USING ADVANCED AMR SYSTEM IN LOW VOLTAGE DISTRIBUTION NETWORK MANAGEMENT

Pertti JÄRVENTAUSTA
Tampere University of Technology (TUT) - Finland
pertti.jarventausta@tut.fi

Antti MÄKINEN
TUT – Finland
antti.makinen@tut.fi

Kimmo KIVIKKO
TUT – Finland
kimmo.kivikko@tut.fi

Pekka VERHO
TUT – Finland
pekka.verho@tut.fi

Matti KÄRENLAMPI
ABB Oy - Finland
matti.karenlampi@fi.abb.com

Timo CHRONS
Aidon Oy - Finland
timo.chrons@aidon.fi

Seppo VEHVILÄINEN
MX Electrix Oy - Finland
seppo.vehvilainen@electrix.fi

Petri TRYGG
PowerQ Oy - Finland
petri.trygg@powerq.net

Aimo RINTA-OPAS
Koillis-Satakunnan Sähkö Oy - Finland
aimo.rinta-opas@ksat.fi

ABSTRACT

The future of AMR technology is in openness and interoperability, both horizontally and vertically. Using AMR meter as a smart terminal unit and gateway for real time two-way communication it is possible to enlarge SCADA and distribution automation for managing also the low voltage (LV) network. The paper presents results on a development project which aim is to develop a comprehensive technology solution of new functions of AMR and related information systems for low voltage network monitoring and management; indication, location, isolation and registration of low voltage network faults, and power quality management at low voltage level.

INTRODUCTION

Since the time the first energy meters were introduced in 1870's, their basic function has remained more or less the same. The primary role of AMR systems is to provide real time energy consumption data to the utility, but the cost of retrofitting the existing energy metering system may not be justified if the meters are used merely for reading energy consumption data. The implementation of AMR systems will change the function of basic energy meter, which will become a smart terminal unit and gateway for multiple service providers and enable real time two-way communication between customers and utilities. From that viewpoint the AMR system can also be seen as an extension of SCADA and network management systems for controlling and monitoring the last parts of the network (i.e. the low voltage network) between medium voltage network and customer.

To be able to implement AMR system the whole meter chain from the customer site to the business systems has to be improved to assure the quality of the metered values. AMR implementation will change structure of information systems, too. Depending on the whole system features information systems dealing with AMR can be divided into different levels and functions, as illustrated in Figure 1. The idea is to fully utilize benefits of the AMR investment in all the levels. This is one important element of cost effectiveness of the AMR investment.

The possibilities of using AMR include, for example, real-time energy information, customer service, demand side management, disconnection and reconnection of electricity supply, determination of load profiles for network calculations, network planning and secondary transformer condition monitoring, more accurate interruption statistics, more sophisticated power quality monitoring facilities, and the management of low voltage distribution networks.

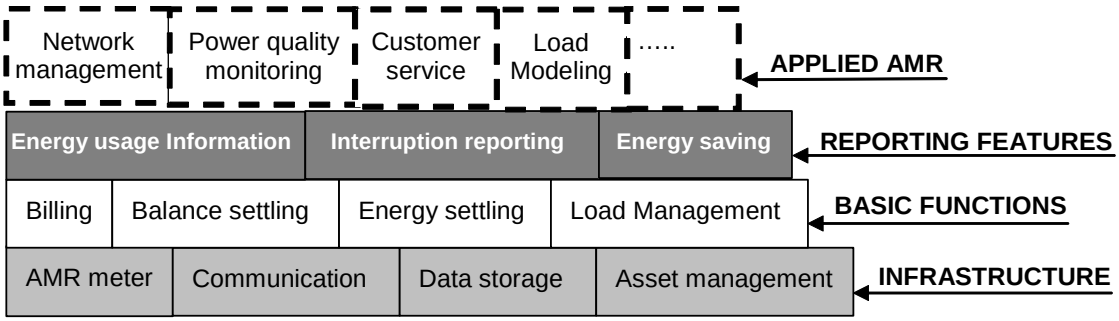

Fig. 1. AMR system levels

The AMR technology will change metering processes of distribution companies [1]. Changes cover variety of resources inside the companies. AMR can be seen as automation which replaces human resources in certain part of the process. Annual and change reading processes become as the same. The lifecycle of the new technology may be different compared to the previous one. The whole implementation process should cover closer analysis on every aspect of the business model.

ARCHITECTURE OF THE ADVANCED AMR SYSTEM

The open AMR market needs the whole new AMR platform. The future is in openess and interoperability, both horizontally and vertically, as presented in Figure 2.

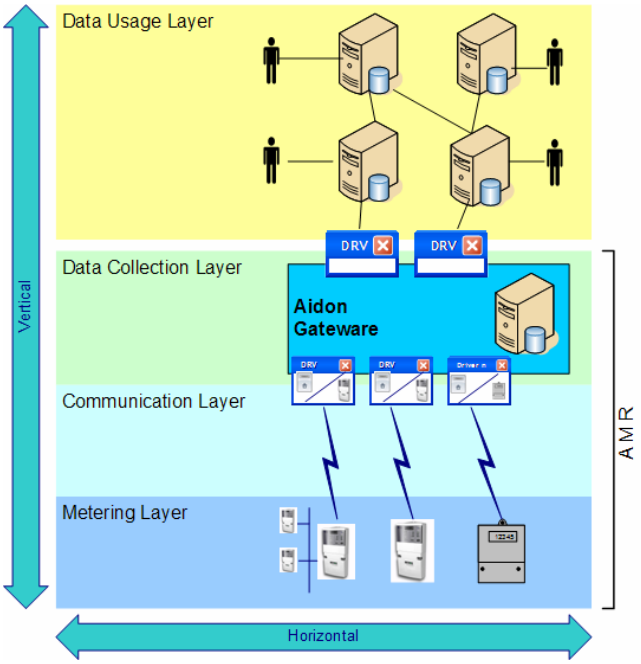

Fig. 2. Aidon AMR – openess driven solution.

Horizontal dimension means possibility to build metering system by buying system parts from different vendors. This means less risk in compared to one supplier and possibility to select best fitting technology over the system life cycle. Vertical dimension emphasizes that total system functionality can be built from appropriate parts, each replacable if needed. This is achieved by role based functionality with minimum overlapping and well defined, open interfaces.

Aidon AMR system is designed to its role as 'metering engine'. Different metering devices are integrated with drivers like printers in office systems. Even communication layer is replacable as AMR meter consists of core Meter and System Module. Also integration to business systems like CIS is encapsulated in drivers. The metering applications can be remotely updated thus making it possible build the required functionality gradually.

Aidon AMR system supports communication solutions which enables real time events to be sent spontaneously from AMR meter. Polling all the meters from reading system would be too slow. There are fast enough communication possibilities that are usable also in rural areas (e.g. GPRS) but taking into account the huge number of devices it must be carefully planned what kind of events will be sent from meters and how meters shall be configured. Without limitations and configuration options the number of events would exceed the capacity of practically any communication media.

LOW VOLTAGE NETWORK MANAGEMENT FUNCTIONS BY USING AMR SYSTEM

As mentioned, AMR offers two-way communication to the customer site, which makes it possible to enlarge on-line monitoring also to the low voltage network. This enables alarms on exceptional events, e.g. network faults and voltage violations, and here meters can also have some protective functions adding the safety. The use and integration of AMR in network operation can be seen as an extension of SCADA and distribution automation to the low voltage level. So far automatic monitoring has been used mostly in 20 kV medium voltage networks.

Low voltage network management includes functions, for example, to indicate automatically if a fuse in the low voltage network has burnt or a conductor is broken, to locate the fault, to provide accurate interruption data, to monitor voltages at customer site in real-time, and provide power quality information for customer service.

Pilot implementation

At present, there is going on a development project which aim is to develop a comprehensive technology solution of new functions of AMR and related information systems for low voltage network monitoring and management. The aim is to achieve this by combining new-generation energy meters, data communication solutions and distribution management systems into an entity with an open architecture. The project consortium includes different equipment and system vendors and the pilot distribution company. The Figure 3 illustrates the overall IT-architecture in the pilot case of Koillis-Satakunnan Sähkö Oy.

The pilot company has an advanced distribution management system (DMS) for real time network analysis (load flow, fault currents), fault location, switching planning etc. However, low voltage network management has been totally in off-line mode since on-line information has been available only from primary substations and from some secondary substations along medium voltage feeders. The integration of AMR makes it possible cost effectively to monitor low voltage network and analyze fault situations since AMR communication infrastructure can be used.

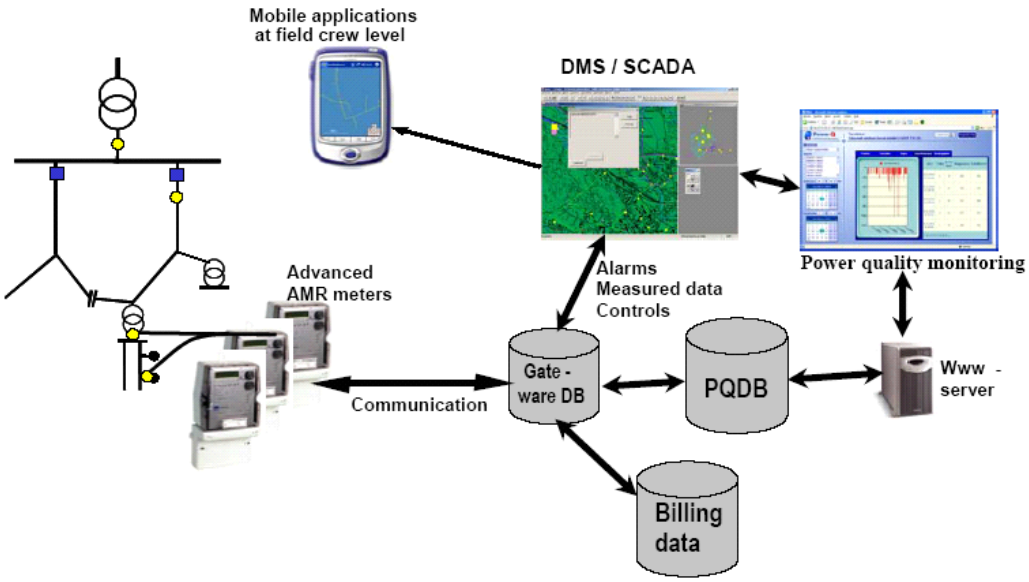

Fig.3. The overall view of IT architecture in the pilot case

Because network monitoring in SCADA/DMS requires that events from meters are received in near real-time manner an effective way to forward data from data collection layer is required. In this project OPC (originally OLE for Process Control) technology is selected for this purpose. The main reason is that OPC is an open standard and used very widely in industrial automation and in the enterprise systems that support industry. In electrical power industry the usage of OPC is coming more common all the time.

Fault indication, location and isolation in low voltage network

Traditionally fault in low voltage network is cleared automatically by blown fuse, and no information about that is received to the control centre. The existence of a low voltage network fault is usually based on customer calls.
An advanced AMR meter work as an intelligent monitoring device and utilize the communication infrastructure to provide spontaneous event or alarm information to control center with vital information on low voltage network faults and voltage levels. The meter includes algorithms to inference the existence of a fault and type of the fault. In certain cases, e.g. when neutral conductor is broken, the advanced AMR meter even isolates automatically the customer from the network. This requires a specific switching device which can be integrated into the Aidon AMR meter.
When event data from meters are combined with topological network model in the DMS the original reason or faulted component can be located. This gives enormous benefits for low voltage network management when, for example, blown fuses, broken conductors and voltage problems can be presented to the operators at control center almost in real time manner. The fault data can be studied also in mobile applications of field crew being responsible to repair the low voltage network fault.

Power quality monitoring

At the moment, voltage quality is usually monitored temporarily at customer sites based on customer reclamations, not comprehensively and continuously from the entire distribution network. Power quality monitoring including continuous voltage quality monitoring in larger extent gives however important information for various operations of distribution company. The development of systematic procedures for power quality data management supports in general:

- Customer services (e.g. quality reports, clarifying customer requests, planning of compensation of reactive power, instructions for the use of various equipment)
- Distribution network design and operation (e.g. investment plans and management of voltage drops and fluctuations, harmonics and other disturbances)
- Outage statistics (e.g. needs of the Energy Market Authority).

In recent years the Institute of Power Engineering at Tampere University of Technology has actively been developing a comprehensive power quality management system together with distribution utilities and several different equipment and data system vendors. [2, 3, 4]
The novel AMR technology makes it possible to integrate basic power quality functions to AMR meter. In addition to register interruptions, voltage dips and swells with time-stamps it is also able to meter the following quantities for each of the three phases: voltage and current variations, active power, apparent power, total reactive power (according to Fryze), fundamental frequency reactive power, total distortion of the supply voltage, some harmonic voltages, DC-voltage component, frequency of the supply voltage, voltage unbalance between the three phases. [3, 4]
All the measurement data (i.e. even over several years) is

stored in the open relational Power Quality Database (PQDB). MS SQL Server 7.0 has been used as a database tool in the pilot case. The measurement data of the PQDB can be studied using the Web–based application, PQNet system, in addition to DMS and network planning systems. The use of Web-based technology in PQ monitoring may be an internal or an outsourced service for distribution companies. Web-based PQ monitoring is an example of ASP (Application Service Provider) functions. Power quality data can also be offered to the customers (e.g. industrial customers) with their energy consumption and billing data through the Web.

Factors that increase the need and possibilities of monitoring power quality also on low voltage level are e.g.:

- need for better customer service
- reasonable priced meters
- telecommunication development
- applications which can use the power quality data in network planning and operation
- regulation requirements

The idea is to gather information from low voltage level and integrate it, for example, to network data bases and different planning and operation systems to increase knowledge with much larger amount of information.

Using AMR data for interruption reporting and statistics

DMS includes functions for interruption and fault reporting as well as calculation of interruption indices. Currently accurate interruption statistics cover only the interruptions borne by medium voltage network. DMS systems include tools for low voltage interruption reporting, but it is done manually, and the interruption durations are estimates.

AMR interruption data offers more accurate measured interruption times and makes interruption reporting more fluent since automatically collected information of low voltage network interruptions can be presented to the person finalizing the interruption reports. It can also be point out, e.g. which interruptions are borne by low voltage network. Quality of supply (e.g. SAIFI, SAIDI, interruption costs) is widely used in the regulation of distribution network companies [5]. As improving the reliability of interruption reporting, AMR also improves the quality and plausibility of the interruption indices used in regulation. In Finland the customers are entitled to compensations in interruptions longer than 12 hours, and together with customer information system the determination of compensations can be automated using AMR data. As presented in Fig. 4, AMR interruption data can be used in

- supporting registration and reporting of low voltage interruptions
- verification of DMS fault reporting
- supporting fault management and reporting in major disturbances
- determination of compensation for long interruptions
- generating interruption indices for network business regulation purposes.

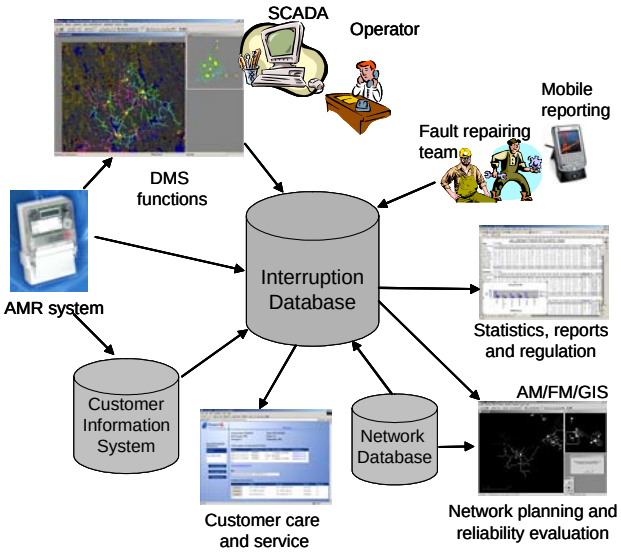

Fig. 3. Use of AMR system in interruption reporting.

REFERENCES

[1] Trygg P., Kulmala H., Järventausta P., Comparison of life-cycle costs of energy metering processes. *The 19th International Conference on Electricity Distribution (CIRED 2007)*, May 2007, Vienna, Austria

[2] Antila S., Lampo V-P., Mäkinen A., Järventausta P., Web- and event-based power quality monitoring systems proved by application service provisioning model. *International Energy Journal*, Volume 6, Number 1, 2005, pp. 119-126

[3] Koponen P., Mäkinen A., Vehviläinen S., Supply voltage dip monitoring with a sparse sampling kWh-meter. *Proceedings of the 6th IASTED International Multi-Conference on Power and Energy Systems (PES 2002), Symposium on Harmonics and Power Quality (HPQ 2002)*, Marina Del Rey, CA, USA

[4] Mäkinen A., Järventausta P., Verho P, Rinta-Opas A., Comprehensive development of power quality management and evaluation of voltage dip problems. *Proceeginds of the 17th International Conference on Electricity Distribution (CIRED 2003)*, Barcelona, Spain

[5] Kivikko, K., Antila, S., Järventausta, P., Mäkinen, A., Lassila, J., Viljainen, S., Tahvanainen, K., Partanen, J., Mogstad, O., Tapper, M., Comparison of interruption statistics and their use in network business regulation in Nordic countries. *Proceedins of the 18th International Conference on Electricity Distribution (CIRED 2005)*, June 2005, Torino, Italy