Data-driven models for estimating heat pump power consumption

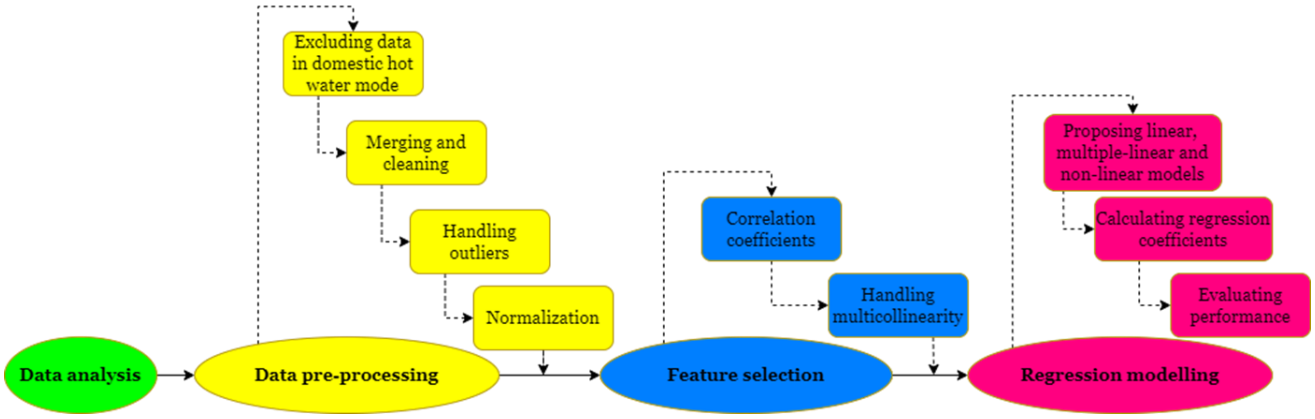

Figure 1: Framework of soft sensors utilization targeting heat pump monitoring systems.

Summary of project

Network operators have to conduct adequate network simulations required for network planning because of the substantial increase in electrification. These network simulations help the network operators to propose optimal solutions for network enhancement and congestion management. The network simulations can be complemented by electricity load profiles of the devices connected to the grid, including heat pumps, to improve these simulations. Thus, developing heat pump models that would estimate the heat pump power consumption can help in evaluating the impact of the increasing deployment of heat pumps on the grid.

The aim of this project is to develop data-driven heat pump models which would estimate the power consumption of a heat pump using features measured during heat pump operation from installations that are currently in operation. Thus, this project analyses anonymous real time monitoring data from residential heat pump installations, which are obtained from heat pump manufacturers or other stakeholders. Further, this project identifies which features from the obtained data sets are most relevant for developing models which can be used for estimating heat pump power consumption. The objective of this project is also to evaluate the proposed models based on their accuracy.

The goal of the project is to answer the following research questions:

- What are the most important features measured during heat pump operation for modelling heat pump power consumption?
- How can the power consumption of a heat pump be estimated using a limited number of input features measured during heat pump operation?

To answer the above mentioned questions, this project developed both polynomial and machine learning models to estimate heat pump power consumption. Prior to model development process, one essential step: feature selection was conducted. The main benefits of feature selection include reducing dimensionality, the risk of overffiting, training time of the model and also improvements in model accuracy. In this project, feature selection also means the number of sensors can be reduced, which can make the power estimation work more convenient in practice. So the most important features for modelling heat pump power consumption were identified based on the correlation coefficients between power consumption and the measured parameters. Further, the number of selected features as the input features to the models were reduced based on variance inflation factor (VIF) so that the features had no multicollinearity problems. Apart from this method, a built-in feature importance method in machine learning algorithm was also applied.

The accuracy and complicity of the data –driven models were analyzed against field measurements.

Learnings and results

- To answer the first research question, the feature selection was done in order to identify the most important features measured during heat pump operation for modelling the heat pump power consumption. The features were preselected based on calculating two different association metrics (Spearman and Pearson correlation coefficients). Further, the features were eliminated by selecting only not multi-correlated features by calculating the variance inflation factor. Plus, a built-in feature importance method in XGBoost algorithm was also applied. The result showed that heat pump power consumption can be estimated by limited number of parameters.

- Regarding the second research question, the power consumption of a heat pump can be estimated using various types of models. The scope of this thesis included polynomial regression models and XGBoost model. Various polynomial regression models were proposed, ranging from first to fourth-degree models, with and without the interaction terms. Additionally, the models with different number of input features were defined. The results showed that the non-linear regression models performed with higher accuracy compared to the linear regression models and the accuracy was usually increasing with the increasing degree of the model. Including the interaction terms in the regression models resulted on the one hand in higher accuracy, but on the other hand in significantly more complex models. XGBoost model performed better in accuracy than polynomial models.

FACTS ABOUT THE PROJECT

IoT Catagory: Optimize heat pump operation, Predictive maintenance or Performance benchmark

Goal: To estimate heat pump power consumption with limited number of parameters.

Beneficiary: End-user and grid operator

Data required: Operational data from heat pumps

Analysis method: Data analysis and modelling

Modelling requirements: Polynomial regression and machine learning models.

Quality-of-Service: Real-time and hourly for online monitoring and control.

Project participants: KTH, AIT

Time schedule: 2022-2023

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