Whither TSO-DSO coordination for power systems reliability management

Abstract: The increasing penetration of renewables and the progresses in sensors, power electronics and data processing are strong drivers and enablers of changes in the way transmission and distributions systems will be planned, maintained and operated in the future. Both in Transmission and in Distribution, the stakes are to reduce costs while ensuring a proper level of reliability, by taking advantage of more sophisticated models, more data, and better computational tools, so as to enable more agile designs and more flexibility in operation. In this context, this talk will revisit the opportunities for coordinating reliability management practices of TSOs and DSOs.

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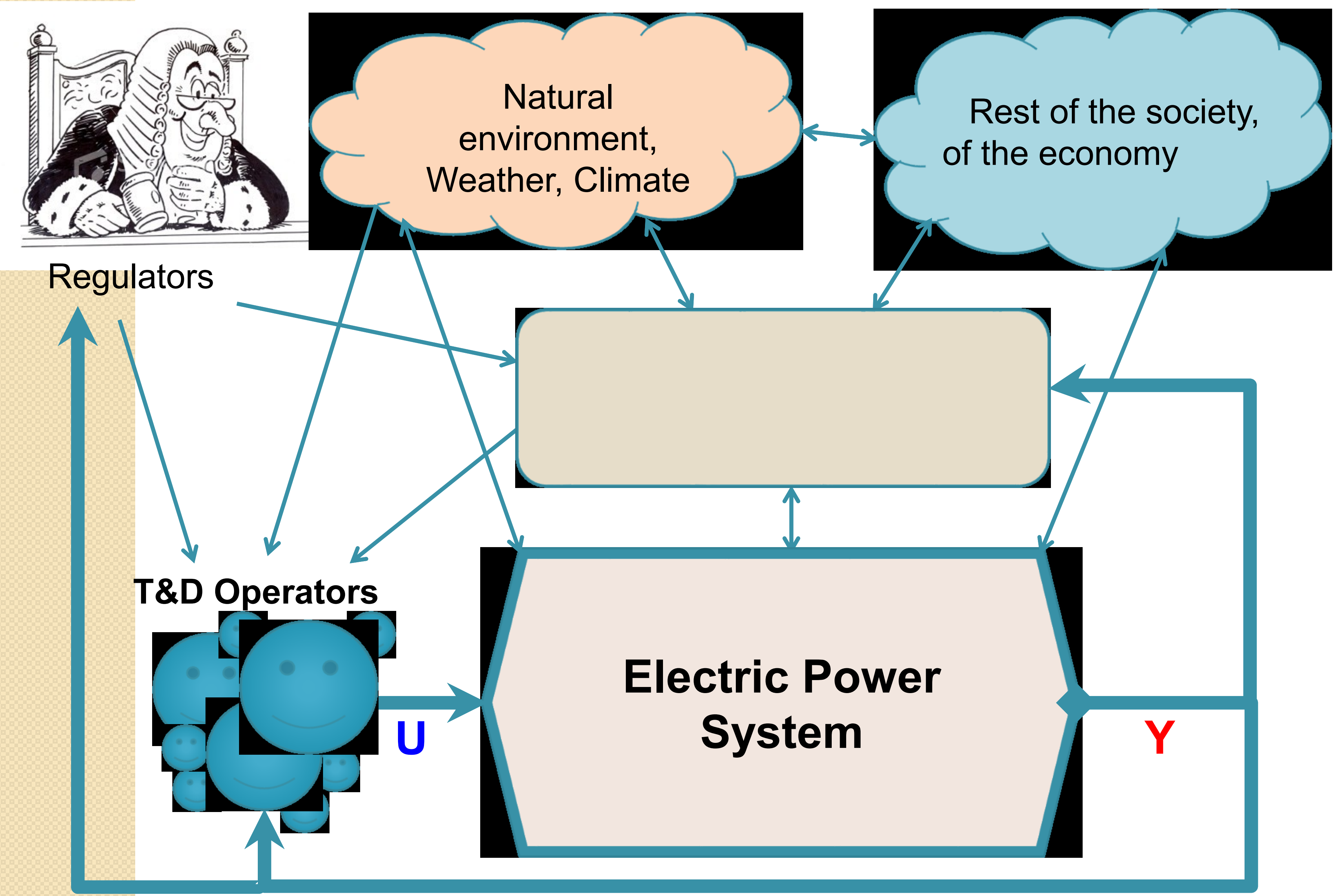
Apologies

These slides do not contain any equation,

and only one picture…



U: design/control decisions

Y: technical/economic performance measurements

Reminder

- Reliability Management consists of taking decisions under uncertainty in order to meet a Reliability Criterion at the lowest possible cost
- High enough Reliability means ‘sufficiently’ low expectation of Service Interruptions

NB: To denote the **R**eliability **M**anagement **A**pproach and **C**riterion used by a TSO or a DSO we use the acronym **RMAC** in this talk.

Overview

- Past and current RMACs
- Drivers for change in RMACs
- Trends / Solution pathways
- TSO-DSO Cooperation
- Open problems

NB: focus is on the operational time-scales (from a few weeks ahead in time to real-time)

Past and Current RMACs

- In Transmission Systems
  - Redundant design and operation to comply with the N-1.x criterion at any time
- In Distribution Systems
  - Design grid to fit the peak-load in N-0.y condition and forget as long as peak-load has not significantly changed (SAIDI/SAIFI…)
- Consequences
  - Service interruptions mostly local, short, and rare
  - High costs of T&D (> 50% of end-user bill)

Drivers for change in RMACs

- Technical
  - Renewable and dispersed generation sources
  - Ageing grid infrastructures
  - New sensors, data, algorithms, storage devices, micro-grids, robotics
- Socio-Economic
  - Decrease in marginal cost of energy production
  - Increase in costs/tariffs of DSOs and TSOs
  - Demand Flexibility, Electric Vehicles, Prosumer Communities

Trends / Solution pathways

- More explicit arbitration between the cost of taking reliability management decisions and the socio-economic impact of potential service interruptions
- More flexible and smarter operation
  - Towards probabilistic RMACs for TSOs
  - Towards active distribution management

Probabilistic RMAC for TSOs

- Explicit modeling of uncertainties
  - Forecast error distributions
  - Failure rates & contingency probabilities
- Monetization of risk of service interruptions
  - E.g. via (VOLL) x (Energy) x (Probability)
- Stochastic (multi-stage) programming
  - Multiple horizons, from minutes to weeks
  - Minimize first-stage + expectation of recourse costs including risk of service interruptions
  - Subject to Reliability Target, e.g. in the form of a chance constraint on HILP events

Active Distribution Management

- Target
  - Act dynamically on Grid, Demand-side, DG, and Storage, so as to maintain flows and voltages within limits, and prepare to reduce extent & duration of eventual service interruptions
- Enablers
  - Fine-grained Demand and DG forecasts
  - Localized flexibility "markets"
  - Novel control schemes/algorithms
- Problem statement
  - Frame as a (multi-stage) stochastic programming problem, similar to the probabilistic TSO RMAC

TSO-DSO Cooperation

- Why ?
  - Similar objectives
  - Overlapping control means
  - Overlapping data and modeling requirements
- How ?
  - (Sharing of experience and methods)
  - Sharing of data and models
  - Coordination of operational practices
- **There is only one power system…**

Sharing of data and models

NB: focus on sharing additional data and models needed by probabilistic RMACs

- Forecast errors of Load and DG
- Monetized risk of Service Interruptions

Although important as well, we do not discuss

- Sharing data about “Balancing activities”
- Physical response models

Load and DG forecast errors

- Load and DG as seen by DSO
  - Fine grained at MV or even LV level
  - Weather and time dependent probabilistic models
- Load and DG as seen by TSO
  - Coarse grained at EHV or HV level
  - Weather and time dependent probabilistic models
  - Depends on DSO operation and control strategy
- Sharing of data and models
  - End-users' data collection by DSOs
  - DSOs provide up-to-date models to TSO in the form of joint probabilistic models at common interface buses
  - TSO data collection at common interface buses
  - TSO responsible for modeling correlations among multiple interfaces of different DSOs

Monetized service interruption risk

- VOLL as seen by DSO
  - Fine grained at MV or even LV level
  - Weather and time dependent
  - Depends on End-users’ preferences and facilities
- VOLL as seen by TSO
  - Coarse grained at EHV or HV level
  - Weather and time dependent
  - Depends on DSO operation and control strategy
- Sharing of data and models
  - End-users’ data collection by DSOs
  - DSOs provide up-to-date models to TSO in the form of ‘suitable’ VOLL curves

Other data and models

- Data about balancing activities
- Physical response models

A similar bottom-up approach could be used, giving the responsibility to the DSOs to establish, communicate, and commit towards the TSOs how the load and generation connected to his grid would respond to various physical and economic signals.

DSO-TSO Coordination

- How to share control resources ?
- How to share costs and benefits ?
- Black-box models of DSOs ?

NB: these are open questions

Coordination of control resources

Demand flexibility, storage, and DG/load-shedding are both useful for handling DSO problems and TSO problems

- Direct control by TSO vs Indirect via DSO ?
  - Two competing viewpoints
    - Any control of DSO connected load or generation via DSO
    - Preemption by TSO in “emergency” conditions
  - Choice depends on time-scales, infrastructure costs, and regulatory situation
- In any case, formal models need to be defined for the coordination of control resources

Sharing costs and benefits

- When a TSO uses resources located in a particular DSO grid, it is to serve himself and end-users not connected to the concerned DSO grid
- When a DSO uses resources located in his grid, it is to serve himself and the end-users located inside his own grid
- The sharing problem is thus tantamount to deciding how to distribute social welfare among end-users in a region concerned by several TSOs and DSOs, while using resources connected both at the distribution and the transmission level
- This sharing problem may also occur in the future at a smaller scale with the emergence of micro-grids and local prosumer communities

Black-Box models of DSOs ?

- DSO “offers” a choice of several (P,Q,V) capability “regions” to TSO
- TSO selects one of them, to use it as a black-box (BB) model of DSO behavior
- Once TSO & DSO agree, they both commit to comply with the chosen BB.
- TSO pays DSO for the service of complying with the chosen BB model

Outlook

- The reliability level perceived by end-users is impacted by both TSO and DSO decisions
- The ADM approaches used by DSOs canalize the behavior of most end-users seen by TSOs
- Low reliability and/or high T&D tariffs may encourage more end-users to invest into micro-grids, which would reduce their value of lost load
- Low value of lost load of end-users reduces the incentives for TSOs and DSOs to increase their level of reliability
- This may lead to a negative spiral for TSOs and DSOs, reducing more or less quickly their business imprint

- **“Micro-economic” approaches are probably not sufficient to understand whether such a scenario would be beneficial to society in a broader and longer term perspective**

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FURTHER READING

- GARPUR FP7 Project

  www.garpur-project.eu
- SmartNet H2020 Project

  http://smartnet-project.eu