Legislative and economic aspects for the inclusion of energy reserve by a superconducting magnetic energy storage: Application to the case of the Spanish electrical system

Antonio Colmenar-Santos[a]*, Enrique-Luis Molina-Ibáñez[a],
Enrique Rosales-Asensio[b], Jorge-Juan Blanes-Peiró[c]

[a] Departamento de Ingeniería Eléctrica, Electrónica y Control, Universidad Nacional de Educación a Distancia (UNED), Madrid, Spain
[b] Departamento de Física, Universidad de La Laguna, San Cristóbal de La Laguna, Spain
[c] Departamento de Ingeniería Eléctrica y de Sistemas y Automática, Escuela Técnica Superior de Ingenieros de Minas de LEON, Spain

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Abstract

With the encouragement from renewable energies, elements of the electrical system are magnified which make possible a suitable connection to the electrical network. Among others, energy storage systems (ESSs) are emphasized because of their impact. This article discusses two essential aspects to take into account for an ESS, that is the regulatory framework and the economic aspect. In particular, it focuses on superconducting magnetic energy storage (SMES) in the Spanish electrical system. An analysis is performed on the legislation and regulations that apply to energy storage systems, which may affect in a direct or indirect manner its inclusion. This is accompanied by an analysis of the legislation in different countries to assess the situation in Spain in this regard, by comparison. Another point to take into consideration, which is crucial for the correct development and inclusion of this type of elements, is the economic viability- showing the costs of manufacturing and maintenance of these systems. Although it is necessary to keep investigating to lower the costs, economic benefits are appreciated, among other things, owing to the increase of the reliability of the electrical network. This increase of the reliability is resultant from a decrease of the cuts of service and the improvement of the quality of the energy.

Keywords: Energy Storage, Superconduction, Economic viability, Legislation.

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* Corresponding author. Tel.: +34-913-987-788
E-mail address: acolmenar@ieec.uned.es.

1. Introduction

The growing concern for the environment and climate change over the past years has led to several voices beginning to question the present electric model. For some decades, the use of energy resources of renewable origin [1], which limits the use of polluting sources, has been promoted. Furthermore, the use of strategies that make more rational and efficient consumption possible, such as demand management, has been encouraged.

Considering the inclusion of sources of renewable energy generation in the electrical system, in which the generation of energy by wind turbines and solar photovoltaic panels stands out [2], the use of elements that make energy storage possible is necessary. This is owing to the generation of irregular power that is largely dependent on weather conditions.

Nomenclature	
AENOR	Spanish Association for Standardization and Certification.
AIT	Average Interruption Time.
BSCCO	Bismuth Strontium Calcium Copper Oxide.
CAES	Compressed Air Energy Storage.
CEN	European Committee for Standardizacion.
CENELEC	European Committee for Electrotechnical Standardization.
CNC	Coal Not Consumed.
COPANT	Panamerican Commission on Technical Standards.
EDLC	Electric Double Layer Capacitor.
EN	European Norms.
ENS	Energy not supplied.
ESS	Energy Storage System.
EU	European Union.
FES	Fly Energy Storage.
FIT	Feed in Tariff.
GDP	Gross Domestic Product.
GHG	Greenhouse Gases
HTS	High Temperature Superconductor.
ISO	International Organization for Standandarization.
LANL	Los Alamos National Laboratory.
LTS	Low Temperature Superconductor.
PHS	Pumped Hydro Storage.
OP	Operating Procedure.
REE	Spanish Electricity Network.

SMES	Superconducting Magnetic Energy Storage.
UNE	Una Norma Española.
UPS	Uninterruptible Power Supply.
YBCO	Yttrium Barium Copper Oxide.

Energy storage systems (ESS) can be characterized by different metrics that facilitate the choice of one device or another [3]. The devices that are currently marketed and/or in development are grouped into four major groups: Electrochemistry (different types of batteries), mechanical (FES, PHS, CAES), electrical (SMES, EDLC) and heat.

Approximately 95-98% of the total, storage at the global level is based on PHS owing to the simplicity and maturity of its technology. In spite of this, the quota of ESS compared with that of PHS has grown from less than 1% in 2005 to more than 1.5% in 2010 and 2.5% in 2015 (a growth rate greater than 10%) [4, 5].

These systems should support the proper functioning of the network. It is necessary to bear in mind that the supply and the quality of energy are categorized as a basic need in everyday life. As a result, electricity consumption has been associated with the level of development of a city, region or country, and its evolution has been reflected in its gross domestic product (GDP). Fig. 1 shows the variation of the demand for energy in peninsular Spain in comparison with the evolution of the GDP in recent years.

Fig. 1. Comparative GDP vs Energy Demand [6].

Considering the characteristics of each of energy storage system, there are plenty of cases of the use of elements. The main applications that the ESS are capable of realizing are load tracking applications, energy storage, emergency elements, systems of uninterruptible power supply (UPS), fitness levels of voltage and frequency regulation and elements of protection [7, 8].

The main aim of this article is to analyse the storage of magnetic energy by superconductivity (SMES) system. This type of systems has not reached commercial ripeness for generalized use in a network, as reported [9], owing to different aspects. These problems can be summarised as resulting from high cost of manufacture / maintenance, technical difficulty in the application in different environments and the lack of normative support.

An SMES system allows the storage of energy under a magnetic field because the current through a coil is cooled at temperature below the critical temperature of superconductivity. The system is based on a superconducting coil, a cooling system that allows the critical temperature to be obtained, and an electrical and control system for the adaptation of currents and the optimization of the process.

Given the large spectrum of research concerning the solution of the problematic technique for the inclusion of SMES systems in different configurations, this article focuses on two important aspects to enhance its use in power system, that is, legislative and regulatory aspects and the economic aspect.

To perform a correct analysis of this type, the status of capacity of the main characteristics of this type of ESS must be born in mind, as summarised in Table 1. The characteristics of these systems may vary depending on the type of SMES. SMES are categorized according to their critical temperature (Tc), LTS (NbTi) and HTS (YBCO, BSCCO), and according to the configuration for their use [10-17], in which the optimization of the performance of the device is searched for in different processes and systems. This implies betting for the investigations of new alloys with higher critical temperature than the HTS [18], the optimization of the elements of electrical adaptation, as well as investigations in the systems of regulation and control [19] or the study of the inclusion of these systems in the microgrids/smart grids [20, 21].

Table 1. Main characteristics of a SMES [3, 7, 8, 22-38].

Owing to the characteristics of these type of systems, applications are restricted to a group of potential uses focused on electrical power systems, which are essential for providing an adequate quality system. Table 2 shows the applications of this type of ESS.

Table 2. Applications of SMES [7, 8, 29, 38-41].

The methods used to carry out the investigation of this article are outlined in Section 2. In this section, the legislation on ESS for the application in the Spanish electrical system is shown as an example of a system in which the penetration of renewable energies has had a high impact. The main problem that prevents the complete maturation of the system, the economic casuistry, and a feasibility analysis of such a system are also addressed in this section. This is why the economic impact of its use in the electrical system, from manufacturing costs to maintenance costs, is analysed. The results of the economic study concerning the inclusion of SMES storage systems in the electricity network are presented in Section 3. This allows the possible economic benefits of the inclusion of these systems in the electricity network, and other indirect benefits to be determined.

The legislative and normative issues are discussed in Section 4, both in terms of standardization of the equipment and regulation, conditioning the implementation of SMES systems and its competitiveness with other systems [42]. Finally, Section 5 is reserved to show the main conclusions obtained from the normative and economic study of these systems.

2. Material and methods

For this case study, an analysis differentiated in two parts has been realized. On the one hand, the Department of Energy of Spain has the legislative and normative information relative to the whole process of generation and energy consumption. All legislation approved in relation to the Spanish electricity system is published in the BOE (Official Bulletin of the State), this being an essential reference. This legislation affects, in a direct or indirect way, the systems of energy storage. With regard to the legislation in other countries, information can also be found primarily in the concerned ministries or departments of the State. The normalization and standardization are detailed in Appendix A.

Various documents were analysed for the economic study: the economic cost of the construction of SMES, the potential economic benefits of the inclusion of SMES in the electrical system and the environmental benefit use of an ESS.

Finally, the amount of harmful gasses generated from coal consumption was analysed and the possible saving from the inclusion of the ESS. For the quantity of generated gasses it is necessary to bear in mind the type of coal that is mainly consumed and the proportion of gasses generated by typology for each kilogram of consumed coal. With this information, it is possible to perform an analysis of the large amounts of these gasses that might be avoided thanks to the ESS, as well as determine the economic implications of reducing the emission of these gasses.

2.1. Theoretical framework

At the legislative level, in Spain there is no law or specific regulations that enable the research, development and implementation of these systems. However, the inclusion of other ESS as kinetic energy storage has been promoted. A laboratory prototype has been developed which an emulator for railway catenary, an emulator of consumption of electric vehicles and a unit for the storage of energy based on ultracapacitor have been integrated and tested on a system installed in the underground of Madrid [43]. Also a flywheel of 25 kW, 10 MJ has been adapted for operation in a microgrid, for the application as compensation during consumption peaks and regulation of frequency [44].

In the case of the Spanish electricity system, we should take into account the different policy levels, in order to ensure an adequate inclusion of SMES systems, enhancing its use and regulation in manufacturing systems. These levels can be summarised as:

- European Union (EU), through the corresponding Regulations or Directives [45].
- National, through ordinary laws, Royal Decree Law or Regulations (Royal Decree, Ministerial Order, Circulars, Resolutions, etc.) [46, 47].
- Other regulations of regional application, such as Decrees or Orders.

The legislation relating to the regional level is very limited in regard to the inclusion of ESS of large or medium scale. Despite this, Spain may grant economic aid to encourage the installation on a small scale, for micro-SMES systems of local storage.

2.2. Calculations

There are several studies that seek to perform an economic analysis on the ESS in a general way [16, 48-54]. In this way, the costs can be grouped in Invested Capital (C_I), Capital of Operation and Maintenance ($C_{O\&M}$) and Financial Capital (C_F), or Capital of Investment.

In spite of everything, it remains that the total storage is:

$$TSC(\$) = C_I(\$) + C_{O\&M}(\$) + C_F(\$) \qquad (1)$$

In which the total invested cost, C_I, can be defined as the sum of costs of material, construction and commissioning, own of this ESS. For this analysis of costs, it is necessary to carry out a revision of the main components listed previously. These systems are mainly composed of:

- Superconductive coil
- Criogenization system
- Electrical system
- Monitoring and control system

The adequacy of analysis takes into account materials and configuration to be treated, as the cost of the superconductor element itself, which is the most expensive element of the device, in either LTS or HTS devices. Fig. 2 shows an example of a coil and the main elements of the SMES storage system.

Fig. 2. SMES System [55].

The investment costs can be grouped into three subgroups:

$$C_I(\$) = C_{st}(\$) + C_e(\$) + C_{BOP}(\$) \tag{2}$$

In which:
C_{st} ($) is the cost of construction of the storage system,
C_e ($) is the cost of the electrical system of the device, and
C_{BOP} ($) is the cost of balance of the plant and cost of the auxiliary system.

Despite how meticulous this analysis can be, in which you can compute the minimum cost of the most basic element, it possible to be simplified using the sizing of the device, that is:

$$C\_st\ (\$) = (C_E \cdot E)/\eta \tag{3}$$

$$C_e(\$) = C_P \cdot P \tag{4}$$

$$C_{BOP}(\$) = C_{BOP}(\$/kW) \cdot P \qquad \text{or} \qquad C_{BOP}(\$) = C_{BOP}(\$/kWh) \cdot E \tag{5}$$

In which:
C_E is the energy cost ($/kWh),
E is the stored energy (kWh),
η is the efficiency of the system,
C_P is the cost of power ($/kW), and
P is the capacity of power (kW).

In equation (5) it is possible to use on formula or another depending on the available data for the analysis.

The cost of balance of the plant incorporates the control module that enables the proper functioning and performance of the system. Fig. 3 shows a schematic diagram of a control module but it can vary depending on the configuration blocks (D-SMES), its application or if it is part of some type of hybrid storage system.

Fig. 3. Control module of a SMES system [56].

The wear of the materials in the working conditions, electrical or thermal, must be considered in the costs of maintenance and operation. It is also important to take into account the energy expenditure at the criogenization to maintain the temperature at the optimum operating conditions, a variable expense that can be supplanted by annex systems. It is estimated that a typical cooling system requires approximately 1.5 kW per MWh of stored energy. [57].

Furthermore, the skilled labour needed for the operation of the system operation should be borne in mind. As with other factors, these operating costs are variable and can be approximated as a function of the capacity of power and the years of operation.

$$C_{O\&M}(\$) = C_{O\&M}(\$/kW) \cdot P \cdot k \qquad (6)$$

Finally, we find a variable term, depending on the interests of the investment and the years. Normally this cost is characterized by:

$$C_F(\$) = C_I(\$) \cdot \delta \qquad (7)$$

With a multiplier factor δ which is given by:

$$\delta = (r \cdot (1 + r)^k)/((1 + r)^k - 1) \qquad (8)$$

In which:
r is the interest of the investment, and
K is the time of life, in years.

After analysing the costs of the manufacture and maintenance of the SMES systems, the economic advantages of the use of these systems must be analysed. To do this, the information of the availability is obtained in the Spanish electrical system.

Energy not supplied (ENS) measures the power cut to the system (MWh) throughout the year resulting only from network service interruptions. Only interruptions of over a minute duration zeros of tension are counted. In this case, the inclusion of an SMES system would reduce the cuts that are limited duration, owing to its low energy density. For electricity cuts of longer duration, hybrid systems could be implemented [58]. Another solution could be the improvement of the energy density of these systems; an extensive number of studies have been performed on this topics [55, 58, 59-61].

Average interruption time (AIT) is defined as the relationship between the energy not supplied and the average power of the system, expressed in minutes:

$$TIM = HA \cdot 60 \cdot ENS/DA$$

In which:
HA is the hours per year, and
DA is the annual demand of the system in MWh.

Appendix A shows some of the aspects to keep in mind about regulation and economic facets not indicated previously but which may have importance for the compression of some aspects.

3. Results

To evaluate the cost of the storage of the SMES system and determine its economic viability, it is necessary to bear in mind that different characteristics play an important role in the manufacture of these elements, such as the size of the element of storage.

This study focuses on systems destined for the regulation and storage of the Network of Transport and Distribution, so neither systems Micro-SMES nor Mini-SMES would be described; their storage capacity is more limited and they would be destined for domestic use.

3.1. Economic Analysis

The costs of an ESS tend to be according to the capacity of potency and/or energy, that is, \$/kW or \$/kWh. In recent years the processes for the production of SMES modules as well as the auxiliary systems have been improved, the price of the manufacture of elements have been lowered, in some cases replacing them with elements that have the same properties but are more accessible economically. All this has allowed a variety of costs across a wide range, as shown in Table 3.

Table 3. Price range of an SMES system [7, 22, 24-29, 31, 36-38, 59-62].

The price of a HTS in recent years has been approximately 35 \$/A·m for a BSCCO and 15 \$/A·m for a YBCO, and it continues to decrese [56]. This also happens with other ESS, for which it is estimated that the costs will be reduced by approximately 20% on average, as shown in Fig. 4 for other technologies.

Fig. 4. Estimation of the cost for storage technology [63].

As example, using the information of the text of S. Sundararagavan [52], Table 4 shows the costs, which depend on the characteristics and on the materials.

Table 4.Example of costs of a SMES system. [52].

With these data, and considering the study by Ren et al. [30] in which there is a SMES system Energy/Power (MWh/MW) = 6,49/1,52, as well as an interest of r=10%, the entire cost of the project is:

C_I (\$)	\$	68.781.524,47
C_{OM} (\$)	\$	304.000,00
C_F (\$)	\$	8.079.052,06
TSC (\$)	\$	77.164.576,53

In this study Ren et al. show a cost of approximately 1.358.300 \$/year, with an average useful life of more than 20 years, for a total of 27.166.000\$. These data indicate the wide ranges in the projects of installation of a system of this type, influenced by different factors and technologies.

With the obtained data, a comparison could be performed show the impact of this cost on the budget of a Spanish city of importance, such as Zaragoza, which has a budget of 744,3 M€ [64] (808 M$), so the creation and operation of such a system would account for approximately 7.7% of its overall budget.

3.2. Economic Benefits

The information of the availability and quality of electricity supply provided by the system operator in the Spanish electrical system (REE) must be analysed to obtain the possible economic benefits. This information for the electricity transport network from 2011 is given in tables 5, 6 and 7 [65].

Table 5. Peninsular transport network.

Table 6. Balear transport network.

Table 7. Canarian transport network.

From this, the total direct losses from energy that has been generated but not supplied can be obtained, as shown in Fig. 5. This figure is generated with data from REE.

Fig. 5. Losses owing to cuts of service [65].

It is necessary to add the indemnifications of the electrical companies to the users to the losses generated by the cost of generation. The minimum established quality according to the regulation will bear in mind both the number of cuts and the total amount of time, in a year, in which there has been no supply, according to the area and how it is categorized.

A user is entitled to receive a discount on the bill for the first quarter of the year after the incident. The clients may also request another type of compensation in case any of their goods are damaged owing to power cut.

The National Commission of the Markets and the Competition (CNMC) has valued penalties to the Spanish electrical distributors at 52,5 M€ for their network losses in 2016 [66].

Furthermore, it is necessary to count the economic losses produced by the time of non- operation of different factories and different productions. In this case, it is more complicated to know the exact amount of the losses, because it depends on factors such as the type of industry, the time it occurs, or the location. It is at this point at which the most significant losses occur.

The industries in which a continuous process is important, in which the shutdown of the production can result in a high amount losses, because a determined time is needed to restart engines. It is in this case that the SMES systems have an important role; the starter time would be reduced considerably owing to the high thickness of potency.

3.3. *Environmental Benefits*

In addition to the direct economic benefits, there are also indirect benefits, which include the environmental benefits. These environmental benefits allow a reduction of energy produced by sources of pollution, such as coal. The consumption of different types of coal produces substances that are harmful to human beings and can produce alterations in the biological cycles of the species, as well as other consequences. These consequences may involve an increase in the costs of treatment of diseases, treatments for environmental recovery as well as treatment for the protection of architectural elements produced as a consequence of the increase in the proportion of different substances diluted in the air.

A great variety of harmful substances appears with the consumption of coal because of its composition. This is the reason why it is necessary to perform an analysis of the amount of derived but not consumed coal from the use of elements of energy storage. The quantity of not consumed coal (CNC) can be estimated as a result of the use of the ESS with the following formula:

$$CNC = E_{SESS} \cdot h_{\%C} \cdot R_{conv}$$

In which:

E_{SESS} is the energy provided by ESS (kWh),

$h_{\%C}$ is the percentage of energy provided by sources of coal (%), and

R_{conv} is the conversion factor of energy of the coal ((kg(Coal))⁄MWh).

The variation of the energy mix during the day must be taken into account, so the formula changes to:

$$CNC_D = \left(\sum_{j=0}^{23} E_{SESS\,j} \cdot h_{\%C\,j} \right) \cdot R_{conv}$$

This formula considers the factor of energy conversion of coal constant, but depending on the mix of used coal it may vary.

With this, the amount of substances emitted to the atmosphere can be calculated. This depends on the emission factor of the different substances. Table 8 shows the emission factor of the main substances:

Table 8. Emission factor of the main substances [67].

As a result it is possible to obtain the quantity of substances released from the coal that are not released owing to the use of ESS by using this formula.

$$R_x = \chi_y \cdot CNC$$

In which:

y; It can be: CO_2, CO, SO_2, NH_3, NO_X

The information from the last few years in Spain of the coal consumption is summed up in table 9.

Table 9. Coal statistics in Spain [67, 68].

The amount of harmful substances is obtained from this information. These substances are generated by coal consumption for the generation of electric power, during the year, in tons, as shown in Table 10.

Table 10. The amount of substances generated by the consumption of coal for the generation of electricity [68].

For these reasons, this is one of the goal for using this systems for the storage of electric power. It is necessary to bear in mind that this information only corresponds to the generation of substances derived by coal consumption. It would be necessary to add the use of other sources for the generation of electricity, such as those of a combined cycle system or fuel oil.

From these data, it is possible to estimate the amount of coal saved as a result of using energy storage systems. Knowing the percentage of energy supplied by coal sources, the energy supplied by the energy storage sources and the energy conversion factor of the coal [71], the carbon saved and the CO_2 emission not made as a result of saving coal were calculated and are shown in Table 11.

Table 11. Saved tons of carbon and CO_2 by ESS [71].

These data are obtained thanks to the energy produced by the PHS systems, because they are the main storage system in Spain. The energy obtained by the other systems can be considered residual at the moment.

4. Discussion

In the current stage in which high capacity SMES systems are (research/pre-sale), economic and financing support and a legislation that regulates their application are important. Therefore, adequate regulation at different levels would allow this storage system to be developed and to provide its advantages or, conversely, to be discarded for inclusion in an electrical system in which the use of other systems is more technically or economically appropriate.

The potential storage of energy that the Spanish electrical system has and the predisposition for the inclusion of the ESS are notorious, as shown in Fig. 6. The power of installed storage and developed storage projects are represented in this figure.

Fig. 6. Stored power – Storage projects [5].

4.1. Community Legislation (EU)

There are numerous resolutions of the European Parliament that aim to promote the use of renewable energy and the reduction of GHG emissions. For example, obligatory targets for 2020 [72], the resolution of February 2014 [73] for the Horizon of 2030 or the Roadmap of the Energy for 2050 [74], among others [75].

Furthermore, there are resolutions of the European Parliament which demand the creation of a long-term system of common incentives to scale the EU in favour of renewable energy sources [76]. These resolutions also support the technologies of smart grids [77], as well as the microgeneration of electricity and heat at a small scale [78], which seeks to support the personal energy consumption of citizens, as well as the need to establish incentives that encourage the generation of energy at a small scale.

To realize a transition to an energy model such as the one proposed by the Parliament in Europe, it is necessary to provide flexibility to the European energy system through the improvement of the technologies of storage of energy.

Innovation activities relating to storage at the local level as, for example, in residential areas or industrial estates, seek to create synergies between technologies and to improve connections of a secure and stable form, even in remote areas without a sufficient connection to the electrical network.

For the large-scale storage, the investment seeks to ensure high rates of penetration of renewable energy sources to cover high electricity demands for longer periods of time. Furthermore, the innovative actions must ensure the integration and management of networks and synergies between an electric network and others.

It also gives importance to the development and improvement of the technologies of energy storage that achieve better results with lower costs. For each technology, the profitability cost-benefit is being studied and analysed using scenarios and simulations, the expansion of the electricity network, the incorporation of other storage systems and the management of the energy economy.

One of the examples of this type is the project "Grid+ Storage" [79]. It identifies actions focused on the integration of the energy storage in the distribution networks with the target of making them more flexible.

Concerning the main regulation relative to the ESS, the European legislation that appears in Table 12 must be taken into account.

Table 12. Main European legislation.

4.2. National Legislation

The European directives involve a series of laws to the Member States such as Spain. These laws are listed in Appendix B. This appendix shows the two main laws governing the electricity sector in Spain, Law 54/1997 [85] and Law 24/2013 [86]. These laws have made possible the liberalization of the electrical sector in Spain. One of the points that distinguishes Law 24/2013 from the previous one is the disappearance of the previous "special regime", which included renewable energies, cogeneration and waste. Article 23 of this law indicates that electric energy producers make economic offers of energy sales in the daily market, with the particularity that all production units must make offers to the market, including those of the former special regime [86].

In these law, as in the others listed in Appendix, SMES storage systems are not refereed to explicitly but the features and functions of the different components of an electrical system are discussed. That is why these and other regulation on the table are important in relation to the SMES storage system and its applications.

Table 13 indicates the Operative Procedures (OP, Appendix A) that can affect the ESS and that are specifically named in the regulations owing to their application in an electrical system.

Table 13. Operative Procedures.

The Operative Procedures seek the technical adequacy of the elements in the transport network. As for storage systems, these procedures focus on pumped storage systems. The companies that own the plants have the obligation to transmit different data to the system operator, such as quotas and volumes stored in the reservoirs or foreseeable variations of availability of the pumping groups, on a weekly basis [87].

It should be borne in mind that storage systems can be considered production units at any given time, so they must meet the requirements of the system operator [92] as well as ensure supply [90] and interruptibility [96].

The main functions of the system operator are presented in the OPs, such as generation scheduling, solution of technical restrictions, resolution of generation-consumption deviations or complementary service of tension control of the transport network, in which it can play the essential role of ESS [92].

It is possible to observe the varied legislation that can affect the ESS as elements of the electrical system. This legislation largely focuses on the part of generation and transportation of energy from the electrical system, with consideration of the system operator (REE). They are based on the technical and regulatory aspects that allow the involvement of the State and society through public subsidies for its development improvement. The importance of knowing the legislative structure and the context regulatory in the electrical system lies here, to encourage the inclusion of these elements, both in the transport network and in the distribution, and to be able to make a synthesis of these aspects that may directly or indirectly affect the inclusion of the SMES storage systems.

The management of subsidies and incentives in the implementation of renewable energies, (and consequently of the storage systems) is the main focus of action, as well as the regulation of technical aspect for its proper connection to the network.

4.3. Regulation and standardization

Appendix C shows the standard UNE that is applied to manufacturing processes, research and development as well as to the operation and maintenance of these SMES systems. It must be born in mind that these systems can also affect standards as the protections of wiring, electrical protection systems, and a long list which focuses on the storage system itself. Much of this regulation will depend on the characteristics, size and application of the system to apply. For this reason, it is necessary to take into account the elements of construction and the type of device to be able to apply this type of standardization.

4.4. Comparison with other countries

In addition to have in mind the grade of adaptation of the ESS in the electrical systems, it is necessary to take into account that the electrical networks are interconnected and that the way of operation of one can affect others. This shows the importance of considering the regulation level of other countries to see the implication of the regulation in the inclusion of these ESS.

Furthermore, the need to know the regulations of other countries with a similar development, and referents in that field, makes it possible for these regulations, or part of them, to be adapted to the Spanish electricity system with the necessary changes with the security of its correct operation.

Therefore, the electrical regulation field of some countries was revised. USA, Japan and Germany can be highlighted for the creation and implementation of ESS of the type SMES, with different characteristics and situations. The made devices they can stand out are:

- Chubu Electric Power Company (Japan): Material Bi-2212, Energy 1 MJ [59].
- Los Alamos Laboratory (USA): Material NbTi, Energy 30 MJ [60].
- ACCEL Instruments GmbH (Germany): Material Bi-2223, Energy 150 kJ [61].

Table 14 shows the comparison of these three energy models with the action plan and the main standard. The table focuses on measures to take into account on the basis of renewable energies and their promotion at the institutional level. It is explained in more detail in Appendix D.

Table 14. Comparative table USA-Japan-Germany [97-100].

Apart from these examples, the Paris Conference on Climate [101] is also important. It was celebrated in December 2015, during which 195 countries signed the first binding agreement on global climate. One of the most important points was to ensure that the global average temperature rise was kept below 2°C above pre-industrial levels. The renewable systems will play a key role in achieving this target and all elements influence.

5. Conclusions and political implications

Considering the importance and the impulse of the generation of energy through renewable sources in the energy mix, the elements that orbit around it become vital for the correct inclusion of renewable sources without an impact on the supply quality.

The need to know the regulation that affects the storage systems, directly or indirectly, implies realizing the potential inclusion of these elements. There are a few legislations in Spain with direct implications for storage systems but there are regulations that indirectly affect them, despite the fact that the contributions from institutions in this regard have been reduced in recent years. Not having a specific legislation can negatively affect SMES systems in favour of other more mature systems, such as batteries or PHS (despite the geographical limitations of these).

The rise of renewable energy at the expense of other less clean energy has enabled the development and investment, both public and private, in storage systems. These initial investments and specific regulation are indispensable to allow the competitiveness of very advantageous elements but in an unfavourable commercial position.

Another critical lever on the inclusion of any element is the economic vision of a project. The technological complexity derives from the materials and the cooling system, which involves always maintaining the coil at a temperature below the critical temperature of the material of the coil. This complexity involves some manufacturing and maintenance costs of SMES systems that make it difficult to apply in the transport network of the electricity network in Spain.

Therefore, the applicable legislation to the storage systems and the economic viability of its construction, commissioning and maintenance, as well as the interrelation between both can be determinants for eventual insertion into the electrical network. The solution seems obvious: greater institutional involvement in the development and research of storage systems and their components, which make possible the improvement of the technical capabilities of the systems at a lower cost. This involvement can not only come from grants from public institutions, but also through tax aid, shared financing or other appropriate formulas that enable this development.

It is a fact that the inclusion of renewable sources of energy and the ESS as a result of its intermittent and unstable characteristics, can bring great benefits of different types: social, environmental and economical. It is necessary to invest in the development of SMES systems, or hybrid systems that combine the strengths of high energy density of the batteries with the high power density of SMES systems.

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[117] Real Decreto-ley 14/2010, de 23 de diciembre, por el que se establecen medidas urgentes para la corrección del déficit tarifario del sector eléctrico. https://www.boe.es/boe/dias/2010/12/24/pdfs/BOE-A-2010-19757.pdf [Accessed on 05/07/2017]

[118] Real Decreto 1699/2011, de 18 de noviembre, por el que se regula la conexión a red de instalaciones de producción de energía eléctrica de pequeña potencia. https://www.boe.es/boe/dias/2011/12/08/pdfs/BOE-A-2011-19242.pdf [Accessed on 05/07/2017]

[119] Real Decreto-ley 1/2012, de 27 de enero, por el que se procede a la suspensión de los procedimientos de preasignación de retribución y a la supresión de los incentivos económicos para nuevas instalaciones de producción de energía eléctrica a partir de cogeneración, fuentes de energía renovables y residuos. https://www.boe.es/boe/dias/2012/01/28/pdfs/BOE-A-2012-1310.pdf [Accessed on 05/07/2017]

[120] Real Decreto-ley 2/2013, de 1 de febrero, de medidas urgentes en el sistema eléctrico y en el sector financiero. https://www.boe.es/boe/dias/2013/02/02/pdfs/BOE-A-2013-1117.pdf [Accessed on 05/07/2017]

[121] Real Decreto-ley 9/2013, de 12 de julio, por el que se adoptan medidas urgentes para garantizar la estabilidad financiera del sistema eléctrico. https://www.boe.es/boe/dias/2013/07/13/pdfs/BOE-A-2013-7705.pdf [Accessed on 05/07/2017]

[122] Executive Order 13693—Planning for Federal Sustainability in the Next Decade. https://www.gpo.gov/fdsys/pkg/FR-2015-03-25/pdf/2015-07016.pdf [Accessed on 05/07/2017]

[123] Energy Independence and Security Act of 2007 PL 110-140. https://www.gpo.gov/fdsys/pkg/BILLS-110hr6enr/pdf/BILLS-110hr6enr.pdf [Accessed on 05/07/2017]

[124] Executive Order 13221—Energy Efficient Standby Power Devices. https://energy.gov/sites/prod/files/2013/10/f3/eo13221.pdf [Accessed on 05/07/2017]

[125] Energy Policy Act of 1992 PL 102-486. http://www.afdc.energy.gov/pdfs/2527.pdf [Accessed on 05/07/2017]

[126] Casado MF. El futuro energético de Japón: entre el regreso a la senda nuclear y el giro hacia las renovables. UNISCI Journal 2016; 41.

[127] Ministry of Economy, Trade and Industry. http://www.meti.go.jp/english/index.html [Accessed on 05/07/2017]

[128] Ley de alimentación de energía eléctrica (Stromein-speisungsgesetz). http://dip21.bundestag.de/dip21/btd/11/078/1107816.pdf [Accessed on 05/07/2017]

Appendix A.

Normative aspects

All community legislation and regulation must be translated in regulatory laws in every Member State. This makes possible the adequacy of the activity to the proposed one of the European regulation. The EU has two bodies with the power to adopt binding decisions and to solve the problems that the national regulatory authorities are unable to resolve:

- The Agency for the Cooperation of the Energy Regulators (ACER).
- The European Network of the Operators of the Systems of Transmission of Electricity

Furthermore, it is necessary to bear in mind that SMES storage systems are in the part of the transport and distribution of electrical system. It is work of the company dedicated exclusively to the transport in the Spanish electrical system, Electrical Network of Spain (REE). This company acts as the system operator and has some technical and instrumental protocols, called Operative Procedures (OP). An adequate technical management of electrical system peninsular and electrical systems outside the Iberian Peninsula is guaranteed. These OP are approved by resolutions of the Ministry of Industry which seek to guarantee the stipulation in the Law.

The study and development of the standards is the responsibility of a number of institutions that have the legal power to its realization. The ISO (International Organization for Standandarization) [102], is in charge of the ISO standards. It is formed by 163 agencies of normalization of their respective countries.

At the European level are the European Committee of Standardization (CEN) [103] and the European Committee for Electrotechnical Standardisation (CENELEC) [104], which are responsible for the development of the European Norms (EN).

The Spanish case focuses on the regulations created by the Spanish Association for Standardisation and Certification (AENOR) [105], which disseminates the Spanish rules that are identified with the acronym UNE (a Spanish Norm). AENOR is the Spanish representation in the international standardization organizations ISO and IEC, European CEN and CENELEC, and the Pan American Commission for Technical Standards (COPANT) [106].

To take into account the specific normative in the manufacture and inclusion of the SMES systems, its construction schema must be considered. A possible schema of a SMES storage system, either LTS or HTS, is shown in the Fig. A.1.

Fig. A.1. Basic scheme of a SMES system [107].

Economics aspects

In this sense, it is necessary to emphasize that the first used SMES for experimentation and for commercial use was designed by Los Alamos National Laboratory (LANL) and constructed for Bonnevile Power Company in 1982. It was in use for 5 years and was dismantled for investigation [60, 108].

This project had an energy capacity of 30 MJ and it was used to stabilize the potency system, because it cushioned the oscillations in a line of transmission of 1500 km long. In this case, the cost of construction of this system of storage was distributed in the following way:

- Superconductive coil, 45%.
- Structure, 30%.
- Labor, 12%.

- Converter, 8%.
- Cooling system, 5%.

Appendix B.

Table B.1 shows a list of legislation related to the Spanish electricity system and which affects, directly or indirectly, the implementation, use and development of storage systems.

Table B.1. Main Spanish legislation relative to the electrical system.

Appendix C.

The main application standards for the construction and development to take into account for a SMES device are found in the table C.1.

Table C.1. Main standards relative to the SMES systems [105].

Appendix D.

D.1. United States of America

In the USA, the normative elements of the electrical system are structured in hierarchical levels, which implies that the energy policy of the United States is fundamentally determined by State and federal public entities. Energy policy may include legislation, international treaties, subsidies and investment incentives, advice for saving energy, taxes and other public policy techniques. The main law in the U.S. electrical system is the Energy Policy Act of 2005 PL 109-58 [97], which regulates the electric system. The rest of the rules and regulations at the federal level depends on this law.

The federal agencies are obliged to comply with the orders of the administration of energy that, apart from the indicated law, include the following federal laws:

- Executive Order 13693—Planning for Federal Sustainability in the Next Decade [122].
- Energy Independence and Security Act of 2007 [123].
- Executive Order 13221—Energy Efficient Standby Power Devices. [124].
- Energy Policy Act of 1992 [125].
- National Energy Conservation Policy Act.

D.2. Japan

The Japanese energy policy is based on the Basic Law of Politics of Energy, which came into force in June, 2002, Law number 71, and it is possible to summarise by the trilemma of “3 E”: the energy safety (article 2), the environment sustainability (article 3) and the economic efficiency (article 4) [126, 127]. The Basic Law does not establish quantifiable targets, but it authorizes the government to formulate a strategic plan of energy that promotes measurements to guarantee an energy supply that satisfies the needs for the demand.

The First Strategic Plan of Energy dates of 2003 and since then it has been checked on three occasions: 2007, 2010 and 2014.

With the Third Strategic Plan of Energy, economic efficiency and energy security were subordinate to the "E" of the environment. This plan supported the forecasts from an energy mix in which nuclear energy (in quality of clean energy, efficient and economical) was called to play a leading role, and renewable energies would complement it.

This Plan was valid at the beginning of 2011, at the time of the Fukushima nuclear accident. However, after the accident of Fukushima, the government took a radical turn to aim at the total abandonment of the nuclear energy model. This rotation is materialized in the Innovative Strategy for Energy and the Environment of 2012.

The Innovative Strategy sought to reduce the dependence of both nuclear energy and fossil fuels, maximizing the "green energy" and enhancing the energy efficiency and the renewable energies. The new strategy also reviewed the objectives for CO_2 emissions for 2030.

A White Paper on Energy 2013 was published in June 2014, preceded in March 2014 by the Fourth Strategic Plan of Power [98] (enerugi kihon keikaku) with a horizon of 2030 without specifying the future energy mix in Japan.

In regard to the lines of the Fourth Strategic Plan of Energy, the new energy policy of Japan aims to simultaneously reduce the costs of generation and purchase of primary energy, distribution and consumption, paving the way for the return of nuclear energy.

D.2. Germany

Germany is in the same status as Spain, it must fulfil the community regulation of the European Parliament. Furthermore, it has a hierarchical legislative structure, in which the first level is the federal government followed by the 16 states that compose Germany, called Länder or Bundesländer, as well as subdivisions of these.

At the federal level, the law of power supply (Stromein-speisungsgesetz) entered into force in 1991 [128]. For the first time the obligation of the big electrical companies to buy electric power generated with renewable conversion processes was regulated, and they have to pay for it at tariffs previously established. This greatly facilitates the access of "green electricity" to the networks [99].

In the year 2000 the Law of Renewable Energies (EEG) entered into force. With the EEG is enshrined the priority of electricity from renewable energy sources and the connection to the network. The EEG is transformed from then on engine for the development of renewable energies, among other reasons, owing to the regulatory framework. Since the year 2000 the EEG has already been subjected to several amendments: EEG 2004, EEG 2009, EEG 2012 and EGG 2014.

It is in this last reform of the Law [100] that it is intended to increase the energy capacity. Renewable energies and converted energy storage is a key aspect for the future. The main objective is to balance the problems of flashing that the renewable energies created in the electrical system.

The German authorities have opted for the storage of water by pumping as a solution to the energy storage. But the research and development of new ESS, as hybrid systems, have increased for the development of the German electrical system.

Part of the amendments that have been mentioned, the reform of the Law on renewable energy, called EEG 2017, entered into force on 1 January 2017. With this reform, the premium is not fixed by the State, but through market auctions, which depend on the type of renewable energy, with an annual amount being fixed for each one. The aim is to increase the share of renewable energies, from the current 33% to 40-45% in 2025 and to 55-60% in 2035.

Figure

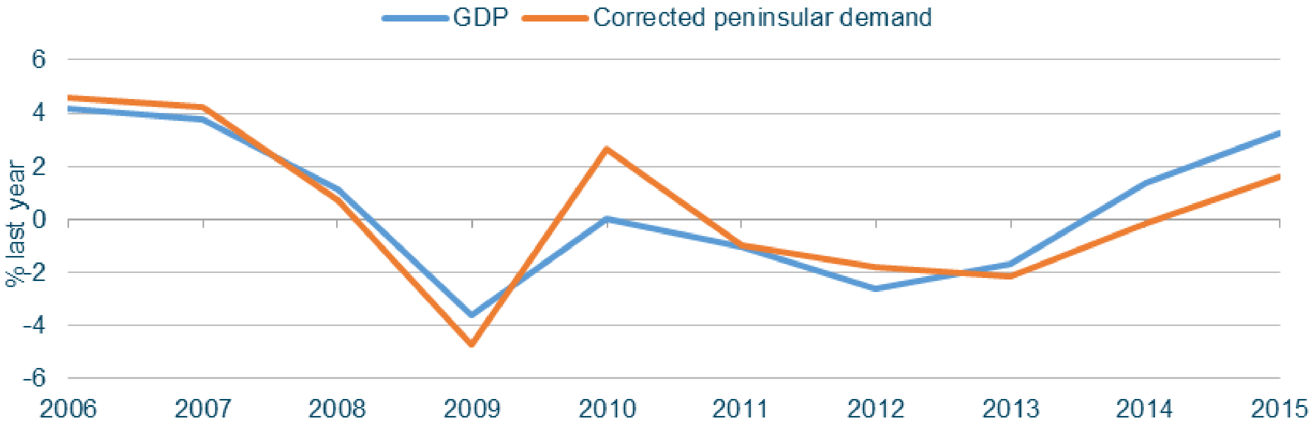

Fig. 1. Comparative GDP vs Energy Demand [6].

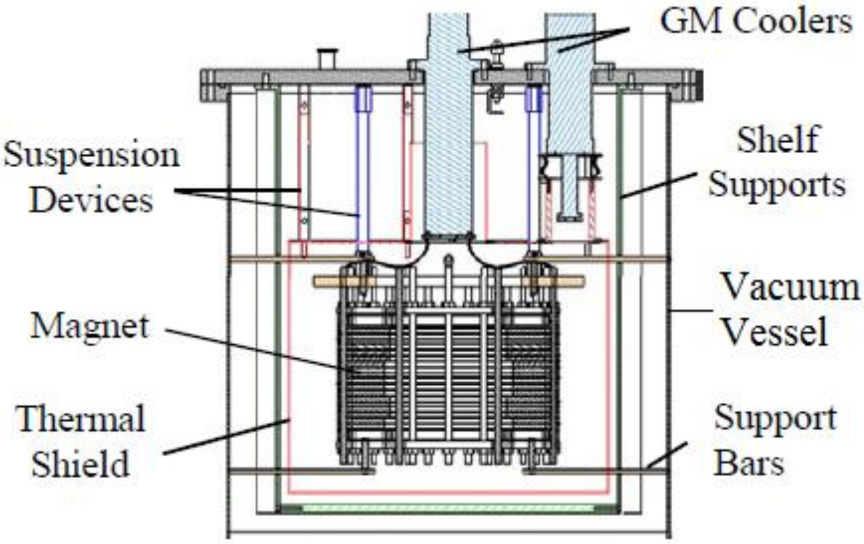

Fig. 2. SMES System [55].

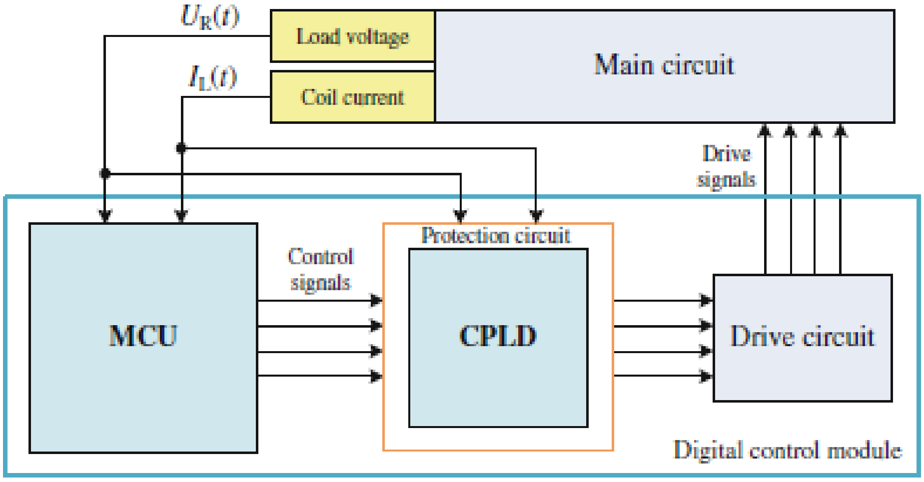

Fig. 3. Control module of a SMES system [56].

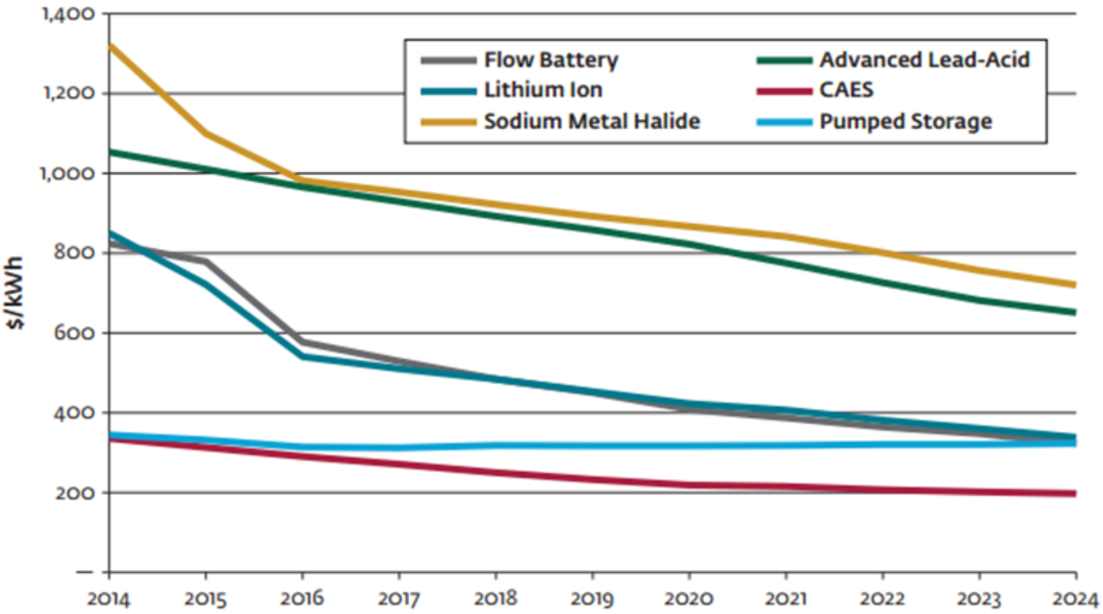

Fig. 4. Estimation of the cost for storage technology [63].

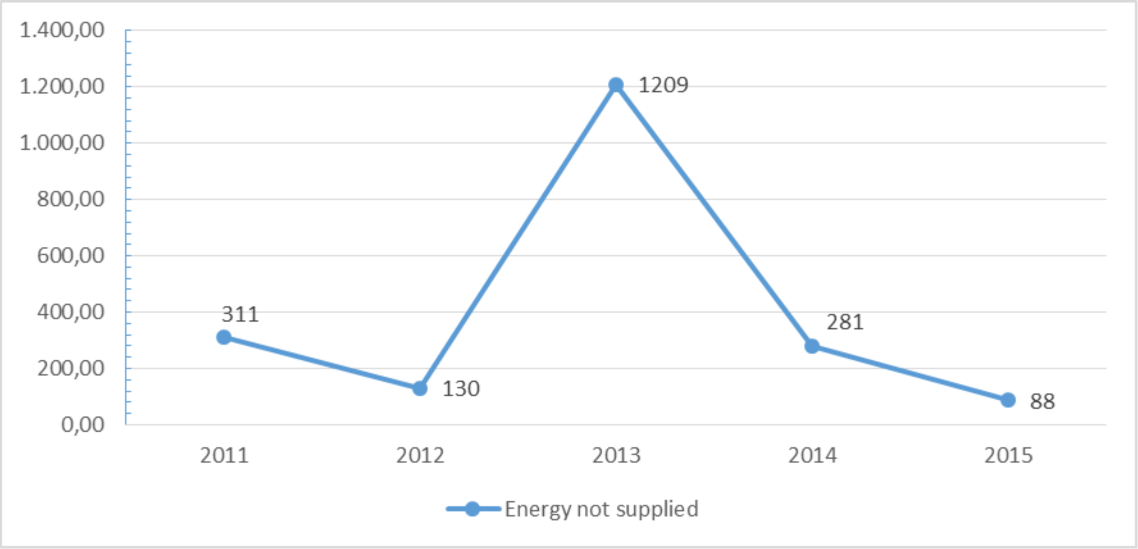

Fig. 5. Losses due to cuts of service [65].

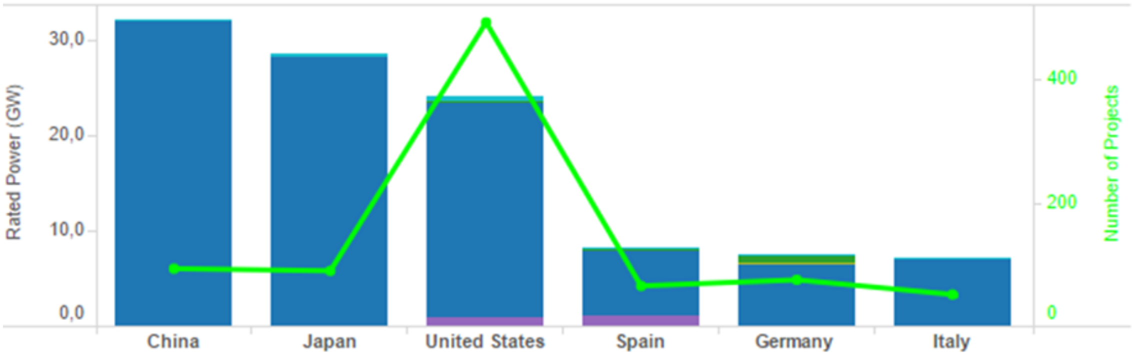

Fig. 6. Stored power – Storage projects [5].

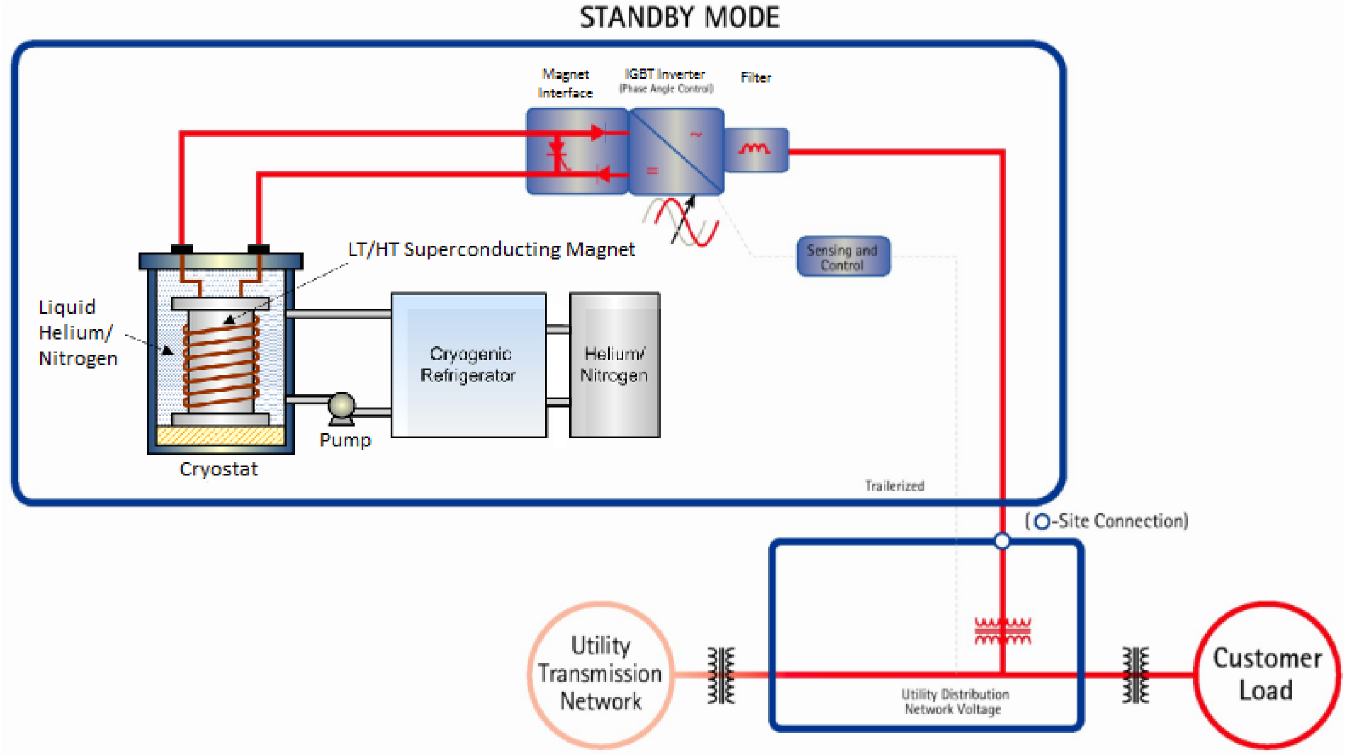

Fig. A.1. Basic schema of a SMES system [107].

Table

Table 1. Main characteristics of a SMES [3, 7, 8, 22-38].

Daily self-discharge (%)	Energy Density (Wh/L)	Specific energy (Wh/kg)	Power Density (W/L)	Specific power (W/kg)	Power (MW)	Response time	Discharge time	Suitable storage duration	Efficiency (%)	Lifetime (yr)	Lifetime (cycles)
10–15	0,2-6	0,5-5	1000-4000	500-2000	0,01-10	<10ms	ms-min	min-h	>90	20+	$5\cdot10^4$

Table 2. Applications of SMES [7, 8, 29, 38-41].

Application area	**Standing reserve**	**Emergency and telecommunications back-up power**	**Load following**	**Uninterruptible Power Supply (UPS)**	**Voltage regulation and control**
	✗	✗	✓	✓	✓
	Black-start	**Frequency regulation**	**Integration of renewable power generation**	**Grid fluctuation suppression**	**Spinning reserve**
	✓	✓	✓	✓	✓

Table 3. Price range of a SMES system [7, 22, 24-29, 31, 36-38, 59-62].

	$C_E(\$/kWh)$	$C_P(\$/kW)$
SMES System	700-10.000	130-515

Table 4.Example of costs of a SMES system. [52].

Technology	Energy cost ($/kWh)	Power cost ($/kW)	Balance of plant cost ($/kWh)	Operation & maintenance cost ($/kW)	Efficiency (%)	Lifetime (yr)
SMES	10	300	1,5	10	95	20

Table 5. Peninsular transport network.

Peninsular transport network	**2011**	**2012**	**2013**	**2014**	**2015**
Network availability (%)	97,72	97,78	98,2	98,2	97,93
Energy not supplied (ENS) MWh	259	113	1.126	204	52
Average Interruption Time (AIT) min.	0,535	0,238	2,403	0,441	0,111

Table 6. Balear transport network.

Balear transport network	**2011**	**2012**	**2013**	**2014**	**2015**
Network availability (%)	98,21	98,07	97,96	98	96,87
Energy not supplied (ENS) MWh	35	7	80	13	7
Average Interruption Time (AIT) min.	3,194	0,678	7,366	1,205	0,642

Table 7. Canarian transport network.

Canarian transport network	**2011**	**2012**	**2013**	**2014**	**2015**
Network availability (%)	98,95	98,91	98,3	98,37	96,76
Energy not supplied (ENS) MWh	17	10	3	64	29
Average Interruption Time (AIT) min.	1,023	0,613	0,177	3,938	1,763

Table 8. Emission factor of the main substances [67].

	Emission factor (χ)	**Units**
Carbon dioxide. CO_2	2,29700	Kg of CO_2/kg of coal
Carbon monoxide. CO	0,00025	Kg of CO/kg of coal
Sulfur anhydride. SO_2	0,05510	Kg of SO_2/kg of coal
Ammonia. NH_3	0,00086	Kg of NH_3/kg of coal
Nitrogen dioxide. NO_X	0,01100	Kg of NO_2/kg of coal

Table 9. Coal statistics in Spain [67, 68].

	Average annual generation (%)	Energy generation (GWh)
2009	12,50%	34.793,03
2010	8,30%	23.700,61
2011	15,60%	43.266,69
2012	19,20%	53.813,42
2013	14,70%	39.527,56
2014	16,50%	43.320,30
2015	19,90%	52.789,04
2016	14,50%	37.474,06

Table 10. Generation of substances by the consumed coal [68].

	Amount of substance generated per year [ton]				
	CO_2	CO	SO_2	NH_3	NO_X
2009	14.027.869,55	1.526,76	336.497,87	5.252,05	67.177,43
2010	9.555.625,39	1.040,01	229.218,53	3.577,64	45.760,50
2011	17.444.287,85	1.898,59	418.450,27	6.531,17	83.538,17
2012	21.696.521,14	2.361,40	520.452,03	8.123,21	103.901,49
2013	15.936.743,31	1.734,52	382.287,57	5.966,74	76.318,75

Table 11. Saved tons of carbon and CO_2 by ESS [71].

	% Carbon	E_{SESS} (MWh)	CNC	CO_2
2010	8,30%	4.457.782,58	3.909,58	8.980,30
2011	15,60%	3.214.959,82	5.299,48	12.172,90
2012	19,20%	5.022.547,79	10.189,62	23.405,56
2013	14,70%	5.957.844,99	9.254,21	21.256,92
2014	16,50%	5.329.590,05	9.292,03	21.343,79
2015	19,90%	4.520.094,18	9.504,59	21.832,04
2016	14,50%	4.819.413,08	7.384,05	16.961,17

Table 12. Main European legislation.

Norm	Date	Ambit	Summary
THE TREATY ON EUROPEAN UNION AND THE TREATY ON THE FUNCTIONING OF THE EUROPEAN UNION [77]	2010	Charter of Fundamental Rights of the European Union.	- To guarantee the functioning of the market of the energy. - To guarantee the safety of the energy supply in the Union. - To encourage the energy efficiency and the energy saving as well as the development of new and renewable energies. - To encourage the interconnection of the energy networks
DIRECTIVE 2009/28/EC OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL [78]	23 April, 2009	Concerning the promotion of the use of energy from renewable sources and which modify and repeal the Directives 2001/77/CE and 2003/30/CE	- Supports the integration into the network of transport and distribution of energy from renewable sources and the use of systems of energy storage for the variable integrated production of energy from renewable sources
DIRECTIVE 2009/72/CE OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL [79]	13 July, 2009	Concerning common rules for the internal electricity market.	- Establishes common rules for the generation, transport, distribution and supply of electricity, as well as rules concerning the protection of consumers, with a view to improve and integrate competitive markets of the electricity in the EU.
DIRECTIVE 2012/27/EU OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL [80]	25 October, 2012	Concerning the energy efficiency, which modify the Directives 2009/125/CE and 2010/30/UE, and which repeal the Directives 2004/8/CE and 2006/32/CE	- Shows the different criteria of energy efficiency for the regulation of the network of energy and for the tariffs of the electrical network
REGULATION (EU) No 347/2013 OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL [81]	17 April, 2013	Concerning the guidelines for trans-European energy infrastructures.	- The projects related to transport and storage of energy should promote the use of renewable sources, storage systems, guaranteeing the supply, opting for financial aid from the Union in the form of grants.

Table 13. Operative Procedures.

Operative Procedures	Ambit
P.O. 1.2 [87]	Allowable levels of load network.
P.O. 2.1 [88]	Demand forecasting.
P.O. 2.5 [88]	Maintenance of units of production plans.
P.O. 3.1 [89]	Programming of the generation.
P.O. 3.7 [89]	Application of limitations to deliveries of energy production in non-resolvable situations with the application of the adjustment of the system service.
P.O. 3.10 [90]	Resolution of restrictions by assurance of supply.
P.O. 7.4 [91]	Complementary service of voltage control of the transport network.
P.O. 8.2 [92]	Operation of the system of production and transport.
P.O. 13 [93]	Criteria of the planning of the networks of transport of the insular and extrapeninsular electrical system.
P.O. 13.1 (94)	Criteria of development of the transport network.
P.O. 13.3 [95]	Transport network facilities: criteria of design, minimum requirements and verification of their equipment and commissioning.
P.O. 15.2 [96]	Management service of demand of interruptibility service.

Table 14. Comparative table USA-Japan-Germany [97-100].

	(USA)	**(Japan)**	**(Germany)**
Main Energy Law at National level.	Energy Policy Act of 2005 PL 109-58	Basic Law of Energy Policy - 4th Strategic Plan of Energy (enerugi kihon keikaku)	Erneuerbare-Energie-Gesetz 2017
Renewable Objectives.	Does not specify	3rd Plan: 50% (2030) 4th Plan: Does not specify	45% (2025)
Financing of Renewable Energies.	The law provides loans guarantees to the entities that develop or use innovative technologies that prevent the sub-production from greenhouse gases.	Sets that renewable energies will expand their market rate by 10% thanks to the "Feed-in tariff" (FIT). FIT is a remuneration set by the government for energy injected into the network.	Sets the FIT as a mechanism of incentives for renewable energy. The cost of the FIT moves to the users through the finalist EEG rate.
Research and Development.	It encourages the research and the development of new elements of generation and energy efficiency that make possible the decline of GHG	Increase in financing of renewable energy and energy efficiency projects. Japan is one of the largest exporters of technology in the energy sector and has a strong program of research, development and innovation backed by the Government.	Aid for the new projects related with the renewable energies and the facilities that are considered for domestic use or that do not come into the consideration of intensive exploitation.
Other.	In Sec. 925 it is explicitly indicated that there should be a focus on storage systems and systems of high-temperature superconductivity research	The storage system introduction is promoted in an explicit way using batteries to ensure the supply and quality. It also refers to other system of electrical energy storage, as the PHS or fuel cells.	Electricity used for temporary storage operators of transport networks to the payment of the surcharge EEG shall not apply if the power is removed from the installation of electricity storage only for feedback on the electricity in the network system.
Example SMES.	Los Alamos National Laboratory: Material NbTi, Energy 30 MJ	Chubu Electric Power Company: Material Bi-2212, Energy 1 MJ	ACCEL Instruments GmbH: Material Bi-2223, Energy 150 kJ

Table B.1. Main Spanish legislation relative to the electrical system.

Norm	Date	Ambit
LEY 54/1997 [85]	27 November 1997	Basic Law of the Spanish electricity sector
REAL DECRETO 2019/1997 [109]	26 December 1997	It organises and regulates the electricity production market
REAL DECRETO 1955/2000 [110]	1 December 2000	Regulates the activities of transport, distribution, marketing, supply and installations of electricity authorisation procedures.
REAL DECRETO-LEY 6/2009 [111]	30 April2009	Certain measurements are adopted in the energy sector and the social bond is approved.
REAL DECRETO 134/2010 [112]	12 February 2010	The procedure of resolution of restrictions by supply guarantee is established and the Royal decree 2019/1997, of December 26 which organizes and regulates the market of production of electric power, is modified.
REAL DECRETO -LEY 6/2010 [113]	9 April 2010	The content of articles 1, 9, 11 and 14 of law 54/1997 of 27 November are modified, in the Electricity Sector
REAL DECRETO 1221/2010 [114]	1 October 2010	Establishes the procedure of resolution of restrictions by security of supply and amending Royal Decree 2019 / 1997, of 26th December, which organizes and regulates the electricity production market
REAL DECRETO 1565/2010 [115]	19 November 2010	Regulates and modifies certain aspects relating to the activity of production of electrical energy in special regime
REAL DECRETO 1614/2010 [116]	7 December 2010	Regulates and modifies certain aspects relating to the activity of production of electrical energy from technologies solar thermoelectric power and wind power.
REAL DECRETO -LEY 14/2010 [117]	23 December 2010	Urgent measurements are established for the correction of the tariff deficit of the electrical sector.
REAL DECRETO 1699/2011 [118]	18 November 2011	Regulates the connection to network of production facilities of electrical energy of small power.
REAL DECRETO -LEY 1/2012 [119]	27 January 2012	Proceeds to the suspension of the procedures of preallocation of compensation and to the suppression of the economic incentives for new facilities of production of electric power from cogeneration, renewable energy sources and residues
REAL DECRETO -LEY 2/2013 [120]	1 February 2013	Urgent measures in the electrical system and in the financial sector.
REAL DECRETO -LEY 9/2013 [121]	12 July 2013	Urgent measurements are adopted to guarantee the financial stability of the electrical system.
LEY 24/2013 [86]	26 December 2013	The electricity sector.

Table C.1. Main standards relative to the SMES systems [105].

Norm	**Ambit**	**European Equivalent**	**International Equivalent**	**CTN**
UNE-EN 286-1:1999	Simple pressure receptacles not submitted to the flame, designed to contain air or nitrogen. Part 1: Pressure receptacles for general uses.	EN 286-1:1998		AEN/CTN 62
UNE-EN 286-1/A1:2003	Simple pressure receptacles not submitted to the flame, designed to contain air or nitrogen. Part 1: Pressure receptacles for general uses.	EN 286-1:1998/AC:2002 ; EN 286-1:1998/A1:2002		AEN/CTN 62
UNE-EN 286-1:1999/A2:2006	Simple pressure receptacles not submitted to the flame, designed to contain air or nitrogen. Part 1: Pressure receptacles for general uses.	EN 286-1:1998/A2:2005		AEN/CTN 62
UNE-EN 13371:2002	Cryogenic receptacles. Couplings for cryogenic use.	EN 13371:2001		AEN/CTN 62
UNE-EN 13275:2001	Cryogenic receptacles. Pumps for cryogenic use.	EN 13275:2000		AEN/CTN 62
UNE-EN 1797:2002	Cryogenic receptacles. Gas / material compatibility	EN 1797:2001		AEN/CTN 62
UNE-EN 13648-1:2009	Cryogenic receptacles. Safety devices for protection against excessive pressure. Part 1: Safety valves for the cryogenic service	EN 13648-1:2008		AEN/CTN 62
UNE-EN 13648-2:2002	Cryogenic receptacles. Safety devices for protection against excessive pressure. Part 2: Safety Devices with rupture disks for the cryogenic service	EN 13648-2:2002		AEN/CTN 62
UNE-EN 13648-3:2003	Cryogenic receptacles. Safety devices for protection against excessive pressure. Part 3: Determination of the required discharge. Capacity and sizing	EN 13648-3:2002		AEN/CTN 62
UNE-EN 13530-1:2002	Cryogenic receptacles Big transportable receptacles isolated in vacuum. Part 1: Fundamental requirements.	EN 13530-1:2002		AEN/CTN 62
UNE-EN 13530-2:2003	Cryogenic receptacles Big transportable receptacles isolated in vacuum. Part 2: Design, fabrication, inspection and testing.	EN 13530-2:2002		AEN/CTN 62
UNE-EN 13530-2:2003/AC:2007	Cryogenic receptacles Big transportable receptacles isolated in vacuum. Part 2: Design, fabrication, inspection and testing.	EN 13530-2:2002/AC:2006		AEN/CTN 62
UNE-EN 13530-2/A1:2004	Cryogenic receptacles Big transportable receptacles isolated in vacuum. Part 2: Design, fabrication, inspection and testing	EN 13530-2:2002/A1:2004		AEN/CTN 62
UNE-EN 13530-3:2002/A1:2005	Cryogenic receptacles Big transportable receptacles isolated in vacuum. Part 3: Operating Requirements.	EN 13530-3:2002/A1:2005		AEN/CTN 62
UNE-EN 13530-3:2002	Cryogenic receptacles Big transportable receptacles isolated in vacuum. Part 3: Operating Requirements	EN 13530-3:2002		AEN/CTN 62
UNE-EN 14398-1:2004	Cryogenic receptacles Big transportable receptacles non isolated in vacuum. Part 1: Fundamental requirements.	EN 14398-1:2003		AEN/CTN 62
UNE-EN 14398-2:2004+A2:2008	Cryogenic receptacles Big transportable receptacles non isolated in vacuum. Part 2: Design, fabrication, inspection and testing.	EN 14398-2:2003+A2:2008		AEN/CTN 62
UNE-EN 14398-3:2004	Cryogenic receptacles Big transportable receptacles non isolated in vacuum. Part 3: Operating Requirements	EN 14398-3:2003		AEN/CTN 62
UNE-EN 14398-3:2004/A1:2005	Cryogenic receptacles Big transportable receptacles non isolated in vacuum. Part 3: Operating Requirements.	EN 14398-3:2003/A1:2005		AEN/CTN 62
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UNE-EN 1252-1:1998	Cryogenic receptacles. Materials. Part 1: Requirements of tenacity for temperature below - 80 ° c.	EN 1252-1:1998		AEN/CTN 62
UNE-EN 1252-1/AC:1999	Cryogenic receptacles. Materials. Part 1: Requirements of tenacity for temperature below - 80 ° c	EN 1252-1:1998/AC:1998		AEN/CTN 62
UNE-EN 1252-2:2002	Cryogenic receptacles. Materials. Part 2: Requirements of tenacity to temperatures ranging from - 80 ° C and - 20 ° C.	EN 1252-2:2001		AEN/CTN 62
UNE-EN 12213:1999	Cryogenic receptacles. Evaluation methods of the yield of the isolation.	EN 12213:1998		AEN/CTN 62
UNE-EN 13458-1:2002	Cryogenic receptacles. Static vacuum insulated receptacles. Part 1: Fundamental requirements.	EN 13458-1:2002		AEN/CTN 62
UNE-EN 13458-2:2003	Cryogenic receptacles Static vacuum insulated receptacles. Part 2: Design, fabrication, inspection and testing	EN 13458-2:2002		AEN/CTN 62
UNE-EN 13458-2:2003/AC:2007	Cryogenic receptacles Static vacuum insulated receptacles.. Part 2: Design, fabrication, inspection and testing	EN 13458-2:2002/AC:2006		AEN/CTN 62
UNE-EN 13458-3:2003	Cryogenic receptacles Static vacuum insulated receptacles. Part 3: Operating Requirements	EN 13458-3:2003		AEN/CTN 62
UNE-EN 13458-3:2003/A1:2005	Cryogenic receptacles Static vacuum insulated receptacles. Part 3: Operating Requirements	EN 13458-3:2003/A1:2005		AEN/CTN 62
UNE-EN 14197-1:2004	Cryogenic receptacles Static non vacuum insulated receptacles Part 1: Fundamental requirements.	EN 14197-1:2003		AEN/CTN 62
UNE-EN 14197-2:2004/A1:2006	Cryogenic receptacles Static non-vacuum insulated receptacles. Part 2: Design, fabrication, inspection and testing	EN 14197-2:2003/A1:2006		AEN/CTN 62
UNE-EN 14197-2:2004	Cryogenic receptacles. Static non-vacuum insulated receptacles. Part 2: Design, fabrication, inspection and testing	EN 14197-2:2003		AEN/CTN 62
UNE-EN 14197-2:2004/AC:2007	Cryogenic receptacles. Static non-vacuum insulated receptacles. Part 2: Design, fabrication, inspection and testing	EN 14197-2:2003/AC:2006		AEN/CTN 62
UNE-EN 14197-3/AC:2004	Cryogenic receptacles. Static non-vacuum insulated receptacles. Part 3: Operating Requirements	EN 14197-3:2004/AC:2004		AEN/CTN 62
UNE-EN 14197-3:2004	Cryogenic receptacles Static non-vacuum insulated receptacles. Part 3: Operating Requirements	EN 14197-3:2004		AEN/CTN 62
UNE-EN 14197-3:2004/A1:2005	Cryogenic receptacles. Static non-vacuum insulated receptacles. Part 3: Operating Requirements	EN 14197-3:2004/A1:2005		AEN/CTN 62
UNE-EN 1251-1:2001	Cryogenic receptacles Portable receptacles vacuum isolated, not more than 1000 litres volume. Part 1: Fundamental requirements.	EN 1251-1:2000		AEN/CTN 62
UNE-EN 1251-2:2001	Cryogenic receptacles Portable receptacles vacuum isolated, not more than 1000 litres volume. Part 2: Design, fabrication, inspection and testing	EN 1251-2:2000		AEN/CTN 62
UNE-EN 1251-2:2001/AC:2007	Cryogenic receptacles Portable receptacles vacuum isolated, not more than 1000 litres volume. Part 2: Design, fabrication, inspection and testing	EN 1251-2:2000/AC:2006		AEN/CTN 62
UNE-EN ISO 21029-2:2016	Cryogenic receptacles Portable receptacles vacuum isolated, not more than 1000 litres volume. Part 2: Operating Requirements	EN ISO 21029-2:2015	ISO 21029-2:2015	AEN/CTN 62

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UNE-EN 61788-12:2013	Superconductivity Part 12: Measurement of the relation between matrix and superconductor volumes. Relation between volumes of copper and the rest of the threads compound superconductors of Nb_3Sn. (Ratified by AENOR in November 2013)	EN 61788-12:2013	IEC 61788-12:2013	AEN/CTN 206
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UNE-EN 61788-16:2013	Superconductivity Part 16: Measures of electronic characteristics. Surface resistance dependent on the power of superconductors at microwave frequencies (Ratified by AENOR in May 2013)	EN 61788-16:2013	IEC 61788-16:2013	AEN/CTN 206
UNE-EN 61788-17:2013	Superconductivity Part 17: Measurements of the electronic characteristics. Local critical current density and its distribution in superconductive movies of big surface. (Ratified by AENOR in May 2013)	EN 61788-17:2013	IEC 61788-17:2013	AEN/CTN 206
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