Use Case Analysis of Real-Time Low Voltage Network Management

S. Repo*, D. Della Giustina, G. Ravera, L. Cremaschini, S. Zanini, J. M. Selga and P. Järventausta

***Abstract*-- Real-time low voltage network management is becoming possible thanks to massive smart meter rollouts, integration of them to distribution network management systems and utilization of distributed energy resources in distribution network management. Nowadays low voltage network management is emerging by integrating automatic meter infrastructure to centralized systems like SCADA/DMS. European project INTEGRIS is proposing a distributed approach based on hybrid and meshed communication. The paper is focused on low voltage network management use cases developed within the context of INTEGRIS and their ICT requirements to test the level of performance provided by the ICT architecture developed in the mentioned project.**

***Index Terms*-- Distributed information systems, distributed energy resources, meter reading, cyber security, networking for the smart grid**

I. Introduction

Distribution system operators (DSOs) operate in a scenario defined by a national and international regulatory framework which on one hand vigorously promotes and rewards customers who install distributed generation (DG) and storage and on the other hand pressures DSO's operating margin. In the most European countries DSO's operating margins are contingent upon regulated prices (price-cap), which tend to decrease over time, and are also subjected to remuneration or penalization mechanism related to the number and the length of outages for both MV and LV customers. The growing complexity, brought about by DG, makes increasingly difficult to meet those quality of service standards. Therefore the only sustainable way for DSOs to cope with this trend and keep their economic model in balance, is to enhance the technological level of the grid and the efficiency of their operations, moving toward the smart grid.

The smart grid promises to make real the next generation of electrical application for grid management: monitoring, control and protection. ICT is considered a key enabler of this transformational process, and several European research projects have been launched to design an ICT infrastructure to support smart grid applications.

Some of them tend to view the grid management of the future simply as an evolution of today's centralized systems like automatic meter infrastructure (AMI) integrated with DMS with modest communication improvements based on traditional media, such as GPRS [1,2]. Other research projects envision a hierarchical and flexible ICT architecture as a requirement for some smart grid advancements, such as Fenix [3] focused on virtual power plant mainly, Address [4] focused on active demand and Adine [5] active network management concept.

The approach proposed by the European project INTEGRIS [6] centers around the development of a novel and flexible ICT infrastructure based on a hybrid broadband power line communication (BB PLC) and wireless integrated communications system, such as Wi-Fi and wireless sensor network. The INTEGRIS hybrid and meshed communication environment pursues a balanced tradeoff between DSOs' investments/benefits and a fairly good and efficient progress on communications - meeting most of the requirements of smart grids. The project takes into account changes on the LV networks due to the introduction of AMI, DG, electrical vehicle (EV) connection and demand response applications. It also considers the unbundling, which demands a strict separation of duties and roles across the players active in the electricity supply chain.

A further objective is to research on the limits and benefits of distributing smart grid applications in the newly designed INTEGRIS system. This will have affect on development of devices and platforms since they will require a certain level of storage and computing capabilities. The paper is focused on LV network management use cases determined within the context of INTEGRIS and their ICT requirements to test the level of performance provided by the ICT architecture developed in the mentioned project.

II. Distribution Network Management

A. Centralized concept

A typical European distribution grid consists of primary substations (PSs) for the HV/MV transformation, secondary substations (SSs) for the MV/LV transformation, and final customers usually connected in LV. Power grids are managed from the control center (CC) where the PSs equipment are

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S. Repo (* contact person) and P. Järventausta are with the Department of Electrical Energy Engineering, Tampere University of Technology, Tampere, FIN-33101 Finland (e-mail: sami.repo@tut.fi, pertti.jarventausta@tut.fi).

D. Della Giustina, L. Cremaschini and S. Zanini are with A2A Reti Elettriche SpA. Brescia, 25124 Italy (e-mail: davide.dellagiustina@a2a.eu, lucio.cremaschini@a2a.eu, zanini.stefano@gmail.com).

G. Ravera and J. M. Selga are with the Department of Computer Science of La Salle-University Ramon Llull.

monitored and are remote controlled through the SCADA/DMS system including detailed network data of distribution network. In advanced DMS also LV network data is involved. This is a very centralized model where the intelligence is concentrated at the CC. Figure 1 describes the combination of advanced distribution network management systems which includes features from many existing systems.

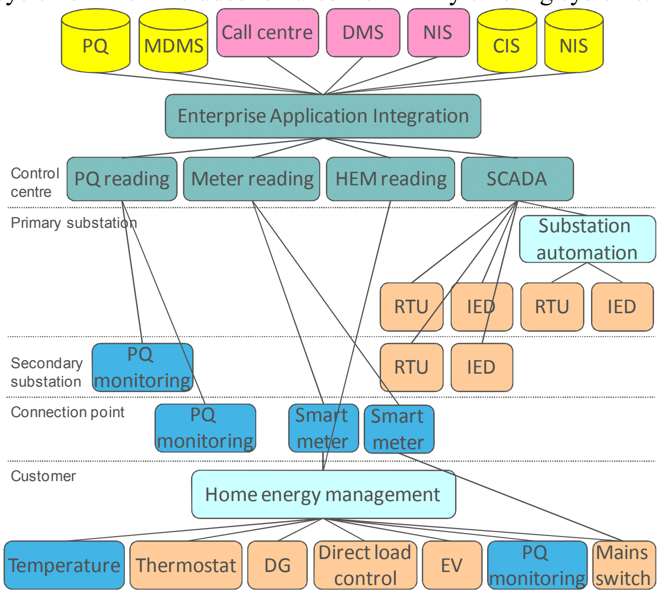

Fig. 1. Centralized distribution network management system.

In today's environment cost/benefits constraints are preventing a real decentralization of the intelligence with possibly the exception of PSs where SA (SA) systems have already been deployed in some cases. The local electronic devices like RTU (Remote Terminal Unit) and IED (Intelligent Electronic Device) have typically limited capabilities. Feeder automation is mainly designed to reduce the duration of MV outages utilizing fast autoreclosing, remotely controlled disconnectors, reclosers and sectionalizers. These devices might have a predefined operation procedure or they may be remotely controlled by SCADA/DMS. Monitoring and control are rarely present at SS level. This is mainly due to the absence of cost effective communication media.

LV network typically has no intelligent features except for the Automatic Meter Reading (AMR) which was defined in most cases for a commercial purpose only. AMR systems may read several million meters although again in a centralized way. The way used today to handle the increased number of devices is by providing levels of concentration.

The biggest ICT deployments today over distribution network management are dedicated to the topic of AMR and its evolution towards AMI where smart meter information would be available for network real-time monitoring purposes and simple controls like mains switch opening. Dedicated power quality (PQ) monitoring system could be used for real-time monitoring of permanent and temporary PQ measurements and disturbance recording downloading.

The second major development topic is the utilization of home energy management (HEM) in smart grids in general. HEM may control selected contracted DERs based on CC commands. Today this is e.g. participation to demand response programs but in the future HEM could also offer services to distribution network management.

Distribution CC systems are typically point to point integrated and using tailored interfaces and therefore utilization of integration layer (e.g. enterprise application integration) and standard interfaces is becoming more and more important when the number of integrated systems increases in smart grid context.

B. Decentralized Concept

Figure 2 represents the proposed concept for electricity distribution network management. It is based on concept which is capable of decentralizing intelligence, applications and communications.

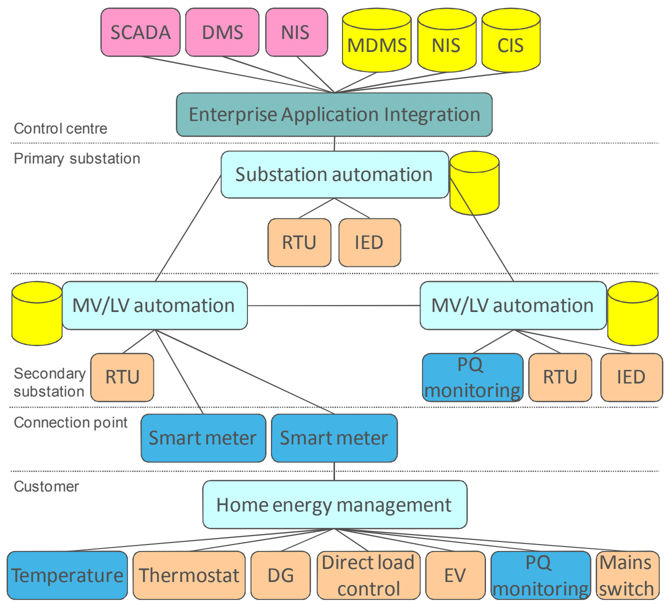

Fig. 2. Decentralized distribution network management system.

Decentralization is becoming possible due to addition of measurement and control devices into MV and LV networks and also due to cheap and capable enough communication. In this way some duties of operators and some completely new tasks may be decentralized to lower levels of automation system. Decentralized distribution network management system is not gathering all information and decision making into CC but some simple decisions could be made automatically at PS, SS or customer site. Decentralized system store and analyze data locally at these sites and send only requested or analyzed information to CC.

Distribution network management may be improved by extending the area directly monitored in real-time, speeding up the decision making and utilizing DERs in distribution network management. This is very important in smart grids where very large number of measurement and control devices is available for network management. The role of operator in CC is to supervise the functioning of these automatic systems and make high level decisions. The benefits of better observability and controllability of smart grid will probably come out first in extreme cases like island operation and microgrids and next in cases where large number of DER are connected and available for control.

Aggregation of information may be realized in many levels. CC is an obvious location to aggregate information and to make centralized complex decisions. However CC does not need to know every detail of small scale resources located at customer sites at least in real-time. If more detailed information is required, this information is available at lower levels of automation system.

Starting from the bottom the first level to aggregate information is HEM system which is managing DERs. It gets measurement data from smart meter, measurement sensors and DER, make decisions to operate DER (e.g. minimize EV charging cost or maximize usage of locally produced energy), realize network management commands from upper level automation systems (e.g. reduce power taken from distribution network in order to relieve network congestion) and send relevant aggregated information to upper level automation systems.

MV/LV automation on the left side of Figure 2 represents SS and LV network monitoring and management, which gathers information from HEM, smart meters and RTUs. Database is used to store real-time measurement data and control commands. SS and LV network management includes for example functions described in Chapter IV utilizing real-time data in decision making. MV/LV automation on the right side of Figure 2 represents MV network monitoring and management, which gathers information from PQ monitoring units, RTUs and IEDs. Functions located on this side are for example improved feeder automation and outage management. MV/LV automation updates aggregated measurement and status information of network condition under its supervision to SA and in some cases also to adjacent SSs.

SA has been influenced a lot by IEC 61850 SA standard which enables interoperability of IEDs to introduce intelligent protection, monitoring and control functions.

The primary idea behind the proposed concept is to utilize the same automation and communication system for all purposes of distribution network management. Parallel reading and automation systems in centralized concept will be replaced with single automation system. The automation system should be expandable and open in similar way than SA systems based on IEC 61850. For example the real-time measurement data from smart meter flows first to MV/LV automation where it is analyzed and aggregated with other measurements. Only final conclusions are sent further to SA and CC. Similarly hourly energy measurements are first concentrated at SS and then further sent to billing system. The aggregation and decentralized analysis of raw measurement data reduces significantly communication burden because major part of data is meaningless for CC operator and should not be send to CC.

III. ICT Architecture

A. Requirements of electrical distribution networks

Smart Grids have to support hundreds of specialized smart grid services, many of which differ very much in nature form the traditional services considered in typical ICT networks. At the same time some of these services have very stringent requirements in terms of reliability and delay. Especially in smart distribution grid there appear new difficulties because of its distributed, complex and partially buried or underground nature. These facts make it very challenging to design ICT systems able to cope with the requirements of smart grids in electrical distribution networks and this is exactly the focus of the European FP7 project INTEGRIS.

The ICT smart grid requirements for PSs are already well established and they define delays as low as a few ms for some services and very high reliability levels not easy to achieve in a massive manner over a distribution network.

Regarding the type of functions, the main difficulty is that, in general, in smart grids they are not amenable to flows as is normally the case for traditional communication services (Voice, video,..), that they are “always on”, with no establishment phase and that there is a very broad array of application requirements. Among them, protection functions are a specific challenge since they have to be resolved with high reliability and with extremely low delays.

The question is, thus, whether those requirements for high voltage smart grid are necessary in the electrical distribution network or, on the contrary, whether they can be relaxed to make it feasible the massive deployment of ICT systems in this environment.

As an answer to this question, in INTEGRIS it has been considered that the Smart Grid requirements can be somewhat adapted for electrical distribution networks and a proposal for classes of services and related requirements in distribution grids have been made. Table I shows the functional classes and requirements set in INTEGRIS.

TABLE I
FUNCTIONAL CLASSES AND REQUIREMENTS ACCORDING TO INTEGRIS D2.2

Class Code	Function class	Class Code	Value/signal	Transfer time (*)	Availability In Grid state	Reliability level
APF	Active Protection Functions (HV/MV-MV/LV level)	APF	Block & trip Signal	<=20ms	Normal Perturbed Crisis	Very High
CMD	Command & regulations	CMD	O/C command Load shedding Peak Shaving	<=2s	Normal Perturbed Crisis	High
MON	Monitoring and analysis	MON	Analogical & Digital TVPP	<=2s	Normal Perturbed Crisis	high
AMS	Advanced Meter & Supply management function (commercial functionality)	AMS	Energy meas., Supply mngt Command; Alarm signals	<= 5m --------- <=10s	Normal	low
IEM	End to end information exchange and DR management	IEM	Energy meas. CVPP/Load Other signals	<=5m <=5s	Normal Perturbed	medium

(*) Time transfer useful to provide efficient functions.

The mentioned high reliability required makes it necessary in most situations to design ICT networks with built-in redundancy similar to some proposals made for PSs such as the Parallel Redundancy Protocol (PRP) [10] as well as other measures such as local computation and distribute and replicated storage.

A further aspect is that smart devices may generate the so called GOOSE messages which are layer 2 messages that have to be treated as such. These GOOSE messages are defined for communication within the PS and normally they are the most stringent ones with respect to delay.

In INTEGRIS the novel idea is to allow layer 2 networking at electrical distribution level so as to make GOOSE messages possible at this level, thus treating it as a virtual substation from the communications point of view.

The five function classes defined in Table I have been supplemented with the definition of high, medium and low priority management classes necessary to manage the Smart Grid plus the typical classes of any data network (Critical and non-critical Management Traffic, File transfer, Best Effort, and Background).

Regarding communication capacities, the challenge is not so high since they do not seem to exceed 4Mbps accumulated over a given MV ring plus its LV feeders [8] [9].

B. INTEGRIS ICT Architecture

Fortunately there are many communications technologies available and partially applicable to the distribution smart grid problem. The problem is that neither of them is able to completely fulfill the requirements of the smart grid and, thus, a combination of them is needed to achieve full coverage of the electrical infrastructure with the required levels of redundancy.

INTEGRIS aims to provide the necessary redundancy by combining several communication technologies. Any technology is applicable under the condition that it offers an Ethernet interface on top of it as is common in most of them.

In INTEGRIS and for the purpose of the field trials, the selected technologies have been BB PLC because of its unique capability to reach the underground electrical infrastructure [7], and wireless in general as well as fiber optics links whenever they exist or could be deployed to provide means to improve BB PLC reliability by meshing it or to provide a second way to access the aerial parts of the infrastructure. In the project trials, and for implementation and development simplicity as well as operator independence and low cost, the wireless technology used is IEEE 802.11n (Wi-Fi). WiMax could have been another option but more expensive and requiring frequency licenses.

The networks formed by these technologies could span over distribution areas formed by a MV ring plus its LV feeders forming a new kind of access network that finally will be connected to Wide Area Networks such as is the Internet.

Figure 3 depicts the specific network that is targeted within the scope of the project. This network is connected to the Wide Area Network at least in one point but preferably in more points to reach the required reliability levels.

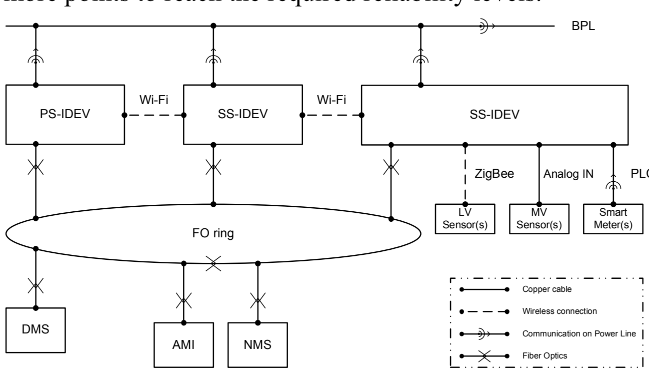

Fig. 3. ICT network envisaged by INTEGRIS.

Besides, provisioning the distribution grid with computing and storage capacities integrated with the communications facilities can be a way of improving the availability of the data and of reducing the latency of some functions.

The challenge is to combine the many ICT technologies in a flexible, transparent and efficient manner capable to fulfill the requirements of the distribution smart grid, thing which is still an unsolved challenge.

In INTEGRIS the different communications, computing and storage resources needed in the smart grid have been integrated in a single device called INTEGRIS Device, I-Dev for short.

All the I-Devs in the network are technologically similar but they may perform different electrical functions and for this reason there may be two types of I-Dev, PS I-Dev and SS I-Dev.

Any of the mentioned layer 2 communication technologies will be interfaced with the I-Dev which in turn will be responsible of creating a layer 2 network integrating all the mentioned technologies, but potentially also others, in a layer 2 network spanning a defined electrical distribution area thus allowing the direct application of IEC 61850 protocol over the defined area which could be thought as a virtual substation. For doing so the technology being used is the one defined in the TRILL [11] project that in INTEGRIS has been extended for the use in the Smart Grid.

Each I-Dev collects the data from its immediate surrounding devices. The data collected locally may use low capacity links such as IEEE 802.15.4. The links used to connect and mesh the system should be of broadband capacity (above 10Mbps).

For practical reasons, internally the I-Dev in INTEGRIS implementation is formed by several components which could be integrated in other ways while keeping the same functionality in other implementations.

Figure 4 is a representation of the SS I-Dev components. Basically the RTU collects local data from the substation which is polled by the RTU Data collector in the PC, the data from smart meters is gathered through the Meter Data Collector. The INTEGRIS Communication Functionalities inside the PC platform manages the communications with the rest of the system, the replication of data and the security aspects. In addition, the PC Platform may contain electrical functions as well.

To deal with the different function classes defined in section A, the necessary mappings with the communication classes of service or priorities defined in each layer 2 communications technology have been defined and developed and a Low Latency Queuing system has been designed to handle them in the best possible way.

From the cybersecurity point of view, the system leverages the most secure options of the layer 2 technologies being used (BB PLC, Wi-Fi,..). Over this, IP-sec [13] and certificates are used to authenticate the I-Devs. A combination of passwords for off-the-shelf devices plus certificates for the I-Devs is used. To secure the IEDs connected to the network IEC62351-6 [14] is mandatory. Nevertheless it has not been developed over the I-Dev because of lack of IEDs supporting this standard in the trials.

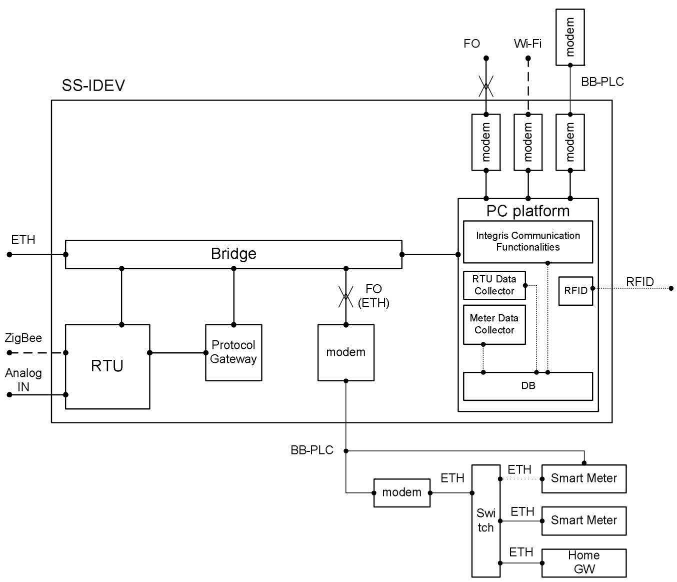

Fig. 4. Internal structure of the INTEGRIS SS I-Dev.

IV. LV Network Management

INTEGRIS project is going to demonstrate distribution network management system described in Chapter II based on ICT system described in Chapter III. This chapter describes the use cases going to be demonstrated. The following three use cases represent the overview of LV network management system where customer owned DERs are available for network management. It is also expected that distribution network might have occasional congestion problems due to consumption increment of heat pumps, air conditioning devices and EVs or due to production increment of DG e.g. photovoltaic cells. Congestion problems are not however allowed to cause inconvenience to end customers. From DSO’s viewpoint the network management should improve network management processes and end customer service quality.

A. MV/LV Network Monitoring

The basic idea of MV/LV integrated network monitoring use case is to push the limits of monitoring from the higher stack of the grid all the way through to MV and LV, up to end users and gather all these data where they are needed.At the present time, only HV/MV data from PSs are gathered and sent to the CC via the SCADA system. Tomorrow, when all the grid is monitored, moving all the data from the edge to the CC will be inefficient and even not really necessary. It will be more convenient to store and to process data locally, and moving to the CC only computed results such as alarms or aggregated information.

For this reason, integrated monitoring use case defines a local repository in each node substation. At PS level, MV busbars and lines are monitored. At SS level, measurement related to MV/LV busbars and LV lines are collected and merged with data from smart meters and HEMs.

According to a DSO point of view, having a more accurate understanding the electrical state of the grid allow to reduce both the number and the average length of failures, pinpoint investments where are really needed as opposed to spreading capital and operating costs evenly.

More in details, measurement values from SS RTU are phase voltages, transformer MV and LV side phase currents, and LV feeder phase currents, zero current, active and reactive power, and energy. Smart meters measure phase voltages and currents, active and reactive power, and energy. It also sends fault indication information (no outage, outage in phase L1, L2 or L3, broken zero conductor, wrong phase order). HEMs provide phase currents of DERs. Power quality values like total harmonic distortion are available at RTU and also at HEM if customer connection point PQ monitoring units are available. PQ monitoring unit measure voltage level, rapid voltage changes, harmonics, etc., sends these values every 10 minutes to I-Dev via HEM and smart meter. PQ quantities are 10 minutes mean RMS values, number of events, etc. defined according to EN 50160.

RTU, smart meters and HEMs collect real-time measurements and calculate average values from measurement data. HEM provides its data to smart meter which aggregates its own values and values from HEM to same DLMS message. Meter data collector in I-Dev reads aggregated values from all smart meters. Similarly there is a RTU data collector to receive data from RTU to I-Dev. Both collectors store received data to SQL database. RTU and smart meter data are requested via protocol gateway to translate it into IEC 61850. In that way I-Dev has only IEC 61850 interface.

Measurement values from RTU are received every 10 seconds and values from smart meters every minute. All measurement values include timestamp which are synchronized using SNTP. GPS based master clock at PS is used to distribute the clock to all I-Devs which will further distribute the clock to measurement devices. If measurements indicate a severe disturbance, an alarm to SCADA/DMS will be sent immediately. Otherwise the MV/LV network monitoring application in I-Dev reviews measurements every day, compares data to certain threshold levels, and creates a report of each monitored measurement value. Reports based on continuous measurements from different parts of the system are used to inform system planner both the MV and the LV network investment needs. Similarly, real-time information read from I-Dev database may be utilized to improve customer service in CC. Customer complaints e.g. about PQ problems may be checked and given immediate feedback. Real-time data in I-Dev’s database is also utilized in LV network congestion management and LV network fault management.

B. LV Network Congestion Management

The purpose of this function is to manage power flows and voltage level in LV network by controlling DERs by means of smart meters and HEMs.

The state estimation of radial networks estimates currents and voltages in all phases and all parts of LV network based on static network data and the latest real-time measurements in database [15]. The accuracy and reliability of state variables may be improved by state estimation, when the observability of LV network is not high enough (too few measurements from the same time interval) or measurements include high uncertainty or bad measurements.

The CC has the complete model of the distribution network up to the single final LV customer in the network information system. Network data (network topology, feeder and transformer electrical data and location of customers) are sent (replicated) from CC to I-Dev. Only the LV network and SS data are required in details for the LV network congestion management, rest of the system may be modeled as an equivalent system.

The calculation results of state estimation are compared to operational limits of SS and LV network. If some thresholds are exceeded then the location of the problem is find out, the location of controllable resources capable to solve the problem are looked for and finally the operational commands (e.g. to reduce power flow) are send to selected HEMs. Load-flow algorithm is used to check the validity of control decisions from electrical engineering viewpoint. The control commands are sent by meter data collector via protocol gateway and smart meter to HEM. The control command includes following information:

- what kind of control is expected (reduce or increase demand / production)
- when control may be released or will the system also send the release command
- how much control is needed (total control need is shared among the available and suitable control resources)
- where the control should be realized (identification of correct control resources).

The location, availability, resource size, etc. information of DERs is managed by HEM system. HEM aggregates the DER information and send this to I-Dev utilizing smart meter communication. Overall decision where and how much control is needed is done in I-Dev. However, the final decision how the control need of single HEM is shared to individual DERs is made by HEM because customer may want to prioritize the utilization of resources and the most recent information about DER availability and controllability is at HEM. The prioritization of DERs might also depends on external factors like outside temperature or predefined conditional situations like EV charging or the presence of high-consumption home appliances such as electrical sauna.

C. LV Network Fault Management

The LV network fault management represents how the real-time information about LV network faults and dangerous circumstances can be provided to the CC operator in order to reduce LV network outage time, to reduce the number of customer trouble calls and to improve safety of LV network operation.

When a smart meter detects a fault it sends an alarm to I-Dev which may identify the faulted area of LV network. The fault area is detected by locating alarming smart meters on network and assuming fault located prior to them. If it is necessary, I-Dev may send verification query to smart meters to be sure about connection point status. This information with LV network topology is used to detect fault locations. If there is only one smart meter not-reachable then the problem is probably connected to the single user. When there are many not-reachable smart meters on same LV feeder then the problem is on that feeder. If there are many not-reachable smart meter connected on different LV feeders of the same SS then the problem is on the SS transformer or on the MV network.

Only single and two phase LV network faults may be detected locally at three phase smart meter. If all three phases are missing, then smart meter polling from I-Dev is needed to ensure if the fault is on MV or LV side. If the fault is on LV network, then a message to SCADA/DMS is send about faulted area.

The overall concept requires that fault detection applications are running at all customer connection points and communication to smart meter is available also during the fault situation which might not be the case with BB PLC. If the communication during a fault is not working, then requests from I-Dev to smart meters are used to detect faulted area.

Smart meter may also detect dangerous events like broken zero conductor, wrong phase order, and over and under voltages based on measurements in customer connection point. In that case smart meter will isolate the customer by sending a control command to mains switch and it will also send an alarm to I-Dev and finally to SCADA/DMS.

If DG units are equipped with remotely controllable mains switch, it is possible to disconnect DG units remotely by DSO before starting network maintenance work or utilize the disconnection possibility as a backup for loss-of-mains protection. If isolated LV network, e.g. due to blown LV feeder fuse, has a perfect balance between power production and consumption, the operation of loss-of-mains protection might be prevented. Then I-Dev should detect the faulted area and disconnect all DG units on it.

V. Discussion and Future Work

A. ICT requirements

The use cases defined in section IV belong to two classes of the ones defined in the Table I. These classes are MON and CMD and both share the following same ICT requirements:

- Reliability: High
- Delay: less than 2 seconds

The required high reliability level, which corresponds to a figure of 99,99%, normally needs the provision of redundant paths among the devices involved: From the Smart Meter/HEM to the I-Dev and from the I-Dev to the CC. In the former case, if the devices are side by side, one path may suffice. In the INTEGRIS trial redundant paths are provided over the MV systems by the BB PLC system itself and also by supplementing it by the use of WLAN bridges between selected I-Devs. The redundant paths to the CC are obtained by having at least two connections to the WAN network at both sides: the CC and the PLC MV system.

Regarding the required delay of 2s, the bandwidth requirement implied by the amount of data to be transmitted in this time frame depends on the Use Case.

In the case of Use Case IV.A, there is a considerable amount of data to be transferred from Smart Meters and HEMs to the I-Dev that depends on the number of devices being monitored. Our estimation ranges from 50kbps to 500kbps of transfer rate. This is the reason why INTEGRIS does not use these technologies for this purpose. Between the I-Dev and CC, the data to be transmitted will be less because of the aggregation of data mentioned in chapter IV and, thus, no delay problems are expected provided that the system uses broadband transmission technologies as INTEGRIS does.

For Use Case IV.B the critical data to be transmitted are commands which are transmitted locally, downstream of the I-Dev. The expected capacity for this is low and is even compatible with the use of narrowband systems downstream of the I-Dev. The transmission of electrical and topological data from the CC to the I-Dev should not have any special delay requirements and can be easily handled by the INTEGRIS broadband ICT infrastructure.

Finally, Use Case IV.C is not bandwidth intensive since downstream of the I-Dev basically transfers alarms and commands. The only point here is the dialog between the I-Dev and CC explained in chapter IV.C. This dialog is not very data intensive but needs to have its delay guaranteed. This is done in INTEGRIS by a high priority treatment and a correct mapping among communication layers.

To sum up, although all the use cases share the same delay requirement, the bandwidth required by each use case is different. For these reason the ICT network should accommodate the different needs by using a prioritization scheme with adequate mapping among the communication technologies.

B. Functional requirements

MV/LV network monitoring requires accurate synchronization and frequent updating of measurements in order to provide useful information to disturbance management. However the most important application of data is asset management which is slow in nature. Accurate synchronization and frequent updating is not required because the condition of electrical components changes slowly, extensive measurements provide enough information for analysis and the most uncertain part is the relation between electrical measurements and remaining lifetime of components.

The synchronization and updating burden has been relaxed by setting different requirements for MV and LV side. If the use of SNTP is not enough the precision time protocol defined in IEEE 1588 might be used to achieve sub-microsecond range in local area network. However the utilization of precision time protocol would require major changes in devices like RTU, smart meters and HEM. More frequent updating of measurements would require additional RTUs etc. or compromises with measurement values to reduce the number of measured values.

LV network congestion management application is very straightforward at the moment. Application itself might be further developed by considering the uncertainty of DER availability. Also the ICT issues like application dependency on reliable communication should be considered carefully. However this dependency has been already minimized remarkably by applying decentralized concept for distribution network automation.

The state estimation at I-Dev is a valuable tool when some measurements are e.g. missing and there is need to define if further control actions are needed to release LV network congestion. If congestion occurs at SS, RTU measurements give enough information to find out if control commands were effective enough. When congestion occurs on LV feeder additional measurements from smart meters are required to improve state estimation accuracy. However this does not require existence of measurement data from all possible smart meters.

VI. Conclusions

The preliminary results of real-time LV network management developed in the INTEGRIS project have been presented in the paper. Three LV network management use cases called MV/LV network monitoring, LV network congestion management and LV network fault management are defined and analyzed from ICT and electrical engineering viewpoints. According to a DSO point of view, having a more accurate understanding the electrical state of the grid allow to reduce both the number and the average length of failures, pinpoint investments where are really needed as opposed to spreading capital and operating costs evenly.

These use cases are defined for future smart grid environment where advanced communication technology and DER are utilized in decentralized distribution network automation. For this purpose a new ICT architecture for decentralized LV network management as a part of distribution network automation system has been proposed. Heterogeneous communication system of BB PLC, Wireless, Fiber Optics and wireless sensor networks has also been defined and it will be tested in the future with above mentioned use cases. The defined communication system makes possible layer 2 communication over defined electrical distribution areas allowing the use of IEC 61850 protocols over these areas. The information security of proposed system is guaranteed by the application of off-the-self security protocols in the context of smart grid. A combination of certificates and passwords is used to allow newly defined I-Devs to coexist with off-the-shelf communication devices.

The aim of INTEGRIS project is not only to define use cases, ICT architecture and communication system of smart distribution network, but also to demonstrate these in real-life networks. The results of these demonstrations will be published in the future.

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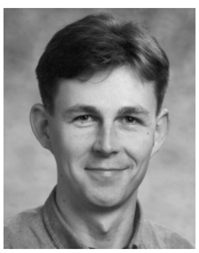
VIII. BIOGRAPHIES



Sami Repo received his M.Sc. and Dr.Tech. degrees in electrical engineering from Tampere University of Technology, Finland, in 1996 and 2001 respectively.

At present he is an associate professor at the Department of Electrical Energy Engineering of Tampere University of Technology. His main interest is the management of active distribution network including distributed energy resources.

Davide Della Giustina (M'07) received his M.S. and Ph.D. in Physics from Università degli Studi di Milano, Italy, in 2007 and 2010 respectively.

He is currently working as system manager for A2A Reti Elettriche SpA, an Italian DSO. His main interests are on the upgrade of the distribution grid and its management. Dr. Della Giustina is a member of AEIT (Italian Association of Electrical Engineer).

Guillermo Ravera M.S degree in Telecommunications Engineering (La Salle-University Ramon Llull, 2008). Currently team leader at the Computer Science Department of La Salle-University Ramon Llull. The carried out projects are related with the migration of power utilities data networks to an IP technology based network, the design and simulation of PLC MAC layer protocols and multipath routing algorithms suitable for Smart Grid communications.

Stefano Zanini received his M.S. in Physics from Università degli Studi di Milano, Italy, in 1980.

He is currently working as consultant in strategy, technology and process innovation and organizational change, with a predominant focus in the energy and telecommunication industries.

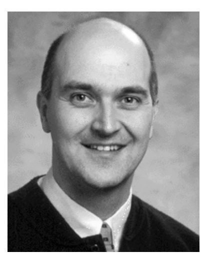
His key focus is on the Smart Grids technology driven changes and process optimization.

Lucio Cremaschini joined A2A in 1989 and has had many assignments – both operational and staff; including a one year assignment to ENDESA in 2005.

Since 2007 he is responsible for the real time network management of the EE distribution network of A2A Reti Elettriche SpA (Brescia area).

He is in charge and supervising many research and pilot projects related to the Smart Grids.

Josep M. Selga received the M.Sc. from the Polytechnic University of Madrid in 1971 and the Ph.D. degree in telecommunications engineering from the Polytechnic University of Catalonia in 1985. He is associate professor at the Computer Science Department of La Salle-University Ramon Llull. He has been manager of telecommunications and control systems of the power utilities ENHER and ENDESA and published some 80 international publications. He has been IEEE member for over 30 years. His main research interests are cybersecurity and computer networking for power utilities control systems.



Pertti Järventausta received his M.Sc. and Licentiate of Technology degrees in electrical engineering from Tampere University of Technology in 1990 and 1992 respectively. He received the Dr.Tech. degree in electrical engineering from Lappeenranta University of Technology in 1995.

At present he is a Professor at the Department of Electrical Energy Engineering of Tampere University of Technology. The main interest focuses on the electricity distribution and electricity market.