System for Remote Meter Reading and Load Management in Electric Utility of Belgrade

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Abstract—In this paper are presented the basic concepts and definitions of the remote meter reading and load management (AMR) in the distribution of electrical energy. AMR system equipment in EPS Distribution (branch Belgrade) - Electric Utility of Belgrade (former EDB), Serbia, and the functioning of this system, are shown through practical examples. Special emphasis was placed on integration of AMR devices in the existing system with the main aim of ensuring interoperability. Implemented solutions of advanced metering infrastructure (AMI) and systems management (AMM) for remote consumption reading, which operates in the EPS Distribution system, were perceived through the development of practical modules. Integration of consumption data management function (MDM) from AMR system and EPS Distribution business information system, was carried out in order to fully automate the process. Possibility of extending the system using new Smart Grids technologies, collecting and processing measurement data of all the energy consumption parameters in buildings in order to achieve greater energy efficiency. Practical examples of using AMI for recognition and sustainable optimal reduction of technical losses and elimination of non-technical losses in electricity transmission and distribution grids were shown.

Index Terms—system for remote meter reading, Smart metering, Smart grids, meter devices interoperability, elimination of non-technical losses

I. INTRODUCTION

System for remote meter reading and load management, electricity meter reading - Automated Meter Reading (AMR), processing and storage of data (Smart Metering) includes advanced metering infrastructure - Advanced Metering Infrastructure (AMI), remote meter management - Automated Meter Management (AMM) and collected data management and storage - Meter data Management (MDM). AMI includes a system whereby the data stored in the meter remotely collected through the hub and transmitted to the control computer in the AMM Center, and on to the centralized MDM system, and connection can be realized in direct communication with meters equipped with appropriate communication modules [1]-[7].

All these systems are part of the concept for advanced energy networks (Smart Grids), which includes the collection and processing of measurement data for all the parameters of energy consumption in buildings. The meter in the AMR system has electrical interface (M-Bus) for connecting other measuring devices that can be placed at the customer's site. In the general case there can be used water meter, gas meter and heat meter in connection with electricity meter, which has a memory registers for storage of data for each of these criteria. Electricity meter can be connected to home display, which is used to forward customer information from the system.

The overall objective of introducing a system for remote meter reading and load management is to improve energy efficiency and encouraging the rational use of energy in line with the European target "20/20/20", i.e. 20% more renewable sources, 20% less CO2 emissions and 20% increase in energy efficiency in the EU by 2020, as part of Smart Grids platform.

Data from AMR system (failure frequencies and durations) can be used, in combination with other methods, for evaluation of the consequences of supply interruptions for different type of customers [8], [9].

II. METHODS – AMR SYSTEM IN ELECTRIC UTILITY OF BELGRADE

The basic task of company Public Enterprise "Electric Power Industry of Serbia"- EPS is meeting all the electric power requirements of the economy and inhabitants of the Republic of Serbia. EPS activities are electric power generation, electric power distribution and distribution system management, electric power trade, coal production, processing and transport, steam and hot water production in combined heating processes, water power utilization and services in river and lake traffic, wholesale

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trade in fuel and similar products. EPS operations are also research and development, design, construction and maintenance of energy and mining plants, design, construction and operation of telecommunication facilities and engineering [10].

The activity of electric energy distribution was performed in five subsidiaries until 1.7.2015. (one of them was EDB) when, according to reorganization of EPS, established unique company Operator of Distribution System "EPS Distribution" Belgrade. In this organization former subsidiaries become branches, and Electric utility of Belgrade (in text EDB) become branch Belgrade.

Electric utility of Belgrade provides continuous and quality supply of electricity to consumers in the consumer area of 2838 km2 and covers 17 urban municipalities, with a population of 1,700,000 inhabitants. In the end 2012, EDB supplies electric energy to 833,400 consumers, of which about 808,000 consumers are in the category of "household". Table I. shows annually delivered energy and active power peak on consumption area of EDB [11].

ANNUALLY DELIVERED ENERGY AND ACTIVE POWER PEAK ON CONSUMPTION AREA OF EDB

	2008.	2009.	2010.	2011.	2012.
W [GWh]	7775	7961	8147	8172	8099
P [MW]	1628,2	1640,9	1667,7	1608,3	1680,6

In last few years EDB have constant growth trend of energy consumption, and as solution for the projecting and planning problems uses new AMR technologies and custom designed engineering tools.

System for remote meter reading and load management in EDB works since 2008. Currently in the system operate AMR equipment as data concentrators in substations TS 10/0,4 kV, electric meters, control meter cabinets, video cameras...

Fig. 1 shows the geographical location and organization of EDB with 3 urban and 6 suburban operational units. Part of consumers in all of these units are connected in unite AMR system.



Figure 1. Electric utility of belgrade - location and organization

Basic functions of the AMR system are remote meters reading and hourly data collecting, remote power management (on/off switch meters, limiting power, tariff, etc.), relocated the measurement (control meter cabinets), power measurement in substations and video surveillance as part of system.



Figure 2. AMR system in EDB

Fig. 2. shows the concept and operation of AMM system in EDB, and the most important feature of the system is the ability to integrate electricity meters from different manufacturers in a single system, i.e. system interoperability (Sagem, Atlas, City, Meter & Control, ... EWG).

Operation of the meters in the system:

- Remote data reading from the meter consumption, current load, fifteen minute power, monthly consumption, status etc.
- Remote power management (on/off switch meters, limiting power, tariff, etc.)
- Measurement of the substation (semi-direct meter on/off switch for semi-direct meter.

III. POWER MANAGEMENT

An important function of the system is a remote power management over the switch off/on meters. Special gain this kind of power management is a preventive action because consumers know that they can be switch off a quick and easy way, and in regions of the substation covered by the system for remote monitoring and management now shortly after they get reminders for lateness in paying, consumers pay their obligations.

As an example can serve the organized consumers switch off in Grocka, in two substation area TS G-92 and TS G-37. In the period from 28.5.2012. to 31.5.2012. was made of all 19 orders for the switch off on these two TS. In this period, all consumers have paid off the debt (total 867.986 RSD) and all switched on again by the system for remote monitoring and control.

By switching off unconscientiously consumers this system proved to be efficient payment methods and preventive action. There were significant effects in the presentation of the technical capabilities of our company and the practical implementation of new technology, which sets us the leading position in the region on the field of remote meter reading and management [12].

In addition to reading of semi-direct meter groups, procedure has been developed for remote on/off switch from the system, which provides power management for larger consumers.

Another important function of AMM system is the ability to remotely entry limiting value in the meter register for limit the power that the consumer can simultaneously withdraw from the distribution network. In this way, the meter function as power limiter. If load on the meter exceeds a limited value (which is adjusted according to the contract), consumer will be switch off automatically. In this way system protect the distribution network, measuring devices and substations TS 10/0.4 kV. Custom designed software made on demand and experience of EDB engineers for meter power limitation is on beta testing.

IV. RESULTS AND DISCUSSION RELATED TO PRACTICAL IMPLEMENTATION OF AMI AND MDM YYSTEMS

As practical implementation of AMI system, with unique technical solutions developed in EDB, we use GPRS control meter cabinets with following functions:

- Constantly remote meter data reading (consumption, current load, switch off/on, meter power management etc.)
- Quick installation and mobility of relocated measurement and remote shutdown in case of inaccessible measurement point (non-allowed by customer)
- Easy way for collecting of evidence of unauthorized connection and consumption
- Integrated video surveillance.

Integration of AMM systems functions and existing business information systems is complex task because they exchange lots of data for every consumer, and that must be solved on many layers, events and security check. For the purpose of integration of system functions for remote meter reading and load management into existing business information systems EPS Distribution, interfaces and procedures are developed, and the goal is complete automation of these processes.

Example is interface for data acquisition of meter readings from AMM system in business information systems. It is designed in a way that does not disturb the existing reading plans for meters (meters data used for billing not always on the first of the month, and meters are grouped by area), and its application is not necessary for the conventional method of data entry (field reading).

The main advantage of this method is the integration of a large number of possibilities for using data from AMM system, creating custom interfaces and procedures. Advanced analysis can be made using data from AMR system. The basic function of remote meter reading and power management is carried out remote reading of consumption, a data periodically (hourly, daily, monthly) are stored in the database. Within the base millions of data collected of hourly load of consumers. These data are of great importance in the analysis of consumption and losses on the low voltage network.

Each substation in AMR system are equipped with semi-indirect measurement group that the system use to control consumption within the entire substation area. In this way, the calculation of losses and peak load in the area of the substation can be made [13].



Figure 3. Calculation - Substation energy balance in AMR system

Based on collected data, AMR system automatically generate energy balance calculations for substation shown in Fig. 3.

Examples of substations energy balance, before and after using AMI for recognition and sustainable optimal reduction of technical losses [14] and elimination of non-technical losses in electricity transmission and distribution grids, are shown in Table II. As data presents, in substations B-474 and B-685 (urban area, non-electric space heating, good cable network with short distances between substations and customers) losses are low and exclusively technical.

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Substation	Month	Number of customers	Controlling meter group (MG) in TS (kWh)	Sum of all meter consumption (kWh)	Difference (kWh)	Difference (%)	Cos φ
B-474	10.2014.	194	67396,200	64263,847	3132,353	4,65	0,975
	10.2015.	194	67274,200	64887,593	2386,607	3,55	0,975
B-685	11.2014.	137	36737,600	34652,769	2084,831	5,67	0,945
	11.2015.	137	36231,400	34382,919	1848,481	5,10	0,949
Z-1408	11.2014.	127	210961,800	126145,884	84815,916	40,20	0,984
	11.2015.	127	213645,000	172678,450	40966,550	19,18	0,985
Z-1073 -	11.2014.	223	92763,200	82754,319	10008,881	10,79	0,983
	11.2015.	224	92846,600	89535,070	3311,530	3,57	0,985

TABLE II. EXAMPLES OF SUBSTATIONS ENERGY BALANCE BEFORE AND AFTER LOSSES REDUCTION

In substation Z-1073, the losses presented by AMR system was very high, and suggested to non-technical losses. By checking on the field we find out that public lighting supply from this substation without metering (billing by installed power). When AMR meter for public lighting is installed, AMR system shows real (technical) losses.

Substation Z-1408 (rural area, electric space heating, old electric network with long distances between substation and customers) is good example of using remote meter reading and power management to reduce non-technical losses. When AMR system recognize significant losses in this area, by use of network analyzers and smart meters, many cases of unauthorized connection and electricity consumption are discovered. In further action, by use of GPRS control meter cabinets, as a part of remote meter reading and load management system, all unauthorized connections are determined and disconnected. In some cases GPRS control meter cabinets with integrated video surveillance are used. Report and video material evidence was submitted in the framework of initiating criminal charges. Non-technical losses are permanently reduced with relocated measurement places and constantly area control with GPRS control meter cabinets and AMR network analyzers, as parts of AMR system.

V. CONTEXT OF AMI/MDM SYSTEM IN ELECTRIC UTILITY OF BELGRADE

Context of AMI/MDM system in EDB from the aspect of directly affected business functions of electric utilities reflects several logic/abstract components (potentially realized as information subsystems), as follows:

- Load analysis Load management system is used for load management control for the purpose of improving electricity distribution system operation reliability, with the execution of different analyses. The most frequently used analyses are as follows: load forecast, security analysis, simulation of various scenarios of load management command issuing, as well as other energy calculations.
- Load management Consumption reading system is frequently used as the communication gateway for the needs of load management in case of individual devices of customers, supplied through special installations. Advanced meters, equipped by switches, enable remote connection/disconnection of customers as well as the power limiter function. Load management may be implemented from emergency reasons or economic reasons.
- Outage management system (OMS) OMS is used by the distribution system operator for the purpose of detecting and monitoring of outages within the electric distribution network, as well as outage verification and/or supply restoration. OMS is a very complex system considering that it is functionally connected with different domains and their business sub-functions. The most important of all domains and business sub-functions are:

fault management under the network management, simulation of management actions within operational planning and optimization, work management and supervision under maintenance and construction.

- *Electric distribution network control* Electric distribution network control system has the need to control the load of system elements, but also to generate the change of electricity price signals in different tariff packages.
- *Network planning* Business function of network planning requires recorded data on consumption, transformer and line load, as well as on past electric distribution network status, for the purpose of execution of various planning optimizations and simulations.
- *Customer information system (CIS)* Customer information system covers the functionalities related to customers and collection. In addition to this, basic functionalities are related to information offering through electric utility information centre, as well as for receiving fault complaints from customers. Customer information system deals with the processes related to accounting complaints, customer disconnection due to non-payment, reconnection after the settlement of financial liabilities and change of tariff packages.
- Point of delivery maintenance Every electric utility possesses an information subsystem for asset management, aimed at maintaining detailed records concerning its tangible assets. Property management is included within the domain of asset management. However, for the needs of point of delivery and meter records, having special requirements, all electric utilities use specialized software modules for asset management of points delivery. Software module for asset of management of points of delivery provides records of physical attributes, as well as data on location and installation of equipment.
- *Work management* Business function dealing with work management is responsible for activities performed within electric distribution network from resources possessed by the electric utility. Compared to activities related to metering, work management includes installation, dismantling and replacement of advanced meters, as well as execution of special readings on request.
- *Education and development* On course Electrical installations and lighting in Study program New Energy Technologies of the School of Electrical Engineering and Computer Science of Applied Studies in Belgrade [15], students learns about smart grids technologies from practical experience of electric utility companies. Presenting practical application of the "Smart Grids" technology with focus on its importance, development, and application in the world, students actively participate in projects for the development of the system. Through education of experience

engineers we provide the conditions for the implementation of many new Smart Grids projects (Smart home, Smart city, energy efficiency in electrical engineering ...)

VI. AMI SYSTEM IN EDB – FUTURE DEVELOPMENT

System for remote meter reading and load management in EDB is installed, planned, and its improvement is made to meet the following requirements:

- Acceptance of a large number of new meters in the system
- Automation of the collection and processing of data from the system
- Process automation for control a large number of orders from system
- Defined procedure for integration in Business Information System
- Connecting in AMR system other measuring devices (calorimeter, water and gas meters, home displays,..) that can be found in electricity consumer use
- Design and manufacturing solutions for the use of AMM system in order to increase energy efficiency
- Availability of AMM system when connecting Distributed Generation (DG), primarily cogeneration sources and solar power plants of different electric power, on the electric power distribution network
- The application of the latest Smart Grids technologies.

VII. CONCLUSION

During the development of the AMR/MDM system in EDB many original solutions and inventions were found and used, which provides reliable operation. In future developing a system for remote meter reading and load management in EDB, based on the demands that are placed in front of the system, expansion of the system will be implemented using the new technology in the field of Smart Grids. The entire system will be conceived that, in order to achieve greater energy efficiency, collects and processes the measurement data of all the parameters of consumption and production of energy in buildings. This will create a solid foundation for the realization of many energy efficiency projects.

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