

Regulatory context of smart grids in Europe and Brazil: current state and trends

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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 be 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 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 customer 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 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 life 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 stakeholders' understanding on energy storage*. The other six and their meanings are explained below.

A. The belief that small power plants are more effective than energy storage

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. The belief that improve energy efficiency of products and processes is more effective than energy storage

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. Low renewable penetration in the grid

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. Geographical Constraints

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. Environmental constraints

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. Grid Size

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.

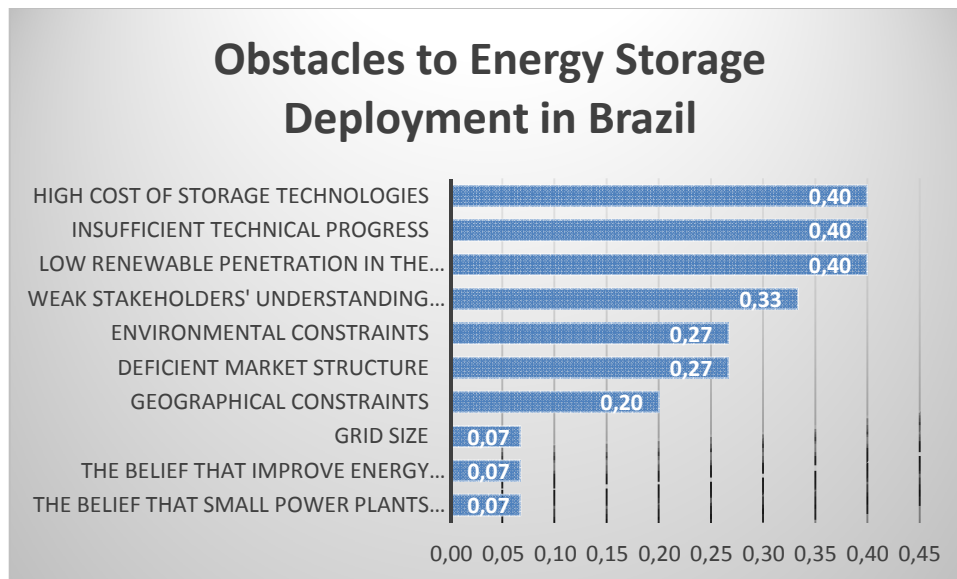
Table 1 – Key terms associated to the obstacles from standpoint of the Brazilians expert

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.

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