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The Long-Term Power System Evolution – First Optimisation Results

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Abstract

The volatile character of the renewable generation plus the fluctuating demand, implicate challenges regarding a stable operation of the power system. To balance generation and demand on temporal and spatial basis, flexibility is required, which can be supplied by different sources, like interconnection of heat and electricity sector, increased grid exchange capacities between generation and demand regions or backup and storage power capacities of different sizes and time scales. Different optimisation approaches for future energy scenarios have already been investigated before by numerous researchers.

We present first results from a novel method which has been developed at RWTH Aachen University and is incorporated into the GENESYS optimisation tool. The updated tool is capable of optimising investments during a long-term evolution period between today and a future time (e.g. 2050), while simulating the operation of all power system elements on an hourly scale. The calculation is demonstrated on a scenario of Europe including several countries. The current structure of the power system has been parameterised with remaining runtimes of thermal power plants according to political roadmaps. CO_2 emission targets, as well as techno-economic developments of the system components follow exogenous boundaries. The results show, on a national aggregated level, the system development and dispatch. The system configuration, however, changes on an annual basis due to the optimised investments in new generation, storage or transmission capacities during the considered period. The optimisation variables are the installation rates per year of each technology component for each region and can be optimised and their range can be set independently. This defines the path of evolution towards a sustainable system in 2050. The optimisation target is achieved by minimizing the capital investment and operational expenditure of the system over the investigated period via annuity calculation for each simulation year.

In this paper, first results based on the novel method are presented and analysed.

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1. Introduction

Initiated by the industrialisation of the 19th century anthropogenic activities caused a massive increase of greenhouse gas (GHG) concentrations in the atmosphere, mainly due to combustion of fossil-based fuels in combustion processes. This has led to phenomena like global warming, which amongst others also affect the electricity production and lead to uncertainty of water inflow to hydro power, cooling water restrictions, heat waves, and damage by hailstorms. . Since these developments represent an enormous threat to society and economy globally, mutual efforts are being taken to address and mitigate those effects, especially by the United Nations (+2 °C targets) and the European Union (EU). The implementation of energy related targets into EU policy was intensified after the acceptance of the Kyoto Protocol in1998 [1]. The main targets of the current EU policy are based on the pillars a) security of supply, b) sustainability and c) competitiveness. The strategy is formulated in the Roadmap Towards a Low Carbon Economy [2], the Energy Roadmap 2050 [3] and the Roadmap to a Resource Efficient Europe [4].

The aims of these initiatives are unified in the EU priority program "Energy Union and Climate" [5], where the aims are formulated as Energy Strategies for the upcoming decades 2020, 2030 and 2030 [6]. The Energy Strategy specifies targets for GHG emissions (-20% by 2020, -40% by 2030 and - 80-95% by 2050 compared to 1990 levels), a share of renewable energy on the total consumption (20% by 2020, 27% by 2030 and 75% by 2050). Another corner stone of the initiative is the commitment to energy efficiency in all sectors (20% by 2020, 27% by 2030 and 41% by 2040 compared to 2005-06) [7]. Since the EU is a net energy importer, this initiative also intends enabling for economic competitiveness and less energy dependency.

The energy sector accounts for more than 80% of the total GHG emission of EU28 in 2014 or 61% compared to the total GHG emission of 1990 [8], therefore most efforts are taken in this field. For policy makers to make appropriate decisions in this complex matter with investment periods of +30 years and multiple uncertainty factors, only a model based approach seems realistic. While studies in the recent past focused successfully on the general feasibility of a renewable energy based power sector without fossil or nuclear power ([9], [10], [11]), more recent investigations concentrate on the development pathway [12], similar to the topic of this work. The EU utilises the PRIMES Model, developed by the E3Mlab of the University of Athens to investigate the effects of possible policy scenarios. Furthermore they have published a full reference scenario to compare against [13]. While [12] shows a brief overview on existing power system models, and points out that a combined investigation of long-term system development and short-term operation is mandatory for an adequate model ([14], [15]), our model GENESYS was extended to meet these challenging requirements. Not only is our model capable of optimising the component configuration from the current system towards a future year (2050) by minimisation of levelized cost of electricity (LCOE), we also incorporate the historic development of component installations to represent a more realistic phase out of older power plants. Furthermore our model is able to simulate the system power plant dispatch behaviour on a variable scale with a maximal resolution of one hour for the full time horizon.

The structure of this paper provides an overview of the methodology, including the developed model, the optimisation approach for investments and dispatch operation, followed by a presentation of the investigated problem, including the model parametrisation and boundaries. That part is trailed by the presentation and discussion of the obtained results. The paper finishes with a concluding statement and summary.