Local Load Optimization in Smart Grids with Bayesian Networks

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Motivation for Smart Load Management

Power distribution companies want to ensure stable power load with minimal transmission losses.

Growing number of customers utilise renewable power sources via solar or wind power plants which makes them contributors to the grid as well.

Current load management practices in the Czech Republic are not flexible enough to adapt in the rapidly changing environment.

Smart Grid technologies enable collection of useful data that can be used to predict future consumer behaviour.

Goals

Implementation of software component and algorithm for localised load management that would minimize transmission losses.

Usage of data about consumer power consumption collected from smart meters.

Challenges

Lack of reliable data.

Integration of weather forecast.

Compliance with rules issued by Energy Regulation Office.

Smart Grids in the Czech Republic

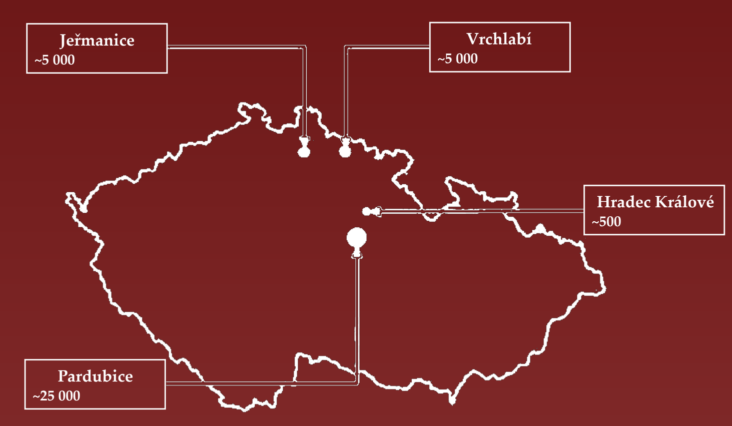
Three major energy distributors.

Local pilot projects of smart grid deployments since 2010.

Total of ~38 000 smart meter installations.

Participation in the international Grid4EU project.

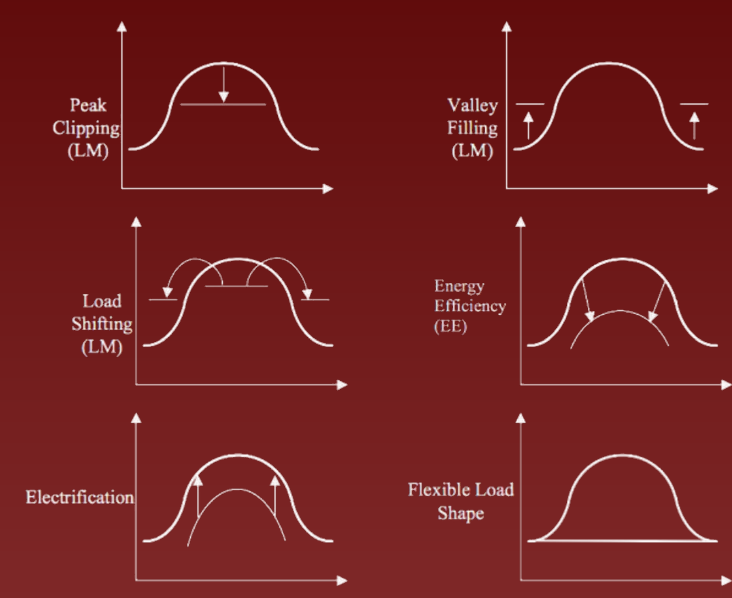
Both industrial and residential customers.



Load Management Practices

Load management aims at flattening the load curve by either increasing or decreasing the load.

Achieved by combination of direct methods (remote appliance control) and indirect methods (Time-Of-Use tariffs).



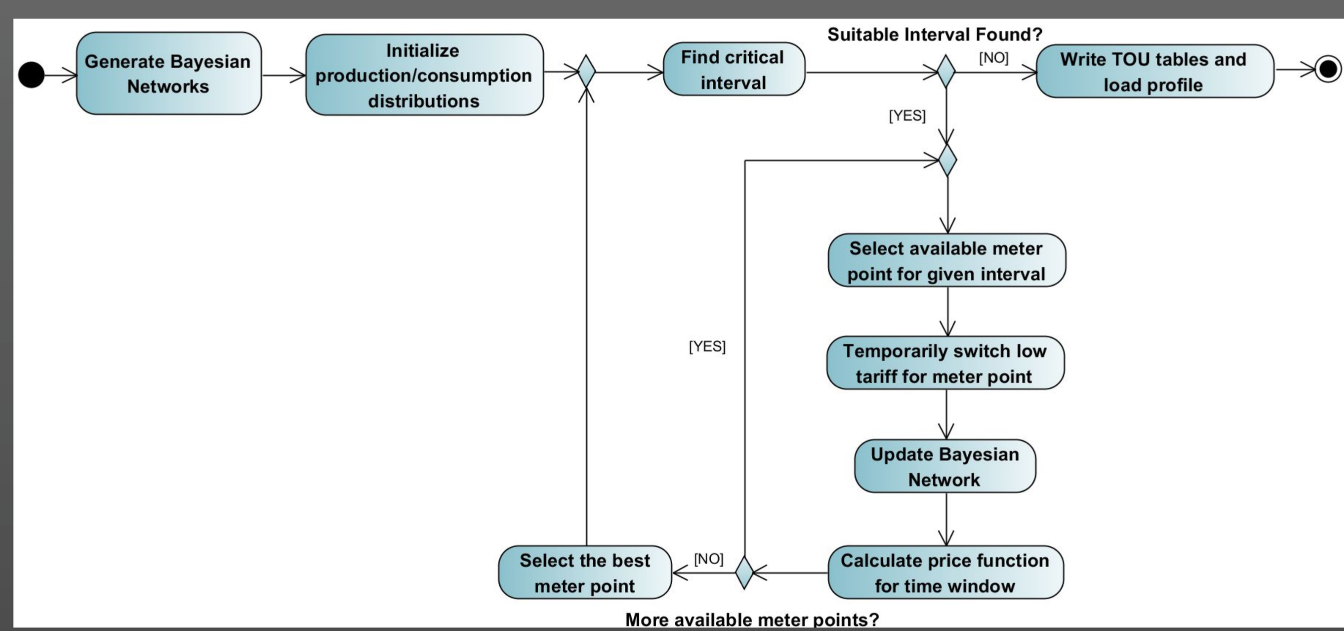
Ripple Control

The most common direct load management method used in the Czech Republic since 1980s.

Based on signal broadcast at specific frequency over the power lines.

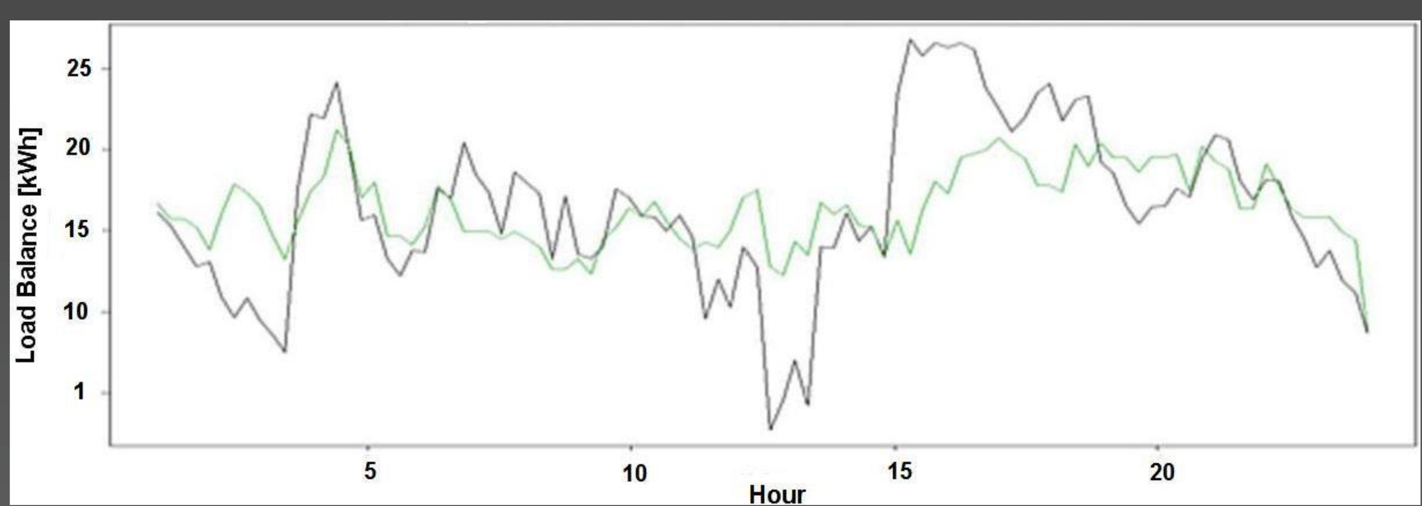
Remote control of larger group of devices only.

The TOU schedule updated unfrequently and does not consider renewable sources.

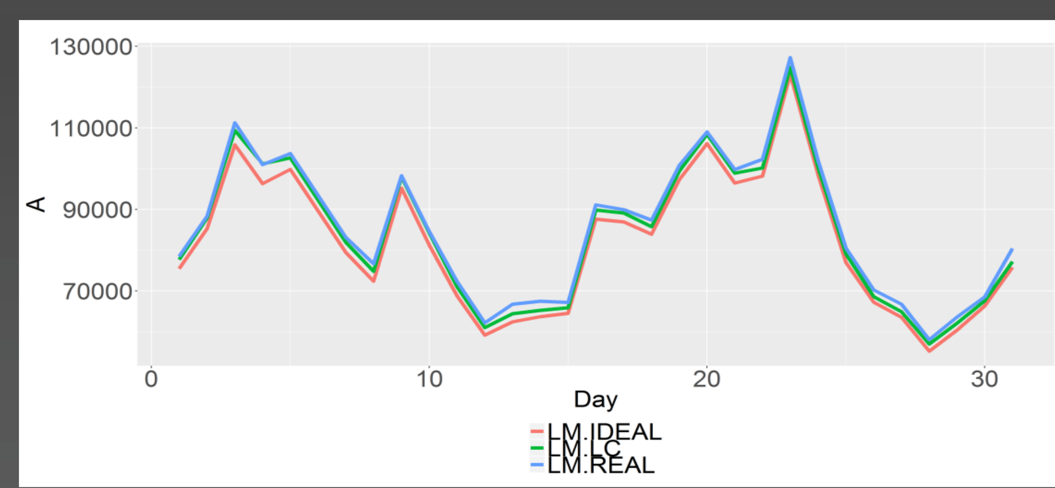


Algorithm for calculation of the TOU tables for water heating appliances.

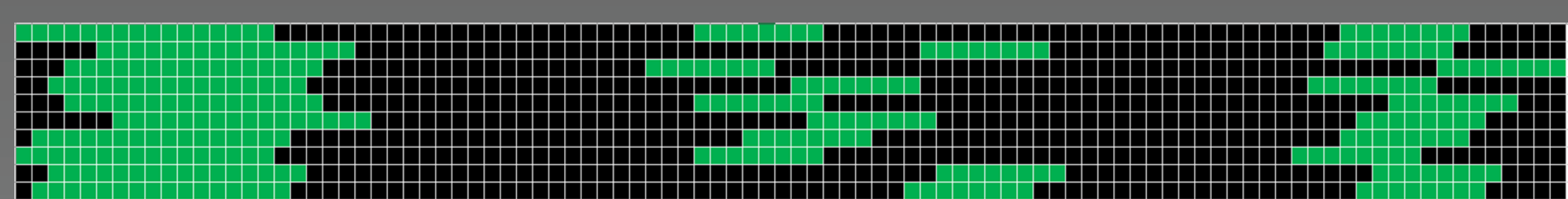
Comparison of old load profile from the ripple control (black) and the predicted load profile from the local load optimization algorithm (green).

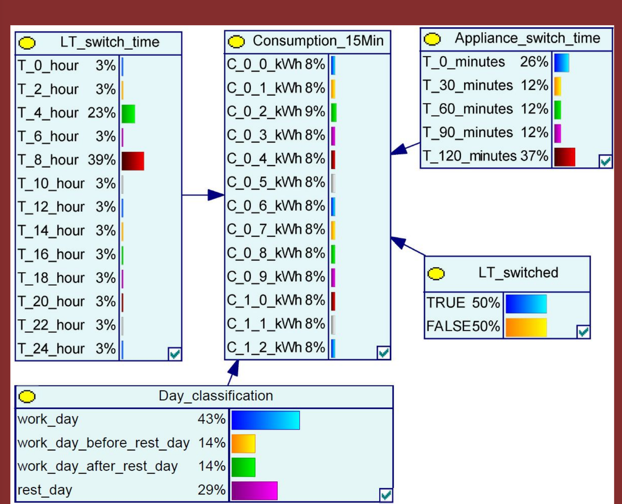


Representation of the transmission losses metric in the ideal case (red), the local load algorithm case (green) and actually observed case (blue).



Example of daily TOU schedule. Rows represent individual water heaters while columns represent 15 min. periods of time. Green squares show the periods during which the water heaters are switched on.





References
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[2] Fenton, N., Neil, M. Risk Assessment and decision analysis with Bayesian networks. Crc Press, 2012.
[3] Neuberg, A. Ripple control in the Czech Republic and demand side management, CIRED, 2009.

Acknowledgements
This work has been done in industrial cooperation with the Mycroft Mind company as a part of the Lasaris smart grid reasearch activities.

Bayesian Networks

Probabilistic graphical model.

Allows incorporation of uncertain data and propagation of observed evidence.

We use them to predict regulated consumption of the water heating appliances.

There is total of 96 Bayesian networks per consumption points, each representing a 15 min. period of a day for a single water heater.

The nodes are initialized with historical consumption data collected from smart meters.

Case Study

Our Load Controller component has been deployed in the production environment of the major power distribution company in the Czech Republic since March 2015.

It is used in three urban areas, each consisting of ~100 consumption points with water heating appliances.

The algorithm is executed daily and it constructs the TOU tables for water heaters control which are then uploaded to the smart meters.

Results

The estimated reduction of transmission losses is 4% on average (7.04% maximum, 2.28% minimum).

The distribution of losses is between 95% and 97% of the optimal distribution.

Local Load Control

Our approach allows individual control of the water heating appliances.

Customer's participation is rewarded with lower tariffs.

Appliance switching is scheduled one day in advance.

Integration of local weather conditions.

Load Controller Component Architecture