INTERACTIVE CUSTOMER INTERFACE FOR ADVANCED DISTRIBUTION MANAGEMENT AND ELECTRICITY MARKET

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ABSTRACT

For developing distribution management and functionality of electricity market one essential objective is to make the customer, or at least customer connection point, an active party for improving e.g. interconnection of distributed generation (DG), efficient use of energy, market-based demand response,., quality of supply, and management of active distribution networks. ***Interactive Customer Interface (ICI)*** *being developed is based on the use of modern power electronics, advanced AMR technology and two-way communication between date bases and applications of the distribution and transmission system operators, service providers and electricity energy market players (e.g. aggregators).*

INTRODUCTION

Electricity distribution networks create a market place for small-scale power producers (distributed generation) and for customers (users of electricity); here, the role of distribution networks is of great significance. About a half of the total price of electricity for small customers and over 90 % of all interruptions for customers come from the distribution process. Also, there is a risk for very long interruptions.

There are many challenges for distribution system to enhance it's functionality as the real market place, as follows:

- improving the capability to serve the increasing amount of distributed generation
- enabling the electricity market development at the customer level e.g. for enhancing market-based demand response
- safe and cost-efficient operation of distribution networks in all circumstances

To meet above mentioned challenges and aims there is need to develop concepts, methods, business models, algorithms and simulation tools for analysis, simulation and verification of **Interactive Customer Interface (ICI)** integrated with supplying distribution system. The interactive customer interface will be based on the use of modern power electronics, advanced AMR technology and two-way communication between date bases and applications of the distribution system operator (DSO), transmission system operator (TSO), service providers and electricity energy market players (e.g. aggregators), as illustrated in Figure 1.

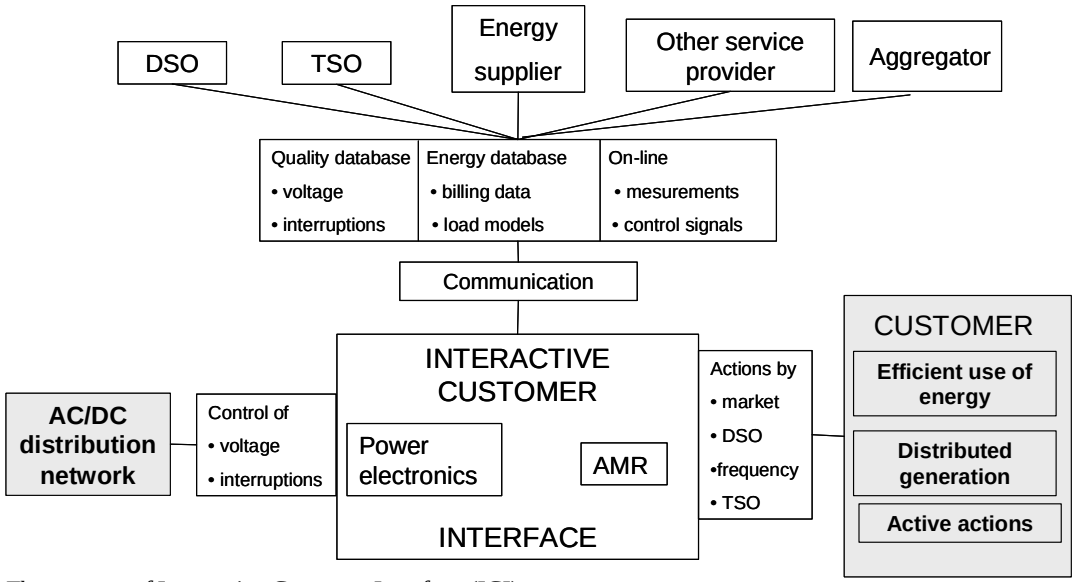

Fig. 1 The concept of Interactive Customer Interface (ICI).

The development of Interactive Customer Interface enables:
- more efficient and flexible network interface for DG and plug-in hybrid cars
- on-line market (price) oriented load and DG control management
- frequency based load control during local or system level load and generation unbalance situations
- services for energy savings and efficient use of energy
- on-line management and control of customer voltages, including also elimination of short interruptions (i.e. reclosings and voltage dips)
- more reliable constructions in distribution networks and advanced management of active distribution networks using data on interactive customer interface

DRIVERS AND TECHNOLOGY TRENDS

There are many drivers which point out needs of new methods, as follows:
- The penetration of DG will continue, because the amount of RES will increase due to environmental and political reasons, and the small-scale combined heat and power due to efficiency reasons.
- Efficient use of energy at customer level and even intelligent demand response have become an essential issue.
- Power quality (voltage quality and reliability) requirements will tighten due to public and regulatory actions at the same time when failure rates will increase due to climate change.
- Many components of existing networks are becoming into end of their lifetime. They need replacement or continuation of their lifetime in safe and controlled way.
- Regulation of network companies will tighten up while companies want to ensure profitability of their business. This will mean rationalization of network management both in short- and in long-term perspective.
- The risk of major disturbances is increasing, both the probability and consequences. The reason for increased probability is the complexity of power network and the increased failure rate due to climate change. The consequences are increasing due to society's higher dependency on the power supply.

Traditionally power generation, distribution network management and loads have been considered as quite independent processes. Along with increasing amount of distributed generation the traditional approach is being gradually changing. Considerable amount of renewable energy resources represents distributed generation, but also energy resources like storages and plug-in electro-hybrid vehicles, which can serve both as consumers and sources, will be increased. One of the main barriers for the penetration of DG at distribution network level is the complexity of the interconnection process of DG into network. From network management point of view the increasing amount of DG is often seen as negative development, which brings the complexity of transmission network to distribution network level. The main reason for the complexity is caused by the present methods for managing the distribution networks as well as the features of different DG components themselves, which are not sufficiently developed to enable easy interconnection of DG. So far loads and customers have also been passive from network point of view. By making the customer connection point more flexible and interactive the demand response functions (e.g. by real-time pricing, elastic load control) are more achievable and the efficient use of existing network and energy resources by market mechanisms can be improved.

There are some technology trends which makes it possible to define the customer interface in a brand new way. Large scale AMR (automated meter reading) implementations are underway or planned in many European countries. Communication technology and computer systems and their integration are under rapid development. Power electronics has typically been used in high-voltage transmission networks. At the distribution level only some applications have been seen. Based on our preliminary research, there seems to be revolutionary potential (technical and economical) for the application of power electronics at the distribution level. Traditionally customer interface has been on-site readable energy meter (i.e. conventional kWh-meter). Now the concept of intelligent customer interface enables the customer or the automatic functions related to the customer to be active in network management and in electricity market based on on-site applications and two-way communication with upper-level applications.

In the vision of Smart Grid Technology Platform smart metering has been seen as an essential part of smart grids, especially for
- interconnection of distributed generation
- demand response
- active distribution management

Remote readable energy meter is being developed to be an intelligent equipment (i.e. interactive customer gateway) including in addition to traditional energy metering also different kind of advanced functions based on local intelligence and power electronic applications as a part of active distribution networks.

OVERALL RESEARCH AIMS

For developing Interactive Customer Interface a joint project is being executed together with Tampere University of Technology, Lappeenranta University of Technology, Technical Research Centre of Finland (VTT), and with several industrial partners and electricity companies.

The aim of the project is to determine and to demonstrate the concept, functions and technological solutions of interactive customer interface, and technical solutions and business models for exploitation it in distribution management and electricity market actions. In the project the interactive customer interface (i.e integration of advanced AMR, power electronics and communication) is determined and modeled by simulations of various tools and demonstrations in order to verify the benefits of interactive customer interface from network management and electricity market point of view. By using and developing simulation tools the viability of the ICI-functions are proved in case of active distribution networks including large number of power converters, flexible loads and distributed generation, plug-in hybrid cars and distributed energy resources.

The research project is divided into the subtasks, as follows:

1) The overall concept; functions, exploiting processes and business models
2) Determination and demonstration of functions and technological solutions of network interface
3) Functions of advanced automatic meter reading (AMR)
4) Network connection of distributed generation as a part of interactive customer interface
5) Network interface of plug-in hybrid cars and effects on network infrastructure and electricity market
6) Technological solutions and business models for market and price oriented demand response
7) Effects of interactive customer interface on overall system-wide energy efficiency and survey of possibilities to develop energy efficiency services
8) Exploiting data of interactive customer interface in enhancing customer load modeling for network calculations, in network asset management and in active distribution management

Some of the above subtasks (not the all) related to power electronics based network interface, advanced AMR and load control are described in more detailed in the following. Management of active distribution network and network connection of DG is discussed e.g. in [1].

Power electronics based network interface

The technical and economic development of power electronics has been fast and continuous. Development of unit prices for conventional components used in distribution networks, e.g. transformers, has been highly ascending. Price erosion for power electronics components has been during past decade about -7 %/a. This makes it possible to harness the power electronics solutions to serve even the customer interface.

In several earlier studies and reports opinions and visions has been illustrated of utilization of power electronics in quality control of electricity supply. Power electronics is already a part of modern electricity distribution, for instance, in network connections of small-scale generation units. In larger scale power electronics are still unexploited in actual customer interfaces.

Apply of power electronics enables the LVDC supply in distribution system. The European Union (EU) low voltage directive (LVD 72/23/EEC) defines the boundaries for the low voltage (LV) levels used in public distribution systems. It covers equipment designed for use with a voltage rating between 50-1000 VAC and between 75-1500 VDC. HVDC systems are used e.g. in power grid connection of off-shore wind power mills having some hundreds or thousands of megawatts rating. Same principle gives many advantages also in low voltage level when connecting small scale distributed generation. E.g. wind mills hand fuel cells having some tens of kilowatt rating can be connected by DC/DC converter into dc-network having DC/AC connection with AC distribution system. Use of high DC-voltages, e.g. ±750 VDC increases dramatically the power transmission capacity of low voltage networks and makes its possible to connect small scale generators without more expensive medium voltage installations.

Power electronic based customer interface improves significantly the quality of supply. The voltage will be constant 230 V independent on load variations. Short interruptions can be eliminated, too. Intelligent power electronics opens new tools for demand side management. E..g. the local control of voltage can be used to decrease the loads. There is also the possibility to connect some loads (e.g. ovens) directly into LVDC supply.

The figure 2 illustrates the way power electronics may be applied in distribution networks.

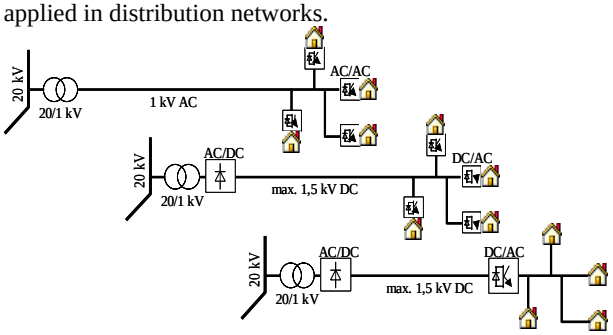

Fig. 2. Possible main principles for power electronics in distribution systems

Practical questions are related to customer level converters, to the DG-converters and to the technically and economically optimal voltage levels to be used in DC-supply. Electrical safety questions and overall fault protection of LVDC system are essential study topics, too.

Advanced automatic meter reading (AMR)

The primary role of AMR (Automatic Meter Reading) systems is to provide energy consumption data to the utility, but the cost of retrofitting the existing energy metering system may not be justified without added value functions. At present many utilities in Europe level are installing large-scale AMR-projects. So far the focus of the installations has been mainly on remote reading of energy measurements. Also some specific applications have been developed, e.g. for load control as described in [2]. The comprehensive concept of using AMR system and data in network and electricity market management is still rare.

The present AMR meters offer the platform (i.e the infrastructure and communication) to determine and develop new upper-level functions. The layer structure of AMR infrastructure is presented in Fig. 3.

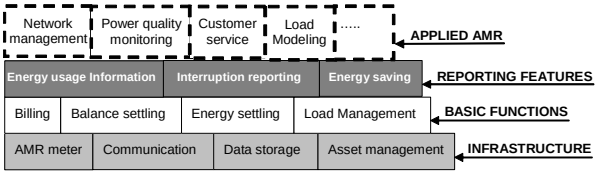

Fig 3. The layer structure of AMR infrastructure

2nd generation AMR meters can be seen as a realisation of three lowest levels in Fig 3. The 3rd generation AMR being developed will prove viability of the upper level in fig 3. These upper-level applications will be used in developing the network asset management, market enhancement as well as the customer service. First implementations of advanced AMR systems have already changed the function of basic energy meter to be a smart terminal unit and gateway for many functions and multiple service providers and to enable real time two-way communication between customers and utilities. As the figure 4 illustrates, AMR system can be utilised in many functions of distribution company (i.e local DSO), e.g. to support network operation (e.g automatic LV-fault indication, isolation and location, precise voltage and load data), network planning and asset management (e.g. exact load profiles for network calculations), power quality monitoring (e.g interruptions, voltage characteristics), customer service, and load control in addition to traditional use in billing and load settlement. Using AMR in low voltage management is discussed in more detailed in [3].

The introduction of AMR is opening entirely new chances for the DSOs in network management and to supply the customer with excellent service. In the history the interface to the customers has been bills and customer complaints mainly. In the future, the most important interface to the customers will be offered by AMR meters and system.

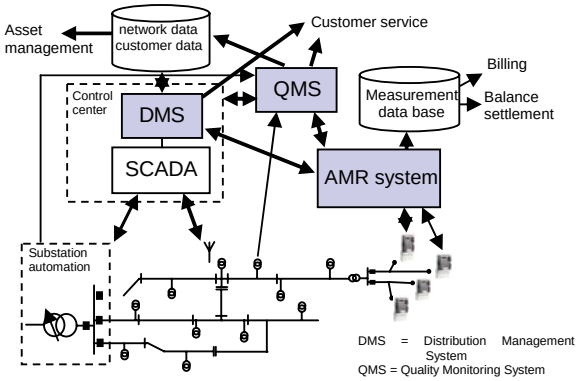

Fig. 4. Using AMR system in comprehensive network management.

Technological solutions and business models for market and price oriented demand response

The full utilisation of market based demand response and DG management requires the development of new business models and tools for aggregators operating between customers and electricity market. These will be developed and tested in the projects.

Automatic demand response at customers based on dynamic price variations (e.g. real time pricing) will be one part of process utilising the intelligence and automation at customers and end-uses. Some of these technologies and functions will be developed and tested in the connection of field tests.

CONCLUSIONS

Interactive Customer Interface being developed improves the functionality of electricity market at customer and DG level, improves the security, quality and efficiency of electricity networks and offers new incentives for energy conservation at customer level.

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