IMPROVED NETWORK ANALYSIS BY USING DATA FROM SMART METERS

Lars Garpetun
Vattenfall Eldistribution AB-Sweden
lars.garpetun@vattenfall.com

ABSTRACT

By using data from smart meters, meter values and Power Quality events, it's possible to improve the analyze methods and network calculations. Better understanding of the grid behavior and customers load pattern will make it possible to better predict the need of reinforcements and avoid unnecessary investments, especially for grid areas with more volatile loads caused by large amount of photovoltaic solar panels (PV) and electrical vehicles (EV).
Both fulfillment of customer promises (supply contract) and acceptable level of distribution fees (tariffs) will set the focus on asset management costs and investment strategies. Up to now the information in the Customer Information System, CIS, are the only source for customer related information regarding load, total energy consumption and the customers load pattern. The network analyses and planning activities will give acceptable good results if these data always are updated and in good shape, but it has been shown that this is not always the case. It has in this report been shown that network analysis and calculations based on meter values instead of traditional methods using static load curves gives better results and most likely large benefits for the asset management process such as avoiding oversized assets in general, possibility to postpone asset investments and allow new customers to be connect to the grid without any mayor asset investments (new substations or upsized transformers).
By measure the total feed-in energy at transformer level in the secondary substation it's possible to monitor the network losses with good accuracy. It's possible to detect wrongly installed meters and none measured consumption if the load is sufficient high. But this also set the focus on data quality issues, reliability of the grid documentation and customer data are crucial. Data has to be in good shape and always be updated immediately when new data occurs or has been changed.
The results show that it's feasible to set up a process for monitoring the network losses from a technical point of view, but will it be justifiable from an economical point of view?

BACKGROUND

Vattenfall Distribution Sweden has since 2003 built up an AMI/Smart metering platform. The main reason for the installation has been to automate the meter value collection and support the customer with bills based on actual consumption. Based on this, Vattenfall has taken the next step and use smart meter information in new areas. Positive Business Cases has been established regarding improvements in grid analyses using hourly meter values and Power Quality information from Smart meters. Reduced cost for asset investment and improved quality of delivery are the main outcome. The possibility to follow up customers Power Quality and network losses are key issues in the project.
The load at customers site are today not align with the past and are also in general unknown and will in the future be more complex regarding the impact of EV (electrical vehicles) and PV (photo voltaic). Network calculations will then be more important for distribution companies in order to optimize the grid and for delivering acceptable power quality. Partial results was presented at CIRED 2012 conference in Lisbon, the whole project will be finalist in Q1 2013 and to be presented at CIRED 2013.

OBJECTIVES

Load profiles:

Compare customers' real consumption patterns based on hourly metering values with what is currently used for network planning (traditional method) based on total yearly consumption and static load curves ("typkurvor") for different defined consumption categories. In traditional methods the static load curves are aggregated for all individual customers and their estimated curve profile and level. For calculations based on hourly meter values all customers hourly meter value are aggregated / summarized hour by hour. The purpose with this project is to investigate how network analysis could be improved by using hourly meter values and power quality events.

Power quality:

Power Quality events gathered from the Smart meters could give indications of unacceptable bad conditions in the LV grid. A comparison will be done between voltage events from smart meters and voltage levels from calculations based on hourly meter values and traditional methods. It will be investigated how power quality events, voltage sag and surge, with high resolution could be used as a complement to network calculations based on static load curves / hourly values.

Network losses:

By aggregate meter values from customer sites and compare with meter values gathered from the secondary substations it's possible to identify a grids network losses. The results will then be compared with calculations based on hourly meter values and traditional methods. The ambition is to clarify if it's possible to monitor the network losses in general and identify none technical losses such as thefts, metering problems etc.

PROJECT SET-UP

The project concerns 14 low voltage grids including secondary substations in both rural and urban areas. Six areas are located in the Uppsala City area and the others are spread all over Sweden.

Approximately 740 customers consumption are powered from those 14 stations and the customer consumption profile differs radically for these 14 areas. More details in table 1 below.

The smart meters in these areas have been reconfigured to measure energy consumption hourly. The meters also measure and register Power Quality events, voltage sag and surge are registered for values out of +/-5 % of the nominal voltage 230V. Hourly meter values and meter events have been stored in the MDM-system for more than 1 year and are accessible for network calculations.

Vattenfall standard network calculation program has been modified to handle hourly meter values.

The knowledge of customers load characteristics is not so good. In Sweden heating systems for houses normally have been based on electricity or district heating. But nowadays a lot of electric powered heat pumps have been introduced and have seldom been registered in utilities customer information system, CIS.

Network ID	Network area / location	Amount of customers	Trafo. size KVA	Load category
61124316AL	Uddevalla	20	200	Residential, farms, electrical heating
HU0870	Huddinge	53	630	Resid. (homog. load), el. heating
76120202AL	Pajala	23	100	Resid., farms, cottages?
TY2118	Tyresö	41	800	Resid. (homog. load), el. heating
61220106AL	Haparanda	25	100	Mostly resid., industry?
N205422AL	Säffle	6	315	Residential, farms
62130126AL	Örnsköldsvik	12	100	Residential., farms
81440041AL	Nävekvarn	7	100	Residential., farms
UP33170AL	Uppsala	67	800	Townhouses, heat pumps
UP31703AL	Uppsala	18	1000	Industry, district heating
UP34976AL	Uppsala	208	800	Distr.heating, flats, stores, schools
UP35419AL	Uppsala	7	800	Distr.heating, offices, workshops
UP37669AL	Uppsala	188	800	Townhouses. (homog. load), el. heating
UP37102AL	Uppsala	74	315	Distr.heating, resid. (homog. load)

Table 1: Project set-up

GOALS AND RESULTS

Load profiles:

In average, traditional calculation methods resulted in 35% higher Pmax than calculations based on hourly meter values for 11 of the analyzed grids. In 3 cases traditional methods gave in average 15% lover Pmax. Compared with measured Pmax in the substations traditional calculation methods gave significant high values in 8 cases and significant low values in 5 cases. The same comparison with calculations based on hourly meter values gave significant high values in just 1 case and significant low values in 3 cases. Table 2 shows the individual results for the substations. If these results are significant for the rest of the grid, calculations based on exact consumption (hourly meter values) will give better conformity with actual conditions and large benefits will likely be achieved yearly regarding avoiding oversized assets in general, possibility to postpone asset investments and allow new customers to be connect to the grid without any mayor asset investments (new substations or upsized transformers).

Network ID	Measured at secondary substation Pmax kW	Calculations based on hourly metering Pmax kW	Calculations based on trad. methods Pmax kW	Aggregated daily and hourly meter values Pmax KWh/h *)
61124316AL	113,8	110,7	84,9	52 ***)
HU0870	424,3	313,5	368,5	400 **)
76120202AL	56,1	51,7	69,0	56
TY2118	236,7	231,7	261,2	220
61220106AL	32,6	31,6	27,9	18
N205422AL	33,3	26,5	64,8	22 ***)
62130126AL	49,3	48,3	57,8	47
81440041AL	34,9	42,2	44,3	53
UP33170AL	454,8	370,8	387,4	410 **)
UP31703AL	749,0	697,7	947,8	780
UP34976AL	463,0	455,0	736,6	470 **)
UP35419AL	552,9	554,0	494,8	540 **)
UP37669AL	617,3	609,5	622,2	630
UP37102AL	163,9	159,7	236,5	180

*) Including 4% network losses, incl. +/-20% daily variations

**) Including 4% network losses, incl. +/-10% daily variations

***) Incomplete data

Table 2: Comparison of Pmax

When doing network analyses based on hourly meter values a lot of new pitfalls occur for the user. Meter values will not always be available due to failures in the meter value collecting process, errors like lack of meter values will occur. In these cases the system has to automatically handle the situation and estimate energy values based on previous consumption values or using traditional methods. The situation could be complex and it's important that the user understand the conditions for the calculations. A classical pitfall are the definition of zero energy value ("0") and no value ("null") caused of errors, a null value will be estimated but not a zero value.

In this project have we noticed that the data regarding the grid, the network connectivity, is crucial for the reliability of the calculations regardless of calculation method, traditionally or based on real meter values. If the ambitions are to monitor the network losses in order to detect illegal usage of power or metering failures it's important to understand how these factors could affect the result.

Power quality:

Analysis will be carried out during Q1 2013 and the results will be included into the presentation at the Cired conference in June.

Network losses:

The results do not give a clear picture if it's realistic to monitor the network losses. There are a lot of pitfalls when dealing with real energy meter values from Smart meters. For 8 of 14 low voltage grids the results are align with expected, the network losses are seen as normal. Figure 3 represents an expected result. But for 6 grids the measured network losses was more or less completely out of range compared with expected. Figure 4 and 5 represents unacceptable results which have to be investigated. The large mismatch could indicate none measured loads, incorrect documented network connectivity, incorrect measuring or thefts.
Each individual grid has been investigated regarding network connectivity and some errors have been identified. It has also been detected that loads like street lightning etc. has been documented only in the billing system and not in the technical systems.
The quality of meter values is also critical. Normally the individual meter value is correct but in some cases meter values are lacking and the problems with "zero" and "null," defined above, will be misleading. It has not yet been clarified if this has been the case for those 6 grids.

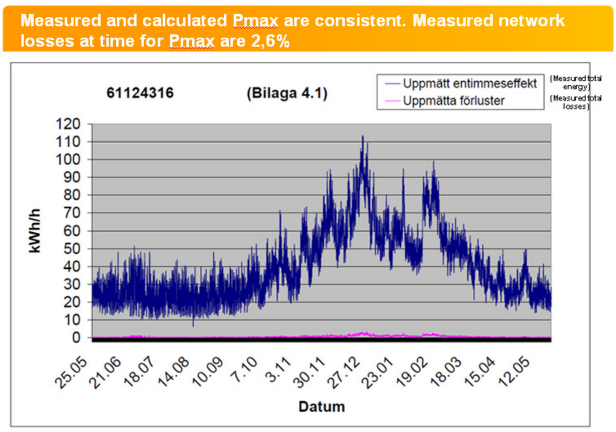

Fig 3: Measured network losses 2,6 % (normal level)

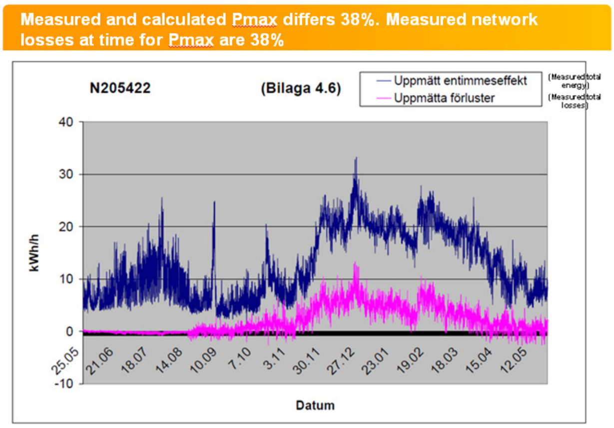

Fig 4: Measured network losses 38 % (abnormal level)

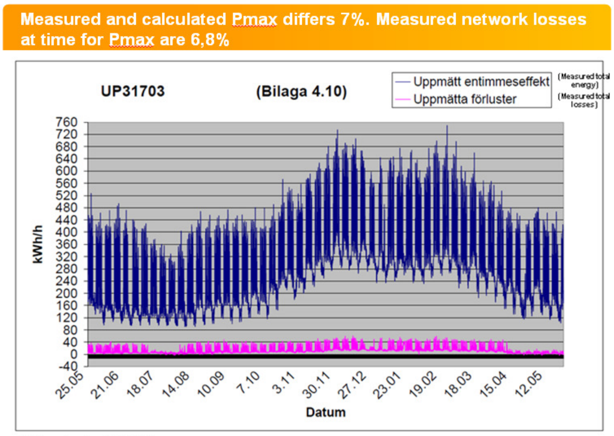

Fig 5: Measured network losses 7 % (to high level)

CONCLUSIONS

By using data from smart meters, meter values and power quality events, it's possible to improve the analyze methods and network calculations. Better understanding of the grid behavior and customers load pattern will make it possible to better predict the need of reinforcements and avoid unnecessary investments, especially for grid areas with more volatile loads caused by large amount of photovoltaic solar panels (PV) and electrical vehicles (EV).
Both fulfillment of customer promises (supply contract) and acceptable level of distribution fees will set the focus on asset management costs, the investments has to be done where it gives best payback in the forms of better quality of delivery.
Up to now the information in the Customer Information System, CIS, are the only source for customer related information regarding load, total energy consumption and the customers load pattern. The network analyses and planning activities will give acceptable good results if these data always are updated and in good shape, but it has been

shown that this is not always the case. As a side effect of installations of smart meters for improvements in the meter to bill process the meter values could also easily be used for network analyses and calculations.

By measure the total feed-in energy at transformer level in the secondary substations it's possible to monitor the network losses with good accuracy. It's possible to detect wrongly installed meters and none measured consumption if the load is sufficient high. But this also set the focus on data quality issues, reliability of the grid documentation and customer data are crucial. Data has to be in good shape and always be updated immediately when new data occurs or has been changed.

In this project we have identified 6 areas of total 14 with unacceptable high network losses (in one case negative network losses). If this is the result of metering errors, unmeasured loads or just a result of bad data quality is hart to say, but it's probably a mix of them. The results show that it's feasible to set up a process for monitoring the network losses from a technical point of view, but will it be justifiable from an economical point of view?