Available online at www.sciencedirect.com

ScienceDirect

Energy Procedia 142 (2017) 3727–3733

Energy Procedia

www.elsevier.com/locate/procedia

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

System dynamics of oxyfuel power plants with liquid oxygen energy storage

Yukun Hu [a,*], Anurag Tewari [a], Liz Varga [a], Hailong Li [b], Jinyue Yan [b,c]

[a] *School of Management, Cranfield University, Bedford MK43 0AL, United Kingdom*
[b] *School of Business Society and Technology, Mälardalen University, Västerås 721 23, Sweden*
[c] *School of Chemical Science and Engineering, Royal Institute of Technology, Stockholm 100 44, Sweden*

Abstract

Traditional energy storage systems have a common feature: the generating of secondary energy (e.g. electricity) and regenerating of stored energy (e.g. gravitational potential, and mechanical energy) are separate rather than deeply integrated. Such systems have to tolerate the energy loss caused by the second conversion from primary energy to secondary energy. This paper is concerned with the system dynamics of oxyfuel power plants with liquid oxygen energy storage, which integrates the generation of secondary energy (electricity) and regeneration of stored energy into one process and therefore avoids the energy loss caused by the independent process of regeneration of stored energy. The liquid oxygen storage and the power load of the air separation unit are self-adaptively controlled based on current-day power demand, day-ahead electricity price and real-time oxygen storage information. Such an oxyfuel power plant cannot only bid in the day-ahead market with base load power but also has potential to provide peak load power through reducing the load of the air separation unit in peak time. By introducing reasoning rules with fuzzy control, the oxygen storage system has potential to be further extended by integrating renewable energy resources into the system to create a cryogenic energy storage hub.

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

Keywords: oxyfuel power plant; oxygen storage; system dynamics; load distribution; AnyLogic

* Corresponding author. Tel.: +44-(0)123-475-1122 ext. 3403
E-mail address: yukun.hu@cranfield.ac.uk

1876-6102
Peer-review under responsibility of the scientific committee of the 9th International Conference on Applied Energy .
10.1016/j.egypro.2017.12.268

1. Introduction

Modern power grids are required to supply constant voltages at a certain frequency. Supply and demand therefore must be balanced across the entire grid (transmission and distribution). Due to anthropogenic activities, demand varyies periodically, which is usually compensated with variable reactive loads and even nonlinear loads, or with electricity provided by generators and distribution and transmission equipment. However, these strategies do not always work, especially in peak time. Increased peak demand to power grids has further stimulated interest in developing energy storage technologies to compensate the varying demand in a large extent. However, so far, most energy storage developments have been focused on stand-alone storage units that consume electricity and store energy in multiple forms for later use in power generation, such as gravitational potential of pumped water and mechanical energy of compressed air. For example, the Ffestiniog power station [1], a pumped-storage hydroelectricity plant near Ffestiniog, North-west Wales of UK, which can generate 360 MW of electricity within 60 seconds of the need arising with average efficiency 72–73%; the Huntorf power station [2], the world's first compressed air energy storage plant located at Huntorf, Germany. This power plant can provide 321 MW output power for 2 hrs daily in peak time. About 1.6 kWh of gas and 0.8 kWh of off-peak based-load electricity are required in order to generate 1 kWh of peak-load electricity. Such traditional energy storage systems have a common feature: the generation of secondary energy (e.g. electricity) and regeneration of stored energy (e.g. gravitational potential, mechanical energy) are separate rather than deeply integrated. Obviously, any form of energy conversion is subject to loss. These energy storage systems need the second conversion from primary energy to secondary energy.

Hu et al. [3] proposed a possible solution that integrates generation of secondary energy and regeneration of stored energy into one process and therefore avoids the energy loss caused by the second conversion (see Figure 1). They demonstrated this solution on an oxyfuel power plant with liquid oxygen energy storage using a techno-economic perspective. Due to the large air separation unit (ASU) in the oxyfuel power plant there is a significant penalty for net electrical efficiency. If the air separation load in peak time can be shifted to off-peak time to produce and store more oxygen, then more electricity will be generated at a higher price resulting in more benefits. Furthermore, oxyfuel combustion capture technology will be more competitive than it is today. However, their study only considered the particular scenario that the ASU operates full-load in off-peak time and it stops in peak time, but did not consider other more realistic scenarios, like derating operations of the ASU when facing a real power market. Building on the proposed solution [3], the scope of the current paper is concerned with integrating storage by using a control strategy to model the system dynamics of oxyfuel power plants with liquid oxygen storage when acting as a virtual power market.

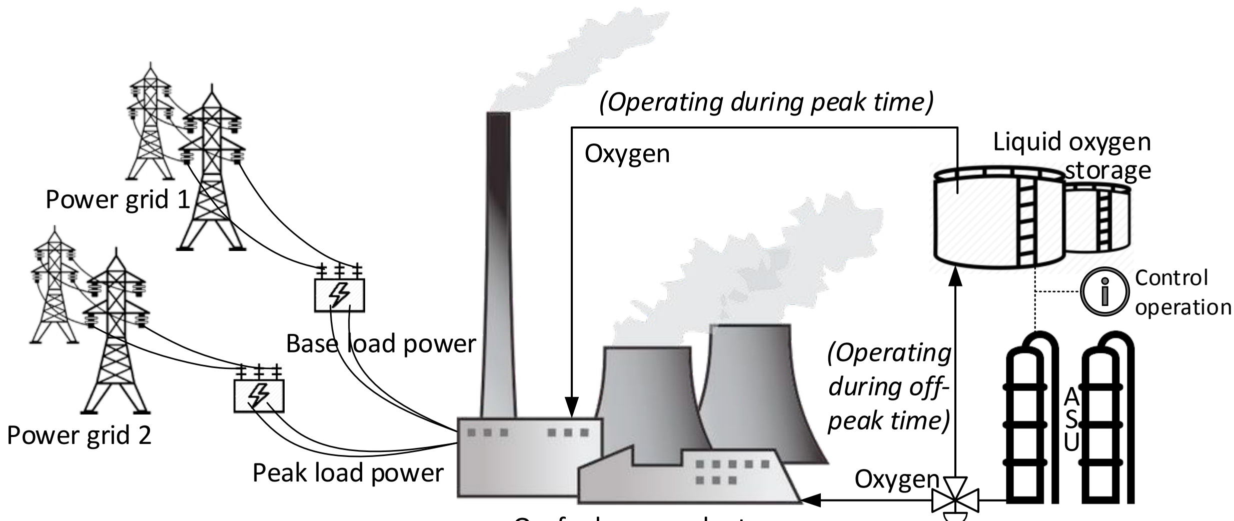

Fig. 1. Conceptual design of oxyfuel power plants with oxygen storage