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Centralized Information-Measuring System of Intelligent Accounting for Electric Network of Middle Voltage

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Abstract: An expanding electricity market sets new requirements for the system of accounting, the control and the management of the electric power system. A key platform increasing the efficiency of interaction between a consumer, grid and energy sale companies is the Intelligent Accounting Infrastructure (IAI) which provides a comprehensive information and technology solution in an open electricity market. The disadvantages slowing the implementation of IAI-systems are the complexity of adjustment and a high cost of Information Collection and Transfer System Deploy (ICTSD) as well as the high cost of individual equipment. The result of modern solution and technology analysis is a centralized information and measurement system offer for commercial/technical electricity metering (CSA) based on passive optical network technology. The developed CSA can be used during the development of new systems for commercial and technical metering of electricity which will significantly reduce the cost of deployment, simplify the commissioning process and will improve the quality and the quantity of collected data.

Key words: AMI, AMR, SOA, SGAM, SMART-metering, operating modes, passive optical networks, smart-grid, data collection system, multi-agent control systems

INTRODUCTION

Now a days a lot of attention is paid to the development of Intelligent Accounting Infrastructure (IAI) in electric networks. Network companies industrial and household consumers are interested in reliability increase, the solution of various control and monitoring tasks (automatic measurements, consumption monitoring, the monitoring of power supply parameters, billing, planning, etc.) as well as in specific task solution concerning a particular consumer.

At present, the number of smart devices that perform Automatic Measurements (AM) is growing rapidly and their functional capabilities are also expanding, up to the implementation of a targeted regulation of the electric power consumption mode for energy saving purposes, the evaluation of power quality indicators, the detection of theft and loss areas. The indicated tendencies are connected first of all with the transition from state regulation to the open market of electric power and other municipal resources, the reduction of centralized investments in regional power engineering which is the result of privatization, encourages energy sales companies and consumers to pay great attention to energy saving and increase the manageability of energy consumption.

IAI tasks include mainly information functions: control and calculation of power supply technological parameters information exchange with adjacent and higher management systems. An open problem is the management of finances: the solution of technological calculation problems, not directly related to the issues of commercial and technical metering of electricity. This problem is solved by the integration with the software package the Production Process Control System (PPCS) (Govindaraju and Putra, 2016).

The main tasks of PPCS are the optimization of time and labor costs to collect information about measurement results by the organization of remote data collection from objects and by the subsequent centralized processing of this information including comprehensive control of the consumption process, the creation and the processing of requests for technical personnel, the performance of service functions (the printing of forms, document management, the assessment of electricity use efficiency, the optimization of consumption modes for active and reactive power, etc.).

The most perspective trends of combining the organization of an enterprise activity and the interaction with a consumer are the Service-Oriented Architecture (SOA) which opens the possibility of

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previously incompatible module and system integration that require a separate platform for work (IMIS, 2017). The practical aspects of SOA allow to solve scalability problems for example, providing the possibility of monitoring and load monitoring system interaction with equipment state monitoring systems, to simplify the design and management procedures for networks and create other applications that interact transparently with the system resources using application software interfaces and open standards through API.

The main problem of AMR/AMI system implementation is the high price of telecommunications equipment (USPD, switches, communication controllers, gateways) and if a system with a wide functionality is required (for example, SMART-metering) there is the increase in the requirements for IIC, leading to the increase in the costs of counters that have an extended functionality in 4-5 times (Rettie *et al*., 2016) which ultimately affects the payback period of the information system as a whole. Also, the payback period is influenced by the amount of work performed for commissioning and design and survey works, often amounting to about 40% from the cost of a project. An important aspect in the creation of new and in the upgrade of existing AMR/AMI is their openness and flexibility in the event of new requirements and standards appearance-one such standard is IEC 61850 which sets new requirements for equipment, communication protocols (Industrial Ethernet), the volumes of data collected (up to 256 points per period) and the compatibility of equipment from different manufacturers (Konka *et al*., 2011). Unfortunately, modern AMR/AMI systems have not only a complex hierarchical structure that requires high costs for equipment installation and design and survey work but also a low level of integration with the equipment from different manufacturers, a low flexibility and the openness to new standards and requirements introduction.

MATERIALS AND METHODS

The architecture of a centralized automated metering system for electricity metering: A centralized automated measuring system for commercial/technical metering of electricity (CMS) based on passive optical networks is proposed as the analysis result of current trends, solutions and technologies.

The main difference between the proposed CMS and the traditional ones is the centralized processing of the main parameter indicators of an electric network on a central computer using specialized software and the data is collected from an unlimited number of sections of three-phase connections with a sampling frequency and a resolution sufficient for a detailed analysis of power quality parameters; According to the requirements of IEC 61850 standard, this value makes 256 samples per period. An important part of the proposed CMS is the Information Collection and Transfer System (ICTS) based on a Passive Optical Network (xPON). This segment significantly reduces the cost of communication channels and their construction length (about three times) for an active communication equipment while being able to synchronize the measurements with the accuracy of up to 125 mcs sufficient to register electricity (80 samples per period). Figure 2 shows the principal CMS diagram.

Taking into account that the Smart Grid Architecture Model (SGAM) is used in the development of new systems within the SmartGrid concept, proposed CMS scheme greatly simplifies the integration of new modular solutions into the information structure of the SGAM component layer (OpenGrid, 2017) due to the lack of the created system binding to a specific hardware solution. In other words, based on the digitized values of voltage and current in the nodes of an electrical network, an information buffer with an optimal volume is created in the server database from which various samples of current and voltage values are extracted using various APIs and the required parameters (active, reactive power, energy, quality parameters, etc.) are calculated (Fig. 1).

CMS principal diagram: The principal diagram of the proposed CMS consists of three main segments (Fig. 2).

Data acquisition segment that represented by input units connected to current transformers and a voltage transformer in a switchgear, an ADC unit that converts analog signals into discrete ones at the frequency of 16000 Hz (256 samples per period), a controller that sequentially compresses the serial data

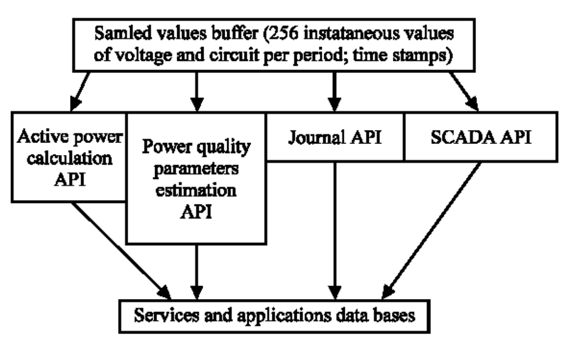

Fig. 1: Information model of CMS

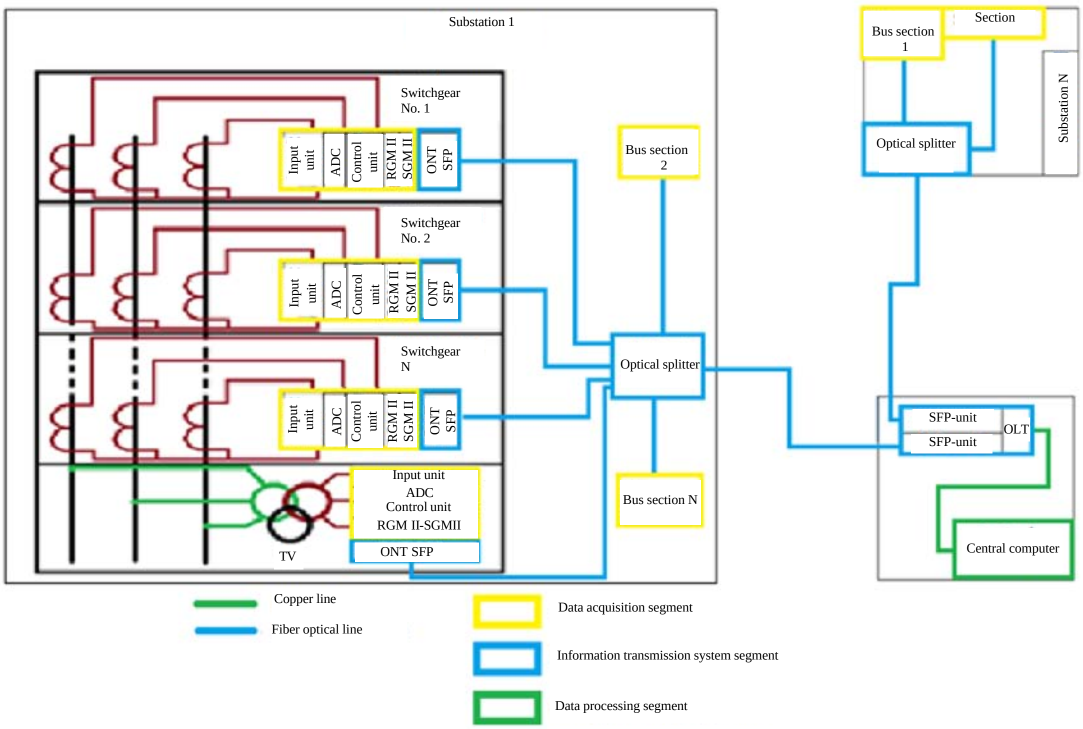

Fig. 2: Principal CMS diagram

stream of discrete current and voltage values from the ADC and the associated media converter RGMII-SGMII which converts ethernet frames to send them over an xPON network; A segment of an information transmission system that is a system of optical splitters interconnected by an optical fiber that combines synchronized light streams from information acquisition units into one OLT SFP module that receives xPON frames and converts them to Ethernet frames and an Ethernet-commutator which has connectors with SFP-modules support.

A data processing segment which is a computer server with a hardware platform that processes the received data in real time according to predetermined algorithms.

The main features of the proposed system are cost, scalability, the possibility of simple integration at an enterprise, modularity as well as the ability to combine remote objects (up to 20 km) within the same network.

As compared to traditional solutions based on decentralized collection and local processing of data, the price of a proposed solution implementation is comparatively less. This effect is achieved by the transfer of costly multiple computing units to one central one. At the same time, it is also possible to access data locally on a server through the microcontroller communication interface with the implementation of two-way communication over a local network.

RESULTS AND DISCUSSION

CMS comparison with the available solutions: The flexibility and the openness of a proposed solution can also be assessed by direct parallels with the stack-oriented IEC 62056 protocol (DLMS-COSEM). The concept of this protocol assumes the creation of a single environment for structural modeling and the data exchange with metering devices which allow to determine the interface model that is valid for any type of energy resource (electricity, gas, water, heat, etc.). Each interface object has a standardized unique identifier that identifies data. This model is completely independent of those protocol layers that transport data. Thus, the system based on DLMS/COSEM protocol is open for expansion by the addition of new interface classes and versions without the change of the services which provide the access to interface objects, thus preserving functional compatibility.

The information model of the CMS provides a similar effect by offering an open, service-oriented functional compatibility model through API. At the same time, it is possible to combine the features of other systems known at the present time, allowing realize the idea of a universal software and hardware platform fully in a rapidly developing competitive electric power market open to innovation and to simplify the modernization of a power grid.

The scalability of this system is achieved by using Ethernet network equipment for data transmission over an xPON network which are open communication systems. Easy integration is achieved by using widely available, compatible equipment from different manufacturers and the possibility of partial use of existing object equipment (computers, switches).

The unification of objects that are remote to each other is achieved through the use of Passive Optical Network technology (xPON). The use of xPON technologies also reduces the cost of infrastructure significantly, due to the use of optical splitters in the nodes of a network instead of active communication equipment. Also, a big advantage of this technology is the high data transfer rate (up to 2.5 GBytes), a wide guaranteed bandwidth, a high-precision of self-synchronization within 125 is and noise immunity of communication channels (ITU., 2017).

The use of an open hardware platform allows to expand the functionality of the system by connecting additional information acquisition units for example, electrical and process parameters sensors, alarms, etc.

At present, the works are performed to implement and develop solutions that involve the partial transfer of hardware and software functions to one device in particular those that register electricity. An example is a multi-feeder electricity meter (Anonymous, 2017; Safin *et al*., 2015, 2016; Kopylov *et al*., 2015; Reshetnikov *et al*., 2015; Burganov *et al*., 2016; Savelyev *et al*., 2016; Kutuzov *et al*., 2000, 2011; Bogdanova *et al*., 2002; Batanova *et al*., 1997) which allows to perform data collection according to 12 three-phase and 36 single-phase connections. In comparison with the hardware solution proposed by CMS, this meter has several drawbacks: a significant number of measuring cables (from each connection) are fed to one counter, so that there may be the problem of search for damaged wires or unreliable contacts which in its turn leads to erroneous measurements of electrical energy parameters. Also one of the disadvantages is a fixed number of measuring contacts on one module whereas the proposed system does not have such limitations. A flexible and open architecture allows you to extend a system to an unlimited number of connections. The concentration of all measuring contacts in one unit is an advantage if the outgoing lines are concentrated in one place (shield) whereas in the case of the need for technical accounting of electric power of electrical devices remote from each other and fed by a radial scheme, this decision becomes difficult for implementation.

Summary: The complete CMS centralization offered by the architecture is a compromise between an existing situation at enterprises with the problem of electricity losses due to the lack of accounting and theft, obsolete equipment and the cost of AMI/AMR deployment in favor of cost reduction and the preservation of modern accounting system full functionality. Based on the foregoing, the conclusion can be made about the perspective of a proposed technical solution and that it can be used in various fields of technology.

CONCLUSION

Modern solutions offer a wide range of functions and nomenclature which take into account the needs of modern enterprises to control the parameters of energy consumption and electricity have useful self-diagnostic functions, cyber defense, logging, etc. However, the concentration of a large number of functions in one device leads to the rise in the cost of the device itself and accordingly of a project as a whole. Based on the foregoing, it can be concluded that the CMS architecture allows to reduce the price characteristics of electricity metering systems to increase their flexibility and the simplicity of new technical and software solution integration.

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