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Potential and limitations for industrial demand side management

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Abstract

The growing share of variable renewable power such as wind and solar photovoltaic (PV) emphasize the importance of demand side management. In a couple of years consumers have to adapt their consumption more to available generated power in order to maintain grid stability and to reduce their electricity costs. In this study the potential and limitations for demand side management in about 15 different companies in Sweden has been investigated. A brief description of some of the company's production process is given, with focus on electrical consumption. Suggestions on different demand side management possibilities are presented as well as limitations. The suggestions are given for different time horizons, from load shifting between hours, to weeks and years. Potential savings achieved with demand side management have also been evaluated based on historical electricity prices from different countries.

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1. Introduction

There has been a large expansion of renewable power over the last years. According to [1] global wind power capacity have had an average growth rate of over 25% the past five years, reaching 238 GW at the end of 2011, solar photovoltaic (PV) had an even higher average growth rate of more than 50% over the past five years. Renewable energy are the fastest growing sources of electricity generation, see [2]. Hence even if this incredible growth slows down a bit there will gradually be a significant change in the way electricity is generated, shifting from controllable stable fossil and nuclear power to variable renewable

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power. The shift in power generation will in the beginning not be noticed by the consumers as long as the renewable energy share is small, there exists sufficient backup power and sufficient grid capacity, but at some point it will be difficult to match demand and supply. In USA for example this has been observed and different demand response related activities are ongoing, see e.g. [3]. For more information about demand side management (DSM) and demand response (DR), see e.g. [4], [5], [6] and [7].

Some consumers allow the power company or grid operator to install a remotely controlled device that can switch on or off electrical equipment at the consumer and in return they receive economic compensation. Another opportunity is to let the grid frequency control the consumption, i.e. if it is lower than the set-point then the consumption is reduced and vice versa, see e.g. [8].

To maximize the profit with demand side management an optimization has to be done that take into account different constraints as inventory levels, machine capacities, required quantity of produced units, etc. see e.g. [9], [10], [11] and [12].

There is also a "green value" in demand response since renewable resources are used more efficiently. A study in [13] showed that demand response increased the use of wind generated electricity and lowered the consumer average price of electricity.

Alternatives and complements to demand side management are energy storages, which for example could be based on batteries, pumped hydro, hot or cold water tanks, electrolysis of water to produce hydrogen, etc. Disadvantages with storages are often high price and small capacity. Another alternative and complement to DSM is improved power transmission between areas and countries with shortage and surplus of energy. Demand side management, energy storages and improved power transmission all reduces the need for expensive backup power that is needed only during a few days of the year.

2. Electrical cost saving potential

Demand side management makes it possible for the consumers to reduce their electricity costs. The saving potential depends on several factors, for example:

- Schedulable capacity, i.e. how large share of total consumption that can be rescheduled.
- Production capacity, i.e. could the production plan be fulfilled despite stops at high electricity prices.
- Inventory capacity, i.e. are buffer sizes sufficient for rescheduling some sub-processes.
- Size of typical price variations over the day, which depends on country, time of the year and day.

Rescheduling production may result in additional costs for labor, extra start up and shut downs, lost equipment life time, product quality reduction, etc. that are not taken into account in this paper.

Theoretical average monthly savings for demand side management is presented in Figure 1 from year 2011-2013 for Sweden (SE3), Denmark (DK1) and USA (NYC). The savings are calculated with the assumption that the power could be switched off during the most expensive 1, 5 or 10 hours and then the plant is run with a constant higher production rate during the remaining hours in order to obtain the same total production volume as if the plant was operated at constant normal speed for 24 hours.

USA has the largest price variations and thus the largest saving potential. The variations in Denmark are large due to a large share of wind power and small share of hydro power that can compensate for the variations in wind power generation. Sweden has smallest saving potential for opposite reasons.

3. Potential and limitations for industrial demand side management

The demand side management potential and limitations in some different industries are presented here. A general limitation is that most processes work better if they run at constant speed without stops. Costs caused by a different schedule have not been considered but must of course be included before deciding whether or not to apply demand response (DR).

Thermo Mechanical Pulp & Paper: Huge electrical energy consumer, 5 grinders, 7 pre- and 5 post-refiners uses up to 208MW, corresponding to 75% of plant consumption. Good potential for DR due to 5-

10% larger pulp than paper production capacity and pulp buffers that can store 6-9 h paper production. The limitation is the paper machine that in practice it is not possible to apply any load shifting to.

Chemical Pulp & Paper: Small potential due to complexity in maintaining mass and energy balances in pulping and chemical recovery process regarding black and white liquor buffer levels, recaustization, steam production, and supplying heat to district heating. The DR potential is in varying power generation in the bark boiler or closing down small units in the factory as debarking during short periods.

Steel: Blast furnaces, casting and coking plant are not suitable for DR since these processes take long time to start up and get stable. There is DR potential if excess capacity exists in the hot rolling mill (11-33MW) and in consecutive heat treatment process (17-30MW), which is partly heated by electricity.

Wire & wire rod: The electrical batch annealing (4MW) is suitable for DR. Another possibility in the studied mill is to shift some of the working hours to nights and weekends, instead of only running at daytime, although in practice this may not be possible due to higher salary costs than DR profit.

Die-casting: Limited DR possibilities, main potential is to shift working hours to nights and weekends.

Cement: Load shifting is possible for the 2x4.7MW and 2x2.8MW cement mills where clinker is ground with gypsum to produce cement. There are large buffers before and after these mills and the capacity of the mills is higher than clinker production in the kiln, see also [14]. If there was a larger buffer at the crushing in the quarry this would be another possibility for DR. The main DR limitation in cement production is the kiln that almost always operates at 100% and put limitations on other equipment.

Atmospheric and combustible gas: Production of liquid and pressurized products in the Nordpool spot area consumes max 100MW and max 20% may be load shifted. A DR limitation is that most gases are produced at customers without energy demanding storage. Another limitation is that the production cannot stop when it is very cold which coincides with the highest electricity prices in colder countries.

PVC: The potential for DR is very limited, at least for the plant we contacted, since they always operate at 100%. The whole plant consumes about 60MW of which 75% is used for chlorine gas production by electrolysis of salt (NaCl).

Oil refinery: The potential for DR is limited for the specialty oil plant we contacted since they always operate at 100%. The majority of their total 7,5MW power is used to heat pipelines and run electric motors connected to the production units or loading/discharges in the harbor.

Milk powder: Scheduling of the batch starting time where milk is evaporated to powder has the largest DR potential. A batch has a duration of about 20 hours and cannot be paused, then dishing with lower power consumption is done. Another DR possibility is to optimize the selection of fuel for the boiler that produces steam for the evaporators, which today runs on biogas (43%), oil (10%) and electricity (47%). About 2-2.5MW electrical power and 1.5-2MW from biogas is used for milk powder production.

Meat production: At the site we visited the largest DR potential was to move the 12 working h/day in the butchery and sausage production to periods with lower electricity prices. The cutting was operative 24h/day. Freezers and refrigerators uses about 1.1MW, corresponding to 60% of total consumption.

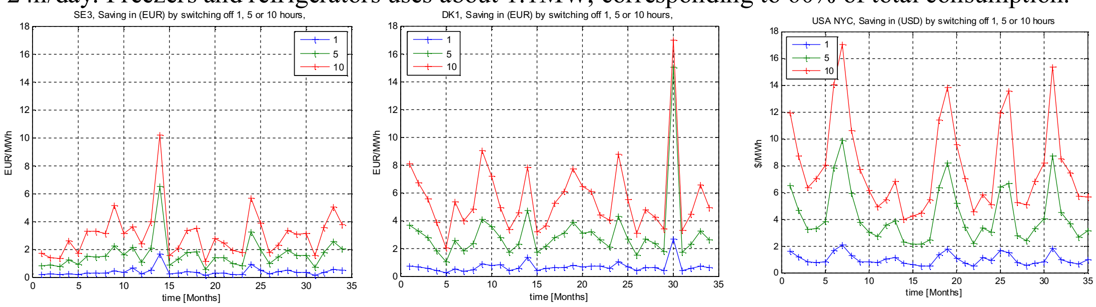

Fig. 1. Average monthly saving potential in EUR/MWh in Sweden SE3 and Denmark DK1, and in \$/MWh in USA NYC, 2011-2013 by switching off consumption for 1, 5 or 10 hours and then run faster the remaining hours to obtain same production volume.

Conclusions

The need for demand side management increases with an increasing share of renewable power. An evaluation of the potential and limitations for demand side management has been done at a number of different Swedish industries. The result was that demand side management is rarely used, there is potential (maybe smaller than we hoped for), and it is not always easy to apply it. To increase the DR potential, investments in increased production capacity, inventories and more flexible working hours may be required.

The reasons why most companies in Sweden do not make use of demand side management are, for example that they are producing at 100% capacity, they have very small buffers, they have no excess capacity in process sections, it takes several hours or days to reach a stable production after a stop, electricity is a small share of total production costs, it is complicated and expensive to do it, they have fixed price contracts for electricity, they have not considered it, etc.

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