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Method for an energy-oriented production control

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Abstract

Increasing energy costs as well as a growing awareness for sustainability are challenging companies to use energy more efficiently. Therefore, a company's production planning and control strategies have to be adapted. This paper presents a method for a short-term production control which aims to synchronize the energy demand in manufacturing with a limited energy supply. The method treats electric energy as a limited production capacity where load profiles for manufacturing are predetermined and integrates load management into the production control in order to minimize energy costs.

Keywords: Production control; energy flexibility; energy efficiency; renewable energies; load management

Nomenclature

$C_{i,0}$	Current level of buffer i
$C_{i,max}$	Maximum capacity of buffer i
$t_{C,i=0}$	Time to empty buffer i
$t_{C,i=max}$	Time to fill buffer i
$t_{op,max,j}$	Maximum operating time of measure j
$t_{act,j}$	Activating time of measure j
P_k	Power demand of operating state k
CT_k	Cycle time of operating state k

1. Introduction

Due to the nuclear phase-out, the energy system in Germany is changing. Baseload power plants are substituted by an increased share of renewable energy sources, mainly wind and solar power [1]. This ongoing process has led to a rise in costs for electric energy for industrial consumers of roughly 150 % in the last 15 years [2]. Also, the power generation by wind turbines and photovoltaics is volatile which can lead to significant differences in regional power generation and to discrepancies between energy supply and energy demand. As a result of the volatility, the stability of the power grid may be compromised and short-term energy prices, e.g. the EPEX SPOT, show increasing fluctuation [3].

Since the energy grid has to be in balance at every time, flexibility on the demand side gains importance to cope with volatile energy supply. While formerly the power generation was adjusted to the prospective power demand, this premise is now reversed. Flexible consumers which are capable of shifting their loads from peak to off-peak hours may contribute to the stability of the power grid. Also, since energy prices in off-peak hours are typically lower, these consumers may gain a financial benefit [4]. This form of Demand Side Management (DSM) is especially attractive for industrial consumers because they can shift loads at a larger scale than domestic homes. Therefore, time variable energy prices should be considered in a company's production planning [5].

2. Minimization of energy costs by production planning and control

In order to benefit from time variable prices, the purchasing of energy must be integrated into a company's production planning process. During production planning machine schedules are created which in turn determine the

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energy demand of the company. If variable energy prices are considered in production planning, the machine schedule as well as the company's energy purchase can be adapted mutually to minimize energy costs [6].

Therefore, in addition to a machine schedule an energy schedule is created which defines the availability of electric energy for a given period. This schedule is generated using different tariffs like baseload tariffs, peak tariffs or spot market blocks. For this article, it is assumed that the energy schedule is fixated on the day prior to the manufacturing process at the latest. This is due to the fact that the intraday market in Germany shows high fluctuation in energy prices which in turn increases the price risk. Figure 1 shows an example of an energy schedule which determines the availability of electric energy for manufacturing. For every period of 15 minutes a mean power demand is specified.

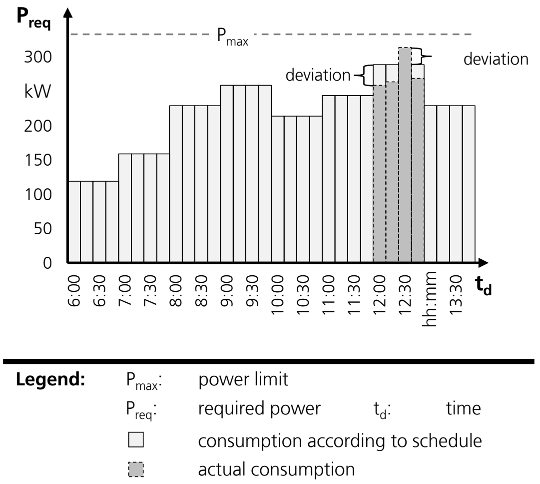

Figure 1: Energy schedule

Since energy suppliers rely on accurate schedules for their own processes, consumers who deviate from their schedule at any time are charged with penalties. This means that consumers who either use more energy or less in any 15 min. interval have to expect additional energy costs. This way, electric energy becomes a quasi-limited capacity for manufacturing comparable to machine capacity and therefore has to be considered during the production control process. The capacity is quasi-limited because from the perspective of a single company the availability of electric energy is not limited technically but costs for penalties might be disproportionately high.

2.1. Cost modelling

To describe costs associated with deviations from the schedule, the following cost model is proposed in Figure 2. For each 15 min. interval an amount of electric energy $E_{0,i}$ is purchased at the lowest possible price $C_{0,i}$. The amount may also be presented as a mean power demand $ØP_{0,i}$ during this interval.

Deviations from the mean power demand might occur in many ways. For example if the operating time for a specific job is longer than planned the power demand will be increased or if a machine breaks down the demand will be decreased. When positive or negative deviations are expected during this interval, the difference between planned and actual power demand has to be evened out by purchasing or selling the amount of energy on the intraday market at the current price c_{Spot}. Otherwise, the consumer is charged with cost penalties c_{AEP}. In order to trade on the intraday market, the deviation must be known in advance, e.g. in Germany the trade must be made 45 minutes prior to delivery.

However, energy suppliers typically allow deviations from the schedule within a tolerance of few percent. This corridor (α_{ug}, α_{og}) might be widened if energy self-supply is used which may increase or decrease its power generation for a short time period.

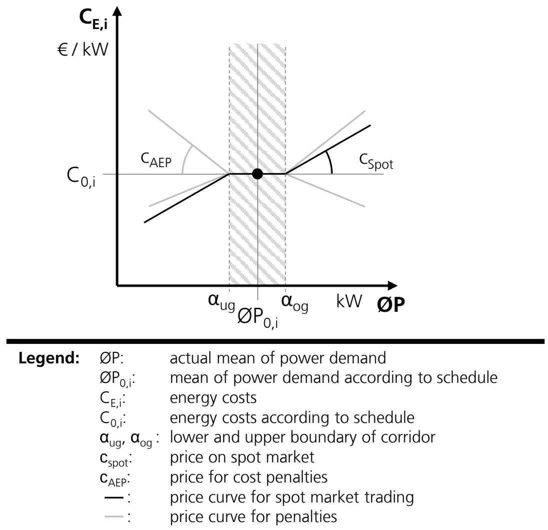

Figure 2: Cost model for a 15 minute interval

Since spot market prices usually fluctuate throughout the day, this cost model has to be evaluated for each single 15 minute interval separately. An energy-oriented production control should consider each interval and minimize overall costs, i.e. minimize the sum of additional costs for deviations of all intervals.

The goal for energy-oriented production control described in this article is to minimize deviations in energy consumption from a given energy schedule in manufacturing in order to minimize energy costs.

3. Energy-oriented production control

3.1. Tasks of production control

Lödding has developed a model to describe the tasks of regular production control which is shown in Figure 3 [7]. The task order generation on the left side of Figure 3 defines the planned values as well as targets for manufacturing and is typically part of the production planning process. According to Lödding production control is composed of the tasks order release, capacity control and sequencing.