MASTER IN THE ELECTRIC POWER INDUSTRY

MASTER'S FINAL PROJECT

STAND-ALONE BATTERY ENERGY STORAGE PROJECT

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1. Project Introduction

1.1. Motivation and Objectives

Contemporary understanding of the effects of human activity on the environment has revealed a fundamental shift in the existing paradigm of energy generation.

Traditionally, large thermal power plants—first coal-fired and later nuclear—formed the backbone of electricity generation in systems such as Spain's, supported by rapidly dispatchable sources like gas-fired combined-cycle plants or hydraulic turbines to meet demand peaks and serve as reserve capacity.

However, the growing awareness of the environmental impacts associated with energy generation spurred, from the late twentieth century onward, an increasing penetration of renewable energy sources. This new approach to energy generation is based on resources naturally replenished by the environment which avoid the emission of carbon dioxide into the atmosphere, the primary driver of climate change, an ever more pressing challenge of our time.

The Paris Agreement, signed by 196 parties to the United Nations in December 2015, set long-term objectives to limit global warming to 2°C above pre-industrial levels. This became the foundation for energy policies aimed at reducing dependence on conventional, carbon dioxide–emitting energy sources in favor of renewable sources that emit no greenhouse gases and whose operating principles also enable energy autonomy, in contrast with sources dependent on imported raw materials.

The first steps toward renewable penetration in Europe were taken through feed-in tariffs and premiums, which ensured investment returns for renewable energy projects with the aim of promoting these technologies in European power systems. By the 2010s, the sharp decline in renewable energy costs—mainly due to mass production of the enabling technologies—removed the need for such premiums, making way for competitive auctions for new generation facilities and long-term contracts for recovering system costs.

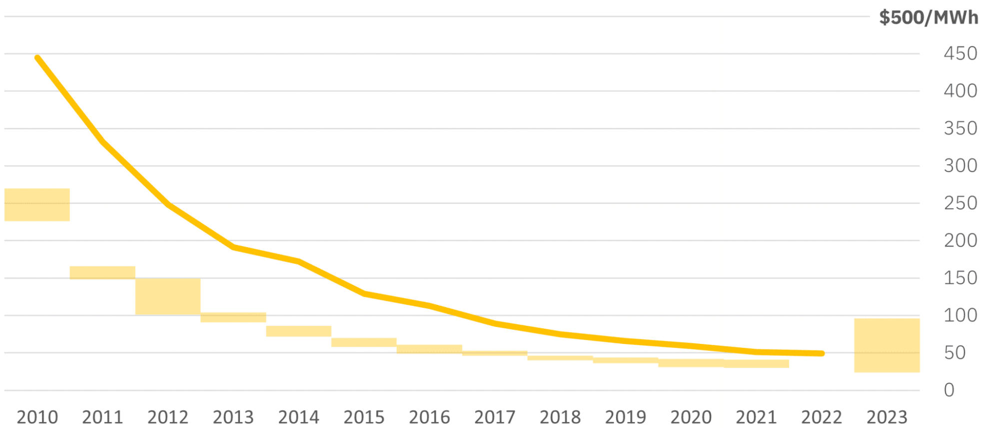


Figure 1. LCOE for Solar Photovoltaic (ALEASOFT, 2022)

The European Green Deal also represents a turning point in the penetration of renewable energies into the European power system by promoting support schemes for new renewable generation facilities. In countries such as Spain, technologies considered free of greenhouse gas emissions account for nearly 70% of the total installed capacity in the energy mix.

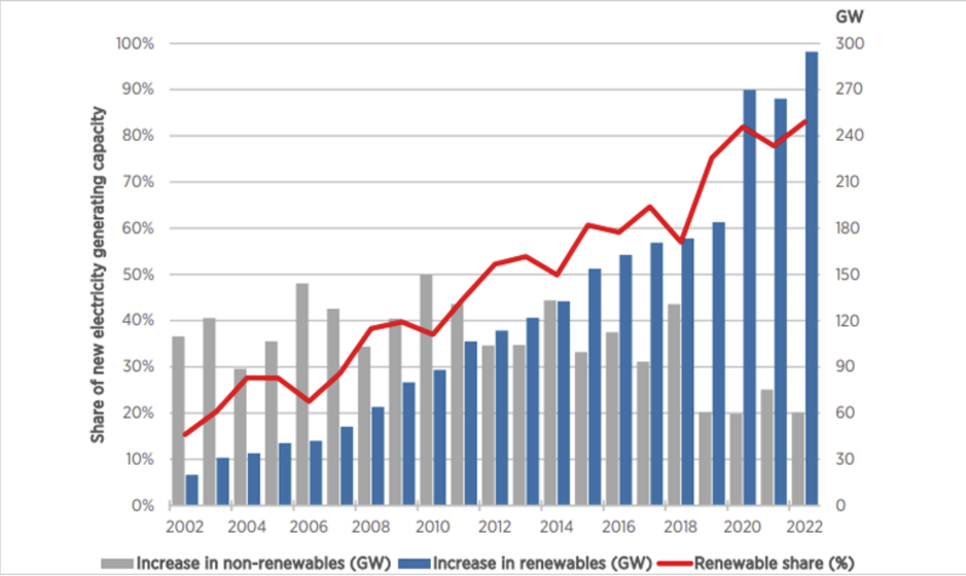


Figure 2. Share of RES in generating capacity

In the context of this energy transition, storage emerges as an enabling player in the proposed shift in the generation structure, both through its progressive role in replacing gas-fired plants during peak demand hours and through the energy management capabilities it offers in relation to renewable energy sources.

The main factor limiting greater penetration of renewable energy is the non-dispatchable nature of these technologies compared with conventional sources, which can increase or decrease their output at will in response to demand.

Renewable energy sources, in contrast, depend entirely on weather conditions for their participation in energy markets and are unable to generate in the absence of wind or solar resources. Moreover, higher penetration of variable generation leads to situations of energy curtailment, in which an excess of energy produced during periods of peak solar generation cannot be absorbed by the system.

This project is framed within the context of the energy transition in generation sources as an initiative for new electrochemical storage in the Spanish electricity system.

From the perspective of a new developer, this work aims to examine the legislative and regulatory framework governing battery energy storage systems (BESS) and to explain the needs driving greater penetration of energy storage in power systems, addressing the challenges posed by the recent increase in renewable energy and outlining the role of storage as a mitigating element for these issues.

From this standpoint, the technical aspects required for the construction and commissioning of the storage system will be analyzed, detailing the steps and decisions taken from the grid connection point through to the justification of the specific selection of the main components that will constitute the whole facility.

The final aspect to be examined will be the economic evaluation of the project, including both an estimate of the total installation cost and an assessment of the potential remuneration the project could obtain from the wholesale electricity market, based on future market forecasts. Possible threats that could jeopardize the project's viability will be studied, thus allowing a conclusion to be drawn on the desirability of pursuing the stated objectives.

1.2. SDG Alignment

This project, in line with the commitment of Universidad Pontificia Comillas ICAI to the Sustainable Development Goals, is framed within the pursuit of targets related to the energy transition, climate action, and the development of sustainable infrastructure, contributing to the integration of renewable energies and the flexibility and resilience of the power system. The main goals affected by this project are:

SDG 7: Affordable and Clean Energy

The project facilitates the integration of renewable energies into the power system by optimizing their utilization through energy storage. This contributes to diversifying the energy mix and reducing pollutant emissions, promoting access to cleaner and more sustainable energy.

SDG 9: Industry, Innovation and Infrastructure

The development of the stand-alone storage system represents an innovation in energy management, strengthening the electrical infrastructure and improving its resilience to fluctuations in supply and demand. This technological advancement drives a more efficient and adaptable energy model.

SDG 11: Sustainable Cities and Communities

By improving grid stability and reducing dependence on fossil fuel sources, the project supports the creation of more sustainable urban environments, with lower pollution levels and greater security of energy supply.

SDG 12: Responsible Consumption and Production

Energy storage optimizes the use of renewable resources, preventing waste and promoting more efficient and responsible energy consumption. This aligns with the need to balance supply and demand within the framework of a sustainable energy model.

SDG 13: Climate Action

By reducing dependence on fossil fuel sources and facilitating the integration of renewables, this project directly contributes to climate change mitigation. Its implementation helps lower greenhouse gas emissions, supporting international climate commitments.

2. Energy Storage in Decarbonization and Energy Efficiency Targets

2.1. European strategic framework: Green Deal and Fit for 55

Within the European Union, the European Green Deal sets out the roadmap for transforming Europe into a modern, sustainable, and climate-neutral economy by 2050. This plan commits to rapidly reducing greenhouse gas emissions by 2030, cutting greenhouse gas emissions by at least 55% compared to 1990 levels, and decreasing dependence on foreign energy, especially from fossil fuels.

The key principles on which the European Commission bases this transition are ensuring a secure and affordable energy supply for the European Union, developing a fully integrated, interconnected, and digitized EU energy market, and prioritizing energy efficiency by improving the performance of buildings and machinery and developing an energy sector based mainly on renewable sources. (Comisión Europea, 2019).

In its definition, the EU highlights the role of storage in the Green Deal and the Fit for 55 packages: the European vision is that the regulatory framework should encourage the deployment of innovative energy storage technologies to facilitate the energy transition. Indeed, achieving these objectives requires addressing the variable nature of sources such as wind and solar, and battery storage is emerging as an enabling solution to manage this problem. In conjunction with established energy storage technologies, battery storage is seen as an essential vector in the energy transition, coinciding with the maturity of this technology.

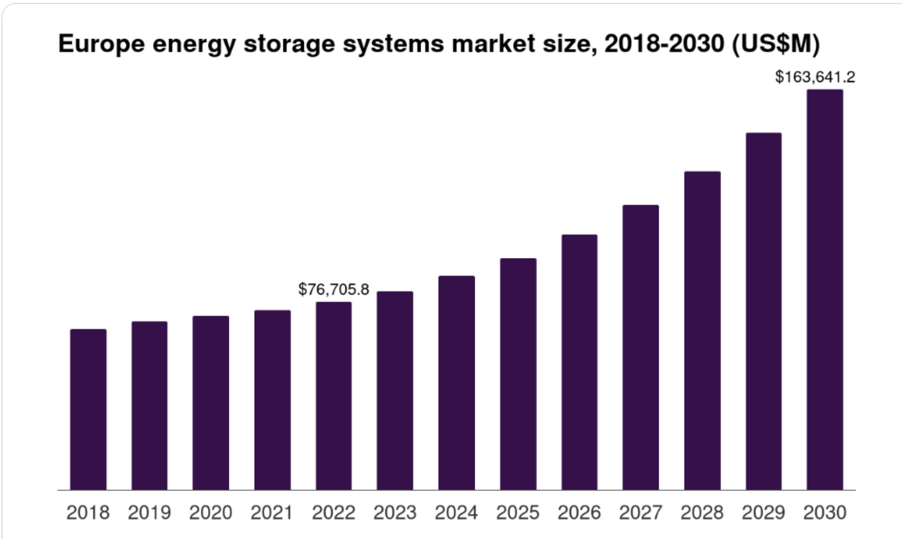


Figure 3. Growth forecast for the storage market (renewablesnow).

Within the European framework, the following financial mechanisms have also been presented, which potentially enable support for the necessary deployment of energy storage through the following plans:

The Next Generation EU instrument, created to tackle the crisis caused by the COVID-19 pandemic, mobilizes €750 billion, of which €390 billion will be channeled as direct aid and

€360 billion as loans. Its main focus is the Recovery and Resilience Facility, with €672.5 billion, which aims to promote reforms and investments geared towards ecological and digital transition, strengthening the cohesion and resilience of Member States. (European Commission, 2020).

In this context, energy storage is emerging as one of the technologies that will drive the transition to a climate-neutral economy, classifying them as projects of joint European interest. (Energy Commision Europe, 2021). These storage projects will therefore be eligible for funding from these funds, particularly through the Member States' own national recovery and transformation plans. In addition, Next Generation EU reinforces other programs such as Horizon Europe, InvestEU, and the Just Transition Fund, which provide support for the development and deployment of energy storage solutions.

The *Innovation Fund* is another major European program aimed at financing innovative low-carbon technologies, with energy storage being one of the priority areas for action. It has an estimated budget of €10 billion for the period 2020–2030, sourced from revenues from the auctioning of emission allowances under the EU Emissions Trading System (EU ETS) and remaining funds from the NER300 program. (CINEA, 2021).

The Horizon Europe research and innovation funding plan also addresses the challenge of the energy transition, structured around three pillars with different action groups in each. Energy storage projects are integrated into their Global Challenges and European Industrial Competitiveness: Climate, Energy, and Mobility. There, a public-private partnership framework for batteries will be developed, aimed at boosting the value chain and promoting investment in new storage facilities. (European Commission, 2021).

2.2. Spanish strategic framework: NECP and storage targets

Spain, in line with the European strategy, has developed its own Integrated National Energy and Climate Plan (PNIEC) 2021-2030 as a roadmap for the national energy transition. Led by the Ministry for Ecological Transition and Demographic Challenge (MITECO), the development of this action plan involves the national adoption of the EU's energy governance objectives, becoming part of a structured joint process.

The PNIEC, which will be updated in 2023 following the increase in European ambition, sets quantitative targets for 2030 in line with Fit for 55. Some of its most relevant data include a 32% reduction in GHG emissions compared to 1990 levels (compared to the 23% proposed in the previous plan), a 43% reduction in overall consumption through improved energy efficiency, and achieving 48% renewable energy in the overall energy mix. (MITECO, 2023).

Regarding the electricity sector, the updated PNIEC proposes a target of approximately 81% renewable energy in electricity generation by 2030, equivalent to an increase of 7 percentage points compared to the target set in 2021. (BOE, 2024).

To achieve this 81% renewable target, which will mainly be supported by new solar photovoltaic and wind power capacities, the government, through the BOE, emphasizes the need to deploy new storage systems that ensure a constant and flexible electricity supply in the face of the variable nature of these technologies: "The PNIEC 2023-2030 forecasts a total installed capacity in the electricity sector of 214 GW by 2030, of which 160 GW will be from renewable generation and 22.5 GW from storage." (BOE, 2024).

The need for this storage stems not only from the intermittency of renewable energy sources, but also as a means of supporting stability and guaranteeing energy supply at all times. Although most of this storage capacity will still come from pumped storage plants, the PNIEC anticipates rapid development of battery storage, either hybridized with a generation park or stand-alone, connected directly to the grid.

To make these objectives viable, in 2021 the Spanish government formulated an Energy Storage Strategy, which identifies challenges and measures to deploy the projected storage capacity by 2030, reaching 30 GW of installed capacity by 2050. (MITECO, 2021)It also establishes regulatory and financial measures to accelerate BESS projects.

An example of these storage support measures is the Recovery, Transformation, and Resilience Plan (PRTR), supported by European NextGenerationEU funds, which allocates investments for storage facilities and demand flexibility. These grants, presented in October 2020, would represent a strategic initiative to revive the Spanish economy during the recovery and reconstruction that began after the COVID-19 pandemic.

In the case of storage, these funds would be allocated to subsidies and grants for pilot projects and regulatory test beds, with the aim of promoting future investment in stand-alone facilities. They would also be used for hybrid facilities, combined with renewable generation or emerging technologies, such as green hydrogen generation. (Presidencia del gobierno, 2023).

In the regulatory sphere, barriers such as double taxation of stored energy have been removed and regulatory frameworks have been created to enable batteries to participate in different electricity markets (balancing services, capacity markets, etc.). All these initiatives aim to recognize energy storage as a central part of Spain's transition model towards the objectives defined by the European Union, acknowledging its role in both safely integrating the significant growth of renewables and reducing external energy dependence from the current 70% to 50% by 2030. (Atalaya Generación, 2024).

This new regulatory framework also sets out the roadmap in Spain for the ELP (Long-Term Decarbonization Strategy 2050), approved in 2020, which aims to achieve climate neutrality by 2050, in line with the Paris agreements and European targets.

The ELP agrees with the PNIEC on the enabling role of storage in achieving climate neutrality, assessing, among the available technologies, different forms of energy storage, both large-scale and distributed:

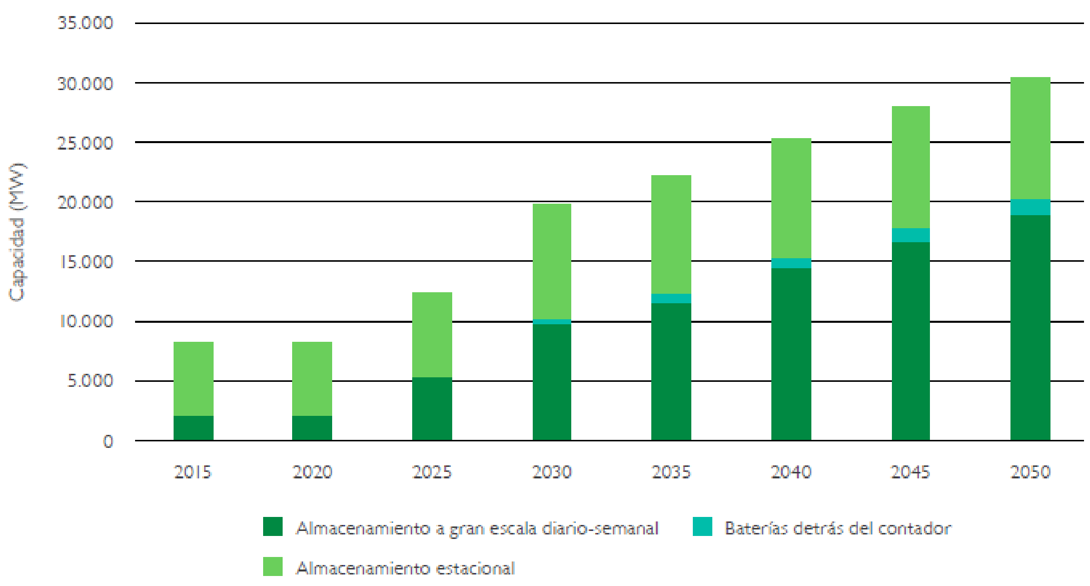


Figure 4. Forecast of energy storage needs (MITECO)

This figure shows the minimum energy storage requirements for the desired horizon in this decarbonization strategy. It estimates an increase from the 8.3 GW available at the time of preparation. (MITECO, 2021), mainly from hydraulic pumping and storage systems in solar thermal power plants, to the projected values for 2030 and 2050 already explained.

This confirms that battery energy storage systems (BESS) have found their place as a fundamental pillar in the energy transition, both for their technical contributions to the electrical system and for their strategic benefits in meeting climate and efficiency targets.

Within the European Union, initiatives such as the European Green Deal and the Fit for 55 packages have recognized that without a massive rollout of storage, it will be impossible to achieve the goals of climate neutrality and high renewable penetration in the coming decades. For its part, Spain has translated these lines of action into specific objectives within the PNIEC 2021-2030, raising the ambition for renewables and setting quantifiable targets for new capacity in BESS (22.5 GW by 2030) to ensure the stability and flexibility of the system.

3. The Need for Energy Storage

3.1. RES effects on the electricity system

As has been studied, the energy transition promoted by European regulations and in relation to both the targets to be met in 2030 and beyond, implies a large increase in the penetration of renewable energies in the international energy generation mix. The main challenge presented by this increase in the installation of renewable energies is the inability to manage their production on demand, which is known as intermittency.

The intermittency of renewable energy sources refers to their inherent variability: electricity generation from the sun or wind will fluctuate depending on weather conditions and natural cycles. This variability manifests itself continuously on a daily basis, with the clearest example being photovoltaic production, although the same phenomenon occurs in wind generators due to wind variability. There will also be seasonal intermittency, due to the greater availability of natural resources at different times of the year.

In Europe, the growing penetration of renewable energy sources and the move away from dependence on generation sources mean that this characteristic poses a challenge for the operation and planning of the electricity system. The characteristics of electrical energy mean that its production must be always matched to demand, allowing operators to manage fluctuations in the grid in accordance with consumption needs. However, the massive penetration of *unmanageable* energy sources, whose peaks and troughs in generation do not always coincide with consumption patterns, requires the creation of a strategy that allows the necessary instantaneous balance between production and consumption to be maintained.

It is therefore a question of making electricity systems more flexible through firm generation, robust networks and interconnections, energy storage, and active demand management. (IEA, 2024) to enable the correct coupling of energy generation and consumption in the electrical system. Next, we will delve deeper into this issue and study the role of battery storage to alleviate these problems.

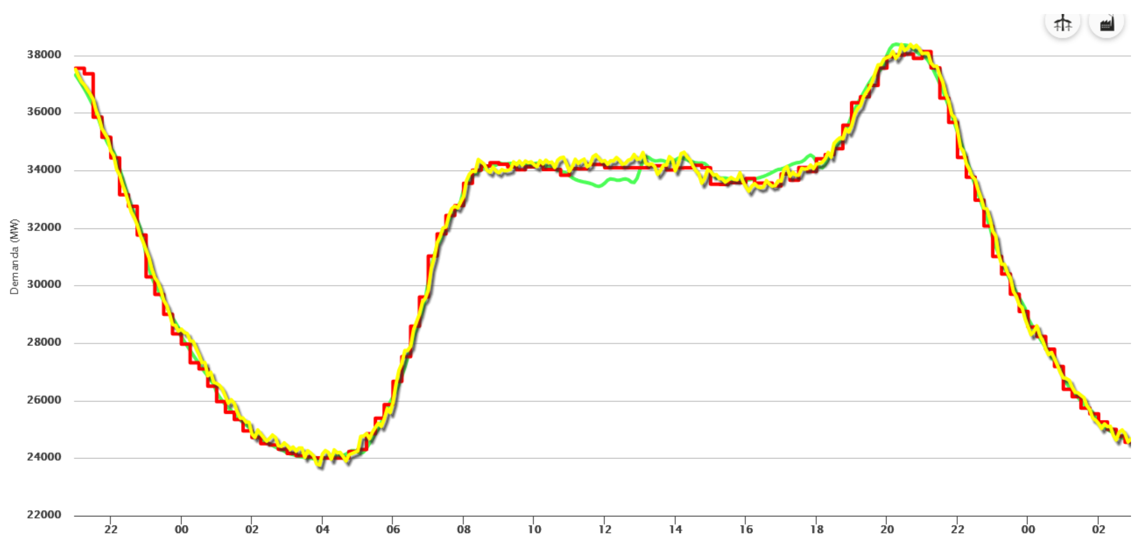


Figure 5. Houly electric demand (REE, 2025)

Electricity demand in a country such as Spain follows a relatively consistent daily cycle, with consumption peaking during the early morning and peaking during the day, a pattern that remains consistent throughout the year with relatively low seasonal changes. Solar photovoltaic generation, now established as the leading generation technology in terms of installed capacity 35.5 GW (REE, 2025)As it is an unmanageable source, peak demand does not coincide with the hours of highest energy generation from this source, making it necessary to rely on conventional generation sources.

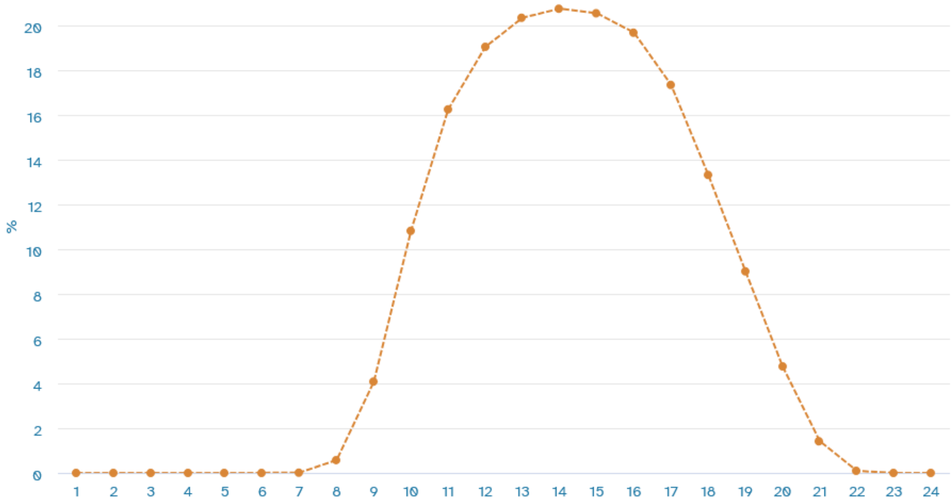


Figure 6. Average hourly PV production (REE, 2021)

Similarly, peaks in photovoltaic generation do not correspond to times of peak energy demand, resulting in an oversupply of installed photovoltaic power, which translates into increasingly common spillage at photovoltaic generation parks. In the last two years, curtailments have affected 2.9% of the photovoltaic energy generated in Spain, most of it (2.5%) without compensation. These are not compensated when communicated one day in advance, causing losses of more than €107 million in total, which is equivalent to an increase in the LCOE of €0.10/kWh and a decrease in the NPV of €27.1/kW for photovoltaic generation facilities. (pv-magazine, 2025).

The consequence of this discrepancy in systems with high photovoltaic penetration, such as in Spain, is the so-called "duck curve," a graphical representation of the difference throughout the day between electricity demand and the portion of that demand that must be supplied by non-renewable energy sources, requiring the entry of generation with the capacity to produce large increases in power generated in short time intervals to match demand during peak consumption hours.

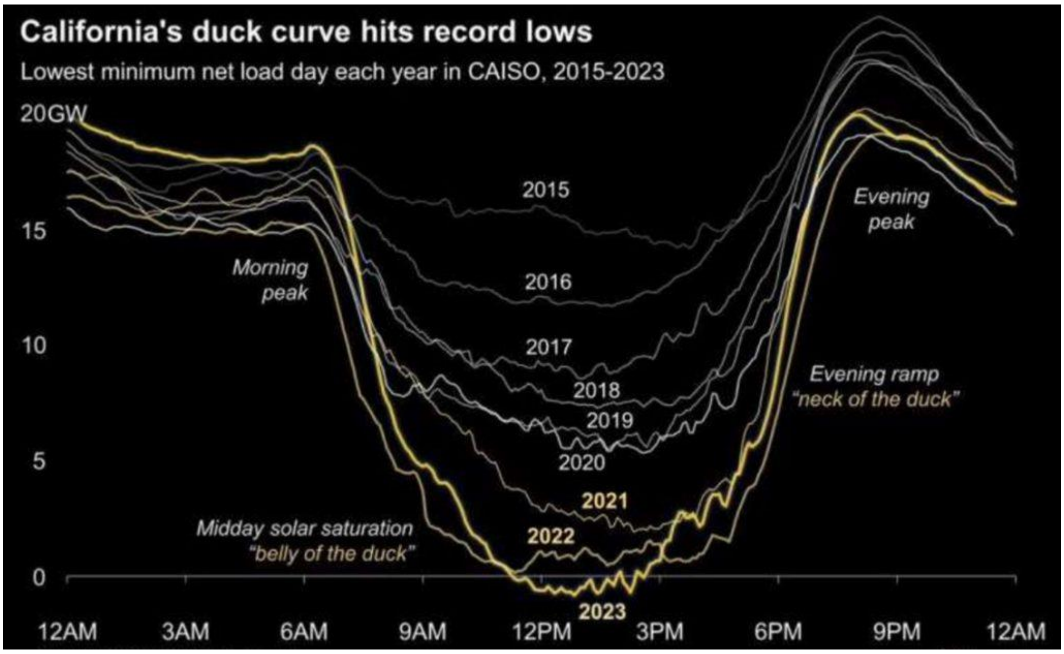


Figure 7. Duck curve in California (CAISO, 2023)

The impact on these energy systems is felt both in terms of security of supply and the effect that this phenomenon has on energy markets.

Security of supply is compromised by the need for energy sources capable of rapidly increasing their generation during periods of lower solar generation and higher demand, requiring the use of gas cycles whose greenhouse gas emissions could be higher than in a system with smoother curves or causing this gradient to be too steep to follow adequately.

In terms of its impact on the electricity market, the increase in renewable generation from non-manageable sources, mainly solar photovoltaic, puts downward pressure on electricity prices during peak hours. In marginalist markets such as the Iberian market, when solar power floods the supply, the hourly price tends to fall dramatically. Spain has experienced an unprecedented proliferation of hours with zero or even negative prices in the wholesale market over the last year, with a total of 113 hours at zero price and 363 hours with negative prices between January and May 2025 (Roca, España desperdicia uno de cada cinco megavatios que genera la energía solar fotovoltaica, 2025) a total of more than 476 hours in five months, which is unprecedented in the Spanish market.

At the end of May 2025, there were more than 70 consecutive days with zero or negative prices during daylight hours. (Roca, España desperdicia uno de cada cinco megavatios que genera la energía solar fotovoltaica, 2025)This situation reflects an excess of renewable generation at certain times of day, which the system is unable to absorb through local demand or export, causing prices to collapse and leading to curtailments that reached up to 35% of total renewable generation, as was the case on May 11.

Similar situations have occurred in other European countries. According to ACER, more than 12 TWh of renewable electricity had to be curtailed in the EU during 2023 due to grid congestion, with Germany leading the way, whose curtailment exceeded 4% of its total generation, and Spain in third place with approximately 1.2%. (Roca, 2024).

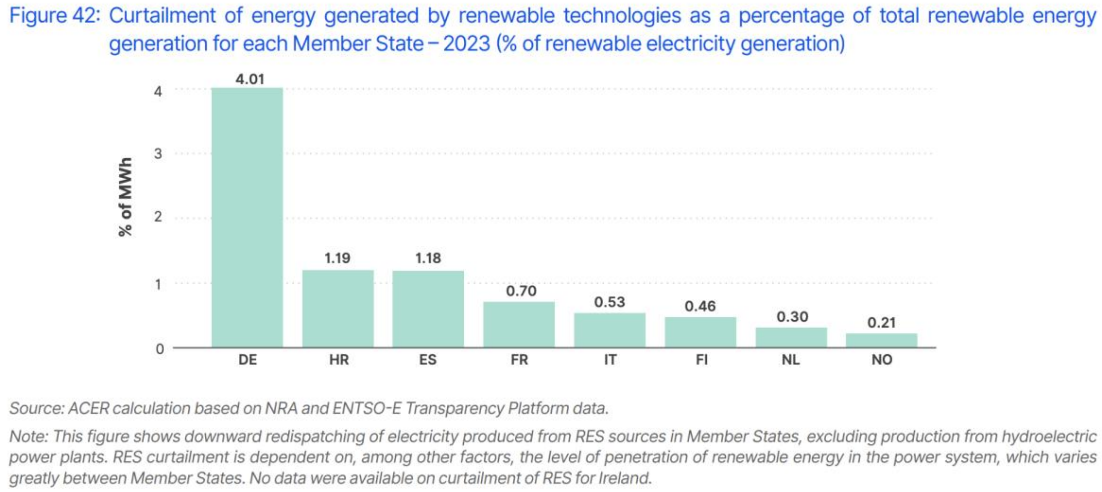


Figure 8. EU MS renewable energy discharges (ACER, 2023)

There are two types of curtailment: economic curtailment, which occurs when producers decide not to inject energy because the market price is zero or negative, and technical curtailment, which involves reductions in generation ordered by the system operator to maintain system security in the event of congestion or overload.

In Spain, during 2024 and 2025, most of the unused energy was due to economic reasons. In April and May 2025, economic curtailments averaged 15% of hourly renewable generation, rising to 18% in the case of solar photovoltaic energy. (Roca, 2025)Pure technical losses have remained at low levels, but locally they can be very high in certain parts of the grid, such as Aragón-Catalonia due to its abundance of wind resources, or Extremadura-Castilla La Mancha due to the large number of photovoltaic installations. In these cases, local renewable losses due to evacuation capacity limitations reached peaks of up to 20%. (El Periódico de la Energía, 2025).

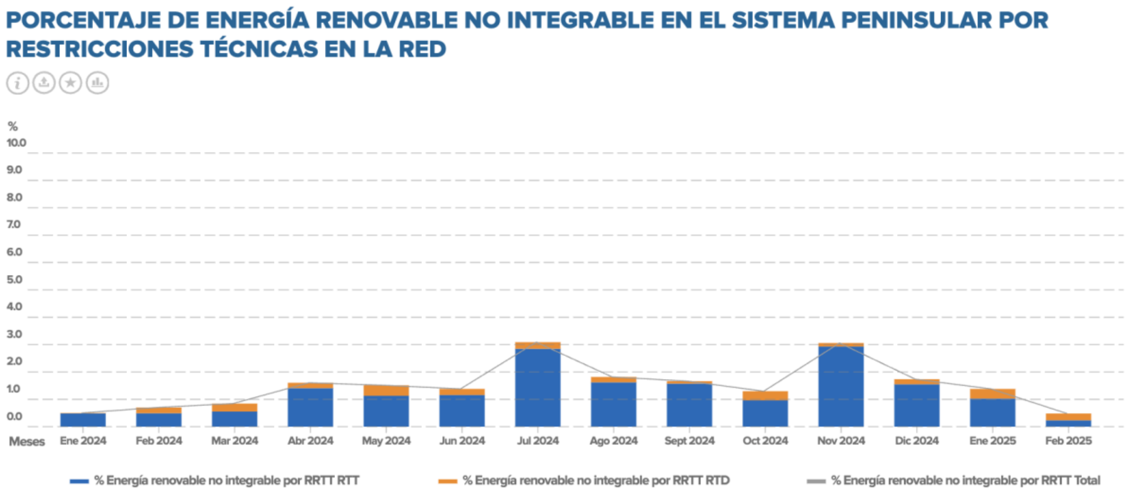


Figure 9. Renewable energy not integrable due to technical restrictions (El Periódico de la Energía, 2025)

For generators that depend on the daily market, such as photovoltaic parks themselves, this has a significant economic impact. The abundance of solar production at midday erodes the market price, drastically reducing the average income per MWh. This phenomenon of price cannibalization means the imminent end of economic profitability for generation parks that receive income solely from the wholesale market.

Both in the current context and in the close term, Power Purchase Agreements (PPAs) are emerging as the best option for ensuring the economic viability of existing and developing photovoltaic power plants. According to the consulting firm LevelTen, the first quarter of 2025 saw a 5.6% increase in PPA buyers in the country. However, these contracts are also experiencing a price decline, falling 5% during the first quarter of 2025 to €2/MWh. (Sánchez Molina, 2025).

Precios de ofertas de PPA Solar P25 por país:

Índice	Precio Q1 2025	Cambio euro Trimestral, Q4 2024 a Q1 2025	Cambio Porcentaje Trimestral, Q4 2024 a Q1 2025	Cambio euro Interanual, Q1 2024 a Q1 2025	Cambio Porcentaje Interanual, Q1 2024 a Q1 2025
Bulgaria	54,95 €	-8,54 €	13,5%	-	-
Dinamarca	63,00 €	13,04 €	26,1%	-	-
Finlandia	47,50 €	0,88 €	1,9%	-5,75 €	-10,8%
Francia	71,19 €	4,19 €	6,3%	-5,31 €	-6,9%
Alemania	57,00 €	-6,25 €	-9,9%	-10,25 €	-15,2%
Irlanda	124,00 €	-	-	-	-
Italia	69,75 €	4,75 €	7,3%	0,30 €	0,4%
Polonia	70,00 €	-8,00 €	-10,3%	-15,03 €	-17,7%
Rumania	66,75 €	3,75 €	6,0%	-9,25 €	-12,2%
España	37,00 €	-1,97 €	-5,1%	-1,50 €	-3,9%
Suecia	44,35 €	1,35 €	3,1%	-11,65 €	-20,8%
Reino Unido	92,79 €	1,87 €	2,1%	0,11 €	0,1%

Figure 10. PPA Solar offer prices by country (LevelTen Energy, 2025)

Through PPA contracts, solar prices remain stable, supported by European regulations that aim to promote the inclusion of clean energy generation in member countries. Prices varied by only 1% compared to the previous year.

3.2. The role of batteries in the energy mix

The effects that the increased integration of energy generation from non-manageable renewable sources has had on both the Spanish and European electricity systems highlight the need to complement this with greater deployment of energy storage.

Energy storage is therefore a fundamental tool for mitigating the effects of renewable variability, both in the short term, in the daily generation curve, and in the medium term, in seasonal intermittency. The ability to store electricity at times of low demand or high renewable production and release it at later times of greater need allows generation and consumption to be temporarily decoupled. In this way, it acts as a buffer that increases the flexibility of the electricity system, allowing generation and demand curves to be reconciled according to the needs at any given time and facilitating the safe integration of high percentages of wind and solar generation.

Figure 11. Classification of energy storage technologies (MITECO, 2021)

Energy storage systems are classified according to the technology used for energy storage. The European Energy Storage Association (EASE) distinguishes between four main means of storage: chemical, electrical, thermal, mechanical, and electrochemical.

Mechanical systems are the most established technology in electrical systems. They work by pumping water between two levels using pumps when electricity needs to be stored and releasing the water to drive turbines when electricity needs to be generated.

Pumped storage is therefore the most widespread form of storage, accounting for a total of 3,331 MW of the total 3,356 MW of installed capacity in the Spanish electricity system. (REE, 2024).

Although it is an effective storage technology that is completely free of greenhouse gas emissions (if the energy used is from renewable sources), the development of pumped storage is limited by the presence of natural slopes and the possibility of carrying out major engineering works in the heart of the natural environment, which entails significant administrative difficulties and very long construction periods.

The following image shows the percentages of installed power in the Spanish electricity system over the past five years. Since the number of pumping installations has not increased and remains constant at the same installed power (3,331 MW), it's apparent that the percentage of storage is reduced year on year due to the expansion of other technologies, mainly wind and solar photovoltaic:

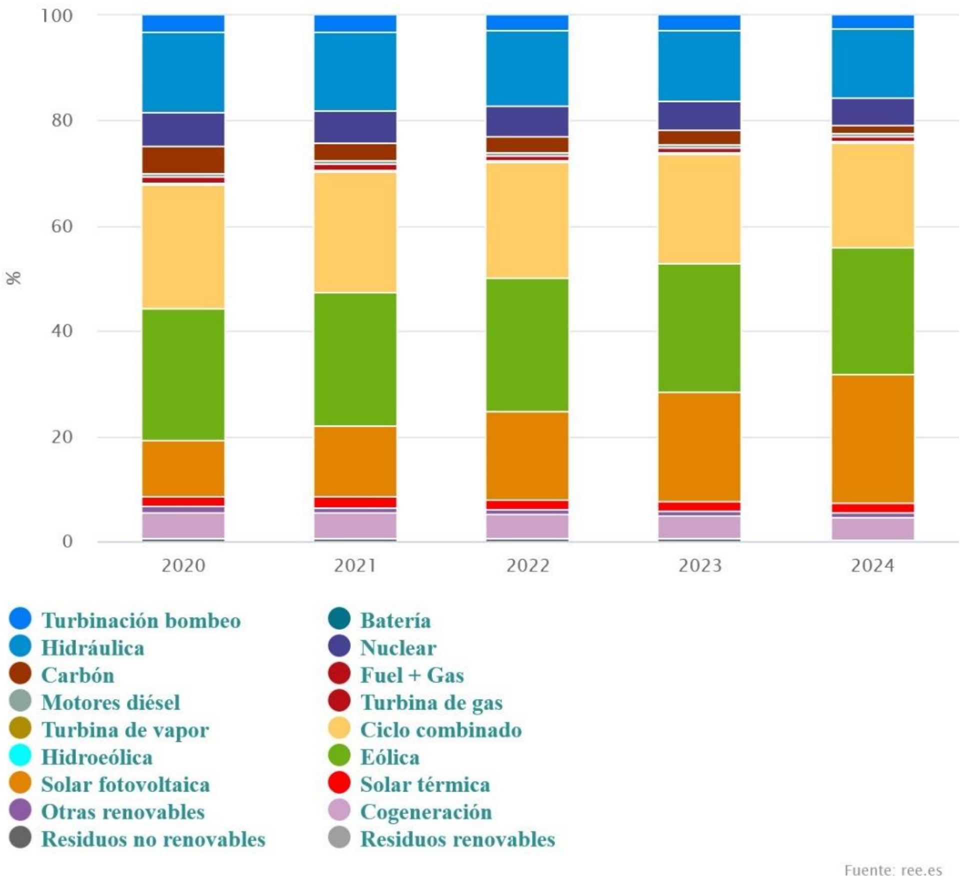


Figure 12. Generation percentages of the Spanish system (REE, 2024)

This highlights the importance of expanding installed energy storage capacity to compensate for the proliferation of renewable energies in the system.

Battery storage is classified, in terms of technology, as an electromechanical storage medium. The technology used is, of course, not a recent invention, as its operating method is based on electrolytic reactions between two electrodes that allow the oxidation and reduction of two components for its operation. The most widespread are those composed of nickel-cadmium, sodium, or lithium-ion.

The novelty of battery storage technologies lies in the maturity that their manufacturing and implementation technologies have achieved in recent years, moving from being an emerging solution to an increasingly competitive one. Factors such as increased energy density and longer life have influenced this, coupled with a huge drop in costs due to mass production, mainly driven by the boom in electric vehicles (Chinea, 2024).

The main solutions emerging in relation to energy storage driven by the boom in batteries are both the hybridization of renewable installations and the implementation of stand-alone systems that allow direct connection to the grid.

Hybridization consists of integrating multiple generation technologies into a single plant or connection point. In this case, it involves combining the unmanageable production of a generation park such as photovoltaics and integrating its production with the possibility of storage at will. This is particularly advantageous for photovoltaic installations because, unlike wind power, they can only generate during hours when prices are low, as we have seen.

Hybridization, therefore, allows for maximizing the resources of a renewable generation facility and receiving higher market prices, improving returns on investment. The main drawback is the increase in CAPEX that the installation of batteries entails, significantly increasing the LCOE of the plant depending on the installed storage capacity.

In Spain, although there is no direct remuneration for energy storage, policies to support hybridization have been introduced. In 2023, the Ministry for Ecological Transition launched its first specific auction for hybrid projects to encourage the combination of renewables with storage; this call awarded 36 projects totaling nearly 1 GW of new battery capacity linked to wind and solar farms. (Review Energy, 2024)In addition, several autonomous communities have simplified the environmental and urban planning procedures for expanding existing renewable energy parks through hybridization, notably Catalonia, which now allows their installation on industrial land.

For their part, stand-alone BESS storage systems are battery systems connected directly to the distribution or transmission grid, whose purpose is to arbitrate between peak electricity prices and managed prices. These facilities provide flexibility to the grid, alleviating moments of high stress, as well as reducing or preventing spillage and mitigating the cannibalization of photovoltaic solar energy prices.

The function of autonomous BESS installations is to stabilize the market, avoiding the sharp peaks and troughs that systems with high renewable energy penetration tend to experience. Their importance has been recognized by the government, which is promoting them with economic initiatives through the Institute for Energy Diversification and Saving (IDEA), which in 2024 awarded a total of 46 Stand Alone facility projects worth a total of €167.8 million. (Roca, 2024).

4. Lines of Action

4.1. Regulatory framework

Energy storage in Spain has undergone regulatory changes in recent years, driven by the need to integrate this technology as a vehicle for the energy transition. Previously, national legislation did not specifically address storage as an autonomous entity within the regulatory framework of the electricity sector, which had created significant regulatory uncertainties and hindered its full integration into energy markets and the operation of the electricity system.

In this context, Royal Decree-Law 23/2020 represents a fundamental milestone, introducing for the first time in the Electricity Sector Law the figure of the owner of storage facilities. (MITECO, 2021), which marks the beginning of the development of specific regulations that recognize storage as an independent actor with the capacity to actively interact at different levels of the electricity system. Through this reform, storage is no longer considered solely as a complementary activity, and the possibility for various agents, producers, or consumers to use or own storage facilities is recognized, thus contributing to greater openness and diversification of the system.

The Energy Storage Strategy promoted by the Spanish government focuses equally on reducing administrative barriers and simplifying administrative procedures to accelerate the deployment of storage technologies in Spain. The strategy proposes measures that reduce the administrative burdens associated with the authorization, construction, modification, and operation of storage facilities. Based on the provisions of Law 23/2020, measures are approved that contemplate the hybridization of generation facilities with storage technologies and the launch of calls for tenders for the development of new facilities. (MITECO, 2021).

Special attention is paid to research, development, and innovation projects, which require a more flexible regulatory environment adapted to technological experimentation. One of the most important tools for promoting innovation in a regulated environment is the implementation of regulatory test beds that enable the development of pilot projects to test new technologies or business models. Their foundations establish that they must guarantee the absence of risks to the electricity system and ensure consumer protection, complying with the principle of economic and financial sustainability. (Magnus Commodities, 2024).

With regard to tariff and tax design, CNMC Circular 3/2020 of January 15, which establishes the methodology for calculating electricity transmission and distribution tolls, provides for an exemption from transmission and distribution network access tolls for grid-connected batteries, in line with EU Regulation 2019/943; recognizing the value of energy absorption at certain times as a tool for flexibility and optimization, thus avoiding penalties for the bidirectional nature of batteries. (MITECO, 2021).

At the same time, the Ministry for Ecological Transition and Demographic Challenge has submitted for public consultation the draft Royal Decree establishing the methodology for calculating electricity system charges, which explicitly excludes storage systems from paying network tariffs. In addition, the strategy proposes the development of smart tariff models, where tolls reflect the real cost of using electricity infrastructure and economic signals are used to encourage or discourage the use of the network.

4.2. Market participation

This line of action seeks to ensure that energy storage facilities can actively participate in different market mechanisms, thereby encouraging greater investment in these technologies and contributing to the necessary deployment of energy storage.

The ways to achieve this goal set by the ministry will be as follows:

Firstly, the Storage Strategy seeks to work on adapting different markets to enable the easy participation of energy storage facilities, either in daily markets, intraday sessions, or continuous intraday sessions. Recognizing that these energy storage systems benefit from greater temporal and spatial granularity in electricity markets. Based on the European Directive 2019/944, flexibility mechanisms and appropriate market signals will be designed to incentivize the construction of capacity and the provision of energy storage services.

Capacity mechanisms will be reconsidered to make them attractive for energy storage. In this regard, at the end of 2024, MITECO developed a proposal for a capacity market in the electricity system involving auctions in which different technologies can participate, whether they be generation, storage, or demand technologies. (MITECO, 2024), excluding facilities that exceed the specified greenhouse gas emissions limit or consumers associated with generation facilities with a specific remuneration regime. (CNMC, 2021).

Through the CNMC resolution of December 10, 2020, operating procedures relating to network balancing were adapted to allow storage to participate in secondary and tertiary regulation markets, replacement reserves, and technical restrictions, thus enabling its gradual integration. In addition to being able to participate as balance service providers, the aggregation of demand units and energy storage facilities is encouraged, so that they can offer their services in a scheduling area.

Other measures involve the creation of dynamic prices by marketers, incentivizing storage behind the meter; the creation of network markets, where distribution network operations can provide flexibility services; and the promotion of investment signals. These signals for storage would be established based on the analysis of actual capacity signals for different time horizons, encouraging investment aligned with the PNIEC objectives.

4.3. Support mechanisms for storage

The energy storage strategy developed by the Spanish Ministry for the Ecological Transition and the Demographic Challenge (MITECO) includes the main support mechanisms at both

European and national levels that can be applied to storage projects or renewable projects hybridized with batteries:

Name	Description and features	Ammount	Type of aid	Calls
Next Generation EU	New instrument for recovery from the Covid-19 crisis. It includes the Recovery and Resilience Mechanism, with support for the ecological transition.	NGEU: 750.000 M€ / MRR: 672.500 M€	Grants and loans	—
Innovation Fund	Financing for innovative low-carbon technologies, including energy storage.	10.000 M€	Grant (up to 60% additional innovation costs)	July 2020 (€1 billion large-scale), December 2020 (€100 million small-scale)
H2020	Largest European R+D+i financing instrument. Objectives: low-carbon economy, environment, climate action.	€80,000 million (2018-2020: €3,400 million for climate)	Several	Several
Horizon Europe	H2020 successor program. 'Climate, energy and mobility' cluster.	Estimated €75,900 million (35% climate change)	Several	Enero 2021
European Green Deal	Eleven areas including clean energy, circular industry, sustainable mobility.	1.000 M€	Several	Septiembre 2020
Implementing Regulation (EU) 2020/1294 (15/09/2020) – Union Renewable Energy Financing Facility	Support mechanism at EU level, which aims to enable certain Member States to achieve their renewable energy objectives and to promote the ambitious development of renewables in the EU. Storage is contemplated (as long as it is associated with new renewable generation). Selection criteria: Price, in the case of auctions associated with the gap filling function of the objectives; To be determined in each call, in the case of the facilitating framework.	Undetermined.	In the case of gap filling, the only award criterion in the auction will be the price. In the case of the facilitating framework, it will be determined in each call.	The first call is expected in 2021. If funds are available, annual calls will be made.
InvestEU	It aims to mobilise public and private investments by guaranteeing financial partners such as the EIB Group.	€2,800 million + previous instrument flows	Financial guarantee.	2021.
Just Transition Fund	Aimed at supporting the transition of the regions most affected by the need to abandon an economic model based on fossil fuels.	7.500 M€	Grants	2021.
FEDER	Objective: to correct imbalances between regions. It focuses its investments on four thematic areas, one of which is the low-carbon economy.	—	Grants or loans.	Several
InnovFin	Financing of innovative projects for the transformation of the energy system. It includes renewable energies and energy storage. Objective: to reduce the gap between demonstration and commercialization.	Financing between €7.5 and €75 million.	Loans; Loan guarantees; Share of capital.	Several
IPCEI (Important Projects of Common European Interest)	Projects designated as such may benefit from financing mechanisms compatible with the internal market, and therefore not considered State aid.	—	—	—
CEF (Connecting Europe Facility)	Financing instrument for European infrastructures.	€43,000 million (60% climate-friendly). €9,000 million for energy.	—	2021.
EFSI (European Fund for Strategic Investments)	Support for strategic investments in key areas, including clean energy.	—	Financial guarantee.	En 2021, integrado en InvestEU.
European Battery Alliance (EBA250)	Marketplace that connects different players in the battery industry and investment agents. Objective: to achieve a competitive and sustainable European battery industry along the entire value chain.	—	—	—
Eurostars	Support programme for R+D-intensive SMEs in the development of market-oriented transnational projects.	€287 million from H2020 + €800 million from countries.	—	Several
ESF+ (European Social Fund Plus)	Support for job creation, with education and capacity building as the main mechanisms.	—	Grants or loans.	Several
Plan de Recuperación, Transformación y Resiliencia España Puede	Component 8: flexibility of the energy system, electricity infrastructures, smart grids and deployment of energy storage.	1.365 M€	In the design phase	In the design phase
IDAE aid programme for innovative renewable electricity generation	It includes storage associated with new renewable generation.	316 M€	Subsidies of up to 80% of eligible costs depending on the action of the autonomous community	From September 2020

Figure 13. European (blue) and Spanish (red) financing mechanisms supporting storage (MITECO, 2021)

In summary, at the European level, the BESS could be eligible for support from the Innovation Fund, as it focuses on projects that reduce greenhouse gas emissions through low-carbon technologies. As discussed, decreasing wasted renewable energy and reusing it during peak demand hours makes the installation applicable for this funding.

At the national level, the Recovery, Transformation and Resilience Plan offers an opportunity for new BESS projects in Spain, as it is aimed at enhancing power system flexibility, improving smart grids, and deploying large-scale energy storage solutions, financing both grid-connected systems and self-consumption installations.

The European Regional Development Fund (ERDF) calls for proposals to represent another avenue of support, managed at the regional level, allocating European funds to projects that contribute to the energy transition and the low-carbon economy. For a BESS, these programs can finance between 40% and 60% of eligible costs, depending on the region and type of beneficiary (European Commission, 2023).

Regarding ERDF funding, priority is given to initiatives that integrate storage into renewable systems, improve energy efficiency, or strengthen the resilience of local power grids, making them an accessible and complementary option to the Recovery Plan.

5. Threats to Battery Integration

Despite the proven benefits to the power grid of the increasing deployment of batteries, there are some risks associated with battery storage that may compromise the initiatives of new developers to participate in this growing market.

5.1. Degradation

The first risk is inherent to the technology used for storage, namely the degradation of the storage capacity of electrochemical materials caused by numerous charge and discharge cycles.

Electrolytic batteries suffer a gradual loss of capacity and efficiency with each charge and discharge cycle and with natural aging. Because of this, intensive use of batteries causes them to store less energy and deliver it less efficiently, reducing their effective performance and having an economic impact on the initially projected results of the storage facility.

Battery degradation can be classified into two types:

- Calendar degradation: is accounted as the effect on the battery's capacity due to the passage of time. This degradation will depend on the BESS technology and location (in particular, due to atmospheric conditions) but can be generally estimated around 0.75-1.25% per annum on average (JLL, 2023).
- Cycling degradation: the effect of the active charge and discharge of the battery. This effect varies greatly among different batteries, even from the same manufacturer, but, as a benchmark standard, it is usually modeled as 0.003-0.004% per cycle (JLL, 2023).

The useful life of a battery is usually defined by a degradation threshold: it is typically considered to have reached the end of its useful life when it loses around 20% of its initial capacity. From that point on, its performance may no longer meet design requirements or contractual commitments.

The economic impact of ignoring degradation can lead to an initial overestimation of the profitability of a BESS, assuming NPVs up to 50% higher per installed energy than the actual effective value. (Wankmüller, 2017)To reduce the impact of degradation, both from an economic standpoint and in terms of the proper operation of the facility, the practices recommended by the sector involve a combination of the following:

- Repowering**:** maintaining the state of health by replacing all the battery units in a given year, as a basis, either 1 repowering in year 15 for a 1.5 cycles/day or 2 repowerings in years 10 and 20 for a 2.0 cycles/day.
- Augmentation: maintaining the state of health by adding new additional battery cells over time, typically on an annual basis (JLL, 2023).

5.2. Cannibalization

Price cannibalism refers to the significant reduction in prices in the electricity market when there is a simultaneous oversupply of the same technology, which leads to lower revenues for those facilities. In the context of BESS, their massive proliferation and similar operation in the single market would lead to a tendency to flatten the daily price curve, raising prices during valleys (charge cycle) and reducing them during peaks (discharge). This would largely eliminate the appeal of energy arbitrage between hours of peak generation and peak demand, which, while benefiting system stability, erodes the arbitrage opportunities that could economically justify investment in BESS.

Investment in batteries, therefore, may lead to a cannibalization phenomenon similar to that explained in the case of solar photovoltaic generation, where massive penetration of this technology could cause its own revenues to plummet, ultimately flattening the electricity market price curve. Sources in the energy sector claim that in the current Spanish electricity system there are more than 22,000 MW of requests for access to the grid from battery storage facilities (Ojea, 2024), which could cause the LCOE associated with each of them to fall below the threshold for recouping their investment.

To address the risk of price cannibalization, the main strategy is to diversify the revenue sources of BESS. It has been shown that relying solely on energy price arbitrage is not sufficient to make a BESS installation profitable; rather, it is necessary to combine multiple additional services from which remuneration can be obtained. Participation in additional service markets provides sources of income beyond the daily market, thereby avoiding the cannibalization effect and taking advantage of the technical benefits of battery storage.

Chapter II: Solution Analysis

1. Project Proposal

The previous chapter analyzed the sectoral context of energy storage in Spain. It reviewed the development vectors that seek to promote the penetration of battery storage in the electricity system and highlighted its importance in ensuring security of supply and energy efficiency.

In summary, battery energy storage is an essential element for the expansion of renewable technologies in the Spanish electricity system, due to the support it provides to non-manageable technologies such as solar and wind power generation.

This project, based on the defined needs, addresses the construction of a Stand-Alone BESS facility in the Spanish electricity system, outlining the steps that a new developer wishing to carry out a storage project of this nature in the electricity system must follow.

The project under evaluation will involve the construction of a battery storage facility connected to the distribution network, following the planning steps from project design to equipment selection and economic evaluation.

1.1. Geographical location

The autonomous battery system is planned to be located in an electrical system that experiences peak demand, i.e. high demand during peak consumption hours, in order to maximize the flexibility benefits provided by the battery installation, reduce congestion in situations of high renewable generation, and participate as support in ancillary services markets.

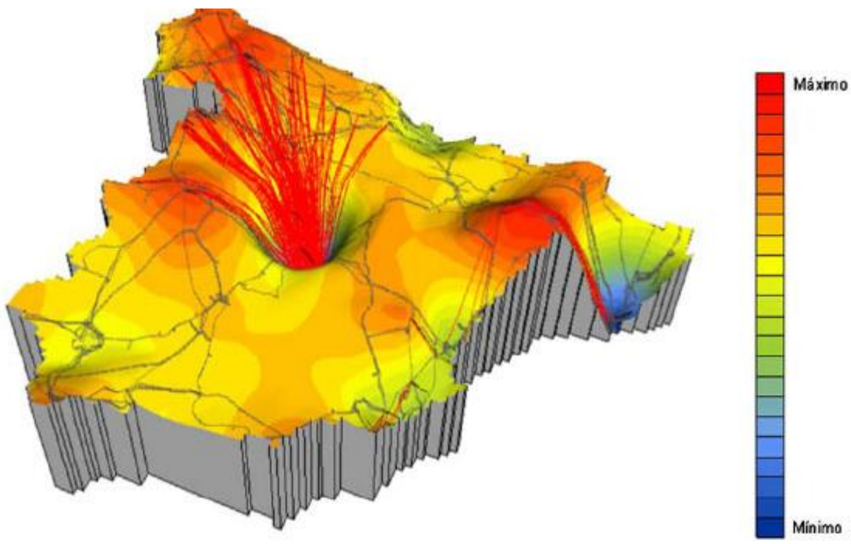


Figure 14. Net electricity production in Spain (AlmacenNuclear (wordpress), 2017)

Based on this criterion, one of the two main cities, Madrid or Barcelona, is chosen as the location for the facility. As can be seen in the image, these cities account for a large proportion of the total energy generated on the peninsula. The decision is to install the battery park near

Barcelona, as there is a large peak in generation near the province due to the high penetration of wind power in the Aragon region, which has a total of 376 MW of installed capacity spread across eleven wind farms. (Iberdrola, 2022).

As can be seen, the transmission network in this area is very extensive, with numerous booster substations scattered around the city. For this reason, this region has been chosen as a location where the system operator can make the most of the facility to support the network and maximize revenue from support services.

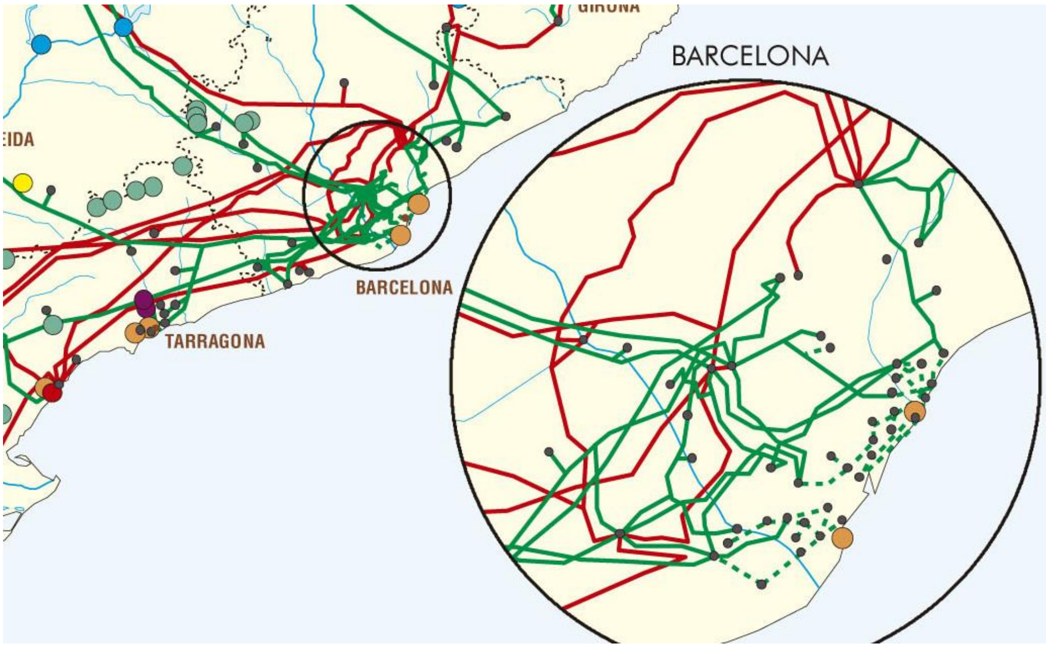


Figure 15. Red de transporte 400 kV (rojo) y 220 kV (verde) en Barcelona (REE, 2020)

The electricity distribution system is divided into regulated monopolies according to the region of the country. In the proposed case, the DSO in the region where the BESS installation is planned will be e-Distribución, the Endesa parent company responsible for ownership, operation, and maintenance in the northeast and south of the peninsula, as well as in the Spanish islands.

Figure 16. Map of DSO in Spain (Elekluz, 2015)

Network access capacity is understood to be the maximum active power value, expressed in megawatts (MW), that a generation, storage, or consumption facility can inject or extract at a specific connection point of the electricity network in accordance with the technical, safety, and quality conditions required by the operator.

This capacity is determined based on the available capacity of the network elements (lines, transformers, protections, etc.), the operating limitations of the system, and compliance with the regulatory criteria established in the current regulatory framework, especially the provisions of Royal Decree 1183/2020, which regulates access and connection to electricity transmission and distribution networks.

The BESS installation must be located in a place that allows it to be connected to the distribution network at a substation that is not saturated, i.e., that has free access capacity for the installation of new generation or storage.

E-Distribución offers a capacity map where users can interactively consult a map of the region, view the substations present and their connection capacity, detailing voltage and power requirements and explaining future expansion plans or possible problems in providing access to new installed capacity.

After analyzing the potential locations available on the access capacity map, the PALAU substation, in the municipality of Palau-Solità y Plegamans, was chosen. The reason for choosing this location is the available access capacity of more than 10 MW, both in terms of injection and extraction, in the medium-voltage network (25 kV). This substation also connects to the 220 kV transmission network, which will allow the batteries to be charged with the power generated by wind farms in nearby regions and discharged to the Barcelona metropolitan area during peak hours.

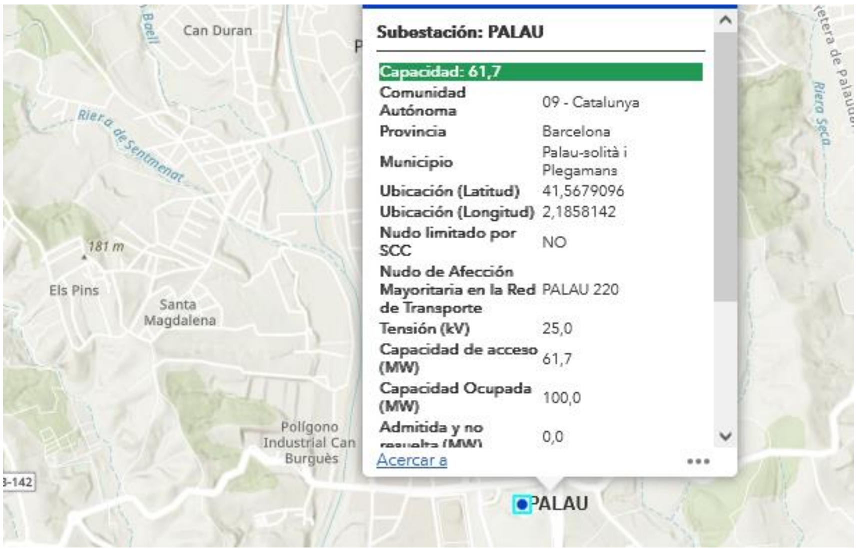


Figure 17. Selected substation on e-Distribución capacity map

Therefore, the areas surrounding the PALAU substation will be taken as the starting point for the location of the BESS proposed in this project. Specifically, a plot of land that, for simplicity's sake, is assumed to be accessible for the installation of the storage facility, subject to a request to the city council and the necessary technical and regulatory assessments to obtain permission to use the land.

Figure 18. Satellite view of the proposed site for the BESS

This image shows the boundaries of the land selected for the battery park. It is a 1-hectare site on the outskirts of the municipality of Palau-Solità i Plegamans. This will be the location of the Stand-Alone BESS installation, which will be dimensioned as the project objective.

1.2. Technological solution

The distribution system operator for the proposed connection, e-Distribución, sets out in the document "Access capacity for generation at nodes of the distribution network operated by e-Distribución Redes Digitales" the general considerations regarding the access capacity available to new participants wishing to connect as generators to the distribution network. (e-Distribución, 2025).

Its main consideration regarding available capacity is the limitations imposed on new players with regard to the network access capacity that they will be allowed to access in accordance with the specifications detailed in CNMC Circular 1/2021. This will unbundle the available capacity in accordance with the maximum values detailed in the table below:

Nivel de tensión (kV)	Capacidad de acceso máxima para conexión mediante posición en subestación (MW)
132-110	100
66	60
55-50	50
45	40
30	30
24-25	20
20	15
>1 ≤ 15	10

Figure 19. Maximum accesible power for each voltage level

Therefore, the first criterion for designing the battery installation will be to define the power to be delivered to the grid. In this case, as it is connected to a 25 kV substation, the maximum available access capacity of 20 MW will be used.

The technology used for energy storage will be lithium-ion batteries. This technology, most commonly using LFP electrolytes, has developed enormously with the rise of electric vehicles, and many manufacturers offer battery systems housed in containers similar in size to shipping containers. Standardized battery storage is around 5 MWh, which can be discharged in two or four hours, determining the power discharged to the grid.

Figure 20. Iberdrola's stand-alone battery site

Following this criterium, the park will be sized to maximize both the income received from arbitrage and from network support services. The aim will be for the BESS facility to be capable of feeding 20 MW of power into the grid for eight consecutive hours. The purpose of this will be to take advantage of the rapid charging of the batteries during the hours when the daily energy market price collapses (10:00 a.m. to 6:00 p.m.) and be able to discharge it during peak electricity price hours, as well as serving as adjustment services until solar energy regains influence over the market to recharge the batteries.

The park will therefore be considered of 32 battery containers installed at around 5 MWh each, enabling it to maintain the 20 MW output to which it has access for a maximum of eight hours.

The power demanded and discharged from the battery park will be connected to the e-Distribution substation via an indoor transformer station, which will enable the electricity to be stepped up to the 25 kV required for feeding into the grid. The sizing of the necessary transformers and the sizing of the medium-voltage cells required for the system will be studied below.

From the battery park transformer station, hereinafter referred to as CT BESS, a medium-voltage overhead line will connect the evacuation transformer to the PALAU substation.

Figure 21. Projected high voltage line, connecting the substation with the BESS

As can be seen on the map, the proposed route crosses a two-lane road. According to the High Voltage Line Regulations, the elevation of the line above the road surface must exceed 7 meters (BOE, 2023).

With this, all needed parameters for the design and sizing of the proposed battery installation are known, setting a starting ground for the technical analysis of it.

2. Grid access and connection permits

2.1. Connection point requirements

As studied, the substation node located in the municipality of Palau-Solitá has 61.7 MW of accessible capacity at the time of this study. Of this total amount, a request for access to 20 MW will be submitted for both generation and demand.

The requirements for connecting new loads to the connection point involve compliance with medium-voltage connection technical standards, which include maintaining supply quality (mainly voltage levels and harmonic distortion) and grid security. As an energy supplier, the 20 MW BESS must behave like any other distributed generator, providing voltage control through power factor management or reactive power injection in accordance with the relevant grid code. As a load, a congestion study must be carried out to ensure the technical feasibility of its connection without saturating the existing infrastructure.

As studied, the substation node located in the municipality of Palau-Solitá has 61.7 MW of accessible capacity at the time of this study. Of this total amount, a request for access to 20 MW will be submitted for both generation and demand.

To this end, the operating characteristics of the BESS can be exploited, as it will demand energy at times of lower demand, which is a favorable consideration to be taken into account in the technical evaluation of the project.

In terms of equipment, the connection criteria of the DSO, e-Distribución, must be respected for its connection facilities: 25 kV cells, protections, measurement systems, and remote-control systems that comply with its internal regulations. According to the guide for the management of e-Distribución generation connections (e-Distribución, 2025), the necessary facilities owned by the customer are as follows:

- Evacuation installation: located between the distribution network boundary point and the customer's property, it will be delimited by a high-voltage disconnector at the location of the generation installation.
- Connection installation: located at the boundary point, it allows connection to the distribution network of the facilities owned by the customer. It must include the protection elements required by current legislation.
- Customer's indoor installation: located in the generation facility, it allows the connection of the different generation elements. Although the DSO is not responsible for possible faults in the customer's indoor installations, compliance with the low and high voltage electrotechnical regulations is an essential requirement to guarantee the right of access and connection.

2.2. Soliciting procedure

The formal process for obtaining access and connection permits is governed by Royal Decree 1183/2020 and associated regulations. As this is a stand-alone storage facility connected to a distribution network with a voltage greater than 15 kV, the general connection procedure (not abbreviated) applies.

In accordance with RD 1183/2020, both the capacity access permit and the technical feasibility permit for connection at the point are processed jointly through a single application. As this is a node shared with the transmission network, a report on acceptability may also be required from Red Eléctrica regarding the impact on its network, assessing whether the proposed injection meets safety and quality requirements at the associated node.

This image presents a summary of the steps to be followed for the energization of the installation, which must be submitted to the distribution network operator, i.e., e-Distribución Redes Digitales S.L.U., which will act as a one-stop shop throughout the procedure (e-Distribución, 2017):

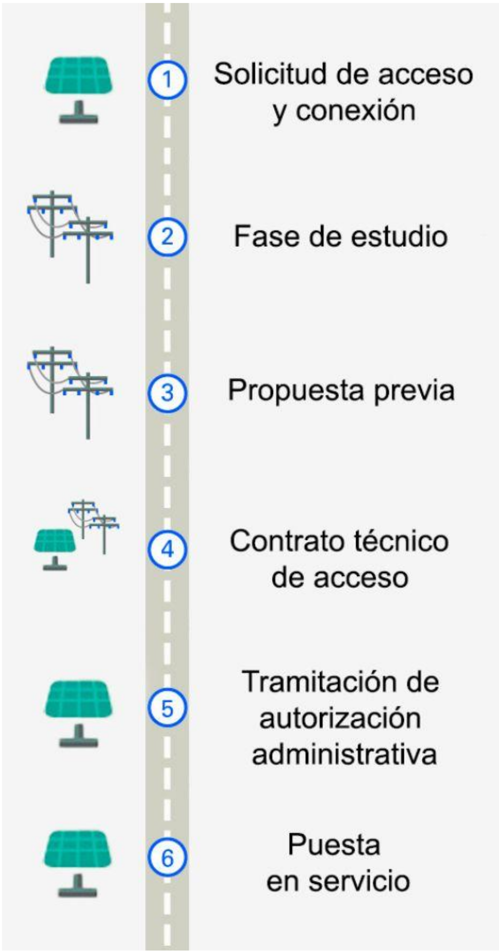


Figure 22. e-Distribution access solicitation procedure

1. Access and connection request:
   The developer will submit the access and connection request to *e-distribución*, preferably via the online platform, attaching all required documentation. Prior financial guarantees must be in place, and a specific connection point must be proposed— in this case, the 25 kV busbars at the PALAU substation.

2. Study phase:
   The grid operator, *e-distribución*, has 30 business days to review the request (BOE, 2020). It must request corrections if information is missing or, where applicable, reject the request. If a REE report is required, this period is extended by an additional 60 days. Royal Decree 1183/2020 stipulates that access denials must be justified based on objective CNMC criteria, such as insufficient available capacity. Regarding storage facilities, the CNMC has resolved disputes stating that a battery installation cannot be rejected by applying conventional demand criteria without considering flexible operating scenarios. During this period, *e-distribución* may request additional information from the applicant, granting 10 days to resolve any issues.

3. Preliminary proposal:
   An accepted request leads to the issuance by *e-distribución* of an access and connection proposal with the technical solution and economic conditions for the requested point. This proposal will include the necessary connection works or reinforcements, capacity limits, and operating conditions, as well as the connection budget. The proposal will reflect both distributor requirements and REE requirements (e-Distribución, 2017).

4. Acceptance and issuance of permits:
   Once the established period has passed and any issues arising during the process have been resolved, the applicant has an additional 30 days for final acceptance. The proposal is not considered formally accepted until the applicant signs a payment agreement for the infrastructure to be developed by the distributor.

5. Technical access contract (CTA):
   Once the connection permits are obtained, the facility owner must sign a technical access contract with *e-distribución*, establishing the technical conditions for its connection and safe operation in the grid. Under current regulations, storage facilities must act both as generation and demand installations for permitting purposes.

   In the case of a stand-alone BESS, since it will operate as both a generator and a consumer, an additional demand access contract will be required for charging energy. To withdraw energy from the grid, it will be necessary either to contract a retailer or to participate directly in the market for charging operations.

2.3. Mandatory documentation and studies

- ***Report and technical data of the facility:***

A preliminary project is presented in accordance with Article 3 of CNMC Circular 1/2020, including the description of the BESS, single-line diagram, characteristics of the installed equipment, power ratings, and operating modes. The chosen connection point is also specified, with UTM coordinates and cadastral reference of the site (e-Distribución, 2025).

- *__Connection request form:__*

A standardized form in which the applicant is identified as either a natural or legal person, along with the landowner and the location details of the plant. The basic characteristics of the facility and its intended operating regime are stated. In the case of the BESS: production under the special regime, without a renewable primary source (BOE, 2014).

- *__REE acceptability form:__*

Mandatory when the power to be connected to the distribution grid exceeds 5 MW in a single facility (REDEIA, 2025). This is carried out using the standardized T.243 form, which collects technical information on the electrical and operational characteristics of the facility, enabling the TSO to assess whether the project's connection could have negative impacts on the transmission network.

- *__Land agreement documentation:__*

Authorization from the landowner will be required, granting consent for the installation and the connection request when the developer is not the owner, thereby preventing disputes over access rights to the proposed location.

- *__Grid Code compliance guarantee:__*

In accordance with Royal Decree 647/2020, compliance is required with the grid code applicable to generation modules, demand facilities, and high-voltage equipment. The inverters must therefore meet the parameters for fault-ride-through capability, frequency control, and other relevant requirements imposed by the transmission system operator (BOE, 2020).

3. Technical Project

This chapter aims to describe the technical project for the storage facility and to determine the equipment required for its connection to the grid, enabling it to absorb and inject energy in accordance with the desired operating regime.

It will detail the connections between the elements of the facility, as well as the purpose of each. This document will serve as the basis for estimating the budget for the construction of the entire storage park.

3.1. Operation description

As explained, the purpose of the facility is to store energy absorbed from the distribution grid in high-capacity battery systems (5 MW).

Due to the characteristics of the system, the facility can be studied in three sections according to the nominal power at each stage: low voltage, where the battery systems and energy conversion systems will be located; voltage step-up, consisting of the voltage conversion systems for both the storage system and the auxiliary service supply; and the voltage evacuation system, comprising the high-voltage transformer and the evacuation line that will connect the BESS installation to the substation at the designated point.

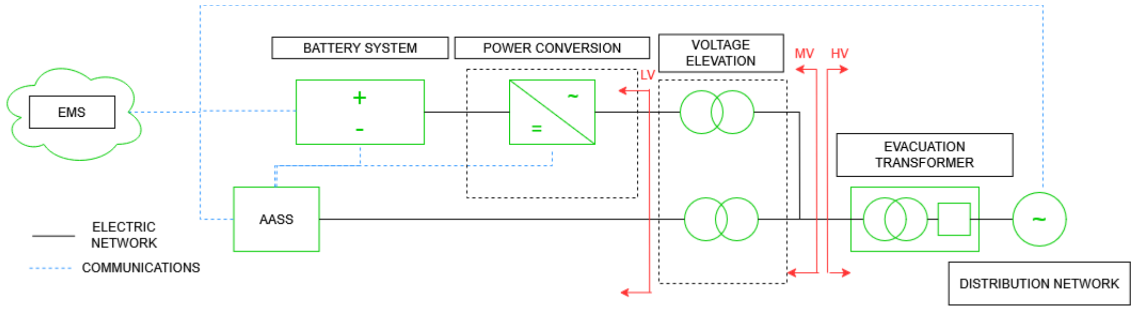


Figure 23. Functioning diagram

The power system will be managed thanks to the Energy Management System (EMS), the central control unit responsible for monitoring the installation and managing the operation of the battery system according to the desired hours of charge and discharge. It is also responsible for giving an appropriate response to the power grid, allowing the installation to act accordingly to the network codes.

3.1.1. Storage system

The storage system is designed to provide the grid with the 20 MW of access capacity for eight hours following a single charge. Based on the project's initial sizing, this entails the use of 32 battery systems, each with an average storage capacity of 5 MWh.

A battery system refers to the storage assembly housed within a standard shipping container. This is an industrially manufactured unit composed of two battery racks connected in series within each container, thereby achieving the voltage and current levels required for connection to and operation within the grid.

Battery charging is carried out in direct current, making it necessary to include a bidirectional power conversion system capable of managing energy flow in the required direction depending on the intended operating mode at any given time.

3.1.2. Power conversion system

The power conversion system is responsible for charging and discharging the batteries and for adjusting the direct current voltage at the system output. Its operation is based on inverters and rectifiers that convert the batteries' direct current output into alternating current suitable for voltage step-up.

Its two main components are:

- Bidirectional AC/DC converter: Hybrid inverters capable of managing energy flow in both directions, forming the core of storage systems.
- Bidirectional DC/DC converter: Functions as a charger, stabilizing voltage during charging and discharging phases, and boosting the battery output to the appropriate level for the converter.

The electrical power output from the conversion system will then be transformed to the voltage level that supplies both the evacuation transformer busbars and the auxiliary services.

3.1.3. Voltage transformation system

Voltage transformation system: This system is responsible for stepping up the low-voltage output from the conversion systems to the medium-voltage level required (11 kV) for evacuation or for use in auxiliary services. Its two main components are:

Low-to-medium voltage transformers: Step up the alternating current voltage from the output of the solar panels and batteries, approximately 0.6 kV, to 11 kV.

Medium-voltage switchgear: Equipment responsible for the protection, switching, and isolation of the transformer, ensuring safe operation and coordination with the park's electrical system.

The medium-voltage switchgear will be located in the control building, supplied by a medium-voltage cable from the LV/MV transformers in the power conversion system, and will serve as the starting point for the final step-up to 25 kV, enabling connection to the distribution grid.

3.1.4. Power evacuation system

The first element between the internal transformers and the distribution network will be the HV/MV transformer, which will serve as the electrical interface between the high voltage (25 kV) connection to the power grid and the medium-voltage switching level within the park (11 kV).

The power evacuation system is responsible for stepping up the medium-voltage electrical power to 25 kV for transmission via the overhead line. It will consist of:

- Power transformer: responsible for the voltage exchange with the power grid, it will be a three-phase transformer with a nominal capacity of 20 MW, operating between 20/11 kV, and cooled with oil. An N+1 redundancy conFiguretion will be applied to ensure energy flow even in the event of grid failures.
- Isolators: mechanical switches installed to ensure the proper de-energization of the installation from the grid for maintenance or safety purposes.
- Circuit breakers: switchgear designed to interrupt the flow of electricity automatically or manually during normal operation or in the event of a fault, protecting equipment and ensuring system safety.
- High voltage line: enables the connection of the facility to the power grid. It consists of an overhead line supported by poles along its route, in compliance with the regulations applicable to high-voltage lines

The power transformer will be located in the control building, near the receiving switchgear for the battery park and the auxiliary services.

3.1.5. Energy Management System (EMS):

The Energy Management System is the central control system of the energy storage plant, responsible for coordinating all operations in compliance with grid code requirements.

The EMS is tasked with controlling the Power Conversion System and the Battery Management System, while continuously monitoring critical parameters such as state of charge and state of health to ensure optimal performance and longevity. The EMS comprises both hardware and software components, including programmable logic controllers (PLCs) and advanced control algorithms. It also integrates a SCADA system for remote monitoring and efficient system supervision.

3.2. Layout and Electric Infrastructure

This section aims to position the elements that will make up the battery park within the area designated for its construction, justifying the design decisions and explaining the resulting single-line diagram of the electrical connections between its components.

First, let us recall the location where the project will be situated:

Figure 24.Satellite view of the proposed site for the BESS

On this site, 32 battery containers for energy storage will be installed, in accordance with the sizing described in the previous section. The decision is to arrange them in groups assigned to the same inverter, facilitating the connections between different elements of the system and reducing the total length of cable required for interconnection.

Due to the technical characteristics of the selected equipment, which will be detailed in the next section, the relationship between components will be as follows: three batteries per inverter, two inverters per LV/MV transformer, and one auxiliary service transformer for every four battery groups—or, equivalently, for every two LV/MV transformers.

Accordingly, the layout of the facility is divided into three aisles: the first two consisting of 12 batteries each, and the last consisting of 8 batteries.

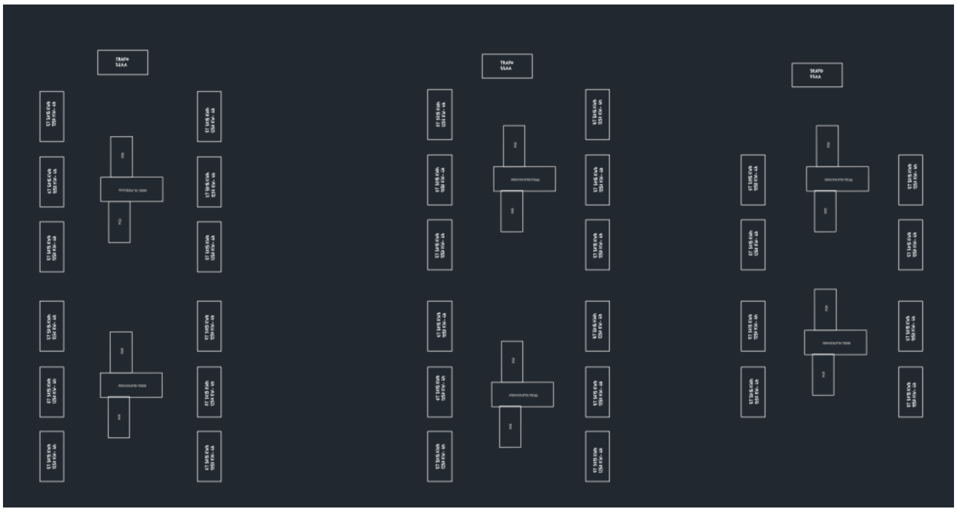


Figure 25. Preliminary layout of batteries, conversion equipment and AASS transformers

The conversion of direct current from the batteries to step-up-capable alternating current, and vice versa, is carried out using equipment from the manufacturer Power Electronics, which allows for the seamless integration of inverters and LV/MV transformers into a single unit.

The inverters will convert the energy exchanged between the batteries and the substation from direct current to low-voltage three-phase current. The chosen inverter model offers the possibility of easily integrating it, in a "plug&play" manner, in a single skid compact system from the same manufacturer with the low-medium voltage transformer, allowing a native incorporation of two inverters and a single transformer without the need for additional connective equipment. Moreover, the skid system allows for

This model will also allow the outputs of two transformers to be connected to each other, integrating them into the same circuit. This will allow SKID systems to be "sewn" between them, reducing the number of conductors needed for power transmission, thus reducing the cost of the installation.

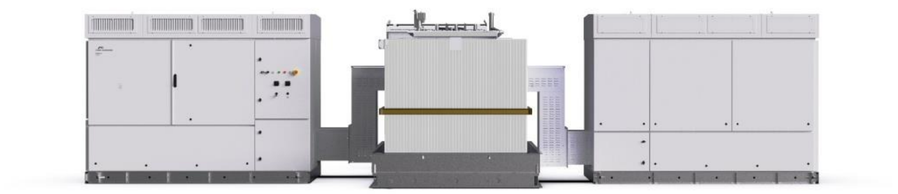


Figure 26. Power Electronics Twin Skid System

Therefore, each lane will feature two skid systems, accounting for the four inverters needed for each battery lane and allowing a straightforward distribution of the elements that enable the projected energy storage.

The project proposes the construction of a building intended for shared use by the evacuation system and the facility's control operations. Inside, the building will house the SCADA systems for the battery plant, along with the control and handling instruments necessary to ensure the proper operation of the park.

This control building will also include a switchgear room that will serve as the receiving point for the power cables coming from the power transformation system. There will be one medium-voltage switchgear unit for each LV/MV transformer, in addition to a dedicated switchgear unit for the auxiliary service supply.

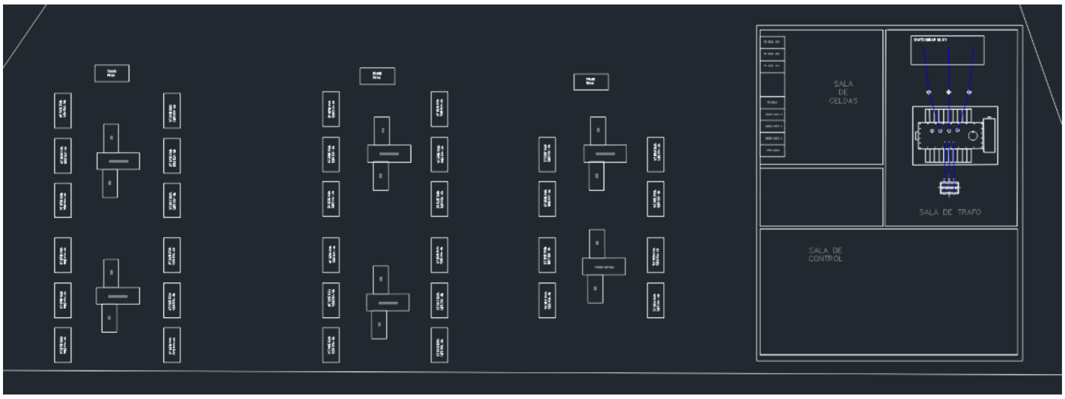


Figure 27. Preliminary layout and control building on the right

The presented single-line diagram provides a straightforward means of assessing the electrical infrastructure of the facility. Three voltage levels can be distinguished, structured as previously described according to the conversion and transformation elements between them. The lowest section represents the battery voltage level, divided into the structural blocks described earlier.

Moving upward in the diagram, the medium-voltage switchgear is shown, which supplies power to the conversion elements from the evacuation transformer, as well as all the protections and additional components associated with this transformer to enable power conversion while ensuring safety and operational conditions.

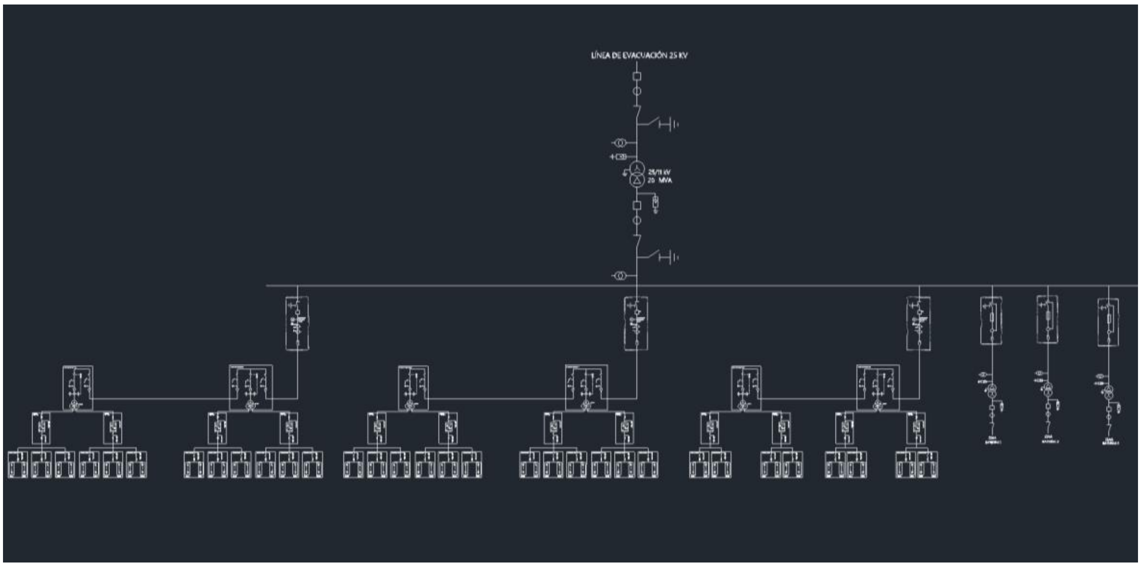


Figure 28. BESS SLD

At the low-voltage level, three elements of different sizes can be distinguished, each corresponding to one of the battery groups that make up the aisles. On the far right, three switchgear units can again be identified, corresponding to the auxiliary service supply for each of the three battery aisles.

In Annex 1of this report, this single-line diagram can be found in greater detail, indicating each of its components separately and showing more clearly the connections between them.

Using this diagram as the operational basis for the connections between electrical equipment, and given the known layout, it is possible to trace the cable routes required for the battery project. These will be installed in an underground trench, thereby ensuring that their path does not obstruct circulation within the facility.

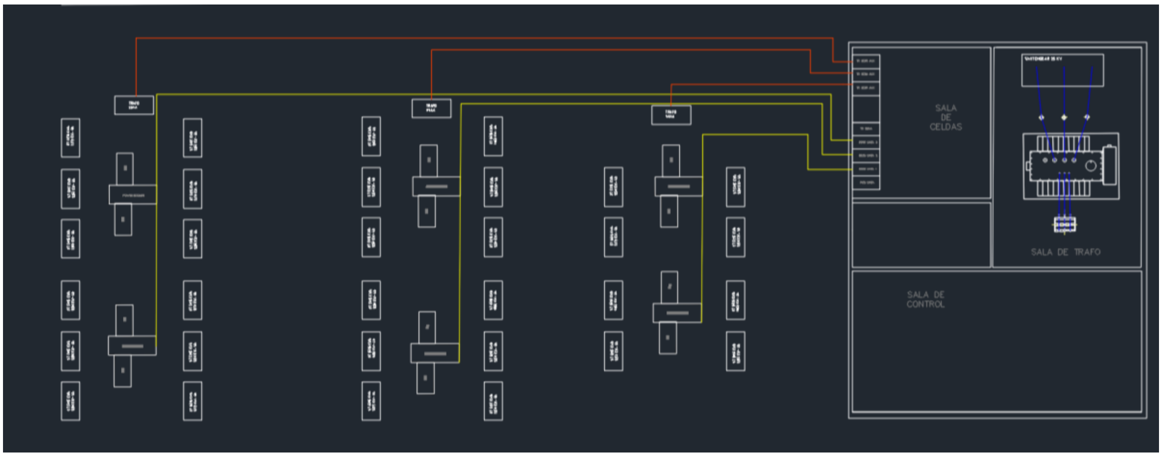


Figure 29. MV connections, power lines in yellow, ancillary services in orange

This diagram provides a representation of the medium-voltage conductor connections, at 11 kV. They originate from the medium-voltage switchgear, energized by the evacuation transformer, to the auxiliary service transformers, whose connection is shown in orange, and to the SKID groups, shown in yellow. As stated, the connections between SKID groups are tied every two LV/MV transformers, allowing for a single output from each battery system aisle.

The low-voltage connections will originate from each of the auxiliary service transformers and the PCSk, reaching each of the batteries to which they are assigned. In blue are the auxiliary service connections, which will supply the cooling services for the AC battery connections. The connections shown in green will represent the direct current circuits corresponding to the charging and discharging of the batteries during normal operation of the storage system.

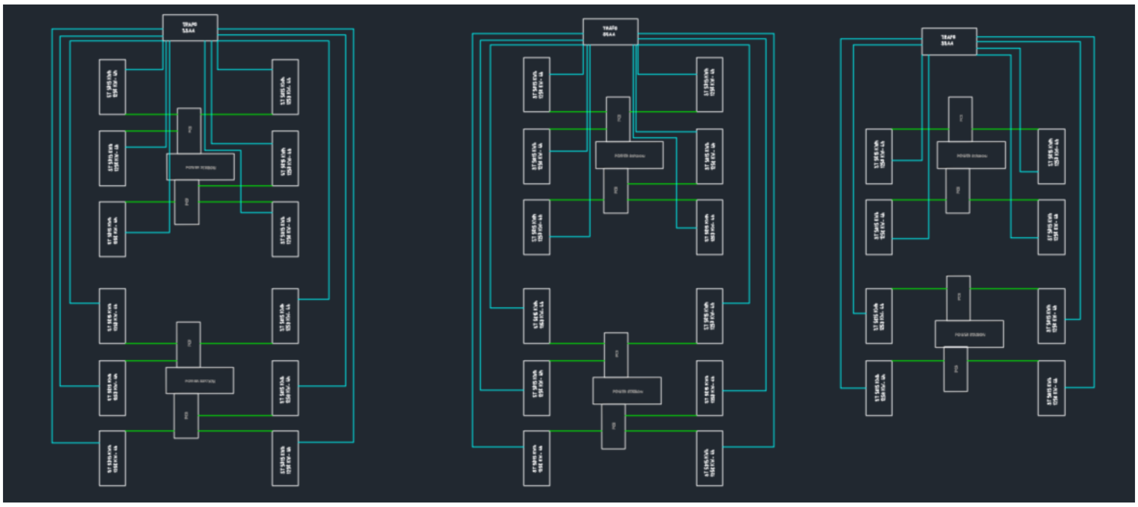


Figure 30. LV connections: Power transmission in green, ancillary services in blue

The analysis conducted on the electrical connections within the storage facility, along with the single-line diagram of the electrical systems present in the installation, enables the subsequent selection of the required equipment, which will serve as the foundation for developing the preliminary budget for the entire battery park.

3.3. Equipment Selection

3.3.1. Battery system

Energy storage will be based on lithium iron phosphate (LFP) electrolytic battery systems, housed in shipping container-sized containers, which are currently the most widely used solution for storing electrical energy in both isolated and integrated generation systems such as this plant.

The model selected for this purpose will be the *PowerTitan 2.0 ST5015kWh* from the manufacturer Sungrow. This will enable the temporary management of the energy generated, either by delivering its storage in four or two hours to optimize the benefit of the energy delivered to the grid, or by enabling stability and firmness services in the grid.

Figure 31. Battery system PowerTitan 2.0 ST5015kWh

This model was selected because of the capacity compliance of the estimated energy storage for a single battery system, being 5015 kWh and able to provide variable nominal power that allows it to deliver its capacity in a minimum of two hours.

It is a prefabricated, factory-assembled battery system, facilitating installation and reducing risks and failures during field assembly. This model also features intelligent liquid cooling, which improves battery life and increases discharge capacity in demanding conditions.

Each container will contain battery rack cabinets connected in parallel. In turn, each cabinet is composed of battery modules. There will be DC connection cabinets for wiring between containers and PCS. The cabinets will be protected with fuses and surge arresters. Finally, advanced safety features are available, including gas detection systems, fire suppression, emergency ventilation, and compliance with UL and NFPA standards.

- Battery technology: LFP 3.2 V / 314 Ah per cell
- Nominal energy capacity: 5015 kWh
- Maximum discharge power: 2500 kW (2 hours)
- DC operating voltage: 1123.2 – 1497.6 V

- Cooling system: intelligent liquid cooling
- Dimensions (L × W × H): 6058 × 2896 × 2438 mm
- Total weight: 42–43 tons
- Mechanical protection: IP type 3S, corrosion resistance C3
- Certifications: UL 9540A, UL 1973, UL 1741SB, NFPA 855, IEEE 1547

The budget estimate starts at around €360,000 per battery container of this model. The battery park is designed, in accordance with the initial sizing criteria, to be capable of injecting 20 MW into the grid for eight hours after a single charge. Given that the individual capacity of each battery container is 5,015 kWh, with a discharge capacity of 1,253 kW over four hours, a total of 16 battery units will be required to achieve the desired capacity.

The total estimated budget for the battery system is therefore €5.76 million for the entire battery storage system.

3.3.2. Power conversion system

The power conversion system consists of a set of devices responsible for transforming the direct current from the battery into alternating current synchronized with the electrical grid to which the system is connected. This equipment must be bidirectional, as it is also responsible for rectifying the alternating current from the grid to recharge the batteries.

Every two inverters of this model will be integrated into the same SKID, allowing for simpler and more efficient integration than if done using independent equipment. This facilitates the conversion of electrical energy from the batteries to the 11 kV three-phase circuit, where it can be incorporated into the medium voltage cells

The final conFiguretion of the plant can be found in Annex 2 of this report. The equipment used in this section will be:

Freemaq PCSK: bidirectional power inverters specifically designed for applications with direct current energy storage batteries. Selected for its robustness, efficiency, and high integration capacity with different types of batteries. Includes complete AC and DC protections, Modbus TCP monitoring, and compatibility with third-party plant controllers and SCADA systems.

Figure 32. Conversion equipment Freemaq PCSK

The main technical characteristics of this equipment for the proposed application:

- Nominal AC power (at 40°C): up to 5125 kW
- DC operating voltage range: 976 V – 1500 V
- Nominal AC voltage: 690 V
- Network frequency: 50/60 Hz
- Adjustable power factor: 0.5 capacitive to 0.5 inductive
- Maximum continuous DC current: up to 4590 A
- Maximum efficiency: up to 98.95%
- Cooling: forced air cooling

Twin Skid Compact: will act as described above as an integrating element for inverters and medium-voltage transformers in individual elements for the battery system. Its design is geared towards facilitating quick and compact connection, with an architecture that reduces installation times, space occupied, and commissioning work in the field.

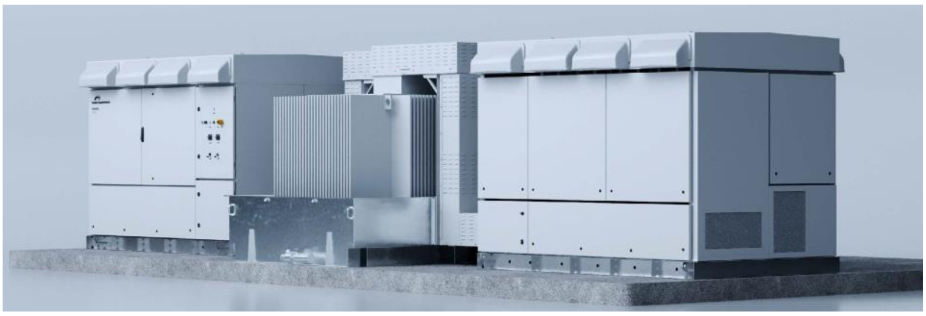


Figure 33. Transformation equipment Twin Skid Compact

The transformer can be selected from ONAN or KNAN cooling, and its vector group will be Dy11y11. In addition, the system includes medium-voltage cells with circuit breakers, safety interlocks, oil retention accessories, and the possibility of incorporating an uninterruptible power supply (UPS) for auxiliary services.

Its most relevant technical characteristics are:

- Nominal power range: 3050 kVA – 8780 kVA at 40°C
- Medium voltage (MV): conFigureble between 11 kV and 34.5 kV
- Low voltage (LV): 480 V – 690 V
- Transformer cooling: ONAN / KNAN
- Vector group: Dy11y11
- MV cells: dual feed conFiguretion (2L), protection circuit breaker included.
- Cell short-circuits capacity: 16 kA / 1 s

The estimated budget for this equipment is €160,000 per unit for PCSK inverters, of which the energy storage system will have a total of 32 units, amounting to a total of €1,920,000.

The Twin Skid group has an estimated value of €300,000 per unit. The total battery park has six units like this, adding up to a total of €1,800,000 for this power transformation equipment.

3.3.3. Power Evacuation System

The main power transformer serves the purpose of pouring the stored energy into the grid and retrieving it in order to charge the battery systems. It steps up the voltage, from the 11 kV installation inside the storage park (Medium Voltage) to the 25 kV at which the distribution grid operates (High Voltage).

From a technical perspective, the reduction in current minimizes cable and line losses, provides galvanic isolation between the BESS and the grid, enhancing safety and protection coordination. It serves to establish a neutral grounding point and supports short-circuit level control.

The transformer will also enable voltage adjustment through tap changers to meet the grid’s voltage profile, allowing the installation to ser as ancillary resources for keeping the grid’s stability.

Figure 34. ONAF power transformer

The selected transformer for power evacuation into the grid will be according to the following specifications:

- Rated power: 20/26.6 MVA (ONAN/ONAF)
- Voltages: LV 11 kV / HV 25 kV
- Recommended vector group: YNd11 (HV star with neutral accessible for grounding; LV delta to block inverter harmonics)
- Frequency: 50 Hz
- Short-circuit impedance: 8–10% at rated power
- Cooling: ONAN/ONAF, radiators with 1–2 stages of forced ventilation
- Indicative losses:
    - No-load loss $P_0 \approx$ 10–20 kW
    - Load loss P_k (at 75 °C) $\approx$ 120–180 kW
- Standards: IEC 60076 (series), IEC 60076-5 (short-circuit withstand), distribution utility requirements.

The manufacturer Elsewedy will be selected for the installation of the transformer. The estimated budget for this equipment is approximately €500,000, to which the cost of the transformer protection components and the required testing must be added. In total, the power evacuation system is estimated at €150,000.

3.3.4. Ancillary Services

The elements of the battery system especially require receiving external power supply to ensure the proper operation of the systems that complement energy storage. This auxiliary services system is studied below, with an estimate made of the auxiliary service transformers and uninterruptible power supply (UPS) units needed to continuously power the storage system equipment that requires it.

Ancillary Services Transformer:

Recalling the proposed conFiguretion, the output of each two SKIDS groups will be integrated into one output due to the possibility offered by this equipment to connect the output together. This means that the auxiliary services will be powered by auxiliary service transformers, each of which will power a group consisting of the two SKIDS in the manner proposed.

In this way, each of the auxiliary service transformers will have the function of powering the cooling and support services of 12 batteries, 4 PCSK inverters, and 2 medium-voltage transformers of the SKID group.

The specifications for this equipment indicate the power required to supply the auxiliary services that ensure its proper functioning. Since the maximum power demand for auxiliary services will come from the batteries, an estimate is made of the power that each transformer must be capable of supplying to all the batteries, which will be increased to include the rest of the equipment.

The electrochemical operation of batteries requires cooling systems to ensure that the temperature of these systems always remains within specified limits to prevent damage to battery racks or degradation that reduces their service life. In addition, monitoring systems and communications with SCADA also require a stable AC power supply.

Annex 3 contains a study that shows the consumption in auxiliary services involved in the use of batteries during their operation:

Table 4-1 Aux. Consumption of ESS Container

Test Conditions	-20°C		0°C		25°C		35°C		45°C	
	0.25P	0.5P	0.25P	0.5P	0.25P	0.5P	0.25P	0.5P	0.25P	0.5P
Operating average power (kW)	6.1	13.2	7.5	14.1	10.6	27.5	14.7	32.2	22.0	35.1
Rest average power (kW)	2.8	3.5	2.9	3.5	1.7	3.2	4.9	6.6	6.3	9.6
24h Aux. energy consumption (kWh)	95	127	109	132	119	186	201	273	285	343

Figure 35. Aux consumption of ESS container

As stated in the table, the average value under operating conditions is around 35 kW at the peak power consumption points of auxiliary services, i.e., during battery charging and discharging operations.

Due to the conFiguretion explained above, the auxiliary service transformers must be capable of simultaneously powering 12 batteries each during their charge and discharge cycles:

Therefore, each auxiliary service transformer must have a capacity of 420 kW to comply with the auxiliary service specifications in the battery containers. Applying an oversize factor, the capacity of each transformer intended for this purpose is concluded to be 450 kVA.

These transformers will be located outdoors, at the head of each row of battery groups defined by two SKID systems. Therefore, oil-immersed transformers capable of withstanding these conditions are selected. These transformers will be connected to the medium-voltage park of the evacuation substation (30 kV) and, thanks to this, will be able to power the auxiliary services as required.

The summary of its specifications is detailed below:

- Nominal power: 450 kVA
- Nominal frequency: 50 Hz
- Primary/secondary voltage: 11,000/400 V (three-phase + neutral)
- Vector group: Dyn11
- Cooling type: ONAN
- Level and temperature indicator
- Buchholz with contact

The estimated cost of these transformers will be lower than that of large power transformers because, as they are lower-power transformers, their design is standardized, and equipment with these characteristics can be found for around €10,000.

For all three auxiliary service transformers, the total estimated budget will amount to €30,000.

Uninterruptible Power Supply:

The importance of auxiliary power supplies in energy storage systems justifies the need to always guarantee continuity of supply to these systems. To this end, uninterruptible power supply (UPS) systems are incorporated.

These UPS units will be located inside the control building and will be powered from the same substation busbar as the auxiliary service transformers. Due to the power demand (a total of 1800 kVA), high-capacity UPS units are selected.

Figure 36. Delphys UPS MX Elite+

The selected model will be the MX Elite+ model from the manufacturer Delphys. This high-capacity UPS allows for a maximum power output of up to 600 kVA, so two of these units will be sufficient to power all auxiliary services.

The complete specifications for this equipment can be found in Annex 3. The most relevant feature will be the ability of these systems to power auxiliary services for up to 30 continuous minutes in the event of a power loss on the busbar, assuming that the two units in parallel achieve a storage capacity of 900 kWh.

The estimated price of this equipment is €60,000 per unit, reaching an estimated total of €120,000 for the entire uninterruptible power supply system that guarantees power to the battery system's storage and transformation equipment.

3.3.5. Conductor Selection

Following the distribution proposed in the electrical infrastructure section of this chapter, the required conductors for power transmission are divided into medium-voltage cables and low-voltage cables. The latter must be capable of carrying direct current from the batteries and power conversion equipment, as well as alternating current to supply the auxiliary cooling services for the batteries:

<u>Low voltage cables:</u>

Recalling the proposed low-voltage cable layout, two different types of cables can be distinguished, each represented in a different color in the attached diagram:

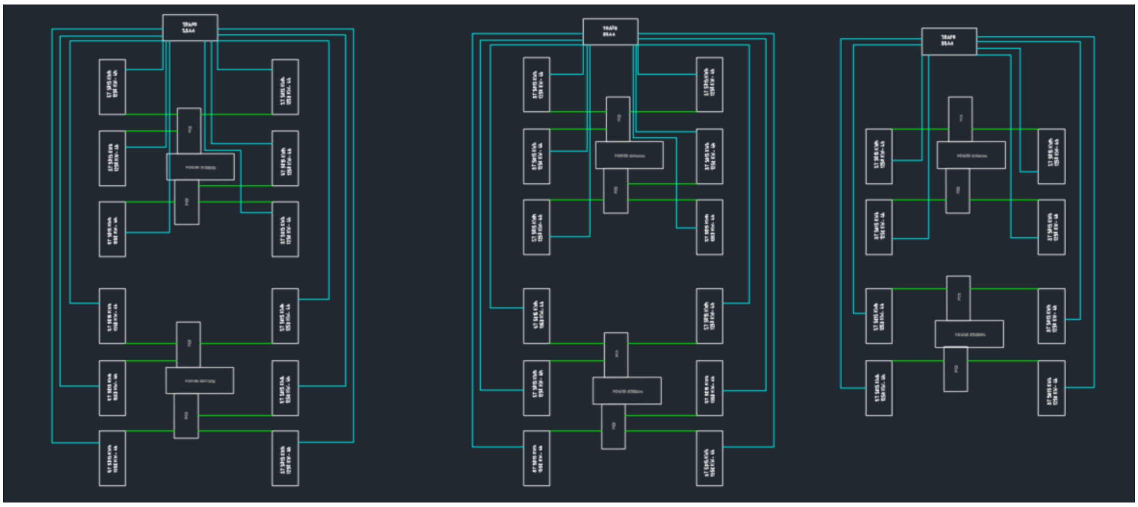


Figure 37. LV Connections

The conductors used for low-voltage direct current transmission will be installed in underground trenches and will be made of copper to maximize the available capacity of each conductor. In accordance with the applicable Spanish regulations on maximum conductor capacity (ITC-BT-19), single-phase cables with a cross-section of 240 mm² will be selected for this application. Due to the single-phase conFiguretion, two phases must be sent to each receiver. The designation for this cable is 2×(1×240 mm² Cu), and based on the measured layout, approximately 500 m of this conductor will be required, at an estimated cost of €28/m.

The cables for auxiliary services will have a three-phase conFiguretion and will also be buried in underground trenches. Due to the power transmission requirements and the maximum capacity of low-voltage conductors regulated in Spain under ITC-BT-19, the selected cable for this application will be a three-phase aluminum cable to each receiver, designated 1×(3×240 mm² Al). The total length of cable needed for auxiliary services is estimated at 1,500 m, based on the measured layout, with an estimated unit cost of €8.34/m.

<u>Medium voltage cables:</u>

The cables intended for medium-voltage power transmission exhibit lower specific losses due to the reduced current flowing through them. For this reason, only aluminum conductors are considered for feeding power from the medium-voltage switchgear in the control building to each of the voltage transformation units in the storage system.

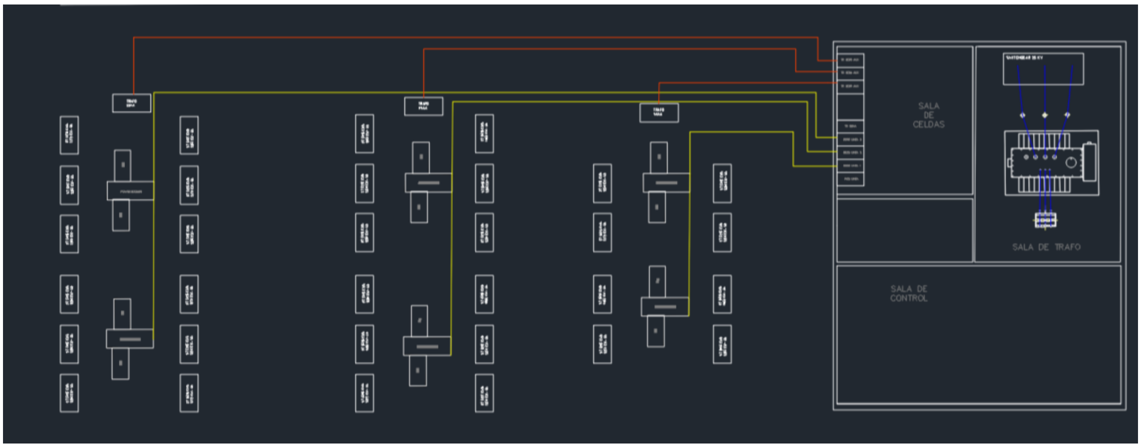


Figure 38. MV Connections

The total cable length for both purposes will be 800 meters, supplying power to both the auxiliary service transformers and the interconnected SKID systems. The cable selected will be the minimum cross-section permitted for this application under the Spanish medium-voltage conductor standard ITC-RAT-07, in line with the energy transmission requirements for this project. The chosen cable will be single core, with a cross-section of 400 mm², designated 3×(1×400 mm² Al), and its estimated cost is €6.72/m.

The initial budget estimate therefore places the expenditure for power conductors at €60,000, based on the measures taken from the layout and cost estimates derived from prior available quotations. However, this outlay could be reduced by placing the order with a single manufacturer or by bundling the purchase with vendors supplying the preceding systems.

Chapter III: Financial Evaluation

1. Project's Budget Estimations

Based on the equipment selection carried out in the previous chapter, the overall cost estimate of the stand-alone battery system will be determined. This budget will serve as the starting point for the project's economic analysis, providing the basis for assessing its financial sustainability.

This chapter will be divided into three sections. In the first one, the resulting contract offer developed from the initial data will be detailed, divided into items according to each's purpose.

Following, a comprehensive study on the Spanish energy market is carried out, focusing on the BESS expected operation and interaction with it. This study will feature historical data retrieved from OMIE's archives and will develop from it a reasonable forecast for the BESS first ten years of operation.

Based on these estimations, the system's production assumptions will be stated, detailing the expected operating expenses of the plant after construction, the estimated revenue for energy delivered to the grid, and the concluded financial viability of the project.

Finally, conclusions from the economic study carried out in this master's thesis will be presented. This synthesis aims to provide both the conclusions regarding the economic feasibility of the project and the role of the project within the context of the system in which it is integrated, analyzing its significance as part of the overall Spanish energy system.

1.1. Bill of quantities breakdown

As a conclusion of the equipment selection carried out in the previous chapter, Annex 4 includes a technical-economic document detailing, in a structured manner by characteristics, the works, materials, and equipment required for the execution of the project.

This bill of quantities serves as the basis for justifying the CAPEX estimated in the project, providing a substantiated estimate of the overall project cost. This document would also allow for comparison between offers from different manufacturers, allowing the selection of the most competitive contract proposal.

In the case of the present project, this budget item is broken down into the following components:

1. *General purpose:* this refers to the budget allocated for the mobilization of machinery and labor to the site, as well as the utilities required to enable work during the project's duration; engineering and management studies, as well as additional costs related to project execution such as insurance, testing, and contingency reserves. The total cost associated with the general purpose item amounts to €260,000.

2. *Installation and assembly:* divided into civil works, trench excavation, fence installation, preparation of the electromechanical installation, general grounding system, and monitoring system. Thes section covers all the site preparation works for the generation park, including the cost of civil works depending on the square meters of surface to be prepared and the expected cubic meters to be moved during the process. This section also includes the budget for the external control building, including both the equipment inside it and the civil works for the foundations. Altogether, this item is estimated at €1,335,250.
3. *Storage system:* according to the equipment described in the previous chapter and the available offer data, the cost of the equipment for the 160 MWh battery storage system amounts to €8.742.787.

1.2. Total Allocated Budget (TAB)

The budget detailed in the Bill of Quantities defines the estimated cost required to cover the expenses related to the supply of the equipment necessary for its construction, as well as the supervision and proper assembly of the project from its beginning until commissioning, serving as the cost baseline for measuring project performance (PMB).

This cost, however, will not cover the entirety of the budget allocated for the execution of the project, since, according to project management theory, reserves must be considered for both management and general contingencies that may arise until commissioning, thus serving as a response measure to the risks that may be identified during project execution.

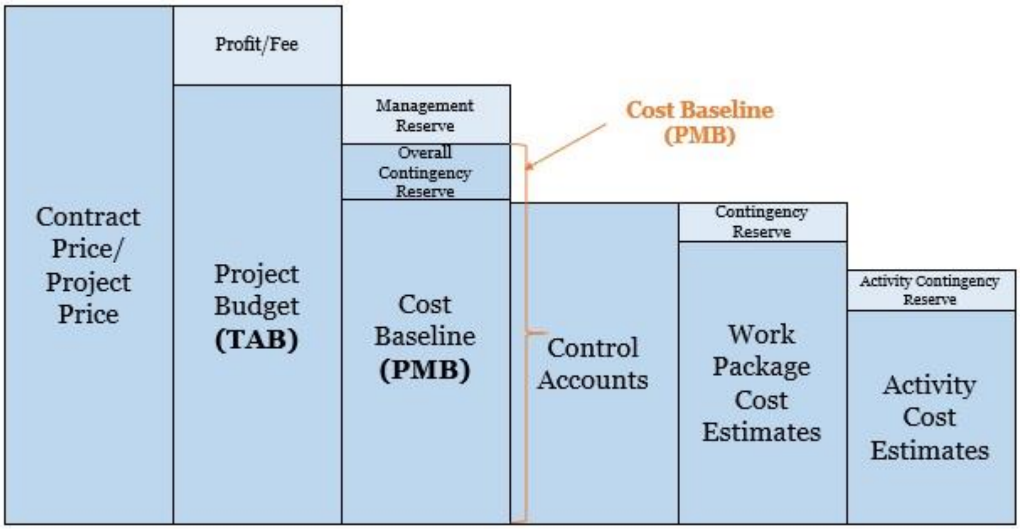


Figure 39. Project budget breakdown

The first identified risk will be the delay in the completion of the system's construction, since, motivated by different causes such as the extension of administrative procedures or difficulties in the supply of equipment, failure to meet the established deadlines for the completion of construction is one of the most common causes of exceeding the estimated budget in renewable generation projects.

Indeed, an extension of the construction period entails both an increase in costs due to the additional expenses of the construction team during that period and a delay in the commissioning of the system, postponing the moment when the benefits that justify the investment begin to be realized, and consequently reducing the internal rate of return.

The next identified risk concerns the cost of the budgeted equipment, where market fluctuations or supply difficulties may cause an increase in the initially estimated cost. Defects in the equipment or technical manufacturing failures will also be included in this risk, grouping together all cost overruns associated with the equipment and materials necessary for construction.

Finally, risks related to unforeseen events during the construction of the system are identified, such as adverse weather conditions that prevent work for a prolonged period, regulatory changes that require reconsideration of part of the installation, or workplace accidents that cause stoppages or legal liabilities.

The default measure in the face of the identified risks will always be the attempt to avoid them, and if that is impossible, to mitigate them. This contingency reserve will act as a safeguard for the project, constituting the total allocated budget (TAB).

Overall, the total allocated project budget is estimated to be 15% above the bid value received in the EPC offer, amounting to a total cost of €11,888,742 (ELEVEN MILLION EIGHT HOUNDRED AND EIGHTY-EIGHT THOUSAND SEVEN HOUNDRED AND FORTY-TWO EUROS).

This total cost will cover both the budget of the submitted offer and the contractor’s profit, the established contingency reserves, and will act as a financial cushion against possible unforeseen events from the beginning until the system is operational.

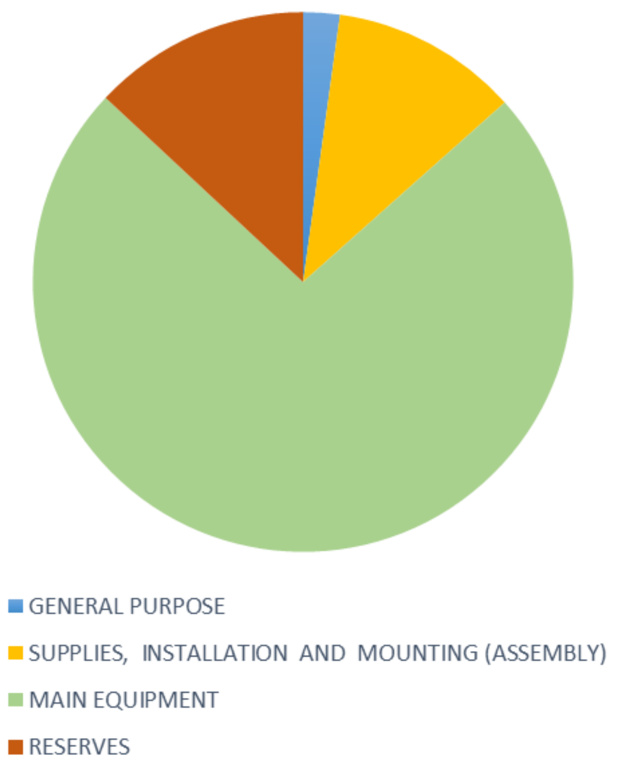


Figure 40. Itemized project assigned budget

2. Market Study

Energy arbitrage, that is, the purchase or absorption of energy during the lowest-price hours of the daily wholesale market and its sale or discharge during the highest-price hours, is the most basic revenue source for a BESS system. This business model takes advantage of daily price fluctuations in the energy market, which are amplified by the volatility caused by renewable penetration, driving prices down during midday hours and pushing them up during peak consumption hours.

It is therefore necessary, in order to carry out a complete economic evaluation of the project, to understand how the BESS installation will interact with the energy market, defining its operating patterns and anticipating how its evolution can be expected in the coming years of operation.

2.1. Day-ahead market analysis

Nowadays, the purchase and sale prices of energy in the daily market reach their minimum values during the eight central hours of the day (11:00–18:00), followed by a sharp increase in prices during the late hours of the day, which maintain a higher average price until 10:00 the following day. Based on market operator data for a day this year, a pronounced trough can be observed during this period, despite a larger amount of energy being traded compared to the preceding and subsequent periods of the day.

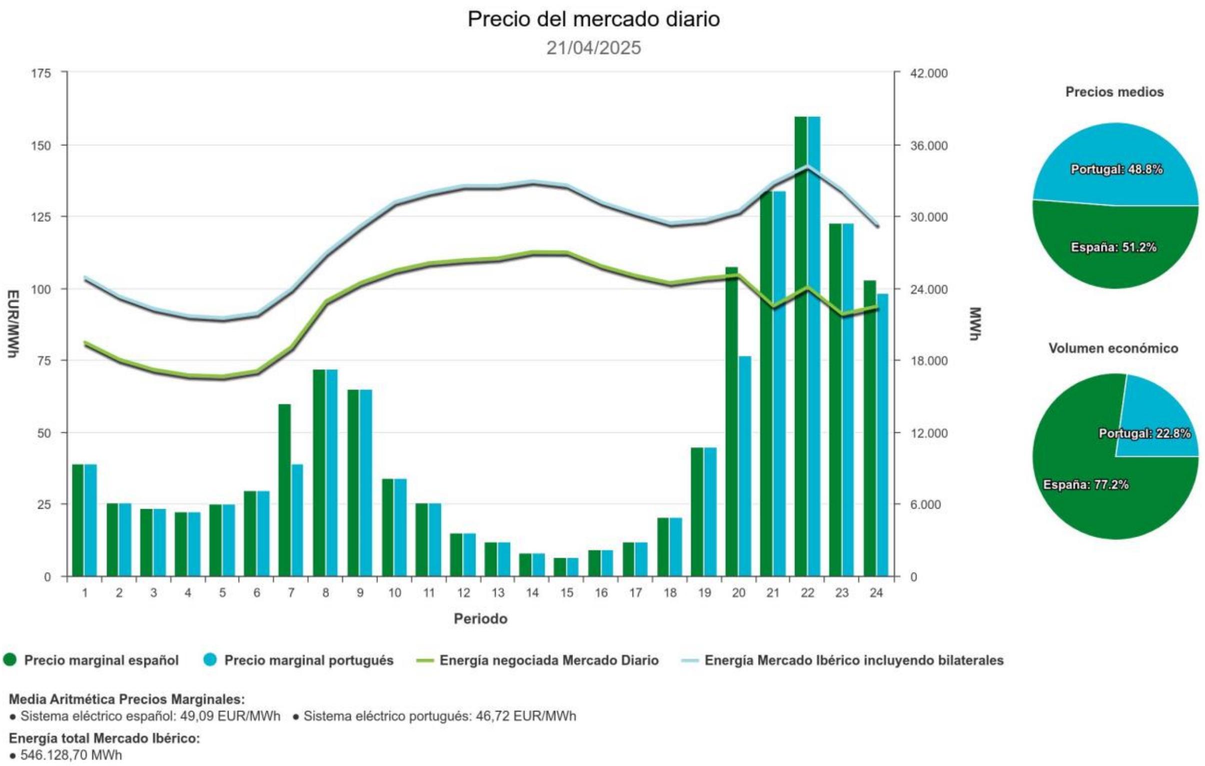


Figure 41. Energy market prices for 21/04/2025 (OMIE)

This phenomenon represents the practical application of the so-called duck curve explained in the first chapter of this report. The strong presence of solar photovoltaic generation in Spain drives energy prices down due to the inability to manage its generation on demand, creating a clear market opportunity for energy storage installations.

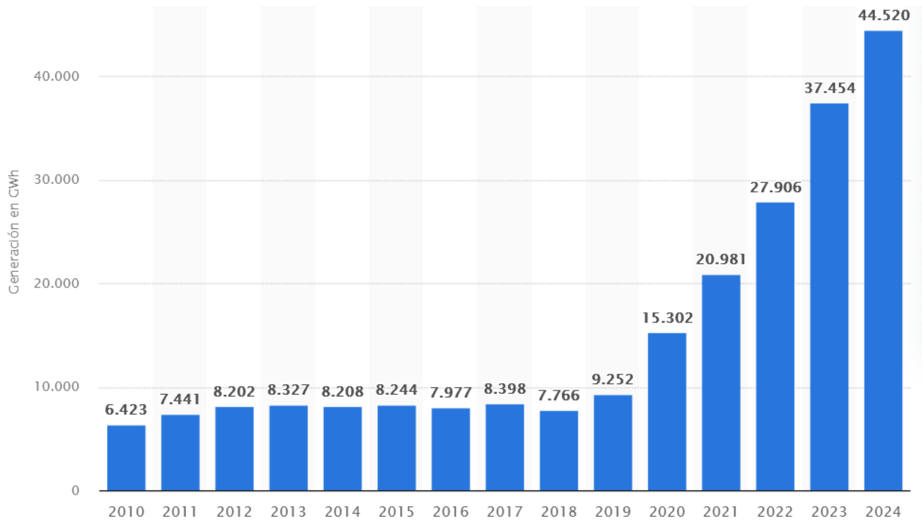


Figure 42. PV penetration since 2010 (Aleasoft)

The existence of such a pronounced duck curve in the Iberian energy market is due to the increase in renewable penetration, especially photovoltaic, since the turn of the decade, with solar photovoltaic generation in 2024 having increased by 500% compared to values from the previous decade. As an example of this, the daily market price for the same day shown in figure XX ten years earlier is presented:

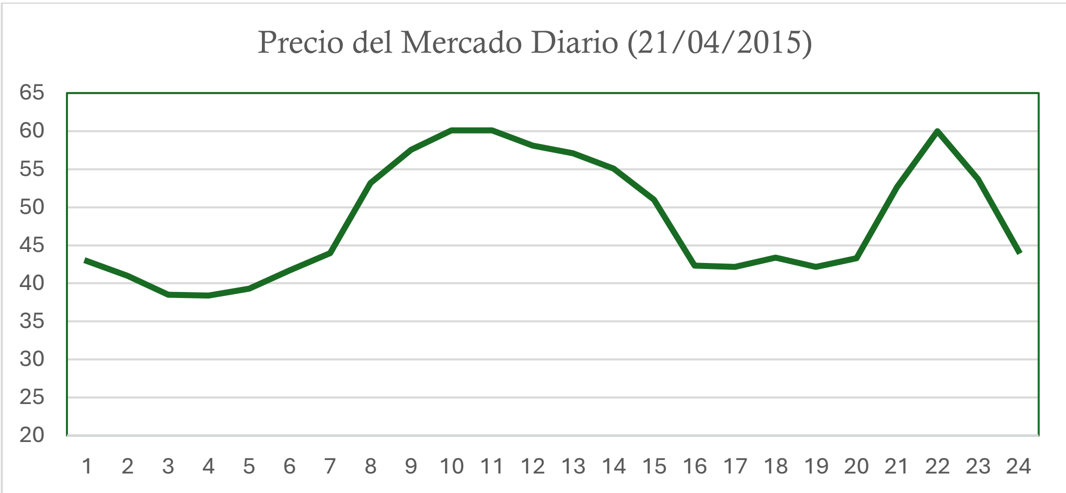


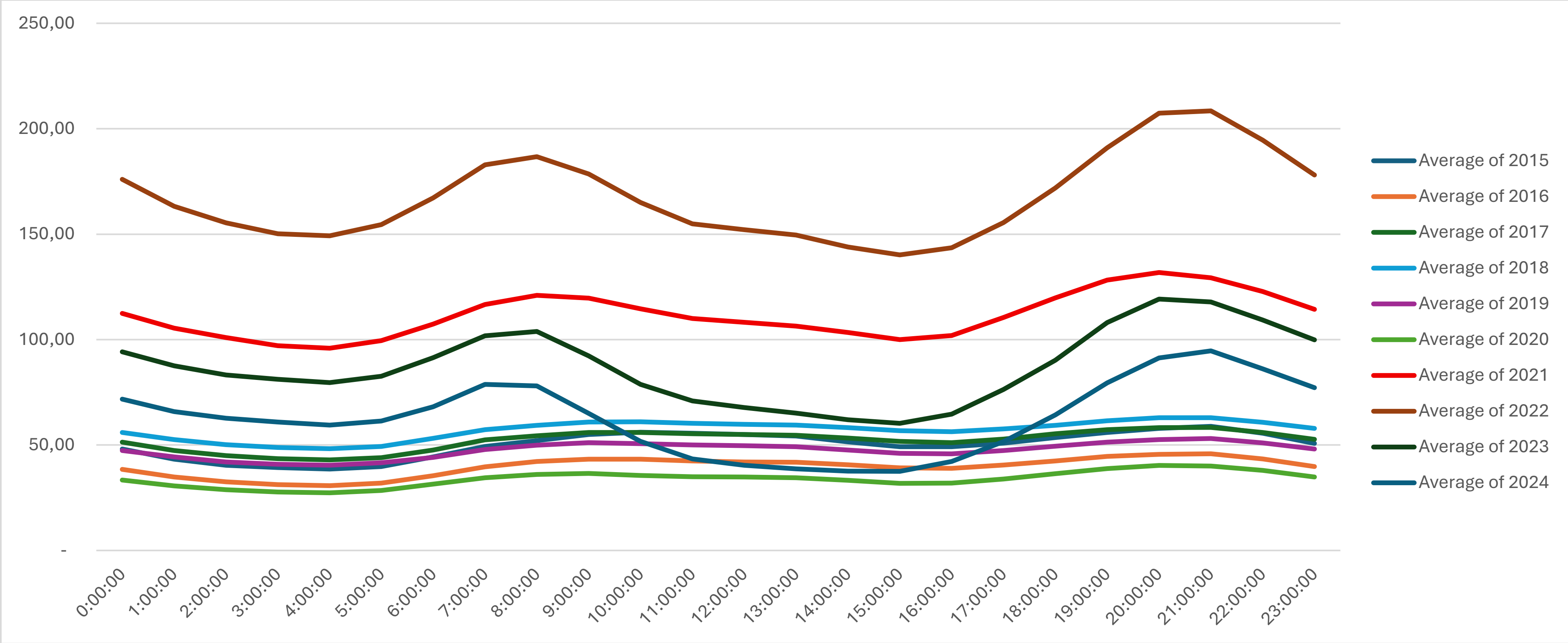
Figure 43. Hourly market price for 21/04/2015

This behavior makes it difficult to accurately estimate the hourly price of the energy market, since the existence of such pronounced price depressions is relatively recent and was barely noticeable until 2021.

The following image provides a combined visualization of the evolution of the annual average of hourly energy prices over the past 10 years. It shows the emergence of duck curves starting in 2021 and the evolution of the average price throughout the years:

2.1.1. Annual average of hourly prices (2015-2024)

Self-elaboration based on OMIE data.



The proposed operating mode hypothesis is therefore confirmed: charging during the central hours of the day (11:00–18:00) and discharging at the beginning of the demand peak and during the night.

The figure also shows the high prices reached in the market during 2022, due to the energy crisis caused by the combination of the strong post-pandemic economic rebound and the Russian invasion of Ukraine, which reduced gas supplies and drove global prices up. It can be observed how, during the hours when the entry of combined cycle plants into the generation mix becomes essential, prices rose significantly.

This crisis is a factor to be considered in subsequent future market estimates, since the price reduction between 2022 and 2023 was not solely due to higher renewable generation, but was also linked to the abnormal overcost caused by the situation described.

2.2. Market outlook

To conclude the BESS production estimates, justifying them through the purchase and sale of energy in the wholesale market, daily market price data from the last ten years are collected, analyzing their temporal evolution and the viability of energy arbitrage as a business model over the years.

Charge: 11:00-18:00		2015	2016	2017	2018	2019	2020	2021	2022	2023	2024
ANNUAL	Charge	52,55	40,93	53,83	58,67	48,29	33,90	107,77	151,84	69,81	44,26
	Discharge	51,06	40,21	52,98	57,90	48,50	35,09	117,15	181,61	100,10	75,56
SPRING	Charge	44,94	25,60	44,20	45,67	48,41	21,35	52,77	196,12	50,40	6,23
	Discharge	45,98	27,22	45,91	47,26	50,45	23,67	63,96	239,03	97,23	31,92
SUMMER	Charge	59,67	41,60	50,60	63,21	48,50	33,47	88,92	137,25	71,96	42,54
	Discharge	56,50	40,19	48,54	61,47	48,11	34,92	97,75	168,15	106,86	91,57
FALL	Charge	53,36	52,62	56,28	68,03	44,44	40,27	175,59	110,06	71,96	60,84
	Discharge	51,54	51,43	55,79	66,60	44,82	41,47	192,13	143,89	96,88	97,19
WINTER	Charge	50,03	34,62	65,14	54,33	59,55	39,07	46,69	194,34	93,22	52,70
	Discharge	48,55	33,14	63,05	53,45	59,15	39,74	47,70	210,49	109,35	63,94

The presented table shows the averaged values of energy prices divided into columns by year. The rows represent the temporal consideration used in each case: annual average or seasonal prices.

Each row is further divided into two, separating them into "battery charging price," that is, the average energy price during the 11:00–18:00 period, and "battery discharging price," the average energy price during the remaining sixteen hours of the day. This allows for the evaluation of battery profitability over these years, understanding that energy arbitrage would be more profitable the greater the difference between purchase and sale prices of energy.

This profitability is represented by the color chosen for each pair of cells, where red indicates periods in which the time allocated to purchase has a higher price than the time allocated to sale, making energy arbitrage impossible. Yellow cells, on the other hand, represent periods in which the selling price exceeds the purchase price, but with an increase of less than 5%, rendering energy arbitrage economically unfeasible.

From this information, the sharp entry of photovoltaic generation into the Spanish electricity system can be observed: in the first recorded years, prices for the two indicated periods were almost identical, with the midday period even showing higher prices due to the country's economic activity. Starting in 2020–2021, however, nighttime prices began to exceed morning prices, justifying the economic activity of batteries based on the impact of renewable generation facilities on the electricity market.

The green colors in the table show the periods when the selling price considerably exceeded the purchase price, with dark green cells indicating an increase of more than 20% over the acquisition price. It can therefore be seen that this business model only became economically viable from 2022 onwards and that the winter period is the least profitable for this model.

These data will be used as the basis for drawing conclusions on estimates of the selling price of electricity in the wholesale market during the years of operation of the storage facility, distinguishing two scenarios that would affect the profitability of the installation in different ways.
The forecast will be based on variations in price resulting from changes in generation and demand, mainly distinguishing between greater penetration of renewable energy, particularly photovoltaic and wind, and variations in demand.

2.2.1. Bussiness as usual scenario

This first scenario considers a continuous and conservative evolution of the data presented in the market analysis, following the price variation trends discussed and considering the following factors:

First, demand would remain approximately constant, with no significant variations observed over the years. Consumption patterns continue to show very strong peaks in the early afternoon and extended flat periods during the middle of the day.

However, based on the contextual analysis carried out in this report, a change in trend in renewable integration can be foreseen. At present, photovoltaic generation is barely able to maintain profitability, having been subject to massive price cannibalization and daily energy curtailments due to the impossibility of being fully integrated into the electricity system.

Wind generation in Spain, on the other hand, is emerging as the new trend for renewable generation projects. This technology has not experienced the profitability declines seen in photovoltaics, and the push for offshore projects is understood as a trend that would drive further developments of this kind in Spain.

Consequently, this first scenario will consider a reduction in prices in both time slots due to greater renewable penetration: photovoltaic generation during charging hours and wind generation during the evening hours. However, this price reduction will be much more moderate for charging hours, since, as explained, the electricity system is already close to saturation in terms of solar energy generation, meaning that further penetration will be much more limited and tied to possible system expansions.

		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
ANNUAL	Charge	44,26	38,87	37,16	35,45	33,74	32,03	30,33	29,81	29,64	28,27	26,91	27,42
	Discharge	75,56	68,60	66,04	63,49	60,93	58,38	55,83	55,06	54,80	52,76	50,72	51,48
SPRING	Charge	6,23	5,88	5,52	5,17	4,81	4,46	4,10	3,99	3,96	3,67	3,39	3,50
	Discharge	31,92	30,32	28,71	27,11	25,51	23,90	22,30	21,82	21,66	20,38	19,09	19,57
SUMMER	Charge	42,54	40,20	37,86	35,52	33,18	30,84	28,50	27,80	27,56	25,69	23,82	24,52
	Discharge	91,57	87,27	82,98	78,68	74,39	70,09	65,80	64,51	64,08	60,65	57,21	58,50
FALL	Charge	60,84	58,12	55,39	52,67	49,95	47,22	44,50	43,68	43,41	41,23	39,05	39,87
	Discharge	97,19	94,76	92,33	89,90	87,46	85,03	82,60	81,87	81,63	79,68	77,74	78,46
WINTER	Charge	52,70	51,28	49,86	48,45	47,03	45,62	44,20	43,78	43,63	42,50	41,37	41,79
	Discharge	63,94	62,05	60,16	58,27	56,38	54,49	52,60	52,03	51,84	50,33	48,82	49,39

Based on data from the years following the energy crisis, a logarithmic regression has been carried out to show the possible evolution of prices over the first ten years of operation.

It can be observed that these prices gradually converge between charging and discharging hours, reducing the profit year after year, although still maintaining a difference that would justify its economic performance.

As in previous years, the profitability of the storage system is expected to decline during the winter months.

2.2.2. Levelized market scenario

The second scenario considers the penetration of renewable energies similar to that described in the previous scenario: a moderate increase in photovoltaic generation and a more significant rise in wind generation, which would smooth out price curves throughout the day.

This scenario also considers the influence of other actors on the consumption pattern, mainly the entry of other storage systems that would compete for the same arbitrage revenues, as well as the demand from both large and small consumers.

Regarding the influence of demand, Spain is not a region where an industrial boom that would drive demand is expected. However, the country has positioned itself as one of the main points of interest for the construction of data centers due to factors such as its geographical location close to two continents, its transatlantic connectivity, and its energy prices. This would affect market prices, since these involve very high-power demands maintained constantly throughout the day.

Another factor to consider is the initiative, both through European and national measures, to shift demand peaks and distribute them more evenly throughout the day. This can be seen in initiatives such as the 2.0DHS tariff, which offers significant advantages for charging electric vehicles during the system’s off-peak hours (Energigreen, 2021). It is foreseeable that an increase in these regulations would flatten the daily price curve, bring charging and discharge prices closer together as simulated in the model:

		2024	2025	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035
ANNUAL	Charge	44,26	40,46	40,34	40,23	40,14	40,04	39,98	39,95	39,86	39,77	39,68	39,59
	Discharge	75,56	67,84	64,53	61,21	58,92	55,86	54,33	53,31	50,76	48,21	45,66	43,11
SPRING	Charge	6,23	6,58	6,93	7,27	7,52	7,84	8,00	8,10	8,37	8,64	8,90	9,17
	Discharge	31,92	30,00	28,08	26,16	24,83	23,06	22,17	21,58	20,10	18,62	17,15	15,67
SUMMER	Charge	42,54	44,40	46,25	48,10	49,39	51,10	51,95	52,53	53,95	55,38	56,80	58,23
	Discharge	91,57	87,63	83,69	79,75	77,02	73,38	71,56	70,35	67,32	64,29	61,26	58,23
FALL	Charge	60,84	59,16	57,48	55,80	54,64	53,08	52,31	51,79	50,50	49,21	47,91	46,62
	Discharge	97,19	92,11	87,03	81,95	78,44	73,75	71,40	69,84	65,93	62,03	58,12	54,21
WINTER	Charge	52,70	51,71	50,72	49,73	49,04	48,13	47,67	47,37	46,60	45,84	45,08	44,32
	Discharge	63,94	61,62	59,30	56,98	55,38	53,24	52,17	51,45	49,67	47,89	46,10	44,32

Applying the same regression model as in the previous case, the prices of the charging and discharging periods eventually converge during the periods in which the projected wind generation is not sufficient to reduce the price of energy, thereby reducing the revenues obtained from energy arbitrage in the final years of the forecast.

2.3. Revenue Stacking

Based on the forecasts made, it can be concluded that the revenues of a BESS through energy arbitrage are a real source of long-term income, which, however, is threatened by market volatility and the behavior of other market actors that may reduce this revenue to the point of endangering the viability of the installation if it relies solely on this form of remuneration.

BESS installations therefore take advantage of their characteristics of rapid grid injection on demand and firm power service to combine multiple revenue streams, participating in all possible remunerated services and not only in the daily energy market; this practice is known as revenue stacking. The possible sources of remuneration for BESS installations are the following:

- Wholesale market:

The wholesale market represents the main revenue stream for BESS installations, as it allows operators to buy and sell electricity on an hourly basis, with the settlement period expected to move to 15 minutes in 2024. Contracts can be secured from long-term horizons down to just one hour ahead, enabling batteries to capture value by trading energy in both day-ahead and intraday markets.

Recent regulations promote BESS installations thanks to flexible market participation, avoiding the cost of paying twice for the energy bought and sold.

- Ancillary Services

1. Secondary Reserve (aFRR):

The secondary reserve provides automatic frequency restoration to maintain the balance between generation and demand, correcting deviations in real time. With an activation horizon ranging from 20 seconds to 15 minutes, BESS assets can monetize both their available capacity and the dispatched energy. Participation requires being part of a regulating zone with at least 10 MW, passing a qualification test, and offering a minimum bid capacity of 1 MW (CNMC, 2025).

2. Tertiary Reserve (mFRR):

The tertiary reserve complements automatic reserves by restoring secondary capacity when it has been deployed. Activation is manual and must occur within 15 minutes or less, making BESS an ideal resource given its fast-ramping capabilities. Remuneration is based on dispatched energy, with a minimum bid capacity of 1 MW, and the service is also subject to regulatory approval (CNMC, 2025).

3. Replacement Reserve (RR):

It is designed to solve imbalances that appear after the intraday market closes, re-establishing both secondary and tertiary reserves. For BESS, this represents an additional flexibility revenue stream, as assets can provide quick injections or absorptions of power. Participation requires a minimum bid capacity of 1 MW, and remuneration is tied to the dispatched energy.

4. Technical Restrictions (TR):

The dispatch of energy production that addresses system security, quality, or reliability issues that may arise from programmed generation. Because remuneration depends on the physical location of the asset, BESS located at strategic grid nodes can achieve higher margins compared to other balancing services. This makes TR particularly attractive for storage operators positioned in constrained areas of the network, like the metropolitan Barcelona area where this BESS is located.

- <u>Capacity Markets:</u>

While this remuneration for installed capacity is still in draft stage, with regulation first proposed in 2021 and the approval process stalled since then. The Spanish capacity market is designed as a pay-as-bid auction remunerating firm capacity in €/MW-year, with contracts lasting up to five years for main auctions or one year for adjustment auctions. Eligible participants include low-emission generation, storage such as BESS, and demand response.

Beyond the draft framework, recent regulatory updates clarify that the Spanish Capacity Market aims for technological neutrality and will be managed by REE via competitive tenders that define capacity needs by network node and invite bids from eligible resources (Vector Renewables, 2025). This design reinforces system firmness by remunerating resources for availability, whether to inject electricity or reduce consumption upon system operator request.

In the scenario proposed by market experts such as Luis Marquina (Aleasoft, 2023), most of the revenues of BESS would come from participation in the secondary reserve band, followed by price arbitrage. This remuneration is favored by the growing volatility of the secondary reserve market system.

Participation in this market would, however, be severely affected by cannibalization as storage penetration in the electricity system increases, leading to an annual reduction and creating the need for an additional revenue source that would allow these BESS systems to achieve an IRR of 9%. According to Luis Marquina, the emerging capacity market would achieve this objective (Aleasoft, 2023).

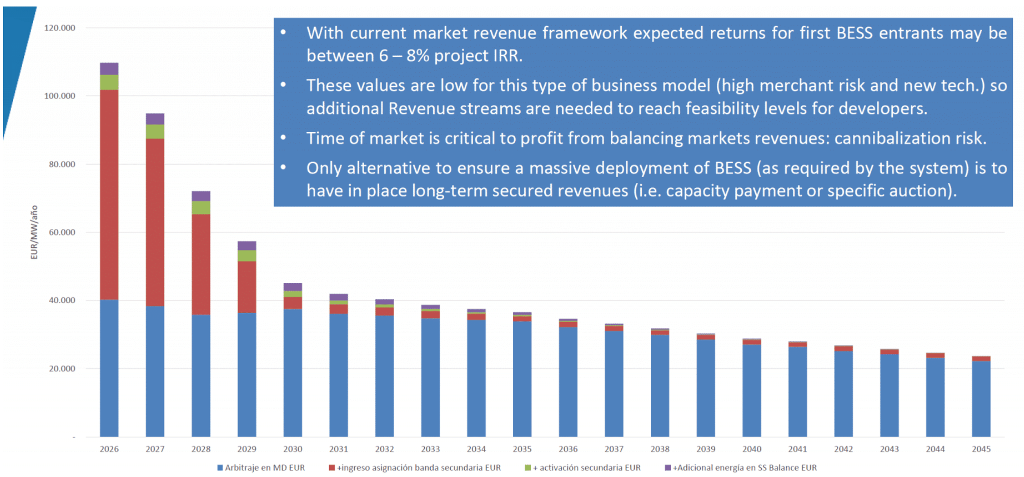


Figure 44. Future revenue stacking for storage (Aleasoft)

3. Cash Flow Analysis

The project's total allocated budget establishes the steppingstone for the system's financial viability, serving as the initial capital expense needed to kickstart the project.

This economic viability will depend on the ability to recover the CAPEX invested in the construction of the storage system in due course and with an adequate rate of return. To this end, the possibilities of interaction of the installation with the market will be studied, estimating the potential cash flows generated during its operating life.

The objective, therefore, having already assessed the benefits that such an installation provides to the electricity grid as a whole, will be to determine whether it also represents a sound financial investment and can be sustained as a business model over time.

The energy market forecasts will be based on estimates derived from historical data from ESIOS of Red Eléctrica, as well as contextual estimates based on the different possible scenarios assumed for the energy market.

3.1. Operating expenses

Following the proposed operating criterion, the main expense in the operation of the system will be the purchase of energy during the lowest-price hours of the daily market for its subsequent economic arbitrage or injection into the technical constraints markets.

This cost will be estimated together with the selling price of energy in the market study section, making a comparison between different hypotheses that reflect its evolution over the first ten years of the plant's operation. However, there are other costs that affect the overall viability of the system and will condition its cash flows, which will be evaluated below:

- Operation and maintenance costs: in the case of battery energy storage systems, the main maintenance costs arise from the need to carry out periodic repowering tasks throughout the useful life of the battery park.
- Land costs: payments related to the ownership of the land where the generation plant is located, in case it is not owned by the developer.
- Payments for grid access and use of the electrical network infrastructure, due to the connection of the installation to the transmission substation.
- Compensatory measures from the Environmental Impact Declaration: the public administration may require the payment of fees intended to compensate for possible negative effects of the project on the natural or social environment.
- Regional or state taxes, including property tax, business activity tax, or municipal fees for services or use of public domain.
- Additional costs: this category includes all expenses related to site security contracting, equipment insurance, and administrative or legal management costs.

EXPENSE	ANNUAL COST (YEAR 1)
O&M	100.000,00 €
Terrain Costs	50.000,00 €
Grid Access	20.000,00 €
Taxes	30.000,00 €
Environmental Compensation	30.000,00 €
Others	20.000,00 €
TOTAL	250.000,00 €

This operating cost will depend on price revision clauses linked to the CPI and the cost of materials, as well as on changes in legislation that may increase expenses related to taxes or grid access fees. Consequently, both inflation and possible additional payments will be represented in the economic estimate as an annual increase in operating costs.

3.2. Income Expectations

The energy storage system involves the construction of a total of 160 MWh of installed capacity, absorbed daily during the eight lowest-price hours of the day and sold during the most expensive hours.

This operating principle, together with the market estimates made in the previous section, allows for an estimation of the revenues obtained from energy arbitrage activities.

According to the operating criteria, the 160 MWh of capacity are charged and discharged daily throughout the 365 days of the year. Applying a 90% availability factor, this results in the possibility of exchanging 52,717.68 MWh per year with the grid.

The production estimates will use the annual average values from the market forecast, both for the purchase and for the sale of energy. This determines the final factor of the installation's OPEX needed for the economic viability assessment.

As studied, revenue diversification through energy sales is an essential element in the business model of a BESS. However, calculating this benefit is extremely complex, as it depends on factors such as the location of the installation, the intermittency of renewables in a given period, or the operating procedures of the distribution system operator.

Consequently, the criterion applied is to assume, through a conservative estimate, that 25% of the stored energy is allocated to balancing and frequency regulation services, with the sale of this energy being 50% more expensive than its sale in the wholesale market.

In this way, all the necessary elements for the economic evaluation of the project are concluded.

3.3. Economic evaluation

BAU Market Scenario:

	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
STORED ENERGY												
Batteries (MWh)		52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68
Arbitrage (3/4)		39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26
Additional Markets (1/4)		13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42
INCOME		**4.481.015,34 €**	**4.068.461,73 €**	**3.916.936,40 €**	**3.765.411,06 €**	**3.613.885,72 €**	**3.462.360,38 €**	**3.310.835,05 €**	**3.265.377,45 €**	**3.250.224,91 €**	**3.129.004,64 €**	**3.007.784,37 €**
Discharge price (€/MWh)		75,56 €	68,60 €	66,04 €	63,49 €	60,93 €	58,38 €	55,83 €	55,06 €	54,80 €	52,76 €	50,72 €
Revenue stacking (+50%)		113,33 €	102,90 €	99,07 €	95,23 €	91,40 €	87,57 €	83,74 €	82,59 €	82,20 €	79,14 €	76,07 €
EXPENSES												
Charge price (€/Meh)		44,26 €	38,87 €	37,16 €	35,45 €	33,74 €	32,03 €	30,33 €	29,81 €	29,64 €	28,27 €	27,42 €
Charge cost		2.333.452,52 €	2.049.099,19 €	1.959.012,08 €	1.868.924,97 €	1.778.837,86 €	1.688.750,75 €	1.598.663,65 €	1.571.637,51 €	1.562.628,80 €	1.490.559,12 €	1.445.515,56 €
O&M		100.000,00 €	102.100,00 €	104.244,10 €	106.433,23 €	108.668,32 €	110.950,36 €	113.280,32 €	115.659,20 €	118.088,05 €	120.567,90 €	123.099,82 €
Terrain		50.000,00 €	51.050,00 €	52.122,05 €	53.216,61 €	54.334,16 €	55.475,18 €	56.640,16 €	57.829,60 €	59.044,02 €	60.283,95 €	61.549,91 €
Grid Access		20.000,00 €	20.420,00 €	20.848,82 €	21.286,65 €	21.733,66 €	22.190,07 €	22.656,06 €	23.131,84 €	23.617,61 €	24.113,58 €	24.619,96 €
Taxes		30.000,00 €	30.630,00 €	31.273,23 €	31.929,97 €	32.600,50 €	33.285,11 €	33.984,09 €	34.697,76 €	35.426,41 €	36.170,37 €	36.929,95 €
Environmental Compensation		30.000,00 €	30.630,00 €	31.273,23 €	31.929,97 €	32.600,50 €	33.285,11 €	33.984,09 €	34.697,76 €	35.426,41 €	36.170,37 €	36.929,95 €
Others		20.000,00 €	20.420,00 €	20.848,82 €	21.286,65 €	21.733,66 €	22.190,07 €	22.656,06 €	23.131,84 €	23.617,61 €	24.113,58 €	24.619,96 €
OPEX		**2.583.452,52 €**	**2.304.349,19 €**	**2.219.622,33 €**	**2.135.008,04 €**	**2.050.508,67 €**	**1.966.126,65 €**	**1.881.864,44 €**	**1.860.785,52 €**	**1.857.848,92 €**	**1.791.978,85 €**	**1.753.265,11 €**
CASH FLOW	**-11.888.742,55 €**	**1.897.562,82 €**	**1.764.112,55 €**	**1.697.314,07 €**	**1.630.403,02 €**	**1.563.377,05 €**	**1.496.233,73 €**	**1.428.970,61 €**	**1.404.591,92 €**	**1.392.375,99 €**	**1.337.025,79 €**	**1.254.519,26 €**

Levelized Market Scenario:

	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
STORED ENERGY												
Batteries (MWh)		52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68	52717,68
Arbitrage (3/4)		39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26	39538,26
Additional Markets (1/4)		13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42	13179,42
INCOME		**4.481.015,34 €**	**4.023.404,17 €**	**3.826.821,27 €**	**3.630.238,38 €**	**3.494.142,52 €**	**3.312.681,39 €**	**3.221.950,82 €**	**3.161.463,77 €**	**3.010.246,16 €**	**2.859.028,54 €**	**2.707.810,93 €**
Discharge price (€/MWh)		75,56 €	67,84 €	64,53 €	61,21 €	58,92 €	55,86 €	54,33 €	53,31 €	50,76 €	48,21 €	45,66 €
Revenue stacking (+50%)		113,33 €	101,76 €	96,79 €	91,82 €	88,37 €	83,78 €	81,49 €	79,96 €	76,14 €	72,31 €	68,49 €
EXPENSES												
Charge price (€/Meh)		44,26 €	40,46 €	40,34 €	40,23 €	40,14 €	40,04 €	39,98 €	39,95 €	39,86 €	39,77 €	39,68 €
Charge cost		2.333.452,52 €	2.132.998,66 €	2.126.811,02 €	2.120.623,38 €	2.116.339,63 €	2.110.627,97 €	2.107.772,14 €	2.105.868,25 €	2.101.108,53 €	2.096.348,81 €	2.091.589,08 €
O&M		100.000,00 €	102.100,00 €	104.244,10 €	106.433,23 €	108.668,32 €	110.950,36 €	113.280,32 €	115.659,20 €	118.088,05 €	120.567,90 €	123.099,82 €
Terrain		50.000,00 €	51.050,00 €	52.122,05 €	53.216,61 €	54.334,16 €	55.475,18 €	56.640,16 €	57.829,60 €	59.044,02 €	60.283,95 €	61.549,91 €
Grid Access		20.000,00 €	20.420,00 €	20.848,82 €	21.286,65 €	21.733,66 €	22.190,07 €	22.656,06 €	23.131,84 €	23.617,61 €	24.113,58 €	24.619,96 €
Taxes		30.000,00 €	30.630,00 €	31.273,23 €	31.929,97 €	32.600,50 €	33.285,11 €	33.984,09 €	34.697,76 €	35.426,41 €	36.170,37 €	36.929,95 €
Environmental Compensation		30.000,00 €	30.630,00 €	31.273,23 €	31.929,97 €	32.600,50 €	33.285,11 €	33.984,09 €	34.697,76 €	35.426,41 €	36.170,37 €	36.929,95 €
Others		20.000,00 €	20.420,00 €	20.848,82 €	21.286,65 €	21.733,66 €	22.190,07 €	22.656,06 €	23.131,84 €	23.617,61 €	24.113,58 €	24.619,96 €
OPEX		**2.583.452,52 €**	**2.388.248,66 €**	**2.387.421,27 €**	**2.386.706,45 €**	**2.388.010,44 €**	**2.388.003,87 €**	**2.390.972,93 €**	**2.395.016,25 €**	**2.396.328,64 €**	**2.397.768,54 €**	**2.399.338,64 €**
CASH FLOW	**-11.888.742,55 €**	**1.897.562,82 €**	**1.635.155,52 €**	**1.439.400,00 €**	**1.243.531,93 €**	**1.106.132,08 €**	**924.677,52 €**	**830.977,89 €**	**766.447,52 €**	**613.917,52 €**	**461.260,00 €**	**308.472,29 €**

4. Conclusions

The economic assessment for the first proposed case indicates an internal rate of return (IRR) of 6.83% over the first ten years, with a payback period of approximately six and a half years. This reflects relatively low profitability for projects of this nature, which are highly exposed to merchant and technological risks.

In the levelized market scenario, the project is deemed non-viable during the first ten years of operation, primarily due to the assumed near-convergence between purchase and sale prices, which significantly limits arbitrage opportunities. Under these conditions, relying solely on price spreads is insufficient to cover investment and operating costs; furthermore, it can be concluded that the proposed scenario reflected an exceedingly aggressive change in market trend, hostile for storage investment.

Since the main challenge for large-scale BESS projects is their high upfront investment cost, which significantly impacts financial feasibility, seeking government support mechanisms should be a key enabler for deployment. Examples mentioned include direct grants for capital expenditure (such as Spain's PERTE framework). In addition, capacity payment schemes that provide long-term revenue certainty, and auction-based remuneration mechanisms designed to incentivize storage integration are determinant for promoting new investment in storage.

Once operational, BESS projects could benefit from the future Capacity Market, which aims to provide long-term secured revenues through firm capacity payments. Additional opportunities include entering into bilateral agreements or PPAs with renewable developers to capture value from flexibility, as well as providing balancing or synthetic inertia services to TSOs. By diversifying income streams through this multi-layered approach, projects can significantly enhance their IRR, reduce payback time, and mitigate exposure to the wholesale market volatility.

Nevertheless, the significant benefits and potential incentives make it a valuable opportunity to consider. BESS offer critical advantages for grid stability, renewable integration, and emission reduction, all of which align with long-term energy transition goals. These environmental and system-level contributions are the focus of many government support programs, including direct grants and capacity payments. Therefore, and in line with international energy objectives, even in scenarios of low market spreads or high investment costs, battery projects remain a cornerstone element in the energy mix of the future.

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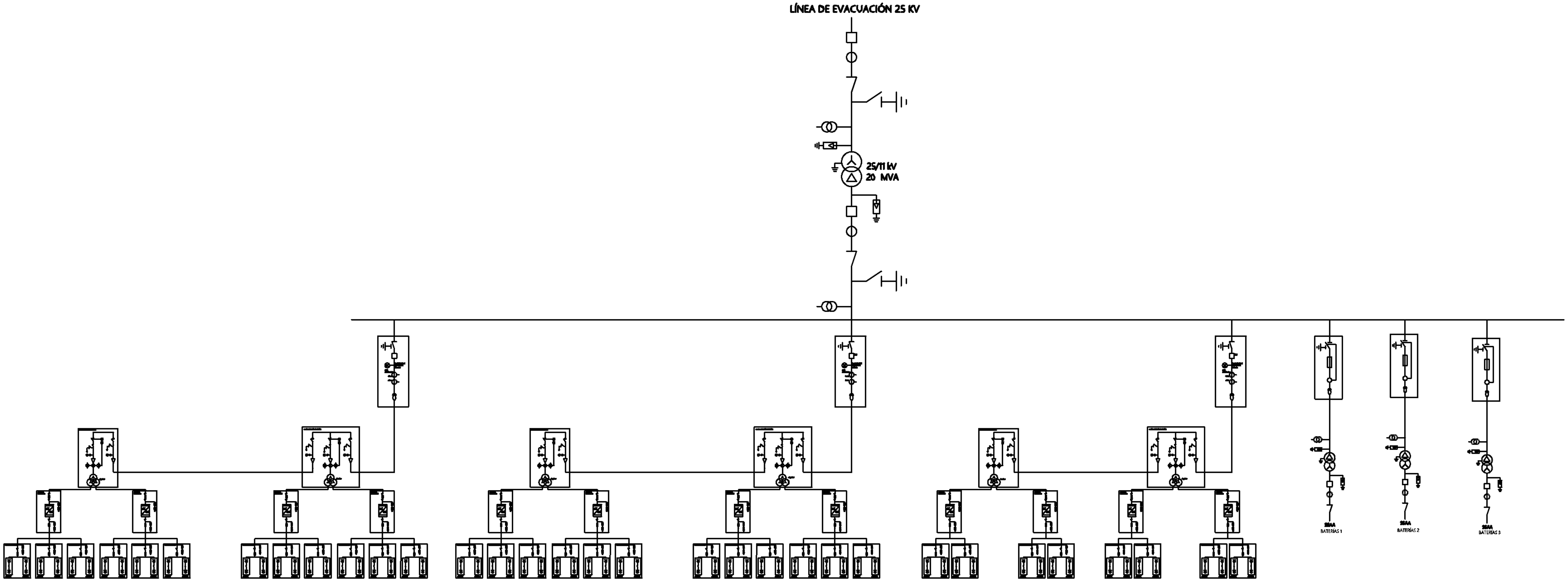
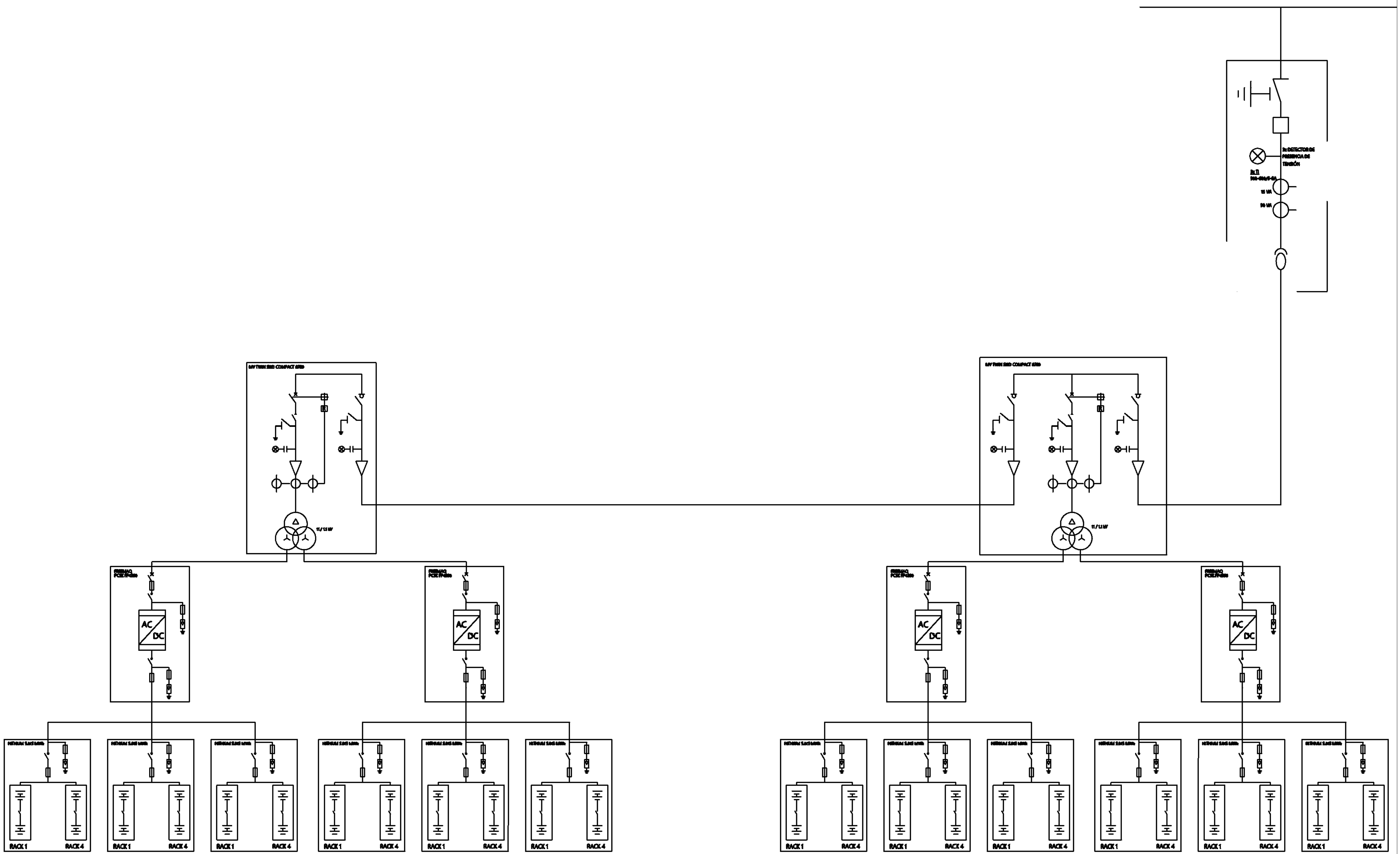
ANNEX 1: Single Line Diagrams

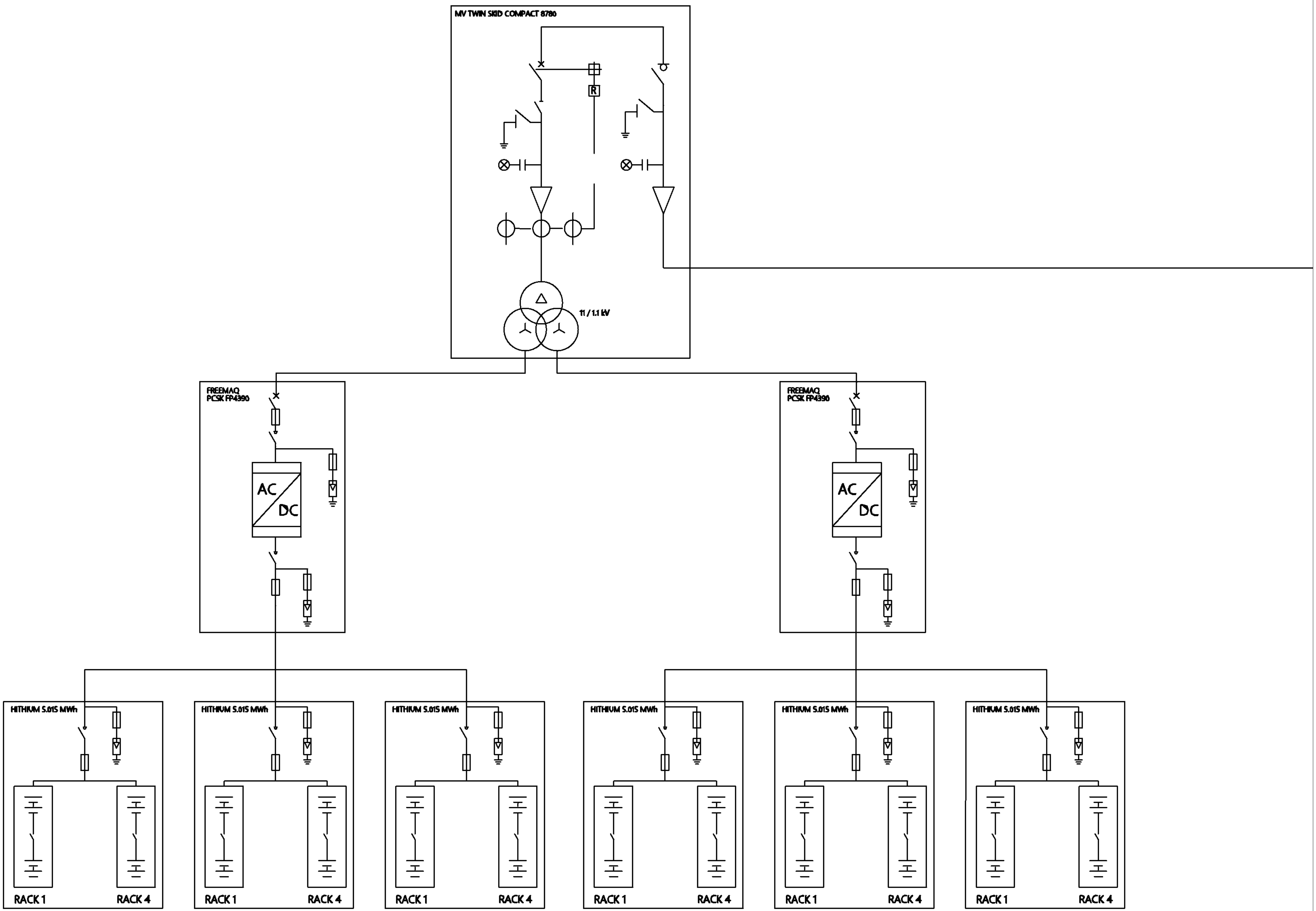
1.1. General SLD

1.2. Transformation Bundle Focus

1.3. Conversion pack focus


LÍNEA DE EVACUACIÓN 25 KV
25/11 kV
20 MVA
SSAA
BATERÍAS 1
SSAA
BATERÍAS 2
SSAA
BATERÍAS 3


3x DETECTOR DE
PRESENCIA DE
TENSIÓN
AC
DC
RACK 1
RACK 4

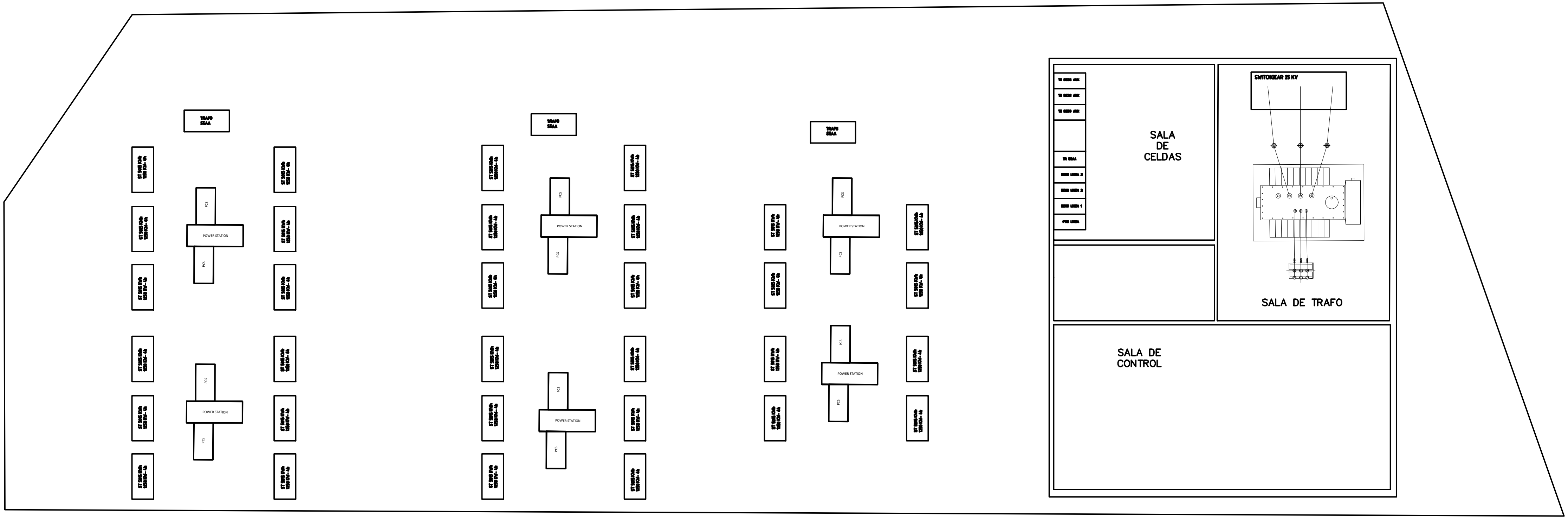

MV TWIN SKID COMPACT 8780
R
11 / 1.1 kV
FREEMAQ
PCSK FP4390
AC
DC
FREEMAQ
PCSK FP4390
AC
DC
HITHIUM 5.015 MWh
RACK 1
RACK 4
HITHIUM 5.015 MWh
RACK 1
RACK 4
HITHIUM 5.015 MWh
RACK 1
RACK 4
HITHIUM 5.015 MWh
RACK 1
RACK 4
HITHIUM 5.015 MWh
RACK 1
RACK 4
HITHIUM 5.015 MWh
RACK 1
RACK 4

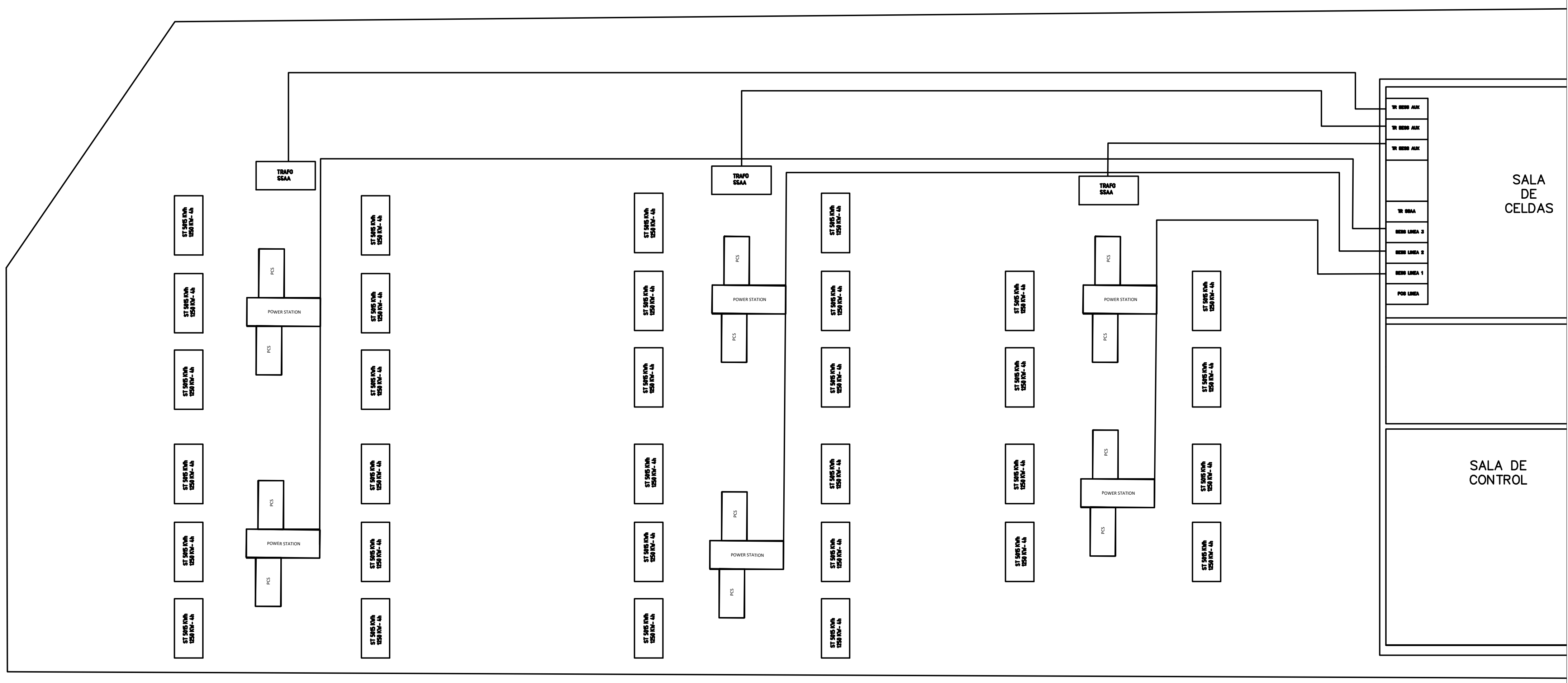
ANNEX 2: Layout Representation

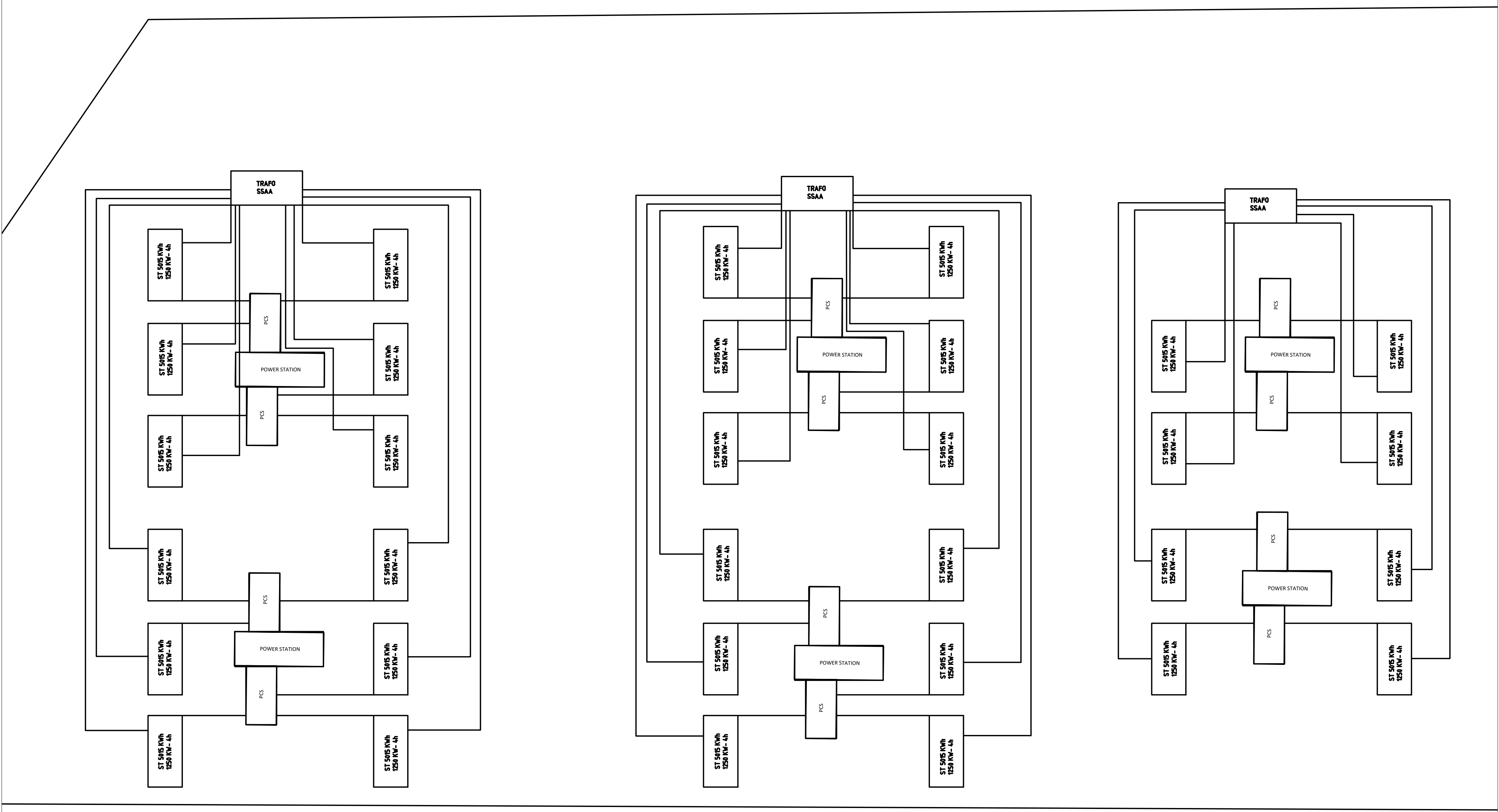
2.1. General Layout

2.2. MV Connections

2.3. LV Connections


TRAFO SSAA
TRAFO SSAA
TRAFO SSAA
POWER STATION
PCS
SALA DE CELDAS
TR SSAA
SWITCHGEAR 25 KV
SALA DE TRAFO
SALA DE CONTROL


ST 5015 KWh
1250 KW- 4h
TRAFO
SSAA
PCS
POWER STATION
TR BESS AUX
TR BESS AUX
TR BESS AUX
TR SSAA
BESS LINEA 3
BESS LINEA 2
BESS LINEA 1
POS LINEA
SALA
DE
CELDAS
SALA DE
CONTROL



TRAFO SSAA
ST 5015 KWh 1250 KW - 4h
PCS
POWER STATION

ANNEX 3: Equipment Datasheets

3.1. Battery Systems

3.2. Power Electronics PCSK

3.3. Power Electronics TWIN SKID

3.4. Ancillary Power Consumption

3.5. UPS Systems

3.6. Ormazábal MV Cells

ST5015kWh-2500kW-2h-US
ST5015kWh-1250kW-4h-US

NEW

PowerTitan 2.0 Liquid Cooled Energy Storage System

OPTIMAL COST

- Intelligent liquid-cooled temperature control system to optimize the auxiliary power consumption
- Pre-assembled, no battery module handling on site, transportation of complete system

SAFETY AND RELIABLE

- Electrical safety management, overcurrent fast breaking and arc extinguishing protection
- The electrical cabinet and battery cabinet are separated to prevent thermal runaway

EFFICIENT AND FLEXIBLE

- High-efficiency heat dissipation, increase battery life and system discharge capacity
- Front single-door-open design, supporting back to back layout drawing
- Function test in factory, limited on-site work, accelerate commissioning process

CONVENIENT O&M

- One-click system upgrade
- Automatic coolant refilling design
- Online intelligent monitoring

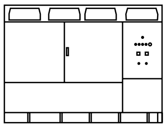
SUNGROW
Clean power for all

Product Name	ST5015kWh-2500kW-2h-US	ST5015kWh-1250kW-4h-US
DC side		
Cell type	LFP 3.2 V / 314 Ah	
Battery configuration	416S12P	
Nominal capacity	5015 kWh	
Nominal voltage range	1123.2 V - 1497.6 V	
AC side		
Nominal AC power	210 kVA * 12	210 kVA * 6
AC current distortion rate	< 3 % (Nominal Power)	
DC component	< 0.5 %	
Nominal AC voltage	690 V	
AC voltage range	607 V - 759 V	
Termination (LV)	352 A * 3 Phase * 6	352 A * 3 Phase * 3
Power factor	> 0.99 (Nominal Power)	
Adjustable range of reactive power	- 100 % to 100 %	
Nominal frequency	60 Hz	
Isolation method	Transformerless	
System parameter		
Dimension（W * H * D）	6058 mm * 2896 mm * 2438 mm 238.5'' * 114.0'' * 96.0"	
Weight	42500 kg 93696.5 lbs	42000 kg 92594.0 lbs
Degree of protection	Type 3S	
Anti-corrosion degree	C3	
Operation ambient temperature range	- 30 ℃ - 50 ℃ (> 45 ℃ Derating) -22 °F - 122 °F (> 113 °F Derating)	
Operation humidity range	0 % - 100 % (Non-condensing)	
Maximum operation altitude	3000 m 9842.5 ft	
Temperature control method	Intelligent Liquid Cooling	
Fire suppression system	NFPA 68 compliance vent panel, smoke and heat, detectors, Mini FACP(Default) Sprinkler, sound beacon, NFPA 69, compliance ventilation system, Flammable Gas detector (Optional)	
Communication	Ethernet	
Standard	UL 9540A, NFPA 855, NFPA 68, NFPA69 (with optional purchase) IEEE1547: 2018, UL1973,UL1741SB, UL9540	

PCSK

Modularity.
Easy maintenance.
Advanced grid support.
Compatible with all battery technologies.

Freemaq PCSK



COMMON FEATURES PCSK		FRAME 2	FRAME 3	FRAME 4
AC	Max. AC Output Current (A) @40°C	1837	2756	3674
	Operating Grid Frequency (Hz)	50/60Hz		
	Current Harmonic Distortion (THDi)	< 3% per IEEE519		
	Power Factor (CosPhi) [1]	0.5 leading ... 0.5 lagging		
	Reactive Power Compensation	Four quadrant operation		
DC	DC Voltage Ripple	< 3%		
	Max. DC Continuous Current (A)	2295	3443	4590
	Max. DC Short Circuit Current (kA)	250 kA with a time constant of 3ms		
	Battery Technology	All type of batteries (BMS required)		
CABINET	Dimensions [WxDxH] (ft)	9.8 x 6.5 x 7.2		
	Dimensions [WxDxH] (m)	3.0 x 2.0 x 2.2		
	Weight (lbs)	11465	11795	12125
	Weight (kg)	5200	5350	5500
	Type of Ventilation	Forced air cooling		
ENVIRONMENT	Degree of Protection	NEMA 3R / IP55		
	Operating Temperature Range [2]	From -25°C to +60°C, >40°C power derating		
	Operating Relative Humidity Range	From 4% to 100% non-condensing		
	Storage Temperature Range	From -40°C to +60°C		
	Max. Altitude (above sea level)	2000m / >2000m power derating (Max. 4000m)		
CONTROL INTERFACE	Communication Protocol	Modbus TCP		
	Power Plant Controller	Optional. Third party SCADA systems supported.		
	Keyed ON/OFF Switch	Standard		
PROTECTIONS	Ground Fault Protection	Insulation monitoring device		
	Humidity Control	Active heating		
	General AC Protection & Disconn.	Circuit breaker		
	General DC Protection & Disconn. [3]	High-speed fuses, Motorized DC disconnect switches		
	Overvoltage Protection	Type II for AC and Type I+II for DC		
CERTIFICATIONS & STANDARDS	Safety	UL 1741 / CSA 22.2 No.107.1-16 / IEC 62109-1 / IEC 62109-2 / IEC 62477-1		
	Installation	NEC 2023 / IEC		
	Utility Interconnect [4]	IEEE 1547:2018 / UL 1741 SA & SB/ IEC 62116:2014		

		690 V			660 V			645 V			630 V		
FRAME		2	3	4	2	3	4	2	3	4	2	3	4
REF.		FP2195K	FP3290K	FP4390K	FP2101K	FP3151K	FP4200K	FP2055K	FP3080K	FP4105K	FP2005K	FP3005K	FP4010K
AC	AC Output Power (kVA/kW) @40°C [5]	2195	3290	4390	2100	3150	4200	2055	3080	4105	2005	3005	4010
	AC Output Power (kVA/kW) @50°C [5]	2035	3055	4075	1950	2925	3900	1905	2855	3810	1860	2790	3720
	Operating Grid Voltage (VAC)	690V ±10%			660V ±10%			645V ±10%			630V ±10%		
DC	DC Voltage Range [6]	976V - 1500V			934V - 1500V			913V - 1500V			891V - 1500V		
	Maximum DC Voltage	1500V			1500V			1500V			1500V		
EFFICIENCY	Efficiency (Max) (η)	98.84%	98.87%	98.94%	98.86%	98.89%	98.95%	98.85%	98.88%	98.81%	98.79%	98.82%	98.88%
	Euroeta (η)	98.34%	98.49%	98.51%	98.36%	98.51%	98.53%	98.24%	98.39%	98.41%	98.28%	98.43%	98.45%

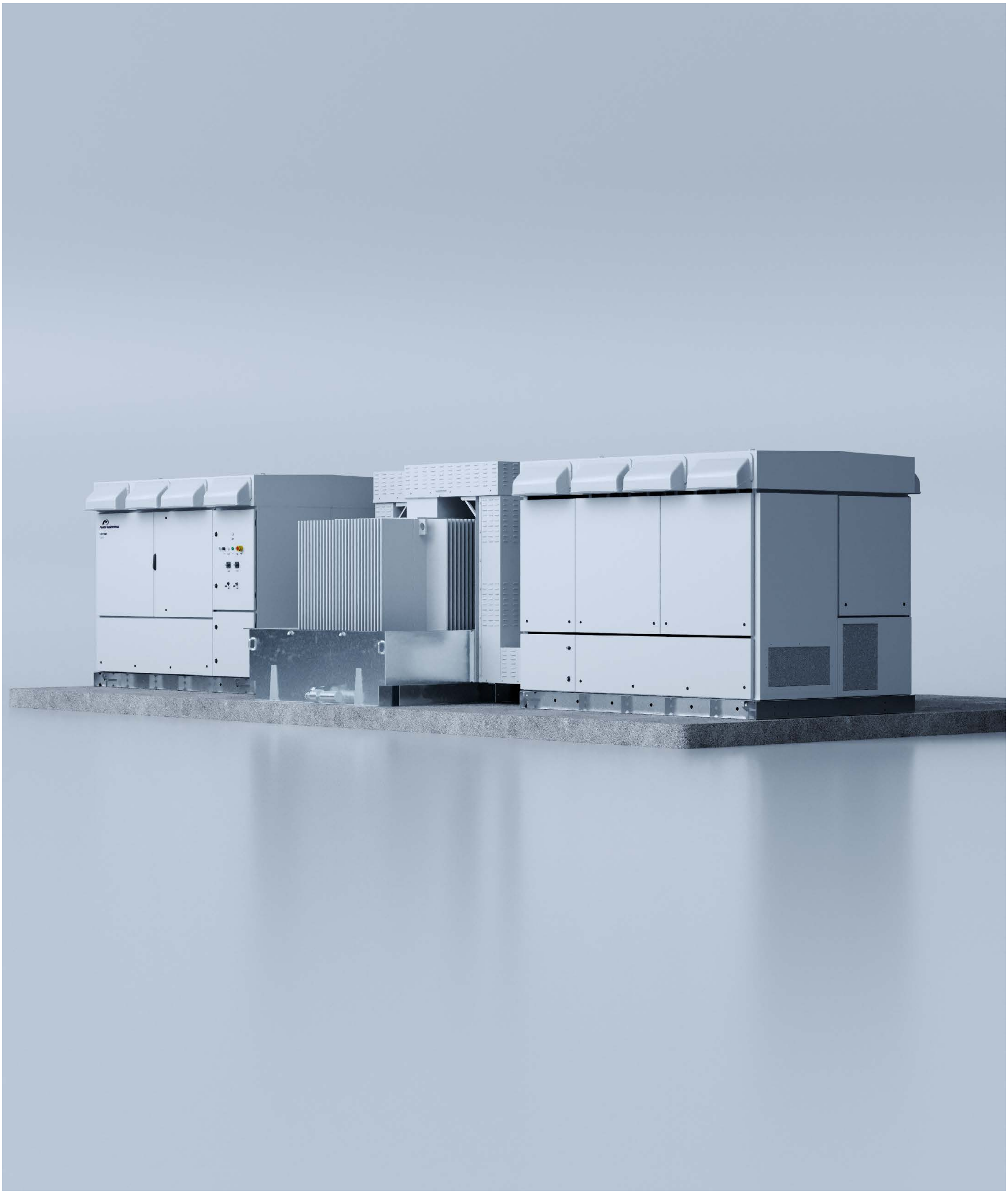
	615 V			600 V			530 V			500 V			480 V		
FRAME	2	3	4	2	3	4	2	3	4	2	3	4	2	3	4
REF.	FP1955K	FP2935K	FP3915K	FP1910K	FP2865K	FP3820K	FP1685K	FP2530K	FP3370K	FP1590K	FP2385K	FP3180K	FP1525K	FP2290K	FP3055K
AC	1955	2935	3915	1910	2865	3820	1685	2530	3370	1590	2385	3180	1525	2290	3055
	1815	2725	3635	1775	2660	3545	1565	2350	3130	1475	2215	2955	1415	2125	2840
	615V ±10%			600V ±10%			530V ±10%			500V ±10%			480V ±10%		
DC	870V - 1500V			849V - 1500V			750V - 1300V			708V - 1250V			679V - 1200V		
	1500 V			1500V			1300V			1250V			1200V		
EFFICIENCY	98.75%	98.78%	98.77%	98.82%	98.85%	98.78%	98.78% (preliminary)			98.78% (preliminary)			98.78% (preliminary)		
	98.20%	98.35%	98.37%	98.18%	98.33%	98.35%	98.35% (preliminary)			98.35% (preliminary)			98.35% (preliminary)		

NOTES

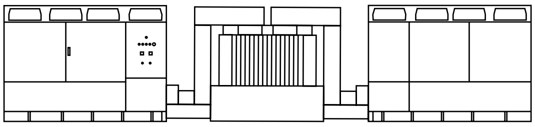
[1] Consult P-Q charts available: $Q(kVAr)=\sqrt{S(kVA)^2-P(kW)^2}$.
[2] Optional available for temperatures down to -35°C.
[3] Battery short circuit disconnection has to be done on the battery side.
[4] Consult Power Electronics for other applicable standards/grid codes.
[5] Values at 1.00·Vac nom and CosPhi=1. The maximum AC output power must be limited to meet the P-Q capability requirement at the inverter level of some grid codes. Consult Power Electronics for derating curves and overload capability in grid forming mode.
[6] Consult Power Electronics for derating curves. In the event of overvoltage in the grid, the minimum DC voltage will vary proportionally with the AC voltage.

Twin Skid Compact

Turn-key solution.
Easy and fast connection.
Compact design reducing space requirements.
Simplifies commissioning.



Twin Skid Compact



RATINGS	Power range @ 40 °C	3050 kVA - 8780 kVA
	Power range @ 50 °C	2830 kVA - 8150 kVA
MEDIUM VOLTAGE EQUIPMENT	MV voltage range	11 kV / 13.2 kV / 13.8 kV / 15 kV / 20 kV / 22 kV / 23 kV / 25 kV / 30 kV / 33 kV / 34.5 kV
	LV voltage range	480 V / 500 V / 530 V / 600 V / 615 V / 630 V / 645 V / 660 V / 690 V
	Transformer cooling	ONAN / KNAN
	Transformer vector group	Dy11y11
	Transformer protection	Protection relay for pressure, temperature (two levels) and gassing.
		Monitoring of dielectric level decrease.
		PT100 optional.
	Transformer index of protection	IP54
	Transformer losses	IEC standard or IEC Tier-2.
	Oil retention tank	Galvanized steel. Integrated with hydrocarbon filter. Optional
	Switchgear configuration	Double feeder (2L)
	Switchgear protection	Circuit breaker (V)
	Switchgear short circuit rating [1]	16 kA 1 s (optionally 20 kA or 25 kA)
	Switchgear IAC [1]	A FLR 16 kA 1 s
CONNECTIONS	LV-MV connections	Close coupled solution (plug & play)
	LV protection	Motorized circuit breaker included in the inverter
	HV AC wiring	MV bridge between transformer and protection switchgear prewired
ENVIRONMENT	Ambient temperature range [2]	-25 °C… +50 °C (T > 50 °C power derating)
	Maximum altitude (above sea level) [1]	Up to 1000 m
	Relative humidity	4% to 95% non condensing
AUXILIARY SERVICES	User cabinet	Integrated in the inverter (by default). Optionally, LV cabinet in the skid.
	UPS system [1]	1 kVA/1 kW (12 minutes). Optional
OTHER EQUIPMENT	Safety mechanism	Interlocking system
	Fire suppression system	Transformer oil tank retention accessory. Optional.
STANDARDS	Compliance	IEC 62271-212, IEC 62271-200, IEC 60076, IEC 61439-1

NOTES

[1] Consult with Power Electronics for other options.
[2] For lower temperatures, consult with Power Electronics.

Auxiliary Power Consumption

1. Introduction

This document describes the auxiliary power consumption of the ESS container (INF5015K050PG1).

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2. Definitions

1) Full Charge: The ESS container charges at the rated power from SOC 0% to SOC 100%.
2) Full Discharge: The ESS container discharges at the rated power from SOC 100% to SOC 0%.
3) Pre-conditions: The process of testing auxiliary power consumption at different temperatures. Prior to testing, the liquid cooling unit is preheated or precooled according to its temperature control strategy until it reaches the defined standby state.

3. Descriptions

The auxiliary power supply of the ESS Container is mainly for the liquid cooling system, the UPS power supply and others.

1) For ESS Container following the IEC standards, the supply voltage is 3-phase, 400Vac.
2) For ESS Container following the UL standards, the supply voltage is 3-phase, 480Vac.

Table 3-1 Loads of Power Distribution Container

	Item	Voltage	Standby (W)	Normal (W)	Emergency (W)
Aux. loadings	Liquid cooling unit	EU: $400V_{AC}$ US: $480V_{AC}$	3600 (Self-cycle)	37000 (Cooling)	0
	Power meter	$230V_{AC}$	3	3	0
	Fire protection system	$230V_{AC}$	5	5	162
	Socket	EU:$230V_{AC}$ US:$115V_{AC}$	0	0	0
	Environment control system	$230V_{AC}$	0	182	0
	Ventilation system	$230V_{AC}$	0	0	194
	CBMU	$24V_{DC}$	18	18	18
	SBMU	$24V_{DC}$	10	10	10
	Network device	$24V_{DC}$	1.58	2.84	2.84
	Intermediate relay	$24V_{DC}$	EU: 2.4 US: 0.48	EU: 2.4 US: 0.48	EU: 2.4 US: 0.48
	Indicator	$24V_{DC}$	6.48	6.48	6.48
	Current sensor	$12V_{DC}$	36	36	3.74
	Flood sensor	$24V_{DC}$	4.32	5.76	4.32
	HV relay	$24V_{DC}$	60	60	0
	Pre-charge relay	$24V_{DC}$	0	15.6	0
Total	AC loading	/	3608	37190	356
	DC loading	/	EU: 138.78 US: 136.86	EU: 157.08 US: 155.16	EU: 47.78 US: 45.86
	AC+DC loading	/	EU: 3746.78 US: 3744.86	EU: 37347.08 US: 37345.16	EU: 403.78 US: 401.86

Note: It is recommended that the transformer selection consider the peak auxiliary power supply during the operation of the control panel, which is 41.5 kVA.

4. Aux. Consumption

The auxiliary power consumption takes into account the power consumption in both operating and resting states. The test conditions are as shown below.

Equipment Under Test: 20ft Container, 5.016MWh

Test Conditions: 1cycle/day at different P-rate & Temp.

Test procedures:

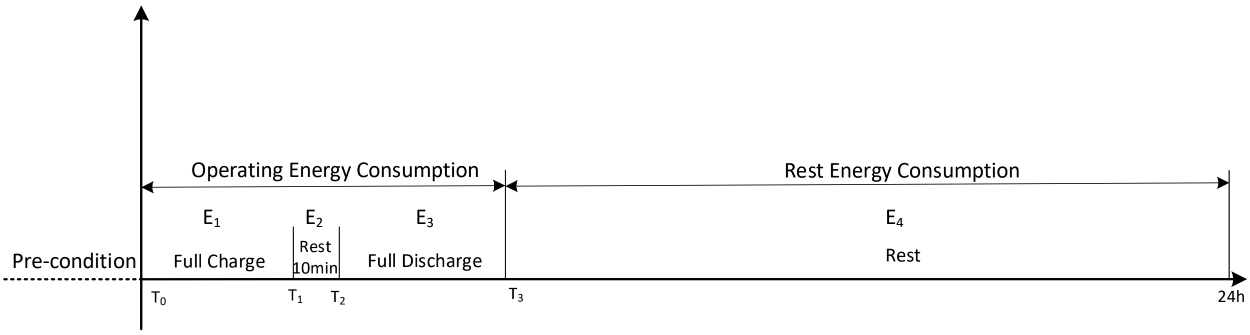

Fig. 4-1 Test Procedures

Operating average power= $(E_1 + E_2 + E_3) / (T_3 - T_0)$

Resting average power= $E_4 / (24 - T_3)$

24h Aux. energy consumption= $E_1 + E_2 + E_3 + E_4$

Table 4-1 Aux. Consumption of ESS Container

Test Conditions	-20°C		0°C		25°C		35°C		45°C	
	0.25P	0.5P	0.25P	0.5P	0.25P	0.5P	0.25P	0.5P	0.25P	0.5P
Operating average power (kW)	6.1	13.2	7.5	14.1	10.6	27.5	14.7	32.2	22.0	35.1
Rest average power (kW)	2.8	3.5	2.9	3.5	1.7	3.2	4.9	6.6	6.3	9.6
24h Aux. energy consumption (kWh)	95	127	109	132	119	186	201	273	285	343

Xiamen Hithium Energy Storage Technology Co., Ltd.
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Web: www.hithium.com

Superior

DELPHYS MX Elite+

High performance UPS with an embedded galvanic isolation transformer to meet your requirements

from 160 to 600 kVA

DEFYS_245.PNG

The solution for

- > Healthcare
- > Energy
- > Infrastructure & Transport
- > Industry
- > Building

Strong points

- > The best protection for your load
- > Robust & resiliant design
- > User-friendly
- > High availability and cost-effective equipment

Conformity to standards

- > IEC 62040-1
- > IEC 62040-2

Expert services

We offer services to ensure your UPS has the highest availability:

- > Commissioning
- > On-site intervention
- > Preventive maintenance visits
- > 24-hour call out and rapid on-site repairs
- > Maintenance packages
- > Training

Function

DELPHYS MX Elite+ is a Three-phase UPS with a embedded transformerbased inverter designed to provide a continued power supply for your most critical installations. The isolation transformer provides galvanic isolation between the power converters and the user output.

Advantages

The best protection for your load

- Permanent operation in VFI mode (online double conversion).
- Provide accurate output voltage under all load conditions.
- High short-circuit current capacity, which facilitates the selection of protection devices in downstream distribution.

Robust & resiliant design

- Isolation transformer embedded with the inverter to ensure complete electrical isolation between the DC circuit and the load output.
- Fault-tolerant architectures with essential functional redundancy.
- Rugged mechanical and electrical properties for industrial environments.
- Redundant LED display for consistent UPS control.
- Standard PCB tropicalisation

User-friendly

- 10-inch color touch screen.
- User friendly HMI.
- Communication upgradable.

High availability and cost-effective equipment

- IGBT rectifier with PFC controller: high efficiency, high and constant input power factor, low current harmonic content.
- These features help limit the size of the upstream network infrastructure.
- ECO Mode with 99% efficiency.
- Accurate diagnosis ensures the power supply of the load.
- Prevent cascading failures of parallel systems.
- Rectifier soft start function, prevents generators loadstep ensuring smooth operation.
- Specifically designed to be adapted to different industrial environments: higher IP protection capability, longer backup time.
- Field-proven technology.
- Easy maintainability reduces MTTR thanks to pull-out sub-assemblies and full front accessible components.

DELPHYS MX Elite+

Three-phase UPS

from 160 to 600 kVA

General characteristics

- 10-inch touch screen display.
- Backfeed protection: detection circuit.
- Customizable IP protection solution.
- N+X redundant parallel architecture.
- Up to 6 units can be connected in parallel.

Electrical options

- Extended top outlet solution
- Higher IP protection level.

Standard communication features

- Full communication function, RS485, RS232 and other communication interfaces.
- Dry contact board with 8 NO/NC contacts.

Communication options

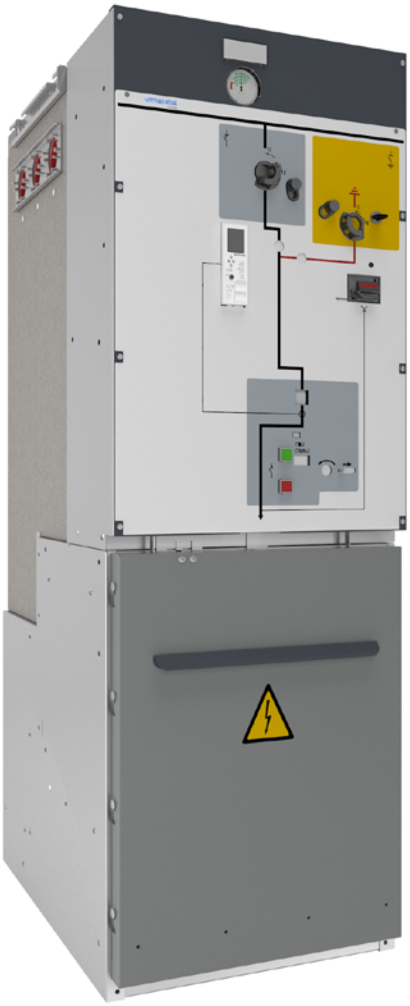
- NET VISION: professional WEB/SNMP Ethernet interface for secure UPS monitoring and remote automatic shutdown.
- REMOTE VIEW PRO supervision software.
- IoT gateway for Socomec cloud services and SoLive UPS mobile app.

Technical data

	DELPHYS MX Elite+						
Sn [kVA]	160	200	250	300	400	500	600
Pn [kW]	144	180	225	270	360	450	540
Input / Output	3/3						
Parallel configuration	Up to 6 units						
INPUTS							
Rated voltage	380 V - 400 V - 415 V						
Voltage tolerance	± 20% (1)						
Rated frequency	50/60 Hz						
Frequency tolerance	+/- 10%						
Power factor	≥ 0.99 @ full load						
Current harmonic content (THDI)	≤ 3% full load						
OUTPUTS							
Rated voltage	380 V - 400 V - 415 V						
Voltage tolerance	± 1%						
Rated frequency	50/60 Hz						
Frequency tolerance	Self-Oscillation ± 0.1%						
Total output voltage distortion - Linear load	≤ 1%						
Total output voltage distortion - Nonlinear load	≤ 5%						
Overload	up to 150% for 1 minute, 125% for 10 minutes						
Crest factor	3 : 1						
Short circuit current	Up to 3.5 In (100 ms)						
BYPASS							
Rated voltage	380 V - 400 V - 415 V						
Rated frequency	50/60 Hz						
Frequency tolerance	± 5%						
EFFICIENCY							
Online mode	Up to 94 %						
Eco mode	Up to 99 %						
ENVIRONMENT							
Ambient operating temperature	from 0 °C up to +40 °C (1)						
Humidity	0% ~ 95% without condensation						
Maximum altitude	1000 m without derating						
Acoustic level (as per ISO3746)	< 68 dB			< 72 dB			
UPS CABINET							
UPS dimensions (W x D x H)	1000 x 850 x 1900			1500 x 1000 x 1900		2200 x 1000 x 1900	
Weight	1350 kg			2000 kg		2800 kg	3000 kg
Standard protection rating	IP20 / IP21 (optional)						
Colours	RAL 9006						
COMPLIANCE TO STANDARDS							
Safety / EMC	IEC 62040-1, IEC 62040-2						

(1) Conditions apply.

ormazabal
velatia



Smart & digital grids
Green mobility
Sustainable buildings & infrastructures
Green generation & storage

CELDAS DE DISTRIBUCIÓN SECUNDARIA

cgm.800

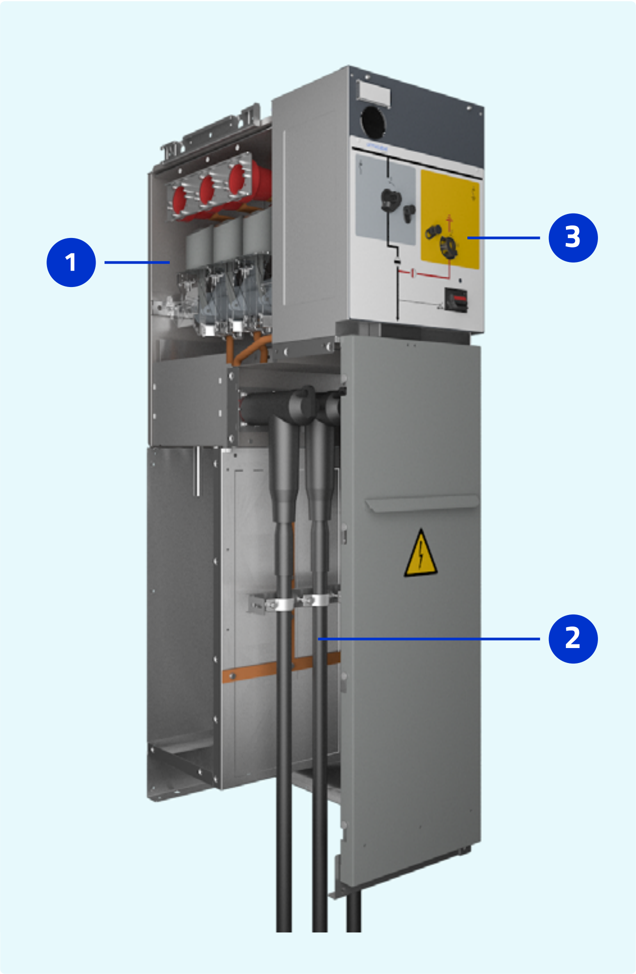
Sistema modular con aislamiento integral en gas

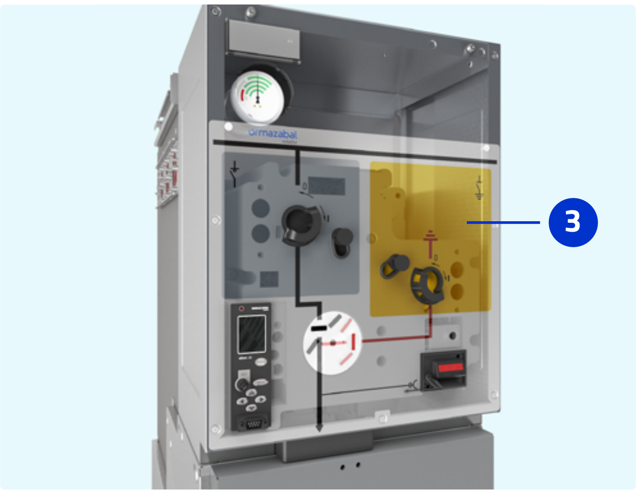
Hasta 36 kV
Hasta 38 kV

Normas IEC
Normas ANSI / IEEE

ormazabal.com

Estructura constructiva





1 Cuba de gas

La cuba, estanca y aislada con gas, contiene el embarrado, así como los dispositivos de corte y conexión.

2 Compartimento de cables

El compartimento de conexión de cables de entrada/salida de media tensión se encuentra en la parte inferior de la celda y se puede acceder a él retirando la tapa frontal.
En su interior encontraremos:

- Pasatapas
- Conectores y cables
- Soporte abrazadera cables
- Pletina horizontal de puesta a tierra

3 Compartimento de mando

Zona de maniobra para operaciones de conexión y desconexión en los circuitos de media tensión. Se incluyen:

- Mecanismo de maniobra
- Esquema unifilar e indicación de posición
- Indicador de tensión
- Relé de protección control y medida
- Manómetro

Opcionalmente se podrá añadir en la parte superior de este compartimento, un cajón de control para la instalación de relés de protección, así como dispositivos de medida y control.

cgm.800-l

Función de línea

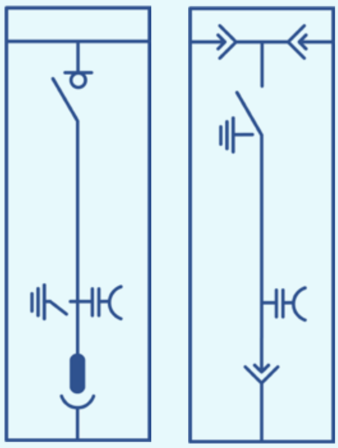
Celda modular de línea, equipada con un interruptor-seccionador de tres posiciones: cerrado, abierto o puesto a tierra.

Características eléctricas			IEC				ANSI/IEEE			
Tensión asignada	U_r	[kV]	24		36		27		38	
Frecuencia asignada	f_r	[Hz]	50	60	50	60	50	60	50	60
Corriente asignada										
Interconexión general de embarrado y celdas	I_r	[A]	800		800		800		800	
Bajante de transformador	I_r	[A]								
Tensión asignada de corta duración soportada a frecuencia industrial (1 min)										
Fase a tierra y entre fases	U_d	[kV]	50		70		60		70	
A través de la distancia de seccionamiento	U_d	[kV]	60		80		66		77	
Tensión soportada asignada a impulso tipo rayo										
Fase a tierra y entre fases	U_p	[kV]	125		170		125		150	
A través de la distancia de seccionamiento	U_p	[kV]	145		195		137,5		165	
Clasificación arco interno	IAC		AF/AFL 20* kA 1 s/25 kA 1 s AFLR ** 20 kA 1 s / 25 kA 1 s				IEEE C37.20.7 Clase 2B			
Tensión CC soportada		[kV]	50		72		78		103	
Interruptor-seccionador			IEC 62271-103 + IEC 62271-102				IEEE C37.74			
Corriente admisible asignada de corta duración (circuito principal)										
Valor t_k= (x) s	I_k	[kA]	20* (1/3 s)/25 (1/3 s)				20* (1/3 s)/25 (1/3 s)			
Valor de pico	I_p	[kA]	52*/62,5	52*/65	52*/62,5	52*/65	52,5*/62,5	54,6/65	52,5*/62,5	54,6/65
Poder de corte de corriente principalmente activa	I_1	[A]	800		800		800			
Poder de corte cables en vacío	U_a	[A]	50		50		15		20	
Poder de corte bucle cerrado	I_{2a}	[A]	800		800		800			
Poder de corte de falta a tierra	I_{6A}	[A]	160		160					
Poder de corte de cables y líneas en vacío en condiciones de falta a tierra	I_{6b}	[A]	90		90		15	15	20	20
Poder de cierre del interruptor principal (valor de pico)	I_{ma}	[kA]	25		25		52,5*/62,5	54,6/65	52,5*/62,5	54,6/65
Categoría del interruptor										
Endurancia mecánica			1000-M1/5000-M2		1000-M1/5000-M2		1000/5000			
Ciclos de maniobras (cierres en cortocircuito)- clase			5-E3		5-E3		3 (ensayado para 5 operaciones)			
Corriente de intersección combinado interruptor - relé (ekor.rpt)										
I_{max} de corte según acc. T_{Dito} IEC 62271-105		[A]	52*/62,5	52*/65	52*/62,5	52*/65	52,5*/62,5	54,6/65	52,5*/62,5	54,6/65
Corriente de transferencia combinado interruptor-fusible										
I_{ma}x de corte según acc. $T_{Ditransfer}$ IEC 62271-105		[A]								
Seccionador de puesta a tierra			IEC 62271-102				IEEE C37.74			
Corriente admisible asignada de corta duración (circuito de tierra)										
Valor t_k= (x) s	I_k	[kA]	20* (1/3 s)/25 (1/3 s)				20* (1/3 s)/25 (1/3 s)		20* (1/3 s)/25 (1/3 s)	
Valor de pico	I_p	[kA]	52*/62,5	52*/65	52*/62,5	52*/65	52,5*/62,5	54,6/65	52,5*/62,5	54,6/65
Poder de cierre del seccionador de puesta a tierra (valor de pico)	I_{ma}	[kA]	52*/62,5	52*/65	52*/62,5	52*/65	52,5*/62,5	54,6/65	52,5*/62,5	54,6/65
Categoría del seccionador de puesta a tierra										
Endurancia mecánica			1000-M0		1000-M0		1000 (manual)			
Ciclos de maniobras (cierres en cortocircuito)- clase			5-E2		5-E2		3 (ensayado para 5 operaciones)			

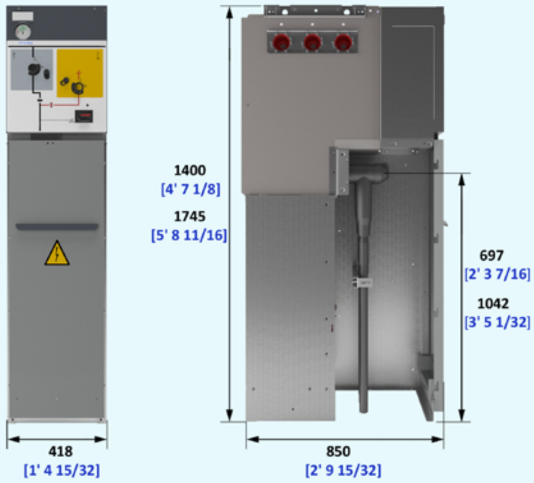
* Ensayos realizados a 21 kA/52,5 kA. ** Con salida de gases a través de chimenea. Valores para 50 Hz.

Dimensiones

147/162 kg
324/357 Lb



IEC ANSI/IEEE



Configuración

◉ Estándar ○ Opcional

Clasificación IAC

Arco interno IAC AFLR

○ 20 kA 1 s ○ 25 kA 1 s ○ Class 2B

Arco interno IAC AF/AFL

○ 20 kA 1 s ○ 25 kA 1 s

Arco interno: cuba

○ 20 kA 1 s ○ 25 kA 1 s

Altura de celda

◉ 1745 mm

○ 1400 mm*

Cuba de gas

Indicador de presión del gas:

◉ Manómetro sin contacto

○ Manómetro con contactos y compensación de temperatura

Conexión frontal:

◉ Pasatapas de cable

Extensibilidad:

◉ A ambos lados

○ A la izquierda / derecha ciega

○ A la derecha / izquierda ciega

Tipo de conexión lateral:

Tulipa

○ Derecha ○ Izquierda ◉ Ambas

Pasatapas

○ Derecha ○ Izquierda ○ Ambas

Mecanismos de maniobra

◉ Palancas de accionamiento

◉ Mecanismo manual tipo B

○ Mecanismo motorizado tipo BM

Enclavamientos adicionales:

○ Enclavamientos eléctricos

○ Enclavamientos con cerradura

○ Candados

Indicadores

◉ Alarma sonora ekor.sas

◉ Indicador capacitivo de presencia de tensión ekor.vpis

○ Indicador capacitivo de presencia / ausencia de tensión ekor.ivds

○ Indicador capacitivo de presencia/ausencia de tensión ekor.ivds-pd con salida de alta frecuencia (AF)

Conducto de expansión de gases

○ Conducto posterior

Algunas configuraciones específicas pueden ser incompatibles entre sí.

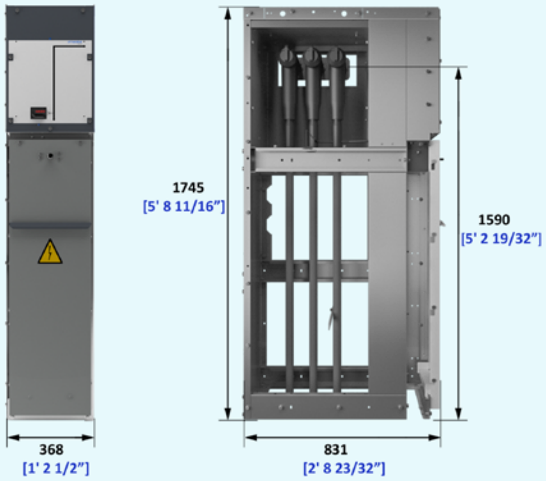
* IAC AFL 20 kA 1 s

Dimensiones

42 kg
93 Lb

IEC

ANSI/IEEE



Opciones

Algunas configuraciones específicas pueden ser incompatibles entre sí.

ANNEX 4: Bill of Quantities

Nº	NAME	SECTION	UNITS	AMMOUNT	PRICE/u.	TOTAL
1	GENERAL PURPOSE					260.000,00
1.1	MOBILIZATION, ESTABLISHMENT AND DEMOBILIZATION					50.000,00
		COMPLETE MOBILIZATION AND ESTABLISHMENT, SITE COMPOUND MAINTENANCE, SURVEILLANCE AND SECURITY DURING CONSTRUCTION.	u	1,0	50.000,0	50.000,0
1.2	ENGINEERING, STUDIES AND MANAGEMENT					80.000,00
		PRE-CONSTRUCTION AND AS-BUILT ENGINEERING, PROJECT MANAGEMENT, HEALTH & SAFETY MANAGEMENT, QUALITY MANAGEMENT AND SITE STUDIES	u	1,0	80.000,0	80.000,0
1.3	GENERAL COSTS					130.000,00
		INSURANCES	u	1,0	65.000,0	65.000,0
		CONTINGENCIES	u	1,0	35.000,0	35.000,0
		SPARE PARTS	u	1,0	20.000,0	20.000,0
		TESTING AND COMISSIONING	u	1,0	10.000,0	10.000,0
2	SUPPLIES, INSTALLATION AND MOUNTING (ASSEMBLY)					1.335.250,00
2.1	CIVIL WORKS					85.200,00
		PLOT CLEARING, CLEANING AND GRUBBING	m2	6.000,0	1,2	7.200,0
		EARTH MOVEMENTS. CUTTING	m3	1.000,0	3,0	3.000,0
		EARTH MOVEMENTS. FILLING	m3	1.000,0	2,5	2.500,0
		CONSTRUCTION OF ACCESS ROAD	m	1,0	16.000,0	16.000,0
		SUPPLY AND INSTALLATION OF DRAINAGE SYSTEM	u	1,0	14.000,0	14.000,0
		INSTALLATION OF CONCRETE SLAB FOR MV TRANSFORMER STATIONS	u	3,0	2.500,0	7.500,0
		INSTALLATION OF CONCRETE SLAB FOR BATTERY STATIONS	u	32,0	900,0	28.800,0
		INSTALLATION OF CONCRETE SLAB FOR CONTROLLER STATIONS (BESS & PCS STATIONS)	u	1,0	5.000,0	5.000,0
		FOUNDATIONS FOR CCTV POLES	u	4,0	300,0	1.200,0
2.2	TRENCHES					5.600,00
		MECHANICAL EXCAVATION OF LV TRENCHES	m	2.000,0	2,0	4.000,0
		MECHANICAL EXCAVATION OF MV TRENCHES	m	800,0	2,0	1.600,0
2.3	FENCING					20.000,00
		SUPPLY AND INSTALLATION OF FENCING	m	500,0	30,0	15.000,0
		SUPPLY AND INSTALLATION OF AUTOMATIC-OPENING GALVANISED MESH METAL GATE	u	1,0	5.000,0	5.000,0
2.4	ELECTROMECHANICAL INSTALLATION					42.250,00
		INSTALLATION OF BESS STATIONS	u	32,0	800,0	25.600,0
		UNLOADING AND PLACEMENT ON FOUNDATIONS OF PCS FREEMAQ PCSK FP4390K2	u	12,0	700,0	8.400,0
		UNLOADING AND PLACEMENT ON FOUNDATIONS OF BESS STATIONS TWIN SKID COMPACT 8780	u	6,0	1.000,0	6.000,0
		UNLOADING AND PLACEMENT ON MV PS OF CONTROLLER STATIONS	u	3,0	350,0	1.050,0
		UNLOADING AND PLACEMENT ON BESS AUXILIARY TRANSFORMER	u	3,0	400,0	1.200,0
2.5	GROUNDING SYSTEM					24.200,00
		INSTALLATION OF THE GROUNDING SYSTEM	u	1,0	15.500,0	15.500,0
		SUPPLY OF COPPER GROUNDING CABLES	m	200,0	20,0	4.000,0
		INSTALLATION OF COPPER GROUNDING CABLES	m	200,0	10,0	2.000,0
		SUPPLY OF GROUNDING RODS	u	60,0	30,0	1.800,0
		INSTALLATION OF GROUNDNG RODS	u	60,0	15,0	900,0

2.6	**CONTROL & MONITORING SYSTEM**					**158.000,00**
		SUPPLY OF OPTICAL FIBER	m	10.000,0	1,0	10.000,0
		INSTALLATION OF OPTICAL FIBER	m	10.000,0	0,2	2.000,0
		SUPPLY AND INSTALLATION OF CORRUGATED CONDUIT	m	10.000,0	0,6	6.000,0
		CONNECTION OF MONITORING AND CONTROL CABLING	u	1,0	45.000,0	45.000,0
		SUPPLY AND INSTALLATION OF CENTRAL MONITORING RACK	u	1,0	20.000,0	20.000,0
		INSTALLATION AND COMMISSIONING OF ENERGY MANAGEMENT SYSTEM	u	1,0	75.000,0	75.000,0
2.7	**CONTROL BUILDING**					**1.000.000,00**
		SUPPLY AND FULL INSTALLATION OF CONTROL BUILDING. Control Building will include, offices, control room, meeting room, washrooms, warehouse for main equipment, etc. Including all necessary Civil Work, Electrical Installation and additional facilities (fire-detaction systems, ventilation, sanitary, etc.).	u	1,0	1.000.000,0	800.000,0
		FOUNDATION OF CONTROL BUILDING	u	1,0	200.000,0	200.000,0
3	**MAIN EQUIPMENT**					**8.742.787,00**
3.1	**BESS STATIONS**					**5.200.000,00**
		SUPPLY OF BESS STATIONS (containersCATL Ener X 5,644 MWh)	u	32,0	160.000,0	5.120.000,0
		SPARE PARTS	u	32,0	2.500,0	80.000,0
3.2	**CONTROLLER STATIONS**					**88.000,00**
		SUPPLY OF CONTROLLER STATIONS (POWER ELECTRONICS Controller Stations)	u	8,0	10.000,0	80.000,0
		SPARE PARTS	u	8,0	1.000,0	8.000,0
3.3	**INVERTERS & MV POWER STATIONS**					**2.480.000,00**
		SUPPLY OF MV TRANSFORMER STATIONS : Supply of MV Transformer Stations model TWIN SKID COMPACT 8780 : • Medium-voltage transformer • MV switchgear: trafo protection fuses and disconnector 11kV, 20kA (1s) / 630 A	u	4,0	300.000,0	1.200.000,0
		SUPPLY OF PCS: Supply of PCS Model FREEMAQ PCSK FP4390K2.	u	8,0	160.000,0	1.280.000,0
3.4	**LOW VOLTAGE INSTALLATION**					**28.010,00**
		SUPPLY OF CABLE RHZ1 0,45/0,75 kV; 2×(1×240 mm² Cu) XLPE Cable	m	500,0	28,0	14.000,0
		SUPPLY OF CABLE RHZ1 0,45/0,75 kV; 1×(3×240 mm² Al) XLPE Cable	m	1.500,0	8,3	12.510,0
		INSTALLATION OF CABLE RHZ1 Cu XLPE Cable	m	500,0	0,5	250,0
		INSTALLATION OF CABLE RHZ1 l XLPE Cable	m	1.500,0	0,5	750,0
		SUPPLY AND INSTALLATION OF LV JOINTS: ut. Supply and installation of LV joints	u	50,0	10,0	500,0
3.5	**MEDIUM VOLTAGE INSTALLATION**					**946.777,00**
		INSTALLATION OF MV TRANSFORMER STATIONS	u	1,0	1,0	1,0
		SUPPLY OF CABLE RHZ1 12/20 kV UNDERGROUND MV: Supply of 11 kV underground MV line, single cable RHZ1 Al conductor, single circuit, for MV stations connection. According to IEC Standards.	m	800,0	6,72	5.376,0
		INSTALLATION OF CABLE RHZ1 12/20 kV UNDERGROUND MV: Installation of 11kV underground MV line, single cable RHZ1 Al conductor, single circuit, for MV stations connection. According to IEC Standards. Laid in trench including warning tape items, entirely installed according to Local Standards.	m	800,0	0,5	400,0
		SUPPLY AND INSTALLATION OF MV CELLS: Power output	u	3,0	30.000,0	90.000,0
		SUPPLY AND INSTALLATION OF MV CELLS: Ancilary services	u	3,0	15.000,0	45.000,0
		SUPPLY AND INSTALLATION OF MV JOINTS: ut. Supply and installation of MV joints for RHZ1 type cables	u	12,0	500,0	6.000,0

		SUPPLY AND INSTALLATION OF POWER TRANSFORMER 11/25 kV – 20000 kVA Dny11: Supply and installation of power transformer for BESS power output	u	1,0	500.000,0	500.000,0
		INSURANCE AND TESTING FOR POWER TRANSFORMER 20000 KVA FAT Tests and SAT tests	u	1,0	150.000,0	150.000,0
		SUPPLY AND INSTALLATION OF ANCILLARY SERVICES UPS	u	2,0	60.000,0	120.000,0
		SUPPLY AND INSTALLATION OF ANCILLARY SERVICES TRANSFORMER 11.000V±2,5%/400V – 30 kVA Dny11: Supply and installation of power transformer for BESS Auxiliaries Systems	u	3,0	10.000,0	30.000,0
	TOTAL					**10.338.037,00**