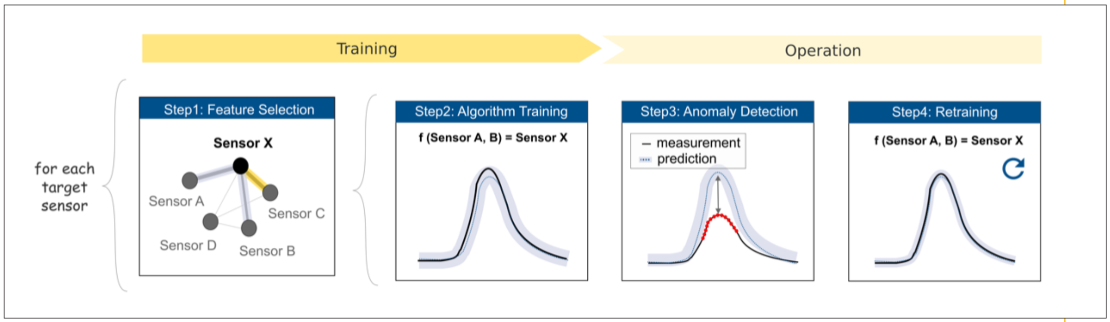
Task 68

Fault-Detective – Fault Detection Based on Artificial Intelligence

Good monitoring is essential to ensure the performance of solar thermal systems. Only then can solar thermal systems live up to their full potential and provide as much renewable energy as possible.

To support monitoring personnel with their work, researchers from SOLID Solar Energy Systems, Best Bioenergy and Sustainable Technologies, and Links Foundation developed a new Fault Detection algorithm, called Fault-Detective. Using machine-learning, it allows to spot any abnormal system behavior. The main advantage over other algorithms is that Fault-Detective can be applied very easily. As the algorithm is purely data-driven, it can be applied to any solar thermal system and only requires some monitoring data. All other information is automatically extracted based on the measurements.

How It Works



Four-step approach of Fault-Detective.

The algorithm uses a four-step approach.

1. Find correlations

In the first step, a small portion of the historical data (~1 week) is analyzed to identify correlations between sensor measurements. In principle, this step allows the Fault-Detective to understand the system's structure.

2. Create models

In the second step, machine learning is used to model the correlation between sensors. After this, predictions about sensor values can be made using the data of its related sensors. Put in another way, Fault-Detective models the relations between the parts of the system.

3. Detect anomalies

In the third step, these models are used to detect abnormal system behavior during the system's operation. As soon as new data from the system is available, predictions for the sensor values can be generated. If the predictions (trained fault-free system behavior) and measurements (actual system behavior) differ too much, this indicates that a problem occurred in the system.

4. Retraining

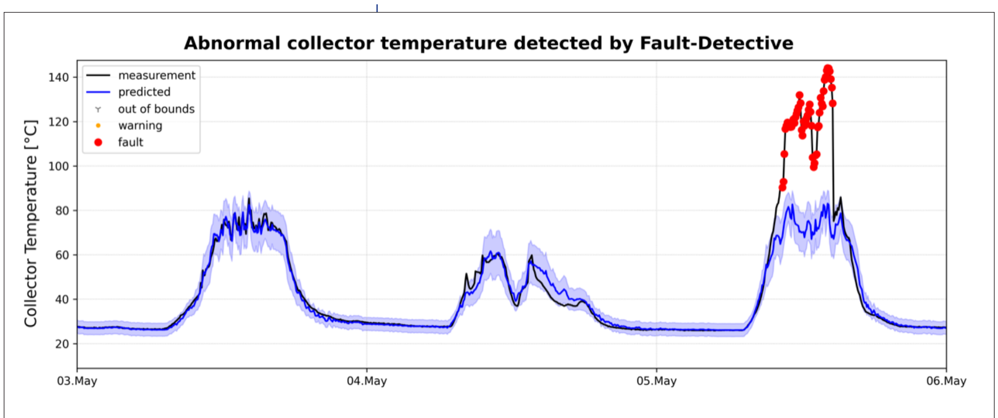
Finally, one last step is needed to keep the models of the system up to date. This step is required as normal system operation might change over time - for example, if operating conditions are changed seasonally or if parts of the system are replaced or added. Hence, models are updated frequently.

continued on page 16

Fault-Detective *from page 15*

Test Results

This approach was tested using the data of three different solar thermal systems – targeting three different types of sensors. The results show that the Fault-Detective can successfully model the behavior of the sensors and detect faults well. All faults spotted by the monitoring personnel were also found by the Fault-Detective. Moreover, the algorithm even identified some faults that the domain experts missed.



▲ **Exemplary results of Fault-Detective showing how it successfully detects abnormally high collector temperatures.**

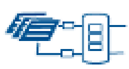
One limiting factor is that anomalies due to rare operating conditions cannot be distinguished from anomalies due to faults. As a result, alarms are sometimes raised even though the anomaly has less or no impact on future system behavior.

These results are based on the H2020 Project Ship2Fair. The algorithm and similar topics in the context of fault detection of solar thermal systems will be further discussed and pursued in the SHC Task 68: Efficient Solar District Heating Systems.

In addition, a publication on the Fault-Detective algorithm is currently under review for the open-access journal Solar Energy Advances.

This article was contributed by Viktor Unterberger of BEST and SHC Task Manager of Task 68: Efficient Solar District Heating Systems, viktor.unterberger@best-research.eu, Lukas Feierl of SOLID, l.feierl@solid.at and Sabine Putz of SOLID, s.putz@solid.at.

What makes this Fault Detection algorithm different from others?

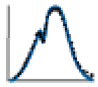


Flexible

Some algorithms require very specific measurement devices, measurement conditions or system layouts. Instead, our algorithm can be used at any system due to its flexible training mechanism.

Easy to Configure

Often, a considerable amount of time needs to be spend to configure algorithms, set parameters and adapt to special system layouts. In contrast, our method uses Machine-Learning to do so automatically.



Accurate

Sensor data of solar thermal systems is not always easy to interpret. Many correlations between measurements have to be kept in mind when analysing the data. In contrast, our algorithm is able to mimic the multi-dimensional, time-dependend and non-linear data very well.