MSc thesis proposal

- **Title of the research**

Uncertainty analysis within a probabilistic modeling and simulation framework for the risk assessment of power grids exposed to floods.

- **Objectives of the research**

Power grids are critical infrastructures (CIs) whose functionality can be severely affected by floods, potentially causing widespread power outages with significant social and economic consequences for affected communities. A probabilistic modelling and simulation framework has recently been proposed for assessing flood-induced damages to power grids (Asaridis et al., 2025). This framework combines hydrodynamic models to simulate natural hazard scenarios, fragility curves to represent component vulnerabilities, and power flow models to analyze the effects on power transmission and distribution networks. Additionally, it includes a service area analysis for evaluating the impact of power outages on affected customers. Uncertainty affects several relevant key inputs to this framework (Asaridis and Molinari, 2023), including hydrograph accuracy, Digital Terrain Model (DTM) resolution and roughness coefficients for hydrodynamic modelling, vulnerability parameters in fragility curves, power generation and demand values in power flow models, and the number and spatial distribution of customers served by the grid.

The thesis objective is to design, implement and operationalize a probabilistic approach capable of accounting for the above uncertainties through mathematical representation and propagation by simulation. Specifically, the research will focus on the analysis of epistemic uncertainties using interval-uncertainty and imprecise probability methods, enabling a more comprehensive characterization and quantification of uncertainties in the system.

The activity will consist of the following steps:

i. Literature review on uncertainty analysis methods for probabilistic risk assessment, emphasizing on interval-uncertainty and imprecise probabilities approaches;
ii. Characterization of the uncertainties affecting the modelling and simulation framework, distinguishing between aleatory and epistemic uncertainties;
iii. Development of the methodology for uncertainty analysis, integrating interval-uncertainty and imprecise probability techniques to capture epistemic uncertainties;
iv. Implementation of the algorithms in MATLAB and/or Python for uncertainty propagation and risk quantification.

References

- Asaridis, P. and Molinari, D.: A conceptual model for the estimation of flood damage to power grids, Adv. Geosci., 61, 1–21, https://doi.org/10.5194/adgeo-61-1-2023, 2023.
- Asaridis, P., Molinari, D., Di Maio, F., Ballio, F., and Zio, E.: A probabilistic modeling and simulation framework for power grid flood risk assessment, International Journal of Disaster Risk Reduction, 120, 105353, https://doi.org/10.1016/j.ijdrr.2025.105353, 2025.

For further information, please contact
Prof. Enrico Zio (enrico.zio@polimi.it)
Prof. Francesco Di Maio (francesco.dimaio@polimi.it)
Prof. Daniela Molinari (daniela.molinari@polimi.it)
Dr. Panagiotis Asaridis (panagiotis.asaridis@polimi.it)