Needs and Challenges for the optimization of large power systems

GO Competition Outreach

New Orleans

18th February 2020

Patrick Panciatici
Scientific Advisor
European electricity today

36 interconnected countries (43 TSOs)
- Security of the power system in real time
- Economic optimization
- Security of supply

5 synchronous zones
- Scandinavia
- United Kingdom
- Ireland
- Continental Europe
- Baltic countries

Installed capacity: ~1140 GW
Consumption: ~3,600 TWh/year
Peak Load: ~500 GW
Physical exchanges: ~425 TWh/year
Population: 500 Million +
RTE: French Transmission System Operator

SO & TO: system operation, grid maintenance, grid access, grid development

Transmission grid owner
• 105,000 km transmission assets (63 kV to 400 kV): local level to European level
• 2800 Substations
• 22,000 km optical fibers
• 48 interconnectors

Transmission grid operator
• 8 control centers
• Founder member of CORESO European Coordination Center
• Homemade software: system adequacy, integrated study chain from development to operation, ...

Enabler of new market designs
• Market coupling at European scale with flow-based method
• Market based capacity mechanism
• Most advanced market design for demand side management in Europe (SEDC* source in 2015)

* SEDC: Smart Energy Demand Coalition
RTE Key Figures (2019)

- Exports: 84 TWh
- Imports: 28 TWh
- €4.5 billion Turn Over
- €1.5 billion Investments
- 8,500 Employees
- 473 TWh: Total energy injected in the French grid
- 89 GW Peak Load – 100 GW (2012)
- €35 million/year - 130 full time people

Who are our 490 customers?

- 135 market players
- 54 power generators
- 258 industrial consumers
- 32 distribution network operators
- 11 railway companies
- SMEs (tertiary)
- Households
A huge increase of the system complexity!

A power system undergoing significant changes

Renewable energies with zero marginal costs, power electronics interfaces, intermittent generation, smaller, more distributed and less controllable.

“Load” that is declining in average (Energy) and is more volatile (Power). A portion of the Load is becoming controllable. Impact of electro-mobility?

More power electronics: decrease of inertia involves faster dynamics but emerging solutions on storage.

An increasing number of stakeholders – economic & technical – x 1000 – prosumers promoting autarchy! Still NIMBY & BANANA syndromes.

Ageing of grid assets: Significant part of the grids' assets is more than 60 years old. Large number of assets approaching simultaneously the end of their life times.
Making «Good» Decisions ➔ “Optimization”

Developing, Maintaining, Operating the Power Grid requires many complex decisions to be made on different time scales:

- Building new infrastructures,
- Maintain or renew existing structures
- Operate existing facilities to best satisfy the users of the power grid

Making a "good" decision involves a trade-off between benefits and costs

- while respecting physics-related constraints and regulatory frameworks
- taking into account uncertainties
- but also the decisions that will still be possible in the future (Last Time to Decide).

All our processes to support decisions making are in fact "optimization problems"

- although the optimization problem is not always very clearly stated and generally not solved using optimization methods.
Open questions and challenges

• More local closed loop controls?
• Modeling of uncertainties?
• Coordination layer and operators in the loop?

Proxy = Simplified Abstraction!

Borrowed from Prof. L. Wehenkel!
Grid flexibilities and advanced local controls in centralized optimization?

- All centralized operational and market processes must take into account the existence of local advanced controls, **to avoid expensive preventive limitations and actions**.

- Grid flexibilities *(including switching of busbar couplers and DLR)* can bring significative value, [Mobilizing Grid Flexibility for Renewables Integration through Topology Control and Dynamic Thermal Ratings], J. Shi & S. Oren, IEOR and TBSI, Berkeley – PSERC Webinar.

- Towards a new architecture: *hierarchical controls using proxies*?
  - **Optimize**: Upper level (“market zone”) defines an “optimal” trajectory
    - Using a proxy of the lower level = *simplified abstraction*
  - **Control**: Advanced local (area) controls follow the trajectory and react in case of contingencies to avoid actions of local protections
    - Using a proxy of the protection level (e.g.: DLR)
  - **Protect**: Local protections in substation (*simple rule: one measurement/one action*)
    - Ensuring safety
Probabilistic approaches require modeling of uncertainties!

- “Accurate” forecasts are mandatory but modeling uncertainties is critical to make efficient decisions. *(some actions need time to be implemented)*
  - Uncertainties are forecast errors and depending on forecasting methods (Bias–Variance tradeoff)!
  - Spatial and temporal correlations must be captured for the grid management when location matters
  - The modeling framework could be chosen depending on each decision process and the associated problem to solve: pdf & copula, Gaussian processes, GAN, ....

- Some variables (data) are not purely random variables but are impacted/censored by some existing policies/controls (DSM, wind power curtailment, maintenance of wind turbines, ...) ; how to take into account these effects (counterfactual inferences?)?

- Example: Interface between Distribution and Transmission grid
  - “Loads” in Transmission grid are power flows on transformers affected by the “unknown” topology of Distribution grid. *Simplistic illustrative example*:
• Upper level (“market”) knows more information about the future: weather forecasts, planned outages, generation schedules … Definition of an “optimal” trajectory for local controllers taking into account their limited capabilities (via proxies), coordination between them.

- **Operators** make decisions based on an advanced **security assessment (SA)**
  - For operator-defined trajectories; assessment of the risk of “unserved energy”, a reliability criteria must be defined going beyond traditional N-1 (see Garpur project: [https://www.sintef.no/projectweb/garpur](https://www.sintef.no/projectweb/garpur))
  - The computation power required for probabilistic security assessments is huge ➔ screening techniques based on Machine Learning: Speed up using imitation of computationally intensive simulations, offline learning or from past analyses, possible supergeneralisation (e.g.: N-2)

- Learning “good” decisions by **imitating operators** ➔ propose them back these decisions after assessing the associated risk.
  - Possible to explain: “similar” conditions in the historical database, validation using the same SA.
    Gather and use operator’s feedbacks (socially guided ML): Assistant / NLP?

- **“Optimal” decisions:** optimization problems: Mixture between mathematical programming and reinforcement learning? Proxy for computationally intensive optimizations? Relaxations guided by ML? Explainable? Validation using the same SA.
Organizing two competitions!

- **Potential solutions to complex optimization problems**
- Real time agent controlling the grid topology including bus merging/splitting. L2RPN (Learning To Run a Power Network)

Machine Learning for Power System

- Grid operation-based outage maintenance planning

Optimal planning regarding an operational **risk-based objective** with all job-related realities such as **resources constraints**.

Attracting the **Operational Research** community
**L2RPN: Sequence of competitions**

**IJCNN: Feasibility challenges**
- **2019**
  - Small Grid, no events, Winter month, only topology

**Spring 2020**
- Medium Grid, maintenance, all year long, only topology

**Proposal to NeurIPS Real-World challenges**
- **Summer 2020**
  - Resiliency
    - Medium Grid, adversarial attacks, Topology & redispaching actions
  - Adaptability
    - Large Grid, 2 environments, Topology & redispaching actions

**Grid2Op**: Open source testbed platform to model real-time operations, run & benchmark control algorithms

**Competitions**: more information at [www.l2rpn.chalearn.org](http://www.l2rpn.chalearn.org)
Grid operation-based outage maintenance planning

Organized with the French Operational Research (OR) and Decision Support Society (ROADEF: https://www.roadef.org/challenge/2020). This international competition will be announced on February 20th during the annual conference of this society.

TSO’s missions

Operation-based maintenance outage

Security assessment

Energy transition

Big challenges

Two key points:

1. Better maintenance planning
2. Long term grid expansion planning in network: maintenance scheduling still possible in 20 years?
THANK YOU FOR YOUR ATTENTION

patrick.panciatici@rte-france.com
www.rte-france.com
Large power systems are the most complex machines ever built by mankind

National Academy of Engineering in USA: [http://www.greatachievements.org/?id=2949](http://www.greatachievements.org/?id=2949)