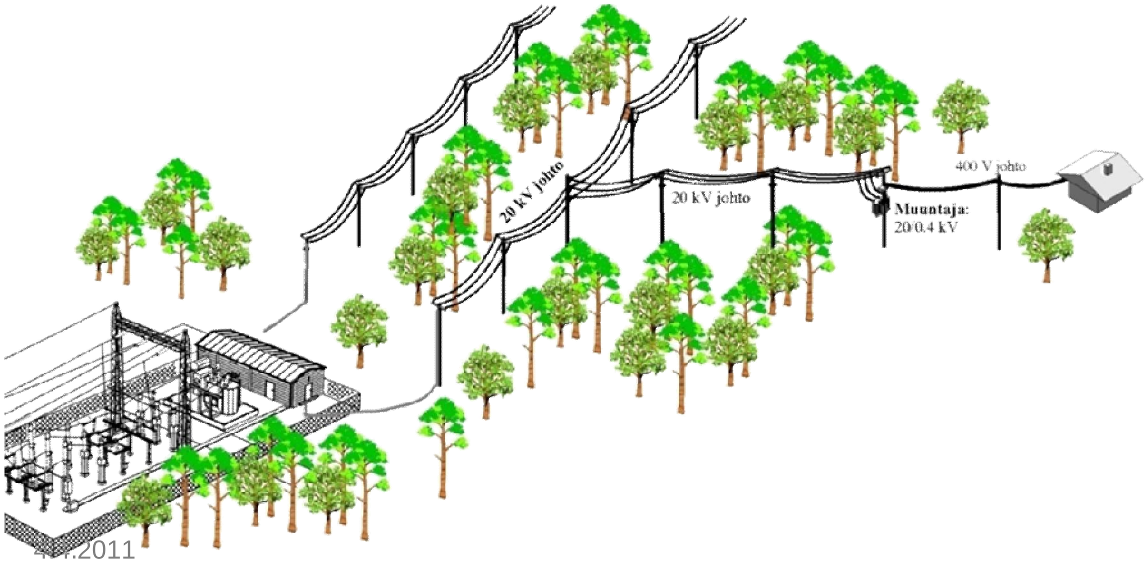

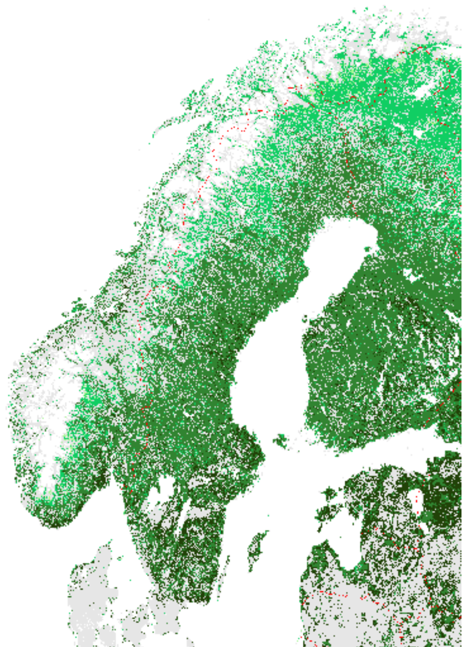

Underground cabling
Drivers

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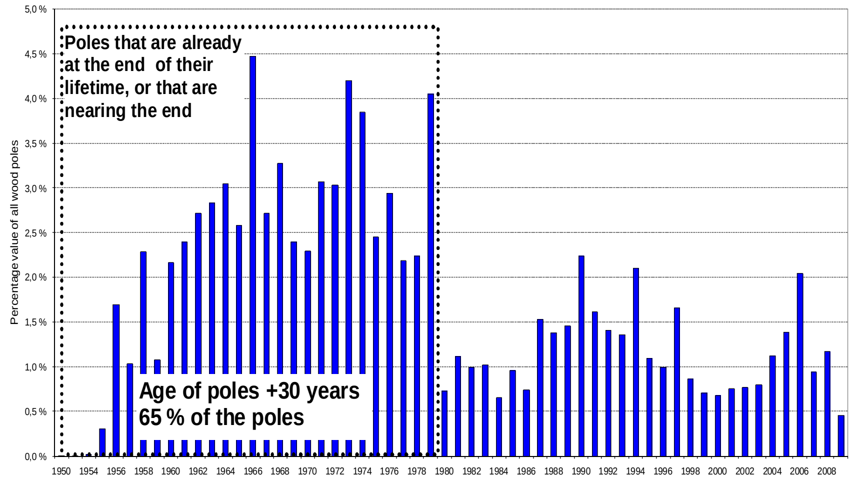
- ❑ Aging of network
- ❑ Need of better reliability
- ❑ Economic regulation
- ❑ Technical challenges
- ❑ Environmental issues
- ❑ Energy policy
- ❑ Needs of society



Underground cabling
Strategy process

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General strategic planning

Consideration of the potential of exploitation of different network structures

Reliability of the distribution should be improved

Aged network structure

Reliability analysis

Network topology

A) Strategic analyses
- Comparison of technologies
- Reliability evaluation
- The goals of network development
- Evaluation of the state of present network
- Assessment of parameters

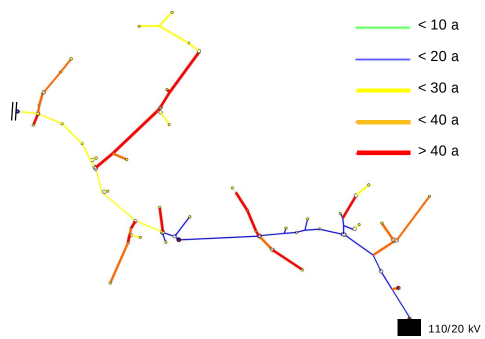
B) Strategic decisions

Network structure is changing towards underground cabling

C) Assessment of the underground cabling process (*Cabling concept*)
- Locating of suitable targets
- Evaluation of the timing
- Priority of the targets in the renovation
- etc

30 fault during last 4 years, network length 100 km

7,5 fault/100 km



Assessment of the considered method: Underground cabling

Underground cabling
Strategy process

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Cabling process

1. *Where the cabling is implemented?*
2. *When the cabling is started?*
3. *How the cabling is implemented?*
4. *What is the priorization of the cabling sections?*
5. *Is there any opportunity to decrease costs with cooperation with other service providers (tele operation, district heating, water distribution, etc)?*

Underground cabling
Cabling process

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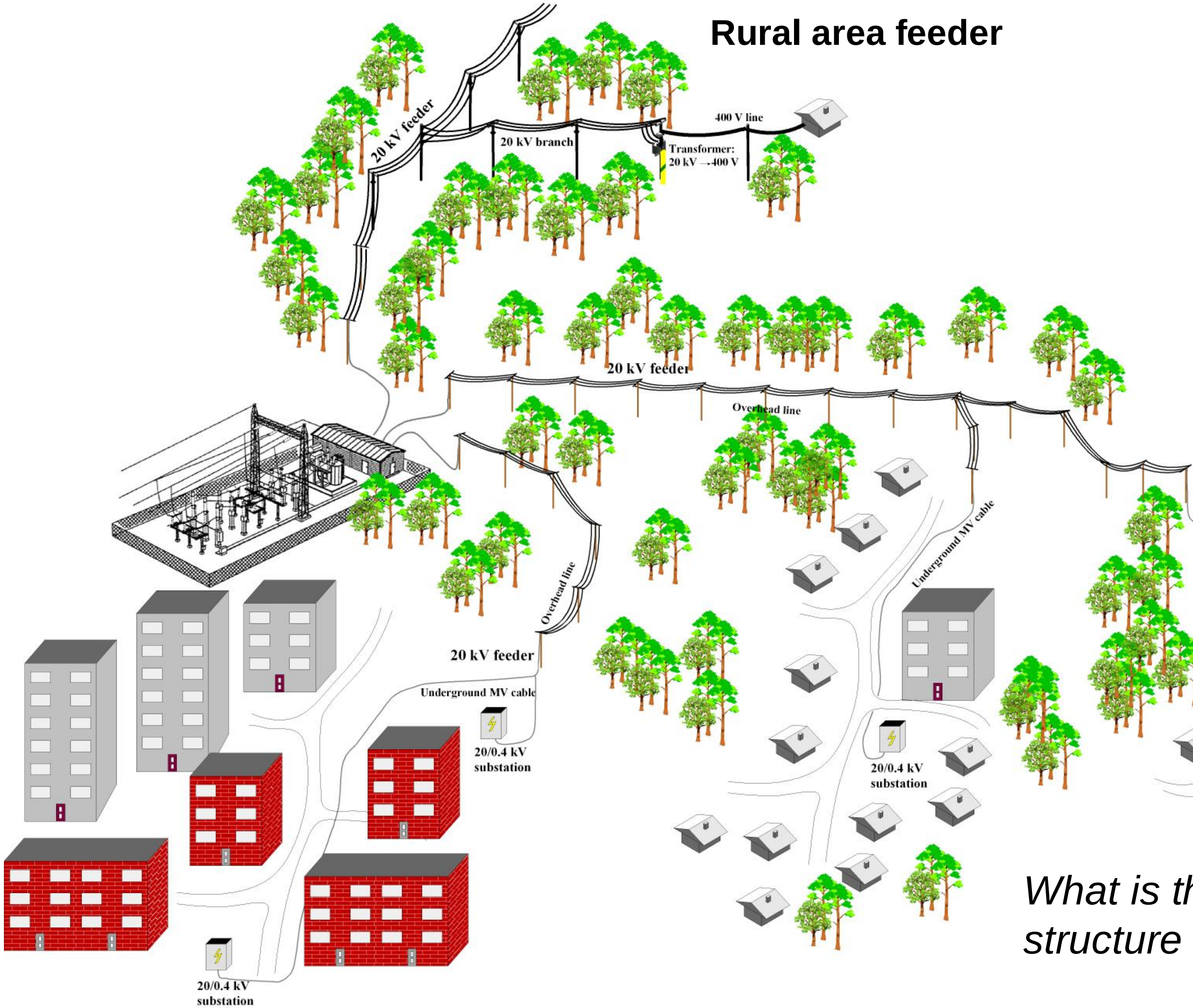
Where the cabling is implemented?

Rural area feeder



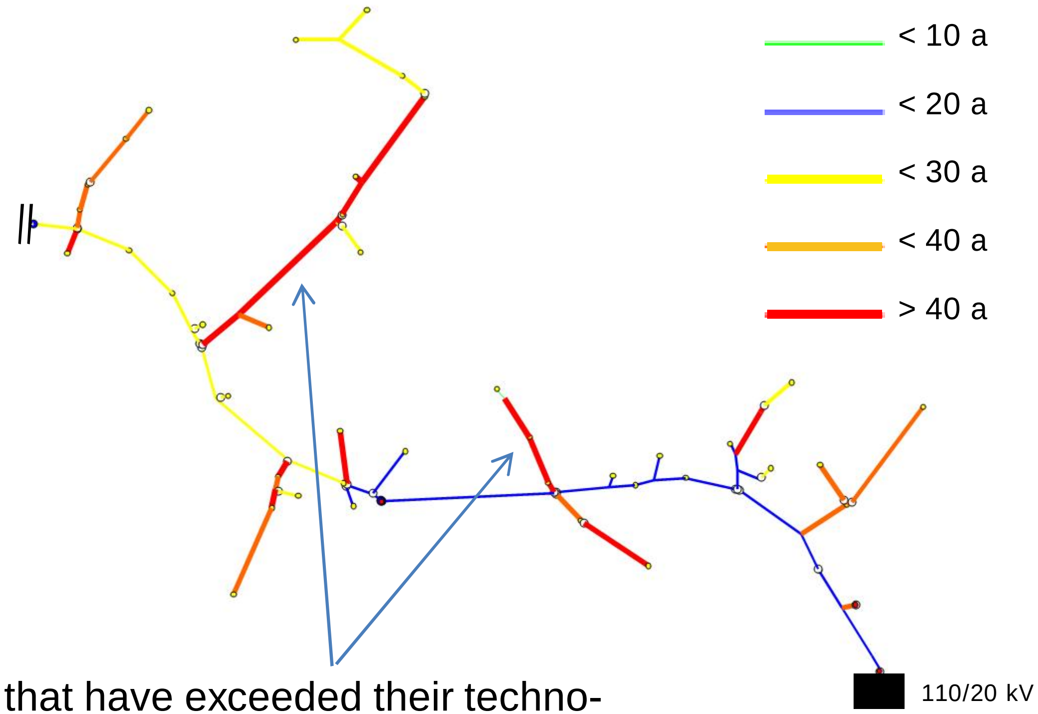
Urban area feeder with lower load density

Urban area feeder with high load density

What is the age and line structure in the studied areas

Underground cabling
Cabling process

When the cabling is started?



Feeder sections that have exceeded their techno-economic lifetime and which are in bad condition

Is the cabling needed to start within the next years or is it reasonable to delay the starting point by 10 years

a) *Step by step carried out renovation (small section are renovated each year) is suitable for networks that have lines from all age groups*

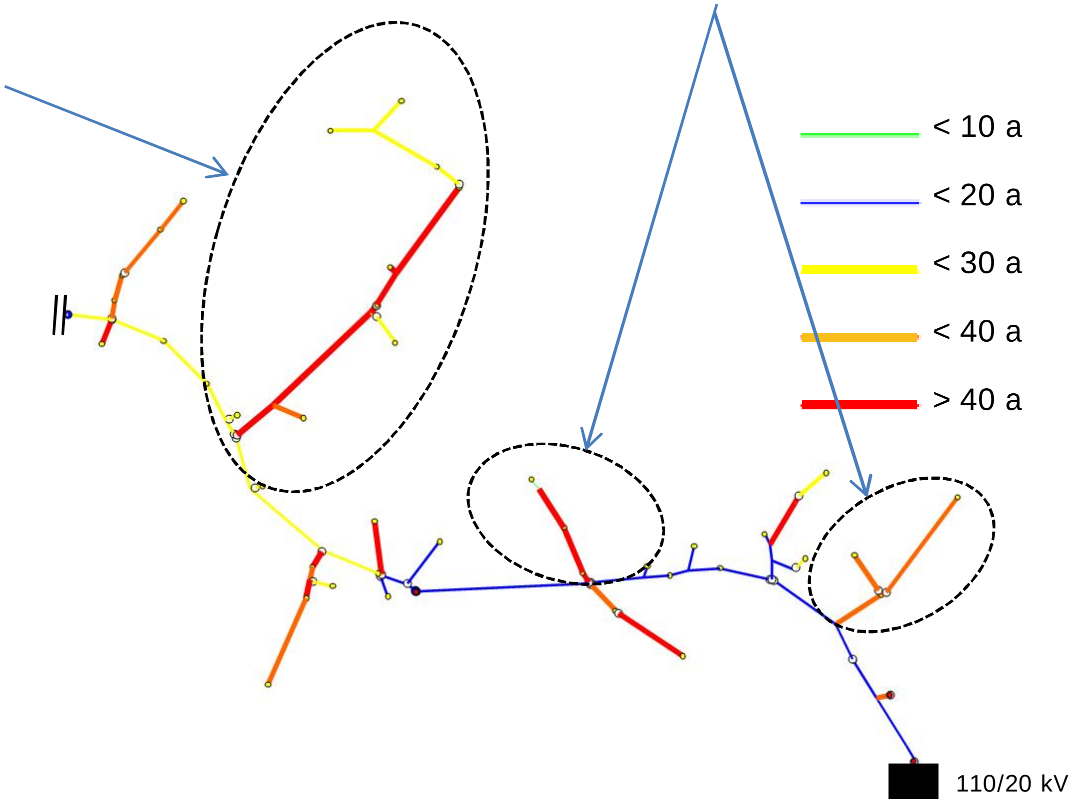
b) *Rapidly carried out cabling (renovation is completed fast) process removes workable lines from the network if age varies significantly between the line sections*

Underground cabling
Cabling process

When the cabling is started?

Rapid cabling process:
This provides an opportunity to improve reliability in the renovation area remarkably with lower unit costs [€/km], but on the other hand it may cause massive write downs because of removal of the workable lines

Step by step renovation:
Gradual cabling can be focused on the targets, where it is most necessary.



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Cabling process

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How the cabling is implemented?
Utilization of cabling techniques

1. Traditional excavation

2. Plowing method

3. Use of chain excavator

Significant part of the total excavation costs consist of the cost component that depends on the used cabling method or technique.

The costs of the cable installation can vary significantly between the techniques. In the suitable ground the costs from the plowing can be only a fraction of costs of traditional excavation. It has been studied that costs from plowing are averagely 50 % from the costs excavation and the suitable ground to plowing method can represent even 80% of the targets.

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Cabling process

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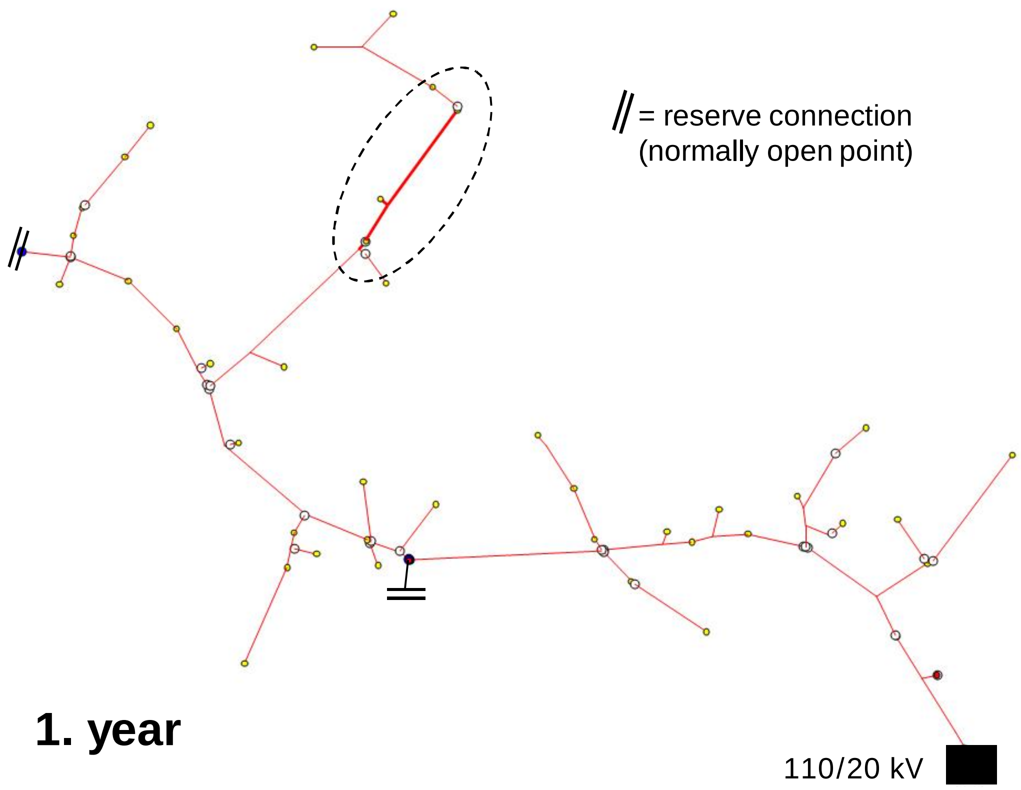
What is the priorization of the cabling sections?



An example of priorization order in the examined network

A. Technical restrictions
B. Age of the lines
C. Faulting vulnerability
D. Suitability of ground
E. Branch lines
F. Other reasons

In this case the priority is: An old branchline locating in conditions where faulting vulnerability is high

Underground cabling
Cabling process

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Co-operation with the other infrastructure operators

- Planning of the infrastructure investments together with other operators
- Utilization of excavation for several purposes e.g. electricity distribution cable, optic fiber, water pipes.
- The unit price of cabling can be significantly lower

Underground cabling
Compensation of earth fault currents

Centralized compensation

- *Compensation coil is located to substation*
- *Typical size of the unit is from 50 A to 100 A*
- *Can be used to reduce autoreclosing*
- *Automatic control of system*
- *Big unit size -> risk of failure*

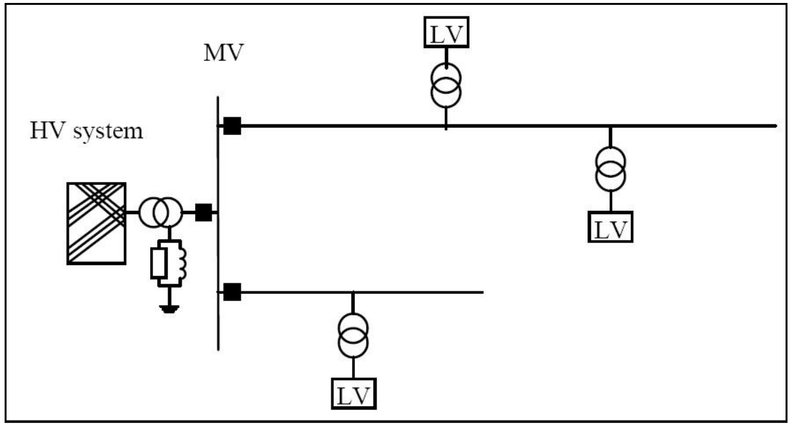
For instance:
100 A = 100 k€
→ 1 k€ / A

Decentralized compensation

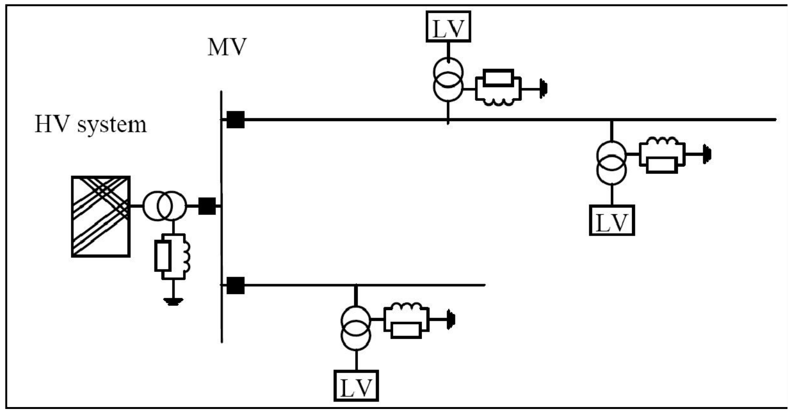
- *Can be divided all over network*
- *Suitable for changing network topologies*
  - *Flexible in renovation that is carried out steply*
  - *Adapts well into exceptional situation such as back-up supply*
- *Technique is developing*

For instance:
5 A = 10 k€
→ 2 k€ / A

Centralized



Combined compenstion



Underground cabling
Back-up power arrangements

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Reserve connections
- *More loops into networks*

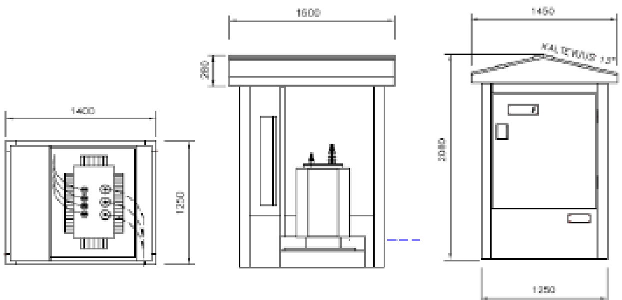
Movable aggregates
- *What is needed amount of aggregates*
- *Requirements for the network*
    - *Connection points: substations, RMU units in the network*
    - *Restriction of fault, power of aggregate has to be enough to supply the interrupted load*

Back-up cables
- *Length of reserve cable (0.5 km)?*
- *Operation with crossing of the roads*
- *Requirements for the network*
    - *Connection points: substations, RMU units in the network*

Underground cabling
Network topology

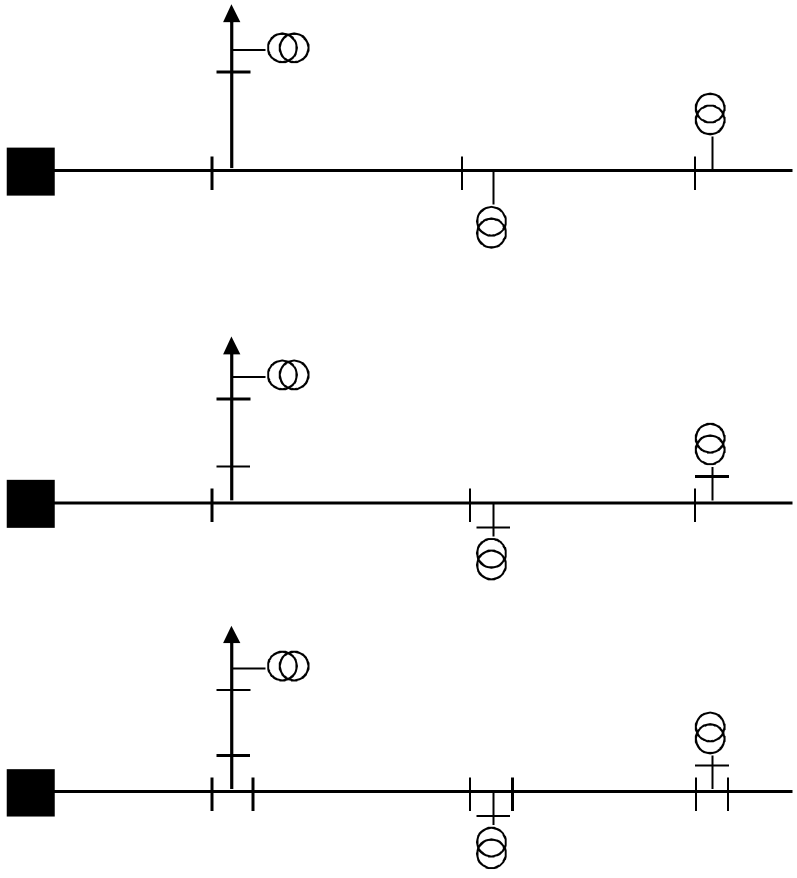
1) Open questions
   - What are suitable technical structures to rural area cable networks
   - The costs and interaction of solutions to network topology
2) Substations
   - Satellite substations with simple structures (price approximately 5 k€ without transformer)
   - With one or zero disconnect device
   - Possibility to connect reserve power
3) Disconnectors
   - MV link box, which includes air insulated line disconnector or 2+1 SF6 disconnectors
   - RMU devices are installed into substation structures
   - Costs are approximately equal to polemounted disconnector stations (+10-20 %)
   - RMU-units always remotely controled

Substation

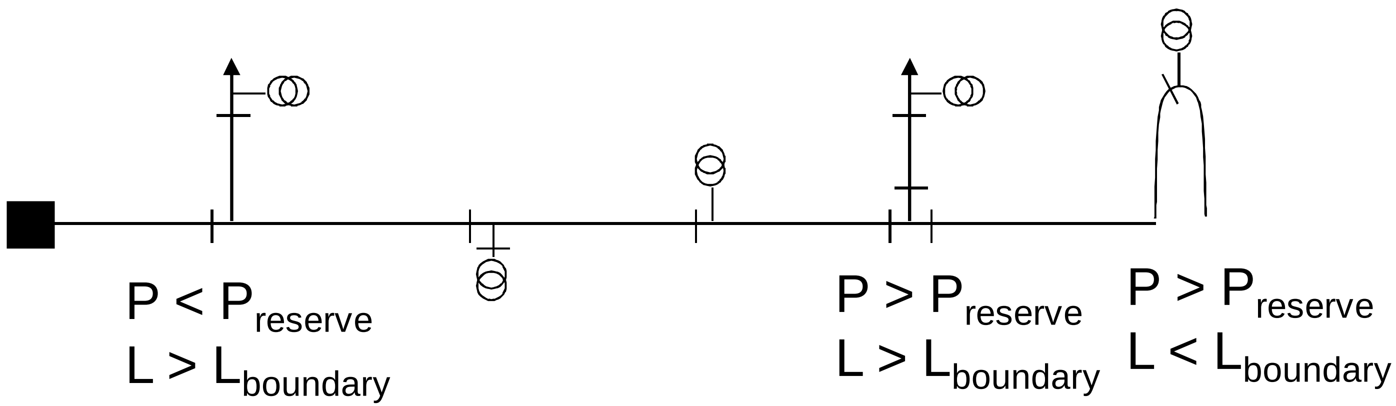


MV link box

Underground cabling
Network topology



- Each cable is possible to disconnect so that faulted area includes max. one distribution substation
- In case of branch lines the solution depends on the power of load, length of branch, costs of disconnectors and back-up supplies



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Underground cabling
Network topology

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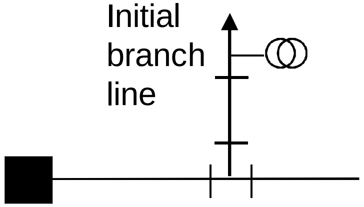
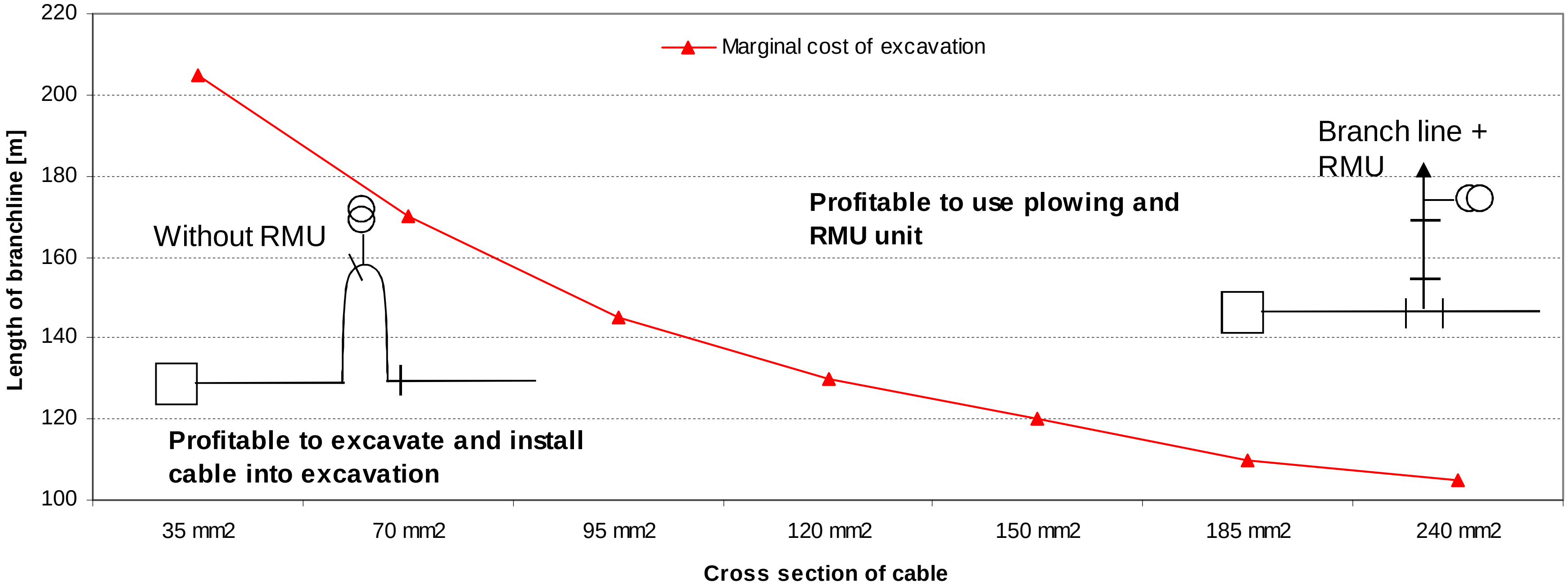
Profitability of installing cable with or without ring main unit (RMU)



Excavation 10000€/km, Plowing 5000€/km + RMU 5000 €/unit



Underground cabling
Cost components

Investment costs of cabling consists of:

$$C_{\mathrm{inv}}(t)=\begin{pmatrix} C_{\mathrm{cab}}(t)+C_{\mathrm{exc}}(t)+C_{\mathrm{comp}}(t) \\ +C_{\mathrm{subs}}(t)+C_{\mathrm{res}}(t) \end{pmatrix}$$

where C_{cab} = material costs
C_{exc} = excavation costs
C_{comp} = compensation costs
C_{subs} = substation costs
C_{res} = reserve power costs

CABLE

For instance
70 mm²
25 € / m

CABLING

Excavation:
10-15 € / m
Ploughing (plowing):
2-4 € / m

RENOVATION OF DISTRIBUTION TRANSFORMER

Depending on transformer density in the area, for instance
5 € / m

COMPENSATION OF EARTH FAULT CURRENTS

Depending on technology (centralised or distributed), for instance
1-3 € / m

BACKUP POWER

For instance 500 kVA
50 k€/unit
Case area 500 km:
→ 0.1 € / m

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Economic analyses

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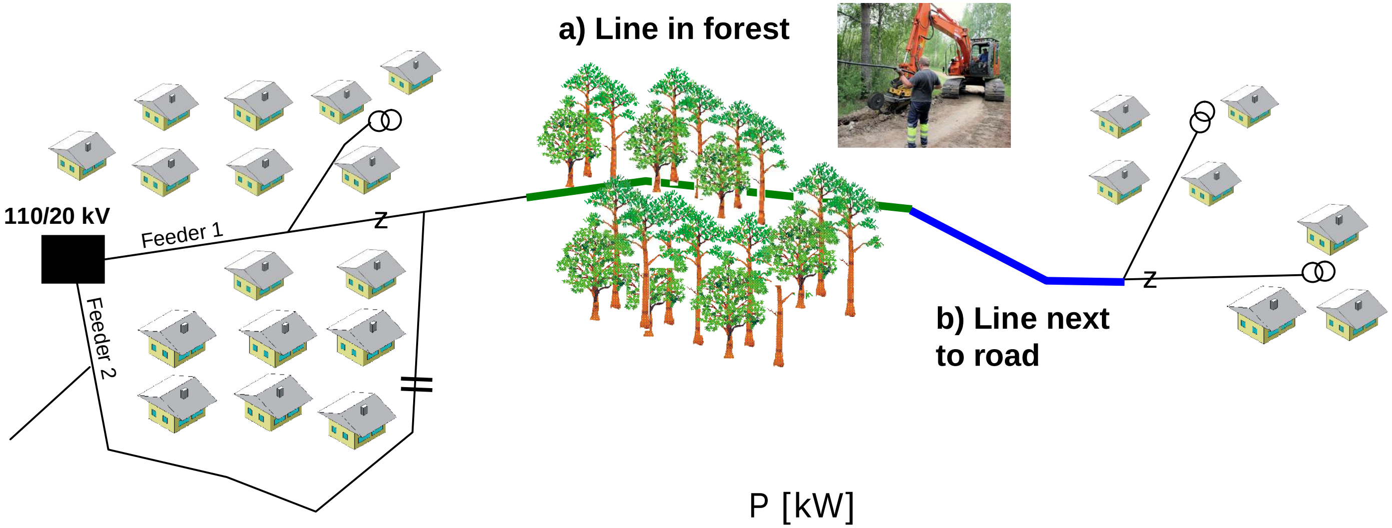


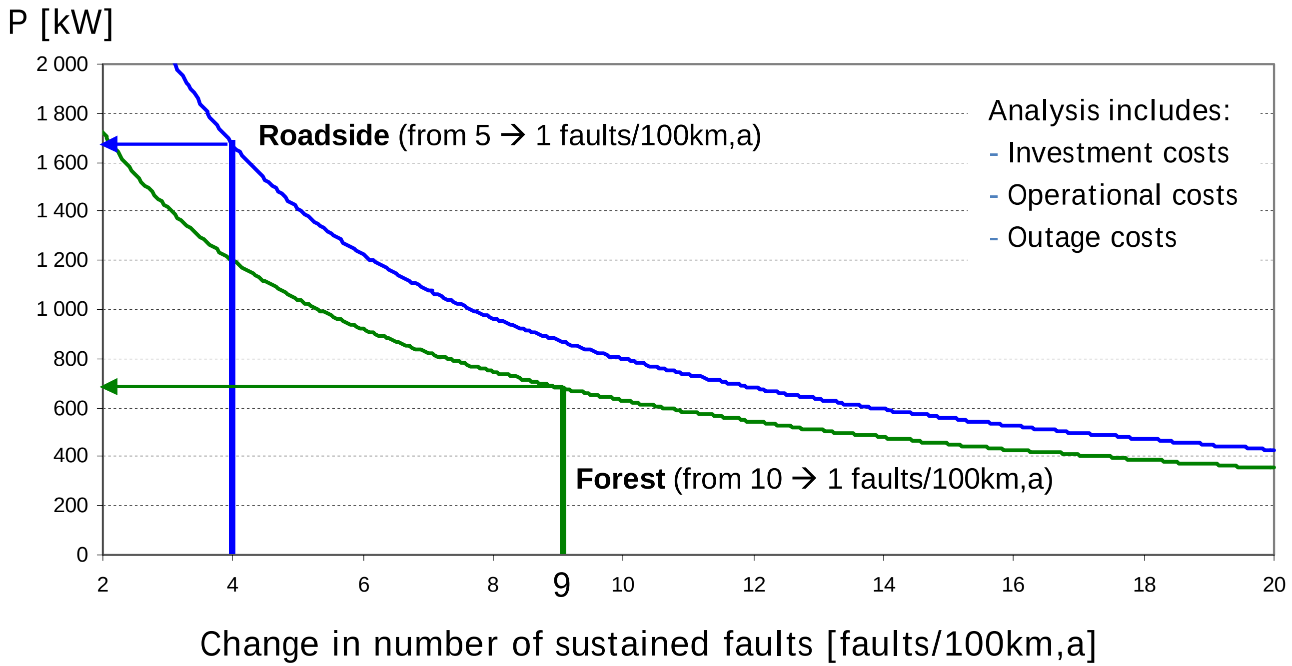
When **road side OH-line** is renovated to underground cable, sustained fault rate will decrease from **5 to 1 faults/100km,a (= change 4 faults).** If peak power of the feeder is **more than 1700 kW**, renovation is profitable.

When **forest OH-line** is renovated to underground cable, sustained fault rate will decrease from **10 to 1 faults/100km,a (= change 9 faults).** If peak power of the feeder is **more than 700 kW**, renovation is profitable.

Based on long-term statistics:

Fault rate	UG cable	OH forest	OH roadside
- **Sustained faults**	**1**	**10**	**5** faults/100km,a
- HSAR	-	25	14 pcs/100km,a
- DAR	-	10	5 pcs/100km,a
- Maintenance	58	153	124 €/km,a
- Fault repair	44	100	60 €/km,a

HSAR = High-speed autoreclosing (~ 0.3–0.5 s)
DAR = Delayed autoreclosing (~ 1–2 minutes)
OH = Over head line
UG = Underground cable



Underground cabling
Case study, network renovation

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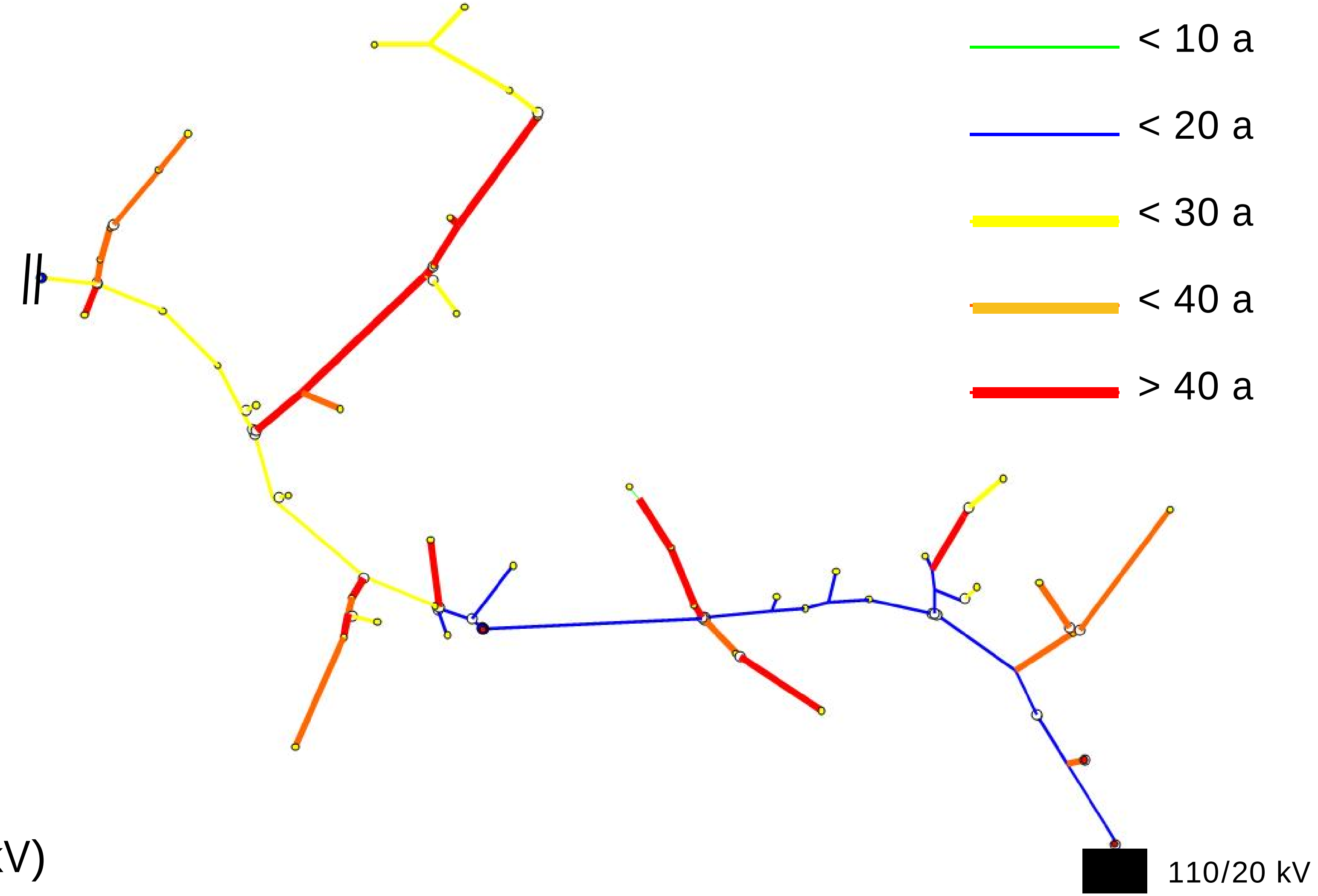
Studied medium-voltage feeder



Initial information

Forest rate: 45 %

Average age: 30 a

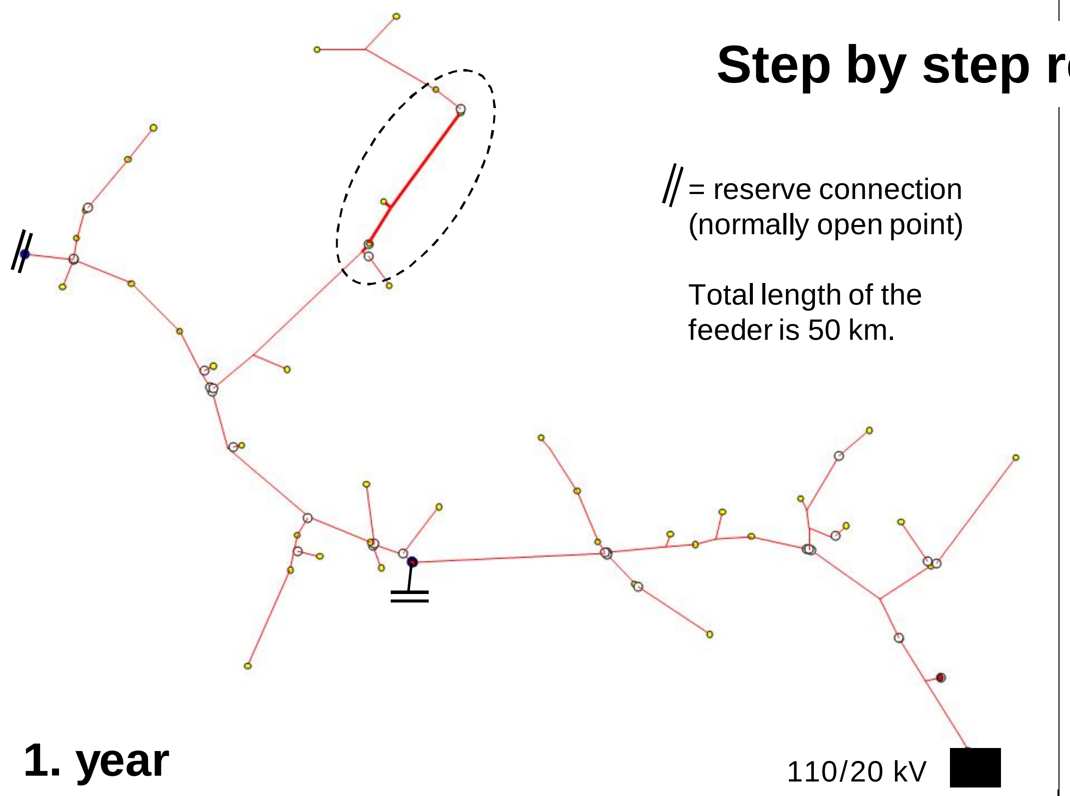
Length: 52 km (20 kV)

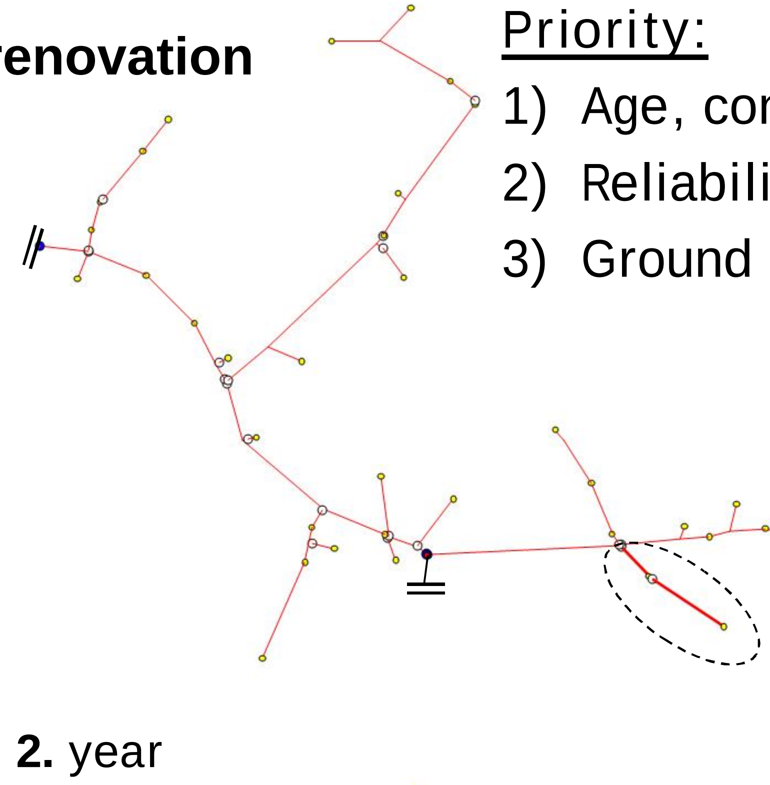
Locates in rural area

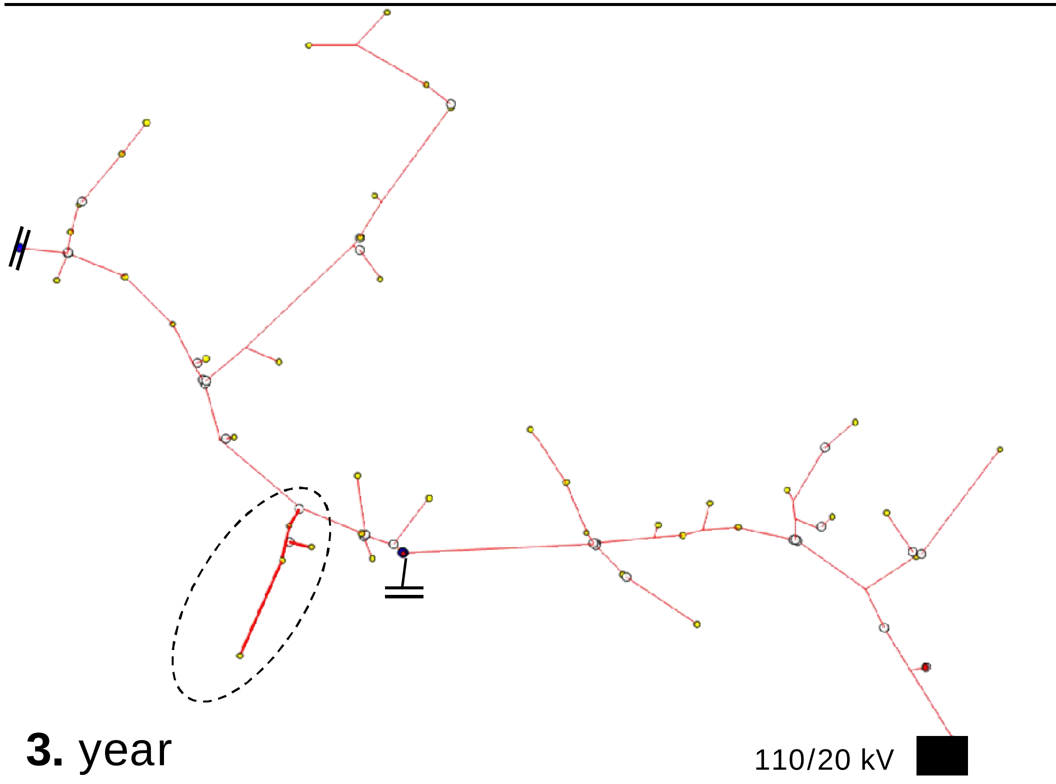
Step by step renovation

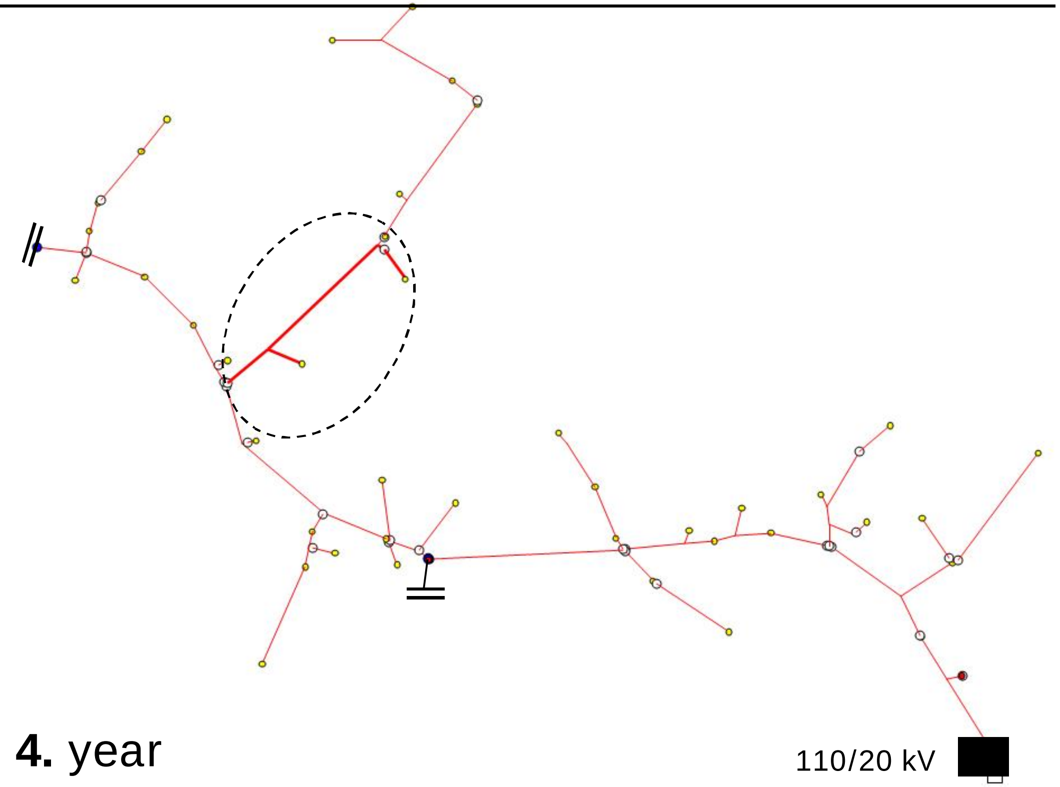
<u>Priority:</u>

1) Age, condition
2) Reliability (forest)
3) Ground properties



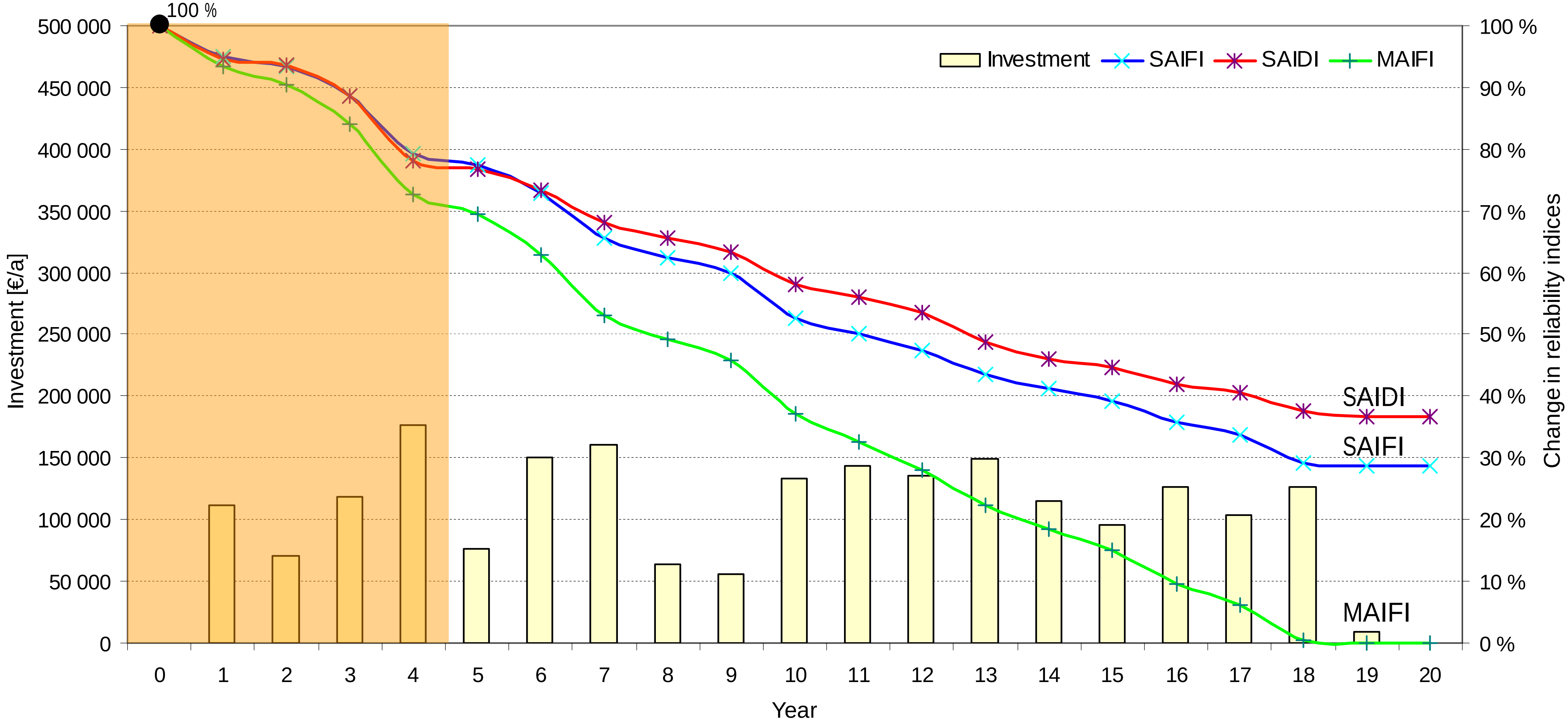






Underground cabling
Case study, network renovation

Studied feeder:
Annual investments and development of the reliability indices



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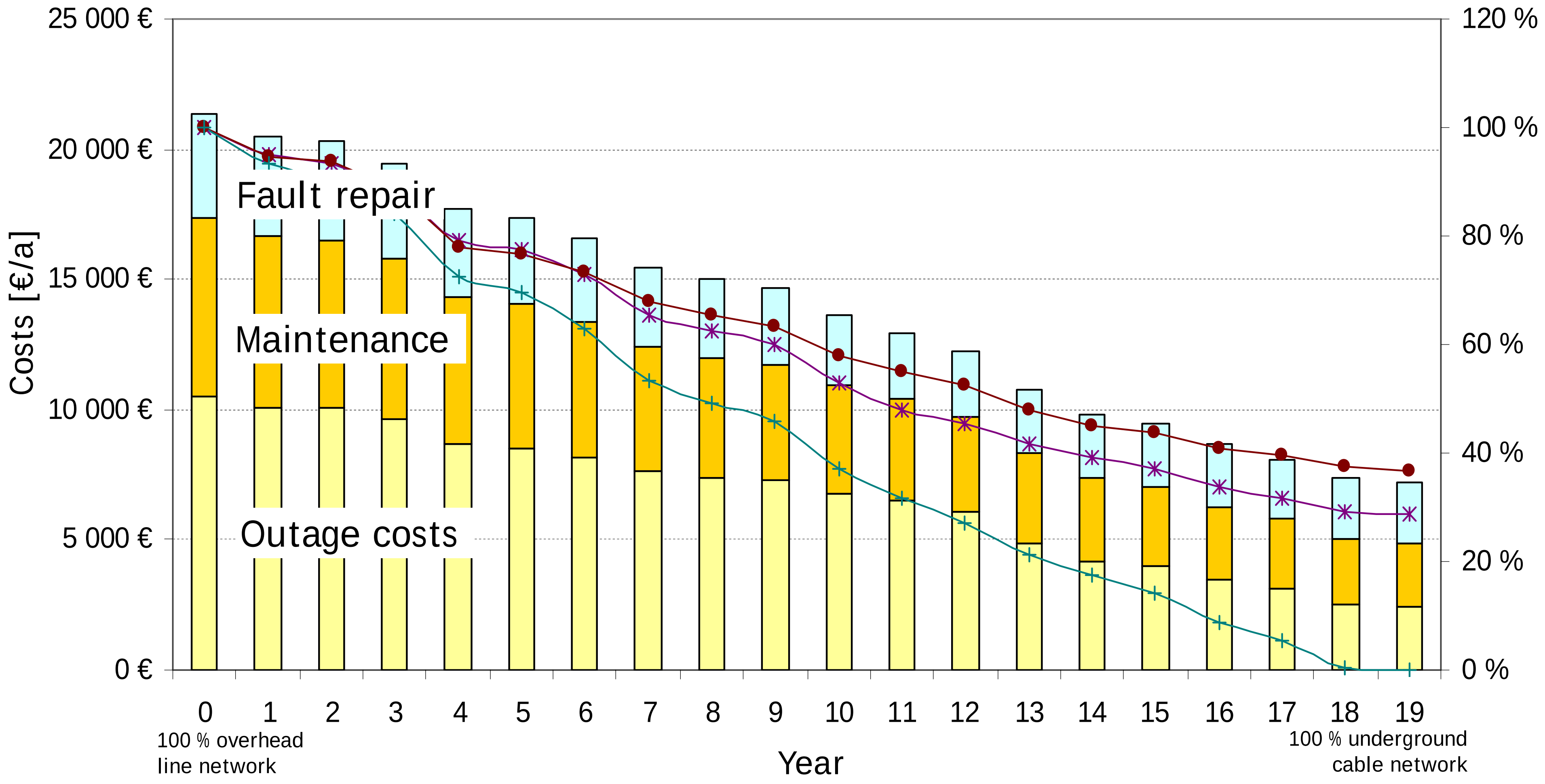
Case study, network renovation

Studied feeder:
Development of operational costs (Fault repair and maintenance) and Customer outage costs



Underground cabling
Case study, network renovation

Effect of cabling on distribution fee

Alternative 1: UG cabling vs. Line renovation to the existing line route (= wooden pole renovation)

Investments: UG 2 M€ vs. OH 0.6 M€ → Distribution fee: + 1.4 snt/kWh
(+ 1.3 snt/kWh if OPEX benefits included)

UG-cabling

Vs.

Pole renovation

or

OH-line to roadside

Alternative 2: UG cabling vs. Line renovation to roadside (= fully new OH-line)

Investments: UG 2 M€ vs. OH 1.2 M€ → Distribution fee: + 0.8 snt/kWh
(+ 0.7 snt/kWh if OPEX benefits included)

SAIFI: -72 %

SAIDI: -63 %

MAIFI: -100 %

Outage costs: -77 %

OPEX benefits = long term (40 a) economic benefits in maintenance and fault repair costs

P = 5 %, t = 40 a
E = 100 MWh/km

Underground cabling
Case study, network renovation

Effect of cabling on distribution fee

Alternative 1: UG cabling vs. Line renovation to the existing line route (= wooden pole renovation), difference in investments 1.4 M€

Alternative 2: UG cabling vs. Line renovation to roadside (= fully new OH-line), difference in investments 0.8 M€

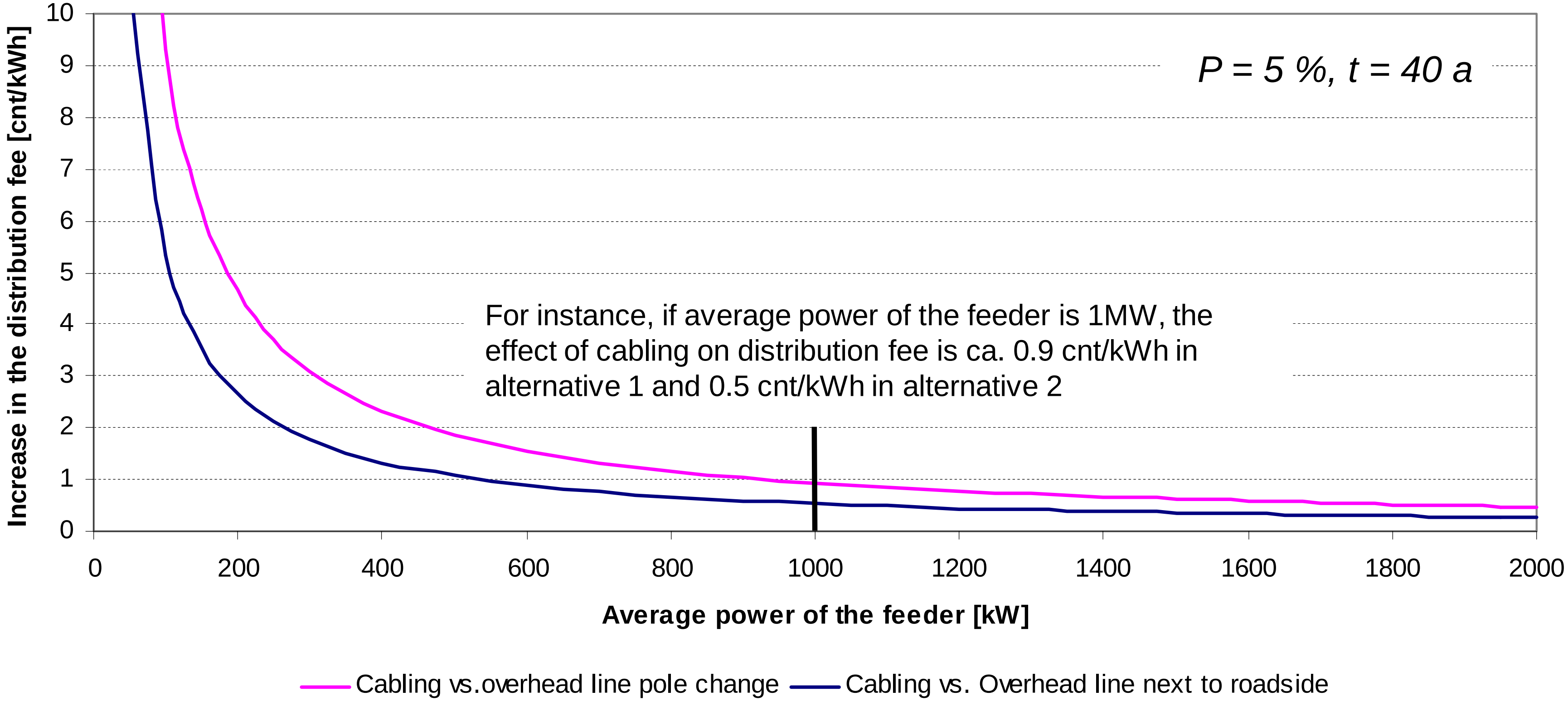
UG-cabling

Vs.

Pole renovation

or

OH-line to roadside



Alternative 1 **Alternative 2**

Underground cabling
Case study, network renovation

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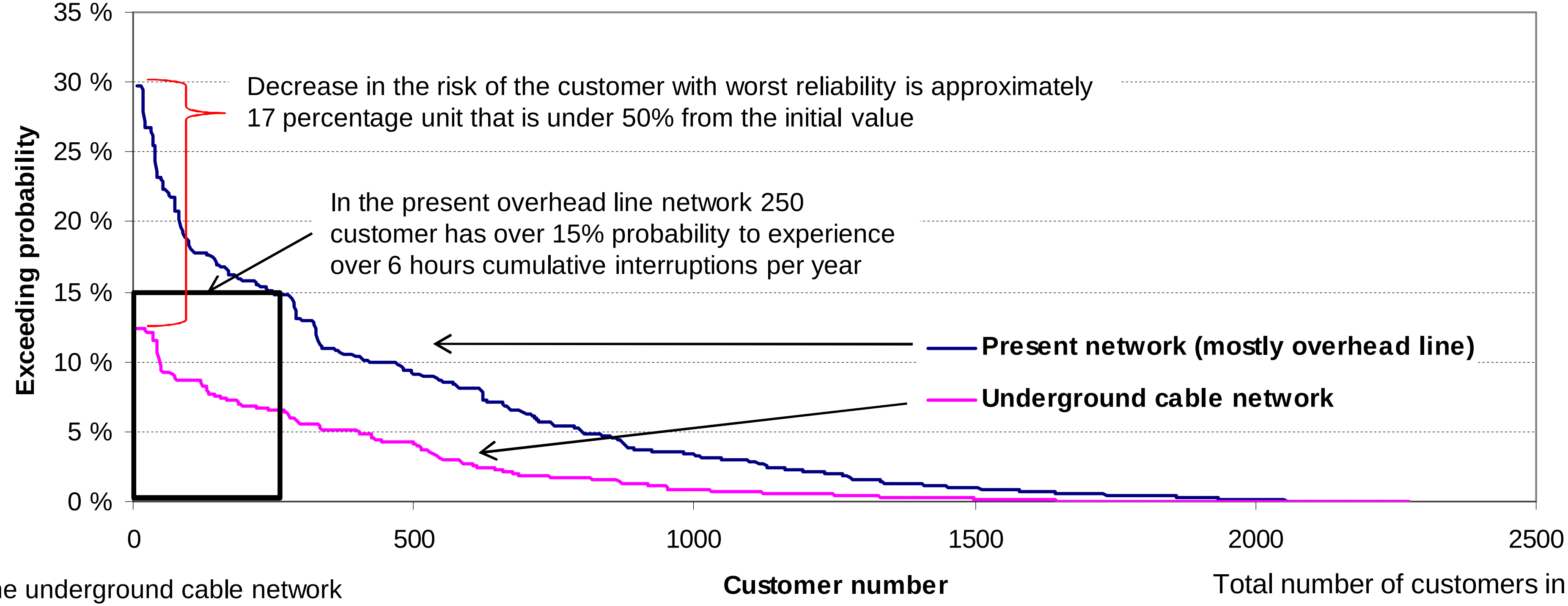
The effect of underground cabling on risk of experiencing long interruption times within a year

Probability of customer to exceed 6 hours cumulative interruption duration



In the underground cable network the risk to experince over 6 hours annual cumulative interruption is under 15% within all customers

Total number of customers in the case network **2300**

References

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Underground cabling
Conclusions

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- Underground cabling needs a lot of ground work
- Cabling process includes several phases or questions such as where, when and how it is carried out
- Operational costs decrease because reliability is improved
- Customer outage costs decrease because of improved reliability
- Effect of cabling on the distribution fee is moderate, for instance in a case where average power of the feeder is 1000 kW, the increase in the price can vary between 0.5 to 1 cnt/kWh
- The risk level of customers to experience long interruptions decreases significantly

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