INTEGRATION OF AMM FUNCTIONALITY INTO OPERATING SYSTEMS OF ELECTRICITY DISTRIBUTION COMPANY FOR LV NETWORK FAULT MANAGEMENT

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ABSTRACT

AMR meters are significant part of Smart Grid providing information from each connection point of the network. Traditionally, AMR meters are used for billing purposes, but by developing meter functionality and system integration, AMR meters can also be utilised in other processes such as outage management and asset management. In this paper, DMS functionality regarding LV network monitoring and fault management powered by operative data of AMM implemented in Vattenfall Nordic Distribution Networks Finland is described.

INTRODUCTION

Traditionally, the main benefit of Automated Meter Reading (AMR) systems has been automated collection of energy consumption information. However, modern energy meters consist of variety of sophisticated functions in addition to energy measurement including average and momentary monitoring of voltage, current and power providing information i.e. for asset management as power quality information, and for outage management as LV network monitoring and operation. Meter functionality and the meter data gathering and transfer information system build up Automated Meter Management (AMM) system.

Data from AMR meters to AMM system can be divided into three categories: traditional energy consumption values, administrative data including hourly based power series and power quality measurements, and operative data including alarms and response of status queries. Actually, traditional and administrative data could be combined into one category, since energy consumption values can be calculated from the hourly based power series.

Vattenfall Nordic Distribution Networks Finland has been a pioneer in developing AMM system. The final decision of changing a new AMR meter to all 380 000 customers was made in 2004 and the last meters were installed in 2008. The AMR project has been significant for the whole distribution business for several reasons, since it was the first large scale AMR project in Finland. The meter with sophisticated functionality was specially developed for the AMR project. The business concept as one full service provider and Vattenfall just paying for the information was a totally new and radical way of thinking.

From the beginning, the business case of AMR project has included much more than just benefits from automated collection of energy consumption information. For example, benefits from energy loss management, improvement of network calculation and low voltage network monitoring and fault management were included.

A completely new function for the distribution network management and operation is the utilization of operative data of AMM in operating systems. Actually, operative data removes the missing link between operating systems and consumption points in low voltage network. At the moment, operating systems, such as SCADA, provide information from primary substations, the feeding points of the distribution network. AMM operative data consists of alarms and response of status queries. This information is integrated into Distribution Management System (DMS), which is the system integrating also SCADA, network and customer information. Functionality and system integration is a result of intensive development project in co-operation between Vattenfall Nordic Distribution Networks Finland and Tekla Oyj. This functionality was implemented into production of operative systems in February 2010 including query functionality. Alarm functionality is implemented into test system and will be taken into production after acceptance tests in the future.

Figure 1. Basic concept of AMM-DMS integration

TECHNICAL CONCEPT OF AMM-DMS INTEGRATION

The interface between DMS and AMM enables transferring alarm notifications spontaneously from smart meters to DMS. DMS utilizes this data for managing the real-time switching state. To accomplish this optimally, the following is required: Unsolicited delivery of alarms should take place without undue delay, i.e. within a few minutes, preferably in seconds. This is a rational requirement due to reason that a notification arrived only after a substantial amount of time is worthless because the cause and the extent of the incident will already be deducted from received trouble calls.

Several alarm types are supported by the interface: "broken neutral" (i.e. zero conductor fault), "phase voltage missing" (separately per phase), "asymmetry" (i.e. voltage unbalance), "voltage level violation" (separately high and low and per phase), "wrong rotation", "reverse current", "enforcement of consumption limiter" and finally, "tripping" (of the device's internal circuit breaker). Alarms generated by device self-diagnostics, like "malfunction" or "tampering" are also supported. It is noteworthy that transfer of deactivation events (i.e. indication off) is also supported by the interface but currently ignored by DMS.

For the time being, lot of variation exists regarding how well different equipments, communication technologies and AMM systems on the market covers the listed alarm types and the following performance and pre-processing requirements. When two (or three) phases are lost they all should be part of a merged "two phase voltages missing" (or "all phase voltages missing") indication, instead of being sent as two (or three) separate indications. An unsolicited alarm should not be sent many times within a short time span. This may occur when a value hovers close to a threshold. An unsolicited alarm should not be sent if it would be followed by a more specific alarm within a short time. An example would be a voltage level violation which is immediately followed by asymmetry detection.

The interface between DMS and AMM also enables DMS to request and receive asynchronous read-outs from the meters regarding currently active alarms and measurements. It should be possible to query read-outs of a large set of devices and receive the results without undue delay. The expected response time is the same as for unsolicited delivery. In practice, the amount of targeted devices is limited by the software operating systems and/or runtime environment's buffer limits and configuration. Those should easily support a few hundred targets by default. It is up the AMM to deliver the requested data in a single invocation (if the number of items is reasonable), or in chunks while data collection is still proceeding. However, it is desirable to start delivering as soon as possible to provide feedback to the user who made the query. Running several queries in parallel must be supported. In practice, there may be a few dozen.

Following query types are supported by DMS: Manual query allows user to select targets and start a query at any time. In semi-automatic query, which is used immediately after final supply restoration step, DMS selects the targets automatically and prompts a user to start the query. After receiving unsolicited "broken neutral" or "phase voltage missing" type of alarms, DMS can send queries automatically (without any confirmation by users) in order to locate the fault. Another fully automatic query type is called as reference query. Here DMS performs a query to pre-defined targets periodically, e.g. once in 24h, in order to find presumably de-energized consumption sites of special interest.

In this paragraph, the meaning of different responses is shortly discussed. In case of "unknown device" response, there is an identification information mismatch between the systems and the query becomes worthless in this respect. On the other hand, an OK type of response, i.e. targeted device responds with no active alarm status values, is a proof for DMS that the consumption site is energized. An alarming type of response i.e. targeted device responds with one or several active alarm status values, gives a plausible indication about an unacceptable situation. In both OK and alarming type of responses, the message can include (when supported by AMM) instant measuring or average values about load currents and phase voltages. The remaining types of response (to be presented next) are perhaps even more interesting. In case the target is unreachable, AMM should response with "device not responding". Unfortunately, interpretation of this information is ambiguous: The consumption site might be affected by an outage or it is locally de-energized with intent or the communication is out-of-operation due to another reason. In order to make interpretation easier, it is profitable if AMM is able to distinguish intentionally de-energized cases from the other ones. For this purpose, the interface includes additional response values: "electric service suspended" (e.g. due to unpaid bills) and "site disconnected" (e.g. residential site without inhabitants).

The interface also specifies an additional service: DMS can request and receive asynchronous read-outs of last contact times. AMM is assumed to return this information from its database. This information helps control centre operators to take stock of the situation e.g. when browsing the results of the latest reference query that includes single or few "device not responding" results for consumption sites expected to have supply.

The interface is implemented using Web Service technology, based exclusively on WSDL and XML-schema definitions adhering to Web Services Interoperability (WS-I) recommendations. Each request message carries a header with authentication information. The message exchanges can take place over HTTPS.

DMS development

Major part of the development project was focused on developing functionality regarding analysis and usability of DMS. Operators in control center were participating development project to give practical input and experience for the project.

User can easily browse ongoing interruptions, actual events, trouble calls, alarms and queries with clear presentation of the interconnectivity between the items.

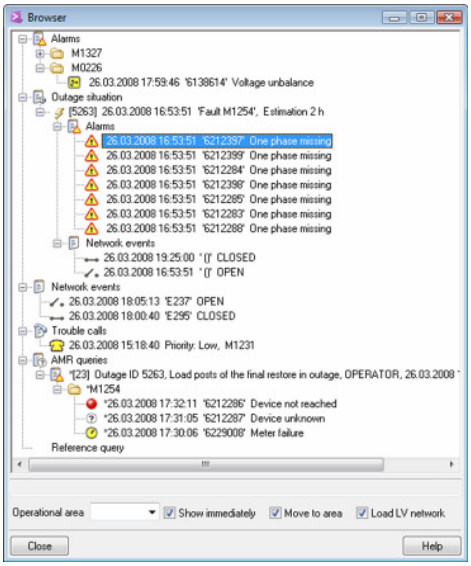

Figure 2. Tree-structure tool for browsing operational data

DMS executes analysis of AMM data constantly against network topology and known outage situation. It responds to conflicting situations by means of automatic outage registration: The software concludes the most suitable fault location in order to bound affected zone correctly. It records an appropriate event (typically opening the fuse expected to be blown) and performs the other assigned tasks like generating a new interruption record and updating the data in outage communication services.

DMS includes many advanced features related to visualization of actual alarms and query replies including automatic de-cluttering of close-together symbols and tooltips. User may view the selected information from the browser also on network map. The following picture present an example where an interruption is registered automatically based on several "phase voltage missing" type of alarms received from one LV feeder.

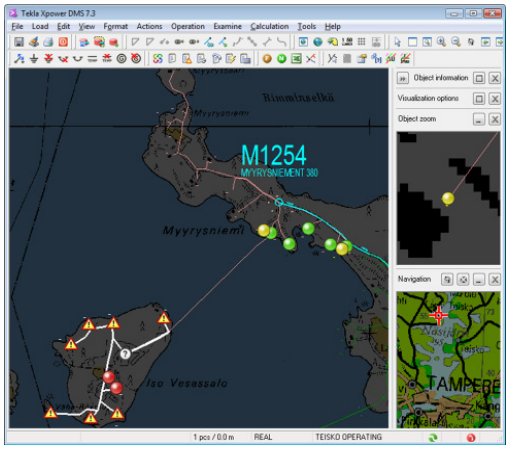

Figure 3. Integrated visualization on map in DMS system

In the figure, dynamic colouring indicates the de-energized network (white lines) and the location of the fuse expected to be blown. A query is sent to other consumption sites in the same feeder, meters in five customer points have already replied OK (green symbols) but DMS is still waiting replies from two customer points (yellow symbols). In addition, there is one customer point without proper device (question mark symbol) and the devices of two customer points are not reached (red symbols).

BENEFITS OF AMM-DMS INTEGRATION

DSO can gain variety of benefits from their smart metering investments in outage management process by integrating AMM meters into existing operative systems such as SCADA and DMS. Meters provide nearly real-time information from the customer level which can be elevated to more accurate switching state monitoring and outage management by automatic low voltage fault location and interruption registering. This enables more accurate and extended reporting and statistics of interruptions.

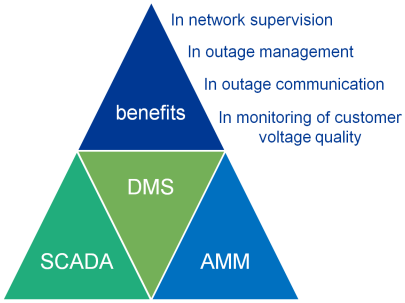

Figure 2. Benefits reached by system integration.

One of the major benefits is improved security by getting real-time information of voltage level and zero conductor faults. These phenomena are always potential risk for humans, animals and equipment. By getting the information automatically, risk can be reduced by informing customers or by disconnecting parts of network to eliminate further damages.

By analysing information of individual meters in DMS system, faults can be relatively accurately located by the system. Analysis can be also benefited not only in low voltage network faults, but also in medium voltage network faults not causing tripping of network protection, such as high impedance single phase breaks. This leads into faster fault repairing and reduction of interruption time not only in low voltage network but also in medium voltage network, since seeking time of faults in the field is significantly reduced.

The fault can also be located into customer's own network, i.e. if just one individual meter is indicating one phase missing alarm while all the other meters nearby indicate no alarm. Consequently, faults located in customer's own network belong to customer's responsibility causing unnecessary visits to customer site by DSO, which can be avoided by utilising AMR data.

Data gained from low voltage network by AMR meters can also be integrated into multi-channel communication systems of interruptions, such as web, SMS, e-mail or IVR. This reduces the need of trouble calls of customers, since information is provided proactively.

As a summary, following impact was able to be realised as benefits of AMM-DMS integration since implementation of the functionality in February 2010 until October 2010:

- 75 000 queries to meters by operators
- 40% reduction in unnecessary visits to customer sites
- 400 zero conductor faults detected
- 30 medium voltage single phase breaks detected

CONCLUSIONS

In the field of electricity distribution, AMM systems are becoming more and more common, and companies worldwide are looking for new ways to exploit the system. At Vattenfall Nordic Distribution Networks Finland, AMR meters have been installed at every customer site. In addition to billing purposes, information obtainable from the meters is utilized also for example in network planning and network operation. In order to be useful for operation, the AMM data should be received to the control centre nearly real-time. This is realised by integrating the AMM system with the DMS.

After the introduction of AMR-DMS, only very few faults remain outside the automation that informs control centre about faults in the network. AMR meters are able to reveal most of the faults in the LV network as well as MV phase conductor breaks. Every customer site will be within the control system, and an operator will receive alarms to the DMS user interface about abnormalities in the LV network. Zero conductor faults, missing of one or two phases, voltage unbalance and too low or high voltage level are reported as alarms. In addition, the operator can perform queries to verify the status of a meter or a group of meters. If a device is responding, the operator can ascertain whether the meter is all right or if there are active alarms. Otherwise the response is device not reached, device switched off or device unknown. The noticeable thing with queries is that possible LV three-phase outages can be concluded from device not reached responses.

The introduction of the AMM-DMS integration has certinly a major effect on network operation especially regarding management of LV faults. Before AMM-DMS integration, automatic real-time information has not been available from the LV network. With the AMM-DMS integration, most of the faults will be detected almost immediately, which will produce many benefits but also some new challenges and changes to old operation practices. Benefits will include, among other things, savings in repair expenses and improvements in electrical safety and customer service.

Since AMM-DMS integration of Vattenfall Nordic Distribution Network Finland is one of the first implementations of such functionality, it was difficult to get any benchmark or input based on experience for developing the system. For this reason, there are things that can be improved and the system must be tested in practice before final comments about the usability of different features can be stated. However, even if the AMM-DMS realises as it is now defined and described in this paper, it will be a significant step forward in the operation of distribution networks.

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