Smart Metering Handbook

Contents

Foreword

In Brazil, there are only a few active companies that are more than a hundred years old. One of these is Light—the electric power company in Rio de Janeiro. Light began as a private Canadian company and subsequently became a Brazilian government–controlled entity. In 1996, Light was privatized, and control was acquired by the French utility company EDF. In 2006, Light became a private Brazilian company with shares traded on the stock market.

Fabio Toledo was 14 years old when he began working at Light. At that time, the company was still state-owned. He went through all the stages of the long process of professional development, starting as an apprentice and eventually becoming the manager of the Metering Department (during the French administration), responsible for new technologies and revenue protection for large accounts. He learned by practicing and studying—practicing and studying a lot!

Energy theft has been one of the faces of the decadence of Rio de Janeiro since the capital moved from Rio to Brasilia in the early 1960s. Fighting this social plague then as well as now is a difficult and, in some circumstances, dangerous task. In the early 2000s in Rio, the government found itself upable to govern some of the poor areas of the city, known as Favelas, and criminal gangs took control of those areas. Some large energy consumers were also stealing high volumes of energy from the distribution network, to the extent of hundreds of thousands of U.S. dollars per month. Light employees faced risky situations fighting energy theft. Today the risk is lower, but still present.

More than an economic challenge to receive fair payment for goods and services delivered, the challenge is also a social one. In the Favelas, where the power utilities have the most problems with theft, there is also what economists call the "tragedy of the commons." There, citizens feel the access to the product is a social right and one that can be freely accessed without concerns about costs or consequences to neighbors or society. When local inhabitants seek only their individual interests, performing unauthorized or illegal activities within the electricity distribution network, it contributes to a collective tragedy. In this case, energy services in areas affected by this social behavior are much worse than those in regularly serviced areas. In the Favelas, where criminal gangs are dominant, there are frequent and long outages, followed by voltage fluctuations that damage electrical appliances.

The electric company found itself engaged in a "guerrilla war" to reverse this situation. Fabio was continually followed by bodyguards to protect him from the wrath of those who felt harmed by the suppression of energy theft. This protection was not enough to prevent an attack on Fabio's car. Several shots hit the vehicle, but fortunately not him. The French executives of Light were understandably concerned about this event, and considering Fabio's expertise acquired throughout his career at Light, they decided to send him to Paris to work in the Research and Development Company of EDF.

At EDF's research and development division, Fabio had an opportunity to improve his skills and knowledge of the concepts of smart metering and learned about a technological novelty—the smart grid, which appeared to attend to the specific needs of electric power companies in Europe, finding solutions to accommodate new forms of renewable energy generation, mainly wind and solar. These forms of energy generation were either concentrated in large production plants or scattered throughout the territory within small consumer premises.

In this new reality, consumers also become producers, but are still dependent on the electricity network, as both wind and solar sources are intermittent. To avoid affecting the reliability of the system, for each new kilowatt from these new plants—which may or may not be producing depending on weather—another kilowatt from installed conventional sources must function as backup. From both an economic or operational point of view, this is not an ideal situation.

In response to this problem, several solutions were developed to make the electricity networks dynamic—networks with changing topologies in real time depending on inputs from energy generation and energy consumption patterns. New concepts based on new techniques in the fields of electrical engineering, communication, and optimization led to the automation of substations, allowing consumers to know in real time the price of electricity, which can vary almost instantaneously according to the marginal cost of producing it. These include bidirectional metering to account for the power flow in consumer-producer units and remote command-and-control capabilities to allow remote connections and disconnections.

Fabio's expertise in the themes and challenges encountered by EDF R&D in France led to assignments in other countries, including South Africa. There, he was involved in the development of a technological breakthrough of great interest for countries with large amounts of poverty, as in the case of Brazil: prepayment meters.

In 2009 Fabio returned to Brazil and to his former company as advisor to the distribution board. I had the opportunity to talk with him and instantly realized the immense potential of this young professional to help solve the same problem that had forced him to move away some years before, but attacking on the other flank: technological advancement.

As president of Light, I promoted Fabio to chief technology officer and tasked him to create a comprehensive smart grid program within a budget of R$36 million from Light's R&D. The first and main step of this program was to develop, within two years, a new metering system smart enough to be competitive with those in Europe, one in which the management capabilities of energy consumption is of the utmost importance. But, above all, this could become an essential tool for fighting energy theft in Brazil and in other developing countries, as it is economically viable, tamper-proof, and capable of remote command and control.

I had a responsibility to maximize the creative potential of Fabio and ensure that he would have the freedom to reach the goals that we defined together. The results we've achieved thus far allow me to be very optimistic.

Jerson Kelman
President of Light (March 2010 to July 2012)
General Manager of ANEEL—Brazilian Regulatory Agency for Electric Energy, January 2005–January 2009
General Manager of ANA—Brazilian Regulatory Agency for Water, December 2000–December 2004

Preface

Energy suppliers and utilities throughout the world are making decisions to deploy smart metering systems for their customers on a grand scale. The drivers are global incentives for reduced energy consumption and carbon emissions, opening of energy markets, strong pressure of regulators in several areas of energy management, and growing customer demand for new metering system services.

Energy suppliers and utilities have an even stronger perception of their metering systems as necessary and strategic. Opportunities with these systems to retain existing customers and gain new ones are increasingly evident.

A smart metering system project requires multidisciplinary teams (marketing, regulation, metering, R&D, finance, etc.) who are well trained and understand both local challenges and those faced by smart metering deployments throughout the world. This book aims to fill a gap in the available global literature on this subject and to meet the high expectations of these professionals.

For this reason, the book uses language that is meaningful to all who might develop or work on these systems. Nevertheless, the reader should have a basic understanding of the energy market and the metering services of an energy utility, as well as IT, telecommunications, and measurement systems.

As such, the book is intended for a wide audience of professionals who may interact with the subject of smart metering and its opportunities—in universities, energy distributors, energy suppliers, research institutes, standard-setting bodies, laboratories, regulators, metering system manufacturers, suppliers of metering system equipment and components, consulting firms, information system integrators, and other sectors. My goal is for this book to become recommended reading for:

- Technical and R&D managers
- Project managers
- Consultants
- Executives
- Researchers
- Engineers
- Teachers

- Technicians
- Students

I must point out that although this book involves, in principle, both gas and electricity metering systems, its focus is mainly on electricity metering, given its important role in smart energy metering systems. Hence, although other energy (e.g., heat) or nonenergy (e.g., water) metering systems could use some of the concepts in this book, they are beyond its intended scope.

Figures and related information in this book are for illustrative purposes only, not for any comparison between different solutions and companies. The same applies to any other information about companies and deployments mentioned in this book. I do not intend to promote any company or solution. All the companies mentioned are somehow involved with smart metering projects. If for any reason their smart metering solutions (pictures, information, etc.) are not published in this book, this does not mean they do not exist or that a particular company is less qualified than another. The same applies for any company not mentioned here. Because of the large number of companies involved with smart metering projects in the world, it is almost impossible to mention all of them.

It is also important to highlight that although the term *smart metering* is widely employed internationally to refer to the central subject of this book, other terms may be used for the same purpose by different participants of the energy market throughout the world. Examples are the terms *communicating meters* and *advanced metering*.

Also, I cannot assert that this work is complete, as international markets and technology evolve quickly. I could add many other subjects. However, in my opinion, it meets what I intended it to achieve. I thank all my colleagues for their interest and assistance, prior to publication.

Finally, it was a pleasure to write this book and I hope you enjoy it. Any constructive criticisms and suggestions will be gratefully accepted.

Introduction

Smart Metering System Projects: International View

Analysis of the global energy market, with its thousands of distributors and suppliers and its millions of customers, suggests that it is difficult to ensure proper management of all customers without a smart metering system, whether it is a market open to competition (completely or partially) or not.

Until recently, almost all participants throughout the world managed metering systems manually. This results in significant losses, particularly those associated with incorrect customer billing, inefficient operational management of metering equipment, and underutilization of the functions of these systems and associated opportunities.

Advantages versus Constraints

Some of the problems that hinder the widespread deployment of these systems by distributors and suppliers are related to the difficulty of making these deployments profitable and selecting, among the available technologies, the most appropriate technology for specific features of the market.

It would be tempting to imagine that the smart metering systems and services that these systems can offer to customers are treated as one of the top priorities of all of the world's energy participants, but unfortunately, this is not the reality.

Fig. 1–10. Example of socket (left) and plug-in meters (right). (Photo by Itron and BMS Imaging, courtesy of Actaris.)

Socket meters are used in a similar way in North America (fig. 1–10). These differ only in base design and component locations.

Another interesting design is that of the rack meter, which is generally an indirect measurement system, used in panel arrangements for substations. This meter may be quickly and safely replaced in the field for different purposes. Its base normally has an internal mechanism to automatically short-circuit the secondary current and open the voltage circuit in order to isolate the meter prior to removal.

In general, modular meters offer more flexibility. They may allow the replacement of components in the field, such as communication modems and switches, through the use of fully isolated meter compartments. This may significantly reduce the cost of the field operations.

Direct and indirect measurement systems. Regarding the way they are connected to the grid, meters can be classified as direct or indirect measurement devices. Their application depends on the customer's load requirement. Direct measurement meters are usually applicable for residential customers, and indirect meters for bigger load customers.

Credit and other prepayment data management can be accomplished two different ways:

- Locally in the debit meter: As with key meters or smart card meters, the monetary credit is locally managed, and any consequential taxes or fees are managed by the meter itself.
- Remotely in the IT system: Meters are connected to the server in an online mode. Credit management and any other data management are executed remotely by the IT system and frequently displayed in the meter. A typical credit meter may be also used for offering prepayment services, with all calculations and management centralized in the IT system.

Several technologies are being used to provide this kind of prepayment system, such as SMS or GPRS meters. They are being implemented in many countries. This technology provides a very advanced level of prepayment services. This kind of technology, its potential services, and other future-proofing services are essential in smart metering systems.

Emergency credit and social disconnection

Prepayment systems are recognized as a way to avoid local interventions for energy supply disconnection, as debit meters can self-disconnect the energy supply. But, as with any other service, it can always be improved. In order to help their consumers with financial difficulties, research and development departments of utilities and solution providers are working toward creating new services and opportunities for customers.

Emergency credit was the first known initiative in this direction. When the meter credit reaches zero, customers may activate an emergency credit. In other words, an emergency credit level can be added once the previous one has been exhausted. This is common for avoiding disconnections during nights, weekends, or holidays. Similarly, some energy suppliers around the world, often subsidized by local governments, offer monthly free energy credits to their customers.

This solves some problems, but can also generate new debt to consumers that will have to be managed in the future. The energy supply may still be cut off once the emergency credit ends. Some utilities in the world have implemented social disconnection services to deal with this challenge. With the social disconnection method, an initial emergency credit is offered to customers. While this credit lasts, energy demand is fully available for the customers' consumption, without any power limitation. When this credit topology selected, a virtual point-to-point environment is established between middleware and the devices in the field. Examples of technologies using this arrangement are SMS- and GPRS-based metering systems (SMS = short message service and GPRS = general packet radio service) (fig. 2–8). In this case, data traffic between the middleware and devices is via Global System for Mobile (GSM) communications.

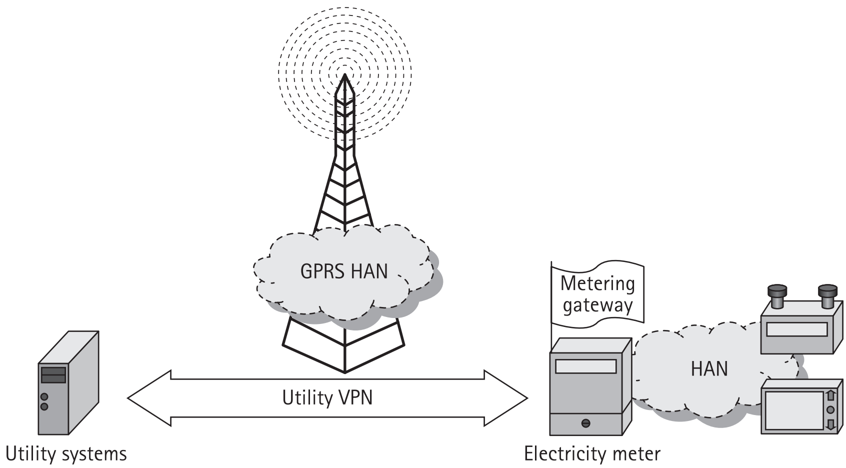

Fig. 2–8. A virtual point-to-point arrangement

Another common example uses an in-home metering gateway to provide a network address translation (NAT) service for communications between the middleware and other HAN devices such as gas meters and in-home displays. It is usually a hybrid topology because the HAN network may use several types of physical and logical topologies.

For short deployments, modem-to-modem dial-up applications are commonly used. This may be an interesting solution for trials that are not testing technology and for low-scale deployments, although it is not advised for medium and large smart metering rollouts.

An advantage of this topology is the simplicity of access from the middleware infrastructure to the devices in the field. One of the disadvantages is the dependence on a single route for communications. This problem can be mitigated by use of other media-related protocols for backup purposes with different features related to the signal strength, such as a GPRS meter that uses SMS and circuit switched data (CSD) as secondary communication options.

sensors, home automation devices, appliances, and customer display units. Interoperability becomes a primary feature, with clear need for integration.

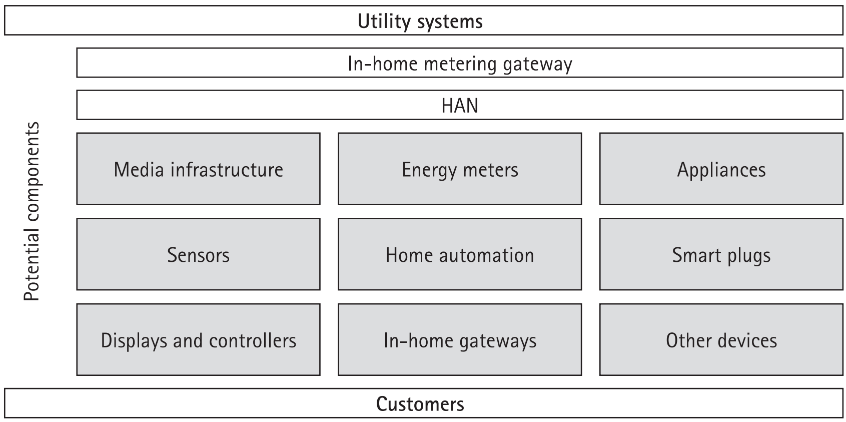

Fig. 2–31. Architectural environment diagram: HAN

A single medium does not necessarily provide the network infrastructure part of this layer. On the contrary, it tends to be composed of a hybrid combination of media. This is due to the difficulty of forecasting communication technologies to be used by different market segments that may be integrated such as appliances, meters, and in-home automation. It can be expected that an in-home metering gateway provides interoperability using different HAN media. The media devices embedded in it do not need to be part of its initial deployment. Depending on the business case, this capability may be upgraded for specific targeted customers that the utility would like to offer a specific group of advanced services. For example, assuming a HAN using one medium was massively deployed to all utility customers, they could be offered a package of services. The quantity of services could be then limited by the interoperability this medium is able to provide. Available compatible devices would define this boundary. When it becomes necessary to provide a new package of services to a market segment or niche customers, these targeted devices could be physically and logically upgraded with a new HAN using a second, different medium. New agents and applications could then be downloaded to enable interoperability with the new scenario. This kind of segmented option is sometimes important to business cases and to the customization of solutions according to individual customer needs.

Another common use of PSTN is coverage exceptions. Thanks to strong penetration, PSTN lines are almost everywhere and can efficiently cover remote exceptions. This could apply to data concentrators and isolated nodes.

Licensed RF

RF broadcast technology is often able to broadcast a signal for several miles. There are various radio technologies available around the world with different telecom features. One example is use of very high frequency (VHF) technology. The first versions were implemented as one-way technologies and offered only a few bps of bandwidth. New versions offer two-way capability and up to tens of kbps of bandwidth.

A clear advantage of broadcast technologies in relation to others is coverage. A few telecom masts may cover an entire energy utility area. Another is that this medium may act as a WAN, LAN, and HAN. Depending on the targeted services, it could enable in-home services without additional HAN devices. It also provides an opportunity for sharing telecom infrastructure with other networks such as smart grids or smart metering for water companies.

Potentially covering the HAN, RF broadcast technology is often unlikely to be compatible with devices such as gas meters and in-home appliances. This incompatibility is due to several factors, such as trends in home automation, the high transmission power of this technology, and high consumption of these devices. Another aspect is the size of antennas for these devices and sometimes the devices themselves. They may be incompatible with existing applications and built-in designs and require the use of separate gateways.

This produces a centralization of processing of all devices in middleware management. This may be compatible with some services but may be an issue for online and real-time local services.

Despite the benefits in a private network, such as legal freedom from interference due to temporary band concession and opportunities afforded by sharing the infrastructure for competitive energy market environments among different energy suppliers, there are disadvantages with the management of telecom infrastructure. Because this management is more complex than the management of low-power RF systems and requires more specialized people to manage it, these kinds of deployments are normally executed in turnkey arrangements that generally include network maintenance.