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Procedia CIRP 61 (2017) 416 – 421

www.elsevier.com/locate/procedia

The 24th CIRP Conference on Life Cycle Engineering

Integration and Interaction of Energy Flexible Manufacturing Systems within a Smart Grid

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Abstract

The need for clean, safe and inexpensive energy provision is driving many countries in the transition towards renewable energies. Due to the characteristics of solar and wind power, a volatile energy provision and therefore an increasing instability of the grid can be observed. Hence, a fast and efficient communication and interaction of energy providers and energy consumers within the grid is necessary. Manufacturing companies can enable the efficient integration of renewable energies to the grid and can additionally gain a competitive advantage through the concept of energy-flexibility. This paper presents findings of the future interaction of factories and an approach for integrating manufacturing systems into a smart grid environment.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering

Keywords: energy efficiency; energy-flexibility; manufacturing systems; production planning and control

1. Motivation

In December 2015, the United Nations Framework Convention on Climate Change (UNFCCC) agreed on a global climate agenda, in order to limit the global warming due to manmade green-house-gas emissions [1]. Therefore, an annual decrease by 1.9 % of energy related CO_2 emissions between 2013 and 2040 is strived for, so as to reach the set 2 degrees Celsius agreement. Besides efforts to use energy efficiently, the goal is to steadily substitute fossil fuels by increasing the share of renewable energies to 30 % [2]. This forces economies worldwide to change their current energy supply towards a higher share of renewable and CO_2 neutral energies within their energy system. As an example, Germany is shifting the public electricity supply strongly towards a sustainable energy provision, and at the same time opts out of nuclear power generation [3]. By the year 2050, Germany aims at an 80 % share of renewable energy source in the country's electricity generation, mostly using solar and wind power plants [4]. Due to the volatile provision of these energy sources, the German power grid is facing an imbalance of electric demand and supply and is becoming increasingly instable [5]. This results in rising power grid infrastructure costs [6], redispatching efforts [7] and a need for demand response alternatives, in order to control these imbalances [8]. In the past, the power distribution by the grid can be described as unidirectional [9]. Therefore, imbalances were stabilized by the power suppliers. As the supply side is currently facing the volatile electric feed in, bidirectional approaches, e.g. demand response, are needed in a so called smart grid environment [10].

Besides households and commercial consumers, the industry can contribute significantly to the effectiveness and elasticity of demand response by adapting its electricity demand towards the gird [8]. This concept is defined as energy-flexibility, which describes the ability of a manufacturing company and its manufacturing systems to adapt the production to short-term changes in the energy provision with as little loss in time, effort, costs and performance as possible [11, 12]. In order to realize these load adaptions, manufacturing systems need to be integrated into a smart grid with a short-term communication approach.

Peer-review under responsibility of the scientific committee of the 24th CIRP Conference on Life Cycle Engineering
doi:10.1016/j.procir.2016.11.250

Thereby, manual or automated changes in the load profile can be performed between the grid and the production within an immediate timeframe. Thus, energy-flexibility in production has the potential to contribute to the power system's stability. Currently, the German energy system is facing an organizational change, called energy-market 2.0, which will impact future market designs and regulation [13]. The importance of demand-response is clearly expressed, but the conditions and implementation is still not defined. Therefore, this paper presents findings from expert panels how energy-flexible manufacturing systems can be integrated to a smart grid approach and how a possible interaction can be technically realized.

2. Integration of energy-flexible manufacturing systems

2.1. Current situation in Germany

The possibilities of a factory to provide energy-flexibility to the grid can be divided into long-term and short-term markets [14]. For the increasing demand-response-applications, short-term markets are focused. In Germany, these markets consist currently of a *Spot Market* and a *Control Power Market*. The Spot Market is divided into a *day-ahead market* and an *intraday market*, where electric demands can be traded one day before or during the day on a public exchange. Therefore, the load adaption can be made shortly before the physical energy provision. The Control Power Market is an auction-based system, which aims to balance the power grid whenever an imbalance occurs. Therefore, the request for flexible loads is unknown and uncertain for the company and is requested during the production process. At the moment, the market structure and regulation design in Germany is not sufficiently adapted to the consumers' flexibility potentials that are already available or yet to be developed. This is the reason why the consumers' participation that could be beneficial for the system is limited by hindrances and market entry barriers at present [15]. Main obstacles for manufacturing companies are the requested high loads, the fixed bidding and holding periods as well as the limited reimbursement potential [16]. To ensure that industrial companies are able to offer and market their loads appropriately, such hindrances, e.g. distorted price signals on the Spot Market, need to be reduced. Furthermore, market entry barriers that are caused by the design of tender procedures need to be revised [16, 17]. As the regulation and demand response market are in an undergoing change process, expert groups were surveyed in order to gain knowledge about future developments.

2.2. Expert groups surveys about future electricity market developments in Germany

In 2015, two expert groups were surveyed about the future developments of the German electricity market with the focus on industrial demand response. The first group consisted of production companies, which were interviewed and surveyed in collaborative workshops alongside the joint research project FOREnergy [16]. The second group consisted of pre-selected German market experts and was surveyed in individual in-depth interviews. The scope of the interviews contained the current and future power grid situation in Germany in general as well as for industrial companies. Table 1 summarizes the two surveyed groups.

Table 1: Surveyed expert groups in Germany

Group	n	Sectors	Method
Production experts	8	Chemical, metal production, metal processing, mechanical engineering, electronics, food processing	Research Workshops
Market experts	9	Government, research, consulting, association, utility	Selective Interviews

The production expert group generated insights about their capabilities to provide energy-flexibility to the power grid. The market expert group was surveyed about the future developments in order to market the flexible industrial loads to the grid.

2.3. Production group survey: Assessment of possible market options

In two consecutive workshops the production companies evaluated the options to provide their flexible loads to the *Spot Market* as well as to the *Control Power Market*. In collaboration with utility companies and research institutes, the results were summarized in advantages and disadvantages [16].

2.3.1. Integration in the Spot Market

The Spot Market is an attractive option for manufacturing companies to adapt themselves to a given energy market situation [16]. The crucial factor is the signaling effect of the electricity price and the related individual opportunity costs of each consumer. As a result, there are additional revenue potentials for the consumers if they adapt their demand temporarily and voluntarily. Therefore, companies need a direct access to the Spot Market or an indirect participation option, e.g. via a utility company through real time pricing contracts (RTP) [16]. The group stated three advantages of the Spot Market integration. Table 2 summarizes the results of the workshops.

Table 2: Results of the Spot Market and RTP assessment

Spot / RTP	Advantages	Disadvantages
	- Leveraging low and negative prices - Integration in production planning and control - Plannability of costs	- Price risk - Collision with load-maximum agreement

At first, low and negative prices are accessible for the production and can be transformed into value creation. Secondly, the integration in conventional planning and control process is possible, because the adaption is made before the energy provision and the start of production. As a result, the