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Spatio-temporal modelling of electrical supply systems to optimize the site planning process for renewable energies – the case study Power-to-Mobility

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Abstract

The energy-transformation towards renewable energies requires also storage systems to ensure security of supply. Motivated by strategies to implement renewables up to 100 % at a regional scale, this paper presents a simulation of the power production from a virtual power plant based on 13 photovoltaic plants to integrate the "Power-to-Mobility"-technology, an innovative storage-technology to compensate fluctuating power production. The aim is to develop a simulation methodology with spatial-temporal and electrical parameters for a better management of the storage system. The project is work in progress but first results of the simulation show synergies between virtual power plants and Power-to-Mobility.

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Keywords: QGIS, OpenDSS, Distribution system simulation, Power-to-Mobility

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1. Introduction

The current UN resolution "Transforming our world: the 2030 Agenda for Sustainable Development" in September 2015 [1] or the Climate Treaty "UN Conference on Climate Change" in November 2015, Paris [2] point out the need of the energy transition towards low-carbon and resource-efficient. Besides the advantages to protect the climate and fossil resource, however, new challenges to security of energy supply arise with increasing expansion of renewable energy. The challenge mainly concerns the spatial and temporal variations of the energy demand as well as in the energy supply especially from wind or photovoltaic. Therefore it is a goal to develop a portfolio of different power plants at various locations, to minimize the variations of supply. Despite these so called virtual power plants [3], storage systems remain essential to quickly and flexibly respond to changing environmental conditions.

The storage of electrical energy is deemed to be the central challenge for the integration of renewable energies in the power grid [4]. Beside the known technologies like pumped storage plants or compressed-air storages [5] the focus is directed increasingly on decentralized electric power storages and technologies which allow a change of the power into methane [6]. Although these technologies offer a promising potential, the technology is at the moment still in the development phase. The presented project analyzes the possibilities to integrate a Power-to-Mobility (PtM) plant into a regional power grid. Methane is generated microbiologically in the reactor of the system by using hydrogen and CO_2. The hydrogen is produced by electricity in the electrolyzer. The methane can either run into the gas distribution system or can be used as a fuel for natural gas-powered vehicles. When required, the process of methanation can also be reversed via thermic power plants to generate electrical power. Therefore, an efficient coordination with the supply and demand of the current network situation is necessary for both economic and grid stability reasons. The aim of the research is to analyze this bidirectional energy flow and its effects on the power grid and to indicate potentials for the integration of the technology in existing supply structures to promote thereby a further extension of renewable energies at regional scale.

2. Virtual power plants and storage technologies

2.1. Demand of the PtM system

Especially the methane production is viewed as a seminal technology with a high level of innovation potential, since the existing natural gas net could be used for storage. In this so called power to gas method, the water-electrolysis uses electrical energy from renewable sources in order to split-up hydrogen and oxygen. The produced hydrogen is used directly or is synthesized into methane with carbon dioxide and so fed into the existing natural gas net as synthesized natural gas (SNG). The needed carbon dioxide can be produced from renewable energy sources such as biogas or wastewater treatment plants [7].

Biological methanizing is a method of microbial conversion from hydrogen and carbon oxide to methane and a counterpart for the chemical-catalytic procedure. The methanizing reaction hereby takes place via methanogenic archaea and is generally described with the following stoichiometric equation:

$$4\,H_2 + CO_2 \rightarrow CH_4 + 2\,H_20$$

In the PtM project (MicroPyros GmbH 2016) the results of the prior technical phase are transferred and further developed with extended periphery and additional components in an upscale research facility. The methanation is supposed to take place in combination with at least two bioreactors in order to use synergies in concurrence with the other plant components (methane storage, gas purification) as well as the integration of the electrolyzer into the power grid (Fig. 1). For the operation of the electrolyzer renewable energy is supposed to be used and, at the same time, the hydrogen storage is to be technically small and efficient. Either a market-oriented real-time regulation of the facility or the integration into a virtual power plant will be used in order to ensure a tailored to need power supply. Both development options for the first time lead to a flexible and economic mode of operation of a complete power to gas facility, where either cost-efficient excess current or in-house produced power is used.