Energy Policy 58 (2013) 6–16

Contents lists available at SciVerse ScienceDirect

Energy Policy

journal homepage: www.elsevier.com/locate/enpol

The impact of electricity storage on wholesale electricity prices

Batsaikhan Nyamdash *, Eleanor Denny

Department of Economics, Trinity College Dublin, Dublin, Ireland

HIGHLIGHTS

- ▸ The effect of storage on the simulated shadow price of electricity and the production cost.
- ▸ Comparison of the savings in the consumer cost and the reduction in the production cost.
- ▸ Actual effect of storage on the wholesale price.

ARTICLE INFO

Article history:
Received 29 September 2011
Accepted 14 November 2012
Available online 22 March 2013

Keywords:
Electricity storage
Electricity price
Production cost

ABSTRACT

This paper analyzes the impact of electricity storage on the production cost of a power system and the marginal cost of electricity (electricity price) using a unit commitment model. Also, real world data has been analyzed to verify the effect of storage operation on the electricity price using econometric techniques. The unit commitment model found that the deployment of a storage system reduces the fuel cost of the power system but increases the average electricity price through its effect on the power system operation. However, the reduction in the production cost was found to be less than the increase in the consumer's cost of electricity resulting in a net increase in costs due to storage. Different storage and CO_2 price scenarios were investigated to study the sensitivity of these results. The regression analysis supports the unit commitment results and finds that the presence of storage increases average wholesale electricity prices for the case study system.

© 2012 Elsevier Ltd. All rights reserved.

1. Introduction

The European Union has committed to reducing greenhouse gas emissions by increasing the share of renewable energy in the energy mix and increasing energy efficiency by 2020 (European Commission, 2006, 2007). In meeting these commitments, wind energy has attracted more attention than other renewable energy sources (RES) (*i.e.* tidal, wave, geothermal, etc.) as it is currently considered to be the most economical renewable generation type.

As the role of RES increases in the power system, changes to the power system operation are required such as greater reserve capacity from conventional power plants to deal with unanticipated reductions in renewable energy generation (Doherty et al., 2005; Dany, 2001). In order to accommodate the variability and uncertainty of wind generation, thermal generators are often required to operate on a sub-optimal regime which can impose additional cycling on these units (Denny and O'Malley, 2007). Moreover, it requires increased network enforcement due to the wide and remote geographic dispersion of wind farms.

Therefore, the use of electricity storage systems, which store electric energy in terms of water in elevated reservoirs or compressed air in underground caverns, etc., are attracting more attention in a bid to increase renewable energy penetrations (McDowall, 2006; Weis and Ilinc, 2008). Such systems are able to provide fast startups and rampings, thus allowing the power system to offset the impact of renewable energy generation (Brown and Lopes, 2008; Zeng et al., 2006; Abbey and Joós, 2007; Li and Joós, 2007; Carton and Olabi, 2010). The integration of storage in weak networks with an intermittent energy source improves power quality and reduces the cost of electricity significantly (Kaldellis et al., 2009). Korpaas et al. (2003a) and Benitez et al. (2008) found that the deployment of storage reduces the need for generating capacity. Also, it may decrease the wind curtailment and shift off-peak wind power output to the peak hours. However, large scale storage units are site specific and capital intensive (Susan and Hassenzahl, 2003; EPRI, 2003, 2004).

It has been shown that optimally sized electricity storage could result in more economic operation of both wind farms and the storage itself by taking advantage of arbitrage, ancillary services, and transmission and balancing costs (Korpaas et al., 2003b; Castronuovo and Lopes, 2004; Leou, 2008; Greenblatt et al., 2007; Lund et al., 2009; Kaldellis et al., 2009; Zafirakis and Kaldellis, 2009; Sioshansi,

* Corresponding author. Tel.: +353 1 8962325.
E-mail address: batsaikn@tcd.ie (B. Nyamdash).

0301-4215/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.enpol.2012.11.033

2011; Tuohy and O'Malley, 2011). In addition, the distributed storage system has the potential to reduce the electricity cost of the household (Ahlert and Block, 2010). The hydrogen storage concept has been studied from an investment perspective and it was found that the use of hydrogen storage for electricity generation is uneconomical (Taljan et al., 2008). Nyamdash and Denny (2010) found that electricity storage is not viable if it is considered only from the perspective of the developer for 2007 Irish power system since the peak and off-peak price differentials are insufficient to cover round-trip efficiency losses. Storage benefits depend on the location of the storage, whether it is close to the transmission line or the utility and also the type of the system (Nieuwenhout et al., 2005). Sioshansi (2010) shows that storage utilization depends on whether it is operated by the individual power plant, consumer or operated as a standalone unit. Troy et al. (2010) looked at the large scale storage benefits from the power system perspective.

From the perspective of the power system, storage benefits would be significant when failure occurs in the power system. However, most of the storage benefits, such as reduction in the variability of renewable generation, deferring of transmission and distribution investments, and capacity investments, are case-specific. Benefits relating to the supply of ancillary services are also market specific.

One way of looking at the storage system from the perspective of society, which has received relatively little attention, is to estimate the effect of storage on the electricity price. In a purely theoretical framework, the operation of storage is able to decouple the load from the generation, and reduce the electricity cost for consumers (Crampes and Moreaux, 2010; Sioshansi et al., 2009; Weissensteiner et al., 2011). However, this is challenging to explicitly examine, as the electricity price often consists of various elements and the methodology is not uniform through different markets. But, implicitly if storage can affect the average wholesale price of electricity generated, it is likely to have a similar effect on the end-use electricity price. Since electricity storage uses the electricity produced by power plants, the operation of the storage unit affects the economic dispatch of thermal power plants; hence, the wholesale electricity price. Thus, the effect of storage on the power system operation and the electricity price is unlikely to be specific to the storage technology adopted but it will depend on the case system.

This paper looks at large scale electricity storage, which is used to minimize the total cost of the power system, from a societal perspective. This is done by estimating the value of storage in terms of its effect on the wholesale electricity price for the case study system for various storage scenarios as well as estimating its effect on the total production cost of the power system. The WILMAR[1] (Wind Power Integration in Liberalized Electricity Markets) tool is used to model the unit commitment decisions. The impact of storage operation on the shadow price of electricity of the Irish Single Electricity Market is investigated econometrically.

The rest of the paper is organized as follows. Section 2 reviews the case system, scenarios, the unit commitment model and the econometric model. Section 3 shows the results, Section 4 presents the discussions and Section 5 concludes.

2. Methodology

2.1. Case study system and scenarios examined

The case study system is based on the 2009 Irish power system and the plant portfolio is adapted in the WILMAR tool to match the 2009 system. The maximum demand was 6467 MW, whereas the minimum demand was 1826 MW in 2009.[2] The thermal capacity consisted of coal, gas, oil and peat fired power plants. In total, 46 conventional power plants are modeled and they are summarized in Table 1. The renewable capacity consists of an aggregated hydro unit and an aggregated wind farm in such a way that there is only one combined hydro and one combined wind unit. Renewable electricity generation has a priority dispatch in the Irish system meaning that generations from RES are given precedence when dispatch decisions are made (CER, 2008). The maximum wind power output in 2009 was 1054 MW. The largest conventional unit modeled has a maximum power capacity of 480 MW (SEMO, 2011). There is one interconnector in the Irish system and its import capacity is assumed to be 400 MW while its export capacity is assumed to be 80 MW. A simplified Great Britain power system with aggregated power plants is also assumed when modeling interconnector flows. There is one existing storage system in Ireland which is a pumped hydro system and it is currently utilized to minimize the overall production cost of the power system.

The base-case scenario for the analysis is 'no-storage'. This scenario assumes 0 MW of installed storage capacity. Storage scenarios with 200 MW, 400 MW, 600 MW and 800 MW of installed capacities with an energy capacity of 5 h are compared against the base-case scenario, in all cases replacing the existing pumped hydro system. Storage unit is assumed to be the power system asset; hence, the power system operator decides when the storage unit should pump and generate.[3] The plant mix is not assumed to be affected by the addition of the storage unit to the power system (*i.e.* new storage units do not displace any thermal unit) as the storage unit is energy limited and is not the perfect substitute for conventional power plants (Walawalkar et al., 2007; Tuohy and O'Malley, 2011).

The assumed fuel prices are shown in Table 1. Fuel prices are assumed to remain constant throughout the year. A carbon price of €30/ton was assumed.

2.2. Unit commitment model

The WILMAR Planning Tool, which is a dynamic partial equilibrium model of the electricity sector, finds the economic dispatch of generating units over the optimization period based on the demand and wind forecasts. It takes into account power plant constraints, such as minimum downtime (the minimum time a unit must remain offline following shutdown), synchronization times (time taken to come online), minimum operating time (the minimum time a unit must spend online once synchronized), heat rate (efficiency of the generator) and ramp rates. The model has an hourly resolution, with planning being done for the next 36 h on a rolling basis. The deterministic version of this tool, which assumes the perfect wind forecast, was used in this paper. Definition of the objective function and further details are given by Tuohy et al. (2009) and Troy et al. (2010). The electricity price is determined by the marginal cost of an extra 1 MWh of electricity produced by the power system.

[1] The WILMAR planning tool is a unit commitment model that is being widely used in power system analysis (National Laboratory for Sustainable Energy, 2010; AIGS, 2008; European Wind Integration Study, 2010; Tuohy et al., 2009).

[2] SEMO (2011) publishes the system load rather than the demand level. Therefore, the proxy for the demand level is estimated by the following expression: $Demand_t = SystemLoad_t + Import_t - Export_t - StorageCharge_t$. The system load includes the generations of all generating units including renewable generations in the Republic of Ireland and Northern Ireland.

[3] Thus, electricity price is not taken into account when storage outputs are being scheduled. However, if the storage unit is operated as merchant type, which it buys electricity from the market place and sell back, the selling price of the electricity should at least be 1/(efficiency of the storage unit).

Download English Version:

https://daneshyari.com/en/article/995523

Download Persian Version:

https://daneshyari.com/article/995523

Daneshyari.com