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Data-driven Nonlinear Prediction Model for Price Signals in Demand Response Programs (Lærkevej)

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Introduction

In dynamic prices-based demand response (DR) schemes, electricity consumers receive a **time-varying price** signal by their home energy management systems (i.e., local controllers) to schedule their individual generation and consumption, aiming to minimize the overall cost while providing services to the grid.

Although dynamic price-based DR programs neither affect consumers' autonomy nor privacy, they expect DR operators to formulate electricity price signals. By influencing consumers' aggregate price response, dynamic prices might also affect power system' security. Therefore, a **robust price generating model** considering heterogeneous consumers' dynamics and different DR capabilities needs to be developed.

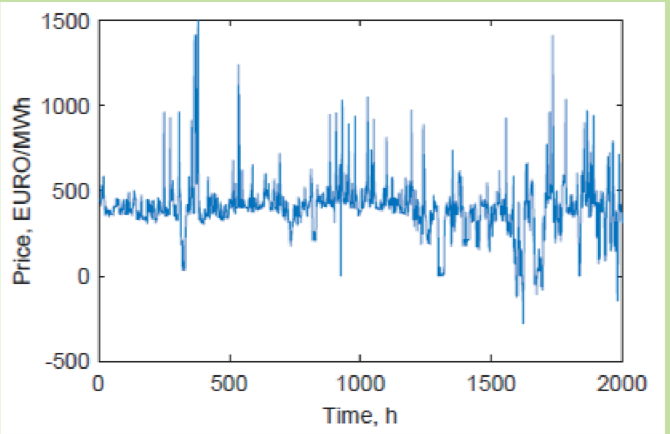
In this paper, we propose a nonlinear auto-regressive with exogenous inputs (NARX) model to predict dynamic electricity prices. The main objective of this study is to learn **consumers' flexibility behavior** in relation to different factors. Such an understanding can be exploited by a DR operator to formulate adequate electricity prices that can achieve a certain change in load under dynamic prices-based schemes.

The method

It is common to observe the long-term dependence in the time-series data (e.g., electricity price) observed in the real-world power systems. To model such real-world time series, the recurrent **artificial neural networks** (ANN) are commonly used.

The NARX model structure is a specific kind of recurrent ANN which can be used to efficiently model a time-series with long-term dependencies.

The NARX model structure is used to learn from available data to **predict appropriate electricity price signals**.



Nodal electricity prices

Data

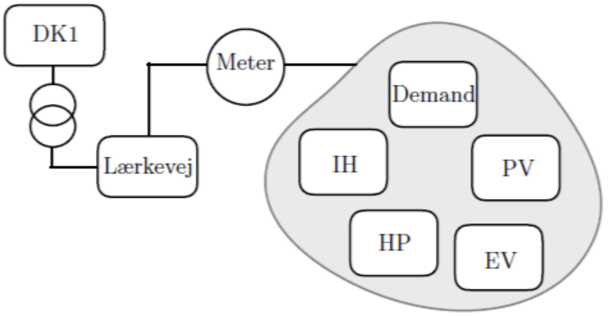
For the validation of the model in predicting consumers' price-response, the data from 10 Danish households is utilized, which has provided by the Danish TSO **Energinet**.

Case study

To generate suitable price signals, we need to have information about **consumers' aggregate price-response.**

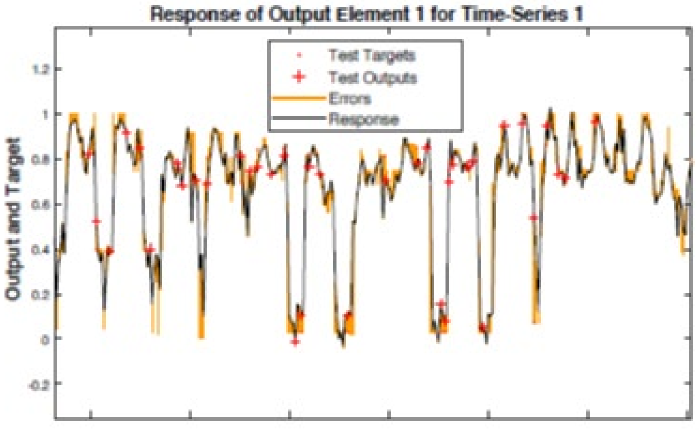
The figure presents the case study considered in this paper, **Lærkevej** (i.e., "Lark street"), a **typical street in Denmark** with 10 different houses.

To generate the DR data necessary for the estimation of a nonlinear electricity price model, the configuration of Lærkevej was **simulated for 2 years through** the long-term energy planning tool **SIFRE** (Simulation of Flexible and Renewable Energy sources) at Energinet.



Simulation setting for the case of Lærkevej. DK1 consists of the Danish transmission area; the meter is placed at the level of the feeder. The electricity demand of each household includes: immersion heater (IH), photovoltaic (PV) panel, electric vehicle (EV), heat pump (HP) and a certain inflexible household electricity demand.

The SIFRE tool assumed perfect knowledge
for every useful parameter (i.e., outdoor temperature, dynamic electricity price, solar irradiation and so on).



Performance of the ANN model (top); Model performance (bottom).

R Train	R Valid	R Test	MSE Test
0.923	0.896	0.901	0.0093

Results

Results show that a relative **simple ANN** of 18 hidden neurons and 18 delay value is able to achieve **high predictability** for the testing data-set.

In fact, it reaches a R value of 90.1% and a mean squared error (MSE) value of 0.0093.

It represents the **best performance** of the models analyzed in the study.

Conclusion

We can conclude that a single ANN is a **promising tool to estimate the appropriate dynamic electricity price to alter consumers' behavior**, using estimated values of outdoor temperature, PV generation, time and electricity demand.

About the authors

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