Universities' Implicit Demand Response Participation

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Abstract—Universities are large energy consumers and can potentially benefit from the participation in the implicit demand response. However, universities usually concern the security of the energy budget and might have larger electricity bill if real-time prices are frequently higher than fixed prices. Therefore, this study investigates financial benefits and risks for a selected university to participate in the implicit DR programs with two scenarios: 1) purchasing electricity from the Nord Pool Spot market directly, and 2) participating in the up-regulating market via an aggregator. With the investigation of the yearly hourly-based electricity consumption, the Nord Pool Spot market prices and several interviews, the results show that the financial benefit by purchasing electricity from the Nord Pool Spot market directly instead of a fixed price is not significant if the fixed electricity prices negotiated with the electricity retailers are low. The universities can have significant revenue by participating in the up-regulating market if the flexibility capacity increases dramatically.

Index Terms—Demand response, energy saving, regulation markets, and energy budget

I. INTRODUCTION

This paper presents results from a study developed for the Smart Campus Program at the University of Southern Denmark (SDU) to estimate potentials and benefits for the university to participate in demand response programs. The study was developed under the framework of the university 2% annual energy cost saving.

There are two types of Demand Response (DR) programs: explicit and implicit demand response. The two types of DR programs are activated at different times and serve different purposes in markets [1]. Consumers receive a lower bill by participating in implicit DR, and receive a direct payment for participating in an explicit demand response program [2].

Explicit DR is divided into traditional-based (e.g. direct load control, interruptible pricing) and market-based (e.g. emergency demand response programs) [3]. Implicit DR is the voluntary program with time-varying electricity prices or time-varying network tariffs [4].

Usually, large electricity customers have opportunities to participate in implicit DR programs [15]. For instance, consumers reduce electricity usage at peak periods or shift their electricity usage to off-peak periods to participate in real-time pricing [9].

Universities are large energy consumers [5] and usually can negotiate electricity prices with energy retailers in Denmark [13]. For instance, the SDU buys the majority of electricity with a fixed price from the electricity retailer and buy a small percentage (around 10%) from the wholesale market – the Nord Pool Spot market, partly due to the security of the university electricity budget. However, other large electricity consumers, e.g. greenhouses, have shown a positive financial return by directly participating in the in real-time pricing. Meanwhile, participation in real-time pricing can be risky and have larger electricity bill if the spot prices are frequently higher than the fixed prices.

Therefore, this study aims to investigate the financial benefits and risks for SDU to participate in the implicit DR programs. Two scenarios for SDU to participate in the implicit DR are investigated in this study: 1) purchasing electricity from the Nord Pool Spot market directly instead of a fixed price, and 2) participating in the up-regulating market via an aggregator.

This paper firstly investigates the electricity consumption patterns at SDU, and then examines the potential benefit by purchasing electricity from the Nord Pool Spot market with the historical consumption data and spot prices between 2014
to 2017. Thirdly, the financial profits for SDU to participate in the up-regulating market are calculated in a developed MATLAB model.

II. BACKGROUND

A. Nord Pool Spot market

Nord Pool is the leading electricity market in the northern Europe that 380 companies from 20 countries trade electricity in different markets. Nord Pool is owned by Nordic and Baltic TSOs (Transmission System Operators) and the market contains the day-ahead and intraday markets. Furthermore, there is a regulating market that is run by TSOs in different countries.

- Day-Ahead market

The day ahead market is the market where more than 70% of electricity in the Nordic market is traded. The day-ahead market is an auction that power is traded for delivery during the next day. In Denmark, there are two markets (DK1 and DK2).

- Intraday market

Nord Pool offers an intraday market covering the Nordic, Baltic, UK, and German markets. The intraday market supplements the day-ahead market and helps secure the necessary balance between supply and demand in the power market for Northern Europe.

- Regulation market

The Nordic regulation market differs from the markets at Nord Pool. The Nord Pool markets are organised as a common market place with common member agreements and bidding rules. The Nordic regulation market (or regulation list) on the other hand is a compilation of bids given to the national balancing market places under rules and agreements set by the TSOs.

B. Demand Response potentials in Denmark

Currently, the electricity retailers or balance responsible parties take the role of aggregators in Denmark. This means that there is no independent aggregator in Denmark. However, according to the interviewed manager from Energinet (the TSO in Denmark), the process of approaching the legislation ready to allow independent aggregators to enter the market has begun. However, the rules for the independent aggregators are not yet determined. The proposal of Energinet has to be approved by Energitilsynet (the national energy agency) and then the new rules might be complied in 2019. When independent aggregators enter the market, it increases the competition and provides incentives to consumers to enter the market too.

III. METHODS

Due to the requirement of the Intraday market, electricity consumers like SDU can only participate in the day ahead market and regulating market. However, there is no significant benefit for SDU to participate in the down-regulating market. The electricity prices in the down regulating market is not much different from the Day-Ahead market under the current market conditions. Meanwhile, the participation in the down-regulating market means that the university must increase its electricity consumption and this extra consumption would cost a little less than the spot price. If storage would be installed on campus, it could be a possibility to participate in the down-regulating market by purchasing and store extra electricity when the electricity is cheap.

Therefore, to develop a feasible plan for SDU’s participation in the implicit DR program, this study 1) investigate the monthly, weekly and daily electricity consumption pattern for SDU buildings (2014-2017), 2) interviews with the technic service at SDU (for the current energy strategy), an interview with the SDU current electricity retailer- Energifyn (regarding possible energy purchasing approaches for large electricity consumers) and an interview with the TSO-Energinet (for the potentials of DR programs in Denmark), 3) investigate the Nord Pool Spot market.

IV. CASE STUDY

A. The University energy profile

The current negotiation contract with the electricity retailer is for a period of three years, and the fixed price changes every year (shown in Table I). the electricity retailer for 2014 to 2016 SDU is SEAS-NVEStrømmen A/S and since 2017 the electricity retailer changed to Energifyn.

<table>
<thead>
<tr>
<th>Year</th>
<th>Fixed Price [Øre/kWh]</th>
<th>Year</th>
<th>Fixed Price [Øre/kWh]</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>38.94</td>
<td>2017</td>
<td>26.59</td>
</tr>
<tr>
<td>2015</td>
<td>40.81</td>
<td>2018</td>
<td>28.00</td>
</tr>
<tr>
<td>2016</td>
<td>41.77</td>
<td>2019</td>
<td>29.49</td>
</tr>
</tbody>
</table>

According to the former energy coordinator at the SDU technical service, the expected amount of electricity bought with a fixed price is approximately 2000 MWh per year; and approximately 200 MWh of electricity is bought from the Nord Pool Spot market for the two newly built buildings.

According to the interviewed manager at Energinet (the TSO in Denmark), the procedure of consumers’ participation in the Nord Pool Spot market is: consumers make a contract with an electricity retailer, and this retailer is chosen by tendering the electricity consumption and the one provides the lowest price surcharge is chosen. This surcharge is a price per kWh which is charged on the top of the spot price. The surcharge is the main revenue for electricity retailers. According to the interviewed manager at Energifyn (electricity retailer), this surcharge is between 2-5 øre per kWh for private consumers and 0.3-2 øre per kWh for bigger consumers, such as SDU. The surcharge varies depending on retailers.

According to the electricity bill for February 2018 (only electricity with a fixed price is billed), the fixed electricity cost is 0.2979 DKK per kWh. This is only 15.7 % of the total electricity price (is 1.89 DKK per kWh including taxes). The potential saving by participation in the Nord Pool Spot market takes only a certain share of the actual electricity cost.
The PSO (Public Service Obligations) tax is going to be totally removed in 2022 in Denmark, and the share of the electricity cost in the total electricity price will increase. If only the PSO tax is removed without any other changes, the benefits to participate in the Spot market will be more significant.

- **Electricity consumption pattern**

The electricity consumption patterns of SDU show a typical working-hour pattern. Figure 1 shows the consumption pattern for Wednesday and Saturday in week 3 in 2017. Figure 1a shows that there is large electricity consumption during daytime and relatively low consumption at nights. The consumption does not vary a lot in Figure 1b due to few occupants on campus during weekends, and the electricity consumption is close to the standby electricity consumption.

![Electricity consumption on Wednesday](image)

(a) Electricity consumption on Wednesday

![Electricity Consumption per Day](image)

(b) Saturday in week 3 2017

Figure 1. Electricity consumption at SDU in week 3 (2017)

Figures 1 and 2 show that there is a base load of around 1 MWh per hour, and larger electricity consumption during weekdays than weekends, and low electricity consumption during national holidays e.g. Easeters (usually in late March or early April), summer breaks and autumn breaks (Week 42).

### B. Participation in the Spot Market

Figure 2 shows that the consumption patterns for SDU do not vary much from one year to another. Therefore, in this study, the investigation of the potentials for SDU to purchase electricity directly from the Spot market is based on the historical data for 2017.

The taxes are similar no matter with fixed prices or flexible prices from the Spot market. The only difference is that a spot surcharge is introduced for spot prices. As mentioned earlier, this surcharge is usually 0.3-2 øre/kWh excluding sales taxes. Therefore, the only cost that is used in the calculations in this study is the spot surcharge besides electricity prices.

In this study, the electricity spot prices for the given year is imported from the Nord Pool spot market to MATLAB, and the electricity consumption data for the year is also imported to MATLAB. Some of the consumption data is provided by KMD (the company that stores data for public sector in Denmark) and the rest is provided by the SDU technical service.

The data from KMD is the total electricity consumption for the whole SDU and the data from the SDU technical service is the consumption data for the two newest buildings at SDU. Both data is needed because the electricity consumed by the two newest buildings is purchased from the Nord Pool Spot market. Meanwhile, to achieve a better result, the electricity consumption for the two newest buildings should be subtracted from the total electricity consumption.

The data from the SDU technical service was not hourly based, so the data is divided into minutes and then a sum of the hourly consumption is constructed to coordinate with the consumption data from KMD and the data from Nord Pool spot market which is hourly based.

The fixed electricity prices are provided by the SDU technical service. The fixed electricity prices are negotiated every three years. For 2017, 2018 and 2019 the electricity prices were 265.9 DKK/MWh, 280.0 DKK/MWh and 294.9 DKK/MWh, and provided by EnergiFyn. All prices are without taxes.
The spot prices and the fixed electricity price for 2017 are shown in Figure 3. Since the spot price varies a lot from hour to hour, the consumption in a given hour is essential for the revenue. A large consumption in an hour with a low spot price would provide a saving for the total electricity bill, and a large electricity consumption in an hour with a high spot price would result in an expense.

![Figure 3. Spot prices and fixed electricity price for 2017](image)

The electricity price per hour is calculated as:

\[ \text{Cost of electricity}_{n} = \text{electricity price}_{n} \cdot \text{electricity consumption}_{n} \]  

\( (n \text{ is the number of hours in the year) } \)  

To calculate the revenue by purchasing electricity from the Nord Pool Spot market instead of fixed price, the difference between these two costs are calculated as:

\[ \text{Difference}_{n} = \text{fixed price} - \text{spot price}_{n} \]  

\( (2) \)

The total financial saving for each year if SDU had purchased their electricity at the spot price is calculated as:

\[ \text{Revenue}_{\text{total}} = \sum_{n=1}^{\text{N days}} \text{consumption}_{n} \cdot \text{Difference}_{n} \]  

\( (3) \)

- Results

Figure 4 shows the hourly spot price and fixed electricity price for 2017 (the spot surcharge is not added here). The difference between the electricity cost with fixed price and spot price is much smaller in 2017 compared to the years of 2014, 2015 and 2016 because the fixed price for 2017 was significantly lower than other years.

The surcharge for the spot price is usually 3-20 DKK/MWh. To investigate the significance of the magnitude of the surcharge, the total financial saving (equation (3)) is calculated with the spot surcharges. Table II shows that the potential savings vary between approximately 209,000-218,000 DKK/MWh and depend on the spot surcharges. There are significant savings by purchasing electricity from the Nord Pool Spot market for the years of 2014, 2015 and 2016. Therefore, there would not be a risk to purchase electricity from the Nord Pool Spot market. However, the saving in 2017 is fairly low compared to the other years due to a low fixed electricity cost.

![Figure 4. Hourly spot prices and fixed electricity price for 2017](image)

<table>
<thead>
<tr>
<th>Year</th>
<th>Yearly Savings in DKK/year Spot Surcharge of 3 DKK/MWh</th>
<th>Yearly Savings in DKK/year Spot Surcharge of 20 DKK/MWh</th>
<th>Difference in DKK/year</th>
</tr>
</thead>
<tbody>
<tr>
<td>2014</td>
<td>1,842,516.98</td>
<td>1,633,282.90</td>
<td>209,234.08</td>
</tr>
<tr>
<td>2015</td>
<td>2,765,946.00</td>
<td>2,556,493.80</td>
<td>209,452.20</td>
</tr>
<tr>
<td>2016</td>
<td>2,702,367.66</td>
<td>2,483,779.80</td>
<td>218,587.86</td>
</tr>
<tr>
<td>2017</td>
<td>408,503.83</td>
<td>193,448.81</td>
<td>215,055.02</td>
</tr>
</tbody>
</table>

C. Participation in the Up-Regulating Market

The assumption for this scenario is that SDU participates in the up-regulating market via an aggregator by shifting consumption of one or two hours per day. The analysis is done with the data from 2017. The flexibility capacities vary between 5 kW-0.5 MW based on the analysis of SDU energy consumption patterns. Another assumption is that SDU provides energy flexibility at the highest up-regulating market price during the working hours (7 AM to 7 PM). Meanwhile, up-regulation does not happen every day, and therefore the regulation volume is also considered in this study. In 2017, there were 116 days for the up-regulation. Therefore, the revenue by providing flexibility is calculated only for these 116 days.

Two sub-scenarios are considered in this section. The first scenario is that SDU can provide flexibility every weekday (excludes holidays) for one hour per day. The second scenario is that SDU provides flexibility for two hours per day, and the two hours cannot two consecutive hours. For instance, SDU cannot shift its electricity consumption from both 8-9 AM and 9-10 AM.

For the first scenario, the highest price between 7 AM and 7 PM is found and multiplied with the energy flexibility capacity for all weekdays that are not national holidays. The yearly revenue is the sum of the revenue from all these as:

\[ \text{Yearly Revenue}_{\text{hour}} = \text{capacity}_{n} \cdot \sum_{n=1}^{\text{X days}} P_{\text{max}} \cdot \text{days} \]  

\( (4) \)
The analysis of the electricity consumption at SDU shows that the consumption patterns do not vary significantly between 2014-2017. The saving by purchasing electricity from the Nord Pool Spot market directly instead of a fixed price is not significant due to the low fixed electricity prices negotiated with the electricity retailer. The savings for 2014-2016 vary from 1,633,282.90 DKK/MWh to 2,765,946.00 DKK/MWh depending on the spot surcharges. The fixed price for 2017 was significantly lower than the years of 2014-2016. The potential saving is 193,448.81 DKK/MWh to 408,503.83 DKK/MWh depending on the spot surcharge. The study finds that the magnitude of the spot surcharge can increase the yearly electricity cost by approximately 209,000-218,000 DKK.

The potential revenue by participating in the up-regulating market varies from 344 DKK/year to 34,394 DKK/year. Therefore, the optimization of the ventilation system might be considered in the future due to the large energy flexibility and demand-control potentials by the ventilation system.

Some costs for participation in the regulating market are not considered in this study, e.g. the costs to update building control systems that allow aggregators/SDU to shift the energy consumption based on the grid/aggregators’ signals. However, these costs are difficult to calculate in the current circumstance. Meanwhile, the calculation of the revenue by participating in the up-regulation market is based on an assumption that SDU always get the highest spot prices in the given days, and SDU always wins the bids. This is unrealistic and the revenues would be smaller for the two up-regulation scenarios if these factors were considered.

The interviewed manager at Energinet stated that there was no record that the spot prices were too high for consumers to have a higher electricity bill by purchasing from the Nord Pool Spot market compared to a fixed price. However, the interviewed energy coordinator at SDU states that there is a strong concern of the uncertainty in the energy budget plan, especially the energy saving is not significant by participating in the implicate DR now. However, the electricity price will be hourly based from 2020 and PSO will be removed, and there will be a high risk for SDU to have higher electricity bill if SDU does not consider participating in the implicate DR. Therefore, a long-term energy plan should be considered instead of a yearly plan.

**ACKNOWLEDGMENT**

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