Power outage profiles generation to assess thermal and indoor air quality resilience

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ABSTRACT

Climate change amplifies the frequency of extreme weather events, leading to increased risk of power outages. Power outage is a critical disturbance for buildings because it disrupts heating, ventilation, and air conditioning systems, simultaneously challenging the resilience of a building's thermal and indoor air quality performance. Resilience means the ability of a building or system to maintain acceptable indoor environmental quality during shocks such as a power outage and recover after it ends. Existing building resilience studies often rely on simplified and unrealistic assumptions, such as outages that last for multiple days or outages that occur during the worst weather conditions, without considering the actual probability of occurrences. Such subjective assumptions, lacking empirical data, can easily lead to misjudgments on the actual impact of power outages on thermal and indoor air quality resilience.

This work introduces a data-driven methodology combining geometrical probability with Monte Carlo sampling to generate power outage profiles from historical outage records. These profiles can be used as boundary conditions in building simulations and support more objective assessments on resilience. A lecture room at the KU Leuven campus in Ghent, Belgium, is used as the case study to demonstrate the methodology. The building and air handling unit system is modelled in Dymola and has been validated in previous work. Historical outage data from mid-June to mid-October 2024 is collected from a local electricity supplier. A total of 163 distinct profiles were generated to represent the local power outages. For each profile, one outage case and one paired benchmark case are simulated. In the outage cases, the air handling unit is interrupted according to the outage defined by the profile; in the benchmark cases, the system operates normally, enabling direct comparison of the performance changes. Resilience is quantified through cumulative exposure over a threshold, defined as the time-integrated portion of an indicator that exceeds a predefined limit. The results show that carbon dioxide concentration is the most sensitive to power outages in the case study building. The number of cases with exceedance rises by over 70 % under outages, with the strongest impacts when outages overlap with the occupancy schedule. Volatile organic compounds exhibit only a modest increase in cumulative exposure, as many benchmark cases are already close to saturated levels. Particulate matter concentrations remain almost unchanged because the increased indoor accumulation is offset by lower outdoor particle infiltration. Thermal resilience is barely affected, since the simulations use typical summer weather without heat waves. Overall, the responses of different thermal and indoor air quality resilience indicators vary markedly, underlining the need for probability-based power outage profiles to assess the resilience.

The proposed methodology offers a transparent and transferable framework that links power outage with resilience assessment based on building performance simulation. It avoids subjective assumptions on power outages and can be readily extended to other cases. Future works will focus on applying the methodology to combined heat wave and power outage conditions, where higher outdoor temperatures, increased cooling demand, and more severe grid disturbances are expected to challenge resilience more strongly.

KEYWORDS

Building modelling simulation, Thermal resilience, Indoor air quality resilience, Power outages, Monte Carlo sampling