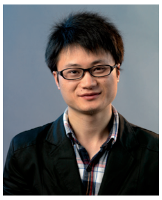
Risk and Resilience of Complex Systems

Contact: anne.barros@centralesupelec.fr

Partners:
EDF (historic partner), SNCF, Orange

Anne BARROS
Professor
Chair holder



Yiping FANG
Assistant Professor

Zhiguo ZENG
Assistant Professor

William FAURIAT
Postdoctoral Researcher

Andréa BELLE
PhD Candidate

Research

Operation
The RRCS chair is taking over a previous chair on Systems sciences and Energy Challenges supported by EDF for 9 years. The aim is to use the past experience and to wide the scope with no limitation to energy production systems. It is a multi-partner chair with as main partners:
-EDF (historic partner)
-SNCF
-Orange

The interest is that the partners can share common concerns, contribute to the development of pooled models and exchange on use cases. Ultimately, they will benefit from the methods and tools developed by all the members of the chair. The chair is based on a team of 3 experienced permanent staff (two associate professors and one professor) and several PHD students. The chair has two main missions: to ensure a level of scientific excellence and to promote the transfer of knowledge / technology.

Scientific project
The main topics covered are risk analysis and optimizing the resilience of complex systems. The three lines of work identified to date by the partners are:

1. **Modeling systems of systems and interdependencies for risk management and resilience between several operators**
The objective is to understand how different systems interact with each other and to have, via modeling and then simulation work, an overall vision that allows to anticipate and optimize decisions.
Anticipating means predicting the dysfunctions of a subsystem (beyond on / off, studying and characterizing degraded modes), predicting the impact of a subsystem (including organizational and human factors) on the global system, anticipate disruptions from outside, identify the most critical elements to allocate surveillance, investment efforts. Optimizing means improving the capacity to optimize the service overall, taking into account the multiplicity of players and their own objectives.
The proposed approaches are based on i) the sharing of methods to analyze incidents between systems, and to assess and manage the criticality of subsystems ii) the definition of appropriate metrics, iii) the development of a heritage policy, with a global vision, iv) enhancement of modularity and interchangeability between models to take into account the different building blocks of telecoms (very intertwined with obsolescence problems), energy and transport.

2. **Modeling and optimizing maintenance phases to reduce their impact on intra- and inter-operator service continuity**
The objective is to reduce costs (failure costs, CAPEX, etc.) through physical modeling of the system (digital twin) and its use to simulate and then optimize the planning of corrective, preventive and predictive maintenance actions.
Optimizing an effective predictive maintenance policy involves being able to aggregate the maximum amount of information from systems, including information not coming from sensors (human flows, behaviors for example) and to

exchange these information between different actors. This makes it possible to have reliable predictions about future failures and to anticipate them.
Optimal maintenance planning involves jointly optimizing predictive, preventive and corrective actions and managing the constraints specific to each actor to ensure continuity of service (allocation of resources in particular).
The envisaged approaches focus on critical costs such as those associated with the movement of teams, putting in competition strategies of the distributed system type versus movement of equipment. They must also take into account the fact that the systems evolve by themselves, repair themselves, reorganize (like the rerouting of Telecom traffic for example). The self-healing properties and issues to improve the next generations will have to be integrated.

3. **The development of a common platform of models and methods and the implementation of sensitivity studies**
This work axis is transverse to axes 1 and 2. It aims to feed them on the scientific level but also to contribute to the transfer of knowledge and technology between the partners and towards the operational staff.
On the scientific level, it is a question of characterizing and evaluating the sensitivity of the models developed for axes 1 and 2 to the quality of the data and information available to feed them. This data can be input data for the simulation (online data, type of degradation level or operating mode) but also learning data to estimate the parameters or the structure of the models (historical data).
In terms of transfer, it is a question of promoting the emergence of a common platform of models and methods, and of taking into account the difficulties linked to communication between models, multi-scale and multi-domain modeling, specification of interfaces, development of dedicated prototypes.

These three axes are fed by use cases proposed by the partners.

Publications

- **Zeng Z., Fang, Y. P.**, Zhai, Q., & Du, S. A Markov reward process-based framework for resilience analysis of multistate energy systems under the threat of extreme events. Reliability Engineering & System Safety.

- **Bani-Mustafa Tasneem**, Roger Flage, Dominique Vasseur, **Zhiguo Zeng**, Enrico Zio (2020) «An extended method for evaluating assumptions deviations in quantitative risk assessment and its application to external flooding risk assessment of a nuclear power plant.» Reliability Engineering & System Safety 200.

- Zhang Nan, Mitra Fouladirad, **Anne Barros**, and Jun Zhang (2020) «Condition-based maintenance for a K-out-of-N deteriorating system under periodic inspection with failure dependence.» European Journal of Operational Research 287, no. 1: 159-167