

methods can be used simultaneously by the district heating utility. Starting from historical data, the cluster-based approach can be used to gradually detect malfunctioning substations. It can be re-evaluated on a periodic basis, for instance monthly. The instance-based approach can be used in parallel. Given that the instance-based method uses historical data, it would not be known from the start if the behaviour modelled is for the well-behaving or faulty substation. For that, the cluster-based method can help. As a faulty substation is corrected, the model is recalibrated, and any further deviations can be an indication of a fault in the substation. Another point of improvement is how the deviating behaviours are detected for the instance-based approach. Currently, this is done by visual inspection of the residuals. To be able to use the instance-based approach on a larger scale, the identification of deviating residuals must be automated. This could be done by introducing, e.g., threshold values that the deviations may not exceed (in similarity to the threshold values used in the cluster-based approach). Overall, the two approaches show great promise for fault detection. The next steps include testing the methods on labelled data sets, and to develop a solution for fully automating the fault detection methods.

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6. Data access statement

The datasets analysed during the current study are not publicly available because of privacy requirements.

7. References

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