Evaluating the Resilience of Energy Supply Systems at the Example of a Single Family Dwelling Heating System

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Introduction and Previous Work

Since the 1980s, the term "resilience" occurs more and more frequently in energy system analysis. However, the consideration and definition of the term primarily occurs in a qualitative way. In the last century, the term was mainly defined by Holling (1973) as a "measure of the persistence of systems and of their ability to absorb change and disturbance". Francis and Bekera (2014) and Nan and Sansavini (2017) introduce quantitative assessment methods that are adapted in this paper to be used for Modelica® simulation results.

Definition of the Resilience Index

When evaluating a system's answer to disturbances, a physical value needs to be defined as indicator for the system's functionality, e.g. the room temperature for the heating system. The room temperature profile after a disturbance is characterized by the recovery time RT, the maximum deviation MD outside of the value's tolerances and the performance loss PL. These elements can be used to determine the resilience index:

$$RI = \frac{1}{1 + RT \cdot MD \cdot PL}$$

To obtain a dimensionless figure, normalization values are introduced for each element.

Case Study

The presented assessment method is applied to a heating system of a single family dwelling in which heat is supplied by a gas boiler.

For this system, the failure of the supply pump and the failure of the boiler are modeled. Furthermore, the reference system is improved by implementing windows with a lower heat transfer coefficient or/and a hot water buffer storage. The results of the simulations are used to compute the resilience indices for each disturbance and improvement.

Conclusion

Overall, it becomes obvious that large temperature drops and recovery times lead to small resilience indices which shows that the resilience index reliably reflects the resistance and recovery ability of the system.

Another general aspect that becomes evident, is that the resilience indices vary for the same system in accordance to the disturbance it is exposed to. Hence, one can derive that there is no "absolute" resilience index, especially when keeping in mind that the concept of resilience also contains the system's capability to keep its functionality up when facing unknown disturbances. Therefore, the significance of a resilience analysis rises with its number of considered incidents.

Furthermore the resilience analysis enables the location of a system's weak points which helps to choose and initiate system improvements that are the most efficient in regard to increasing the resilience.

Further research should focus on using the resilience index on more complex systems including integrated energy systems and the evolutions that are necessary for these kinds of systems. Hence, it is proposed to allocate one resilience index for each integrated sector and combine them into one overall index which will make it possible to evaluate complex system changes, e.g. a rising share of renewables, with regards to resilience aspects.

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