D2.1.5 Study of future requirements from DSO and society point of view

Revision history

Edition	Date	Status	Editor
v1.0	26.4.2012	Final	Strandén, Janne

1 Introduction

Meanwhile the electricity dependency has increased and is still increasing, many major disturbances have lately taken place in distribution networks in Finland. These wide and long-lasting interruptions have caused enormous troubles in the operations of modern society. Consequently, the lacks of preparedness of both operational actors and customers have been observed and got great attention in media and public discussion.

Recent major disturbances have initiated many measures to improve the situation including legislative reformations, tightened economic regulation, actions among distribution system operators (DSO) and some other actions. It seems that DSOs' planning and other operations will be more complicated, not only traditional optimization of total costs, in the future.

2 Definition of major disturbance

Typically major disturbances in the supply of electricity have been defined very technically and system-oriented way. For example Finnish researchers have defined a major disturbance in 2005 as follows:

> *A major disturbance is a condition in which more than 20 % of customers are without electricity, or the 110 kV line, the 110/20 kV primary substation or the primary transformer is out of operation for several hours because of a fault.[1]*

In IEEE Standards major disturbance (major event) is defined this way:

> *"Major event: Designates an event that exceeds reasonable design and or operational limits of the electric power system. A Major Event includes at least one Major Event Day (MED).*
>
> *Major event day: A day in which the daily system SAIDI exceeds a threshold value, T_{MED}. For the purposes of calculating daily system SAIDI, any interruption that spans multiple calendar days is accrued to the day on which the interruption began. Statistically, days having a daily system SAIDI greater than T_{MED} are days on which the energy delivery system experienced stresses beyond that normally expected (such as severe weather). Activities that occur on major event days should be separately analyzed and reported." [2]*

A research project *Development of the Risk Analysis and Management Methods in Major Disturbances in the Supply of Electric Power* was carried out in Tampere during the years 2009-2011. In this project, the perspective was more from the whole society point of view and therefore the definition of major disturbance is slightly different:

> *Major disturbance is a long lasting and/or a widespread interruption in the supply of electric power, during which the fire and rescue services and one or more other public actor (municipality, police, etc.) need, in addition to the distribution system operator (DSO), to start implementing measures for reducing possible severe consequences to people and property. [3]*

Also this study and report are based on the perspective presented in the latest definition, i.e. problems are tried to solve not only from DSOs but also from the whole society point of view.

3 Causes and consequences – example cases

The different origins of major disturbances can be divided into two sections: interruptions caused by weather (e.g. storms, snow loads, lightning) and interruptions caused by other incidents (e.g. human error, wrong protection settings, vandalism/terrorism). Herein major disturbances caused by weather conditions are considered and some example cases are presented.

3.1 Pyry and Janika

Two storms named Pyry and Janika brought heavy snow loads in November 2001 causing about 90,000 trees to fall on the lines. This resulted in over 30,000 faults in the low and medium voltage networks affecting over 860,000 customers around southern Finland. Interruptions lasting longer than five days affected over 1,600 households. The network repair costs of these two storms amounted to over 10 million euro. [4] The forest damages exceeded 7 Mm^3 of fallen trees [5].

The most significant societal consequences caused by the interruptions were interruptions in telecommunication networks, troubles in water supply and sewerage and troubles in farms with no reserve power. One big problem was poor situation awareness mostly due to communication and cooperation problems between some main operational actors and lack of informing in many cases (e.g. estimations about the duration of the outages). The biggest reason for these troubles seemed to be the lack of preparedness of most actors. [6]

3.2 Gudrun and Per

The societal consequences of two winter storms – Gudrun and Per – were basically similar in Sweden as in Pyry and Janika. The first and more severe one i.e. Gudrun was experienced in the southern parts of Sweden in January 2005. Also the regional networks were partly destroyed in the same way as distribution system. It has been estimated that 730,000 customers were without electricity during the worst time, some of them for up to 45 days. Restoration costs for DSOs were roughly 240 million euro (2,400 million in Swedish Kronor) and voluntary compensations for customers about 60 million euro. Total amount of compensations paid by insurance companies were roughly 400 million euro. Forest damages were 70 Mm^3. [7-8]

Two years later, storm Per was experienced in somewhat the same areas as Gudrun. The forest damages were 16 Mm^3 of fallen trees and 440,000 customers experienced interruptions. The longest interruptions were approximately 10 days. Restoration costs for DSOs were about 65 million euro and standard compensations paid for customers 75 million euro. Amount of compensations paid by insurance companies were 55 million euro. [8]

3.3 Asta, Veera, Lahja and Sylvi

In 2010 between July 30th and August 8th, i.e. during 10 days, four summer storms named Asta, Veera, Lahja and Sylvi with unusually strong lightning and thunder squalls left over 480,000 customers without electricity in Finland. The longest interruption lasts 42 days. The total costs for DSOs were over 32 million euro (standard compensations 10 M€, operational costs 18 M€ and investments 4 M€). Forest damages were 8.1 million m^3, and the related compensations paid by the insurance companies were 81.5 million euro. [9-10]

The societal consequences were somewhat similar as in former cases. Especially interruptions in telecommunications networks and troubles in water supply and sewerage appeared. Lack of resources, interruptions in communication networks and difficult conditions (many storms sequentially) made restoration operations of DSOs very hard. Again, communication between different operative actors led to poor situation awareness and troubles of managing the situation. Also informing the citizens was poor in many cases. [10]

3.4 Tapani and Hannu

The most recent major disturbances were experienced after Christmas 2011 when two storms called Tapani and Hannu cut the power of 570,000 customers, over two weeks in the worst cases. Total costs for DSOs were over 60 million euro (standard compensations 30 M€ and repair costs 31 M€). Forest damages were 3.5 million m^3, and costs for the insurance companies were about 70 million euro. [11-13]

Power cuts caused (again) troubles especially in telecommunications and water supply and sewerage. Even some urban areas were totally without electricity. Due to winter time, also some evacuations were carried out. DSOs were criticized because of failures in informing their customers. According to a consumer survey carried out after storms the biggest problem seems to be unawareness about the possible duration of interruption [14].

4 Measures against major disturbances

4.1 Legislative reformations

In 2001 after storms Pyry and Janika the price reductions and compensations that were paid according to the Finnish Electricity Market Act were small and case-specific, and hence considered inadequate for covering the real losses experienced by customers. The status of a customer was improved by reforming the Act in 2003 by so called standard compensation practice. Thus, a customer is entitled to stepwise increasing compensation (10 - 100 % of the annual system service fee but 700 € at the maximum) after interruption lasting 12 hours or longer. [15] Similar but stricter standard compensation practice was also added into the Swedish Electricity Act from the beginning of 2006. At the same time obligation to draw up annually risk and vulnerability analysis and action plan for improving the reliability as well as maximum duration of an interruption (24 hours from the beginning of the year 2011) were introduced. [16]

Due to recent storms and experienced long-lasting interruptions, there are some reformations of the Finnish Electricity Market Act under consideration at the moment (April 2012). Limit values for the duration of an interruption experienced by a customer have been proposed. Maximum duration would be six hours in urban areas and 24 (or 36) hours in rural areas from the beginning of 2028 (100 % of the customers). DSOs should prepare development plans how these limits will be achieved. In order to facilitate the development of reliability, roadside cabling will be made easier and DSOs will have entitlement to preventatively clear forest nearby overhead lines. DSOs should draw up provision plans for major disturbances; cooperate with other actors, contribute local situation awareness and arrange independent communication connection to other actors; inform customers about local reliability of supply, how to be prepared for interruptions and in disturbance how long interruption will last. DSOs should also take part in emergency planning. Standard compensations will be increased by adding more steps and setting the maximum value gradually from 700 to 2000 euro (from 2018). Figure 1 illustrates the stepwise increasing function of standard compensations. [17]

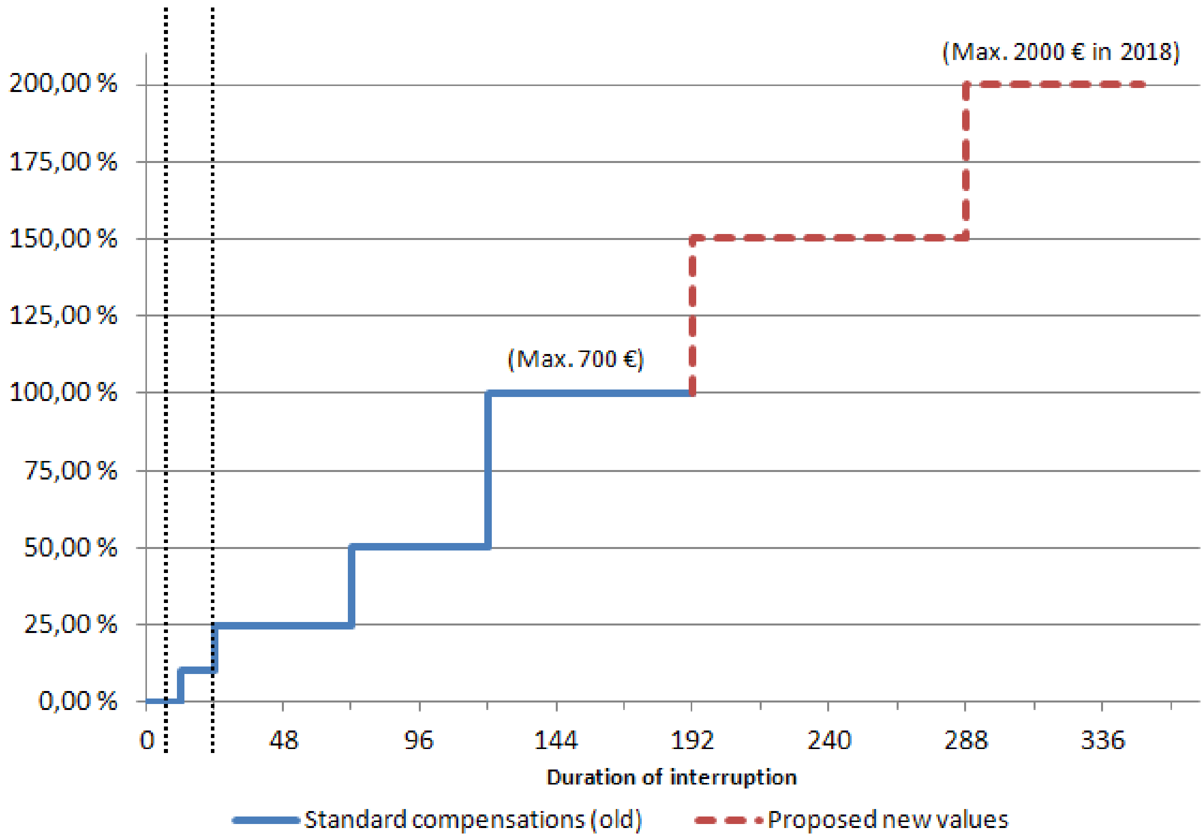

Figure 1. *Function of standard compensation and proposed limit values for duration of an interruption [17].*

In figure 1 also values for the maximum duration of an interruption both in urban and rural area are shown. In [17] is also considered if exceeding of these limits may lead to extra financial sanctions for DSO.

4.2 Tightened economic regulation

Because DSOs operate as monopolies the operations of those should be regulated. From the beginning of the second regulatory period (2008-2011) the regulation was tightened in Finland by taking also the interruptions (in the MV networks) into account when calculating the acceptable profit of the DSOs. In addition to the power quality incentive, also an efficiency incentive for each DSO was added. Moreover, the standard compensations were included in the controllable operating costs, whereas they were earlier treated as pass-through components, and thus did have no effect on the acceptable profit. [18]

The value of interruptions is determined with the help of energy weighted reliability indices of networks and in advance defined interruption cost parameters, and this is compared with the calculated reference value. Half of the interruption costs have a direct effect on DSOs' acceptable profit and half of them affect indirectly via efficiency incentive. From the beginning of third regulatory period (2012-2015), the maximum effect of interruption costs (power quality incentive) was increased from 10 to 20 % per cent of the reasonable return calculated for capital invested after taxes. New regulation models have some other reformations as well, like investment incentive, new model for efficiency incentive, innovation incentive among others that try to encourage DSOs towards better reliability of the supply (e.g. underground cabling). [19]

4.3 Actions among DSOs

The Finnish Electricity Association (nowadays Finnish Energy Industries) published the guidelines for a provision plan against major disturbances in 2002. Among other instructions the importance of cooperation with other actors and crisis communications are emphasized. [20] According to the questionnaire study carried out in the project [3], about 80 per cent of the DSOs have prepared some kind provision plan and it was seen useful although inadequate in many cases.

Some projects in order to improve the cooperation with other actors have been executed. One example is the cooperation organized by the Finnish Forestry Centres against the forest damages. In order to be prepared for storms the Forestry Centres with the representatives of fire and rescue services, forest industry and DSOs have created regional provision plans. [21] However, many DSOs have found these plans not that effective from repairing the faults point of view but they are rather aiming at minimizing the economic losses of forest damages.

One good example is also the project mentioned above, in which the management of major disturbances has been developed. The management includes cooperation and communications between different actors participating in the recovery operations during the major disturbances. According to the questionnaire, DSOs seemed to have made contracts with some other actors for major disturbances. Major part of respondents has contracts with neighbouring DSOs, network contractors, excavator contractors and local forest workers. Minor part also has contracts with local electricians, transport companies, forest harvester contractors, farmers and forestry societies. Also helicopter company was mentioned by one respondent. Over half of the respondents have carried out training, and about half of these mentioned that they have had training also together with other actors, above all with fire and rescue services. [3]

The lack of the information for customers was seen a big problem during the 2001 storms. After the storms many DSOs have developed their customer communications considerably by utilizing SMS and email services, and real time map-based web service. The questionnaire showed that 72 per cent of the DSOs use internet, 8 per cent SMS or email services, 56 per cent automatic answering machine, 72 per cent (local) radio channels and 78 per cent conventional phone service as communications channels during major disturbances [3]. Three level of DSOs' customer communications could be found : some delivered information in real time (e.g. map-based web service), some gave daily bulletins and some published information at longer intervals. Many DSOs also have good instructions for households about how to be prepared for outages on their websites.

It is obvious that one measure for the better reliability of electricity supply and against major disturbances is network investments. DSOs have recently invested in underground cabling and network automation among others but quite often these investments aim at better reliability at system level. This may often be an optimal solution from interruption costs perspective but easily leads to a situation where some customers may still experience bad reliability of the supply. In Finland the Finnish Energy Industries together with DSOs has decided to implement new supply reliability criteria as planning criteria into long-term network development. The criteria cover sum of duration of long interruptions and number of short interruptions (< 3 min) experienced by a customer per year. This way the status of a customer can be improved. Customers will be divided into three groups: city, urban and rural area customers. This classification is based purely on community structure, not on present network structure as usual. One exceeding of these target values within three years period is allowed. The criteria are presented in detail in [22].

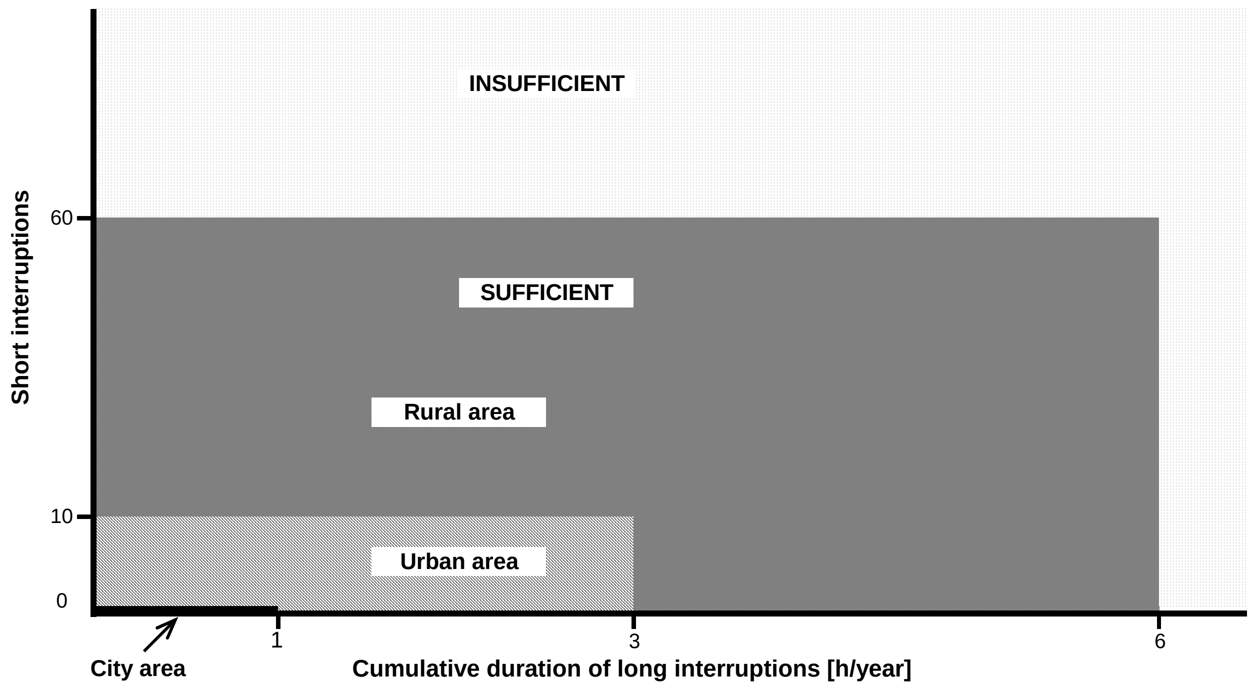

Figure 2. *Criteria for reliability of supply [23].*

After Gudrun, some measurements were carried out by the Swedish DSOs. A tree securing programme for the regional networks has been carried out, DSOs have invested more in underground cabling due to new tightening in the Electricity Act, and using of the computerized support system (SUSIE) for cooperation between DSOs has been trained by the personnel. [7-8]

4.4 Some other actions

The Government Resolution on the Strategy for Securing the Functions Vital to Society determines the measures for upholding national sovereignty, the security of society and the livelihood of the population in Finland. In the resolution the vital functions, their threat scenarios, the strategic tasks assigned to competent ministries, and the focus areas and schedule are defined. The importance of the reliable electricity supply has been considered since the second version of the strategy (2006): the electrical infrastructure (information systems, telecommunications networks, power grid etc.) is mentioned first in the list of the threat scenarios and the security of energy supply is decided to be one of the focus areas of the strategy. [24] In December 2010 the new update of the strategy was published. Former 'disturbances in the electrical infrastructure' is now divided into smaller parts and serious disturbances in the power supply (including electricity and district heating) are on the top of the threat scenario list while serious disturbances in the information systems and telecommunications (cyber threads) are mentioned second in the list. [25]

In order to improve the preparedness of certain customers some measures have been taken by different authorities: for instance farmers have had a possibility to get financial support for a reserve power supply system and the Finnish Communications Regulatory Authority has set a new regulation [26] that defines the priority rating of the components of the communications networks and the securing of their power supply.

Moreover, the Ministry of Defence of Finland has published a guide about preparation for citizens in 2008 [27]. A more comprehensive guide about long blackouts and their effects on the functions of the society has also been introduced mainly for the use of the authorities. [28]

5 What is still under development?

5.1 Situation awareness and cooperation

Typically after all major disturbances the lack of information about situation has be seen one of the biggest problems for managing the operations. Both operational actors, like DSOs, teleoperators, fire and rescue services and municipalities, and citizens have confronted this problem. This issue has now noticed also by government and as mentioned above some amendments have been proposed to be added into Electricity Market Act [17].

One main result of the project, reported in [3], was a sketch of an information system for major disturbance management. The idea of this system is to extend DSOs' existent web services so that graphical information is served for authorities like fire and rescue services and municipalities. The information contains not only the interruption data but also information about critical customers' location and criticality. Need for the prioritization of customers is also mentioned in the amendments [17] to be part of both development and provision plans. In the sketch of the system, defining the criticality is realized with a web service where the actors responsible for critical sites maintain the information by themselves. The system could also be used as a tool of planning by combining comparing the estimated criticalities of critical sites with realized interruption statistics, with calculated probabilities or with proposed limit values for the maximum duration of interruption. For a critical customers' point of view this makes it possible to focus the preparing on the most critical sites. The DSO could take the criticality as initial data for the network development. The sketched system could also be used as a simulator in major disturbance exercises. A small scale demonstration made in the project verified the viability of the system and development of the system will continue in SGEM -project (Smart Grids and Energy Markets).

5.2 Incentives of network planning

Incentives of strategic network planning seem to be changing. Traditionally, the main aim has been optimizing (i.e. minimizing) total costs including interruption costs which is quite a simple optimization task based on money. Interruption costs calculations are based on SAIDI, SAIFI and MAIFI weighted by annual energies and cost parameters are the same to all customer groups, thus there is a great incentive to prioritize most consuming sites higher than smaller ones. The effect of legislative standard compensations is similar. Therefore reliability can be good at system level but inadequate to some customers.

The reliability criteria together with proposed maximum values to the Electricity Market Act try to improve the reliability of supply more from the whole society point of view. Most of the functions vital to society's operation are in urban (or city) areas and therefore it is reasonable to have better reliability in general in these areas. All the investments are not necessarily economically reasonable based on traditional optimization, but some focused extra network investments by DSOs are needed. However proposed sanctions if limit values are exceeded will encourage DSOs to do these investments.

As mentioned, serious disturbances in the power supply are on the top of the threat scenario list in the Government Resolution [25]. Moreover in the amendments to the Electricity Market Act prioritization of the societally critical customers are proposed to be part of the development and provision plan. This makes the optimization of future investments even more complicated process – the task is not only mathematical and DSO cannot carry out the whole process alone but need information about these customers classified as critical.

The traditional planning process done by DSO seems to be exchanging to be one part of continuity management of society which means more cooperation with other operational actors.

5.3 Securing the supply of customers – case example

In this very simplified case is presumed that all customers supplied by example feeder should be secured against weather-related interruptions either by underground cabling or local generation (aggregate). Fictional example feeder is presented in figure 3 and specifications of it in table 1.

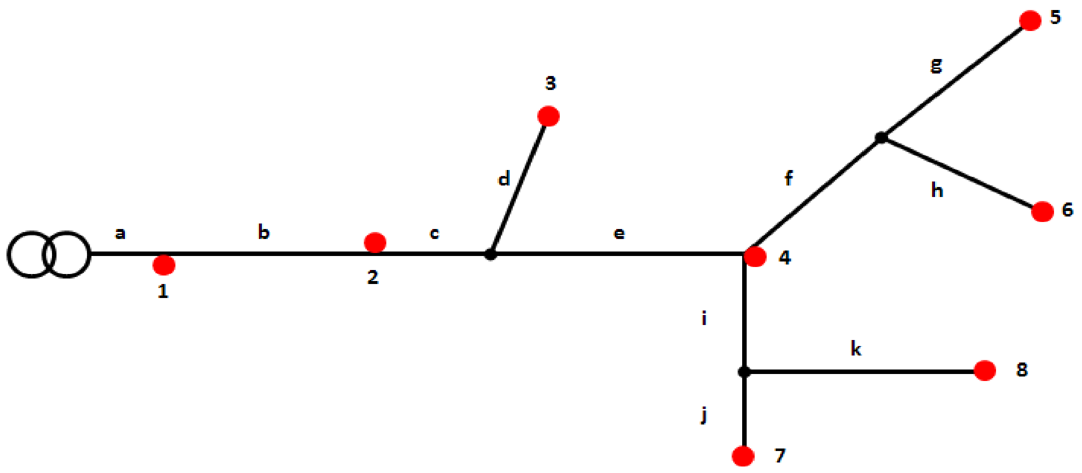

Figure 3. *Example feeder (fictional).*

Table1. *Specifications of the feeder.*

Transformer	Customers
1	100
2	60
3	30
4	25
5	15
6	15
7	10
8	10

Connection	Distance (km)
a	2
b	5
c	3
d	5
e	7
f	5
g	5
h	5
i	3
j	2
k	7

The main idea of this example is to show the total costs when the supply of all customers is secured by cabling or local generation. Cost parameters used are 40 000 €/km for underground cabling (generally used value) when the cost of local generation varies between 1 000 - 15 000 €/customer in different cases because of the uncertainty of costs for this kind of equipment. The underground cabling process is carried out alphabetically starting from the connection *a*. The customers not within the cabled network are secured with the help of local generation. In figure 4 is illustrated the function of total costs depending on the rate of underground cabling.

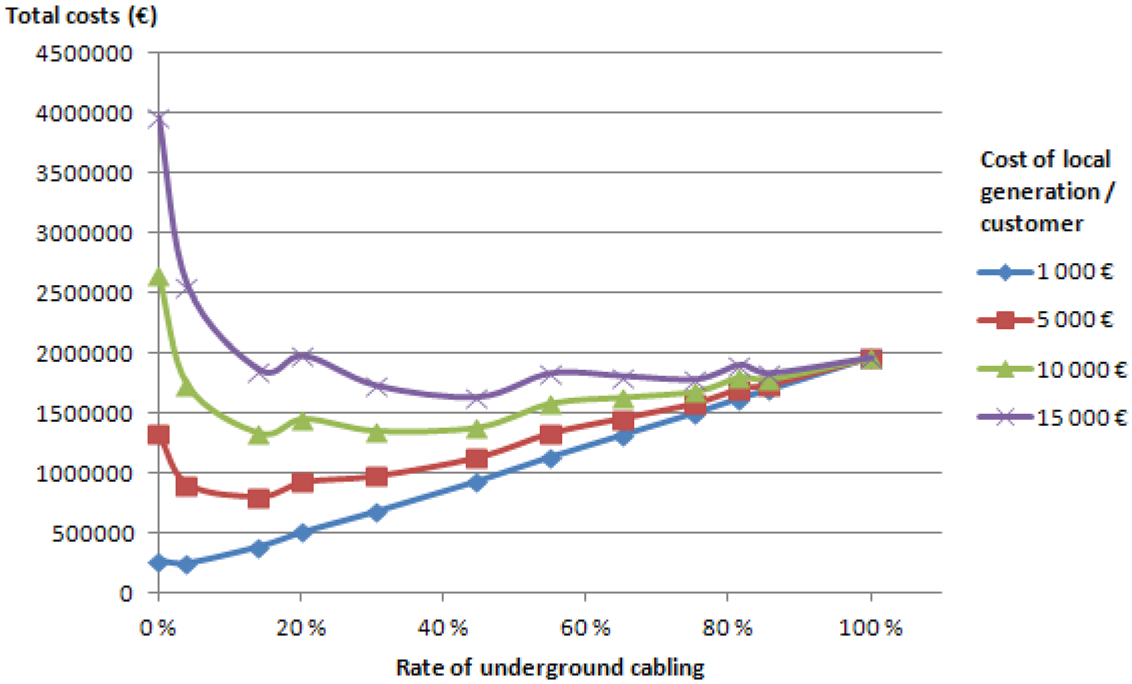

Figure 4. *Function of total costs of securing the supply.*

Figure 4 shows that despite the cost parameter of local generation cabling the whole network is not cost-efficient in any case. It should, however, remember that case is very simplified and cost parameters still have much uncertainty, for example the maintenance costs of the aggregate. The electricity market issue – who will pay to whom if using local generation – is also excluded.

In [17] is presented quite a similar example case when the costs of securing the supply of the critical base stations of communication networks. Calculations show that by cabling it would cost over 350 000 euro per base station whereas the investment costs of a fixed reserve power plant would be no more than 35 000 – 60 000 euro. This illustrates quite well that investing to the grid might be socioeconomically very expensive in comparison with other solutions.

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