SERVICE DE METROLOGIE NUCLEAIRE
RELIABILITY AND SAFETY OF POWER SYSTEMS

MASTER THESES

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1. Contribution to multi-indicator assessment of power system resilience

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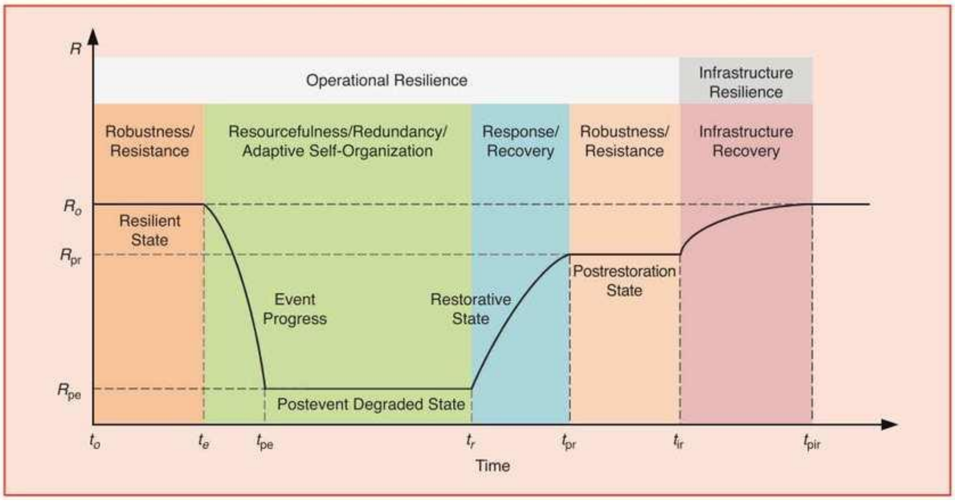
Context

The N-1 security rule has been traditionally used to design, plan and operate power systems. Although such a criterion ensures high levels of security of electricity supply, resulting power systems might still be vulnerable to extreme events such as tornadoes, earthquakes, snowstorms, wildfires, etc. Though the probability of occurrence of such extreme events is usually low, they could lead to catastrophic consequences. It implies that the risk of unsupplied energy associated with those High-Impact, Low-Probability (HILP) events is high. Consequently, it is critical to ensure that power systems are resilient, in order to minimize the consequences, and thus the risk, entailed by these HILP events.

The resilience of a power system can be formally defined as its “ability to limit the extent, severity, and duration of system degradation following an extreme event”. A 4-step approach to assess the resilience of power systems is usually proposed:

- Threat characterization – what are the threats to my system and their likelihood?
- System vulnerability – how well can the elements of my system resist the threat?
- System reaction – what is the impact on my system?
- Restoration process – how fast can I restart normal operation?

The typical time-dependent evolution of a grid performance indicator, following the occurrence of a disruptive HILP event, is given in the next figure (Panteli et al., Boosting the Power Grid Resilience to Extreme Weather Events Using Defensive Islanding, IEEE Trans. On Smart Grid, Vol.7:6, 2016).



Such an evolution could be that of the load served in the power system, and consequently the area between this curve and the initial performance level corresponds to the Expected Energy Not Served (EENS), which is a classical grid resilience indicator.

Motivation of the work

However, considering a unique resilience indicator like the EENS above turns out to be questionable. Indeed, depending on the magnitude of the disruptive event, the response of the power system could be different. As an example, a limited earthquake could affect the system in such a way that its full restoration can be envisioned within a limited amount of time. But a more severe seismic event could lead first to isolate the damaged part of the electric system in the neighborhood of the epicenter, in order to restore the electricity supply everywhere else as quickly as possible. The characteristic times of the sequel of the restoration could be much longer, together with a different objective in load supply, compared with the pre-event conditions.

These observations lead to looking for multi-dimensional resilience indicators, likely to capture the full scope of outcomes after the disruptive event occurrence. They also tend to indicate that, depending on the magnitude of the HILP event and the initial response of the system, very different types of restoration strategies could be considered, each of them likely to be characterized by specific indicators.

Objectives

The master thesis will start with a state-of-the-art study on power system resilience indicators proposed in the scientific literature, for different types of HILP events (seismic events, weather-related events…). In a second stage, decision-tree structures representing the different options for the restoration strategies, depending on the consequences of the initial HILP event, will be proposed. Multi-criteria indicators will then be associated with the different branches of these decision trees, for the different types of HILP events under study. These indicators will be assessed on specific test grids, and a decision-making approach for resilience enhancement will be sketched from these first results.