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COMPARISON OF GLOBAL MEAN TEMPERATURE SERIES STRATEGIES FOR BEGINERS

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ABSTRACT

This paper discusses general aspects of smart grids and focuses on some smart grid features at distribution levels like interconnection of distributed generation and active distribution management, using automated meter reading (AMR) systems in network management and power quality monitoring, application of power electronics in electricity distribution, plug-in vehicles as a part of smart grids, and frequency-based load control as samples of interactive customer gateway.

KEYWORDS: Smart grid, electricity distribution, distributed generation, active distribution management, automated meter reading, plug-in vehicles, frequency-based load control.

INTRODUCTION

The energy markets are in transition and there are many drivers for creating a replacement quite power delivery system for the long run. There are many drives and wishes as follows:

•The penetration of distributed generation (DG), especially supported Renewable Energy Sources (RES), will continue because of environmental reasons.

• The North American vision is to own common electricity market areas with a high penetration of distributed power generation.

• Efficient use of energy at the customer level and intelligent demand response has become an important issue.

• Power quality (supply reliability and voltage quality) requirements will increase because of public and regulatory actions and at the identical time, failure rates are expected to extend thanks to global climate change.

• There's a necessity, thanks to economical reasons, to extend the employment rate of the prevailing network. The normal way of developing a distribution network would be the investment in passive wires, resulting in a decrement of utilization rate.

•Many components of existing networks are getting to finish of their lifetime. They have replacement or continuation of their life in a very safe and controlled way.

•Regulation of network companies will restrain while companies want to confirm the profitability of their business. This may mean rationalization of network management both within the short- and during a long-term perspective.

- The chance of major disturbances is increasing, both the probability and consequences. The explanation for increased probability is that the complexity of the ability network and therefore the increased failure rate thanks to temperature change. The results are increasing thanks to society's higher dependency on the facility supply.

There are much research, and lots of visions and ideas for future power delivery system, sort of a super grid, smart grid, micro grid, intelligent grid, active network, power cell, etc. a number of them concentrate on transmission level functions (e.g. integration of large-scale alternative energy or utilization of FACTS -devices) as some cover low voltage level and customer interface (e.g. large-scale advanced AMR).

The concepts have many common features but also some differences, but they're not analyzed more deeply here. The most aims to satisfy the above needs are still the identical. A shared vision of a wise grid, or corresponding concept, is a crucial issue to develop commercially successful and useful products for future power delivery systems. This vision should be shared by network companies, product vendors, and network customers.

This paper focuses mainly on general aspects of smart grids at the distribution level and provides some samples of studied and developed smart grid features.

2. CHALLENGES FOR DISTRIBUTION SYSTEM

Electricity distribution networks create a marketplace for small-scale power producers (i.e distributed generation) and customers (i.e users of electricity). Here, the role of distribution networks is of great significance. as an example in Finland, about half the entire price of electricity for tiny customers and over 90 you look after all interruptions come from the distribution process. There are many challenges for the distribution system to boost its functionality because the real marketplace, as follows:

- improving the aptitude 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 and customer-oriented services.
- Safe and cost-efficient operation of distribution networks all told circumstances.

Traditionally power generation, distribution network management, and loads are considered as quite independent processes. Together with the increasing amount of distributed generation the normal approach is being gradually changing. a substantial amount of renewable energy resources represents distributed generation, but also active energy resources like loads, storage, and plug-in hybrid vehicles are going to be increased. one among the most barriers to the penetration of active resources at the distribution network level is that the complexity of the interconnection process. From the network management point of view, the increasing amount of DG is usually considered with reluctance because it brings the complexity of the transmission network to the distribution network level. The most reason for the complexity is caused by this methods for managing the distribution networks additionally because the features of various active resource components themselves, which don't seem to be sufficiently developed to enable easy interconnection. up to now loads and customers are passive from the 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 therefore the efficient use of existing network and energy resources by market mechanisms are often improved.

3. GENERAL FEATURES OF SMART GRIDS

the smart grid concept has different aspects as shown in Fig. 1. It includes novel solutions of infrastructure for future power distribution, e.g. use of power electronics and DC. Active resources (i.e. distributed generation, loads, storages, and electric vehicles) actually change the standard passive distribution network to be a full of life one. New network

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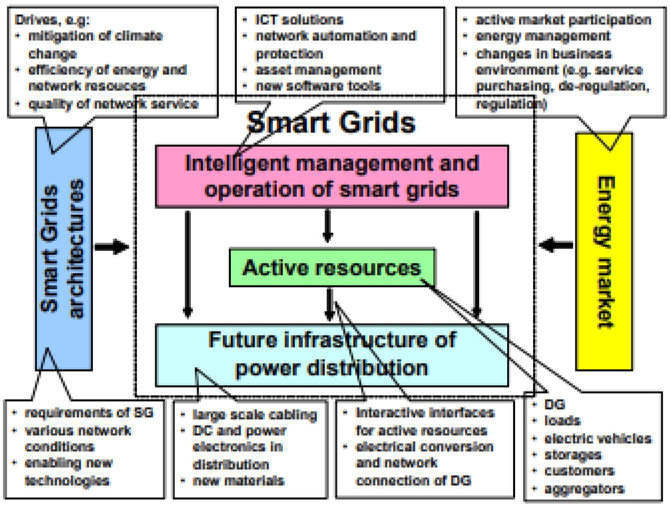
solutions and active resources need novel ICT solutions for network operation and asset management providing intelligence to active networks. Smart grids enable the active market participation of shoppers and also affect changes in an exceedingly business environment. Smart grids are customer-driven marketplaces for DG and consumers.

Fig. 1. Aspects of smart grids



Smart grids are often characterized as follows.

•interactive with consumers and markets

• adaptive and scalable to changing situations

•optimized to create the simplest use of resources and equipment

• Proactive instead of reactive, to stop emergencies

• self-healing grids with a high level of automation

•integrated, merging monitoring, control, protection, maintenance, EMS, DMS, AMI, etc.

• having plug-and-play –features for network equipment and ICT solutions

• Secure and reliable

Traditional grid includes centralized power generation and at distribution level one-directional power flow and weak market integration. Smart grids include centralized and distributed power generation produced substantially by renewable energy sources. They integrate distributed and active resources (i.e. generation, loads, storages, and electric vehicles) into energy markets and power systems. Smart grids will be characterized by controllable multidirectional power flow. Smart metering has been seen as an important a part of the vision of smart grids. Remote readable energy meter is being developed to be a bit of intelligent equipment (i.e. interactive customer gateway) including additionally to traditional energy metering also different forms of new advanced functions supported local intelligence. This gateway opens possibilities for network companies, energy traders, and repair providers to supply new varieties of added-value services to finish customers. The concept of smart grids could also be characterized by words like flexible, intelligent, integration, and cooperation. Grids are flexible because they utilize controllable resources throughout the network. Respectively the passive network has flexibility by network capacity i.e. network itself may handle all probable loading conditions. Intelligence is solely investments in protection, controllability, and data and telecommunication technologies rather than pure passive lines, cables, transformers, and switch gear. DG and existing controllable resources like direct load control, reactive power compensation, and demand-side integration provide a decent potential as a controllable resource for the smart grids. the mixing of DG and versatile loads within the distribution network will benefit the network when managed appropriately. the standard passive network management or “fit & forget” principle in DG connection has to be turned into active network management. the mixing of DG and other active resources into a distribution system could be a requirement so as to completely exploit the advantages of active resources in network management. With proper management of active resources, the system performance could also be improved from presently used practices.

Smart Grid architectures, Energy market, Future infrastructure of power distribution. Active resources intelligent management and operation of smart grids Smart Grids.

• Requirements of SG

•various network conditions

• enabling new technologies Drives, e.g.:

• Mitigation of temperature change

- Efficiency of energy and network resources
- Quality of network service
- Large scale cabling
- DC and power electronics in distribution
- new materials
- DG
- Loads
- Electric vehicles
- Storages
- Customers
- Aggregators
- Interactive interfaces for active resources
- electrical conversion and network connection of DG
- ICT solutions
- Network automation and protection
- Asset management
- New software tools
- Active market participation
- Energy management
- changes within the business environment (e.g. service purchasing, de-regulation, regulation)

One important control task in power systems is to take care of a balance between power production and consumption which suggests keeping the facility system's frequency at an appropriate level. This process is becoming more and tougher thanks to the rise of penetration level of intermittent power production, as an example, wind and solar energy. In recent years there has also been much serious frequency instability associated with wide-area facility blackouts in Europe and therefore the USA, and their costs, both economic and social, are high.

4. ACTIVE DISTRIBUTION MANAGEMENT

4.1 Impacts of distributed generation

On distribution network the assembly of electricity near consumers will reduce the transfer of electricity. this may also affect network losses. Network losses may increase when an oversized DG unit, e.g. wind farm, is found removed from consumption, and therefore the electrical distance of transferred electricity increases compared to a situation without a DG unit.

The intermittent (non-dispatch able, uncertain, and uncontrolled) production into the passive network doesn't benefit network rating. The load ability of the distribution network is decided by voltage profile (decrease or rise), power quality, and thermal ratings. The intermittent production in an exceedingly weak rural distribution network may cause voltage rise problems. The dimensioning of the network becomes quite challenging when there are different sizes and kinds of DG units together with the network. The worst-case planning principle of DG interconnection in passive networks should get replaced with a statistical planning approach in active networks (Repo 2005). The increment of fault current level thanks to new DG units may cause investments in networks if the rating of components is exceeded. The voltage control or reactive power capability of DG units could even be utilized in network management. Requirements for the protection of distribution networks are changing considerably (Mäki 2007). Protection schemes designed for unidirectional power flow may become ineffective. Unnecessary tripping additionally as undetected faults or delayed relay operations may occur thanks to high DG penetration. DG can also disturb the automated re-closing.

The operation sequence of protection devices during a fault is thus important. Due to DG, the prevailing methods employed in fault location could also become inappropriate this operational practice of distribution network requires disconnection of DG units when a fault occurs. This can keep the operational conditions simple and clear, safe, and suitable for auto-reclosing. The aim of DG unit connection point protection (e.g. frequency and voltage relays) is to eliminate the feeding of fault arc from a DG unit and to forestall unintended island operation. When the penetration level of DG increases the implications of immediate tripping of DG units may become adverse when short-circuit within the transmission grid is seen by several DG units. Even during a fault at the distribution network unnecessary disconnection of DG units may occur thanks to unwanted trips of feeder or DG unit protection relays, loss of synchronism of synchronous generators, sustained over-speed, and over current of asynchronous generators network safety and stability. However the implications of stability issues for the entire facility and also for DG owners and other distribution network customers are becoming more important when the disconnection of DG units may cause system-wide stability or local power quality problems.

4.2 ADINE Project For Active Distribution Management

A joint demonstration project called ADINE financed by the 6th Framework Programmed of the ecu Commission, Priority 6.1 Sustainable Energy Systems is ongoing (ADINE, Repo 2008). The partners of the project are ABB Oy Distribution Automation, AREVA Energietechnik GmbH, AREVA T&D Ltd, Com-Power AB, Lund University,

The Tampere University of Technology, and Technology Centre Hermia Ltd because the coordinator. The project is under execution between October 2007 and September 2010. The ADINE project aims to develop new methods for distribution network management including DG. When the distribution network is managed in step with the ANM (i.e active network management) method the interactions of different active network devices will be planned and controlled to profit the operation and stability of the network. One feature of this project is that it develops and demonstrates the ANM method and therefore the enabling solutions simultaneously.

The Project Will Develop And Demonstrate:

- protection of distribution network including DG. Application of communication-based relays at distribution network o fault location with the influence of DG. co-ordinated protection planning application on Network system (Mäki 2007)

- Voltage control of distribution network including DG o droop control of small-scale micro-turbine. Coordinated voltage control application on SCADA/DMS which is controlling the setting values of local voltage/reactive power controllers. (Kulmala 2007).

- new-generation medium-voltage STATCOM o capable of filtering harmonics, eliminating flickers and compensating reactive power (Lauttamus 2008) o on top of the above characteristics it can participate in mitigation of voltage dips and in controlling the voltage level of the distribution network.

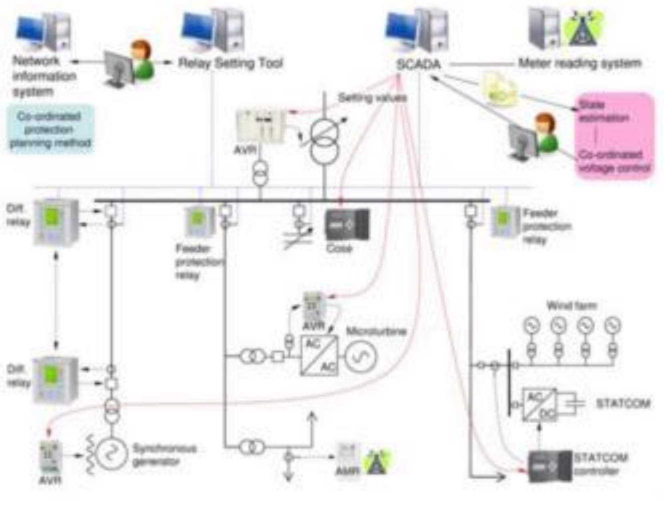


Figure 2 is visualizing the control levels of the distribution network and the way the ANM method affects them. All hardware devices are basically performing on a neighborhood level. They get measurements from local measurement devices and operate supported this information. This is often a de-centralized operation of protection and control like they’re operated today. However, the locations of protection and control devices don’t seem to be limited to primary substations but they’ll locate together with the distribution network. Some control devices may additionally locate on a customer-owned active device like DG or STATCOM. Protection relays are engaged on very cheap level like in passive networks, but new feeder protection schemes like directional over current, distance and differential protection, and new fault location applications are introduced. Automatic voltage regulation (AVR) of DG units, AVR of OLTC, STATCOM controller,

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and power factor controller are added to the automated system level. The new issue in ANM is that the utilization of automatic control systems in distribution network operation greatly. Demonstrations will show how the protection and voltage regulation in distribution networks are often improved through advanced protection schemes and decentralized control of DG units.

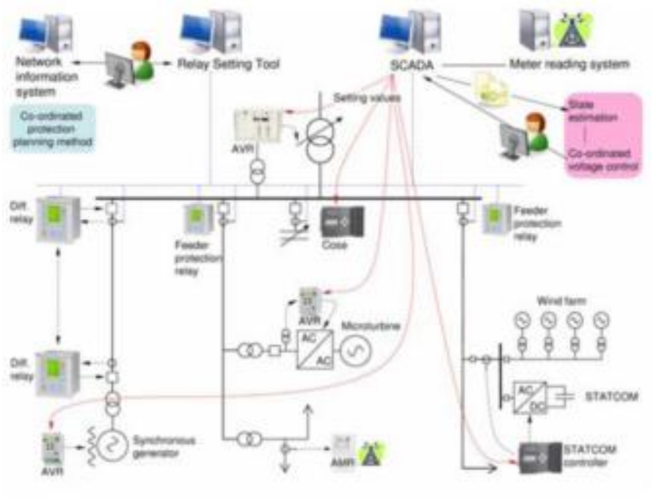

Fig.2. Overview of the active distribution network within the ADINE project.

The ANM method doesn’t take into consideration practical communication challenges e.g. communication media or protocol for satiny low DG unit. The tactic itself could be a conceptual description of the management of a full of life distribution network. It’s capable of applying any communication medium and protocol which is however restricted by the capabilities of individual devices and software. Naturally, the entire system would be more scalable, cheaper, and straightforward if multi-functional and -vendor open interfaces (e.g. IEC 61850) and data models (e.g. IEC 61970 and 61968) are applied at information exchange.

4.3 Real-time simulation and demonstration environment.

The ANM method is tested and demonstrated during a real-time simulation environment which mixes the simulation environments of RTDS (real-time digital simulator for electricity network) and d SPACE (real-time digital simulator for power electronics) as illustrated in Figure 3. It includes also a library of simulation models of DG units and their control algorithms. RTDS/d SPACE isn’t a standard simulation environment rather it’s test bed for secondary devices of power grid like protection relays and controllers of DG units integrated into the facility system model.

The electricity network is modeled and simulated in transient level on the RTDS side and developed applications in d SPACE side via Simulink interface. The individuality of the simulation environment is that the military operation of those two simulation environments. It provides a general simulation environment for any combination of devices and situations which don’t seem to be possible to demonstrate in real network without special arrangements. The 2 simulators are combined to take advantage of the capabilities of both simulators for interaction studies of power systems and power electronic devices. Further, the simulation environment used makes it possible to develop control strategies for wind turbines to qualify for more demanding grid codes within the future. Minimization of the simulation time and therefore the possibility to distribute calculation power between two simulators may be considered as additional benefits.

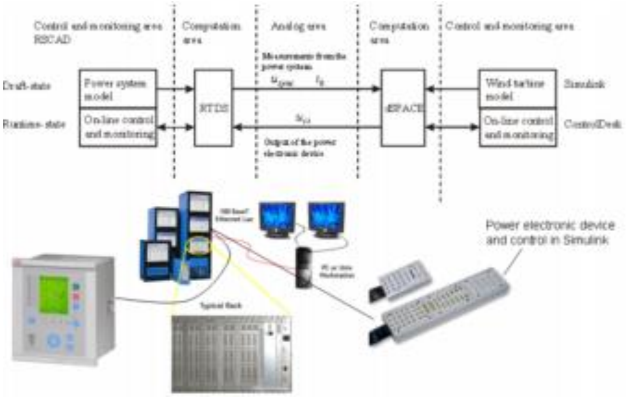

Fig.3.Combined simulation and demonstration environment of RTDS and d SPACE.

5. USING AMR IN NETWORK MANAGEMENT

The primary role of AMR (Automatic Meter Reading) systems are to supply energy consumption data to the utility,

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but the value of retrofitting the prevailing energy metering system might not be justified without added value functions. at this time many utilities at European level are installing large-scale AMR projects. up to now the main target of the installations has been mainly on the remote reading of energy measurements. Also, some specific applications are developed, e.g. for load control. The excellent concept of using AMR systems and data in network and electricity market management continues to be rare.

One requirement for creating additional value functions is that the open architecture in AMR systems to supply necessary integration possibilities. Standard integration ways e.g. OLE for Process Control (OPC) or open connectivity via open standards make it possible to develop new sorts of intelligent system integrations.

Traditionally AMR and Distribution Management System (DMS) are separate systems with none integration with one another as illustrated in Figure 4. the first role of AMR has been to supply energy consumption data to the utility for billing and balance settlement purposes. AMR system has also been used for load control in some installations. to this point automatic monitoring and centre measures by the DMS are used mostly for operating 20 kV medium voltage networks. A fault in an exceedingly low voltage network is cleared automatically by a blown fuse, but no information that is received to the center. The existence of an LV-network fault is sometimes indicated only by customer calls.

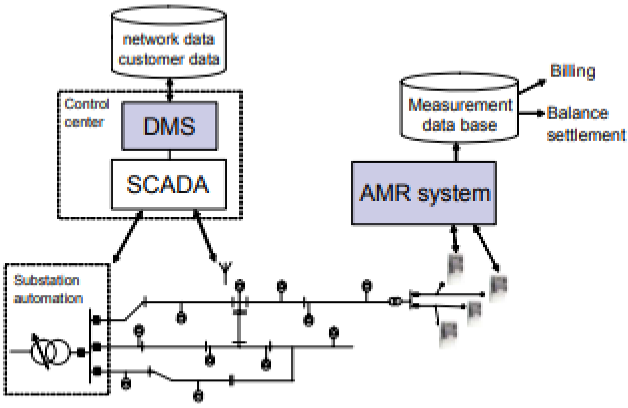

Fig. 4. The normal way of network management.

The present AMR meters offer the platform (i.e the infrastructure and communication) to work out and develop new upper-level functions (see Figure 5). These are going to be employed in developing the network asset management, market enhancement also because the customer service. First implementations of advanced AMR systems have already changed the function of the essential energy meter to be a wise terminal unit and gateway to enable real-time two-way communication between customers and utilities. In advanced meters alarms supported exceptional events i.e. network faults and voltage violations are enabled. Meters may additionally have some protective functions adding safety. The employment and integration of AMR in network operation will be seen as an extension of SCADA and distribution automation to the low voltage level. As Figure 5 illustrates, the AMR system may be utilized in many functions of the distribution company, e.g. to support network operation (e.g automatic LV-fault indication, isolation and placement, precise voltage and cargo 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 cargo control additionally to traditional use in billing and cargo settlement.

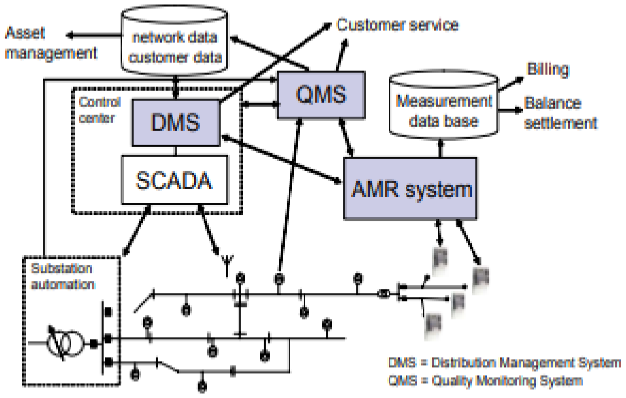

Fig. 5. Integrated information systems for comprehensive network management.

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The integrated AMR, DMS, and power quality monitoring systems offer information to be employed in overall asset management and network planning. at the present advanced network calculation applications of network information systems and DMS use hourly-load curves as load information. AMR system offers a mass of measurement data to work out more detailed load models for various purposes in network management and cargo prediction. Real-time AMR data may be utilized in state-estimation; except for network planning purposes load models are still needed. For network operation purposes more accurate real-time state estimation of the the full network gives information on voltages, loads, losses, and stressing of components, and also make it possible to optimize e.g. configuration, voltage control, and cargo control actions. In network planning more accurate load models (e.g. more accurate division of customer groups, regional models, etc.) for network calculations and knowledge on realization of power quality (i.e. interruptions, voltage dips, voltage levels) are often accustomed allocate measures and investments. More accurate information on hourly variation of losses is additionally valuable for the network company.

5.1 An application for low voltage network fault indication.

Low voltage network management may include functions, for instance, to point automatically if a fuse within the low voltage network has burnt or a conductor is broken, to locate the fault, to produce accurate interruption data, to watch voltages at customer site in real-time and supply voltage level as power quality information for customer service.

In one Finnish distribution company (i.e. Koillis-Satakunnan Sähkö Oy) a development project were realised for developing a comprehensive technology solution of latest functions of AMR and related information systems for low voltage network monitoring and management (Järventausta 2007). The aim was to mix new-generation energy meters, digital communication solutions and distribution management systems into an entity with an open architecture. The project consortium included different equipment and system vendors (i.e. ABB Oy, Aidon Oy, MX Electrix Oy, PowerQ Oy), the research organisation (i.e Tampere University of Technology) and also the pilot distribution company.

The pilot company has a sophisticated DMS for real time network analysis (i.e. 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 as presented in Figure 4. the mixing of AMR makes it possible cheaply to observe low voltage network and analyze fault situations since AMR communication infrastructure may be used. Because network monitoring in SCADA/DMS requires that events from meters are received in near real-time manner an efficient thanks to forward data from AMR is required. Within the development project OPC technology was selected for this purpose.

An advanced AMR meter works as an intelligent monitor and utilizes the communication infrastructure to supply spontaneous event or alarm information to regulate center with vital information on low voltage network faults and voltage levels. The meter includes algorithms to inference the existence of a fault and kind of the fault. In certain cases, e.g. when neutral conductor is broken, the advanced AMR meter may even isolate automatically the customer from the network. this needs a particular switching device which may be integrated into the advanced AMR meter.

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Figure 6 illustrates part of DMS screen during a case of broken neutral conductor. Network coloring shows the results of inference to locate the broken line-section.

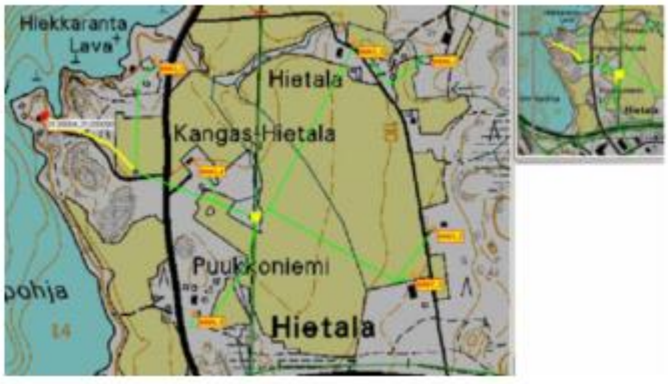

Fig. 6. A case of broken neutral conductor (Kärenlampi 2007).

When event data from meters are combined with topological network model within the DMS the first reason or faulted component will be located. this provides enormous benefits for low voltage network management when, as an example, blown fuses, broken conductors and voltage problems will be presented to the operators at center almost in real time manner.

Corresponding comprehensive integrated data system entity for network management supported installation of advanced AMR meter to all or any 350 000 customers is additionally being introduced in real operation Vattenfall Verkko Oy in Finland (Keränen 2009).

5.2 Power Quality Monitoring

At the instant, voltage quality is typically monitored temporarily at customer sites supported customer reclamations, not comprehensively and continuously from the complete distribution network. Power quality monitoring including continuous voltage quality monitoring to a bigger extent gives however important information for various operations of the distribution company. The event 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 employment of assorted 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 Department of power engineering at the Tampere University of Technology has actively been developing a comprehensive power quality data management system along with distribution utilities and a number of other differing kinds of kit and information system vendors. (Koponen 2002, Mäkinen 2003, Antila 2005) The novel AMR technology makes it possible to integrate basic power quality functions into the AMR meter. additionally to register interruptions with time-stamps, the subsequent quantities for every of the three phases can even be able to meter counting on the meter configuration: voltage and current variations, active power, apparent power, total reactive power, first harmonic reactive power, voltage dips, and swells, a complete distortion of the provision voltage, some harmonic voltages, DC-voltage component, frequency of the provision voltage, voltage unbalance between the three phases. (Koponen 2002, Mäkinen 2003). The idea is to assemble information from low voltage level and integrate it, for instance, to network databases and different planning and operation systems to extend knowledge with a much larger amount of data. The measurement data (i.e. even over several years) may be stored within the open relational Power Quality Database (PQDB) (see Figure 7). The measurement data of the PQDB are often studied using the Web-based application, PQNet system, additionally to DMS and network planning systems. The utilization of Web-based technology in PQ monitoring is also an enclosed or an outsourced service for distribution companies. Web-based PQ monitoring is an example of ASP (Application Service Provider) functions. Power quality data can even be offered to the customers (e.g. industrial customers) with their energy consumption and billing data through the online.

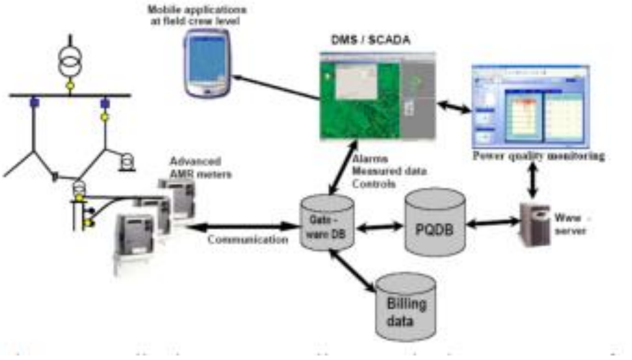

Fig. 7. Realized power quality monitoring as a part of integrated information systems

Factors that increase the requirement 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 might use the ability quality data in network planning and operation

•regulation requirements

6. INTERACTIVE CUSTOMER GATEWAY

For developing distribution management and functionality of electricity market one essential objective is to create the customer, or a minimum of customer connection point, active for improving e.g. interconnection of distributed generation, efficient use of energy, market-based demand response, quality of supply, and management of active distribution networks. An overseas readable energy meter is being developed to be intelligent equipment (i.e. interactive customer gateway) including additionally to traditional energy metering also, different quite advanced functions supported local intelligence and power electronic applications as an element of active distribution networks. The interactive customer gateway are supported the utilization of recent power electronics, advanced AMR technology, and two-way communication between date bases and applications of the distribution system operator (DSO), gear operator (TSO), service providers, and electricity energy market players (e.g. aggregators), as illustrated in Figure 8.

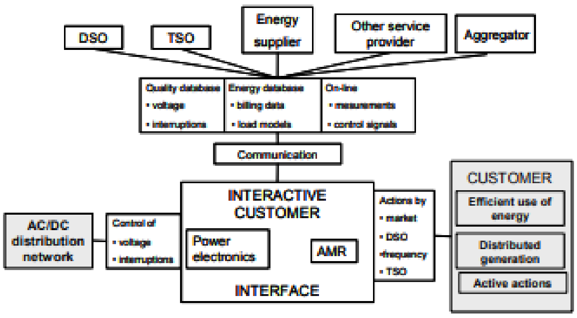

Fig. 8. The concept of Interactive Customer Gateway (INCA)

For developing an interactive customer gateway a joint research project is being executed along with Tampere University of Technology, Lappeenranta University of Technology, Technical Research Centre of Finland (VTT), and with several industrial partners and electricity companies. (Järventausta 2008).

The development of interactive customer gateway enables:

• more efficient and versatile network interface e.g. 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 the elimination of short interruptions (i.e. reclosing and voltage dips).

• more reliable constructions in distribution networks and advanced management of active distribution networks using data on interactive customer gateway Some technology trends make it possible to define the customer interface during a latest way. Large scale AMR implementations are underway or planned in many European countries. Within the European level vision of smart grids smart metering has been seen as a necessary a part of smart grids, especially for interconnection of distributed generation, demand response, and active distribution management. Communication technology and computer systems and their integration are under rapid development.

Power electronics have typically been utilized in high voltage transmission networks, but at the distribution level, only some applications are seen. Traditionally customer interface has been bills, customer complaints, and on-site readable energy meter (i.e. conventional kWh-meter). Now the concept of intelligent customer gateway enables the customer or the automated functions associated with the customer to move in network management and electricity market supported on-site applications and two-way communication with upper-level applications.

7. POWER ELECTRONICS IN ELECTRICITY DISTRIBUTION

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

INTERACTIVE CUSTOMER INTERFACE

Power electronics AMR CUSTOMER Efficient use of energy Distributed generation Active actions by

- market
- DSO
- frequency
- TSO Control

Interruptions

AC/DC distribution network

Communication Quality database Energy database On-line

- Voltage
- billing data
- Measurements
- interruptions
- load models
- control signals

DSO TSO Energy supplier Other service provider Aggregator In several earlier studies and reports opinions and visions are illustrated of the employment of power electronics in internal control of electricity supply. Power electronics are already a component of recent electricity distribution, for example, 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 within the distribution system. The eu Union (EU) low voltage directive (LVD 72/23/EEC) defines the boundaries for the low voltage levels employed in public distribution systems. It covers equipment designed to be used with a voltage rating between 50-1000 VAC and between 75-1500 VDC. HVDC systems are used e.g. in power system connection of offshore wind generation mills having some hundreds or thousands of megawatts rating. the identical principle gives many advantages also in low voltage levels when connecting small-scale distributed generation. E.g. windmill’s hand fuel cells having some tens of kilowatt rating may be connected by DC/DC converter into DC-network having DC/AC reference to AC distribution system. the employment of high DC-voltages, e.g. ±750 VDC increases dramatically the facility transmission capacity of low voltage networks and makes it possible to attach small-scale generators without dearer medium voltage installations. Figure 9 illustrates the way power electronics is also applied in distribution networks. Power electronic-based customer interface improves significantly the standard of supply. The voltage is going to be constant at 230 V independent of load variations. Short interruptions will be eliminated, too. Intelligent power electronics open new tools for demand-side management. E.g. the local control of voltage are often accustomed decrease the masses. There’s also the chance to attach some loads (e.g. ovens) directly into the LVDC supply.

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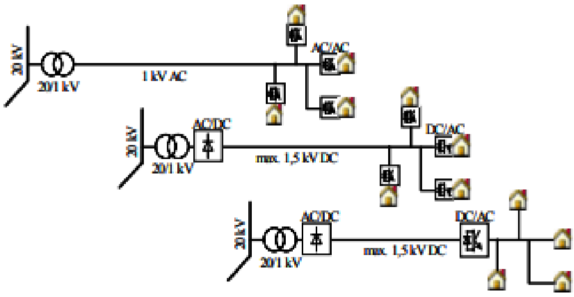

Fig. 9. Possible main principles for power electronics in distribution systems.

Practical questions are associated with customer-level converters, to the DG-converters, and to the technically and economically optimal voltage levels to be employed in DC supply. Electrical safety questions and overall fault protection of LVDC systems are essential study topics, too. More detailed descriptions and results are given e.g. in (Kaipia 2008) and (Lassila 2009b)

7. PLUG-IN VEHICLES AS a part of SMART GRIDS

Transportation contains a vital function in today's society. Globally, the energy production of transportation systems is sort of completely oil-dependent. The transportation sector is additionally a major consumer of energy and a major source of greenhouse gases and other emissions. Today's climate and energy policies imply strong diversification of transportation fuels, improving energy efficiency, and reducing emissions. the utilization of voltage in an exceedingly broader manner utilizing plug-in hybrid electric vehicles (PHEV) and electric vehicles (EV) offers a good potential to meet these challenging requirements.

This creates a challenge to the present electricity distribution infrastructure. Reckoning on the electrical car charging methods, the facility demand may increase dramatically or stay almost at the current level. The present electricity distribution infrastructure sets some limitations on the large-scale adoption of electrical cars. With none intelligence included within the system, charging electric cars may increase the height power much higher compared with the current load level while annual energy needed by the car remains low (i.e. some thousand kWh). (Lassila 2009a) Plug-in vehicles (PHEV and EV) could even be accustomed produce different sorts of ancillary services to regulate and manage power systems as a full.

7.1 Frequency-dependent charging.

As part of the above-mentioned development of Interactive Customer Gateway (INCA) also frequency-dependent charging has been studied (Rautiainen 2009). In these studies, the control method of the battery chargers is predicated on local frequency measurements dole out within the vehicles' grid interfaces. Control supported local measurements is an efficient thanks to utilize an outsized number of distributed resources that must react to frequency disturbances in a very very dynamic manner. Frequency-dependent battery charging is wont to enhance the facility system's frequency regulation capacity (which operates in normal grid conditions), to reinforce the facility system's disturbance reserves (which operate in abnormal grid conditions), or enhance both of those. a way to form a charger frequency-dependent is to regulate the charging power directly at the subsequent frequency. the foremost simple thanks to realize this is often to prevent the charging (regarding those chargers which are charging) when grid frequency falls under a predetermined level, or in some cases charging can begin (regarding those chargers which aren't charging and which are engaged with a non-full battery) if frequency rises to a high enough level. Power may be controlled constantly as a function of frequency. In Figure 10, this principle is illustrated in three different appliances: frequency regulation, disturbance reserve, and a mixture of those two.

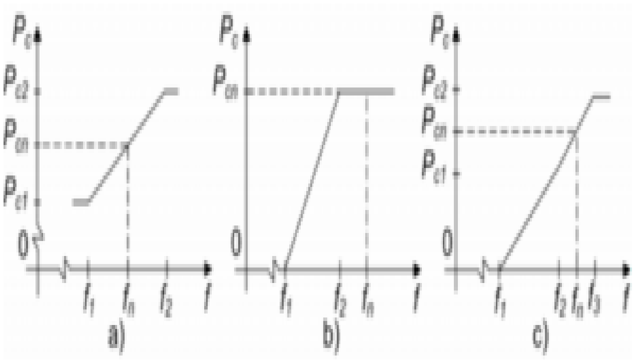

Fig. 10. Controlling charging power in accordance of frequency in a) frequency regulation application b) disturbance reserve application c) combination application (the figure isn’t in scale).

In frequency regulation application, when frequency varies at interval f1…f2, the facility drawn from the grid by the charger is varied continuously at interval Pc1…Pc2. At nominal frequency fn, a charger draws power Pcn. In frequency regulation application chargers regulate their power demands in frequency interval which is accepted as normal variation. for instance, in Nordel (i.e. Nordic interconnected transmission grid) interval f1…f2 can be 49.9…50.1 Hz. Varying charging power causes some uncertainty of the charging time of the batteries, and interval Pc1…Pc2 should be limited so the charging of the vehicle isn’t disturbed an excessive amount of. to zero. for instance, in Nordel the operation frequency interval f1…f2 of this application can be 49.5…49.9 Hz. In this application chargers are set able to participate in the management of huge power unbalances of the grid, and are thus usually fairly rarely used. the mix application, which is presented in Figure 10 c) combines the 2 other applications presented earlier. During small frequency deviations (f2…f3) the charger changes its power within interval Pc1…Pc2, and if the frequency falls low enough (<f2), power are often move zero. More detailed descriptions and simulation results will be found in (Rautiainen 2009). Frequency-dependent charging of plug-in vehicles offers an an effective thanks to enhance an influence system’s frequency stability. Distributed controllable loads offer a resource that can very rapidly react to frequency disturbances and therefore the harm (charging energy which isn’t received) to the vehicle users caused by the charging control will be negligible. However, wide utilization of the frequency-dependent charging requires economical incentives for the vehicle users or legislative actions. The number and availability of controllable load depends strongly on many things including plug-in vehicle penetration, driving habits, energy consumption of the vehicles, charging opportunities (including battery replacement service) and charging habits. Plug-in vehicles aren’t yet widely within the markets and thereby embedding new functions to the vehicles are technically fairly easy and will be executed with low costs. In the future, plug-in vehicles might communicate with different parties via wireless communication networks, and using this gateway the gear mechanism operator could update the parameters of the frequency-dependent controller. The frequency dependency function could even be implemented with vehicle-to-grid (V2G) concept. the utilization of V2G offers a a wider range of operation ((for example ±nominal power) than frequency-dependent charging, although it’s more complex.

8. FREQUENCY-BASED LOAD CONTROL

As a component of the above-mentioned development of Interactive Customer Gateway (INCA) also a frequency-dependent space heating has been studied to manage frequency disturbances in power systems. Setting value of warmer thermostats are made keen about locally measured network frequency. Studies are dole out through time-domain simulations, and also by laboratory testing by implementing a brand new function to the advanced AMR meter described in chapter 5. Studies imply that the employment of frequency-dependent loads in frequency disturbance management is an efficient tool for managing power unbalances. This sort of load control method’s consequences and harm to the users of the space heaters can be negligible, but the importance of this controllable load to the power system will be very high. it’s important to coordinate the operation of the frequency-dependent load carefully with other control actions taking into consideration the cold load pick-up phenomenon associated with the employment of this kind of load. In this study, the dynamic demand control (DDC) method, presented in (Schweppe) and further explored in (Short 2007), is applied to electric space heating loads. within the method, the temperature settings of the electrical warmer thermostat are frequency-dependent following local frequency measurement. Figure 11 illustrates the control method of the hundreds employed in the study. Figure 11 a) depicts normal thermostat action. The heater is switched on whenever the temperature falls under a specific level and off-switching occurs when the temperature rises high enough. Thereby temperature varies around desired temperature Tides, which is set by the user of the load through a manual thermostat adjustment. Figure 11 b) illu trates the DDC method in an exceedingly disturbance reserve appliance. The setpoint value of temperature is now a function of the grid frequency. Load reacts only at frequencies under f1 and maximum temperature deviation from normal operation is ready to ΔTmax.

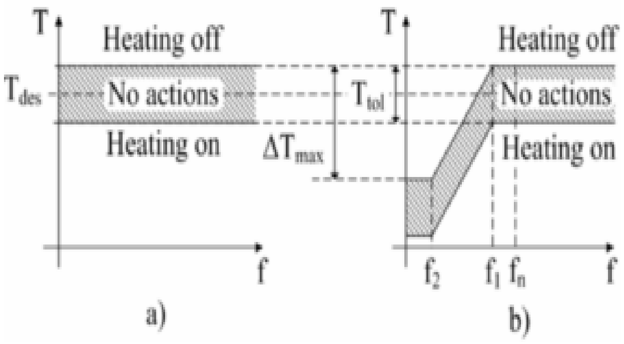

Fig. 11. a) Conventional thermostat action b) Control method of frequency-dependent electric space heating load utilized in these studies (Figure isn't in scale.)

This paper discusses aspects of smart grids generally and gives some samples of smart grid features studied and developed in Finnish research projects. The paper presents some smart grid features at the distribution level coping with interconnection of distributed generation and active distribution management, using automated meter reading (AMR) systems in network management and power quality monitoring, application of power electronics in electricity distribution, plug-in vehicles as a part of smart grids, and frequency-based load control. Remote readable energy meter is being developed to be a bit of intelligent equipment (i.e. interactive customer gateway) including additionally to traditional energy metering also different quite advanced functions supported local intelligence and power electronic applications as part of active distribution networks. The interactive customer gateway are supported the employment of modern power electronics, advanced AMR technology and two-way communication between databases and applications of the distribution system operator (DSO), transmission system operator (TSO), service providers, and electricity energy market players (e.g. aggregators).

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