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ScienceDirect

Energy Procedia 142 (2017) 841–848

Energy Procedia

www.elsevier.com/locate/procedia

9th International Conference on Applied Energy, ICAE2017, 21-24 August 2017, Cardiff, UK

Techno-economic assessment of battery storage and Power-to-Gas: A whole-system approach

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Abstract

The power systems in many countries are undergoing a radical transformation through employing a large capacity of renewable generation technologies such as wind turbine and solar photovoltaic. The power generation by wind and solar resources are variable and difficult to predict. Therefore, growing capacities of such technologies is expected to introduce challenges regarding balancing electricity supply and demand. This paper investigates the role of battery storage and power-to-gas systems to accommodate large capacity of intermittent power generation from wind and solar and therefore facilitates matching electricity supply and demand. The Combined Gas and Electricity Networks (CGEN) model was used to optimize the operation of gas and electricity networks in GB for typical weeks in winter and summer in 2030. The role of different capacity of battery storage and power-to-gas systems in reducing the wind curtailment and operating cost of the system were quantified and compared with the annualized cost of these technologies.

Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.

Keywords: Energy Systems Integration; Gas Networks; Power Systems.

Nomenclature

$CAPEX$	Capital Cost
CRF	Capital Recovery Factor
i	Discount rate (%)
n	life time (years)

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1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.135

1. Introduction

The United Kingdom has legally binding targets to increase the share of renewable sources in electricity generation mix. Due to the abundant wind resources across the country, wind is expected to play a very important role in the future generation mix [1].

The intermittent nature of wind speed and the resultant electric power output poses challenges to the balancing of electricity supply and demand. In Great Britain (GB) in particular, gas-fired generators are expected to compensate for the variations in wind generation, and therefore accommodate increased integration of wind generation. However, the frequent ramp up and ramp down of gas-fired generators caused by wind intermittency is transferred to the gas network and result in more variable gas demand for power generation [2].

There are number of potential solutions to address the supply and demand balancing challenge, from which battery storage and power-to-gas were assessed in this paper. The value of these options in the operation of integrated electricity and gas networks were quantified for a low carbon energy system in 2030.

1.1. Battery storage

Battery Energy Storage Systems (BESS) have seen significant growth in recent years. Though some of this will be research-driven, it can be assumed that in many regions of the world, the benefits of battery storage now outweigh the significant capital investment costs.

The need for energy storage has increased with the increasing deployment of renewables. For power system security to be maintained, demand and generation need to be matched at all times. With traditional thermal generation, output can be varied to match demand. Given the recent success of lithium-ion, this paper will focus on that technology.

Much of the interest in lithium-ion battery costs has focused on battery cells for electric vehicles because of the interest in when electric vehicles may become cost-competitive with combustion engine vehicles. The capital costs in 2030 is estimated to range from $150 to $300 per kWh, a reduction of approximately 50% from 2014 prices [3].

1.2. Power-to-Gas (P2G)

Power-to-Gas is the use of excess renewable electricity from power grid to produce hydrogen via electrolysis process and inject the hydrogen into the existing gas network. The structure of P2G is shown in Fig. 1 [4]. P2G systems can be operated to [5]:

- absorb otherwise curtailed wind and solar electricity
- use a combination of grid electricity and local renewable electricity to produce low carbon gas and consequently contribute to decarbonizing heat sector
- operate on a time base that meets load levelling and balancing services objectives.

The potential of large scale integration of hydrogen technologies in balancing the Spanish power system was studied in reference [6]. Qadrdan et al [4], investigated the role of P2G in an integrated gas and electricity system in Great Britain, and showed that P2G has a significant potential to reduce wind curtailment that caused by insufficient power transmission capacity. Furthermore, it was shown that injecting the hydrogen produced from renewable electricity into the gas network contributes to the reduction of gas import dependency.