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Review of supporting scheme for island powersystem storage

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ABSTRACT

This paper proposes a support mechanism for energy storage devices for island power systems where intermittent renewable generation is rapidly growing. We base our proposal on the maturity level of storage devices (Chen et al., 2009 [7]) and on the linear model for the development of innovations [14]. We focus on storage technologies that can be technically developed in island power systems and that achieve the technical needs of these systems. We conclude and recommend the adoption of a feed-in tariff with a price varying with the time of day to push for the deployment of power storage avoiding the curtailment of massive intermittent renewable generation.

Contents

1. Introduction

The integration of massive photovoltaic and wind power into island power systems in Europe is confronted by a number of problems. These systems can only accommodate a very limited capacity of Renewable Energy Sources (RES) power. Indeed, beyond a certain amount of intermittent renewable power, it is not possible to cut some conventional thermal plants to balance generation and load because these conventional thermal power plants are used to provide the necessary reserve margin to balance the power system instantaneously [5]. This technical constraint can reach different levels according to the size and the maturity of the island system. In the example of Reunion Island, the limit is 30% of intermittent RES that can be integrated in the system. When the 30% limit is reached, the system operators will cut intermittent RES production surplus to maintain the balance between generation and load. This technical constraint limits the integration of more renewable energy in island power systems and makes it more difficult to achieve objectives of energy independence and reduction of Greenhouse Gas (GHG) emissions. There are several technologies already available to overcome the constraints of integrating large amounts

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of RES. Among the most traditional ones, it is possible to develop highly flexible conventional thermal power plants such as small oil-fired power stations. But these plants have two major drawbacks. First, their use makes the power system more dependent on external resources that are already difficult for the isolated island systems to obtain at a low price. Second, if the integration of more intermittent RES entails the parallel insertion of flexible thermal power plants, the net CO_2 balance could be negative for the island systems. Another solution that we study here is to rely on electricity storage.[1]

Storage facilities have multiple positive impacts on the electricity systems. First, electricity storage logically makes it possible to insert more intermittent RES while participating in the global balance between generation and load in a more predictable way. Second, storage can flatten the load curve of the system. The renewable or baseload power plants are then more called on to fill in the storage facilities during low consumption periods. And during periods of high consumption, the stored energy is returned to the system, thereby reducing the need for peakload power plants that relatively emit more CO_2 than renewable or baseload ones. If pumped hydro storage technologies are already known to be profitable for island power systems in limited situations [6,34], other storage technologies adapted to massive deployment on islands are still in the early stages of industrial development despite their potential attractiveness.

As highlighted by He and Zachmann [20], the literature about electricity storage in the power market has mainly focused on the calculation of the arbitrage value of energy bought at a low price and stored and subsequently sold at a higher price. This exercise has been done in several markets (PJM and New York in the USA by Walawalkar and Apt [39] and by Sioshansi et al. [37], Nordpool by Lund et al. [25], Spain by Dufo-Lopez et al. [11]). And several assumptions have been used for the operation of the storage facility (fixed period of arbitrage for Walawalkar and Apt [39], optimization of the storage facility over two weeks by Sioshansi et al. [37], over one year by Lund et al. [25], use of the real option theory by Muche [29]). He and Zachmann [20] open the research field and determine the return on invested capital of different technologies for different markets, comparing the arbitrage value with the fixed cost of different storage technologies considering their different power ratings. They conclude that for three representative markets in Europe (France, the Netherlands and Scandinavia), no storage facility is profitable despite the benefits they bring to these power systems. Sioshansi [36] sums up the diversified services that storage can bring to power systems and highlights the inconsistencies in current market designs, which prevent a market-based development of storage. One important reason for this is the lack of suitable mechanisms allowing the investor to capture the overall value of storage by providing multiple services to the power system. The efforts to aggregate several revenue streams often come up against regulatory frameworks which forbid the exchange of information between the regulated and deregulated actors. Sioshansi [36] helps us to understand that the combination of services could lead to a better perspective for the development of storage. Following this line, He et al. [19] develop an initial reflection on a business model that takes account of this problem in power systems. The core idea of their model lies in organizing an auction chain in which the right to use available storage capacities is auctioned among different actors. To sum up, the integration of storage in the power system is faced with threefold market failures. 1° Storage can help the development of intermittent RES and reduces CO_2 emissions from other power plants but the pricing of CO_2 still does not make it possible to internalize this positive externality and to overcome the investment and management cost of storage. 2° The scientific and technological efforts associated with RD&D and demonstration pilots have a public good character and need suitable treatment to be overcome. 3° Innovations in the power system (such as storage) face technological entry barriers due to the pre-existence of mature solutions (such as oil-fired power plants) that can provide a similar service at, currently, a lower cost. Its learning curve is then limited.

The existence of these three market failures then leads us to wonder what suitable form of public support and regulatory framework would be required for the development and deployment of storage technologies in island power systems.[2] In order to answer this question, we will rely on the work by Foxon et al. [14] to associate the adequate support mechanism to technologies depending on their maturity. In particular, this was done previously for renewable generation technologies [12,13]. We will also rely on the work by Chen et al. [7] to characterize the maturity of the different storage technologies. What is more, in order to minimize the reliance on support mechanisms while maximizing the possibility of developing storage technology, we will also consider three characteristics of storage devices when designing support mechanisms for storage technologies. The first characteristic is the optimal use of storage. The public support mechanism should take account of the fact that the efficiency of energy storage for the power system as a whole depends on the specific times of the day when it withdraws and injects energy and on the location of storage devices. The second characteristic that distinguishes the different storage technologies is the set of services they can provide to the power system (power quality–voltage variation, voltage and current transient, harmonic content in waveforms–balancing, at least daily storage duration, location flexibility). Some storage technologies may be able to provide some services to the system while others may not (for instance, balancing). The public support for storage shall take account of the differences between technologies in terms of ability and maturity of service they can provide and the revenue generated from selling these services. The last characteristic is the degree of centralization of storage facilities. Different management schemes could be applied to storage according to the degree of centralization. Consequently support mechanisms shall apply differently depending on the degree of centralization and on the kind of actor responsible for managing storage (fully independent, integrated with production, or possibly with the Transmission System Operator–TSO). Finally, the value for these three characteristics of storage (1) its double function of storing and removing energy, (2) the other services it can provide and (3) its degree of centralization and location on the network) will be all the higher (without support) when the market design is efficient and storage is exposed to market signals. A smaller reliance on support mechanism will then be needed (as shown by [22] in the case of wind power).

The paper is organized as follow. First we identify the services that storage could provide to island power systems to facilitate the integration of intermittent RES. We then establish the electrochemical storage technologies that can deliver these services. Second, we recall the various forms of public support for the development of clean technologies in the electrical system. We can then link the various stages of the technological and industrial development of new technologies with the adequate support instruments. In the last section, we will also recommend the form of adequate support for these technologies given their technical

[1] When possible, another solution that offers greater flexibility is to connect islands together (e.g. the Canary islands) or to connect them to the continental system (e.g. the main Balearic islands connected to the Spanish network).

[2] Note that internalizing the market failures for storage may also benefit consumers by allowing lower prices at peak times [36].