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MSc thesis proposal with international collaboration

(In collaboration with University of California, Los Angeles)

Title	Guided probabilistic risk assessment of complex systems using reinforcement learning optimization
Motivations and objectives of the research	Probabilistic risk assessment of complex systems is primarily for situations characterized by large uncertainties. These situations necessitate the assessment of multiple alternative possible scenarios and, occasionally, unknown scenarios. In multiple studies, it has been shown that the number of possible alternative scenarios increase over time significantly. This will increase the execution time dramatically, and in some cases make the problem unsolvable. One of the presented efficient methods to control the size of the probabilistic risk model is a supervised probabilistic risk model that generates failure scenarios using optimization methods. This approach can generate and sort failure scenarios in a short execution time. As an example [1, 2], an application of the supervised probabilistic risk model on a dynamic positioning system has been developed. In this application, knowledge of the system is explicitly used in an optimization model to predict possible failure scenarios. A supervised learning algorithm is used to find the optimal solution, which is the desired failure scenario, i.e., instead of focusing on obtaining all possible scenarios. In this thesis, a reinforcement learning approach will be developed and used to control the size of probabilistic risk models over time. The proposed methodology will be implemented on a case study to show the effectiveness of the reinforcement learning optimization method. **References** Parhizkar, T., Vinnem, J. E., Utne, I. B., & Mosleh, A. (2020). Supervised Dynamic Probabilistic Risk Assessment of Complex Systems, Part 1: General Overview. Reliability Engineering & System Safety, 107406. Parhizkar, T., Utne, I. B., Vinnem, J. E., & Mosleh, A. (2021).

	Supervised dynamic probabilistic risk assessment of complex systems, part 2: Application to risk-informed decision making, practice and results. Reliability Engineering & System Safety, 208, 107392. Hu, Y., Parhizkar, T., & Mosleh, A. (2021). Guided Simulation for Dynamic Probabilistic Risk Assessment of Complex Systems: Concept, Method, and Application. Reliability Engineering & System Safety, 108047. Parhizkar, T., Mosleh, A. (2022). Guided Probabilistic Simulation of Complex Systems Toward Rare and Extreme Events. The 68th Annual Reliability & Maintainability Symposium (RAMS), 2022, Tucson, Arizona. Hamed S Nejad., Parhizkar, T., Mosleh, A. (2021). Simulation Based Probabilistic Risk Assessment (SIMPRA): Risk Based Design. 31st European Safety and Reliability Conference | 19-23 September 2021, Angers, France. Parhizkar, T., Utne, I. B., & Vinnem, J. E. (2022). Online Probabilistic Risk Assessment of Complex Marine Systems. Springer Series in Reliability Engineering. Nejad, H. S., Parhizkar, T., & Mosleh, A. (2022). Automatic generation of event sequence diagrams for guiding simulation based dynamic probabilistic risk assessment (SIMPRA) of complex systems. *Reliability Engineering & System Safety*, *222*, 108416.
Activities	• Literature review on probabilistic risk assessment of complex systems, optimization methods, and guided scenario generation. • Study of reinforcement learning optimization method. • Methodology development. • Implementation of the algorithms in Python. • Application and validation of the proposed methodology.
International collaborations	University of California, Los Angeles (UCLA)
Required competencies and skills	• Good knowledge of risk assessment and reinforcement learning method. • Good knowledge of Python programming. • Engineering undergrad.
Composition of the research group	Number of Professors: 2
Name of the research director	Enrico Zio Tarannom Parhizkar
Email address	enrico.zio@polimi.it tparhizkar@g.ucla.edu
Web page	https://www.risksciences.ucla.edu/energy-resilience-unit https://www.lasar.polimi.it/
Duration of the dissertation	
Total thesis duration	8 months. At most 2 pending exams

Title	Resilience assessment and management of power grids in response to extreme weather conditions (heat wave, storm, flood, wildfire, etc.)
Motivations and objectives of the research	In the last couple of decades, a large number of climate disasters has happened in the world, resulting in overall damage exceeding US3.5 trillion and particularly US$1.3 trillion in the United States. In recent years, the frequency and intensity of extreme weather and climate-related events have been trending higher. Around 63% of the worldwide disasters has happened after 2010, and seven of the ten costliest storms in U.S. history occurring in the last ten years. The considerable rise in both severity and frequency of occurrences of climatological catastrophes, draws attention to a more climate-resilient electricity sector. In recent years, several databases and platforms have been developed to perform resilience assessment of electricity sector in response to extreme weather and climate-related events. In this thesis, a methodology for resilience assessment of power grids in response to extreme weather conditions (heat waves, storm, flood, wildfire, etc.) will be developed. The proposed model will be implemented on a case study to show the effectiveness of the proposed methodology. **References** Shirvani, R., & Parhizkar, T. (2022). Resilience based Electric Sector Optimization in Response to Extreme Weather Conditions with Distributed Generation Systems. arXiv preprint arXiv:2209.10050. Fang, Y. P., Pedroni, N., & Zio, E. (2016). Resilience-based component importance measures for critical infrastructure network systems. IEEE Transactions on Reliability, 65(2), 502-512. Fang, Y. P., & Zio, E. (2019). An adaptive robust framework for the optimization of the resilience of interdependent infrastructures under natural hazards. European Journal of Operational Research, 276(3), 1119-1136. Rocchetta, R., Zio, E., & Patelli, E. (2018). A power-flow emulator approach for resilience assessment of repairable power grids subject to weather-induced failures and data deficiency. Applied energy, 210, 339-350. Fang, Y., Pedroni, N., & Zio, E. (2015). Optimization of cascade-resilient electrical infrastructures and its validation by power flow modeling. Risk Analysis, 35(4), 594-607. Abdin, I. F., Fang, Y. P., & Zio, E. (2019). A modeling and optimization framework for power systems design with operational flexibility and resilience against extreme heat waves and drought events. Renewable and Sustainable Energy Reviews, 112, 706-719. Fang, Y. P., Pedroni, N., & Zio, E. (2014). Comparing network-centric and power flow models for the optimal allocation of link capacities in a cascade-resilient power transmission network.

	IEEE Systems Journal, 11(3), 1632-1643.
Activities	• Literature review on the effect of extreme events on power generation, transmission, storage, and end users. • Methodology development. • Implementation of the algorithms in Python. • Application and validation of the proposed methodology.
International collaborations	University of California, Los Angeles (UCLA)
Required competencies and skills	• Good knowledge of power grids and optimization methods or a willingness to learn. • Good knowledge of reliability, risk and resilience or a willingness to learn. • Good knowledge of Python programming or a willingness to learn.
Composition of the research group	Number of Professors: 2
Name of the research director	Enrico Zio Tarannom Parhizkar
Email address	enrico.zio@polimi.it tparhizkar@g.ucla.edu
Web page	https://www.risksciences.ucla.edu/energy-resilience-unit https://www.lasar.polimi.it/
Duration of the dissertation	
Total thesis duration	8 months. At most 2 pending exams