Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 2580–2585

Energy Procedia

www.elsevier.com/locate/procedia

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

An economic analysis of part loading generators with a focus on the provision of frequency response

Heather Wyman-Pain[a,*], Cain Thomas[a] Yuankai Bian[a], Furong Li[a]

[a]*Department of Electronics and Electrical Engineering, University of Bath, Claverton Down, Bath, BA2 7AY, UK*

Abstract

The provision of reserve generation is an essential part of maintaining a reliable electricity system and has become an increasingly difficult task with the growing contribution from variable energy sources. Ensuring the cost of balancing supply and demand is minimized is an important aspect which requires an understanding of how generator costs vary depending on their operation. This paper considers the cost of part loading different generator types, providing a cost breakdown and description of the LCOE method of analyzing generator costs. This delivers cost-loading level curves for the generator types with the largest contribution to the UK generation portfolio. The holding payment for provision of frequency response is separated by generator type and compared with the calculated part loading costs.

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

Keywords: balancing services; frequency response; generator part loading; power generation; power system economics

1. Introduction

The cost of electricity provision combines several aspects; including infrastructure, production and ensuring a secure supply. As the contribution from variable energy resources (VER) increases ensuring a secure supply will become a bigger challenge, requiring more flexible generators to ensure there is sufficient reserve available on the system [1, 2].

The provision of resources to ensure supply matches demand is dominated by generators, although responsive demand and energy storage systems do provide some additional services. Balancing services have cost the UK £62.49m and £71.10m in January and February 2017 respectively [3], £24.7m and £20.8m of which was spent on ensuring reserves were available. This reserve payment must cover the loss of income generators experience through reducing their output which is the focus for this paper.

Previous research has focused on ensuring there will be sufficient flexible generation available with an increase in VER [1, 4, 5, 6] using models to optimize the future generation portfolio and predict the costs associated with this new generation mix [7, 8]. These papers consider a variety of costs in their analysis, including the ramping cost when choosing which generators to part load, but the cost incurred by part loading the generator initially was not considered. However this cost is a major contributor to the reserve payment and varies considerably between different generators and across the different loading levels.

Section 2 of this paper explains the main contributors to part loading costs and presents the cost curves for different generator types. In section 3 the holding payment for frequency response is explained, with typical holding payments for mandatory frequency response in the UK. Section 4 compares the holding payment with the cost incurred from part loading generators with the conclusion presented in section 5.

* Corresponding author.
E-mail address: h.r.wyman-pain@bath.ac.uk

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy.
10.1016/j.egypro.2017.12.195

Nomenclature

$Cost_{Loading}$	Cost of electricity production at chosen average loading level (£/MWh)
$C_{Capital}$	Generator capital cost per MWh (£/MWh)
$E_{Expected\ lifetime}$	Total generator output expected over the plant lifetime (MWh)
$E_{Actual\ lifetime}$	Total generator output achieved over the plant lifetime (MWh)
$C_{O\&M}$	Generator Operation and Maintenance cost per MWh (£/MWh)
C_{Fuel}	Cost of fuel (£/MWh)
η	Generator efficiency at chosen average loading level (%)
C_{Carbon}	Carbon price (£/MWh)

2. Part loading cost

2.1. Cost contributors

There are multiple contributors to the cost of electricity production, each generator varying in which cost aspect dominates their expenses. Past costing analysis focused on capital, operation and maintenance (O&M) and fuel costs to provide estimations for the cost of electricity production [9].

The capital cost is a fixed value, including the costs from the planning stage of a new generating plant to the point of commercial operation [10]. The capital cost is a major component for nuclear power stations, contributing 60-70% of the overall cost, mostly due to their significant construction time, 8.63 years in the UK [11]. However coal and CCGT plants, 1-2 years [12] and 2.5 years construction time respectively, have 30-40% of their total cost contributed by their capital investment [10].

The O&M cost can be split into variable and fixed costs: Variable O&M costs change in relation to electricity production whilst fixed remain constant despite operational changes [13]. The fuel cost can be considered an O&M cost or treated separately to demonstrate the impact it has on certain generator types. Coal and CCGT plants have a significant contribution to their overall cost, 50-65% [10, 14], from the price of fuel whilst nuclear is relatively low and stable, 5-10% of the overall cost. Another operational cost is the carbon price, paid by fossil fuel plants to encourage the reduction of CO2 emissions. In the UK in 2017 the carbon price is £18 per tonne of CO2 released, however, future prices may increase [15].

The efficiency of a generating unit is plant specific and linked with the conversion of fuel into useful energy [16]. This efficiency changes over the operation of the plant dependent on several factors, including the loading level, making it an important consideration when calculating the overall cost.

In this paper the capital, O&M, fuel and carbon costs are considered for each generating type, with the efficiency linked to fuel usage where appropriate.

2.2. LCOE

LCOE is a tool used to assess and compare options with regards to the various costs associated with each on a common base [17]. It can consider a wide range of costs but, in the use of electricity generators, typically considers the planning, construction, operation and the decommissioning stages of a generating plant for an assumed lifetime output power.

An alternative tool is marginal pricing, used to quantify the additional cost to produce an extra unit of electricity by considering the additional operational costs this would induce [18]. The lack of a common base to compare between different generators makes it undesirable for this particular application so LCOE is used.

Equation 1, as shown below, details how the different cost contributors are combined to find the total £/MWh cost each generator must charge to recover their investment.

$$Cost_{Loading} = C_{Captial} \times \frac{E_{Expected\ lifetime}}{E_{Actual\ lifetime}} + C_{O\&M} \times \frac{E_{Expected\ lifetime}}{E_{Actual\ lifetime}} + C_{Fuel} \times \left(\frac{1}{\eta}\right) + C_{Carbon} \quad (1)$$

2.3. Generation types

Each generator has restrictions on their operation but there are average values for each generation type which can be used.