Chapter 5

Learnings from Pilot Implementation of Smart City by a Brazilian Energy Utility

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Additional information is available at the end of the chapter

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Abstract

This chapter describes the experience acquired during the implementation of a smart grid pilot project in a Brazilian utility. Learnings in the area of smart metering, telecommunication, information systems and project management are presented. A special focus on Brazilian specificities is given as well as on the management of innovative projects.

Keywords: smart grid, smart metering, advanced metering infrastructure, meter data management, project management

1. Introduction

Smart grid technologies are a set of techniques, systems and equipment that aim to automate grid operations, collect grid information and optimize power distribution, both in power flow and in technical services. These technologies are of great value for energy utilities, since they help reducing costs, avoiding future investments and enhancing its main key process indicators (KPIs). However, benefits coming from the application of smart grid concepts not only may reach the organizational context but also should be transferred to the community in which the companies are present. In that sense, smart grid technologies should be applied in order to result in a smart city, where the energy resources are efficiently used and there is a community awareness about the use and the benefits of such technologies. For that purpose, Elektro has selected the city of São Luiz do Paraitinga, located in São Paulo State, in Brazil, in order to concentrate several smart grid initiatives and evaluate the impacts in the company and on the society, collecting experience to help build a roadmap of future rollout.

In the Brazilian context, the application of some smart grid technologies is in its early stages, with changes needed both in the regulation and the market [1], which is still being developed and some imported solutions may not present prices that result in a positive business case. Some examples are smart metering, whose massive rollout would introduce a representative increase in utility investment and would lead to a tariff increase or a need of government funding, which need further regulatory discussion. Distributed generation is another example that clearly has its financial benefits for the customer, but, due to the current prices, it is still a high investment and long payback application, which is not viable to most people. In this scenario, the massive application of these technologies to create pilot projects is being subsidized by research and development funding from the Brazilian energy agency (ANEEL—Agência Nacional de Energia Elétrica), and a national research has been developed by a group of utilities in order to describe possible scenarios for smart grid deployment [2]. Cybersecurity is also an issue being addressed by ANEEL funded research projects [3], since the introduction of communications on the meters creates a risk of data disruption and also utility infrastructure unsolicited access.

The city of São Luiz do Paraitinga was chosen for this pilot project due to several aspects: the number of customers is representative (5500) and the investment necessary to change all the meters was within the funding limits; the city has extensive rural area and a concentrated urban area, which is a characteristic present in most of Elektro's concession area; the city has a set of hills, which introduce limitations to radio technologies to be studied; the city is a Brazilian historic heritage site, which allows us to understand the relation between the deployment of new equipment and the maintenance of the visual characteristics of the city. The scope of the technologies deployed is below:

- Smart metering: 1.800 ultranarrowband PLC meters + 3.500 RF mesh meters + 80 PRIME PLC meters.
- Distributed generation: 275 solar panels deployed in 12 buildings with generation of 63.25 kW and one wind power generator of 2.4 kW.
- Public lighting: 120 LED remote controlled public lights.
- Distribution automation: 12 automation points, including reclosers, voltage regulators, capacitor bank and fault sensor.
- Electric vehicles: seven electric bicycles and one electric bus.

To engage the customers, a customer portal has been developed in order to present the energy consumption profile and help introduce an energy efficiency culture. The portal is integrated with the meter collection system and can also control the consumption by the means of a consumption goal. The process of meter reading and connect/disconnect has also been fully automated through the development and integration of meter data collectors (MDCs), meter data management (MDM) and customer information system (CIS).

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During all the phases necessary to reach these results there has been important lessons learned. The chapter will present in detail the scope of the project in each area of concentration and bring the relevant knowledge acquired during the specification, architecture, deployment and operation stages in the hope of illustrating the challenges of bringing smart grid technologies to real use cases and helping further smart grid deployments.

2. Smart meters

In the project, smart meters have been used in residential customers not only for billing purposes, but also to collect further information of value for the company and the customers. In order to assess the main technologies in use for smart metering, it has been decided to deploy two different kinds of PLC technology, narrowband and ultranarrowband, as well as RF mesh (915 MHz) (**Figure 1**).

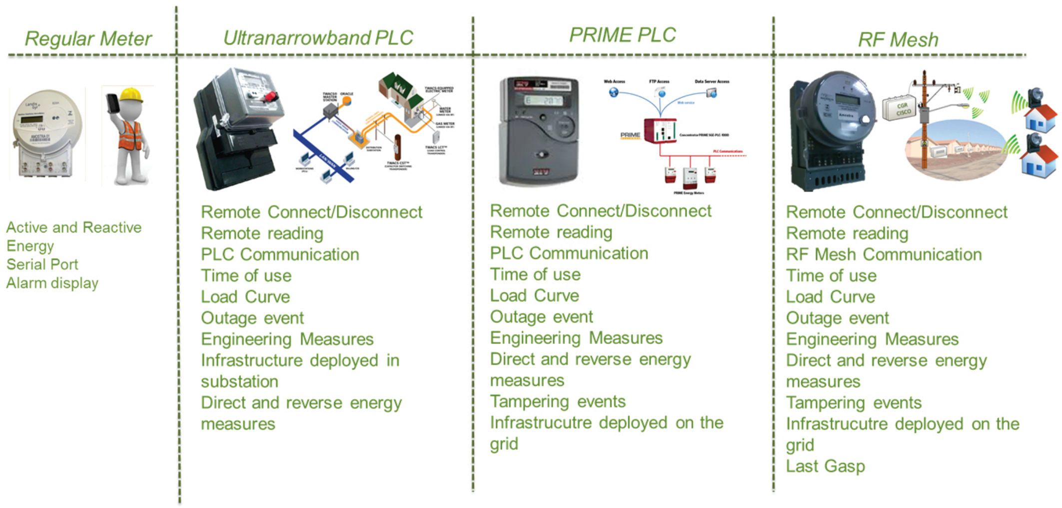

Figure 1. Smart metering technologies.

The process of testing and approving the smart meter models was set in a way that could replicate as closely as possible the field conditions, in special the communication issues.

Currently, Elektro buys usual electronic meters, with a serial output that allows the communication with an external device to collect only meter reads (active and reactive energy). To elaborate a technical specification, a study of the smart meters offered in the Brazilian market has been lead and a specific document and test plan have been developed for the project (**Table 1**).

Note that not all the models on the market covered the whole requirements, therefore, some desirable requirements had to be removed in order to have a sufficient number of meter vendors during the negotiations. However, the requirements removed did not impact the main objectives of the project. This shows how the smart metering market is still under development in Brazil. A lot of vendors have recently developed new meter models to address this new demand and not all of them attend specific utility requirements or have the necessary legal conditions to be marketed. The evolution of the product is a four-hand process in which both the suppliers and the utilities should work closely in order to understand the value of each functionality and shape the products to their reality, which may vary from country to country and even across one single market (**Table 2**).

Requirement	Group	Weight	Compliant models
INMETRO[1] certification	Industry and regulatory standards	19%	77%
Time of use (TOU)			87%
Engineering measures			90%
Clock deviation ≤30 ppm			90%
Metering error ≤1%			100%
Load curve	Basic requirements	27%	77%
Remote connect/disconnect			100%
Optical port			90%
Remote communication			100%
Reconfiguration logs			87%
Remote clock synchronism			70%
Remote firmware upgrade			70%
Overvoltage and undervoltage events	Desirable requirements	54%	70%
Voltage, current and power factor measures			90%
Tamper event—load with no voltage			67%
Last gasp			90%
Reverse energy register			90%
Reactive energy			100%
Duration of reverse flow			20%
Tamper event—voltage on the load side during disconnection			100%
Tamper event—meter opened			60%
Tamper event—reserve energy			90%
Tamper event—meter tilt			80%
Tamper event—DC magnetic field on meter			30%
Duration of meter powered up			10%
Local clock synchronism			40%

[1]INMETRO is the Brazilian Institute of Metrology, legally responsible for approving all the meters available to be marketed.

Table 1. Initial smart meter requirements and adoption.

Requirements	Compliant models (%)
Local clock synchronism	40
Duration of reverse flow	20
Tamper event—meter opened	60
Duration of meter powered up	10
Tamper event—DC magnetic field on meter	30

Table 2. Removed smart meter requirements.

2.1. Testing and validation

Once the meter vendors were filtered by the technical specification, the testing phase took place in Elektro's laboratory, evaluating four samples of meters of each model, summing up 120 samples.

Precision, functional and communication tests were performed. The precision tests were performed according to Brazilian regulation RTM431 [4], from INMETRO. Some of the functional requirements had to be developed during the validation process, demonstrating the innovation characteristic of the project. **Table 3** shows some of the functionalities specially developed for some meter models.

Requirement	Group	Compliant models (%)
Reconfiguration logs	Basic requirements	87
Remote clock synchronism		70
Remote firmware upgrade		70
Overvoltage and undervoltage events	Desirable requirements	70
Tamper event—load with no voltage		67

Table 3. Specific purpose developed functionalitites.

2.2. RF mesh communication tests

For the RF mesh smart meters, a small network was configured in one of the company's premises. The chosen place allowed evaluating the distance between the network elements in which signal attenuation begins to affect communication performance.

The concentrator was located inside a laboratory, while the smart meters were placed in the spots named by "MIB", with an average distance of 70 m between them. As it is shown in **Figures 2** and **3**, the areas in which the concentrator and the MIB1 point are located present a variety of metallic structures and equipment that interfere in radio signal.

MIB2 and MIB3 points were configured to evaluate the behavior of the network for long distances, where a hop between meters is expected. It means that these meters would not communicate directly with the concentrator, but would do it using another meter as a switch.

This behavior was confirmed in the tests and, for some technologies, distances between MIB1 and MIB2 had to be shortened by half in order to establish communication (**Figure 4**).

Figure 2. Area of tests.

Figure 3. MIB1 location.

For the MIB4 point, an enclosed construction was chosen, where a higher attenuation of RF signal was expected and more instability. Instability was measured by the continuous pinging of the meter for the period of test. It was true for most of the technologies, and one specific technology showed no issues with signal attenuation and presented stable communication. Connectivity tests and data collection tests were also successful (**Figure 5**).

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Figure 4. MIB2 and MIB3 location.

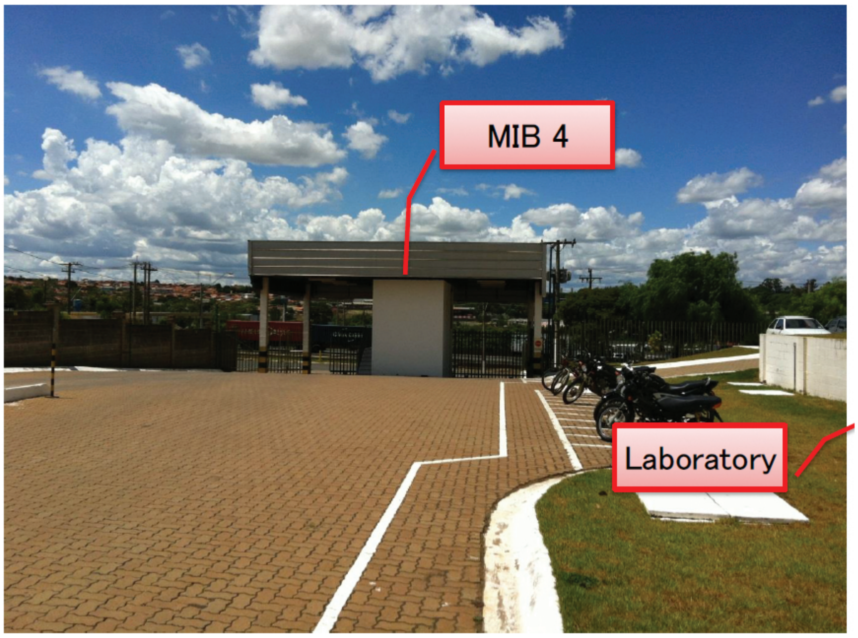

Figure 5. MIB4 location.

3. Telecommunication

The telecommunication network is one of the most important components for the construction of an advanced metering infrastructure (AMI). For the smart city project in Sao Luiz do Paraitinga it has been decided to test three different communication solutions for the last mile and a WiMAX backhaul in unlicensed frequency.

- RF mesh
- Narrowband PLC
- Ultranarrowband PLC

3.1. RF mesh

For communication access to the last mile (NAN—neighborhood area network), it has been chosen a RF MESH IPv6 solution, IEEE 802.15.4e/g, unlicensed frequency, 900 MHz, which ensures a good range when compared to solutions using 2.4 GHz.

The bandwidth for this solution reaches 150 kbps sufficient to traffic information from meters, even when submitted to multiple hops.

The amount of data generated per meter in a residential customer is relatively low, it is not necessary to have high data rates. Energy consumption for transmitters installed on the meters should be low, preventing the increase of technical losses in the distribution system.

To achieve these requirements, the solution was to use the IETF 6LoWPAN—RFC4944—IPv6 [5] over low power WPAN.

The mesh network is the best option for the municipality, since buildings are old and many of them listed by public patrimony. There are examples where the meter is installed in unconventional places. There were cases in which the meter was located within the customer's residence and even behind the refrigerator. In these cases, it would be hardly possible that the meter communicates directly with the data concentrator. It is necessary to use other meters that are closer to the concentrator, creating a more reliable path. To ensure low latency and sufficient bandwidth to traffic information without the need for retransmissions, the limit of hops was limited to 6.

For communication of 3500 m with RF MESH technology it took 20 concentrators with capacity for up to 5000 customers each. The need for 20 equipment was due to low customer density, especially in rural area, where customers are scattered throughout the municipality area. The average occupancy per concentrator is 177 m, and the most occupied one has around 700 m connected to it.

Despite the studies having indicated the need for 20 RF mesh concentrators, not all equipment have been deployed, due to backhaul installation difficulty in the rural area. These points would require investments in expanding the power grid and signal repeating devices, bringing the final communication cost per point as much as 50 times higher than the value of one point of the urban area. Thus, seven concentration points have been canceled, disabling the communication with 694 m.

The RF mesh solution was not feasible technically and financially in areas with low density of meters, requiring high investment in infrastructure to install the backhaul communication and provide connectivity to the AMI concentrator. Another point we should consider is the underutilization of the concentrator, which has the capacity to handle up to 5000 customers and in this environment would not reach even 100 customers.

3.2. Narrowband PLC—PRIME

To test the functionality of the solution in the Brazilian environment, the PoweRline Intelligent Metering Evolution (PRIME) technology of narrowband PLC has been deployed, which

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enables the transmission of data on the grid with speeds up to 1 Mbps. This solution is widely applied in Europe, presenting excellent results. It has a telecommunication architecture open and nonproprietary focusing on interoperability and scalability. The full interoperability of the solution creates very homogeneous competition between vendors. As a result, PRIME meters are among the cheapest smart meters on market, being a huge advantage to distribution utilities.

Two data concentrators have been deployed to communicate with 75 m in two distinct transformer circuits. The solution presented a satisfactory result, being able to communicate with the meters daily at least six times. This result enables also connect/disconnect commands to be executed by the meters with time intervals from around 4 h, which is a completely reasonable timeframe for such kind of service.

As the data signal is injected into the secondary of the power transformer, one data concentrator for each power transformer is needed. With this operational feature, the solution becomes more financially attractive in the cases where the number of customers connected in the power transformer is high. For this project the average number of customers per transformer is less than 20 customers, which is the reason why the testing of the solution was limited to two data concentrators. However, lower cost data concentrators are being developed and recently appeared on the market, making the solution more attractive to be used in a wide range of grid arrangements.

3.3. Ultranarrowband PLC

To test a smart metering solution for customers located in the rural area of the municipality of Sao Luiz do Paraitinga, an ultranarrowband PLC solution that enables two-way communication on the medium and low voltage distribution grid was installed, being able to exceed transformers on the grid and reach distances greater than 100 km, a common distance in the distribution network in rural areas.

The implemented solution uses the power distribution grid as the path of communication from the meter connected to the low voltage up to medium voltage system at the substation. The solution was installed to cover the four feeders that make up the electrical distribution system of this municipality, thereby, any meter with this technology that is installed in the electrical system is able to communicate with the PLC system.

The solution is composed by a collection software installed at the Data Center, equipment deployed at the substation, such as CTs and processing units, and the meters.

3.3.1. Substation communication equipment

The main components that composed the SCE are:

- Central receiving unit—CRU
- Outbound modulation unit—OMU
- Modulation transformer unit—MTU

- Inbound pick up unit—IPU

Once the CRU receives the command of the central system, the CRU sends the instructions across the electrical network via OMU by MTU for the meter. The meter sends a response to the command also across the power grid and the response is captured by the IPU which forwards the response back to CRU. The CRU responds back to the central system.

The CRU sends out commands to the OMU. The OMU then sends the command to the meter by a slight variation of current in the zero crossing of the 60 Hz sinusoid. This mode of operation ensures the solution the range of dozens of kilometers from the power substation.

Similarly, the communication originated from the meter to the IPU is obtained by sending a signal near the crossover point of zero volts. When the CRU sends commands to the meter, the IPUs await an answer in a particular way over the power grid.

Due to this way of information transmission, the bandwidth is very low, on the order of bits per second, limiting the application to one or two daily readings. On the other hand, it does not use signal modulation at high frequency, therefore, it is possible to transmit data over long distances, not suffering relevant attenuation or signal jamming/filtering by other equipment belonging to the electricity distribution grid (e.g., transformers, capacitors, etc.).

Despite the low data transmission capacity, the solution meets the project requirements. The fact that the municipality has only one power substation and only four feeders facilitated the equipment installation process that made up the solution.

3.4. Backhaul

To provide communication between RF mesh concentrators, DA devices, distributed generation and PLC concentrators, a WiMAX network was built using unlicensed frequency −5800 MHz. In this frequency range, Brazilian legislation limits the transmission power of +30 dBm, which becomes a problem when it is desired to achieve distances over 3 km in a hilly terrain, such the one found in Sao Luiz do Paraitinga.

With these features and limitations, it was necessary to build a new communication network, using point-to-point radios in frequency of 900 MHz. Despite achieving a lower bandwidth comparing to WiMAX radio, up to 1 Mbps, the network meets the needs, mainly to attend AMI concentrators which have few connected meters.

All antennas were installed on poles that serving the power grid, with an average height of 6 m above the ground.

A hilltop near the central area of the municipality was used for the installation of base stations. This hill is at an altitude of 935 m above sea level, while the urban area of the municipality is at an average altitude of 760 m above the sea. This difference in altitude allowed the use of a conventional pole with 11 m in height to the antennas installation, rather than a tower, significantly reducing deployment costs of the backhaul network for the urban area.

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Even using this hill, it was necessary to install several repetition points to enable the links to the AMI concentrators installed in the rural area. In the example below, it took two points of repetition, using point-to-point radios at 900 MHz (**Figure 6**).

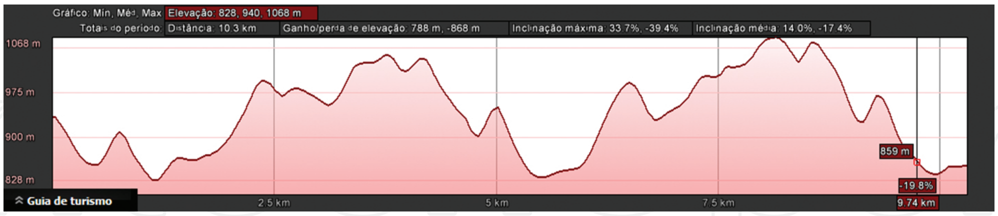

Figure 6. Topology of one link that needed repetition.

For installation of these repeaters, it was necessary to extend the electrical network and install MV/LV transformers to make it possible to feed the radios.

It was not financially feasible to do adequacy in all the necessary points of repetition, being prioritized the points with the highest number of customers per AMI concentrator.

4. Information systems

4.1. System architecture

Data collected and addressed to field devices must be managed by specialist systems. In a general smart metering architecture, the following systems are involved:

- MDC—meter data collector: it collects periodically data from meters and forwards it to the MDM; manages command stacks and is the point of interface between the MDM and the field equipment; implements metering protocols, in order to convert data received and sent to meters to adapt it to the formats expected in interfaces with the MDM; sometimes also plays the role of a network management system (NMS), managing the network in order to access the meters, usually happens when meter reading is not done in transparent mode.

- MDM—meter data management: it manages all metering processes.

- OMS—outage management system: it manages outage information, being able to correlate outage events in order to aggregate them and associate to the most probable point of failure.

- WMS—workforce management system: it manages service orders to be executed by the company specialized human resources and allows operators to schedule and prioritize execution of services.

- NMS—network management system: it manages the communication network equipment, being able to collect communication statistics and control equipment configuration, connectivity and access.

- CIS—customer information system/billing: it manages customer information, such as relation of equipment in customer premises, billing parameters, billing cycles and further commercial processes.
- Customer portal: web interface in which customers access services offered by the company and can visualize information related to their accounts.

All the systems have specific roles in the metering processes, an information flow must exist between them, which is done by the use of system interfaces. Several technologies are available, but all the interfaces built specifically for this project were developed using webservices. In **Figure 7**, the flow of information between systems for the project is presented.

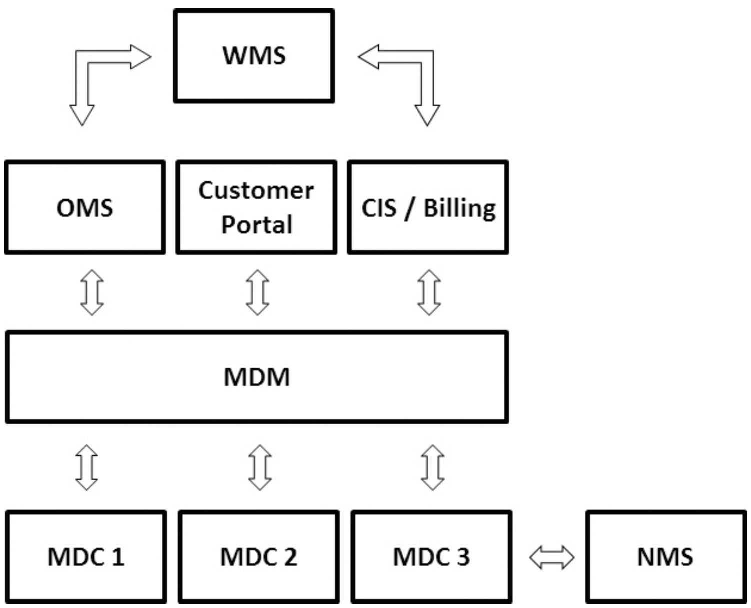

Figure 7. System architecture.

Note that there are three MDC systems, which is not a peculiarity of our implementation. The MDC is intimately related to the meter protocol used on the devices and also the communication technology, therefore it is not unusual to find several MDCs connected to a single MDM. In this project, three different sets of technologies were evaluated, resulting in three different MDCs.

For the RF mesh solution deployed, the communication network is based on IP, and there is a dedicated NMS to manage the radio network, providing connectivity to the meters. In this case, the MDC has to exchange information with the NMS in order to discover the IP addresses of the meters and be able to communicate transparently with them. The NMS also receives last gasp alarms (power outage) from the NIC card present on the meter and forwards it to the MDC, which forwards it to the MDM.

The MDM is the central piece of the solution, gathering information from all the meters, regardless of which MDC they belong to. Its database contains information that must be synchronized with the CIS, such as the meter related to each customer, the billing determinants, the billing cycle and other customer characteristics that are used in the MDM for other processes, such as losses detection. The MDM is also integrated with the OMS, being able to report power outages in its supervised customers. For billing purposes, in Brazilian regulation, only one read is necessary per month, and the MDM sends only the necessary amount of information to the CIS in order to complete the billing process. However, the meters contain much more detailed information, such as hourly consumption, which is of great interest to customers. For that purpose, the MDM is also integrated with a web-based customer portal, in which customers can follow their load profile and also establish a consumption goal, which is monitored by the MDM, which send notices when the customer has reached a predetermined threshold or when the projected consumption exceeds the customer goal.

To complete the processes, some actions on the field must be executed, mainly reading meters that failed the billing process and re-establishing power outages. These actions are executed through service orders, which are generated by the CIS and OMS and managed by the WMS.

4.2. MDC/MDM interfaces

Except for MDC systems, all other components of the architecture are unique and can have specific crafted interfaces. In the case of MDC/MDM interfaces, however, it is more effective to have one single specification, which reduces further costs of integration of the MDM with new MDC systems that might be deployed. This is possible, since the main services that a MDC must provide to the MDM are the same for all the meter and communication technologies. There will be some specific implementations, but the broader scope of the integration is to be less expensive and quicker to put in production.

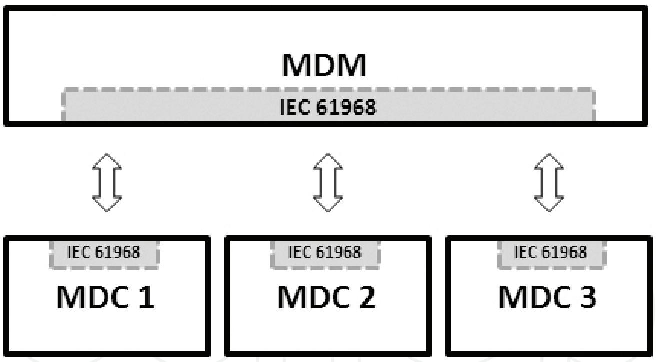

Figure 8. IEC 61968 connectors.

For the project, the services provided by both systems were defined following the IEC 61968 standard [6], which defines a framework of XML structures to represent the most common needs of utility system integrations. A single connector on the MDM is capable of integrating with different instances of the IEC 61968 interface (**Figure 8**).

The interface covers methods for synchronization, reading, configuration and events reporting. **Figure 9** is an example of the message flow for an event query made by the MDM onto the MDC.

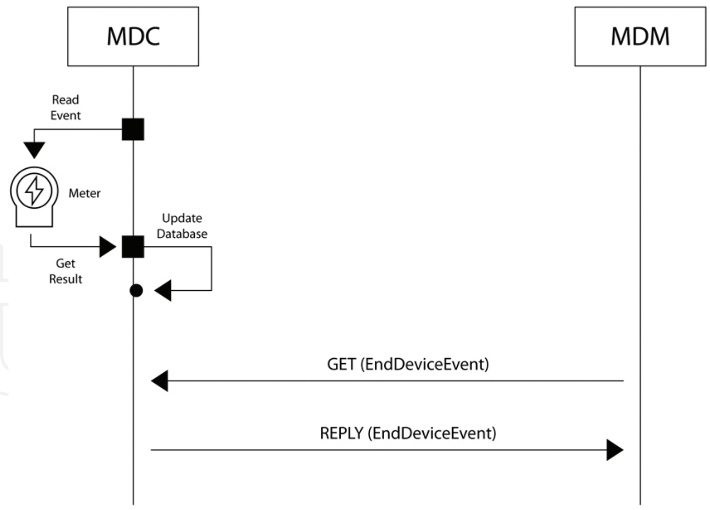

Figure 9. Message flow for one IEC 61968 method.

4.3. The value and cost of data

The MDM is a data repository that can contribute to several areas inside a utility, from energy demand planning to asset management. All the process of collecting and organizing this data is the most important role of the MDM and feeds all its other functionalities. The system is loaded with templates for each type of equipment, defining the variables to be read and the frequency and resolution of each reading type.

Reading	Ultra-narrowband PLC		PRIME PLC		RF mesh	
	Resolution	Reading frequency	Resolution	Reading frequency	Resolution	Reading frequency
Accumulative registers[1]	Hourly	Daily	Hourly	Daily	Hourly	Daily
Load curve[2]	NA	NA	Hourly	Daily	Hourly	Daily
Engineering measures[3]	Instant	Daily	Instant	Daily	Instant	Daily
Events	On demand	Daily	On demand	Daily	On demand	Daily

[1]kWh and kVArh per time of use (peak, off-peak, shoulder, etc.).
[2]Array of kWh and kVArh information with hourly timestamps.
[3]Instant values of current, voltage, frequency, power (W, VA and VAr).

Table 4. Reading frequency and resolution for smart meter's data.

It is very important to understand that there is a limitation in quantity and frequency of readings per meter, which is determined by the communication technology, the meter hardware and the processing performance of the systems and interfaces (**Table 4**). In the project, we have initially worked with the following configuration:

The treatment given to each reading is very important to assure the most cost-effective solution. On one hand, bringing too few information might not suit the business needs; on the other

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hand, bringing too much information might make information access slower and increase storage costs. Therefore, the amount of readings of each variable must be tuned in order to be meaningful and just sufficient.

For instance, RF mesh and PRIME PLC technologies would allow 15-min readings of energy consumption. But the average consumption of the customers where the meters were deployed is 0.07 kWh for this time interval. There is no meaning in collecting this amount of data, since it is more likely to be redundant information. Hourly reads are sufficient for this use case.

On the opposite way, instant readings of voltage and current collected only once a day by ultranarrowband PLC have not contributed to any application of this information. Since there is no meaning in it, these readings could be disabled from the reading process on the MDM, saving several gigabytes of useless data.

4.4. Smart metering processes

The main smart metering processes that the MDM enables are:

- Remote meter reading
- Billing
- Nontechnical losses detection
- Load profile monitoring
- Outage detection

As mentioned in the last topic, the remote meter reading process feeds information to all the other processes.

Billing uses the registers collected daily to calculate the billing determinants and send the information to the CIS in the dates corresponding to each billing cycle. Having a periodic reading allows the system to make reading estimates in the case which the information is not collected on the days preceding the billing of a customer, reducing the impact in the number of service orders sent to the field.

Comparing the consumption from a transformer and all the meters connected to it, we are able to calculate the losses for each secondary circuit. The system then compares this value to a defined threshold and notifies an operator when probable nontechnical losses are found.

The same consumption can be also monitored by the system and compared to a goal defined by the customer through the web portal. When a certain threshold is reached or when the consumption projection by the end of cycle exceeds the goal, the customer is then notified by e-mail or SMS.

Some meters support the last gasp functionality, in which, under a supply loss, the meter sends an alarm before shutting down. This alarm is then forwarded throughout the systems and is received on the OMS that manages the outage and can correlate the information with the information received from other meters, allowing a much more accurate fault detection.

5. Project management

Once this is not a project management book, it will not describe generic tools to implement project management. The project was managed following the market best practices [7] and in this section it will be transposed a little part of experiences, difficulties and lessons learned about how to manage a smart grid pilot project. It may be possible to apply these tips to another type of project design, however it is necessary to consider that the knowledge of this section was acquired on a smart grid application developed in Brazil.

The first important experience to share is how to build a technical specification. This is a very important part of the project; in this step, we can determine the success or failure of the project. This activity is the key process to maintain your project in line with your project management plan. Usually, to write a technical specification, the project manager focuses only on the technical characteristics of products, leaving aside some points that will be fundamental to the quality and project costs. Some important questions that must be answered in a technical specification are related below, each of these items might result in delays or changes in project schedule.

- Which technologies, equipment and technical features are expected?
- Which technical validations are necessary for the equipment and systems approval?
- Where each component of the solution is produced? Is it produced on a third party factory? Is it necessary to import some components?
- Is there subcontracting? In which terms?
- Which training or certification is required?
- How will the project schedule be? This item can be subdivided into several parts, below are three important points:
- Which are the contract terms: technical rounds, trade rounds, internal approvals, contract signatures, production factories, imports, deployments, tests, bug fixes.
- Which problems can impact deadlines: delays in subcontracting, problems in product development, imports, shortage in skilled labor, pioneering deployments.
- The political and economic scenario can influence directly on acquisitions, productions and deadlines, exchange rate changes, tax increases and reduction of subsidies.
- How will the payments to all suppliers be? It is an important point since several problems may occur during the project. Hold, block or suspend payments, supported by the contract, can be effective management tools.
- How interest clauses and penalties will be designed?

Project management means dealing with the unexpected, depending on the extent of the impacts, legal action should be taken. In technical specification it is necessary to establish how the penalties will be applied, this is a tool that could help in harsh situations. It is noteworthy that the application of contractual penalties should be applied in a manner that does not compromise the structure of the project or any supplier. Evaluate project points, deliveries or developments that are on the critical path of schedule, divide the macro project into several subprojects with milestones, deliverables and well-defined responsibilities, with penalties endorsing it, use this as a way to mitigate future risks.

So, how can we map all these points before signing the contract? It is recommended that the procurement process can be divided into parts, which can be carefully evaluated before signing the contract.

5.1. Procurement process

5.1.1. Request for information (RFI)

This is the preliminary technical specification which describes all questions related to equipment, financial health of the company and experiences that must be considered to choose a partner. Through this instrument an initial assessment of suppliers in the market, their prices, their products and relevance on the subject can be made.

5.1.2. Technical visit

During the visits, it will be possible to know the company structure. Possible doubts and solutions can be addressed in order to get the necessary support to have a very complete technical specification and with low risk exposure.

5.1.3. Technical meeting with suppliers

The project technical team needs to discuss with suppliers every issue related to technical implementations. This is the moment when the project team will define or change the technology assumptions related to the expected solutions.

5.1.4. Site survey

The site survey is the moment when the suppliers check the technical assumptions to evaluate and measure the project implementation risks. This step is essential because an error in that process can result in either over or undersized project costs; in both cases this could derail the project.

5.1.5. Preparation of technical specifications

The technical specifications should be established after the knowledge of the previous stages, which technologies to be applied, which solutions were verified in the field, which are the risks and which actions will be taken to mitigate them. At this point we should be aware on aspects of the schedule, delivery and payment method for this type of solution. The payment will be made after commissioning or upon delivery of each equipment?

5.1.6. Request for proposal (RFP)

Submission of all specifications defined with the market. It is noteworthy that the amount of technical specifications is directly linked to the contracting strategy and contract management, a fact that must be decided in the strategy of the project.

5.1.7. Response to RFP

Moment in which suppliers respond to the technical specification by presenting their solution proposal in technical and commercial terms.

5.1.8. Technical evaluation

Formal response to the technical specifications, selecting which suppliers meet all the technical requirements.

5.1.9. Commercial negotiation

Moment in which the commercial negotiation is made among all technically validated suppliers to define the most suited proposal to the project's budget. It is important to notice that sometimes the cheapest solution is not the most suitable, since it may present higher maintenance cost or adaptation needs.

From that moment, we are able to select a set of suppliers that are capable to meet all established requirements in the technical specification process. The next stage is how to elaborate the contract, due to the importance of this activity and the relevance of its impacts, the next session will be devoted to address some of its particularities. This is a topic of great matter, since smart grid is a new concept in Brazilian market and many companies are developing brand new products to supply utility needs. Since these are the very first experiences both for the utilities and for the suppliers, extra care is needed in writing the contract to avoid any issue that could stop the project due to operational or financial impacts.

5.2. Contract management

Once we have built a good technical specification, the next critical process is the contract management. It is very important to rely on tools that can ensure that the supplier can match the project requirements. A good financial analysis is the first step, after this it is important to check who are the subcontractors and who are the suppliers of your provider. China is relevant player to manufacture components or equipment assembly. Exchange rate changes can dramatically affect your budget, for this reason it is essential to define the maximum exchange rate risk, insert in your contracts tools to control and monitor exchange variation. You will need to alert your supplier of this risk, a planning failure of your supplier might lead to delays in your schedule or even new disbursements in your project.

Once you are secure with the financial issues it is time to focus on the technical requirements. To help in these issues it is important to answer some questions: Is the technology expertise of your supplier sufficient to provide the solutions needed to your project? Which

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are the finished products and which are the products that need to be developed? The technical specification helps to answer these questions, however, in this section we need to use this information to design the penalties. To use it as a scope control tool, each relevant milestone should be related to a penalty. Penalties should be sized in order to represent the importance of the milestone, but not high enough to impact financial health of the supply. It is important to have penalties that, once triggered, have their values raised over the time in which the supplier is not attending its compromises. A contract should not be designed to harm its partners. Suppliers are partners in the project, so the penalties must be used only in critical situations. Never place all penalties on a single item or delivery, apply it in partial and time-spaced deliveries. If your supplier delays, try to establish a dialog before the imposition of fines, a conversation is always the best solution, however a small and constant fee can help change the direction of the project and helps engaging all the resources towards the project accomplishment.

5.3. Scope controlling

This section will describe important tips for monitoring project activities and how to monitor the progress of the schedule; this is the point to deal with the unexpected and the possible changes. A relevant tool might help in this part of the project, it is important to bear in mind how the project scope is performing compared to the scope baseline. It is necessary to monitor the work performance, project management plan updates, project documentation updates and other important updates. Every single update must be planned and monitored in project schedule; a small change in a critical path could be the difference between the success or failure of the project.

Not always your supplier knows how to implement project management skills and that would be an unpleasant surprise. It might be necessary a strong management structure in your supplier, these measures must be implemented in the partners or in the project team to maintain the performance closest to the project baseline. First of all, it is important to identify what is delayed and which is critical, after this you must bear in mind that in most cases it is possible to find an alternative path, a tough action of the project manager can often help to find solutions. It is usual that project partners have many other important developments; it is very relevant to find a way to make aware the partner on the project priorities. This can be achieved by project meetings, penalties or rewards linked to the progress of the project schedule. The project manager must understand the difficulties to help the project team to address problems and monitor the solutions implemented and their impact. It is very desirable that the project team understands the impact of each proposed amendment; it will help the team to design better alternatives. For this, everyone must know the needs of stakeholders and what is expected of each phase or goal to be achieved. It is important that the project leader clarifies to the team the relation between each delivery and stakeholder needs.

It is imperative that the project team and partners trust the project manager, who should always keep a respectful and professional close relationship with each member of the project. The relationship between the project team and the project manager is another critical factor in the success of every implementation. The project leader must seek the same relationship conditions with their business partners; the ideal is that it has free access to all information from their suppliers that can avoid unexpected surprises and provide time to react if any unforeseen happens.

It is undesirable, but in some cases the project manager will need to realign expectations with stakeholders; this can occur for several reasons: the failure of the project team analysis, external conditions changes to the project team or any other event that may have altered the initial conditions. Before realigning expectations, the project manager must ensure that everything that can be done to correct the problem is done, should raise all impacts and delays, should propose new actions that can mitigate risks and reduce impacts. The project sponsor must have all analysis before using his influence to change the project conditions. The external regulatory body should be aware of changes to the project schedule, once the financial resources of a smart grid project are often from regulated funds it is very important that the regulator sees you as a partner with whom you can communicate changes and conditions, to mitigate the disallowance risks or other regulatory issues.

5.4. Project closure

At every stage of the project, it is important to keep a very accurate documentation control; this will be very valuable during project closure phase. In this section it shall be prepared delivery reports of products and milestones reached, the balance sheet and any changes that have occurred in the scope of the project. If the project manager played his role there will be no surprise at this stage, all alignments have already been made, and it will be required only a formalization of each item.

The client must already know all the features and the operation mode of each delivery, however, it is extremely necessary to provide documentation required for the use of each solution implemented. The client must receive technical reports containing the test results of each product or solution, in this manner there should be no doubts about deliveries and their use.

All the tools used during the cost management and all generated documentation will be of great help to the financial closing, the disbursement control linked with the project baseline will help it to explain the costs of project, every change must be documented to become part of the final financial report.

All research carried out must have its reports and characteristics found; we should be able to clearly see certain requirements as applicability and relevance to the activities of the project. In the case of a project that uses regulatory funds for research and development, criteria such as originality and reasonability of costs must also be considered.

All information must be present in a final report, which must contain clearly each of the requirements, the manner in which they have been met, the costs and how all research and learning were managed and led to the final product.

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