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Regulatory context of smart grids in Europe and Brazil: current state and trends
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A Research Proposal for Identifying the Obstacles to Energy Storage Deployment in Brazil

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Abstract

An increase in economic activity also increases the demand for electricity, which is not followed by an increase in power supply, creating thus, a gap between consumption and supply. The reduction in this gap requires a significant mobilization of resources for long periods. In addition, the Brazilian energy matrix comes progressively incorporating renewable energy sources (wind and photovoltaic), which are inherently intermittent. This scenario push managers to maintain electric system reliable, available and modern. Energy storage can be a short and medium term solution for these challenges as it has several applications in electrical systems, bringing benefits such as delaying expansions and upgrades of the transmission and distribution systems, integration of alternative energy sources with the electric grid, reducing losses, etc. However, in spite of such benefits, energy storage is not widely used. This paper aims to present the benefits arising from the energy storage as well as a research proposal to identify the main obstacles to spread the use of energy storage in the electric grid.

Keywords: Energy storage, alternative energy resources, transmission system, distribution system.

1. Introduction

Over the past forty years, the electricity consumption has been increasing in Brazil. The electricity consumption between 1970 and 1985 grew at an average rate of 10.6% [1] and between 1996 and 2006 the consumption grew at an average rate of 5.1% [2]. Also according to [2], the projected growth for the period between 2010 and 2020 is around 4.9%. According to [2], to meet the growing demand it would require the power of installed generation to grow at an average annual rate of 4.7% by 2020. However, the annual growth in generating capacity between the years 2005 and 2009 was approximately 2.5% [3].

The Brazilian power system relies mostly on large power plants far from large consumer centers what requires long transmission lines. In 2010, the extension of the national grid transmission lines was approximately 100,000 km. According to [2], it is expected that they extend to 142,000 km, an increase of approximately 40% which means an average annual expansion (in km), about 4% in the transmission grid. Thus, it is possible to conclude that the demand for electricity has been growing steadily at a higher

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rate than the system modernization rate. Such gap does the system gradually decreases its capacity to meet the demand.

Because of such gap, the number of interruptions in the power supply has been increasing [4], [5]. The estimated cost of interruptions to American consumers is approximately $ 80 Billion per year [5]. The interruption in the power supply highlights the inefficiency of the electrical system and emphasizes the need for modernization of the system so that it can adequately respond to the growing demand for electricity.

According to [4]-[6] there is a very high incidence of discontinuations in power supply due to problems at the level of transmission and distribution and such disruptions could be mitigated by adopting a distributed energy storage strategy. While building new generating plants and transmission lines is an expensive and time-consuming endeavor, the energy storage can optimize the current electrical system capacity factor. The storage could be a more economical alternative to the expansion of infrastructure [5]. In addition, alternative sources of energy, particularly wind power and photovoltaics, have increased their participation in the composition of electricity generation facilities [1]-[5]. Although beneficial from an environmental point of view [13], its intermittent character in the supply of electricity increases concerns about the reliability of the system. The literature [4]-[9] points energy storage as a natural solution for the integration of alternative energy sources to the electrical system.

Despite all the benefits brought by energy storage, it is not widespread. What are the factors that difficult the deployment of energy storage technologies? What can be done to overcome such obstacles?

The objectives of this paper are to relate the benefits brought by energy storage and propose a research method to identify and study the main obstacles to the spread of energy storage.

Such a research is justified since it will provide the academic community with relevant information on energy storage, such as the benefits brought by it, the main technologies, how these technologies are classified, the main applications for these technologies, the requirements of such applications, the costs and the efficiency and lifetime of the main technologies.

2. Grid Storage Applications and their Benefits

As previously emphasized, one of the most promising approaches to addressing the growing limitations of the electric grid and the increasing demand for electricity is to incorporate energy storage technologies into the grid. Energy storage can provide multiple benefits, including balancing services such as regulation and load following; supply power during brief disturbances to reduce outages; defer transmission and distribution upgrades; and greatly enhance the electric grid reliability.

According to [4], [5], [11], [12], some of the grid store applications and the benefits associated are the following.

2.1. Electric Energy Time Shift

Charges the storage plant with inexpensive electric energy and discharges the electricity back to the grid during periods of high price [4].

2.2. Improve the Electric Supply Capacity

Reduces or diminishes the need to install new generation capacity [4], [10].

2.3. Load Following

Adjust the power output/input of the storage plant in response to variations between electricity supply and demand in a given area [4].

2.4. Area Regulation

Reconciles momentary differences between supply and demand within a given control area [4].

2.5. Electric Supply Reserve Capacity

Maintains operation, when a portion of normal supply becomes unavailable [4].

2.6. Transmission Congestion Relief

Avoids congestion-related costs by discharging during peak demand to reduce transmission capacity requirements [4].

2.7. Transmission and Distribution Upgrade Deferral

Postpones the need to upgrade transmission and distribution infrastructure [4].

2.8. Substation On-Site Power

Provides power to switching components and communication and control equipment [4].

2.9. Time-of-Use-Energy Cost Management

Reduces overall electricity costs for end users by allowing customers to charge storage devices during low price periods [4].

2.10. Demand Charge Management

Reduces charges for energy drawn during specific peak demand times by discharging stores energy at these times [4].

2.11. Electric Service Reliability

Provides energy during extended complete power outages [4].

2.12. Electric Service Power Quality

Protects on-site loads against poor quality events by using energy storage to protect against frequency variations, lower power factors, harmonics and other interruptions [4].

2.13. Renewables Energy Time-Shift

Stores renewable energy, which is frequently, produced during periods of low demand, to be released during periods of peak demand [4], [8], [9].

2.14. Renewables Capacity Firming

Addresses issues with ramping from renewable sources by using stored energy in conjunction with renewable sources to provide a constant energy supply [4], [10].

2.15. Wind/Solar Generation Grid Integration

Assists in wind- and solar-generation integration by reducing output volatility and variability, improving power quality, reducing congestion problems, providing backup for unexpected generation shortfalls, and reducing minimum load violations [4], [8], [9].

3. Proposed Method to Carry on this Research

According to [4], the bulk energy storage has the potential to transform and modernize the power grid. However, there are a number of factors that hinder their widespread adoption. The challenge to be overcome by such a research, before reaching its overall goal is to understand and prioritize these factors. Then, in order to identify such factors, a survey should be carried out by means of a qualitative stage followed by a quantitative one, as shown in Figure 1.

3.1. Literature Review

Literature review will be made to identify some of the obstacles that hinder the spread of energy storage through the eyes of experts. In addition, it will better place the subject in context, including its characteristics and the benefits arising from its application in the electrical system. This review will be

taking advantage of the research opportunities conducted in the United States, where the issue has been extensively studied.

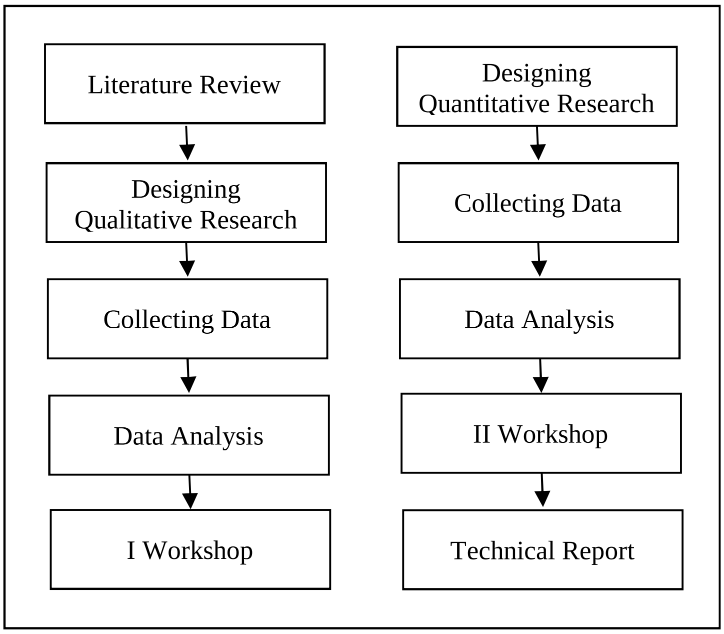

Fig. 1. Step flow for a research intended to identify and classify the obstacles to the deployment of bulk energy storage in the power grid.

3.2. Designing the Qualitative Research

This step will begin with the identification of the target audience of the research. Once identified and quantified this public, it will be defined the approach to be used, census or sample, and the most appropriate technique to the research proposal, open questionnaire, focus group, etc. This stage will be completed with the development of the data collection instruments.

3.3. Collecting Data (qualitative stage)

Consists of the submission of an open questionnaire, prepared in the step before, to stakeholders. Initially it will be conducted, along with a small sample, a pre-test, to make the necessary adjustments. Afterwards it will be applied to a larger sample.

3.4. Data Analysis (qualitative stage)

After a content analysis, the qualitative research results will be summarized in a set of variables, that are, obstacles that hinder the spread of energy storage. This set will be faced with that obtained in the literature review. From this confrontation, it is possible that some of the obstacles perceived by the stakeholders have already been reported in the literature, while others have not.

3.5. I Workshop

This workshop will make possible the stakeholders to discuss the first findings of this research. It is intended that the obstacles and proposals are debated, resulting in new contributions for research. It is possible that ideas for the quantitative phase of the research arise from this debate.

3.6. Designing the Quantitative Research

There are several possibilities of treatment for the variables identified during the qualitative phase, they can be sorted according to their importance; they can summarized in a small number of underlying factors by means of factorial analysis and a variable cluster analysis can be used to group these variables.

Once defined the technique to be applied, it will be necessary to develop the appropriate data-collecting instrument to be submitted to the stakeholders.

3.7. Collecting Data (quantitative stage)

Consists of the submission of the questionnaire designed in the step before, to stakeholders. First a pre-test will be done and afterwards it will be applied to a larger sample.

3.8. Data Analysis (qualitative stage)

The collected data will be processed according to the data analysis techniques that were defined for this study in the planning phase of this stage.

3.9. II Workshop

The overall results of this research will be presented, as well as the proposals for deployment of energy storage throughout the electrical system. Similar to what may occur in the previous workshop, it is possible that new proposals emerge from the discussions.

3.10. Technical Report

The final product of this research will be a technical report. It will be contextualized by a synopsis of the literature review, containing the results of qualitative and quantitative research and a set of strategies suggested to overcome the obstacles that hinder the deployment of energy storage.

5. Conclusion

This paper presented several benefits arising from the energy storage deployment. Despite all the benefits, energy storage is not widespread. In order to identify the main reasons for that, this paper proposed a research method, which has a qualitative stage followed by a quantitative one. The main obstacles to the spread of energy storage will be identified during the qualitative stage and they will be sorted, according to their importance, during the quantitative stage. The results of the further stage will be used to propose strategies to overcome them.

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Obstacles to Energy Storage Deployment in Brazil

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Abstract

According to official data, the Brazilian electric grid has been working at the limit to meet the demand for electricity. This struggle requires a significant mobilization of resources for long periods. Energy storage has been pointed out as a less expensive and short to medium term solution for these challenges as it has several applications at different levels of the power grid. However, despite all the benefits, energy storage is not widespread in Brazilian electric grid. This paper aims to present the obstacles pointed out by literature and those emerged from a survey conducted among research groups, government agencies and utility companies. Among the most cited obstacles are the high cost of storage technologies, insufficient technical progress of storage technologies and low renewable penetration in the grid. Ranking such obstacles, it will possible to take actions to overcome them and improve the energy storage deployment in Brazil.

Keywords: Energy storage, alternative energy resources, transmission system, distribution system.

1. Introduction

Over the past forty years, the electricity consumption increased at a rate of 6.1% per year in Brazil [1]. According to [2], the projected growth for 2024 is about 4.2% per year. Also, according to **Erreur ! Source du renvoi introuvable.**, to meet the growing demand the installed capacity has to grow at an average annual rate of 3.8% by 2024, what means to increase the installed capacity about 55%, which is a very ambitious goal.

The Brazilian power system relies mostly on large power plants far from large consumer centers as long transmission lines are necessary. In 2014, the extension of the national grid transmission lines was approximately 119,426 km and it is expected that they will extend to 195,154 km in 2024, an increase of 63% [2]. The demand for electricity has been growing at high rates and the grid has to follow the demand in order to prevent interruptions in the power supply, but if anything goes wrong like lack of rainfall, and schedule delays, then a gap between demand and supply will be created. The bigger is these gaps, the greater will be the number of interruptions [3], [4]. The estimated cost of interruptions to American consumers is approximately $ 80 billion per year [4]. In order to decrease the risk of interruptions the power grid must be constantly updated. The traditional approach of building new generating plants and

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transmission lines is an expensive and time-consuming endeavor, the literature [7], [8] claims the energy storage is a more economical alternative to the expansion of the power grid as it can optimize the current electrical system capacity factor.

In addition, alternative sources of energy, particularly wind power, have been increasing their share in the electricity generation in Brazil. According to [2] wind power's share of electricity generation will increase from 3.7% (7 GW) in 2014 to around 11.6% (24 GW), and according to [6] their intermittent behavior increase the level of difficulties that have to be managed by the grid. According to [4]-[10] energy storage is a natural solution for the integration of alternative energy sources to the power grid.

The energy storage systems can mitigate the variability of the load by storing the excess of energy at off-peak hours, when its price is low, and discharging it at peak hours, when its price is high.

According to [6], [11] there are several services that can be provided by energy storage systems at the level of generation, transmission and distribution systems as well as at the consumer level.

2. Energy Storage Applications and Their Benefits

There are several applications to energy storage at several levels of the power grid, Generation, transmission, distribution and customer.

At the generation level, applications like Electric Energy Time-Shift and Electric Supply Capacity are supported by Pumped Hydro Power Systems and Compressed Air Systems. There are other applications related to Ancillary Services that can be supported by other technologies, among these applications are Regulation, Spinning, non-spinning and supplemental reserves, voltage support, black start. Related to renewable integration there are applications like Renewable Time Shift and Renewable Capacity Firming [3]-[13].

Applications of energy storage at the Transmission and Distribution systems are able to defer upgrades and provide voltage support and transmission congestion relief [3]-[13].

At the costumer level, there are applications like Power quality, Reliability, Retail electric energy time-shift, demand management [3]-[6], [11].

Table 1 summarizes several services that can be provided by energy storage systems at the level of generation, transmission and distribution systems and consumer.

Table 1 – Applications and benefits from energy storage

Level	**Main Group**	**Service**
Generation	Bulk Energy services	Electric Energy Time-Shift (arbitrage) Electric Supply Capacity
	Ancillary Services	Regulation Spinning, Non-spinning and Supplemental Reserves Voltage Support Black Start
	Renewable Integration	Renewable Time Shift Renewable Capacity Firming
Transmission	Transmission Infrastructure Services	Transmission Upgrade Deferral Transmission Congestion Relief
Distribution	Distribution Infrastructure Services	Distribution Upgrade Deferral Voltage Support
	Customer Energy Management Services	Power Quality Power Reliability Retail Electric Energy Time-Shift Demand Charge Management

3. Energy Storage in Brazil

The Brazilian experience in energy storage reduces to a unique case, the Pumped Hydro Plant of Pedreira that has an installed capacity of 20 MW.

Fig.1. Pumped hydro plant of Pedreira (20 MW), the unique Brazilian experience in bulk energy storage

Despite all the benefits brought by energy storage, it is not widespread in Brazilian grid, and this raises the following questions: What are the obstacles to energy storage deployment in Brazil? What can be done to overcome such obstacles?

In order to answer these questions a research project has been carried on in Brazil. The objective of this paper is to present the main results of this research until the moment.

4. Research Method

According to [2], the bulk energy storage has the potential to transform and modernize the power grid. However, there are a number of factors that hinder their widespread adoption. The challenge to be overcome by such a research, is to identify such factors.

In order to answer these questions the research was designed according to the following steps.

4.1. Literature Review

It was identified the some of the obstacles that hinder the spread of energy storage through the eyes of world experts. In addition, it has better placed the subject in context, including its characteristics and the benefits arising from its application in electrical systems. This review took advantage of the researches conducted in the United States, where the issue has been extensively studied.

4.2. Survey

A survey was conducted among 46 research groups, three government agencies and ten utility companies. The answers were invited to read a short paragraph (83 words) about energy storage benefits and then asked to answer a question stated at the end of the text.

“It is known that demand for electricity has been increasing over the years and this increase has not been followed by a corresponding increase in electricity production and transmission & distribution grid update. This increases the pressure on the electrical system to keep its reliability. However, the necessary investments to reduce the gap between demand and supply are too high and for the long term. Some studies suggest the energy storage as a short term and less expensive means of reducing such deficit.

What are the obstacles for the deployment of energy storage along the grid in your opinion?”

4.3. Collecting Data

The research groups were previously contacted, by phone or e-mail, and invited to take part in this survey. If they agreed, they received an e-mail with the above-quoted text that should be answered within

fifteen days. If they did not return the answers, they were contacted by phone. In some cases instead of an e-mail, an interview was set up with the respondents.

4.4. Determining the key terms

During this stage, all the answers have been read and, after a content analysis, twenty-six key terms were identified. For example, for the following answers it was identified the key terms: lack of knowledge, low energy capacity, short storage duration, high cost, low life cycle and disposal environmental issues.

"*I believe that the main obstacle is the lack of knowledge of the stakeholders on the available technologies.*"
"*Considering the batteries, the main obstacles are low energy capacity, short storage duration, high cost, low lyfe cycle and disposal environmental issues.*"

4.5. Classification of the Key Terms into Obstacles

Once key terms had been defined, they were grouped into eleven categories. In fact, each category is an obstacle having different numbers of key terms associated to it.

For instance, the key terms *short storage duration*, *low energy capacity*, *low efficiency, low life cycle* and *need of power electronics advances*, were classified under the obstacle named *Insufficient Technical Progress.*

5. Results

5.1. Obstacles from Literature

According to [3], there are great opportunities for energy storage, but also there are great limitations for the adoption of grid-scale technologies by electric power industry. The current obstacles preventing the widespread commercial deployment of energy storage technologies include the following:

A. Deficient Market Structure
Energy storage can support generation, transmission and distribution. It has been difficult to classify energy storage from a standpoint and assess its value in comparison to traditional infrastructure. The pricing mechanism of the energy storage depends on its classification. Without a pricing model, it is difficult to ensure stakeholders that they will receive a return on their investment [3].

B. Limited Large-Scale Demonstrations
There are not enough large-scale demonstrations from where data on performance of energy storage technologies can be gathered. Such data are necessary to evaluate device cost, efficiency, durability and reliability, i.e., data are necessary to validate storage devices and prove the benefits of grid-scale storage [3].

C. Insufficient Technical Progress
According to [3] many technologies did not reach a maturity level conducive to commercial deployment because the interest and funding of these projects dropped off after the energy crisis in the 1970s. Then the limited storage duration and energy capacity of technologies are too short to meet the current needs of the power grid as well as the technologies efficiency are not enough to convince the stakeholders of their value.

D. High Cost of Storage Technologies
The high cost of many technologies is a major obstacle to production scale-up and integration of storage devices at grid scale [3].

E. Weak Stakeholders' Understanding on Energy Storage
According to [3] the benefits of grid-scale storage are not well understood by stakeholders. This understanding is fundamental to deploy storage technologies. Utilities and grid operators are unaware of the benefits of the energy storage.

F. Lack of Standards and Models

Lack of standards and models that can help storage system developers and electric power industry design and integrate reliable and high-performing energy storage technologies.

5.2. Obstacles raised from the Survey

The survey pointed out, from the standpoint of the Brazilian respondents, ten obstacles to energy storage deployment, from which four have been already mentioned in the literature, *Deficient market structure, Insufficient technical progress of the storage technologies, High costs of storage technologies and Weak steakholders' understanding on energy storage.* The other six and their meanings are explained bellow.

A. <u>The belief that small power plants are more effective than energy storage</u>
Represents the belief that is much better investing in small hydro power plants near consumer centers than in energy storage. Then, before building storage facilities, it is necessary to increase the number of small hydro power plants located near the large consumer centers.

B. <u>The belief that improve energy efficiency of products and processes is more effective than energy storage</u>
Saving energy is a kind of "virtual storage". Then, before thinking of building storage energy facilities it would be better to increase products and processes efficiency, by means of regulations and awareness campaigns and training.

C. <u>Low renewable penetration in the grid</u>
Energy storage is necessary only if there is a large penetration of alternative energy sources in the grid. Once in Brazil there still are just a few amount of energy from wind, from solar panels and from other alternative sources, energy storage is not necessary. Energy storage makes more sense for electric systems with high renewable penetration.

D. <u>Geographical Constraints</u>
Pumped hydro power plants and compressed air systems (CAES) depend on suitable geographical sites. Since such geographical sites are not available everywhere this is an obstacle to these technologies deployment.

E. <u>Environmental constraints</u>
Considering pumped hydro plants there are some issues like water availability, irrigation, minimum flows, fish passage, long environmental licensing. Considering batteries there are environmental effects associated with battery disposal.

F. <u>Grid Size</u>
Energy storage is not suitable for large interconnected systems.

The key terms used to capture the obstacles from the interviews are shown in Table 1.

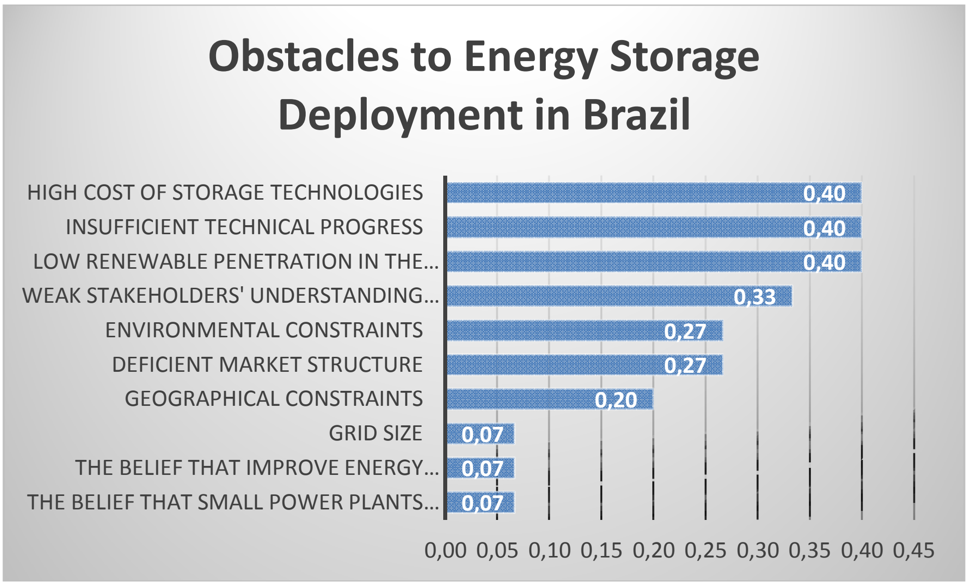
Table 1 – Key terms associated to the obstacles from standpoint of the Brazilians expert

Key Terms	**Obstacle**
Lack of a pricing model, lack of government incentives, lack of government policies	Deficient market structure
Short storage duration, low energy capacity, low efficiency, low life cycle and need of power electronics advances, complex technology, technological limitations	Insufficient technical progress
High costs of production, maintenance, operation, installation	High cost of storage technologies
Lack of understanding, lack of divulgation, lack of research	Weak stakeholders' understanding
Geological constraints, geographical constraints	Geographical constraints
Flood, disposal issues, contamination, residuals	Environmental constraints
Increase the number of small power plants, increase the hydro generation, retrofit small power plants	The belief that small power plants are more effective than energy storage
Increase products efficiency, increase processes efficiency,	The belief that improve energy

decrease losses, virtual storage	efficiency of products and processes is more effective than energy storage
Isolated systems, Grid is big for energy storage	Grid size
Few solar panel, few wind generation, few alternative generation, low renewable penetration	Low renewable penetration in the grid

5.3. Frequency distribution of the obstacles pointed out by the respondents

The Figure 2 shows the frequency distribution of the obstacles according to the respondents.



6. Discussion

Among the obstacles emerged from the survey, deficient market structure, insufficient technical progress, high cost of storage technologies, weak stakeholders' understanding, geographical constraints and environmental constraints have been already identified in the literature.

According to the respondents high cost of storage technologies, insufficient technical progress, low renewable penetration in the grid are the most cited obstacles while grid size, the belief that improve products and processes energy efficiency is more effective than energy storage and the belief that small power plants are more effective than energy storage is the less frequent.

The six obstacles already identified in the literature are valid for the Brazilian case and do not require further analysis.

The belief that improve products and processes energy efficiency is more effective than energy storage seems not to be a valid obstacle as efficiency and energy storage are not mutually exclusive.

The validity of the belief that small power plants are more effective than energy storage is difficult to analyze, once it is necessary to compare the costs to build small power plants with the costs of energy storage facilities of the same capacity. Besides, it is necessary to keep in mind the geographical constraints for such type of hydro plant, it is necessary to have the possibility to install them close to consumer centers.

The obstacle identified as The Grid Size is not a valid obstacle as North American's grid is greater than Brazilian's, as well as the number of energy storage projects, making use of several technologies, as can be seen in Table 2.

Table 2 - Power grid size and storage capacity for several countries

Country	Capacity (GW)	Storage (GW)	Storage (% Cap)
EUA	1110	21.40	1.92
GER	181	7.00	3.87
BRA	133	0.02	0.02
CHI	14	0.07	0.51

According to [2] wind power's share of electricity generation will increase from 3.7% (7 GW) in 2014 to around 11.6% (24 GW). In this case, if the Low penetration of renewable in the grid has been an obstacle to energy deployment, it tends to vanish and the increasing of renewable penetration will be an incentive to energy storage deployment.

7. Conclusion

The power grid struggles to provide enough electricity to meet the demand. This paper presented a short summary of energy storage applications at several levels of the grid and their benefits. Despite all the benefits brought by energy storage, it is not widespread in Brazil. There is only one storage facility in the whole country, the pumped hydro power plant of Pedreira. In order to identify the main obstacle to energy deployment in Brazil a survey was conducted among research groups, government agencies and utility companies. Ten obstacles emerged from the survey from which six had been already mentioned in the literature. The most cited obstacles was the high cost of storage technologies, insufficient technical progress, Low renewable penetration in the grid, but it does not mean they are the most important. It will be necessary to classify them. Analyzing the answers returned by the respondents it is possible to realize that they do not understand the applications and benefits of energy storage, then this becomes the most important obstacle to energy storage deployment, and this makes poor their analysis.

There are not enough large-scale demonstrations from where data on performance of energy storage technologies can be gathered. Such data are necessary to evaluate device cost, efficiency, durability and reliability, i.e., data are necessary to validate storage devices and prove the benefits of grid-scale storage. Thus, the limited large-scale demonstrations might be the second most important obstacle.

Acknowledgements

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