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Energy Efficiency and demand side management: A case study of a holistic energy concept in polymer processing.

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Abstract

The German energy market transition is based on renewable energy systems (RES), energy efficiency and emissions reduction. Achieving sustainability targets requires consideration of the impacts of and interactions between a diverse range of measures and actors. This research presents a case study of a polymer processing factory, and a holistic energy concept intended to improve industrial sustainability. This concept encompasses the technological modification and extension of the production and factory´s energy supply by combined heat and power generation. The additional simulation of demand side management (DSM) enables the adaptation of the electricity consumption in accordance with the volatile RES generation. The application of both machine-based energy efficiency measures and the grid-oriented DSM contributes to a higher usage rate of RES and reduces the emissions of both the factory and the grid.

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Keywords: energy; energy effciency; sustainable development; polymer processing; demand side management

1. Introduction

The energy market transition in Germany relies on a number of pillars, including renewable energy generation, reduction of primary energy demand and emissions, and increased energy efficiency [1]. Environmental policies and energy economical instruments have been established to address different market segments and participants to achieve different goals in their target fields. In the past, the various energy system and market structures that have developed over time, such as top-down organized electricity generation and the transportation system, are continuously changing. This in turn means that different measures and developments are implemented simultaneously. This research aims to take two such energy measures and combine them, with the aim of identifying and using synergies between the two.

One of the effects of the political support for the development of renewable energy systems' (RES) is the additional

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requirement for consumers to become operators (prosumers) of small energy generation plants, such as photovoltaic (PV), wind or combined heat- and power units (CHP). Even so, the motivation of industrial prosumers is mainly driven by the possibility of reducing energy costs; those measures related to the reduction of primary energy demand also have a key role in the decision-making process [2]. The polymer processing company analysed in this study implemented a decentralised energy concept to supply its manufacturing. The innovative approach in this case is the modification of the processes that enables an interconnection of the energy flows and financially, technologically and economically viable usage of a CHP.

For local grid operators, who already face the challenge of non-controllable, seasonal, weather and time-of-day dependent energy generation of PV and wind power plants [3], the increasing number of CHP units is not a grid balancing measure per-se, because it uniformly lowers the base load of the demand. Due to the spatial decoupling of energy generation and consumption, as well as feed-in of the RES on the low and medium voltage levels, distribution grids are particularly stressed. To meet the challenge, the grid operators have two options: on the one hand, the existing electrical grid can be upgraded by means of an extension so that it can withstand the existing fluctuations. On the other hand, non-taxable energy generation and consumption can be reconciled by the increased flexibility of consumers through use of demand side management (DSM) measures. [4]

The tension between RES volatility and decentralisation of the energy supply is the emphasis of this research. The analysis shows the step-by-step development of the new CHP-based energy supply concept for the blow film factory, and the identification of the potential for DSM due to the need for a local grid with a high fluctuation of RES. The case study aims to embed both approaches to a holistic concept for a smart grid.

2. Demand side management – State of the Art

DSM provides an active integration of the customer into the market by influencing its load profile [5]. A variety of factors can affect the need for DSM, such as the reduction of energy costs or provision of system services. In general, a system can be controlled in two directions. In the case of generation being higher than demand, demand can be increased or generation reduced: this is negative DSM. Where generation is lower than demand, demand is reduced or generation increased: positive DSM. Measures that serve the flexibility of a company can be divided into [6,7]:

1. Power-to-battery describes flexibility from operating a battery for direct electricity conservation.
2. Power-to-storage means decoupling of production and consumption over time by storing energy in a converted form, e.g. thermal energy or compressed air.
3. Power-to-product is indirect energy storage from shifting production processes that are mostly batch-operated.
4. Power-to-system refers to the ability to switch between at least two energy sources (for DSM one of them should be electricity) to operate supply systems or machines such as electrical and natural gas-fired boilers
5. Flex-supply requires the existence of a decentralized energy supply which operation plan considers grid-oriented usage, where temporary the supply swaps back to the public grid.

Several studies estimate DSM potential within a number of industrial sectors [7-12]. The focus is particularly on energy intensive industries, such as cement production [13], steel, and aluminum plants, or on single processes such as electrolysis, with the goal of increasing the flexibility of electricity demand. Studies [8, 9, 11, 12, 18] also examine DSM in cross-sectional technologies such as compressed air and refrigeration. However, these industrial consumers are mostly connected to the transmission grid, and the scale of identified flexibility is of the order of megawatts across a single industry. This makes an attractive prospect for the wholesale and energy balancing markets, but such loads are not useful when it comes to balancing RES fluctuations in distribution grids.

Polymer processing is an energy intensive industry characterised by a large number of small- and medium-sized factories that are connected to medium-voltage grids. However, it has not been widely examined in the literature on DSM. One reason for this is that under the current design of the production value chain there is limited opportunity to shift energy loads. The main processing machines, such as blow film extruders have the highest energy demand [14], but operate almost continuously at full capacity, which excludes any possibility of time-based shifting. A high-level analysis shows that through an implementation of energy efficiency measures the potential for flexibility increases by up to 44 % [15]. These results are used in the current study. By illustrating how a new energy concept can be implemented and modelling grid-oriented operation, it estimates the available potential for DSM.