EXPERIENCES OF USING AMI SYSTEM FOR DSO's BUSINESS OPERATION

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ABSTRACT

In the European Union almost all countries have done at least principle the decision to implement smart metering systems. In Finland smart meters are required by a regulation and at least 80 % of all metering points must already be equipped with a smart meter. Total smart metering rate in Finland is now over 95 % in premises where main fuses are at most 63 amperes. Total amount of metering points is 3.3 million. Premises having over 63 ampere fuses are all equipped with smart meters.
Elenia was the first company In Finland who installed smart meters to all residential customers. Roll-out project was finalised at 2008 and since then the meters have been in active use and the supporting systems has been developed actively. This paper present Elenia's experiences about AMI and application method of AMI system.

INTRODUCTION

The primary role of AMI (Automatic Meter Infrastructure) systems is to provide real time energy consumption data to the utility for the billing and imbalance settlement. However, the business case for the implementation of AMI is essentially more positive when taking into account also new AMI based services for the customers and utilities themselves. At Elenia Oy the entire AMI rollout was carried out between years 2003-2008 including for all customers. The Finnish regulation set at 2009 requirement for hourly settlement at least for 80 % of all residential customers to be in use starting at 1.1.2014. Additionally, all commercial customers must be hourly measured and settled since 2012. By the regulation customers also have to have an access to their hourly consumption data. 99,99% of Elenia's customers have AMI meter at their premises when total amount of customers is about 417 000. Elenia has a long track record for using AMI meters and this paper includes detailed descriptions of the practical AMI applications developed for customer service, network operation and network planning being in daily use at Elenia.

AMI system consist of three main parts which are meters, communication system and meter data management. In Elenia the AMI system is mainly outsourced but the meter data management system (MDMS) is owned and operated by Elenia. In the roll-out project about 350 000 Iskraemeco AMI meters were installed. In the recent years Elenia has purchased AMI meters also from Aidon. By using two different manufacturers the availability of the meters has remained high.

AMI communication system is operated by Finnish mobile operators. In the older AMI meters there are available GSM and GPRS. Newer meters have LTE modems. Meters are read once a day and communication system delivers data to the MDM also once a day.

Current Meter Data Management System (MDMS) is EnergyIP from Siemens. The system is used for meter data management, imbalance settlement and data analysis. MDMS controls the data quality and shares the meter data also to other operational systems such as Network Information System. MDMS big data functionality is used to find data quality deviations and broken meters. MDMS also calculates the technical network losses and enables adequate forecasts to purchase network loss energy with the competitive price. MDMS is also integrated to the network information system (NIS) and extranet consumption reporting service to provide more accurate data for network calculations and for (automated) customer service.

AMI FOR BILLING AND SETTLEMENT

The main purpose of AMI is automated meter reading (AMR) remotely enabling factual billing based on the real consumption. Hereby billing needs to be adjusted afterwards only when a mistake is found. Also actual consumption data for balance settlement bring along exact real time data to the energy markets. Exact billing combined to modern consumption reporting services enhances essentially customer's awareness of their consumption profile establishing base for efficient energy usage.

In Finland current imbalance settlement period is one hour and therefore hourly metering is demanded in the regulation. After smart metering rate was high enough in Finland, all imbalance settlement have been based on the measured hourly intervals. This has reduced the need to correct imbalance settlement calculations afterwards. Settled sum per supplier can be changed in the settlement window which is 14 days but will be shorten to 11 days when common Nordic Balance Settlement (NBS) will be taken in use IN Norway, Sweden and Finland.

Parallel to the imbalance settlement, the meter data is used to calculate also technical network losses. The Finnish regulation enforces companies to purchase network losses form the competed markets, so the accurate loss history data is essential for purchasing.

AMI FOR CUSTOMERS

In addition to exact billing AMI system enables energy consumption reporting. Already today, all customers are able to register into extranet service named "Elenia Aina" where hourly intervals are available. By the Finnish regulation the data must offered without any compensation for customers. Data is available in web and parallel there is also mobile service launched for the customers. Using mobile service a customer can supervise personal consumption anywhere and anytime. In the app/webpages the hourly daily, monthly or annual data are shown for the user and this makes possible to compare consumptions of different time periods. Service enables customers also to browse the invoice history.

Mobile application has also a function to request the real time status from a customer site. There exist a large number of summer houses in Finland and the customers aspires a possibility to see remotely if there is electricity on in their premises. This is allowed in real time via mobile service, which sends a request to a meter and return back the status in the meter showing active alarms when activated. In figure 1 shows the developed mobile service interfaces. The mobile service is called "Elenia Mukana".

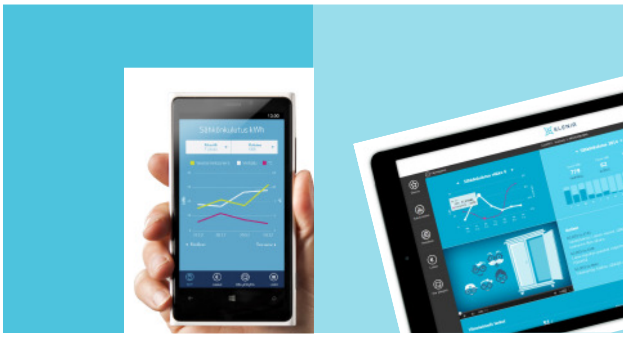

Figure 1. Elenia Mukana mobile service

The figure 2 shows an example how the web service presents daily consumptions shared by tariffs. In the web the same features is available without possibility to ask status from customer premises.

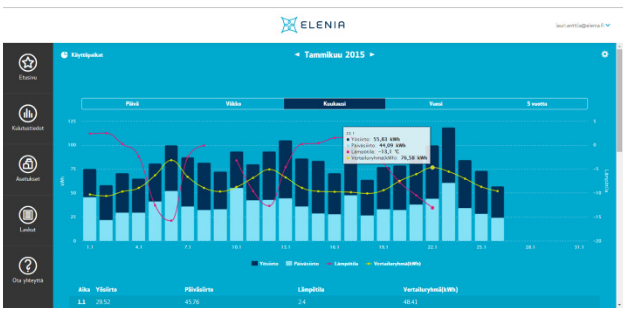

Figure 2. Elenia Aina consumption reporting service.

AMI FOR NETWORK MONITORING

Before AMI system the supervision of Low voltage (LV) network was based on the information from the customers. Medium voltage network have been automatically monitored for a long via primary substations and now AMI enables the same fault management process for LV networks.

One of the major steps utilizing AMI in Elenia has been to integrate AMI data collection system with Distribution Management System (DMS). This is called AMR-DMS integration. The integration has offered totally new possibilities to monitor LV network. This has expanded automatic network supervision to the whole network.

The main functionality of the network fault management process can be divided into the two parts, automatic alarms and status queries. AMR-DMS integration enables status queries directly from DMS to the meters. A query can be sent manually or automatically to one meter or group of meters. After meters have sent spontaneous alarms e.g. about a neutral fault, alarms are shown on the DMS screen in the control center. After receiving spontaneous alarms, DMS can send queries to other meters in the same area [1, 2, 3].

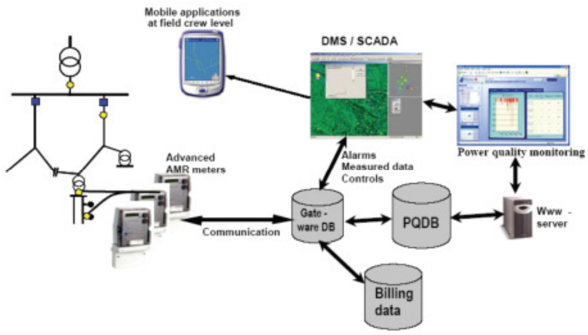

Figure 3. Using AMI system in network management

AMR-DMS integration has been indicated as essential tool in network operation. Numerous spontaneous alarms have been received and for example over one million meter queries are performed since 2010 to establish snapshot from the faulted areas. Experiences are very positive. Integration support shortens outage duration and improves efficiency, improves customer service and reduces unnecessary visits to customer sites.

The most important benefits in medium and low voltage network faults are;

- Verification of power supply at customer premises
- Recognition of neutral current faults, phase faults and faults in customer network
- Location of broken MV conductors
- Reduces unnecessary visits to customer sites

For the needed functionality, meter software has been upgraded twice to all meters. Upgrades were done remotely.

Communication over the AMR-DMS integration happens between meter reading system and DMS passing MDMS. For network monitoring following functionalities are available on the current meter firmware;

- Alarms
  - Phase missing
  - Zero conductor fault
  - Asymmetrical voltage
  - Over voltage
  - Under voltage
- Queries/answers
  - Device responding - no alarms
  - Device responding - active alarms
  - Device not reached
  - Device unknown

In figure 4 is introduced a case where three neutral faults were detected by meters and spontaneous alarms sent automatically to the DMS. The figure shows how the status is shown for a network operator on the screen. After receiving alarms DMS can automatically sent queries to the other premises at the same low voltage feeder and results in the figure point that only three last premises are faulted.

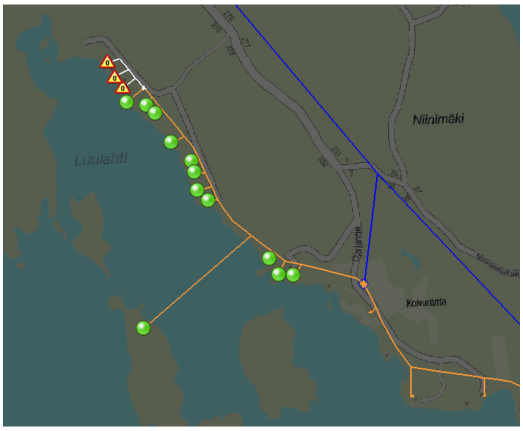

Figure 4. Three neutral faults in low voltage feeder

Figure 5 presents typical case after a storm. A medium voltage feeder was damaged by a storm and after the fault is repaired and delivery of electricity returned in MV level all AMI meters at the low voltage side are queried to control if there are hidden damages behind medium voltage fault. In the figure 5 can be seen that four meters do not answer which are marked by red balls. The query revealed a fault also in the LV network which could be repaired with the same work crew already in place.

Smart meters can see in some cases also recognize medium voltage network faults. In Finland medium voltage networks are delta connected and isolated. When a wire cut happens at medium voltage side it causes significant voltage unbalance to the low voltage network. When one phase is lost at medium voltage side, meters can see at low voltage side that two phase voltages are decreased to half of nominal when transformer connection group is Dyn11. Generally wire cut at the medium voltage network is challenging fault to detect and locate. In the figure 6 is shown that many meters see voltage unbalance and fault is located between two red arrows. In practice location is performed in minutes.
It is possible to establish spontaneous alarm when a fault is detected (alarm set on) and when it is departed (alarm set off). Nowadays only alarms set on are used.

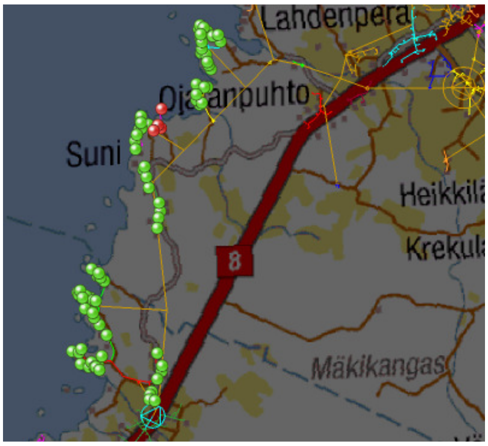

Figure 5. Results of a query after medium voltage fault reparation

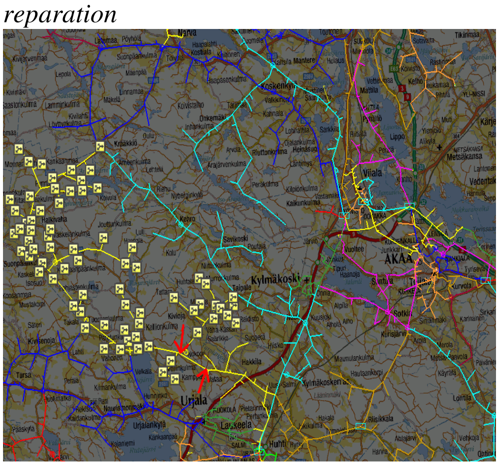

Figure 6. Automatic alarms after wire cut in medium voltage feeder.

Newest meter type installed in Elenia's network can also store instantaneous phase voltages and currents when a fault is detected. These values can be sent to the control center among spontaneous alarm and the information can be shown in the DMS. The experience shows that AMI enables to establish snapshot in a geographical area without further delay especially after storms. It offers also better information for customers in fault situations.

AMI FOR NETWORK MANAGEMENT

Besides storm management, the information provided by AMR can also be used in many other ways for improving the network management process. Following examples models practical cases how AMI system can be used especially to indicate real (historical) network loading instead of modeled loading and power quality monitoring. Both functionalities are supported by smart meters.

Network Loading

Some years ago the network calculations were mainly based on hourly values produced by load curves. Modelled values can differ sometimes a lot from the real values causing errors for network dimensioning. After AMI roll-out it has been possible to compare modelled and measured values. In the figure 7 is presented load comparison (real vs. load curve) from one week. This particular service delivery point is housed at rural area and does not have electric heating. Annual consumption is 4900 kWh.

In this example case modelled load is presented by light blue curve and it is compared to apparent power when also reactive power is noticeable. In the figure can be seen that the highest measured peak is over 3 times higher than modelled value.

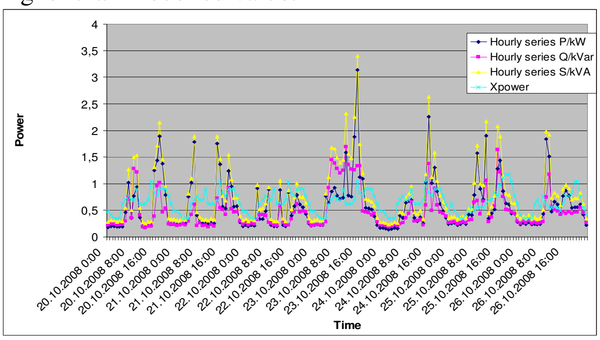

Figure 7. Rural Domestic customer

Power Outages

All meters have long power outage log and event log. In these logs all outages are stored, also very short outages, like reconnections which last typically 0.5 second. Most of the outages caused by a fault are stored also by the protective relays but there are also faults at the low voltage network which cannot be detected by the protective relays.

The Finnish regulation requires that outages longer than 3 minutes must be detected by the smart meters and outage data must be stored at least for 2 years. The regulation also states that outages longer than 12 hours must be recompensed to the customers affected by an outage. The meter provides good tools also for that.

Power Quality

Before the Smart meters, the voltage losses in each part of network were computed based on network information and modelled loading curves if not measured in the field with special equipment. The installed smart meters have a feature to monitor voltage quality. The meters measure 10 minutes averages from all phases which enable voltage supervision similar to EN-50160. Ten minutes averages are stored as a table shown in table 1. It is accuracy table and different voltage levels are presented with counters growing up. Each voltage level thresholds in the table reveals how many measured voltage values have been between the thresholds. Voltage level information must be read and reported weekly to achieve voltage monitoring described in EN-50160.

Table 1. *Voltage level information of the meter lifetime.*

Level	Thresholds	Phase L1	L2	L3
1	Un > +10%	0	1	17
2	+5% < Un < +10%	47	120	158
3	0% < Un < +5%	4092	4704	23705
4	-5% < Un < 0%	19654	25091	12595
5	-10% < Un < -5%	11482	6397	82
6	-10% < Un < -15%	1201	240	1
7	Un < -15%	85	8	2

Smart meters also measure highest and lowest daily voltages from each phase. Measurement period is set to 5 minutes. These measurements support to find "weak" network areas and premises with significant load unbalance combined with measured loading information.

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