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Vulnerability Assessment of Electrical Distribution Systems to Heavy Rainfall Events and Storms

Climate change consequences are evident in more frequent extreme weather events such as heavy rainfall, heatwaves, and severe storms [1, 2]. These events will become more intense and frequent, posing major challenges to the reliability and efficiency of electrical distribution systems [3, 4]. To address this, operators of electrical distribution systems need to evaluate future extreme weather risks and identify vulnerable equipment. Both meteorological and site-specific analyses are needed, as weather data alone lacks the required granularity, usually reported at municipal, district, or city level rather than individual equipment loca-tions [5].

This contribution focuses on assessing the vulnerability of distribution system equipment during heavy rainfall and storms. Specific impacts of each weather event are defined, followed by the identification of rele-vant influencing factors. For heavy rainfall, these include equipment location in flood-risk zones, flood depths, surface runoffs, and sinks. For storms, relevant factors include wind-exposed locations due to to-pography and potentially damaging trees. The basis for both types of analysis are the freely available digi-tal terrain and surface models. The relevance of topographic influencing factors for vulnerability assessment during heavy rainfall events has already been addressed in a previous contribution presented at the CIRED Workshop in Chicago.

Vulnerability is determined by assigning failure probabilities to each influencing factor using threshold values. For example, secondary substations show a markedly increased vulnerability when exposed to impacts from entire trees, as opposed to mere contact with tree canopies. Then, the individual influencing factors are aggregated for each extreme weather event, depending on their interdependencies and impact.

This methodology helps operators identify at-risk equipment and implement suitable countermeasures, improving system resilience. By enabling proactive planning and adaptation, it supports the development of resilient, climate-adaptive and energy efficiency distribution systems. The method is applied and validated using data from a German distribution system operator.

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