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Profitability of an electrolysis based hydrogen production plant providing grid balancing services

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ABSTRACT

Electricity production and consumption on electrical networks must be in permanent equilibrium to maintain the frequency around its nominal value (50 Hz or 60 Hz). The increasing use of intermittent power sources leads to new balancing requirements (entities capable of quickly adjusting their power injection or power consumption). We investigate in this paper the economic viability of an electrolysis based hydrogen production plant which provides balancing services to the network by participating to primary frequency regulation. This investigation is performed by modelling a grid connected electrolyser plant using the CEA's proprietary simulation platform Odyssey. This study focuses on the French context considering the compensation schemes of the French Transmission System Operator (TSO) RTE. Two scenarios are considered: (i) the assessment is made taking into account the economic conditions currently proposed by the French TSO, and (ii) a sensitivity study is conducted for evaluating the conditions for which the participation in frequency regulation would effectively enhance the economical balance and reduce the cost of producing hydrogen. Results indicate first that revenues related to frequency regulation are exclusively driven by the capacity component. Furthermore, the current economic conditions are not sufficiently attractive for a hydrogen production plant operator as they lead to an increase of the production cost. Sensitivity analyses highlight the fact that an increase of the compensation capacity component by a factor 2 to 3 is necessary to expect a reduction in production cost and to encourage hydrogen producers to participate to primary frequency regulation.

Introduction

The European 2020 climate and energy package sets out ambitious targets towards a more sustainable energy system by reducing greenhouse gases emissions, increasing the use of renewable energies and reducing the energy consumption [1]. These political objectives are leading to a new paradigm in the organization of electricity networks in Europe. Transmission System Operators (TSOs), that are responsible for maintaining

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permanent equilibrium between production and consumption, have to deal with increasing share of decentralized and intermittent renewable electricity production and the evolution of electricity uses (such as the development of electric vehicles). Due to these modifications additional needs for balancing services are foreseen.

Balancing services are nowadays mainly provided by conventional electricity generation units. The increasing needs for balancing services may lead to the use of additional technical solutions than the ones currently used. The ENTSO-E Network Code on Electricity Balancing [2] indicates that the participation of demand side response (including aggregation facilities and energy storage) and the participation of renewable energy sources shall be facilitated. The participation of renewable generation units in balancing services becomes even mandatory in some network codes (Denmark offshore wind farms) [3]. Electricity storage (pumped hydro, batteries, flywheels ...) can also be used to provide balancing services, as experienced in the US [4]. Several studies investigate the economic viability of an energy storage system dedicated to grid balancing services. For example, studies implicating Li-ion batteries within the Danish context show that investing in such a storage system for grid frequency regulation can be profitable [5,6]. From a technical point of view, load management can provide balancing services, as shown in various studies and experiments [7–9]. In France the TSO (RTE) has recently published new ancillary services rules describing how electricity storage and electricity consumption sites can now provide short term balancing services [10]. Table 1 provides an overview of the different mechanisms used by RTE to ensure equilibrium between production and consumption.

The participation of hydrogen production by electrolysis to balancing services has already been experienced [11–13] showing that the hydrogen electrochemical production process can meet the technical flexibility requirements. Furthermore, authors in Ref. [13] have also highlighted how the use of electrolysers can help reducing the spinning reserve requirements. However, besides the technical ability of electrolysis process to provide balancing services the cost-effectiveness of such operation has to be evaluated in an industrial business case. In order to address this issue, it is necessary to consider to what extent such balancing services are compensated economically by TSOs.

The interest for electrolysis process to participate to the French balancing mechanism ("mécanisme d'ajustement") has been assessed in Ref. [14]. The authors in Ref. [14] investigated the added-value for a hydrogen producer to purchase electricity on the EPEX spot SE day-ahead market while offering balancing capacity to the TSO through the balancing mechanism and concluded that participating to the balancing market permitted to reduce the hydrogen production cost by 5%–10% compared to the EPEX spot only sourcing.

In the present study we investigate the case where the electrolysis process provides an additional primary reserve service to the TSO (real time response to frequency variation remunerated within a bilateral contract between the service provider and the TSO). Our objective is to evaluate using the simulation if it is profitable for a hydrogen producer to provide both offers on the balancing mechanism and primary reserve service. In a first step, the assessment is made taking into account the economic conditions currently proposed by RTE. A sensitivity study on the capacity component of the remuneration scheme is then conducted for evaluating the conditions for which the participation in frequency regulation would effectively enhance the economical balance and reduce the cost of producing hydrogen. It is worth pointing out that the objective of this study is not to compare the electrolysis process with other technologies capable of providing grid balancing services (such as batteries) but rather to analyse the extra economic value that may be generated from providing such services considering the point of view of the electrolyser operator.

Methodology

The assessment presented in this study is based on the modelling and simulation of an electrolysis based hydrogen production plant participating to the day-ahead market, balancing mechanism and contributing to primary frequency regulation. The modelling and simulation has been done using the CEA made Odyssey platform introduced in Ref. [15]. Odyssey is a generic software platform dedicated to modelling, simulation and optimisation of energy systems and used to perform techno-economic assessments. The following paragraphs introduce the different concepts involved in this paper and describe how they have been modelled in Odyssey. It has to be pointed out that all simulations and optimisation results presented in this paper are based on historical data (market energy prices and volumes, electrical network frequency). Consequently, the results rely on the assumption that the behaviour of the hydrogen production plant does not impact the day-ahead market, the balancing market and the grid frequency.

System modelling

Hydrogen production plant: architecture and models

The system considered in this study is illustrated in Fig. 1. It consists of a main AC (Alternating Current) bus on which an electrolysis stack is connected through a rectifier (AC/DC converter) and auxiliaries (pump, cooling system, etc.) are

Table 1 – Mechanisms used by RTE to ensure equilibrium between production and consumption.

	Primary control reserve	Secondary control reserve	Tertiary control reserve
Implementation	Automatic adjustment of the power level	Automatic adjustment of the power level based on RTE corrective signal	Manual (upon calling from RTE control centre)
Procurement scheme	Bilateral contracts (Mandatory for power producers with power above 40 MW)	Bilateral contracts (Mandatory for power producers with power above 120 MW)	• Bilateral contracts • Market scheme (balancing mechanism OR "Mécanisme d'ajustement")