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Integration of On-site Energy Generation into Production Planning Systems

Fabian Keller[a]*, Stefan Braunreuther[a], Gunther Reinhart[a]

[a]*Project Group Resource-efficient Mechatronic Processing Machines of Fraunhofer IWU, Beim Glaspalast 5, 86153 Augsburg, Germany*
* Corresponding author. Tel.: + 49 821 56883-91; Fax: + 49 821 56883-50. Email address: fabian.keller@iwu.fraunhofer.de

Abstract

Due to the energy turnaround in Germany, the costs for energy are peaking year by year. As a result, industrial companies are investing in on-site generation, preferably from renewable sources like photovoltaic. Companies can profit from an on-site usage in order to hedge price volatility. Therefore, the fluctuating on-site energy and the public energy supply need to be synchronized to the production demand in an efficient way. In order to use the fluctuating renewable on-site generation, a transformation of the production organization and the production planning systems is needed towards the concept of energy flexibility.

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1. Introduction

The German exit from nuclear and fossil-fuel energy poses a challenge for industrial enterprises. Increasing costs and decreasing service security cause essential fields of action [1] especially in terms of production planning and control. Thus in recent years, manufacturing companies in Germany have steadily increased the use of on-site generation in order to provide for their energy demand themselves. The reason for this development is the state subsidization, particularly of renewable energies, leading to cost advantages compared to obtaining the power from the public grid. In addition, an on-site generation results in a greater independence from external utility companies [2]. The status quo, where the energy produced with renewables is sold and fed into the public grid and where the energy needed was obtained from the public grid in return, is becoming less profitable, due to rising energy costs and falling compensation for energy fed into the grid. Therefore, numerous companies switch over to consume the energy of on-site generation themselves [3]. This approach, called on-site generation, covered 9 % of the overall industrial and private energy demand in Germany in 2014. More than 60 % of the companies trusted on power generation by photovoltaics in 2013, 14 % of the companies made use of wind power. Hence, a significant portion of on-site generation is based on renewable energies, which are fluctuant over time and in quantity [3]. That is why the warranty of a reliable and cost-efficient energy supply is to be viewed as a real challenge. In order to master this challenge, the on-site generation must be integrated into production planning and control processes. The power demand is then synchronized with the on-site generation's energy supply. Afterwards the production planning takes measures to adapt the power demands, for example buying additional power from the public grid or delaying the production to a timeframe with lower energy costs due to an energy surplus. Since energy storage allows the compensation of energy surpluses as well as energy shortages, its application should be considered in the production planning and control.

An integrated concept of on-site generation can contribute to cost savings concerning the power supply of the manufacturing.

2. Energy as a Resource in Production Planning and Control

Production planning and control systems support manufacturing companies in aligning logistic and economic

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goals in times of ever-expanding complexity and variety of products. Production planning and control comprises two sectors: Production planning, dealing with long-term and short-term planning processes, and production control, aiming at approving and monitoring the production orders processed at any time [4]. In the production planning, there are individual, consecutive process steps, for example the planning of schedules, the planning of volumes, the planning of dates and capacities, as well as the machine scheduling. Each of these steps contributes to the overall frame, in which the manufacturing schedule is being continually rendered more precisely [5]. In the past, numerous authors in the scientific literature have dealt with integrating energy as a resource into the production planning and control. However, their approaches focus on integrating energy efficiency into production planning [6]. A new approach brings the optimization of the way of obtaining energy into focus. Here, the examination is limited to the public grid; the approach does not consider on-site generation nor the use of on-site generation and energy storages [7]. Yet, integrating the energy market into the production planning and control systems forms the basis for considering on-site generation and energy storage.

3. On-site Generation and Energy Storage

Power plants differ in their characteristic features and show distinct patterns in terms of their energy supply's constancy, which allow a categorization in continuous and fluctuating power plants. Energy storages can be classified into functional storages and power storages, according to their intended use. The aforementioned classification in categories forms the basis for the integration into production planning and control systems.

3.1. Continuous Power Plants

Continuous power plants produce electricity in a largely steady manner by employing constantly accessible energy sources that are not subject to volatility in their amount. Such energy sources can be stored in reservoirs or else their supply is bound by a contract. Important continuous power plants are for example block heat power plants, gas-fired or coal-fired power plants, and power plants using cogeneration of heat and power [2]. Continuous power plants show a constant operation, they have constant key performance indicators (KPIs), which are valid for both the long-term and the short-term planning. By offering this precise information about their production of energy, the power plants allow for planning well in advance. Continuous power plants usually have an optimum operating point at which they achieve the best efficiency factor. The amount of energy produced at this point is measured in *kWh* and is to be embedded into the production planning and control system. However, the power plants remain controllable, i.e. their operation can be accelerated as well as decelerated, depending on the current power demand. Hence, apart from the optimum operating point, they have a maximum and a minimum performance indicator [8], the latter of which is the result of the power plant's deceleration. The production planning and control must be aware of this controllability, in order to demonstrate the production engineers their scope of action.

Moreover, continuous power plants feature calculable operating costs, which are significantly dependent on the fuel costs. These operating costs must as well be integrated into the production planning and control system. The energy generation is integrated using so-called energy plans, which contain all the relevant information concerning the amount of energy produced and thus provide a basis for the production planning and control.

3.2. Fluctuating Power Plants

Fluctuating power plants, on the other hand, do not provide a permanent and guaranteed energy supply, since their energy sources are not steadily available, due to the unsettled weather conditions. Consequently, the amount of energy generation cannot be controlled and the amount can only be projected to a limited extent. In contrast to the continuous power plants, the fluctuating power plants do not offer constant characteristic values in terms of their energy generation. Thus, the planning is based on long-term and short-term forecasts of the energy yield, typically covering the future 12 months to 4 days, respectively [9]. However, the forecast values measured in *kWh* are not reliable; instead they represent the average in a range of calculable variations of the energy amount [10]. The shorter the forecast horizon gets, the higher the reliability, and thus the narrower the range of variation [11]. Figure 1 illustrates this development.

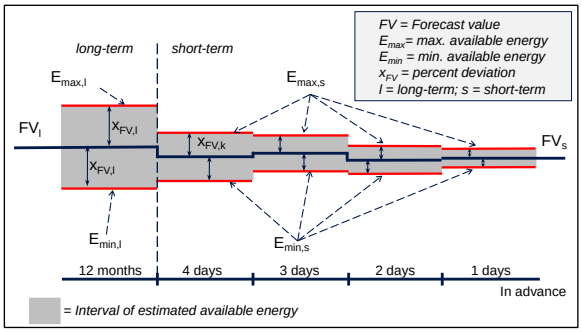

Figure 1: Development of estimated available energy of fluctuating power plants

In order to integrate the fluctuating power plants into the production planning and control systems successfully, the forecast values must be transferred to the system, adding the annotation that they are not reliable. Since the forecasts keeps getting more reliable as the time of production approaches, the production planning and control system must update the forecast values regularly, in contrast to the procedure with continuous power plants. The result is a detailed production planning and control at any time. The integration of the forecast values also considers the aforementioned energy plans.

The greatest advantage of fluctuating power plants is their use of energy sources that are free of charge. If the investment