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Linking energy policy, electricity generation and transmission using strong sustainability and co-optimization

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ABSTRACT

The design of a sustainable electricity generation and transmission system is based on the established science of anthropogenic climate change and the realization that depending on imported fossil-fuels is becoming a measure of energy insecurity of supply. A model is proposed which integrates generation fuel mix composition, assignment of plants and optimized power flow, using Portugal as a case study. The result of this co-optimized approach is an overall set of generator types/fuels which increases the diversity of Portuguese electricity supply, lowers its dependency on imported fuels by 21.30% and moves the country towards meeting its regional and international obligations of 31% energy from renewables by 2020 and a 27% reduction in greenhouse gas emissions by 2012, respectively. The quantity and composition of power generation at each bus is specified, with particular focus on quantifying the amount of distributed generation. Based on other works, the resultant, overall distributed capacity penetration of 11.88% of total installed generation is expected to yield positive network benefits. Thus, the model demonstrates that national energy policy and technical deployment can be linked through sustainability and, moreover, that the respective goals may be mutually achieved via holistic, integrated design.

1. Introduction

A sustainable electricity system is one in which all stages of the energy path are addressed, including the composition of the generation mix, the allocation of centralized and distributed generation, and their subsequent deployment. This work aims to create a link between a national, sustainable electricity policy and the performance of its transmission grid, recognizing that the latter may better fit within the former if they are co-designed and optimized.

The goal of sustainable energy systems is to deliver affordable energy services while raising the living standard for the global population, chiefly through increased energy efficiency and deployment of renewables [1]. In particular, the latter can contribute to mitigating the emissions of greenhouse gases (GHG), namely carbon dioxide (CO_2), and enhancing energy security of supply and independence.

From the beginning of the Industrial Revolution, carbon emissions have increased non-linearly per year to 38 Gt CO_2 in 2004. Three quarters of these emissions were due to human activities, of which fossil-fuel combustion accounted for 56.60% [2]. The consequence of these emissions has been an increase in the concentration of atmospheric CO_2 to the current value of 383.72 parts per million (ppm) [3], which is the highest recorded in the 650,000 years preceding industrialization [4]. Among other effects, the mean surface temperature of the earth has been rising, with average 2007 temperatures being 0.91° higher than in 1907, making the former the eighth warmest year recorded [5]. Various international agreements have been ratified to address this anthropogenic-induced climate change. The most wide-reaching of them is the Kyoto Protocol to the United Nations Framework Convention on Climate Change which requires Annex I countries to achieve an overall target of at least a 5% decrease in emissions below 1990 levels in the period 2008–2012 [6]. A number of regions and countries have implemented national emissions policies, with examples of the European Commission (EC) successor to Directive 2001/77/EC which will require 20% energy from renewables by 2020 [7] and the United States Government 2008 announcement of a halt to GHG emissions by 2025, with sustained reduction from then.

Combining rising oil and gas prices with a recognized dependence of the developed world on foreign resources, the issue of security of supply and energy independence is being raised more commonly. For many countries, achieving the latter may require a switch from imported fossil-fuels to domestic supplies of coal or the stimulation of natural, indigenous wind, solar, geothermal, hydro and biomass resource use. The research conducted in the field of energy security of supply includes: deriving an underestimated cost of 3×10^{-7} €/MWh for each barrel of oil not supplied to the market

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