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ScienceDirect

Energy Procedia 62 (2014) 619 – 628

Energy Procedia

6th International Conference on Sustainability in Energy and Buildings, SEB-14

Great Britain's energy vectors and transmission level energy storage

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Abstract

As an example of the challenges facing many developed countries, the scale of daily energy flows through Great Britain's electrical, gas and transport systems are presented. When this data is expressed graphically it illustrates important differences in the demand characteristics of these different vectors; these include the scale of energy delivered through the networks on a daily basis, and the scale of variability in the different demands over multiple timescales (seasonal, weekly and daily). The paper discusses energy storage in general; the scale of within day stores of energy available to the gas and electrical transmission networks, and suggests Synthetic Natural Gas as an interesting energy carrier that could use existing natural gas infrastructure.

Selection and peer-review under responsibility of KES International

Keywords: Decarbonising heat; energy vector data; GB pumped storage

1. Introduction

This paper examines the scale of energy storage schemes connected to Great Britain's (GB) electrical system at the transmission level, and compares them to the scale of daily energy demand through the gas, electrical and liquid fuel networks.

In energy terms (rather than financial) there are two basic factors in meeting the annual demand of an energy system; the first is that a sufficient quantity is available over the year (the energy), and the second is that the system can match the rate at which this energy is required (the power). For a sustainable energy system, these in turn can be viewed simply as challenges in the harvesting of sustainable primary energy, and the use of energy carriers to allow storage and balancing between primary energy supply and the demand. In the modern era, the majority of

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Selection and peer-review under responsibility of KES International
doi:10.1016/j.egypro.2014.12.425

nations have energy systems with fossil fuels as their primary energy sources, which affords the flexibility to store Terawatt Hours (TWh) of energy until required. Given the length and complexity of fossil-fuel supply chains, it is no surprise to find stores of fossil fuels along the supply chain from the geological resource all the way to the end user. These stores range in size from coal stockpiles of many TWh to a 50-litre vehicle fuel tank (approximately 500 kWh). These stores of energy are based on the storage of fossil fuels, or more specifically, the inherent chemical energy that can be released through their combustion. The energy density of fossil fuels, in volumetric or gravimetric terms, is a major reason that energy systems are so reliant upon them as a source of primary energy. Pumped Hydro Energy Storage (PHES), Liquid Air (LAES), adiabatic Compressed Air (aCAES), Superconducting Magnetic (SMES), and capacitors are an alternative means to store energy at different scales, that do so without the benefit of using the embodied chemical energy of their storage media as the means of energy storage. In comparison Flow Battery (FBES) and Battery Energy Storage (BES) exploit the chemical energy of the storage media through reversible chemical reactions.

Energy systems have evolved based on the flexibility provided by fossil fuels, and as the sources of primary energy for modern societies change over the long-term, future energy systems will have to radically change to accommodate the loss of TWh of stored energy at a regional level.

Nomenclature

EDLC	Electrochemical Double Layer Capacitor
PHES	Pumped Hydro Energy Storage
ACAES	adiabatic Compressed Air Energy Storage
LAES	Liquid Air Energy Storage
SMES	Superconducting Magnetic Energy Storage
FBES	Flow Battery Energy Storage
BES	Battery Energy Storage
DCES	Dielectric Capacitor Energy Storage
CCGT	Combined Cycle Gas Turbine

2. Energy storage and fossil-fuels

Without the critical component of storage, energy systems have little or no ability to withstand exogenous shocks that can have widespread, damaging consequences to the system itself and also to the end users that rely on the system. The concept of a ‘Just-in-Time’ system has been applied to electrical systems and management studies of supply chains, but this is always determined by setting particular boundary conditions for the ‘Just-in-Time’ description to be potentially valid. When looking at these same systems with wider boundary conditions, stocks of material and stores of energy are ubiquitous. In a system where the primary energy is supplied by fossil-fuels, the wider supply chain has a degree of control of when the resource is extracted, transported, stored and finally combusted. The presence of fossil-fuel stocks clearly signifies that electrical energy systems are not ‘Just-in-time’ when a broader view of the supply chain is taken.

In stark contrast with fossil-fuel supply chains, there is **NO** ability to store wind or solar energy before it is harvested; leaving the only option for a store of energy to be provided after energy has been harvested. If a technology transforms wind or solar energy into electricity (rather than heat), the drawback of this fantastically useful form of energy is its difficulty to be stored in an economic manner. (It is technically possible to store electrical energy directly in capacitors, but their costs and the meagre energy density of such devices preclude their use for storing an appreciable amount of energy.) If electrical energy is to be stored, it is therefore