Towards optimal operation and maintenance of electric power grids under uncertainties

John Moriarty & Louis Wehenkel

May 1st, 2019 - Isaac Newton Institute, Cambridge

JM - School of Mathematics, Queen Mary University of London, UK

LW - Montefiore Institute of EE&CS, University of Liège, Belgium

Overall motivations

The TSO (DSO) Problem:

Ensure sufficiently reliable electricity supply at minimal cost.

In the context of

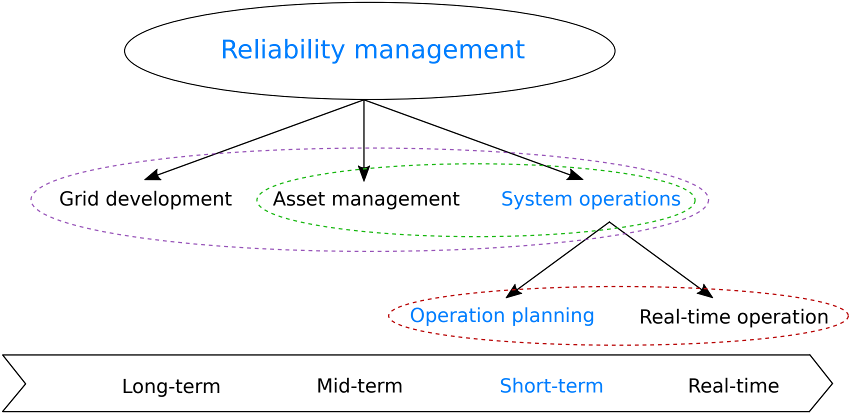
- ageing grid infrastructure;
- shift towards renewable energy sources;
- new needs, new products, new types of components.

The (urgent, difficult) R&D Problem:

Develop better reliability management methods by leveraging Data, Models & Algorithms, over timescales ranging from a few minutes to several years

Power Systems Reliability Management (subtasks & timescales)

Taking decisions in order to ensure the reliability of the system while minimizing socio-economic costs



Overview of some work carried out at INI-MES-2019

- Research Track 1 (Jan 14 - Jan 25)
  "Look-ahead operational planning under uncertainty"
  - Horizon of a few hours to a few days
  - Continuous vs discrete time optimal control formulations
  - Public report + Benchmark proposal
- Research Track 2 (Jan 28 - Feb 8)
  "Budgeting and scheduling of maintenance and replacement of power system components"
  - Horizon of a few months to several years
  - Modelling of failure rates of power system components
  - Maintenance budgeting problem formulation
  - Two working papers + Benchmark proposal

Why benchmarks ? What kind of benchmarks ?

- The Why:
  - Enforce relevance and reproducibility of empirical validations
  - Facilitate sharing of results among researchers
  - Speed-up transfer of results towards industry
- The How:
  - Define scope in collaboration with industry to ensure practical relevance
  - Collect needed data and models, and share them in an open fashion
  - Create a series of "Competitions" around successive versions of benchmark using well agreed assessment criteria and protocols

NB: These issues were raised/discussed at various occasions during the opening workshop MESWO1 of this programme.

Part I

A challenge/benchmark/competition about "Look-ahead operational planning under uncertainty"

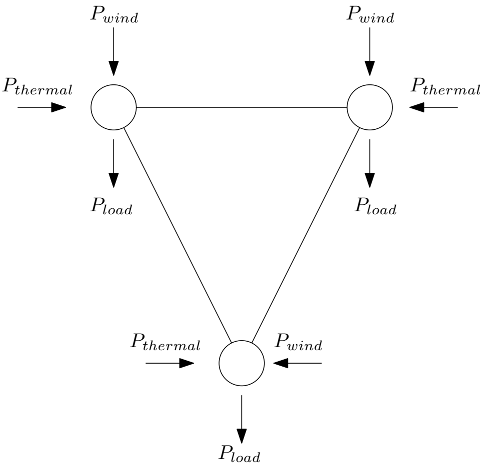
- Motivation
- Three area system
- Uncertainty model
- Workplan

Motivation

- The problem: buy generation reserves ahead in time in order to enable system balancing in real-time, while complying with network constraints and avoiding to the extent possible load shedding and wind-power curtailment.
- Many different strategies may be imagined; the idea is to foster research in terms of methods that would be able to automatically build near-optimal strategies
- A test system, data and simulator will be provided to support R&D.

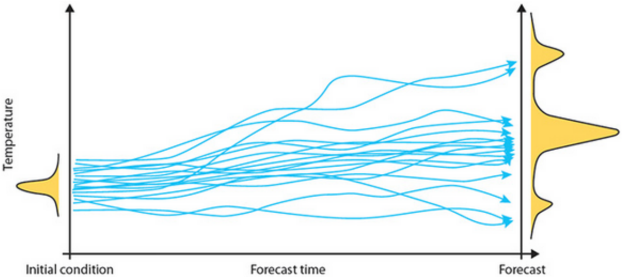
NB: the problem and benchmark layout were defined during the research track and based on discussions with NG and RTE experts

Three area system



- Each area is represented by a single bus, several thermal generating units, lumped wind-power generation, lumped demand net of PV
- Grid represented by three "equivalent" interconnectors with given power flow limits, and linearized powerflow equations
- NB: reactive power, voltage issues, and topology details are neglected in V1; future versions will be made progressively more and more realistic

Uncertainty model



We will provide uncertainty models in the form of ensembles of multivariate trajectories (e.g. wind-power + demand for each area for $t \in [\tau; \tau + 24h]$).

A training ensemble will be made publicly available to the research community, in order to allow them to tune a control policy.

A number of test ensembles will be kept private, and used later on in order to assess proposed control policies

Workplan

- Define all data: physical model, technical constraints, cost functions
- Define control layers: look-ahead, real-time, automatic
- Design of simulator: parallel system operation over large set of exogenous scenarios over 24 hours, while using as input a given open- or closed-loop control policy
- Definition of testing and validation protocols: used to set up first competition
- Planning of future versions: of data, models, simulator, validation protocols

NB: we target 2020 for the first iteration of a competition around the look-ahead operational planning problem

Part II

A challenge/benchmark/competition about "Estimation of failure rates of power system components"

- Motivation
- Proposed approach

Motivation

- Failure rates of lines, transformers etc. are fundamental quantities of probabilistic reliability assessment and control approaches
- They depend on type of component, environmental conditions, stress and maintenance history
- Failures are rare events (say 1 failure/component.yr), so that failure data is scarce
- Real data about power system component failures is currently difficult to share and render public

To foster research on failure rate estimation, it is necessary to provide public datasets that are as large and realistic as possible, and to define criteria for comparing different kinds of failure rate estimates obtained by different methods.

Approach

1. Collaborate with some TSOs and DSOs to gather as much as possible real-life failure data
2. Use real-life datasets, in order to build realistic generative models for different kinds of component failures
3. Use generative models to
   - Generate synthetic training and validation datasets
   - Publish only the training datasets together with methodology used to build the generative models
   - Create benchmarks and launch competition
   - Use the validation datasets to compare methods

NB: this allows to keep real-life datasets unpublished, while having a 'ground truth' for evaluating the accuracy of failure rate estimates.

Part III

RANGL: a platform to post and solve data-centric challenges for infrastructure systems

RANGL: a platform to post and solve data-centric challenges for infrastructure systems

- Who: A collaborative effort open to all, starting with
  - participants from INI MES research tracks 1 & 2
  - members of the Alan Turing Institute, UK
- What: A platform to post and solve data-centric challenges for infrastructure systems
  - characterised by complexity - eg. size, humans-in-the-loop, random exogenous inputs
  - data-centric: eg. historical data, simulation models of the system and its inputs
  - starting with energy systems challenges from RTs 1 & 2 and the Turing
  - open later to other infrastructures eg. transport, other utilities
  - subsequent potential to consider interdependencies between infrastructure systems

RANGL: a platform to post and solve data-centric challenges for infrastructure systems

- Why: as above
  - Enforce relevance and reproducibility of empirical validations
  - Facilitate sharing of results among researchers
  - Speed-up transfer of results towards industry

When: prototype challenge under construction

  - sign up at `www.rangl.org` for updates

Questions / Comments ?