RESERVE POWER – ALTERNATIVE SOLUTION TO THE NETWORK INVESTMENTS IN RURAL AREA NETWORKS?

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ABSTRACT

The new legislative requirements and all the time tightening economic regulation cause a great pressure for Finnish distribution system operators to improve the security of power supply. Underground cabling has been seen in many cases basically the only but at the same time very expensive solution to solve this problem. This paper presents that with the help of reserve power solutions it is possible to fulfill the requirements especially in sparsely populated rural areas. The results show the profitability of utilizing reserve power generators instead of investing in the cabled network. In addition, the calculations support the fact that customers should at least consider purchasing own reserve power.

INTRODUCTION

Due to the storms in 2010 and 2011 causing widespread and long-lasting outages (major disturbances) at customer level, considerable amendments to the national electricity market act were implemented in Finland in 2013 [1]. Especially introduced maximum values for the duration of an interruption experienced by a customer (six hours in urban areas and 36 hours in rural areas) have been found economically challenging to achieve among the distribution system operators (DSO). This requirement must be totally fulfilled by the end of 2028. In other words, the legislative amendments, as well as all the time tightening economic regulation cause a great pressure on DSOs to carry out extensive investments in their distribution networks. That is because, in many cases, underground cabling has been seen the only solution to solve the problem.

In this paper different reserve power solutions to avoid long-lasting interruptions are considered. The paper presents a case study where the total costs of different development plans are compared. The idea of the paper is not to give exact but suggestive results that can be a base for a further study. Possible issues caused by the current legislation and economic regulation of DSOs are excluded from the study.

In addition to the DSOs' perspective, also the cost analysis of customers' voluntary procurement of reserve power is presented. In these calculations, the profitability of various size reserve power generators is considered. Analyzing all the results with the help of sensitivity analyses as well as proposals for the future measures are also a part of the paper.

BASES OF CALCULATIONS

The network under consideration contains ten identical branch lines of a fictional medium voltage feeder in a rural area. The total amount of customers supplied is 100. In order to improve the security of power supply five different development plans are considered: the whole network is cabled (Cabling 100 %), every customer is provided with a fixed reserve power generator (Reserve power 100 %), five of the branch lines are cabled (Cabling 50 %), customers on five branch lines are provided with a fixed reserve power generator (Reserve power 50 %) and customers on five branch lines are secured utilizing a reserve power service (Reserve power service). In all reserve power solutions, the generators are connected directly to each customer's electric system.

The calculation of costs is based on the present value method where all the monthly cost items are discounted to the present day. The initial investment is paid at the beginning of the period under consideration. The maintenance costs and service fees are paid at the beginning of each month whereas the costs due to faults (fuel, fault repairing, interruption costs and standard compensations) are paid at the end of each month.

Reserve power service

The concept of the reserve power service has been created in this study. The idea is that a DSO purchases a certain number of mobile reserve power generators and the delivery to desired location is bought from a third party. In addition to the delivery, the service provider is responsible for the maintenance and the operating costs of the generators. The service provider can be either a commercial company that offers the service as a side business or it can be a non-profit-making organization.

The idea is that the reserve power service would be utilized only in the case of a major disturbance when outages may last several hours or even days. At that time, the DSO contacts the service provider who after that delivers the generators to the desired locations.

Calculation parameters

The parameters used in calculations are presented in Table 1.

Table 1. Calculation parameters used.

Network	
Branch lines	10
Branch length, km	5
Customers / branch	10
Annual energy / customer, kWh	20 000
Cabling	
Underground cabling / km, €	40 000
Reserve power (fixed)	
Reserve power generator, €	10 000
Maintenance / month / customer, €	10
Fuel / customer / h, €	7
Reserve power service	
Reserve power generator, €	8 500
Service fee / month / generator, €	8
Delivery time, h	3
Fault probability	
Normal year	
Faults in network / year	2,5
Major disturbance	
Faults in network / major disturbance	25
Major disturbances / year	0,1
Fault repairing	
Cost / fault, €	1 500
Normal fault	
Duration / fault, h	3
Major disturbance	
Waiting time before repairing, h	10
Duration / fault, h	2
Interruption cost parameters	
€ / kW	1,32
€ / kWh	13,19
Standard compensations	
System service fee, € / kWh	0,07
Others	
Discount rate / year	3,03 %
Period, years	10

The price of the underground cabling has been evaluated so that it contains all the related costs, such as cables, transformers and installation [2]. The reserve power generators have been chosen to cover practically the maximum power of a load point (continuous power 15 kW) and the price contains an automatic start with a transfer switch. The purchase price of the generators used in the reserve power service does not include the automatic start but includes a manual transfer switch. [3]

The fault parameters are based on the public interruption statistics in Finland [4] and other available data. Thus in a normal year the failure rate is five faults per 100 km and tenfold in the case of a major disturbance (once a decade). All the customers experience an interruption in a major disturbance. Due to risky circumstances, the repairing is thought to be able to start after a 10-hour delay in a major disturbance but it does not take as long as in the normal conditions because of the short distances between the fault locations. Underground cables, reserve power generators and the main line supplying the branch lines are considered fault-free. The interruption cost parameters are the same as used in the economic regulation model of DSOs in 2014 [5].

According to the standard compensation practice in Finland, a customer is entitled to stepwise increasing compensation from a DSO when the interruption last longer than 12 hours. The compensation is a certain percentage between 10 % - 200 % of the annual system service fee of the customer. The maximum amount of the compensation is 1 000 euros in the current transition period and 2 000 euros from the beginning of 2018. [1]

The discount rate used is a reasonable cost for capital invested in network operations in 2014 (Weighted Average Cost of Capital, WACC) determined by the Finnish Energy Authority [6]. The period under review could be also longer but it does not make any difference because the techno-economic lifetimes of different investments have been supposed to be equal.

CALCULATIONS AND RESULTS

DSO's perspective

Figure 1 shows the need for the development of the network under consideration. The interruption times of customers in a major disturbance are illustrated and in the original state the longest interruption is 60 hours that evidently exceeds the maximum interruption time of 36 hours presented in the electricity market act.

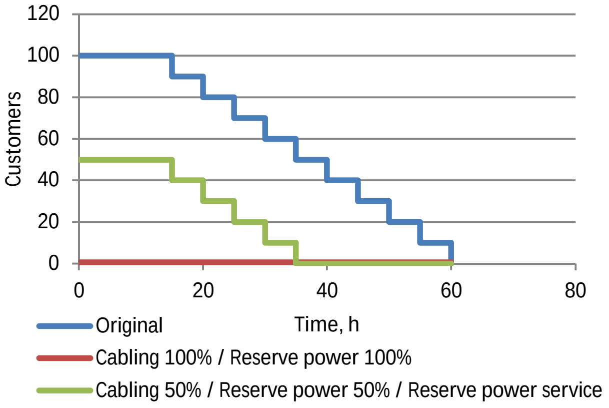

Figure 1. Interruption times in a major disturbance.

The figure shows how the power supply is restored to the customers branch by branch. While the power supply is continuous in the Cabling 100 % and Reserve power 100 % solutions, also in the other development plans the maximum interruption time (35 h) stays under the legislative limit value. In Figure 2, the total costs of each investment plan are presented. The costs of the original network are shown as a reference. Possible financial sanctions due to exceeding the limit values are excluded.

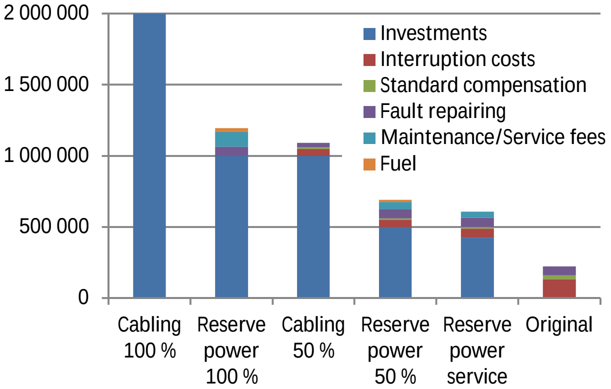

Figure 2. Total costs of different investment plans [€].

Two commonly known facts can be found in Figure 2: that total underground cabling of the network is not economically reasonable and that new legislative requirements cause a great upcoming pressure for many DSOs to invest their networks. The results show that with different reserve power solutions it would be possible to achieve the target with substantially lower costs. The reserve power service seems to be the most cost-effective solution, even if the service fee would be tripled to 24 euros.

Sensitivity analyses

In order to minimize the uncertainties of the calculations two parameters are varied separately: the occurrence probability of a major disturbance and the density of customers supplied. Figure 3 shows the total costs of four scenarios when a major disturbance takes place zero times, once (Fig. 2), twice or six times during the period.

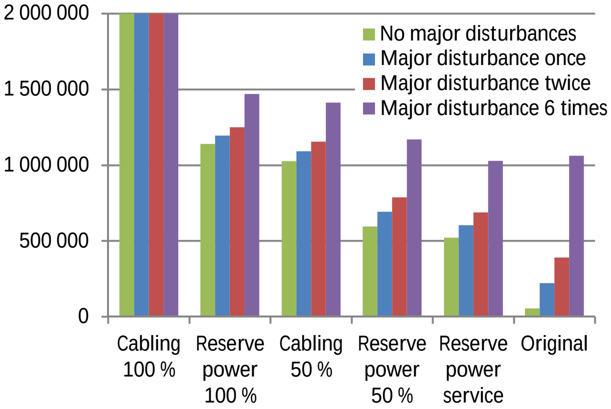

Figure 3. Total costs when the amount of a major disturbance varies [€].

According to the diagram, the order of profitability of different investment plans does not change. Moreover, the scenario of six major disturbances is very unrealistic and it is only included to show how many times a major disturbance should be experienced before the total costs of the original state are not the lowest. Figure 4 presents the effects on the total costs when the customer density is doubled.

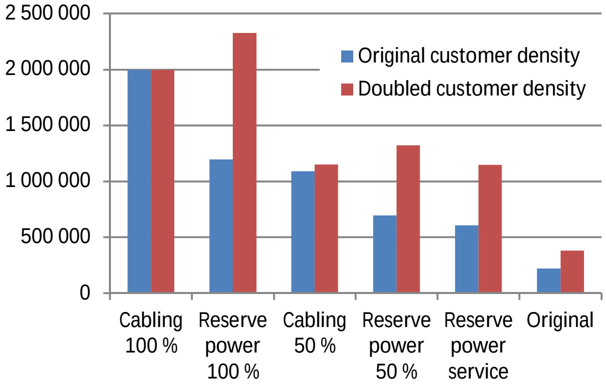

Figure 4. Total costs when customer density varies [€].

The cabling solutions become more economical when the amount of customers increases. Reserve power service is no longer clearly the most inexpensive alternative but Cabling 50 % seems to be now as profitable. Figure 4 illustrates the basic idea of utilizing reserve power this way – the area should be sparsely populated enough with long line lengths per a customer.

Profitability of reserve power service provider

Because the reserve power service has been seen an economical alternative to the cabling it is reasonable to assess its profitability from a service provider point of view. The cost of fuel, the probability of a major disturbance, the discount rate and the length of the period used are the same as in Table 1. The maintenance costs are five euros monthly per a generator (50 generators in total) and delivery per a generator costs 20 euros. The revenue consists of the service fees paid by DSOs.

With these parameters, the service provider gets a positive result of 500 euros in this 10-year period. Therefore it is not a profitable business but it could be offered by a non-profit-making organization, for example by a village committee. If the service fee was raised to 24 euros, when the service still would be the most economical alternative to the DSO, the 10-year result would be over 83 000 euros. Thus, it could be a possible side business to a commercial company alongside other business activities.

Customer's own reserve power

Even though the DSO offers the power supply that fulfills the legislative requirements, this reliability may not fulfill the reliability requirements of a customer in some cases. Therefore customer's volunteer preparation by purchasing reserve power is needed. It can be carried out by buying an own generator or utilizing a reserve power service if there is one available.

The reserve power service offered directly to the customers would be somewhat different than offered to the DSOs. Now a service provider would purchase the generators and the service would be sold to more customers than there are generators available. If a customer did not get a reserve power generator when needed, he would be entitled to compensation (sanction) from the service provider. This sanction as well as the legislative standard compensations from the DSO are incomes from the customer’s perspective.

Figure 5 illustrates the total costs for a customer when the network fulfills the legislative requirements (e.g. Cabling 50 % or Reserve power 50 %) and other calculation parameters are the same as in Table 1 but the service fee is 50 euros, the cost of a transfer switch with installation is 500 euros and the possible sanction is 2 000 euros. The service is sold to all 50 customers but only 25 reserve power generators are available. The sum of costs and incomes is presented above the columns.

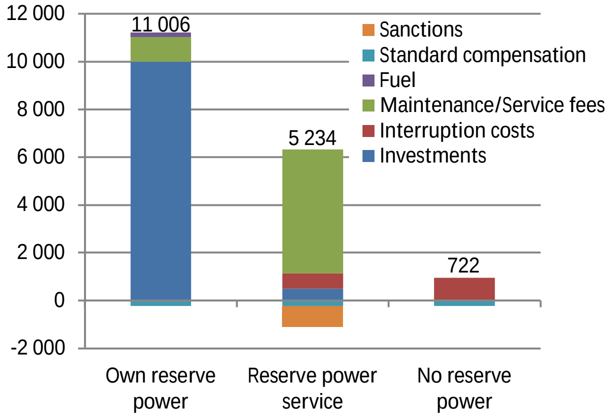

Figure 5. Total costs of a customer [€].

Evidently, it is very unprofitable to a customer to purchase a generator or buy the service. However, it is very probable that if a customer wants to secure his operations also during the outages, the interruption cost parameters of the economic regulation model do not represent the real inconvenience experienced. Moreover there is no need cover the maximum power of the load point to secure the supply of the most critical functions. No automatic start may be needed either.

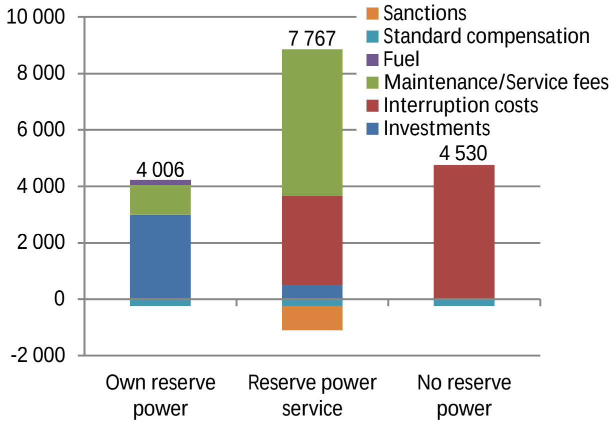

Figure 6. Total costs of a customer (lighter generator and fivefold interruption costs).

In figure 6 customer’s total costs are presented when the cost of a reserve power generator is decreased from 10 000 euros to 3 000 euros and the cost of interruptions is evaluated fivefold. The figure shows that these changes in parameters make the purchasing of a generator the most profitable whereas buying the service is the most expensive option. Lowering the service fee from 50 to 14 euros makes the service the most economical but then it would be unprofitable business to the service provider.

If a customer does not have a lot of critical load and the inconvenience caused by an interruption is not higher than normal, even a reserve power generator of 3 000 euros can be an over-investment. For example, securing the supply to a circulation pump of heating, a refrigerator, a freezer and the most critical lighting can be covered by a much lighter generator.

The prices of 2,0 kW three-phase and 0,9 kW single-phase generators were found to be 799 euros and 139,90 euros, respectively. The bigger one is thought to be connected to the switchboard and therefore also a transfer switch is needed (500 €). When using the smaller one, the loads are connected directly to it. The maintenance costs are considered to be included the fuel cost (7 €/h) that is oversized to these generators. Comparing the total costs of these two alternatives to the solution without reserve power is presented in Figure 7.

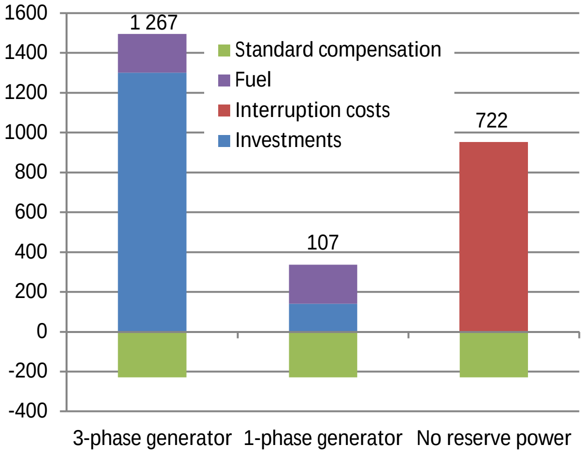

Figure 7. Total costs of a customer (small generators).

Purchasing a small single-phase generator seems to be profitable whereas a bigger three-phase generator is not economically reasonable if the inconvenience of an interruption is evaluated with the help of the original interruption cost parameters used in the economic regulation of DSOs.

Sensitivity analyses

The occurrence probability of a major disturbance is varied (0, 1 or 2 times). In the case where the maximum power of the load point is covered (see Figure 5) no notable changes are found. Figure 8 shows the variation of the total costs of the small reserve power generators.

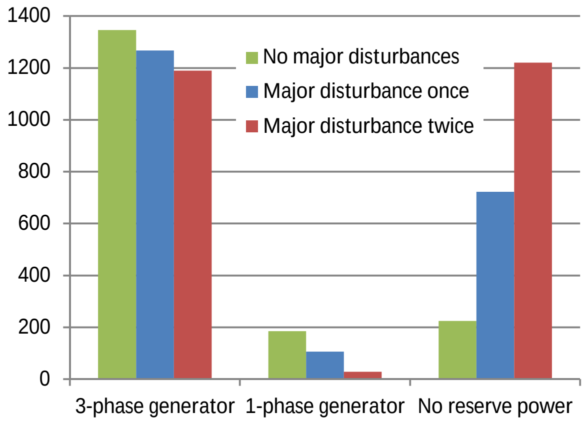

Figure 8. Total costs of a customer (small generators).

If a major disturbance takes place twice during a 10-year period, also the three-phase generator is more cost-effective than being without reserve power. The figure also shows that buying a small single-phase generator is reasonable even if there is no major disturbance during the period. It should be however noticed that the delay of connecting the generator is not taken into account in the calculations. Moreover, the linear interruption cost may not represent the actual inconvenience experienced by a customer – a short interruption may not be harmful at all but when becoming long-lasting the harm can increase exponentially.

CONCLUSIONS

Even though the calculations done in this study are quite simplified and include many assumptions the results show that for both DSOs and customers utilizing reserve power could be rather profitable in the rural area. In this case study, the reserve power service introduced would be the most economical alternative from DSO's point of view if that kind of service were available. However, if the customer density in network increases, the underground cabling solutions become more profitable. Other solutions, such as different network investments and increasing the repairing capacity, are excluded from this study.

The results about customers' own voluntary procurement of reserve power show that it is highly recommended at least to consider purchasing a small reserve power generator that enables securing continuous power supply to the most critical functions. In this study, the inconvenience of an interruption is evaluated based on the cost parameter used in the economic regulation of DSOs, and multiples of them. Even though these parameters are relevant from the point of view of the economic regulation, they not necessarily represent the actual inconvenience experienced by a customer. Thus, customers must evaluate the monetary value for an interruption by themselves and therefore cost calculations of purchasing own reserve power are case-specific.

In addition to economic perspective, the reserve power solutions are also beneficial when the fault is not in the distribution network, for example when the national grid collapses or there is some trouble in the electricity generation. On the other hand, all reserve power generators and installations should be designed and implemented taking into account both electrical safety and the customer's loads and existing electrical system (potential asymmetries and inrush currents of loads, fuse protection etc.). Special attention should be paid to correct connections of the reserve power unit and overcurrent and overvoltage protection of the existing electrical installation. Especially, in case of small and cheap reserve power generators it is important to make sure that the voltage quality (e.g. voltage level, especially with asymmetrically loaded 3-phase generators, frequency and harmonic content) is adequate to minimize the probability of additional costs in the form of e.g. load device failures.

In order to clarify if there is any legislative or regulatory issues when utilizing reserve power solutions as alternatives to the network investments, further study is needed.

REFERENCES

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