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Original scientific paper

INFRASTRUCTURE AND COMMUNICATION TECHNOLOGIES IN SMART METERING SYSTEMS*

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A b s t r a c t: The transformation of a power grid into a Smart Grid is embedded by the development of twoway communication and an architecture that meets current and future needs of both power and communication networks. Smart metering systems (SMS) represent a great opportunity for maximal utilization of existing infrastructure, allowing better monitoring and management. Furthermore, the opportunitiesemerging from new consumption solutions, provide additional capabilities for SMS. This paper provides a review of the basic components of the smart metering systems infrastucture and their communication technologies. Emphasis is on power line communication (PLC)) technology and the opportrunities it introduces in smart mastering systems. The paper also provides a brief overview of implementation of SMS in Macedonia.

Key words: communication; smart metering systems; smart grids

ИНФРАСТРУКТУРА И КОМУНИКАЦИСКИ ТЕХНОЛОГИИ КАЈ ИНТЕЛИГЕНТНИТЕ МЕРНИ СИСТЕМИ

А п с т р а к т: Трансформацијата на електроенергетските мрежи во интелигентни мрежи е овозможена од двонасочната комуникација и соодветната архитектура кои ги исполнуваат сегашните и идните потреби на електроенергетските и комуникациските мрежи. Интелигентните системи за мерење претставуваат исклучителна можност за максимално искористување на постојната инфраструктура, овозможувајќи подобро следење и управување на мрежата. Уште повеќе, можностите кои произлегуваат од новите комуникациски технологии ги надополнуваат можностите на интелигентните системи за мерење. Овој труд дава преглед на основните компоненти на интелигентните мерни системи и комуникациски технологии кои се применуваат во нив. Особено внимание се обрнува на технологиите за комуникација преку електрични водови и на можностите кои произлегуваат од нивната примена во интелигентните мерни системи. Трудот исто така дава преглед на примената на интелигентните мерни системи во Македонија.

Клучни зборови: комуникација; интелигентни мерни системи; интелигентни мрежи

INTRODUCTION

New trends in the electricity systems, especially integration of distributed generation, controllable load and various electronic devices at both network and consumer side, which make it even more difficult to make an assessment of the power system state in real time, are among the main reasons for the gradual shift to substantial changes in distribution networks (DN) and their transformation into smart grids (SG). Smart meters (SM) are considered a key technology that contributes to the transformation of DN into modern networks [1], while SMS are an undivided part of SG [2].

By SMS deployment, efficient monitoring of energy demand component is expected. Peak load reduction and system performance optimization, by providing information to costumers, is one of the main benefits of SMS implementation. SMS represent an excellent opportunity for maximum use of

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the existing infrastructure, through better monitoring and management.

This paper gives a brief, but comprehensive overview of SMS communication and infrastructure technologies. Successful infrastructure, appliances, interfaces and processes testing are a prerequisite for successful and efficient SMS deployment. Coordination of test phases of SMS implementation is shown in Figure 1.

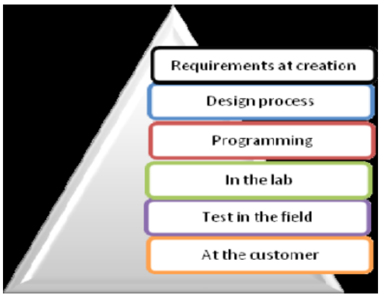

Fig. 1. Test phases of smart metering systems implementation [3]

To achieve a successful execution of the SMS roll out test phases, a good coordination with relevant authorities and all stakeholders is necessary.

The communication system is a key component for successful integration of various functions within the SMS itself, such as checking and analyzing of data.

When evaluating communication platforms, it is important to find a solution that allows [3]:

- cost-effective system architecture,
- standards that enable interoperability,
- infrastructure costs minimizing,
- supporting switches, sensors and home area network (HAN) applications, and
- co-existence with older technologies, such as frequency shift-keying (S-FSK).

Figure 2 shows an exemplary fully fledged smart metering infrastructure.

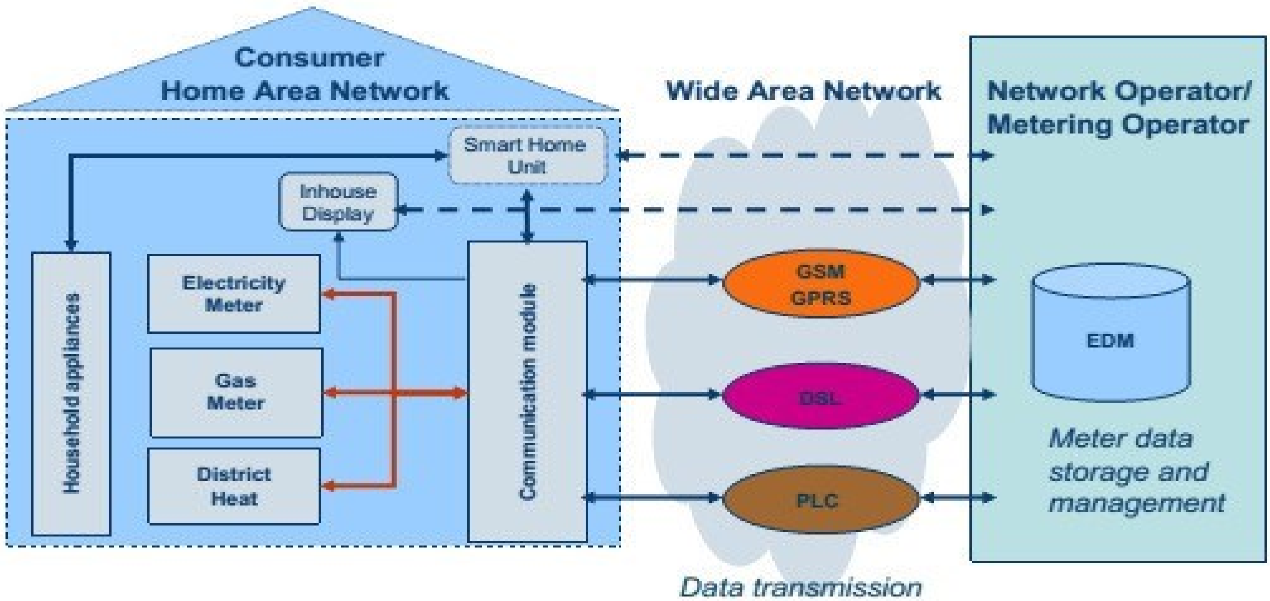

Fig. 2. Smart metering systems infrastructure [4]

SMART METERING COMMUNICATION TECHNOLOGIES

Successful SM implementation relies on appropriate communication selection ([5], [6], [7]).

Although the successful implementation of SMS strongly depends on the choice of communication technology, various aspects, such as location features, network topology, also influence the selection of the communication technology type.

Data exchange in SMS is made by wireless or wired communication. Wireless communication is advantageous due to the less expensive infrastructure and works better in hard-to-reach areas.

Basically, two types of data infrastructures are required for data flow in SMS. The first from sensors and home appliances to the SM, the second from the SM to the data centre. As suggested in [8], the first data flow can be accomplished through PLC or wireless communication, such as ZigBee, IPv6, Z-wave, and others, while for the second information flow, cellular technologies or the Internet can be used.

However, there are key limiting factors that should be taken into account while selecting technology for SMS deployment process, such as time of deployment, operational costs, availability of technology and rural/urban or indoor/outdoor environment, etc. The technology choice that fits one environment may not be suitable for the other.

Power Line Communication (PLC) is one of the most frequently used technologies for meter reading at consumer's premisses.

For that purpose, the equipment is installed in the customer's meter, so the measured data can be sent to the data collection device (data concentrator).

An overview of SMS and SG communication technologies can be found in the Table 1.

T a b le 1

Smart metering systems and smart grids communication technologies [9]

Technology	Spectrum	Data rate	Coverage range
GSM	900 – 1800 MHz	14.4 kbps	1 – 10 km
GPRS	900 – 1800 MHz	170 kbps	1 – 10 km
3G	1.92 – 1.98 GHz, 2.11 – 2.17 GHz	384 kbps – 2 Mbps	1 – 10 km
WiMAX	2.5 GHz, 3.5 GHz, 5.8 GHz	to 75 Mbps	10 – 50 km
PLC	1 – 30 MHz	2 – 3 Mbps	1 – 3 km
ZigBee	2.4 GHz – 868 – 915 MHz	250 kbps	30 – 50 km

PLC communication technology

PLC has been traditionally used in power systems and supports a wide range of applications, both for transmission and distribution, and also within customer premises [10]. Telecommunication integration in electricity makes PLC a very attractive option, both from the aspect of availability and price range.

PLC systems have been used in the network for almost a whole century (as indicated in [11], this technology was first tested in 1918 in Japan, for voice telephony over power lines), with wider implementation since 1927. In fact, variation of the same technology have been used for different applications. With a good combination of different PLC technologies in different segments of the network, it shall be relatively easy to implement them within SG.

Reference [12] deals with PLC systems classification, focusing on the most evident aspects of technology as frequency band, bandwidth, data rate and other. According to [12] PLC systems can be classifieds as follows:

- Ultra-narrowband PLC – this system work on ultra-low frequency (0.3 – 3 kHz), by transmitting data at a very low transmission rate (about 100 bps) to hundred kilometres;
- Narrowband PLC – these systems use the frequency band from 3 kHz to 500 kHz, the same range also covers the range of CENELEC A (the European Committee for Electrotechnical Standardization), i.e. Europe 3–148.5 kHz, FCC (the Federal Communications Commission), USA 10–490 kHz, ARIB, Japan 10–450 kHz and China 3–500 kHz. These systems can be classified into:
    - PLC with low data rate, single carrier technology of the suppressed signal, capable transmitting few kbps,
    - PLC transmitting with high data rate, multicarrier technology, with an ability to transmit in hundred kbps.

This system of communication is used with SM represented in Europe.

Other systems used in SMS are PRIME and G3 systems, which are of similar nature. G3 and

PRIME are the basics of the latest IEEE standardization efforts (1901.2) ([13], [14]), as well as ITU (ITU-T G.9903) [15].

Introduction of PLC with high data rate made possible SMS in the domain of SG [16].

Regarding PLC systems standardization status, in March 2010, an IEEE work group P1901.2 started to work on a standardization for these systems with application in SG, aiming to enable this systems operation in real conditions in the field. According to [17] ITU and IEEE have completed their standards.

There are a lot of challenges on the PLC implementation process. PLC, as a communication medium, is rough and noise sensitive, so channel modulation becomes difficult.

Because of their low-bandwidth, characterristic for this technology, their application is limited. Also, the network topology, number and type of devices connected to the network, the distance between the transmitter and the receiver, negatively affect the transmitted signal quality [18]. By making use of hybrid PLC solutions with other technologies, namely GPRS / GSM, a complete connection that is not possible only with PLC can be provided. The main goal of this type of communication is to reduce costs of implementing domestic PLC networks.

An important element in PLC systems implementation in SMS is the type of grid, i.e. overhead or cable. This is important not only in terms of costs, but also in practical implementtation. The grids' impedance varies depending on the circumstances, i.e. the number of connected consumers, their consumption, which in turn results in noise creation. The network's impedance is different in cable and overhead power lines, which implies a difference in PLC architecture. Overhead lines present a bus topology with mechanical switches in parts of the grid, whereas underground power lines configure a point to point network.

According to reference [12], several topologies used in PLC systems can be distinguished. At medium voltage, these can be classified into:

- radial topology,
- ring topology,
- networked topology.

Low-voltage grids, because of the geographical service area, the grid load, standards, country etc., use more complex topologies compared to those for medium voltage.

Values from the SM are transmitted to the base station via PLC modem. The base station consists of modems, receivers, data concentrators and controllers. Standard communication devices, used by the consumer, are connected with the SM by PLC modem, whereas the PLC base station connects the PLC access system with the network operator and provides multiple communication interfaces. On the other hand, in order to enable communication over longer distances, it is necessary to use a repeater, which helps to separate the PLC network into several segments. To separate the PLC network from the domestic PLC network, a PLC gateway is used, which performs the repetition function and the partitioning of the network at a logical level. Figures 3 to 7 show images of PLC modem, base station, repeater, gateway, and PLC network.

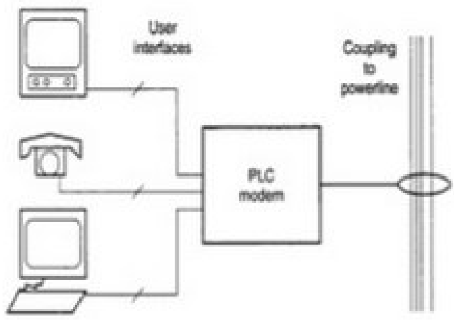

Fig. 3. PLC modem

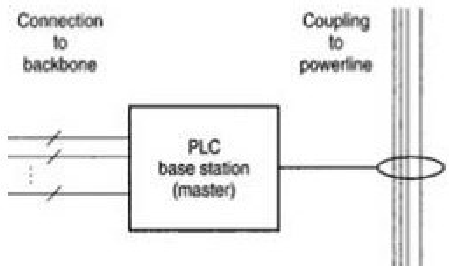

Fig. 4. PLC base station

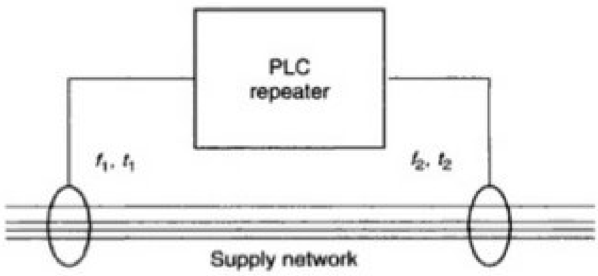

Fig. 5. PLC repeater

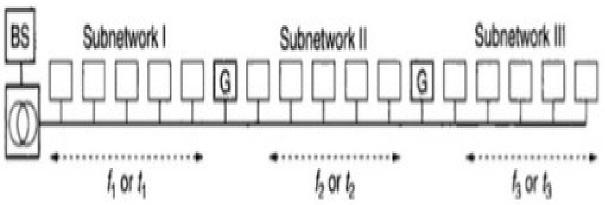

Fig. 6. PLC gateways

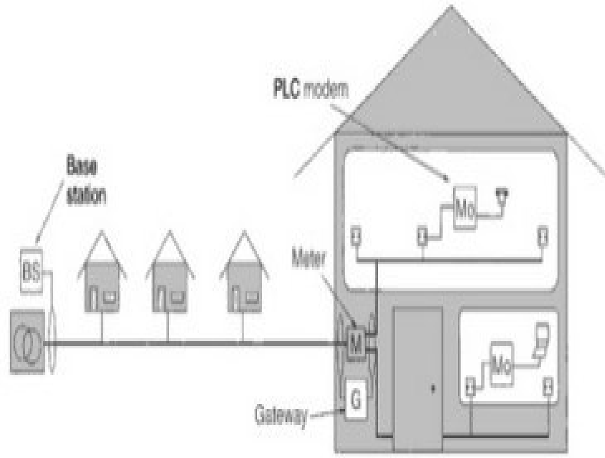

Fig. 7. PLC network

Other communication technologies

As mentioned before, SMS also use GSM technology for data transmission. GSM is known as the second generation of mobile communication technologies (2G) and is the world most used technology standard for mobile communication. Other technologies include:

- GPRS – General Packet Radio Service, extension of existing GSM technology, enabling efficient information exchange.
- GSM/GPRS communication, with higher investment and operational costs, but it can be managed without significant additional infrastructure. This is the main reason this technology is used for direct connection between the SM and the network operator when data concentrator is impossible to be used.
- Fiber optic technology is considered as one of the fastest communication technology offering high bandwidth.
- Another opportunity for direct data communication, from the SM to the network operator is using DSL technology.

Modern SM supports TCP/IP, thus enabling direct internet access so data from the SM are sent to the network operator by internet protocol (IP).

FTTH networks are considered the future of network communication technologies. However, this communication type does not play a significant role in the European market which is related to their high cost of implementation.

SMART METERING SYSTEMS IN THE REPUBLIC OF MACEDONIA

EVN Macedonia is the company which is responsible for power distribution and also provides supply on the territory of the Republic of Macedonia as its primary activity. Besides the projects for old mechanical meters replacement with new digital ones, the company has started introducing SM in its network by implementing dislocation projects, group and individual projects, almost in the whole country. These projects are a prerequisite for the future successful SMS implementation in the country.

Certain transformer stations 20(10) kV/0.4 kV, owned by EVN Macedonia, are part of group dislocation, with an average of 5 to 6 thousand new mounted PLC meters, and about 15 thousand GSM meters. The number of transformer stations owned by EVN Macedonia, which are subject to group dislocation is above 200. As indicated in the previous chapter, when using PLC technology for data transfer, it is necessary to install data concentrators. They are mounted in the transformer stations subject of group dislocation.

Investments made in the low voltage grid are a key factor for establishing a successful PLC communication, where adequate separation of systems (galvanic isolation) is provided.

EVN has also invested in anti-manipulation measures, so secure communication with authentication and encryption is implemented. To prevent the unauthorized access to the meters, measuring cabinets are protected by an alarm system. This alarm system reacts in case detected unauthorized opening or damage, sending information to the end system.

However, the introduction of SM is expected to be accompanied by various problems. Therefore, it is necessary to intensify communication with consumers, in the order they can understand their rights and benefits from SMS implementtation. Consumers should be well-informed about all the functionalities, the type of data collected and information used.

CONCLUSION

Development of efficient and modern networks is essential for protecting life quality.

Smart metering is a complex program, followed by industrial changes. The fact that SMS are not yet mature enough technology, as well as the need to meet the current and future requirements of the SMS, imposes that the choice of appropriate infrastructure and communication technology is one of the greatest challenges that SMS implementers are faced with.

The need for resolving and improving the measurement process occurs simultaneously with the development of DN. For this purpose, the Distribution System Operator needs to be more focused on the new infrastructure investments.

SMS contribute to the progressive emerging of new applications. It is clear that in order to give a complete overview of this subject, many aspects should be considered, including network features, architectures, key elements, pilot projects, applications and research projects. There is a wide range of available technologies for the SMS's communication network, but there is not yet one unique technology that meets all of SMS needs (19], [20], [21]).

According to the European Commission, a big challenge for SMS communication technologies refer to the consumption data updating frequency and their availability to consumers [21]. Data security and reliability are a top priority, because not all technologies provide the same data security level.

On one hand, in a world where the overall communication is digitalized and standardized and where the cost of digital intelligence is rapidly decreasing, the SMS deployment is a logical step. On the other hand, the future of SMS is greatly enveloped by the energy legal framework and the decisions of the responsible government bodies.

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