TECHNICALAND FINANCIAL ASSESSMENTS FOR COMPARISON OF MEASUREMENT TECHNOLOGIES IN THE SMART CITY BUZIOS PROJECT

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ABSTRACT

In the moment of the definition of smart metering technology that will be adopted to look for micro and mini distributed generation, the utility companies should pay attention to technical and financial aspects of this strategic decision. In this study are considered the information of the measuring systems of an electric utility company in Brazil along with data on the deployed smart metering technology used in the Smart City Búzios Project. The ANEEL (Regulatory Agency for Electric Energy in Brazil) presents a methodology for evaluating costs and benefits of electronic measurement implementation in Brazil. So this article is based on the methodological approach described in the document suggested by the regulator. Considering among others the aspects: time horizon, update rate, product quality, energy cost, equipment cost, operating cost, failure rate, final disposal, replacement cost, workforce to change the equipment and idle cost. This research will consider some benefits as: meters replacement, reduction on local measure readings, technical losses reduction, non-technical reduction and change of user habits. These evaluations are made within the Smart City Búzios Project and it serves as the basis for related research in places with different measurement technologies deployed, and the system need a technologically upgrade due to generation distributed deployment systems that will be installed.

INTRODUCTION

The paper describe a part of a research done by Fluminense Federal University (UFF) evaluating different aspects regarding the implementation of new technologies to measure energy consumers. This paper is organized as follows, after the introduction, the metering technologies found in measuring systems deployed by the Ampla S.A. (Electric utility company in Brazil) is presented (Comparative Analysis). In sequence, the methodology of financial assessments for implementation of smart metering is presented. The methodology presented is then applied in two distinct scenarios of mass deployment of smart metering and finally, the main conclusions and discussions are found in the last section.
This research considered as data base the information obtained by Smart City Búzios Project (SCBP) [1]-[2].

COMPARATIVE ANALYSIS OF AMPLA'S MEASUREMENT TECHNOLOGIES

The electronic measurement technology is a great objective of the utility companies and a qualitative analysis of this technology in Brazil is presented by [3]. In this section will present the main features and functionalities of the measurement technologies used by the Ampla [4].

Conventional Electronic Meters (CEM)

The electronic meters record only the accumulated active energy and the customer can view their consumption directly on the meter itself.

Ampla Chip (AC)

This technology also registers only the accumulated active energy, however, consumption visualization can be done through individual query terminals that are updated hourly. Its functionalities are: reading, suspending and remote reconnection through GPRS technology (located between the utility and the primary metering concentrator). The communication between the primary concentrator and secondary can be through technology PLC or by RF.

Sentinel (SE)

This technology offers mass memory with capacity to store information for up to 47 days, records active and reactive energy, voltage, current and power factor. Also has calendar and is able to apply multiple tariffs.

Smart Metering (SM)

The Smart Metering is the most suitable technology for customers who have both micro and mini distributed generation and who adhere to multiple tariff system. The smart meter features are: active, reactive, inductive and capacitive recording; Meter Shutdown Counter, Hourly Demand; Recording of reverse energy per time ranges via display and via serial communication interface; Clock and internal calendar that allow to store date and time of power failures and return of energy; and record the active and reactive energy for up to 6 time ranges.
In order to compare electric energy measurement technologies, Table I summarizes the main characteristics and functionalities available for each technology.

Table I - Comparison of the functionalities of different energy measurement technologies.

Functions	*CEM*	*AC*	*SE*	*SM*
Active Energy	X	X	X	X
Reactive Energy			X	X
Demand			X	X
Voltage			X	X
Current			X	X
Power Factor			X	X
Hourly Consumption			X	X
Calendar			X	X
Continuity Indicators			X	X
Mass Memory			X	X
Optical Output			X	X
Ethernet port			X	
PLC communication		X		X
GPRS communication		X	X	
RF communication		X		X
Remote turning on/off		X		X
Meter Access Control		X	X	X

METHODOLOGY FOR EVALUATING OF THE COSTS AND BENEFITS OF SMART METERING IN BRAZIL

The ANEEL presents in the reference [5] a methodology for evaluating the costs and benefits of implementing Smart Metering in Brazil. Thus, this paper is based on the methodological approach described in the document suggested by the regulator. The main considerations are presented as follows.

Considerations

Time Horizon - The ANEEL suggests that studies should be conducted for a time horizon that coincides with the life of the equipment. Thus, all the benefit that the meter will allow should be captured by the study, without the need to consider the cost of a new replacement. Currently, the regulation considers that the lifetime of the meters is 20 years.

Update Rate - All future values should be brought to the present in order to compare them. The rate adopted should be equal to Weighted Average Cost of Capital – WACC– (9.95% per annum).

Failure Rate - This indicator refers to the percentage of field meters that fail before the end of their useful life. When this occurs there is a cost to replace the meter. The electromechanical meters tend to get a higher failure rate.

Costs

The costs are essentially related to the replacement of the meters, which are composed of workforce to change the equipment, equipment cost, idle cost and cost for the disposal of meters removed from the field.

Workforce to Change the Meter - The annual cost of workforce to replace meters is the average workforce cost to replace a meter multiplied by the number of meters to be replaced annually.

Purchase cost - The purchase costs of the meters is the number of meters to be replaced multiplied by average price of the meters.

Idle cost - The idle cost is the value not yet depreciated of the withdrawn electromechanical meter. ANEEL suggests that for each meter withdrawn, the utility company should be reimbursed for the remaining meter value of the not yet fully depreciated. For study purposes, the methodology considers that the older meters will be removed first, so that the younger ones can "age" and generate the lowest possible cost. It is suggested to carry out simulations for a term of exchange of 5, 8, 10, 12 and 20 years.

Benefits

It is expected that the implementation of smart meters will reduce some of the electric utility's operating costs, which when considered in the reference company may lead to a reduction of the tariff and a benefit to the consumer. Among the costs that would be reduced, the following stand out: replacement of faulty meters, reading and suspending/reconnection.

Meter replacement - Smart meters, in relation to electromechanical meters, can be considered to have fewer defects over their lifetime. In this way, the electric utility will have less expense with the purchase of equipment to replace the defective equipment and with the workforce to replace such equipment.

Reading - One of the advantages of the smart meter is the ability to perform remote reading. With this, it is not necessary for a meter reader to visit each consumer unit on a monthly basis. To perform a reading, a utility company needs to have a remote reading infrastructure. The cost of implementing such facilities is still unknown. It is hoped that pilot projects as Smart City Búzios can help to know the costs of such facilities.

Suspending and reconnection - Through bi-directional communication between the utility company and the meter, the suspending and reconnection operations can be carried out at a distance, without the need to send a representative of the utility company.

Technical losses - There is data showing that the smart meter has its self-consumption lower than the electromechanical meter. In this sense, the electromechanical presents, on average, consumption of approximately 1.3 W, whereas in the smart meter this value is about 0.5 W.

ASSESSMENTS OF COSTS AND BENEFITS OF SMART METERING IN AMPLA’S AREA SERVED

This section shows the results of the application of the methodology presented in the previous section in the evaluating of the costs and benefits of the implantation of the smart metering in Ampla’s area served. This evaluating also considers the data and learning obtained from the Smart City Búzios pilot project.

The financial assessment presented in this section will be performed considering the replacement of electromechanical and electronic meters by smart meters.

In order to carry out the assessment of the costs and benefits of the smart metering implementation, it is necessary to know certain parameters of the Ampla's area served. Table II presents the parameters and their respective values used in the calculation in the financial analysis.

The Table II also includes a series of parameters of great importance for an adequate financial evaluating. Among the several parameters considered in this analysis, some of them were only known from the experience obtained with the Smart City of Búzios Project. These parameters were: costs of the infrastructure of the remote reading system, meter purchase costs, workforce to change the meter, and the failure rate of smart meters.

Costs

Table III shows the annual partial costs that were obtained from the sum of cost of workforce to replace meters, costs of purchasing new equipment, annual costs related to maintenance and installation of the infrastructure of the reading and remote suspending/reconnection system.

The partial costs were calculated for different regulatory deadlines for changing the meter, as suggested by the ANEEL methodology.

According to the values shown in Table III, it appears that the partial annual costs tend to decrease as the regulatory deadline for changing the meter increases.

With regard to the data to calculate the idle cost of electromechanical meters that will be replaced by smart meters, information such as quantity and age distribution of electromechanical meters are essential [5].

Although the values found for the idle cost are not explicitly stated in this article, these values were taken into account in the calculation of the project NPV presented in Table V.

The Total Annual Cost is the sum of the annual partial cost with the annual idle cost.

Therefore, considering the data presented in Table II and the methodology for calculating the annual costs discussed in the previous section, it is possible to obtain the Total Annual Cost for the different regulatory deadlines, which will be used to obtain the NPV of implantation smart metering project in Ampla's area served.

Benefits

Regarding the analysis of the benefits of implantation of smart metering in Ampla's area served, according to the methodology proposed by ANEEL, this analysis can be divided into two parts: Annual financial gain with replacement of meters and partial sum of other annual financial gains.

Table II - Input data for financial assessments calculation

Time horizon **t** (years)		13
Regulatory lifetime of the electromechanical (years)		25
Update rate **TA** (%)		9.95
Price of a new smart meter **R$$_{EL}$** (R$)	Single-phase	322.00
	Two-phase	322.00
	Three-phase	330.00
Price of a new electromechanical meter **R$$_{EM}$** (R$)		400.00
Price of a new electronic meter **R$$_{EL}$** (R$)		300.00
Total number of electromechanical meters		1,199,545
Total number of electronic meters		1,035,337
Total installed meters **Q$_{ntd}$**		2,234,882
Total number of meters by type	Single-phase	1,564,417
	Two-phase	223,488
	Three-phase	446,976
Workforce cost to replace a Meter **MOsub** (R$)	Single-phase	52.00
	Two-phase	72.80
	Three-phase	93.60
Cost of a electromechanical meter reading **R$$_{LF}$** (meter reader) (R$)		0.93
Cost of a smart meter reading **R$$_{MI}$** (remote reading) (R$)		0.53
Number of annual readings **N$_{L}$**		14,394,540
Annual occurrence number suspending/ reconnection **N$_{CR}$**		8,700
Electromechanical suspending/ reconnection cost of workforce **R$$_{MOCR}$**(R$)		16.00
Annual cost of concentrator maintenance (One Concentrator for every 25 meters) (R$)		11.00
Electromechanical Meter self-consumption **P$_{EM}$** (W)		1.3
Smart meter self-consumption **P$_{MI}$** (W)		0.5
Residential electricity tariff **R$/kWh**		0.71601
Cost of workforce to install a concentrator (R$)		200
Electromechanical meter failure rate **TF$_{EM}$** (%)		0.8
Smart meter failure rate **TF$_{EL}$** (%)		1.0

The first part refers to the annual benefits in monetary values due to the lower replacement of electronic meters, since it is assumed that the smart meters have a lower failure rate when compared to that of the electromechanical meters. This benefit is calculated from Eq. (1) and from the data Table II, where the results will be presented in Table IV.

$$Rep = [(TF_{EM}.(Q_{ntd}/n)).(RS_{EM} + MO_{sub})] - [(TF_{INT}.(Q_{ntd}/n)).(R\$_{INT} + MO_{sub})] \quad (1)$$

Where:
Rep: Annual financial gain due to lower meter replacement;
TF_{EM}: Electromechanical meter failure rate;
$R\$_{EM}$: Price of a new electromechanical meter;
TF_{INT}: Smart meter failure rate;
$R\$_{INT}$: Price of a new smart meter;
Q_{ntd}: Total number of meters to be installed;
MO_{Sub}: Average workforce cost to replace a meter;
n: Regulatory deadline (deadline set by ANEEL to complete the replacement of all meters).

Table III - Annual partial cost (workforce to change the meter -workforce-, Purchase of new meters -Purchase- and Maintenance and installation of the Remote Reading infrastructure -RR-, R$ in millions)

Regulatory deadline		*5*	*8*	*10*	*12*	*13*
Workforce		27.89	17.43	13.94	11.62	10.72
Purchase		144,6	90,40	72,3	60,2	55,6
RR costs	Maintenance	1.27	0.79	0.63	0.53	0,49
	Installation	1.92	1.20	0.96	0.80	0,74
Annual partial cost		**172.5**	**107.8**	**86.27**	**71.89**	**66.36**

The second part corresponds to the sum of the annual benefits in monetary values in the operations of reading for billing and suspending/reconnection, in addition to the reduction of technical losses due to the lower self-consumption of the smart meter in relation to the electromechanical meter. The methodology used to obtain the benefits of the three operations mentioned above will be presented.
For the calculation of the benefits that the smart metering will provide in remote reading operations, bearing in mind of the learning obtained with the Smart City Búzios project, the Eq. (2) will be used:

$$Reading = \frac{1}{n} N_L (R\$_{LF} - R\$_{MI}) \quad (2)$$

Where:
Reading: Annual benefits obtained with remote reading;
N_L: Number of annual readings (equal to the number of electromechanical meters multiplied by the reading number in one year, 12);
n: Regulatory deadline;
$R\$_{LF}$: Cost of a Electromechanical Meter Reading (meter reader);
$R\$_{MI}$: Cost of a smart meter reading.

The benefits in monetary values derived from the suspending/reconnection operations executed remotely due to the expansion of the smart metering, in view of the learning obtained with the Smart City Búzios project, the Eq. (3) will be used.

$$SR = \frac{1}{n} . N_{CR} . R\$_{MOCR} \quad (3)$$

Where:
SR: Annual benefits obtained with remote suspending/reconnection operations;
N_{CR}: Annual occurrence number suspending/ reconnection;
n: Regulatory deadline;
$R\$_{MOCR}$: Electromechanical suspending/ reconnection cost of workforce;

The benefits due to the reduction of technical losses (lower self-consumption of smart meters versus electromechanical), this benefit will be accounted for by Eq. (4)

$$TL = (P_{EM} - P_{EL}) . \frac{8760}{1000} . \frac{Q_{ntd}}{n} . R\$_{Tarifa} \quad (4)$$

Where:
TL: Annual benefit obtained with the reduction of technical losses;
P_{EM}: Electromechanical meter self-consumption;
P_{MI}: Smart meter self-consumption;
Q_{ntd}: Total number of meters to be installed;
n: Regulatory deadline;
$R\$_{Tarifa}$: Residential electricity tariff (Applied by Ampla in September 2016).

The results of applying the Eqs. (2)-(4) (3)with the parameters indicated in Table II to obtain the benefits of remote reading, suspending/reconnection and reduction of technical losses are indicated in the column "Partial Sum of Other Annual Financial Gains" in Table IV.

Table IV - Annual Benefits of implantation of smart metering (R$)

n	Annual Financial Gain with Replac. of Meters	Partial Sum of Other Annual Financial Gains	Total Annual Gain
5	-87,445.27	3,377,141.64	**3,289,696.37**
8	-54,653.30	2,110,713.52	**2,056,060.23**
10	-43,722.64	1,688,570.82	**1,644,848.18**
12	-36,435.53	1,407,142.35	**1,370,706.82**
13	-33,632.80	1,298,900.63	**1,265,267.83**

Since the Annual Financial Gain with the Meter Replacement and the Partial Sum of Other Annual Financial Gains are known, it is possible to obtain, from the sum of these two factors, the Total Annual Gain and therefore, to know the benefits of implantation of the smart metering in all Ampla's area served. These benefits are presented in Table IV and are indicated for each regulatory period considered by the methodology.
The negative values of the Annual Gains with the replacement of the meters present in Table IV are mainly justified by the failure rate of the smart meter being greater than the failure rate of the electromechanical meter. Although a 0.2% percentage difference in the failure rate of the meters may appear to be negligible,

simulations show that if the percentage of failure of the smart meter is less than 0.94% and keeping all other variables in Eq. (1) constant. It would be possible to obtain real benefits with the installation of the new smart meters.

Financial assessments

With the partial costs, idle cost and annual benefits, and using the methodology suggested by ANEEL, the NPV of the smart metering project in Ampla's area served is obtained, as shown in Table V.

Table V - NPV for different regulatory deadlines (R$, in millions)

	n=5	*n=8*	*n=10*	*n=12*	*n=13*
VPL	-887.67	-743.26	-664.20	-600.90	-573.76

As can be seen in Table V, over most of the regulatory deadlines considered by the analysis, the annual costs are higher than the annual benefits, making the project NPV negative, indicating the infeasibility of the smart metering expansion in Ampla's area served.
One of the factors that most contribute to the infeasibility of the smart metering implementation project is the high cost of the smart meter. This can be verified through the smart meter purchase annual cost listed in Table III.
The costs of purchasing the smart meters represent about 80% of annual costs over the regulatory deadline.
In view of this, it is interesting to analyze how the price variation of the smart meter impacts the viability of the smart metering project.
Simulations show that for a smart metering project that has the characteristics presented in Table II, only becomes economically feasible if Ampla receives R$ 130.00 for each meter installed over the course of 12 years.

CONCLUSIONS

This paper presented a technical comparison between different metering technologies found in measuring systems deployed by the Ampla S.A. In this comparison it was verified that the most appropriate technology to be used in the Smart City Búzios pilot project is the smart metering.
After presenting the proposed methodology to evaluate the costs and benefits of the massive deployment of smart metering technologies, this paper has brought results of the application of this methodology in the Ampla's area served. The application of this methodology also contemplated the learning and the information obtained during the Smart City Búzios Project.
The analysis presented in this article considered scenarios to identify the economic viability of the utility's own investment for massive deployment of smart metering. As presented throughout this article, these investments only present economic viability if there are subsidies to the purchase of meters. Based on the learning obtained during the Smart City Búzios Project, where more precise estimates of the benefits and acquisition costs, implementation, operation and maintenance of the smart metering system were obtained, such subsidy would be R$ 130.00 per meter.
These results highlight the absence of an economic incentive for electric utility company to carry out their own investments in its area served.
However, ANEEL, through Normative Resolution 733/2016 [6], which establishes the conditions for the application of the multiple tariffs, indicates that the distributor is responsible for the acquisition and installation costs of the metering equipment necessary for billing in this tariff modality. In this new scenario, the smart meter is considered an essential good [7] and is therefore included in the regulatory remuneration base, which reduces the need for the utility's own investment. This recent change in legislation may provide a new stimulus for the smart metering industry.

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