technologies and their possible applications in term of rated system power and discharge time are also included.

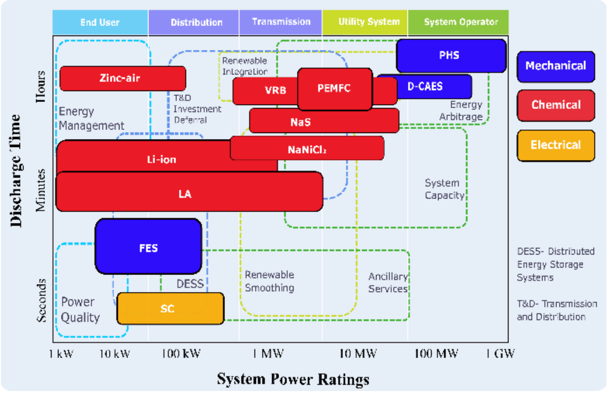

Fig. 4. Comparison between selected ESS technologies (own authorship)

Considering the contents of Tab. I and II, and based on [3, 8], a Tab. III was developed by relating the available energy storage technologies and their application in the Brazilian EPS.

The mechanical energy storage techniques, such as CAES and PHS, can allow the storage of energy at a large level of capacity (Tab. I), being suitable for bulk energy application and frequency regulation [9]. In [3, 9, 10], the PHS technology is classified as suitable for integration of alternative energy, but in the specific case of Brazil, the geographic regions propitious [11] for the PHS installation are far from away of most wind or photovoltaic parks. In this way, it would be inefficient, due to the long distance between the ESS and the application, for using the PHS on this type of application. Therefore, PHS was classified as "possible".

The SC and FES techniques, due to be based on shorter discharge times and higher power, can be used manly as emergency devices or applications for faster time responses [7]. On the other hand, batteries can be modular, easy scalable and used in many different applications [9]. According to the Table III, battery power storage can be applied into the entire system from ancillary services to support a smart network at level of generation, transmission, and distribution. In accordance with the time of response and the power capacity, most of batteries can be used to integrate RE. In particular, slow response time may limit the use of VRB batteries. However, the reduced discharge time limits the use of lead-acid batteries for applications that require high energy capacity [8].

Even though ancillary services are considered as possible for ESS application in the Brazilian electric sector, it is worth to note that there are no mechanisms in the Brazilian regulation for the remuneration of these services. There is also no provision in the regulation for passing on the costs of these services to the tariffs [22]. The poor market structure is one of the major obstacles to the development of energy storage in Brazil [24].

Table III -ESS technologies and their applicability in the Brazilian electric sector.

		Mechanical			Chemical						Elec.
Applications	**Example**	PHE	D-CAES	FES	LA	Li-ion	NaS	Na-NiCl$_2$	PEM	VRB	SC
Bulk Energy	Arbitrage	Suitable	Possible	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Unsuitable
	Peak shaving	Suitable	Possible	Unsuitable	Unsuitable	Unsuitable	Possible	Possible	Unsuitable	Possible	Unsuitable
AncillaryService	Voltage Support	Unsuitable	Unsuitable	Suitable	Suitable	Suitable	Suitable	Suitable	Possible	Possible	Suitable
	Frequency regulation	Possible	Suitable	Possible	Suitable	Suitable	Suitable	Suitable	Possible	Possible	Unsuitable
	Exchange control	Possible	Possible	Unsuitable	Unsuitable	Possible	Suitable	Suitable	Possible	Suitable	Unsuitable
	Spinning Reserve	Unsuitable	Suitable	Possible	Possible	Unsuitable	Possible	Possible	Unsuitable	Unsuitable	Unsuitable
	Load following	Unsuitable	Possible	Suitable	Suitable	Possible	Suitable	Suitable	Suitable	Suitable	Unsuitable
Integration of RES (intermittent generation)	Wind generation in northeast of Brazil.	Possible	Possible	Possible	Unsuitable	Suitable	Suitable	Suitable	Possible	Suitable	Suitable
	Photovoltaic parks in the center and northeast	Possible	Possible	Unsuitable	Unsuitable	Suitable	Possible	Suitable	Unsuitable	Suitable	Unsuitable
Distribution Network	Support for intelligent network integration and distributed generation.	Unsuitable	Unsuitable	Unsuitable	Possible	Suitable	Suitable	Suitable	Possible	Possible	Unsuitable
	Detection of defects and supplies of priority loads.	Possible	Possible	Suitable	Possible	Suitable	Suitable	Possible	Possible	Possible	Unsuitable
	Unbalanced phase compensation	Unsuitable	Unsuitable	Suitable	Suitable	Possible	Possible	Possible	Possible	Possible	Suitable
Island Systems	Continuous supply of energy in isolated systems in the north of Brazil.	Unsuitable	Unsuitable	Unsuitable	Unsuitable	Suitable	Suitable	Suitable	Suitable	Possible	Unsuitable
Transport	Electric vehicles	Unsuitable	Unsuitable	Unsuitable	Suitable	Suitable	Unsuitable	Possible	Possible	Unsuitable	Possible
Applicability		Unsuitable (null)			Possible (Low)				Suitable (High)		

6. Conclusions

This research had as objective to map the main niches of application of ESS in the Brazilian electrical system and consequently also for automotive use.

Although there are benefits brought by energy storage, it is still an incipient technology with limited use in Brazil. Therefore, it was difficult to find studies and researches that cover applications in the Brazilian scenario.

However, due to the variation in generation and the need to balance power and regulate voltage and frequency, the use of energy storage systems is inevitable in the modern network.

For that reason, the results brought by the present work, although they come from a simple analysis, mark the guideline to be taken by governmental organs and regulatory agents referring to ESS its applications.

The present study found that technologies such as batteries, PHS, D-CAES, FES were the ones that present the best applicability to meet emerging Brazilian needs and are expected to be the most prominent at the national level. Supercapacitors have a limited number of potential applications, only on transient issues, such as improving energy quality. The PHS and D-CAES technologies have great potential in application that requires high energy such as arbitrage. Particularly, relative the integration of wind farms and solar power plants, battery storage is the most appropriate because it has the required power and energy density, as well as the appropriate response time. For isolated systems, the association of solar generation with Li-ion batteries and Na-$NiCl_2$can be a solution to reduce the operating costs of diesel generators used today.

It should also be noted that the analysis presented was performed only from the technical point of view and can be used for future work that consider economic factors in the choice of a technology.

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