CUSTOMER DAMAGE EVALUATION AND NETWORK AUTOMATION STRATEGIES FOR DIFFERENT URBAN ZONES

Osmo SIIRTO
Helen Electricity Network Ltd – Finland
osmo.siirto@helen.fi

Markku HYVÄRINEN
Helen Electricity Network Ltd – Finland
markku.hyvarinen@helen.fi

Sanna HAKALA
Helen Electricity Network Ltd – Finland
sanna.hakala@helen.fi

Jonna JÄÄSKELÄINEN
Aalto University – Finland
jonna.jaaskelainen@tkk.fi

Matti LEHTONEN
Aalto University – Finland
matti.lehtonen@tkk.fi

ABSTRACT

The society is more and more dependent on ICT and electricity. In distribution network planning, the diversity of the customer interruption costs (CIC) should also be noticed. As a part of the Finnish Smart Grid and Energy Market research program (SGEM) the customer interruption costs for different urban zones were evaluated. As a part of the research a postal survey was carried out.

Since 2008 the distribution system operator in Helsinki, Helen Electricity Network Ltd (Helen), has gradually been implementing network automation to the medium voltage (MV) network. The selection method of the remote-controllable secondary substations in Helsinki is presented. In the year 2010 Finnish Energy Industries published the new reliability criteria, which are based on area allocation. This paper describes the determination of network automation strategies based on the evaluation of customer interruption costs for different urban zones and based on the new Finnish reliability criteria.

INTRODUCTION

Helen Electricity Network Ltd (Helen) started its network automation undertaking in the year 2008. The pilot system for the control and monitoring system for urban MV/LV substations was presented at CIRED 2009 [1]. The system includes power quality measurements & database, disturbance recordings, fault location, transformer monitoring, and remote control of the MV switches at the substation. After this pilot project Helen has now moved on to the next phase which is gradually implementing network automation to the MV network.

CUSTOMER INTERRUPTION COSTS

The basic reference values for interruption costs are the customer interruption cost (CIC) values for unexpected interruptions on different customer groups by the Finnish Energy Market Authority report from 2007, Table 1 [2]. These values are based on the Finnish CIC research from year 2005. The research analyses the interruption costs in various electrical distribution networks, as experienced by residential, agricultural, commercial, public and industrial customers [3].

Table 1. Customer interruption costs by the Finnish Energy Market Authority (EMA) report from 2007

1 h unexp. interruption, Finnish EMA	
Customer group	€/kW
residential	4,65
industrial	24,45
public service	16,97
commercial	32,54

To estimate the outage cost on urban areas, the following respondent areas from the report were chosen: *All (Finland), Southern Finland and Cable network.* Category *All* covers all the answers from the research, *Southern Finland* is the most populated region in Finland including both rural and urban areas. Category *Cable network* is mostly urban areas, but covers also rural areas.

The other reference research is from Netherlands [4]. Netherlands is very densely populated and thus a good reference for estimating customer interruption costs in urban areas.

Table 2. CIC by the Finnish research 2005 and the Dutch research 2003-2004. [3, 4]

1 h unexp.	€/kW			
Customer group	CIC Fin All	Fin Cable	Fin South	Nether-lands
residential	6,5	8	8,5	5,0
industrial	21,6	27,8	34,3	52,3 *)Firms
public	34,3	71,1	145	
commercial	48,1	62,1	57,7	

The CIC are much higher for commercial customer group, on average the cost of an 1 h unexpected interruption is seven to ten times higher for commercial customers than for residential customers.

CUSTOMER INTERRUPTION COST BY URBAN ZONES

The modelling of urban areas can be based on the zonal approach. Urban areas are organized through the land use control into zones with distinct borders between different types of areas. Based on spatial analysis it is evident that the land use zones describe all relevant features: customer mix, load dispersion and construction restrictions, the last leading to an obligation to use more expensive structures. From an urban and city networks point of view the subdivision into three basic zones - urban core, urban and suburban – is adequate. [5]

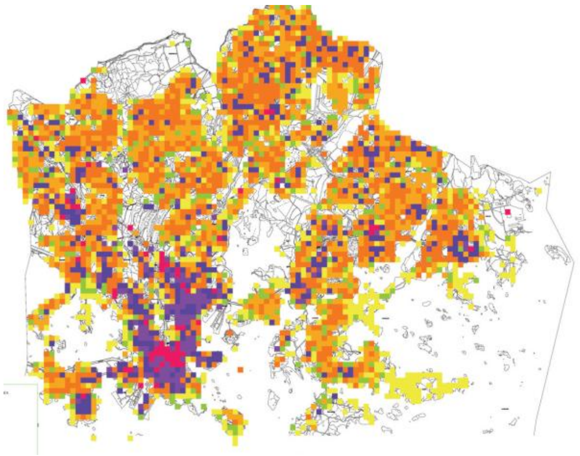

Figure 1. The load distribution and densities of a large city (Helsinki). The darker the colour, the higher the energy density is [5].

The urban core is well visible in Figure 1, as well as the local centres and industrial areas in the midst of suburban areas. In urban core the dominant loads are commercial buildings and public services while in the suburban areas resident loads are in the majority, see Table 3.

Table 3. The customer structure of different urban areas (AH=Apartment houses, SH=Separate houses) [5]

Customer group profiles	residen-tial	commer-cial	public service	industrial
Urban core	10 %	53 %	27 %	10 %
Urban	30 %	40 %	20 %	10 %
Suburban Cent	10 %	53 %	27 %	10 %
Suburban AH	55 %	23 %	12 %	10 %
Suburban Mix	75 %	13 %	7 %	5 %
Suburban SH	85 %	10 %	5 %	0 %

By using the CIC values in Tables 1 and 2 and the customer structure in Table 3, the CIC values were calculated for different urban areas. The results are presented in Figures 2 and 3. The energy density values are the average values on Helsinki sub districts.

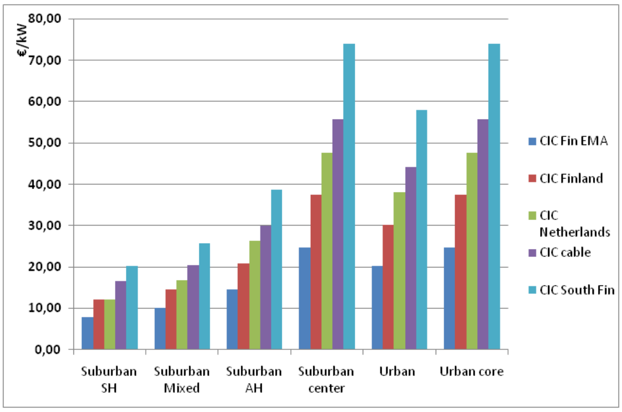

Figure 2. The CIC estimates of urban zones based on different research material and area, 1 h unexpected interruption.

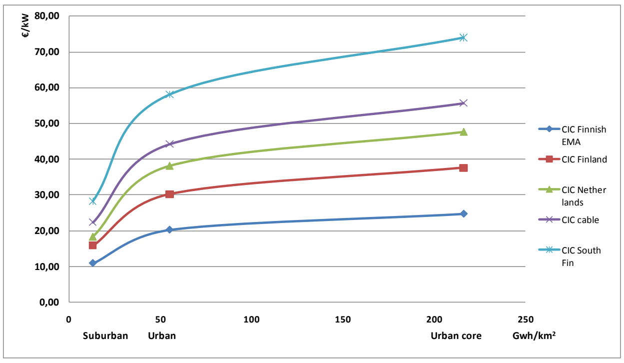

Figure 3. The CIC estimates as a function of energy density based on different research material and area, 1 h unexpected interruption.

From the results in Figures 2 and 3 we can notice that:

- The area based interruption cost values increase the nearer the customer is the city core
- The interruption cost values increase when the energy density of the area increase
- The interruption cost values in urban core are approximately doubled to the costs on suburban area

Postal survey

To estimate the costs of electricity outages to customers, a postal survey and a research study were implemented by Aalto University. The aim of this research was to define the costs of electricity outages caused to customers in diverse urban areas. Selected customer groups were commercial, public services and small industry.

The CIC of the commercial customers were calculated in urban core (city), urban and suburban areas. The response rates of the small industry group and public service were not sufficient to make analysis on different urban areas. The results of the interruption costs of the commercial customer group are in Table 4. The interruption costs of the commercial customers on urban core were about twice the costs on urban and suburban areas [6]. One reason for this is that in city the real estate prices and rents are expensive and thus the companies in urban core are companies with high financial value, heavy flow of customers and with long activity hours: head offices, banks, shopping centres, insurance, consulting companies, law firms etc.

Table 4. The interruption costs of the commercial customers on different urban zones. [6]

1 h	€/kW
All	65,06
urban core	95,62
urban	38,03
suburban	48,86

In the CIC study, the commercial CIC values from the Finnish Energy Authority report (Table 1) were replaced with the values in Table 4. As a result we have the customer interruption cost as a function of the energy density, as illustrated in Figure 4. The relation between the energy density and customer interruption cost is almost linear.

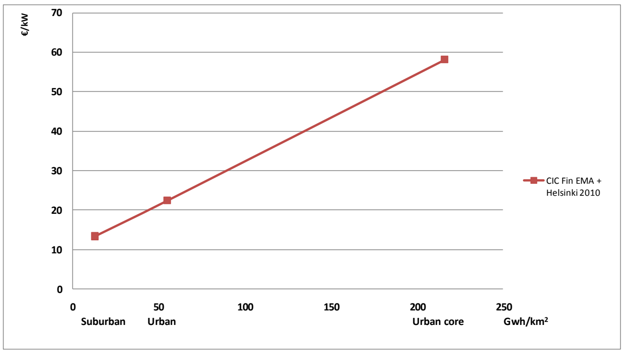

Figure 4. CIC as a function of energy density and urban area.

The CIC on an urban core area are about three times higher than costs experienced on other urban areas. The reason for this is the combination of

- commercial and public services are more dominant in urban core than on other urban areas
- the CIC values of the commercial customers on the urban core are about doubled compared to other urban areas because of the high value of the customers in the city.

NEW FINNISH RELIABILITY CRITERIA

In the year 2010 the Finnish Energy Industries published the "The criteria and target levels for the reliability of the electricity delivery". The criteria and target levels are based on the area allocation. The areas are: city, urban and densely populated area, rural. The target levels for the reliability of the electricity delivery are presented in Table 5. [7]

Table 5. The target levels for the reliability of the electricity delivery

Area	Total interruption time / a, customer	Number of short interruptions / a, customer
City	≤ 1 h	None
Urban, population centres	≤ 3 h	≤ 10
Rural	≤ 6 h	≤ 60

These values are applied as a network planning criteria. Within a three years time period the target levels can only once be exceeded. These target levels should be achieved by the year 2030. The study and the results on area based customer interruption costs are supporting these reliability criteria.

SELECTION OF REMOTE-CONTROLLABLE SECONDARY SUBSTATION IN HELSINKI

The selection of the remote-controllable secondary substations in Helsinki is planned by a topological and a cost-benefit analysis. By installing the network automation to normally open tie points and to the secondary substations that are in the half-energy point of the medium voltage line, the utility can in interruptions restore half of the energy very rapidly by remote controls and by help of fault indicators. [8]

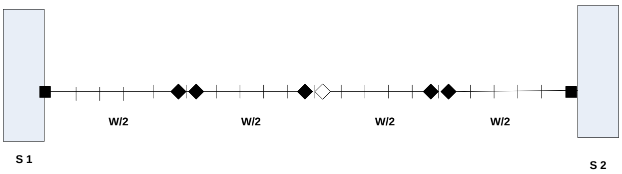

Figure 5. Topological analysis on network automation planning, three secondary substations per feeder pair
| Secondary substation, ◆ remote-controlled disconnector ◆◇ normally open tie point

The cost-benefit analysis is calculated by the annual lifetime cost of the network automation versus the annual benefit in the reduction of the customer interruption costs. By using topological and cost-benefit analysis, the network automation is cost-effective to be installed on about 300 feeders (two thirds of all the feeders). This means 450 remote controllable secondary substations.

Theoretically the layout for network automation can be done by topological and cost-benefit analysis, but in real cases many factors are limiting the installation of network automation on secondary substations. The constraints are for example: the age and type of the Ring Main Unit (RMU), insulation material and the ownership of the secondary substation. [8]

CHANGES IN NETWORK AUTOMATION STRATEGY

The challenge in implementing network automation is how the utility should target the investments so that the cost/benefit ratio is optimum and the decrease in customer interruption cost is the most significant. Long term planning and optimization also requires taking into consideration the new reliability criteria and future regulatory actions.

The Finnish target level for the total customer interruption time per year in city centres is no more than 1 h. Using manual switching it is hard to achieve the below one hour total interruption limit. Also the customer interruption costs in urban core are about three times higher than costs experienced on other urban areas. When taking into account these two factors the new network automation planning target for the urban core is 100 % automation, all secondary substations on the urban core are equipped with remote controls.

The new Finnish reliability target levels for different areas are consistent with the results of the customer interruption costs in different urban areas. The allowed total interruption time per a customer in a year in the city centre is only one third of the time in other urban areas and the customer interruption costs in the urban core are roughly three times those on other urban areas.

The new network automation planning layout takes into account the outstanding differences in customer interruption costs in different urban zones and the new Finnish reliability criteria for different areas. The new network automation long-term planning strategy is a combination of topological and cost-benefit analysis including areal approach.

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