BESS CLASSIFICATION IN LEVELS OF ADOPTION OF DISTRIBUTED ENERGY RESOURCES (DER) WITH FOCUS ON TRANSFORMATION ELEMENTS

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ABSTRACT

Storage Systems are a fundamental part in the growth of the renewable energy market and in the development of transmission networks, contributing to the reduction of fluctuations in the system and maximizing benefits in energy production, by proposing optimization models that help reduce investment costs in the future. The following document reviews the different types of applications and characteristics of Battery Energy Storage Systems (BESS) and their different contexts in which they were used, from various perspectives in order to be classified with respect to their level of adoption in Distributed Energy Resources (DER) between: Massive, medium and low integration versus transformation elements (DER) that are: smart grid, energy storage, distributed generation, electric vehicles, response to demand and energy storage. The objective of the document is to show the multidimensionality of BESS and how it has begun to be used in renewable energies, the need for in-depth research and association with other complementary sectors is also created. The results of the review are intended to provide useful information on the current status and future challenges of incorporating (BESS) into Distributed Energy Resource Systems (DER).

KEYWORDS: *Electric Vehicles, Demand Response, Smart Grid, Distributed Generation & Energy Storage*

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INTRODUCTION

Distributed Energy Resources (DER) is made up of the following topics: energy storage (ES), electric vehicles (EV), smart grid (SG), demand response (DR) and distributed generation (DG), which have played a fundamental role in the world energy market.

In recent years the use of (BESS) in distributed energy resources (DER) has been expanding due to the versatility of its applications, some topics to be addressed are the incorporation of batteries: as a charging point for electric vehicles incorporating panels photovoltaic [23], with network planning algorithms maximizing benefits [2] [6], incorporated in residential areas reducing self-consumption [35], BESS loading / unloading algorithm [7], incorporation in systems with stability problems [6] or as analysis of economic and technical feasibility [33].

Based on what was analyzed, we proceed to establish parameters to classify the different types of paper, taking as a reference the document [1] in which they carry out a study of what types of levels of adoption DER has and what its transformation elements are, this with in order to observe what documents are incorporated into them.

2. FEATURES AND APPLICATIONS OF BESS: LITERATURE REVIEW

In this section a review of the literature on published articles on the subject of (BESS) will be presented, the characteristics and applications given by the authors in each of their papers will be analyzed, these are collected in the period of (2009-2020). Table 1 details the topic covered by each of the authors.

Table 1: Features and Applications of BESS

Ref.	Bibliographical	Scope and Applicability
[2]	Kumar, 2019	It is proposed to develop an optimization method which is developed at different levels, it has some generation units and in the part of energy storage systems, batteries are placed which will serve as backup for the central and distributed auxiliary services. The objective of level 1 is to determine the optimal location and size. In level 2, we proceed to verify that its capacity is sufficient to be able to participate in auxiliary distribution services. The effectiveness of the model is seen with a distribution system located in India that results in more benefits with wider use in wind power generation.
[3]	Aguado, 2017	This document has as an emphasis to control the expansion of the transmission network for it uses an optimization algorithm, it also implements in its system a type of energy storage which are batteries of which it studies its applications and characteristics. The BESS are implemented in order not to expand the transmission network since this leads to new construction which affects the environment, also reduces demand peaks and is considered as temporary solutions, alleviating saturation in the network.
[4]	Divya, 2009	The article presents an economic and technical evaluation on implementing BESS (Battery Energy Storage System) in hybrid electric vehicles and gives a future perspective for battery technologies. The devices Electric Drive Vehicles (EDV) help to make the electricity grid more reliable by locating them in auxiliary services and to economically integrate renewable generation sources.
[5]	Olaszi, 2017	The document presents a comparison of different residential discharge strategies which reduce self-consumption for residential photovoltaic systems and optimize periods of auto discharge. All the simulations that were run were with measurement data in real time, for the base case it seeks to "store and release immediately", the second concept is smart and seeks to incorporate and be "network friendly" is a download algorithm manageable, in the third algorithm is a concept of energy management oriented to the energy market where its behavior is simulated The report carries out an optimization web application in which it incorporates the BESS which help to compare and validate the economic viability
[6]	Kyriakopoulos, 2016	Large-scale storage requires electrochemical storage applications, thermal energy storage is in line with systematic approach system. hydrogen-based energy storage is promising since it can link the main sectors of an energy system, such as transportation and electricity, could be apply to a renewable power plant and rely on hydrogen and fuel cell technologies. The document evaluates the different factors of selection and use of energy storage technologies, reviews advantages and disadvantages of each of them.
[7]	Bengani, 2018	The expansion of network infrastructure has posed several challenges for companies, where the traditional approach is to increase capacity to meet maximum demand and the authors seek to incorporate energy storage systems (ESS), with the purpose of postponing investments in infrastructure and strengthening by meeting maximum demand in the system; giving reliability and stability, maximizing the benefits. The method is based on optimizing the location of the device to observe contingencies and the corresponding results of the nodal analysis.

[8]	Reihani, 2016	The article proposes a algorithm for charging/discharging batteries, this with the aim of smoothing the power charge curve and regulating the voltage of a distribution transformer. These devices are bi-directional and help to supply power during peak usage periods and to manage the network during low demand periods. Control scenarios: in the first scenario you want to reduce the maximum peak where a fairly precise performance is observed, its disadvantage is vulnerability to growth and in the second case based on the first, a power smoothing algorithm is incorporated. This shows that the BESS capacity is effective and helps to decrease spikes and increase power.
[9]	Emmanuel, 2017	The photovoltaic (PV) system is an emerging paradigm of power generation, this is due to the limitations and mismatches between its output power and load, which imply losses and higher power. The article presents various scenarios for the implementation of photovoltaic units and their scope in the smart grid. The solution is analyzed with a Static Synchronous Compensator (STATCOM-BESS), which is presented as a fast response and capacity, smoothing the photovoltaic support avoiding critical contingencies.
[10]	Wu, 2019	This work analyzes the viability of frequency support in batteries, in the first section the concept of frequency support BESS is defined, in section two the design, characteristics and some types of batteries for frequency support are compared and finally in section Three, a cost analysis is carried out and the international experiences that have been obtained in the market are presented.
[11]	Tang, 2009	This document analyzes the feasibility of using BESS to help the stability in steady state of the electrical system, which is studied in three aspects: transfer capacity, small signal stability and limit of stability in steady state; resulting in more active and reactive power control and better damping in the system with BESS rather than with STATCOM.
[12]	Singh, 2010	In this document, a comparison is made between STATCOM, (BESS) and FACTS, which seeks to show the effectiveness of the BESS controller. In this document, the combination of STATCOM and BESS is analyzed and simulated, showing the damping efficiency of the oscillation and the dynamic performance obtained. The control by BESS is also demonstrated, which is more significant than STATCOM and its incorporation helps system performance. of energy.
[13]	Kawakami, 2012	The Japanese network has renewable energy generation in its systems, which makes it find many fluctuations in its system and therefore instability. This document presents the BESS projects that have been built in Japan as a solution to the stability problems inherent in the generation of renewable energy.
[14]	Oka, 2013	The BESS are considered to have a high initial cost, so that in most photovoltaic generation projects they are not considered, however, in this document the authors emphasize the long-term economic study by proposing a BESS schedule of operations. optimal daily, considering the use of the TABU algorithm and the net present value method.
[15]	Takeda, 2014	This document presents hybrid energy storage systems with batteries, in order to reduce costs and size, using energy management algorithms through charge and discharge simulations, thus achieving a 36% reduction in the cost of batteries compared to the typical ones. BESS. Battery modules are also identified in two categories (high power, high energy) that are tailored to the customer's needs.
[16]	Anvari-Moghaddam, 2015	Due to the use of renewable energy sources, microgrids appear, which can behave as an energy center that adds units and can operate autonomously or connected to the network. In this document, the authors propose a control scheme that helps reduce the short-term operating cost of a microgrid connected to a residential network, taking into account the costs of energy exchange and the cost of battery life per cycle. loading / unloading.
[17]	Kim, 2016	In this document, the authors present a laboratory scale microgrid, using real batteries and propose a real-time scheme (GFR) that provides an auxiliary service for rapid regulation in the microgrid, enabling direct load control (DLC) to compensate the high frequency components and thus improving the stability of the system.
[18]	Xia, 2015	In most of the studies and simulations carried out with the BESS, the charge and discharge characteristics of the batteries are taken into account, which can be simulated with great precision compared to reality, but the same does not happen with control simulations with the system connected to the network. In this document, the authors make a model for long-term transient and electromechanical dynamic simulation of BESS connected to the network using the PSASP software.

[19]	Wang, 2017	To achieve effective use in voltage regulation with BESS, in this article, the authors propose a method of managing powers to reduce power loss and minimize the impact of voltage fluctuations from nearby nodes. to the BESS.
[20]	Arif, 2017	The main disadvantage in using renewable energy is the unpredictable and fluctuating production causing stability problems in the network, at this point the use of BESS becomes important as a support for frequency control and voltage support. In this document the authors present the simulation in DigSILENT for the case study to find the appropriate location for the BESS in the system to dampen frequency fluctuations in case of failure.
[21]	Sasmal, 2017	In this paper, the authors present a comparative analysis of energy compensation-based smoothing techniques for photovoltaic systems with BESS using a simple moving window algorithm. They also suggest using a hybrid energy system. The system is confirmed by a bank of supercapacitors and vanadium dioxide batteries, in order to mitigate the power fluctuation due to the penetration of photovoltaic generation.
[22]	Barchi, 2018	In this document, the authors show a prototype photovoltaic generator (PV) and a BESS in a shopping center in Italy, implementing a smart control strategy, in order to promote efficiency, sustainability and contribute to the reduction of emissions. of CO ₂ , imposed by the national government based on renewable energies.
[23]	Sanduleac, 2018	In this document, the authors show the feasibility of using the BESS as the primary frequency control in the electrical network, by simulating and using real measurements, based on the charge / discharge algorithm to find limits on the daily cycles of the batteries, finding its most efficient use and avoiding over wear
[24]	Datta, 2018	In this document, the authors implement a simulation in Simulink / Matlab to analyze faults, which has not been studied much previously, as a result they obtained that to minimize the impact of DC faults in the AC Grid, optimized techniques should be studied as well to select the size of the batteries and to improve safety in case of failures use a control algorithm.
[25]	Jena, 2018	In this paper, is analyze the behavior and performance of a photovoltaic in a line-to-ground fault microgrid with and without BESS using simulation methods in Simulink / Matlab, and discover that the system better overlaps the fault with the inclusion of BESS and an estimate of the battery life is calculated using a probabilistic approximation.
[26]	Rathod, 2018	This document assesses the capacity of the BESS to support have a balance among demand and supply of energy obtained by a wind farm, this is analyzed through simulations in Simulink / Matlab using the energy buffering method and achieving the maximum economic benefit with the maximum extraction of wind energy. .
[27]	Li, 2019	Currently the most developed technologies for electrochemical batteries are lead acid and lithium ion, in this document the lead-carbon battery is presented as the best option for BESS, due to its adaptability to work at high temperatures and the capacity recovery in charge-discharge cycles, improving the useful life for this system.
[28]	Dubarry, 2017	The BESS in recent years have taken a fundamental role in renewable energy. In this document, the authors present the efficiency of a real BESS located in Hawaii and its state of degradation by daily use during 3 years, the laboratory tests estimate its remaining useful life considering the effects of charge / discharge.
[29]	Branco, 2018	The problem of microgrids in isolated places that have renewable energy generation is the intermittent nature of the generation and that makes regulation difficult when there is excess or deficit of supply, in many cases this is compensated by small thermal generators that work with Diesel, which is a costly solution and also harmful to the environment, this makes system operators rethink the use of RESS. In this document, the authors propose a methodology to optimally size a BESS to solve the above problems, achieving a balance between the integration of RES and the VPN in the system.
[30]	Noyanbayev, 2018	The efficiency of a battery is studied in this document as the ratio of energy withdrawn and returned to the grid in a charge cycle and that ratio in a range of operating points allows the construction of efficiency maps, which are used to optimize the operation. The authors perform simulations for BESS with a capacity of 240 kW and 180 KW, finding that most of the energy losses occur in the transformer and the inverter.

[31]	Crosa di Vergagni, 2020	The document proposes a control algorithm, with the aim of managing and controlling DER, which is implemented in an energy resource management (ERM), seeking as objectives to meet: (1) Control the energy consumption of the microgrid, before and after connection in island mode (2) Maintain frequency. The techniques (ERM) are developed in the Matlab environment, seek to operate in microgrid scenarios and have the following objectives: reduce consumption peaks, control energy consumption and participate in activities (ADR).
[32]	Ahmadi, 2020	This document presents an energy management system (EMS) for a micro-grid network (NMG), a two-level EMS is presented for an isolated structure, information is exchanged externally and the internal EMS complies with the programming of energy to each microgrid in case of failure in case of separation from the others. Using a Graduated Demand Program (DRP), we seek to propose a tiered DRP and evaluate a comprehensive NMG model.
[33]	Liao, 2018	This document proposes a BESS sizing and scheduling optimization method. Using a stochastic search optimization algorithm called e-DA (Electron Drift Algorithm) which determines the best combination of batteries and smart inverters that maximize the total revenue of photovoltaic systems.
[34]	Grande, 2018	This document studies different benefits of using PV-BESS off-grid to charge electric vehicles, using climate data from the city of Madrid. Consequently, the author's goal is to design a system that requires a low investment, while providing an offline PV-BESS system.
[35]	Jannati, 2020	This document seeks to reduce energy changes using renewable energies controlled by the charge / discharge cycles of BESS batteries. The study is carried out in three stages, in stage one an algorithm is used that is responsible for efficient energy monitoring. In the second stage, the energy from the wind farm is injected into the grid and in the third stage an algorithm is proposed to load / unload the BESS units. The discussed method seeks to reduce BESS units, ensure utilities, and improve battery life
[36]	Bai, 2019	This article conducts a comprehensive economic evaluation of the benefits of using reused electric vehicle batteries in provincially distributed photovoltaic energy storage systems in China. The results show that, at present, the economic performance is more efficient observing it from each state / municipality, in addition an economic viability is realized.
[37]	Datta, 2020	This study uses a method to control an electric vehicle charging station which has a PV-BESS implemented, this is done in order to reduce the demand for charging that may occur at any time. The design seeks to reduce the demand for grid load during overload conditions, providing smoothing to photovoltaic services. The research is analyzed from the technical perspective and concludes that a reduction of almost 138% in transformer overload can be achieved, which can regulate its output power to reduce transformer overload.
[38]	Howlader, 2016	By implementing Distributed Renewable Generators (GRD) in the system, its penetration increases causing there is no balance between supply and demand. The article proposes a smart grid model in which it is desired to integrate (GRD) and energy storage systems on the supply side and smart homes on the demand side. It is analyzed from different climatic conditions and different demand response rates, concluding that the benefits of using the smart grid model increase significantly when the demand response is considered.
[39]	Jo, 2019	The document proposes an equivalent power system circuit modeling (EPSC) method which simulates an energy system using constant modification method, analyzed the frequency changes in the system before and after integrating BESS to regulate the frequency, giving In conclusion, BESS improves the response to extreme demand
[40]	Rallabandi, 2019	The article analyzes the configuration, design and operation of the photovoltaic (PV) systems connected to the 10 MW grid, simulating the different scenarios such as periods of low irradiation, constant power and superior irradiation using the PSCAD software. The simulations of a 14-node IEEE bus connected to an independent inverter are performed and the advantages and disadvantages that occur when doing it are observed. One of them is to control the smoothing of energy output to the photovoltaic system.

3. CLASSIFICATION TABLE

A classification is made where it is possible to identify at what level of adoption of the distributed energy resources it is and what is the approach given according to its element of transformation, as can be seen in figure 1.

Figure 1: Classification of the Articles of the Adoption Level and its Transformation Element.

It will be observed in the upper right part the type of DER adoption where the articles are most focused according to the following levels:

Massive Integration

- sustainable microgrids (embedded / hard-to-reach areas)
- New business models
- Operation and distributed markets

Medium

- implementation of microgrids
- DER resource optimization

Low

- Research in smart grids
- Analysis of DER resource scenarios
- standardization and regulation

CONCLUSIONS

The most relevant information in which the adoption levels were covered and the elements of transformation of distributed

energy resources (DER) were recognized and recorded in such a way that a classification is analyzed in which it is observed that the topics most treated in The literature is energy storage, distributed generation and Smart Grids, and where the least information is found is in response to demand, advanced metering and electric vehicles. This is done so that other authors have a more general vision of what topics to focus on to investigate.

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