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Report on network condition monitoring and network planning in practice

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Name of the report: Report on network condition monitoring and network planning in practice

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Summary

The purpose of this report was to discuss, what is the role of network measuring sensors in the field operations and what kind of opportunities it creates for service providers and network owners. The objectives of this report included the needs of two parties: Empower and customers (network owners). In addition, the perspectives of Tampere University of Technology and Lappeenranta University of Technology were incorporated into the discussion due to the closely related researches to this topic that the institutions had done.

Utilization of network devices in practice is divided into six phases from service provider view. The first phase is the planning of the locations, where the measuring sensors will be installed. The hypothesis is that the measuring sensors will create the largest benefits in those areas, where there are a great number of network faults. After the locations of the sensors are determined, the actual installation of the devices needs to be initiated. The field workers ensure that the sensors function properly and the data transmission is working. Especially in the “pilot” phase, when the new sensors are just installed, the evaluation and further development is important. Empower’s expertise and experiences from the field work could provide useful information for the re-development.

The last three phases of the network device utilization are related to the actual data captured. When the devices are installed, the data needs to be transmitted effectively and securely to a data warehouse. Then in the next phase the data is analyzed and from Empower point of view it should be performed through a centralized process, where for example Service Center collects and analyzes the data and distributes the processed data to different operators. The last but not least is the data utilization phase, where the measurement data is utilized in network planning and (proactive) maintenance of the network. One of the greatest benefits of the sensors are that operators are able to collect more accurate and timely data of the network’s functionalities, and react proactively before the network faults occur. This proactive way is beneficial for both the customer (network owner) and the service provider.

Tampere, September 2016

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1 Preface

This report is a part of the national research project called Flexible Energy Systems (Flexe). The purpose of the Flexe-program is to create abilities for the Finnish operators to plan, build, manage and use the future smart and flexible energy system. This program is funded by Tekes – the Finnish Funding Agency for Technology and Innovation.

This document is written from the practical perspective by Empower TN Oy. Energy system condition monitoring (electric grid and telecommunications) and measurement data utilization (e.g. in network planning and usability analyzation) are the core subjects of this report. The objective is to describe, how smart network measuring devices could be utilized in the service operations and what is the benefit of these devices for the service provider and customer.

Tampere University of Technology (TUT) and Lappeenranta University of Technology (LUT) have done research, which is connected to the previously mentioned subjects. Empower TN provides a practical viewpoint to this discussion, which is hopefully valuable also to the universities mentioned above.

2 Introduction

Empower Oy offers power and telecom network services, industry services and ICT solutions for its customers to improve the competitiveness of the customer and enable them to keep their focus on the core business. The business operations of Empower are divided into five business divisions, which are power network, telecom network, industry, information management and Baltic-division.

This report is from the viewpoint of Empower telecom network (Empower TN), but besides focusing on the operations related to this particular business, the purpose is to include also other Empower business divisions. Empower TN offers telecom network construction and maintenance services and telematics services for its customers, of which telecom operators are the most significant ones. TN construction and maintenance services include fixed network construction, mobile network construction, network device construction, installation and fault repair.

The purpose in the Tekes funded Flexe-program is to create technological and business concepts that enhance the transition from current energy system to sustainable and flexible future energy systems (Clic Innovation 2016). This program brings together 27 organizations and covers the whole energy system network. The role of Empower TN in this program is specially to bring the practical perspective of telecom network service provider and describe its role in the future flexible energy systems as a data/information collector and utilizer.

The role of network measuring devices in future networks is crucial. The purpose of future flexible network is to ensure that the supply side and demand side in the energy system are matching continuously. This requires that the network conditions are measured in real-time to make sure the usability and functionality of the network is flawless. This measurement data and overall information capture from networks is growing at a rapid phase. The network between devices, buildings, vehicles etc. is called the internet of things (IoT) or in other words, industrial internet. Gartner (2014) has forecasted that in 2015 there will be approximately 25 billion industrial internet devices in use. This imposes tremendous pressure on data management: how is data gathered, stored, classified and utilized effectively?

This deliverable is closely connected to other deliverables in the Flexe-program. Tampere University of Technology and Lappeenranta University of Technology have made two research projects, which cover the topic discussed also in this deliverable – network and automated measurement. TUT has researched the usability monitoring of electric network and based on that has designed a prototype device, which measures the condition (quality of the electricity, cable condition) of the network. They have also published an article related to cost-effective measurements and measurement data management.

LUT on the other hand has studied automated information/data collection and for example open data source utilization. An example of open data source is weather condition measurement data. LUT has looked into this data and they are interested, if the information could be utilized in network planning.

The discussion in this report consists of three main chapters. In chapter 2 the objectives of this deliverable are presented. Chapter 3 takes a stand on utilization of network measuring devices in practice. The main idea in this chapter is to present the effects of measuring devices and sensors (research area of TUT) in practice for service provider (Empower TN) and customers. The practical effect of collected data (open source and real-time data collection) on network planning is also discussed in this chapter. The conclusion and thoughts on future steps are outlined in the last chapter.

3 Objectives

The objectives of this deliverable can be classified into three distinctive categories based on the needs and perspectives of a certain operator. These categories are the following:

- Empower needs
- Customer needs
- Incorporation of TUT/LUT perspectives

The purpose and objective of this report is to satisfy the needs of the first two previously mentioned interest groups and also incorporate the perspectives of the universities. From the viewpoint of Empower needs, the objective is to discuss in this report, what are the practical (business) possibilities that the measuring devices and sensors bring to the table and how the devices and data are used and utilized in the field work and central processes in the company. In other words, the objective from service provider point of view is to improve its business operations and find new opportunities for growth. The transition from current energy system into future flexible and smart energy system definitely offers possibilities that need to be taken into consideration.

The second perspective is the customer view. The objectives related to customer also needs to satisfy the service provider needs so that the goals are mutual for these two parties. One of the objectives is to find ways to improve customer service and seek “win-win” –situations. Then can be discussed, how the improved service provider operational performance affects customers’ operations.

The final point of view is the related deliverables view of TUT and LUT. They have studied e.g. network measurement techniques and open data utilization, and now these researches should be incorporated into practice. This is where Empower TN can provide an input and raise thoughts on how these devices and data can be utilized in the service provider operations and what kind of effect it has on business for both Empower TN and its customers.

4 Utilization of network measuring devices in practice

In this chapter the utilization of network measuring devices in operations are discussed. The main idea is to present thoughts on how to make use of the network measuring devices and the data they produce.

This chapter is divided into five subchapters. The installation of measuring devices begins the discussion. In the second subchapter the data analyzation and proactive maintenance is taken into closer look. The network usability evaluation becomes more accurate with the help of measuring devices and their created data, which is the topic in the third subchapter. The following subject is the “win-win” –possibilities and mutual benefits for the service provider and customer. Finally, the open data and sensor data effect on network planning will end the discussion in this chapter.

4.1 Installation of measuring sensors

TUT has done research on network condition measurement and studied the sensors that measure the functionalities of the network. The first step is to develop measuring sensors based on the target usage and appointed objectives. After sensor development the next step is to install the measuring devices into the network. This is where Empower TN comes into play and has the ability to place the devices on the field. The measuring sensors’ pilot process is presented in figure 1. This basically describes in a general level, how the developed sensors should be applied in operations.

Figure 1. *Measuring device pilot process.*

Before the actual installation work, the location of the devices in the network must be planned carefully. For example, transformer substations could become a new measuring point in the distribution network. Co-operation with the network owners naturally plays a crucial role in order to decide the proper locations for the devices. The best practice would include piloting first a few devices in an area, where the need for more precise network measurement data is the highest. An example of areas like this would be those which have high amount of network faults. The utilization of measurement data enables network operators and service providers to act proactively and prevent faults to occur.

The installation sub process involves the actual work on the field and installation of the sensors to the planned locations. The significant factor in this

phase is also to ensure that the data is collected properly and effectively. So the overall installation process could be divided into two sub tasks: the physical installation work makes sure that the device is in proper place and functions as it should. The second task is to ensure that the data transmission to the data warehouse is flawless and secure.

The final step in the general process is to evaluate the performance and functionality of the measuring sensors. Then further development of the sensors can be made based on the evaluation. In this case the actual product development is done outside Empower organization, but maybe Empower TN as a service provider could still take part in the possible further development projects. Brainstorming and co-operation between the sensor developer and Empower TN brings together the technical capabilities and network business & field view. Empower TN could especially contribute to how the sensors are installed on the field and how it could be further developed. An important aspect in the installation process is that it is cost-effective with short lead-time. These are central indicators in the product development, when the changes and additions are evaluated.

4.2 Data analyzation and proactive maintenance

Once the installation of the sensors to the network is completed and the data transmission functionalities are ensured, the next step is to define where the data is collected and how it is analyzed and utilized. The data warehousing, analyzation and utilization form the general data processing process, which is depicted in figure 2.

Figure 2. *Data processing process.*

When data is measured in the network, the first step then is to send it in a secure way to a secure data warehouse. In order this to be simple and secure, the data should be transmitted into a centralized data warehouse. The installation phase was mostly in the hands of Empower TN, but here in the data processing phase Empower IM (information management) division – a service provider who is specialized in data analyzation – has also a role and capabilities.

After properly storing the data, it needs further processing and classification. As mentioned in the previous section, it is important to centralize the data in to a certain warehouse, and this same applies to data analyzation. To be efficient, the measurement data should be centrally analyzed. In this case the analyzation could be in the hands of Service Center (SC). They could process the data into a form, where it could be sent forwards to other units for utilization in operations. In addition, naturally the network owners are the ones

who are especially interested in the measurement data, so SC should serve them also. This arrangement and operation could be described as Data Service Center, which services the operators who are in need of the network measurement data. Centralized operations management is essential part in Empower's business model. When certain processes/working tasks (e.g. documentation) are feasible to centralize, it should be done. This is because centralizing enables cost-effectiveness, it standardizes the work across the company and business units are able to focus on local key tasks and customer service.

Data utilization includes the targets, where the analyzed data is used and benefited from. One of the most significant areas, where the measurement data could be utilized, is proactive maintenance. The measuring sensors provide data of the quality of the electricity, which could be utilized to detect possibilities for incoming faults in the network. To proactively detect risks is a way for service provider to message customers that particular areas in the network require maintenance. Then the faults are proactively prevented, which is beneficial for both customer and service provider. The end customer is satisfied with the functionality of the network, which is naturally positive sign for network owners. Active measurement data utilization and proactive maintenance also means more work for Empower.

Based on the measured data, service provider has the ability to offer more services to the network owners. This includes the existing services and possibilities to broaden the service offering. One of the possibilities is to take responsibility of making maintenance plans for networks. This would transfer responsibilities from the customer side to the service provider. Hence, the customer can increasingly focus on its core business and ensure the end customer satisfaction.

Another aspect is the pure analyzed data value for the network operator itself. They receive information how the network is functioning and what are the needs for proactive maintenance. This way they have a developed information and understanding regarding the future maintenance costs in the network. They can plan new investments based on the sensor data and ensure that the network is functioning as it is promised to the end customer.

4.3 Network usability analyzation

The usability of the network is the most significant factor, when we take into consideration the end customer view. This makes the network usability the most important operational development area for the network owners. The sensor technology provides accurate and real-time data to make sure that the network usability is meeting the standards.

To be able to ensure the usability of the network, information regarding the quality of the electricity and cables, network load/usage and environmental

risks are needed. The quality of the electricity and network load can be measured with the installed devices. This information is further used to make sure the cabling is of a high enough quality. Besides the technological assistance, also human vision is needed to make sure that especially the network environment is risk free. The biggest environmental risk is the woods near the network. To notice a risk of a tree falling on the lines is in many cases relying on human vision. Another option to map large areas besides field worker's observations is to utilize aerial photography. Empower field workers' observations on the field work and photographing together are excellent ways to bring in information of potential risks in the network. This information could be utilized together with sensor data to analyze and evaluate the usability of the network. Field workers' observations and photographs could be collected centrally by SC (the same way as sensor data, as discussed earlier in chapter 4.2), so that the information could be combined with sensor data. Also historical fault statistics data is useful to include in the usability analysis. Operators and customers receive comprehensive information regarding the condition and usability of the network.

The usability analyzation includes also the evaluation of different components in the network. For example, the fault frequency of various network devices and technical features of the components should be evaluated, which could give an opportunity for service provider to provide network owners with a valuable information. The need for updating of network components could be estimated and then the results communicated to the customer. The same way the analyzation of network usability would help the network owners to prioritize, where and in what order the network overhead lines should be removed and replaced with underground cable. At the same time when electric cables are moved underground, the telecom network cables should also be constructed. Then with one excavation work can both electric and telecom network operators be served.

4.4 Mutual benefits for service provider and customer

The measuring sensors in the network shift the focus from post fault maintenance to proactive maintenance, as discussed earlier. This has a significant effect on how operations are managed and it also guides the objectives of the service provider and network owner to the same direction.

Currently one of the challenges is that the service provider needs and network owner needs are at some extent going different directions. From service provider view, there is naturally a need to have as much as work possible in order to create cash flow and keep their human resources occupied as effectively as possible. This basically means that if maintenance field workers are working at a high capacity, there has to be a number of faults in the network that needs to be solved. On the other hand, the customer side of view is completely different. They naturally do not want any faults or problems in their network that would hurt the usability of the network and end customer

satisfaction. The contradictory perspectives create the basic fundamental challenge in the business between the service provider and the customer.

The measuring sensors provide a new insight and perspective to this challenge. This technology creates better capabilities to evaluate the performance and functionalities of the network and react proactively based on the signals and data that the devices capture. Proactive maintenance is the key to satisfy the needs of both service provider and customer, because it includes benefits for both parties. Compared to reactive maintenance (where faults have already occurred), proactive maintenance requires planning and orderliness. With active planning of maintenance, the potential risks for faults are solved before they occur. From service provider point of view, planning and proactive network tasks are increasing, which increases the efficiency of the field work. One example of this efficiency increase is that evening time maintenance alerts are decreasing, when the risks for faults are eliminated earlier through maintenance planning and proactive field work.

With component life cycle evaluation, it is possible to create continuous maintenance agreements with customer to ensure that the components and devices are replaced before they break down. Component life cycle evaluation builds on the expertise and experiences of the network operators. From customer or network owner point of view, the proactive maintenance decreases the amount of realized network faults. The reliability of the network increases, which has naturally a positive effect on end customer satisfaction. Improved end customer satisfaction further has an effect on customer loyalty and also attracts new potential customers through e.g. word of mouth. From service provider point of view, the decreasing realized network faults means that there is less fault repair work orders, which of course results in less revenue stream from those duties. However, the revenue logic could include new elements, which are made possible by the proactive maintenance. Customers could reward service provider based on the improved network usability and increased end customer satisfaction.

Empower TN has done a case study and a pilot regarding how would Empower TN and its customers develop their operations and revenue generation model to gain mutual benefits. This process is still underway. There is a mutual consensus that the amount of network faults should be decreased. The original plan included that first needs to be determined, where are the biggest “clusters” of network faults. Then the reasons behind the faults need to be clarified. This way it becomes clear for the network owner, what actions need to be done in order to improve the functionality of the network. Then an investment budget is created to improve the network and the responsibility of the tasks falls to the service provider.

The benefit for the service provider is naturally the new work orders that need to be completed in order to improve the network. In addition, the fault repair revenue generation model is slightly fine-tuned to serve the needs of both service provider and customer. First a baseline value for realized network faults is calculated. This calculation includes taking a mean value of realized

network faults for the past three years. When the investments and work for improving the network is completed, the post-improvement fault amounts are compared to the baseline value. This comparison has an effect on how the fault repair work orders are invoiced. If the “post-update” realized fault amount is max. 10% less than the baseline value, the service provider can invoice an agreed amount more per work order. On the other hand, if the network improvement project somehow fails and the fault amount exceeds the baseline value max. 10%, the service provider will invoice an agreed amount less per work order than normal.

The measuring devices would give useful data to justify the needs for network improvement and take forward the efforts to achieve mutual benefits. An accurate data is first processed to useful information, which is used to search for fault clusters and reasons behind them.

4.5 Effects on network planning

With the help of measuring sensors, Empower TN can provide customers with useful information, which also has an effect on network planning. The sensors create data on components and this data can be processed and used to give intel on how well various components function in certain areas under certain circumstances. When we have information on how these components work and what kind of life cycle they have, it affects significantly the way the network is planned and materials/components are chosen.

Lappeenranta University of Technology has researched how open data could be used in network planning. Open data includes for example weather information and it could definitely have an impact on practical energy grid planning. Weather information could be utilized to find out, how different weather types impact the functionality of the network and how the faults occur. It could be utilized regionally to provide planners with accurate historical climate data, which would set requirements for the network structure. This applies especially to the grid planning where overhead lines are used. Besides new measuring sensors, also AMR (automatic meter reading) devices collect data from networks, which could be utilized. AMRs collect for example real-time consumption data. That data is mainly used in customer billing, but consumption information is useful also for network planners, when requirements for new grids are determined. When open data is used together with network sensor data, network planning has a great amount of useful data to support the planning decision making.

As stated earlier, the network measuring sensors provide data that is utilized in maintenance planning. This way the customers receive information, which areas require a lot of maintenance work and which areas are functioning well. In other works, customers can predict and evaluate more accurately, which parts of the network need investments to improve the overall usability of the network. Maintenance planning enables to evaluate the amounts of future

work and network investments. When the future costs are more visible, the pricing and matching of costs and revenues become easier.

5 Conclusion

The purpose of this report was to discuss the effect of network measuring devices on practical field operations and network planning from Empower TN point of view. The objectives included taking into consideration the needs of three different parties: Empower TN, customers and TUT/LUT. The discussion of how measuring sensors are utilized in practice will hopefully give clear insight to universities involved, how significant impact this technology has to the energy system planning, construction and maintenance.

From Empower TN point of view, the starting point in the sensor utilization process is the actual installing of the devices to the network. Empower TN's task is to ensure that the sensors are working properly in the grid and they transfer the data (telecom network functionality) as is required. The data analyzation and utilization phase is a slightly more complex process, where the data transferring methods and communication forwards needs to be defined clearly. The most efficient way is to gather and process the data centrally. One option is to utilize Empower TN's Service Center to take care of this task. In the data processing phase Empower Information Management division could bring in their capabilities to make sure the data is processed into useful information that could be messaged forward to customer. At the same time service provider can use this information to offer services to the customer.

The benefits of the measuring sensors could actually reach three different divisions at Empower. Besides the tasks of Empower TN ja IM mentioned in the last section, also Empower PN (power networks, specialized in electric grid design, construction and maintenance) could take part to take responsibility of the electric grid maintenance tasks. TN (in co-operation with IM) division provides the information (needs for maintenance) to customer and PN, and then PN performs the actual electric grid maintenance tasks on the field. In addition, PN can also participate in the network planning tasks. The network measuring device usage & utilization process and liability distribution is presented in figure 3.

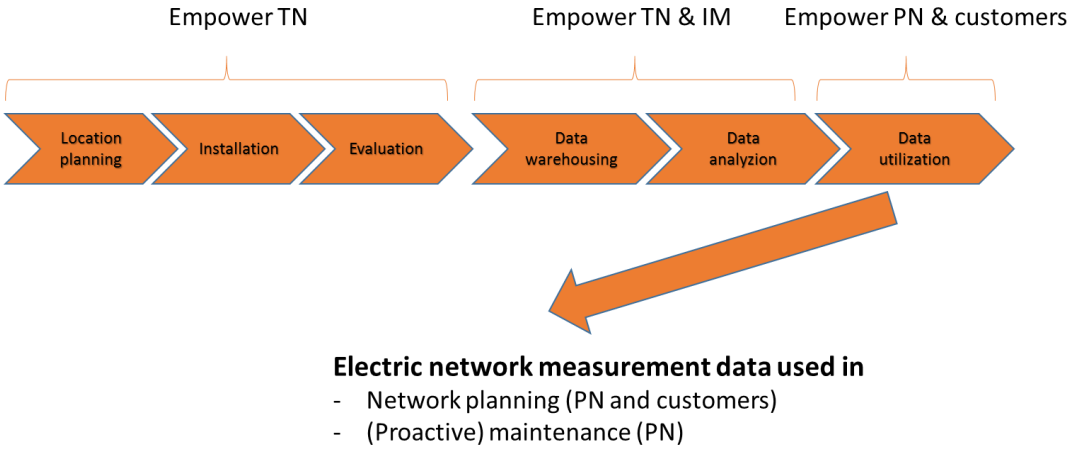

Figure 3. *Network device usage and utilization process.*

Due to more accurate and growing amount of data, energy system network owners have the ability to evaluate the condition of the network more accurately and make proactive decisions before the faults are realized. When the condition of the network is well known, the related costs are also more visible. The network owners have the possibility to give more responsibility to the service providers by assigning them for example continuous maintenance tasks and network maintenance planning. This allows the energy system network owners to concentrate on their core business and cost-effectiveness of energy transmission.

5.1 Next steps and opportunities for new services

The practical possibilities and utilization of network measuring sensors were discussed in this report, and the next step is to perform field tests with the developed devices. The performance and functionality of the test devices are evaluated comprehensively and based on this evaluation re-development might be needed. As discussed earlier, Empower TN could give some useful input to the re-development process. In addition, the internal communication in Empower and external with customers considering the benefits and possibilities of this measuring technology needs to be started.

Besides the development of sensors, also new business opportunities could be identified and utilized. Network measuring sensors data is not the only – even though crucial – data source that could be utilized in network planning and proactive maintenance. As discussed earlier, environmental data together with field worker observations and fault statistics are important additional data sources. When these data sources are combined and used together, it opens possibilities for service provider to offer customers new information products and services. Two new service offering possibilities could be identified: network planning information package and proactive maintenance information package. These packages include relevant data for each planning and maintenance in order to make sure these customer operations are efficient and decision making reasonable. New service offerings are described in table 1.

Table 1. *New service offerings sketched.*

Data source	**Network planning info package**	**Network maintenance info package**
Network measurement devices	Network component functionality data - Component lifecycle evaluation ⇨ Information for network planning to decide appropriate components	Network component functionality data: - Component lifecycle evaluation ⇨ Maintenance plans for component replacements

	Cable quality/condition data ⇨ Information for appropriate planning for cabling	Cable quality/condition data ⇨ Maintenance plans for cabling replacements
	Network load data ⇨ Requirements for network components and cables	
Environmental data	Network usability evaluation: - Aerial photographing for area scanning, risk assessment and clearance plans - Weather information (e.g. climate impact analysis, especially wind and lightning impact) on different areas - Analysis on how to prioritize overhead line replacements with underground cable	Risk assessment: - Climate impact analysis, especially wind and lightning impact ⇨ Forecasts for future network faults ⇨ Forecasts for future maintenance activities
	Open data to support planning: - Maps (nature conservation areas, forest areas on line paths etc.) - Infrastructure investment plans	
Field worker observations	Network usability evaluation: - Observations regarding possible risks (fallen trees etc.) ⇨ Risk assessments and effect on planning	Network usability evaluation: Observations regarding possible risks (fallen trees etc.) ⇨ Reporting and request for maintenance activities
Fault statistics	Number of faults on different areas to support decision making in planning and new network investments	Number of faults per area to support proactive maintenance planning and forecasting for future fault estimations

Based on the information from various sources presented above, Empower would be able to produce reports (information products) for customers that could be utilized in network planning or maintenance. When customers receive a request for new network planning work, they could first send a work order for Empower to analyze the target area and make decisions on components and cabling. Empower has also the capability to perform the actual network

construction. Field worker observations, fault statistics and measurement device data opens the possibility to make proactive maintenance plans and schedules for component replacements from the maintenance point of view. All in all it is clear that network measurement data together with other data sources reveal opportunities for service provider to service customers in a new way and more comprehensively.

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