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# DECREASING THE IMPLEMENTATION COSTS OF SMART METERING SYSTEMS WITH INTEROPERABILITY

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**Abstract:** This paper describes the importance of the interoperability in smart metering systems for modern distribution system operators. The lack of interoperability significantly increases the costs of smart metering system implementation for distribution system operators, especially the costs of purchasing new equipment. The replacement, cleanup and maintenance of electricity meters produced by different manufacturers, which are not interoperable, are also much more complex and expensive. Furthermore, without the interoperability, the system cannot be observable, i.e. the observability exists only for some particular segments of the system. This prevents many functionalities of distribution management system. In terms of interoperability, smart metering systems have gone through four different stages. A comparison of the system implementation costs for these four stages is presented for distribution system operator of Serbia.

**Keywords**—interoperability, smart metering, costs.

## I. INTRODUCTION

The term interoperability represents the ability of diverse systems to inter-operate, i.e. to work together. Needs for interoperability between devices produced by different manufacturers within the smart metering system has been gradually increased during the last two decades.

Initially, smart electricity meter manufacturers used to produce the systems for remote control and automatic electricity meter reading, which were not able to inter-operate with similar systems produced by some other manufacturer. This approach made impossible any massive production of such kind of systems, since distribution system operators did not want to purchase these systems in large quantities, in order to avoid dependency on specific protocols developed by any particular manufacturer. Therefore, some distribution system operators started to buy systems from several different manufacturers, which used different data structures and communication protocols. Those systems were integrated at the highest level by distribution system operators themselves, usually by software implementation that was responsible for processing the data separately collected from systems produced by different manufacturers.

In this stage, the decrease in costs has been already visible from the view of traditional distribution companies [1], but those costs may be decreased further with implementation of four stages of interoperability for smart metering infrastructure.

In the next stage, distribution system operators used to define data structures and communication protocols, requesting from system manufacturers to produce the devices that will operate according to defined protocols. This approach made the devices, produced by different manufacturers, capable to inter-operate between each other. Finally, a necessity for overall data structure and communication protocol standardization was recognized. At the beginning, in 2002, DLMS interoperability appeared as the initial standardization of communication protocols. In 2010, IDIS Association defined a precise interoperability specification, which made possible the development of the devices with full interoperability feature.

Such kind of standardization allowed the reduction of costs for distribution system operators since the maintenance and replacement of the devices produced by different manufacturers became much simpler.

In addition, during these stages, smart metering systems change different names. The usual name for this type of systems initially was automatic reading (AMR) systems, then later changed into automatic meter management (AMM) systems, and at the end advanced metering infrastructure (AMI) systems, which is actual today. This is related to the expansion of functionalities, since the smart metering systems in the beginning only read data, then later with two-way communication provided management, and today realizes management all metering devices in the household (electricity, water, gas, heat).

Swiss company EKZ launched the first project that includes the full interoperability between different smart electricity meter manufacturers in 2017. The goal of this project is the extension of the existing smart metering system by integration of IDIS certified power line communication (PLC) electricity meters from different manufacturers (Landis Gyr, Meter and Control, Iskraemeco) and to maintain

interoperability standard in the system operations and across the diverse supply chain.

## II. INTEROPERABILITY OF SMART METERING SYSTEMS

The block diagram of smart metering system is shown in Fig. 1. Smart electricity meters exchange data with concentrator by power line communication (PLC). Data collected by concentrator are then sent to communication server by GPRS. In addition, some types of smart meters can have direct GPRS connection with smart metering communication server, instead of PLC connection through concentrator. Data collected by smart metering communication server, are used for further processing by distribution system operator.

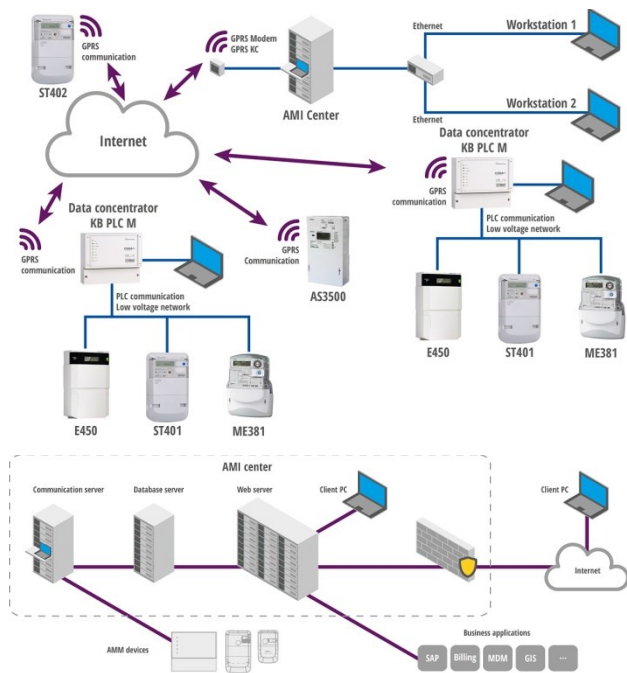


Figure 1 The block diagram of smart metering system

Development of smart metering systems, in terms of interoperability, has passed through four stages that are explained each in separate subchapter.

### A. Non-interoperable smart metering system (Stage 1)

During 1990s, different electricity meter manufacturers produced smart metering systems, which were completely independent from each other, with different communication protocols and data structures [2]. This approach led to the devices and systems that were not capable to inter-operate between each other. This prevented any massive production of smart metering systems, because distribution system operators wanted to avoid dependency on any particular manufacturer, by avoiding dependency on specific protocols developed by that manufacturer. Only in a very few cases, some utilities, like Italian company Enel, achieved some higher number of produced devices, in this stage.

### B. Multi-protocol smart metering system (Stage 2)

Since smart metering systems were bringing many advantages, including the significant reduction of costs, distribution system operators were very interested in installing such kind of systems. In order to overcome described constraints from stage 1, distribution system operators started to buy systems from different manufacturers, which used

different data structures and communication protocols, but which were integrated at the highest level. Distribution system operators themselves did it. The data were separately collected from systems produced by different manufacturers, but processed together by the top-level software designed according to specifications created by distribution system operators.

Such kind of systems were installed in Sweden, by Actaris (110.000 installed electricity meters), Iskraemeco (150.000 installed electricity meters) and Telvent (600.000 installed electricity meters) in period from 2003 to 2006 [3] This led to significant increasing of number of ordered and installed electricity meters which were part of AMI systems.

### C. Closed interoperable smart metering system (Stage 3)

Although installed systems in stage 2 caused significant reduction of costs due to advantages brought by smart metering systems themselves, there was still a room for significant additional cost reduction. Namely, unification of data structures and communication protocols, would lead to additional cost reduction, since data from meters produced by different manufacturers could be both collected by the concentrators and processed together. In addition, this approach would allow easy replacement of the devices produced by different manufacturers.

Therefore, distribution system operators started to define data structures and communication protocols, and to request from system manufacturers to produce the devices that will operate according to defined protocols. Such kind of devices for the first time were able to inter-operate between each other, despite different manufacturers produced them. The replacement, cleanup and maintenance and of the devices produced by different manufacturers became much easier in this stage.

French company EDF and Spanish company Iberdrola, which included significant number of smart electricity meters, installed such kind of devices.

### D. Open interoperable smart metering system (Stage 4)

Stage 3 caused significant cost reduction. However, there still was a room for additional cost reduction. Main drawback of the approach from stage 3 was that only few system manufacturers, selected by distribution system operators, were included in production of devices capable to inter-operate between each other. Increasing the number of potential manufacturers would additionally reduce the costs for distribution system operators, due to competition between different manufacturers of smart meters.

Therefore, it was recognized that data structure and communication protocol standardization have to be implemented, so that any system manufacturer could be able to produce the devices capable to inter-operate with the devices produced by any other manufacturer. It was done initially by standardization of communication protocols within DLMS interoperability. Finally, IDIS Association defined a precise interoperability specification in 2010, which made possible the development of the devices with full interoperability feature. This standardization made possible the additional reduction of costs for distribution system operators since the replacement, cleanup and maintenance of the devices produced by different manufacturers became much simpler. It also opens the door to the unlimited

development of additional services like multi-utility, smart home, smart cities etc.

This type of system is the above-mentioned project in Swiss utility EKZ, where the total number of 400.000 electricity meters will be installed by the end of the project.

### III. BENEFITS OF INTEROPERABILITY

The benefits of interoperability seen and envisaged in those phases can be grouped into four cost categories:

1. Decrease of the operation costs due to faster communication and decreased communication failures making realistic automatic reading a management, and advanced demand response features.
2. Decrease of the unit costs of the products due to competition between different manufacturers of smart meters.
3. Decrease of the costs due to simpler replacement, cleanup and maintenance of the meters and concentrator devices produced by different manufacturers. Decrease of the cost due to stock decrease for the smart meters of different manufacturers.
4. Decrease of the costs for the development of additional services (multi-utility, smart home, smart cities etc.)

The benefits of four stages in decreasing costs due to interoperability principle may be seen at Table 1.

TABLE I. THE BENEFITS OF INTEROPERABILITY

Category	Stage			
	S1	S2	S3	S4
1	Yes	Yes	Yes	Yes
2	No	Low	Medium	High
3	No	No	Yes	Yes
4	No	No	No	Yes

Smart metering system allows more efficient work of distribution system operators and more rational consumption of electrical energy [4]. Potential benefits, which have become much more pronounced with the development of interoperability, are the following: decrease of the costs of reading and maintenance of electricity meters, decrease of the costs of generating the billings and the costs of customer care, decrease of the operative costs and the costs of maintenance of the overall system, postponing the investments into the system for electrical energy transfer and distribution, postponing the investments into the production capacities, decrease of technical and commercial losses in distribution system, decrease of the costs of delivered electrical energy, decrease of the costs of undelivered electrical energy (where interoperability has significant influence since it decreases the time needed for maintenance and replacement of the devices produced by different manufacturers), reduction of the carbon-dioxide emission, reduction of the dust emission and reduction of the nitric oxide and sulphur oxide emission.

Decrease of the costs of system operators in case of interruption of electrical energy delivery is achieved due to shortening of the period of the interruption caused by advanced monitoring of the system in the real time.

Benefits in case of undelivered electrical energy include saving the costs of the undelivered electrical energy itself and

saving the costs of reparations for customers that did not receive the electrical energy.

Decrease of the costs of the maintenance of electricity meters is caused due to possibility for remote checking of the electrical meter functionality (where interoperability additionally decreases this kind of costs).

### IV. IMPACT OF INTEROPERABILITY ON IMPLEMENTATION COSTS OF SMART METERING SYSTEM: SERBIA

The basic costs of smart metering system implementation can be divided into equipment costs, smart metering system software costs, instalment costs and cleanup costs. Equipment costs are the costs of purchasing new smart meters and new concentrators. Instalment costs consist of the costs of hiring labor for the installation equipment, the costs of using the vehicle in the process of transporting the labor and equipment during installation and the costs of installation additional equipment that occur due to the often poor condition of a certain number of measuring points. The cleanup costs consist of the costs of procuring the appropriate equipment and the costs of hiring the appropriate workforce. All of these costs have been decreased with the development of interoperability. The example used to analyze the impact of interoperability on these costs presented in this paper is distribution grid of Serbia, due to data availability. The most significant items in these costs are the equipment costs.

Today in Serbia, there are four smart metering equipment vendors and three companies producing accompanying the software. Distribution grid in Serbia covers 3.3 million customers. Among them 100.000 customers can be classified as commercial and industrial customers and 3.2 million customers can be classified as residential customers. Implementation of PLC smart metering system has been planned for residential customers, while implementation of smart metering system based on GPRS, 3G, LTE or 5G network has been planned for commercial and industrial customers.

The historical development of smart metering infrastructure in Serbia started in 1990's with the small steps. The first and second stage has been occurred with installing 25.000 PLC equipped smart meters. The unit cost of PLC equipped smart meters (with the allocated cost of purchasing the associated concentrator included) in the first stage was around 250€. The unit cost of PLC equipped smart meters in the second stage was decreased to 200€, while the unit cost in the third stage was approximately 160€. The third stage was launched with several thousand PLC equipped smart meters, a few years ago. The historical decrease of unit costs and total costs of PLC equipped smart meter per interoperability stage in Serbia is shown in Fig. 2.

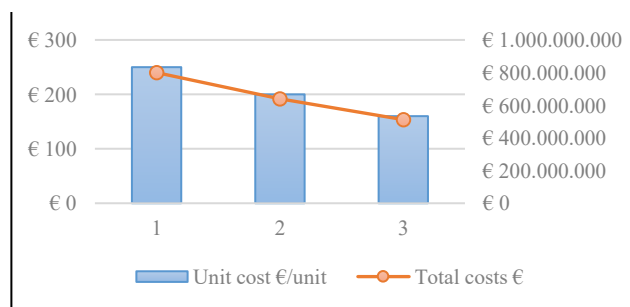


Figure 2 The historical decrease in the unit costs of PLC equipped smart meter per interoperability stage (1-3) in Serbia

The total costs have been calculated based on the total number of residential customers in Serbia (3.2 million customers). It can be noticed that each interoperability stage caused decreasing the unit cost by 20%. Therefore, the estimated unit cost of PLC equipped smart meter in the fourth interoperability stage would be 128€.

The first stage of GPRS equipped smart meters in Serbia started roughly 20 year ago with average unit cost of more than 600€. It has been followed with second stage started around 15 years ago with average unit cost of 400€. In the third stage the meter unit cost decreased to around 250€. The historical decrease of unit costs and total costs of GPRS (or 3G, LTE, 5G) equipped smart meter per interoperability stage in Serbia is shown in Fig. 3 The total costs have been calculated based on the total number of commercial and industrial customers in Serbia (100.000 customers). It can be noticed that each interoperability stage caused decreasing the unit cost by approximately 35%. Therefore, the estimated unit cost of GPRS (or 3G, LTE, 5G) equipped smart meter in the fourth interoperability stage would be 160€.

Having in mind the presented costs, the total costs of smart metering system implementation calculated for the first, the second and the third interoperability stage are 860 million €, 680 million € and 537 million €, respectively. The estimated total costs of smart metering system implementation calculated for the fourth interoperability stage would be 425 million €, which means the fourth interoperability stage will bring 112 million € of savings in comparison to the third interoperability stage.



Figure 3 The historical decrease in the unit costs of GPRS (or 3G, LTE, 5G) equipped smart meter per interoperability stage (1-3) in Serbia

During these three phases, only devices from several domestic manufacturers were procured on the Serbian market. These manufacturers did not export these devices to other countries. The quantities of installed devices by phases are very similar. Therefore, we can conclude that the shown cost reduction is mainly due to the development of interoperability. It is to be expected that possible side effects of mass installation of meters in Serbia, such as an increase in the number of installed devices, entry of foreign manufacturers into the Serbian market, entry of domestic manufacturers into foreign markets may further reduce costs due to economies of scale, maturing technology and improving manufacturing techniques.

The modelling of the economics of interoperability has been performed for the digital television [5] that shows the 21% decrease in average costs and 27% increase in sales for manufacturers. Another study [6] shows interoperable systems lead to the following financial benefits: lower costs per transaction, increased operating efficiency, improved reliability and security lower design and installation costs, lower operations and maintenance costs, lower support, systems restoration and upgrade costs, higher quality of service with fewer mistakes, new services through competitive innovation resulting in possible 1-3% savings in total costs, but they have to be modeled for the case of smart metering infrastructure.

## V. CONCLUSION

This paper presents four stages of smart metering systems development in terms of interoperability. In addition, overview of the progress of smart meter implementation and the costs of procurement of equipment in different phases of interoperability in Serbia has been presented. It was found that they decreased by about 20% for PLC equipped smart meter and about 35% for GPRS (or 3G, LTE, 5G) equipped smart meter after the transition to each subsequent interoperability phase. It was concluded that the transition to the fourth phase of interoperability in Serbia could bring savings of at least 112 million euros. In future research, quantitative analytical investigation of interoperability effect in connection to reliability evaluation can be performed. The barriers for the interoperability can be discussed. Cleanup costs can also be analyzed.

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