ASSESSMENT OF RESIDENTIAL DEMAND SIDE RESPONSE: IMPLEMENTATION OF PRICE-BASED MECHANISMS IN THE DUTCH DAY-AHEAD MARKET

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(1) Overview

Developments in the electricity system need to accommodate the pressure of steadily rising demand, advanced technology integration in addition to increasing penetration levels of renewable energy sources (RES) and distributed generation (DG). As such, European energy policy for 2020 is aimed at reducing greenhouses gases by 20%, increasing RES by 20% and curbing energy consumption by 20%. Renewable generation in the Netherlands accounts for 4% of the national energy use with an expected 14% increase by 2020 [1].

Traditionally, power system control has adapted the supply side to meet fluctuations in consumption, with little attention paid to demand side modifications. As the Dutch veer away from flexible fossil-based electricity supply and towards greener stochastic generation the system will have to consider all available resources for balancing, including the demand side. The implementation of Demand Side Response (DSR) has the potential to provide added flexibility to dynamic system conditions solely based on reshaping the demand for electrical energy. DSR mechanisms entail incentivizing load flexibility in response to an economic stimulus reflective of generation or transport constraint in the power system [2].

Residential consumption accounts for 24% of the total electricity use in the Netherlands. As an untapped resource for dynamic power system control, residential Demand Side Response potential for exploitation remains an unknown challenge which this paper analyzes. Proper coordination of DSR with power generation strives to achieve low electricity prices and higher system efficiency [3]. Our work investigates the value of demand-side flexibility as it is affected by the design of the DSR mechanism for the day-ahead (DA) market in the Netherlands. Currently Dutch households have a fixed regulated retail price in addition to a day and night tariff. Implemented programs for residential consumers include time-of use (TOU) and critical-peak pricing (CPP) programs with hopes of real-time-pricing (RTP) for the future [2]. The implementation of different price-based DSR mechanisms has been shown to yield varying levels of flexibility and economic value for consumers. The emerging interaction between heterogeneous households, DA market prices and DSR mechanisms is studied with agent-based modeling.

(2) Methods

Agent-based simulation is used to model the consumer behavior with respect to Demand Side Response in the liberalized Dutch electricity market. The model inputs include electricity consumption by household type, APX power NL Day-Ahead auction results and selected price-based DSR mechanisms. In order to assess the potential of residential DSR, a bottom-up construction methodology is used to simulate the average domestic electricity consumption for every household type[1]. Household profiles are generated on the basis of current data from domestic electricity consumption of appliances in Dutch households, whereby accurately representing the electricity consumption and flexibility feasibility on a 24 hour basis. Consumer response to implemented mechanisms is modeled based on the potential drivers for Dutch power consumption behavior: *convenience, cost, consciousness and climate* [4]. Furthermore, price results from the Day-Ahead auction are used and DSR mechanisms (TOU, CPP and RTP) are constructed from the resulting hourly prices. The emergent behavior from the hourly interaction between consumer response and mechanism serves as an illustration of the tangible value of aggregated demand-side flexibility.

(3) Results

DSR from residential consumption can be achieved from curtailing and shifting controllable household appliances (washing machine, tumble dryer, dishwasher, refrigerator and freezer), providing flexibility in the magnitude of 63.9 GWh per day for the Dutch power system. Additional DSR comes from households with electric vehicles (EVs) and solar photovoltaic (PV) systems. Currently, domestic PV capacity is 83.1MW_p with only 7,500 electric vehicles (EVs) [1], [5]. Future scenarios will model the large penetration of EVs and PV systems which will increase the load demand in addition to available flexibility. Initial results illustrate that the quantity and value of DSR will differ based

[1] Single under age 65, single over 65, couple both under 65, couple at least one over 65, single parent family and family with 2 parents

on the mechanism (TOU, CPP and RTP) implemented in the system. Figure 1 illustrates the aggregated daily consumption characteristic of electricity use and hourly price variation of the modeled mechanisms.

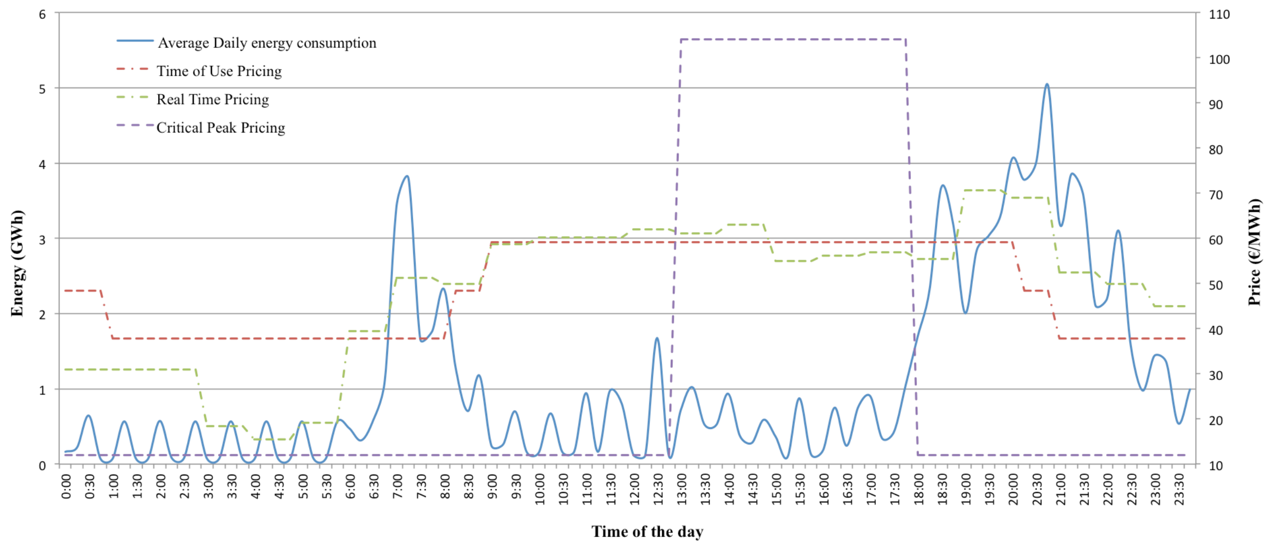

Figure 1: Policy mechanisms and residential electricity demand in the Netherlands

(4) Conclusions

The ultimate objective of the model is to provide insight into the effectiveness and feasibility of residential Demand Side Response to price fluctuations in the day-ahead market, serving as a decision support tool for effective policymaking. Preliminary results indicate that individual household response to price-based mechanisms adds little value to the system in addition to consumer savings. On average, the maximum daily flexibility of a Dutch household is equal to 9kWh with a total value of 0.45€ per day (under an RTP tariff). However, further exploration points to the prospects of aggregation for maximization of net benefits for all stakeholders. For instance, if households are responsive to RTP signals 25% of the time (6pm to 12am) $36.8GWh_{max}$ of flexibility are allocated to the system with a value of 2.2€ million. This analysis is done for the Netherlands, but results can be adapted to other restructured European electricity markets. Demand Side Response is viewed as an important ingredient in the successful large-scale integration of power from RES. For instance, Germany aims to have 80% of its total electricity produced by RES by 2050, thus making DSR a core flexibility resource [6].

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