Improved management of risk in power system development: lessons from the GARPUR project

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The GARPUR project

University of Strathclyde Engineering

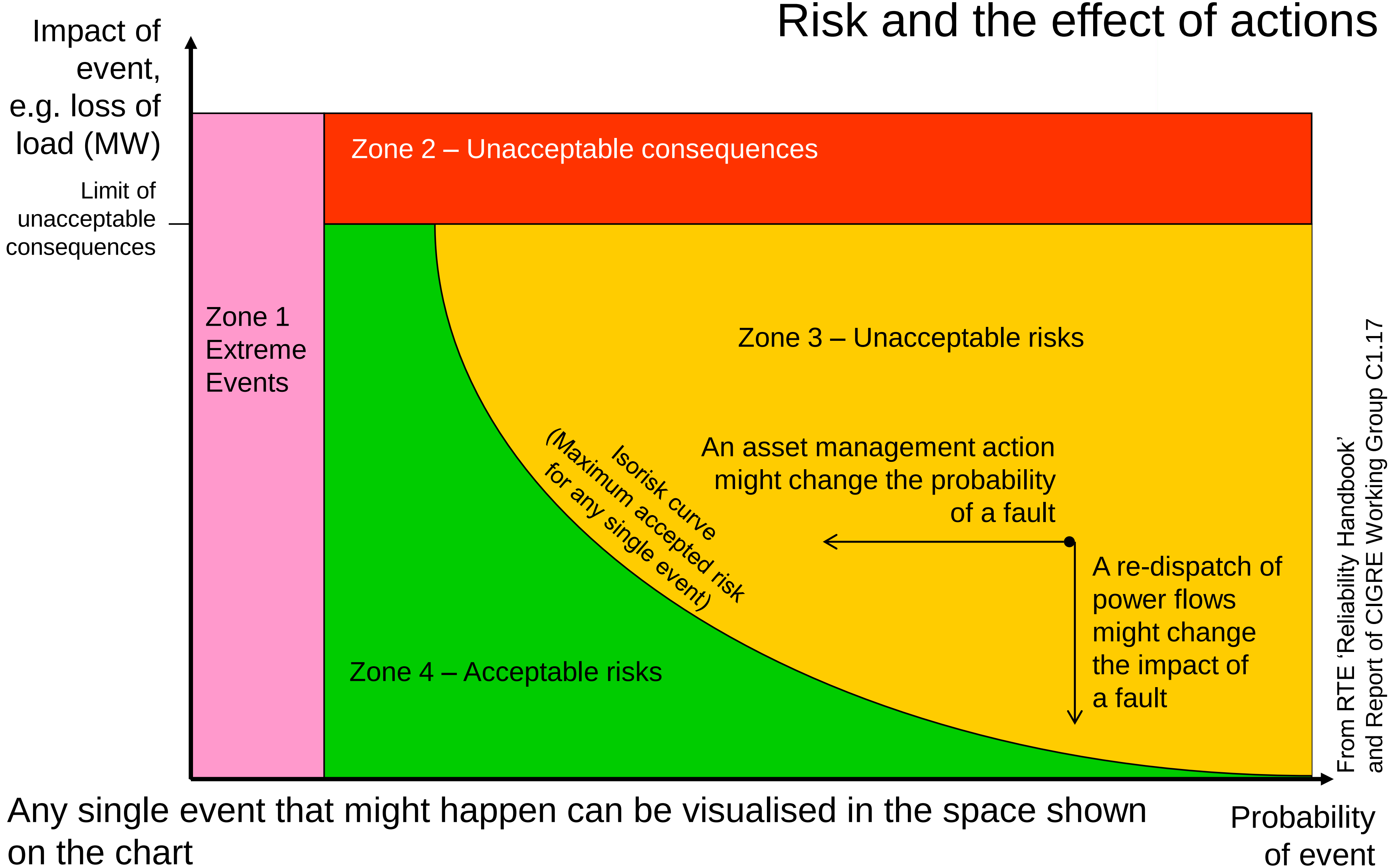
- Generally Accepted Reliability Principle with Uncertainty modelling and through probabilistic Risk assessment
- September 2013 – October 2017
- 7 TSOs and 12 R&D organisations
- Design, develop, and assess new probabilistic reliability criteria
- Evaluate their practical use while maximizing social welfare
- Cover the three Transmission System Operator functions:
  - power system operation and operational planning;
  - asset management; and
  - system development

https://www.sintef.no/projectweb/garpur

GARPUR

Project supported by the European Commission under the 7th Framework Programme and labelled by the European Electricity Grid Initiative (EEGI)

Risk and the effect of actions



Any single event that might happen can be visualised in the space shown on the chart

Action by the system operator, e.g. to change the pre-fault states, or by control equipment to change the system state post-fault, can change the location of an event in the chart

Main ideas in GARPUR

- When making decisions, which events do you need to assess explicitly and take action to safeguard against?
- A mathematical formulation of the main system-security related decisions in terms of:
  - the risk associated with secured events
  - the residual risk associated with all other events
  - a probability that system limits would be breached.
- The idea of ‘proxies’, i.e. approximate representations of considerations or actions
  - e.g. operator actions or asset management decisions, that are difficult to model directly

Mathematical basis

- The overall risk $R(x_0,u_0)$ associated with the operation of a system at a particular initial system state x_0 determined by a given set of values of control settings u_0 is given by

$$R(x_0,u_0)=\sum_{c\in N}\pi_c(x_0,u_0)\cdot c_R(x_0,u_0,c)$$

Risk associated with a particular disturbance c

where N is the set of all possible disturbances

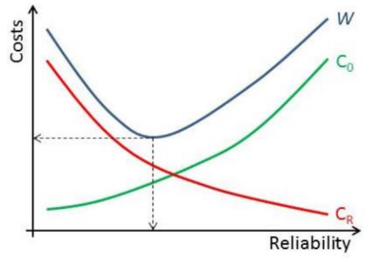
- System operator's aim: choose u_0 such that the total expected cost W is minimised

Cost of unreliability

$$W=C_0(x_0,u_0)+\sum_{c\in N}\pi_c\cdot\left[C(x_0+\Delta x,u_0+\Delta u,c)+c_R(x_0,u_0,c)\right]$$

Cost of corrective actions

- Disregard events for which total risk is small
  - Assess the impact only of $c\in N_s$



In reality

- Don’t know the probabilities of events very precisely
- Optimisations with lots of constraints are difficult to solve
- Models used to compute the impacts of events are only ever approximations
    1. DC load flow
    2. AC load flow
    3. Dynamic simulation

  Less approximate but heavier to do
- There is always a chance of system limits being broken
    - Solve a *chance constrained* optimisation, i.e. the probability of any constraint being breached is within some given tolerance

Which events to disregard when deciding on an optimal dispatch?

- How to be sure that the sum of the risk arising from all disregarded events is small?
  - We can't hope to model *all* the events to quantify their impact…
- Possible heuristics
  - The disregarded events have very small impact?
  - The disregarded events have very low probability of occurring?

In effect, this is done now when defining the set of secured events in the 'N-1' rule

- Both probabilities and impacts change
  - Probabilities are dependent on exogenous conditions, e.g. weather, and, to some extent, on system state
  - Impacts: functions not only of the event and initial system state but also of other events that might be triggered or revealed

System development context

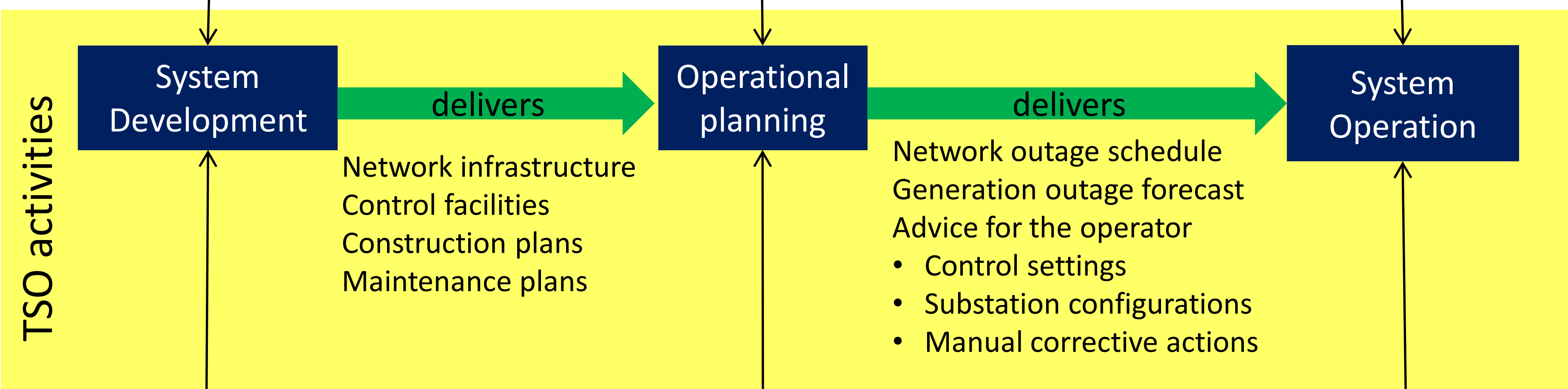
Disturbances and uncertainties

A planner’s job: enable future (sufficiently secure, economic) system operation

Forecast generation openings
Forecast generation closures
Forecast demand growth

Outline generation outage plans
Forecast generation ‘merit order’
Forecast demand
Forecast inter-area exchanges
Urgent network outages
Base wind power assumptions
Base solar power assumptions
Base hydro power assumptions

Generation forced outages
Network forced outages
Variations in area exchanges
Variations in wind speed
Variations in cloud cover
Variations in demand



Security standard: planning
- Main interconnected system
- Connection of generation
- Connection of demand

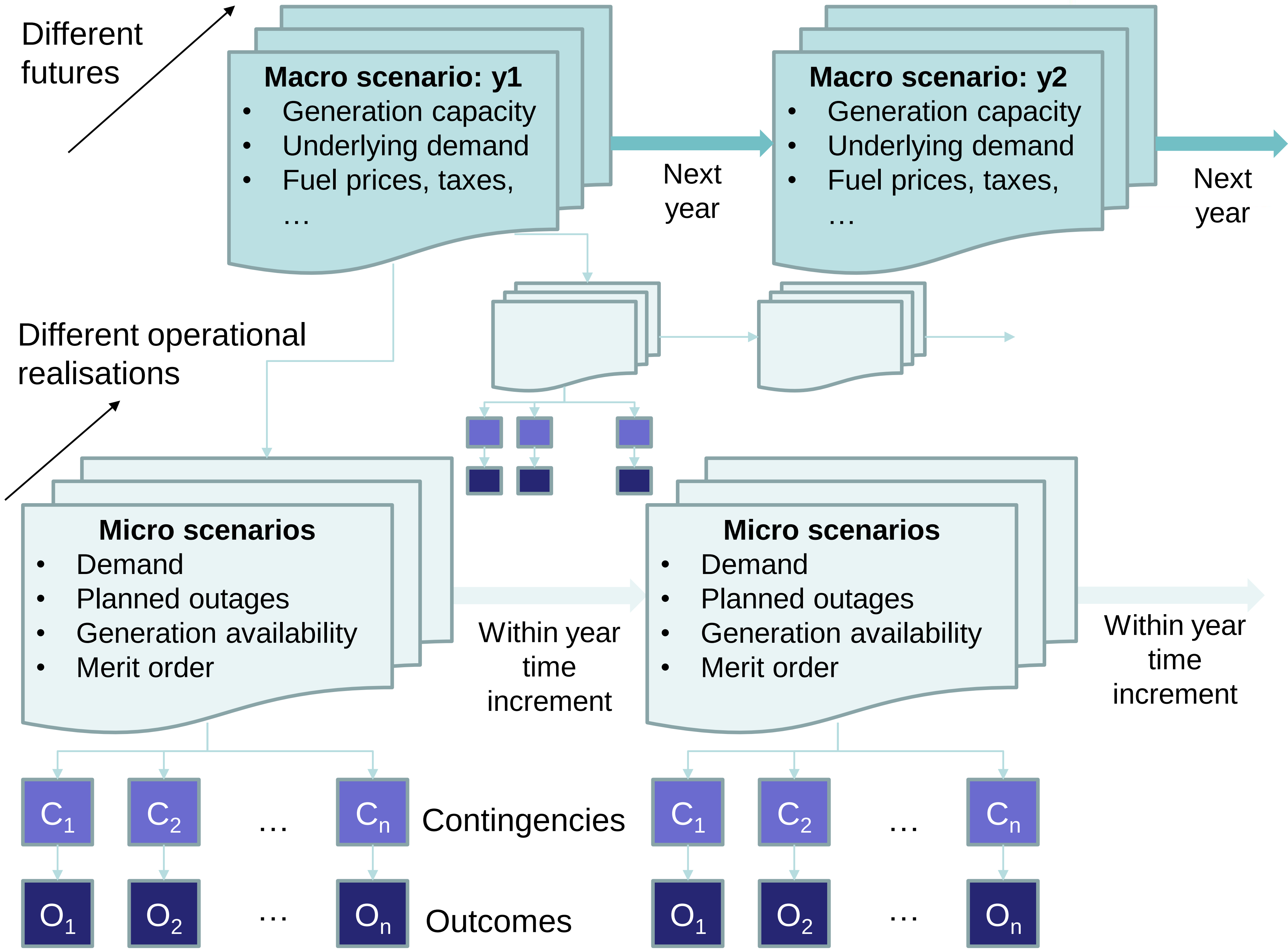
Grid Code
Connection/access codes
Asset management standards

Security standard: operation
Grid Code

Security standard: operation
Grid Code
Balancing service standard

Rules and standards

In spite of rules and standards, a lot of judgement is required on what to study and how to study it



Different futures
Macro scenario: y1
• Generation capacity
• Underlying demand
• Fuel prices, taxes, …
Next year
Macro scenario: y2
• Generation capacity
• Underlying demand
• Fuel prices, taxes, …
Next year
Different operational realisations
Micro scenarios
• Demand
• Planned outages
• Generation availability
• Merit order
Within year time increment
Micro scenarios
• Demand
• Planned outages
• Generation availability
• Merit order
Within year time increment
C_1 C_2 … C_n
Contingencies
C_1 C_2 … C_n
O_1 O_2 … O_n
Outcomes
O_1 O_2 … O_n

Sampling and modelling

Aims of GARPUR Work package 4

- Reduce the analysis burden
  1. Number of conditions to test in respect of network adequacy
  2. Number of conditions to study in respect of solutions to problems
- Let computers do what is laborious but systematic
- Let people do what requires judgement
- Cluster similar operating conditions/‘micro-scenarios’
- Identify common network problems
- Base investment decision on proposed solutions’ cost and their effectiveness across a range of operating conditions
  – How robust are they against different futures?

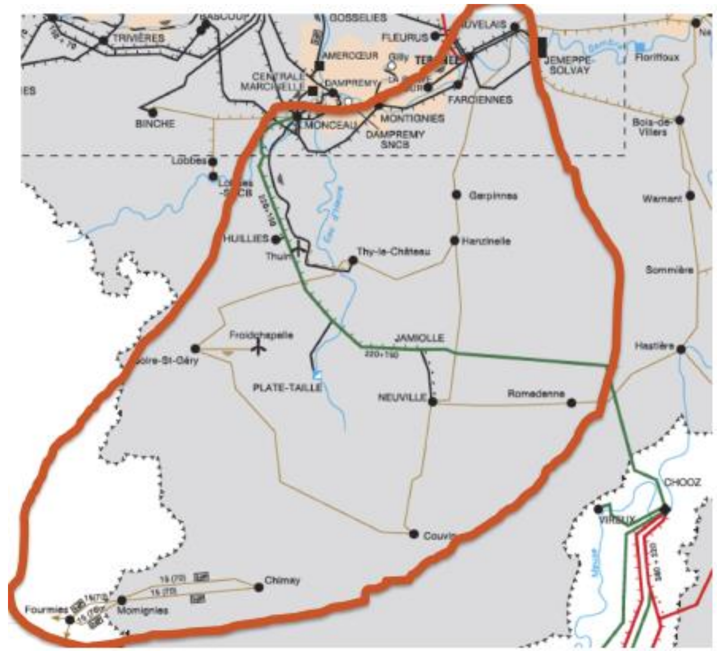
System development pilot study

Algorithm: GARPUR system development framework.

1 Select a *target-year* for the system development studies;
2 Using a pre-defined macro-scenario, identify peaks of various parameters such as demand, RES penetration and fuel prices;
3 Construct hourly operational scenarios of demand and power from renewables;
4 Use a market model to determine the commitment of thermal generators in each operational scenario;
5 Cluster snapshots;
6 Set $j = 1$, and system topology equal to present day topology. Choose N:=number of iterations of system topology;
7 **while** $j \leq N$ **do**
8   Perform assessment on centroids of clusters;
9   Identify system weaknesses and possible mitigations ;
10   System development planner proposes remedial actions ;
11   Update system topology and $j := j + 1$;
12 **end**

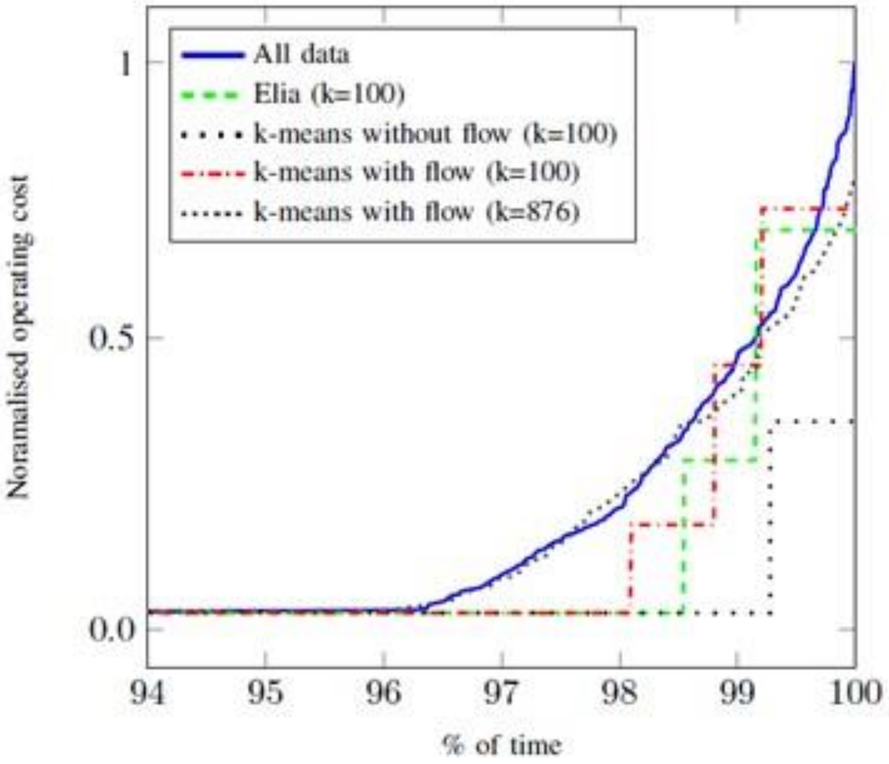
South West Belgium

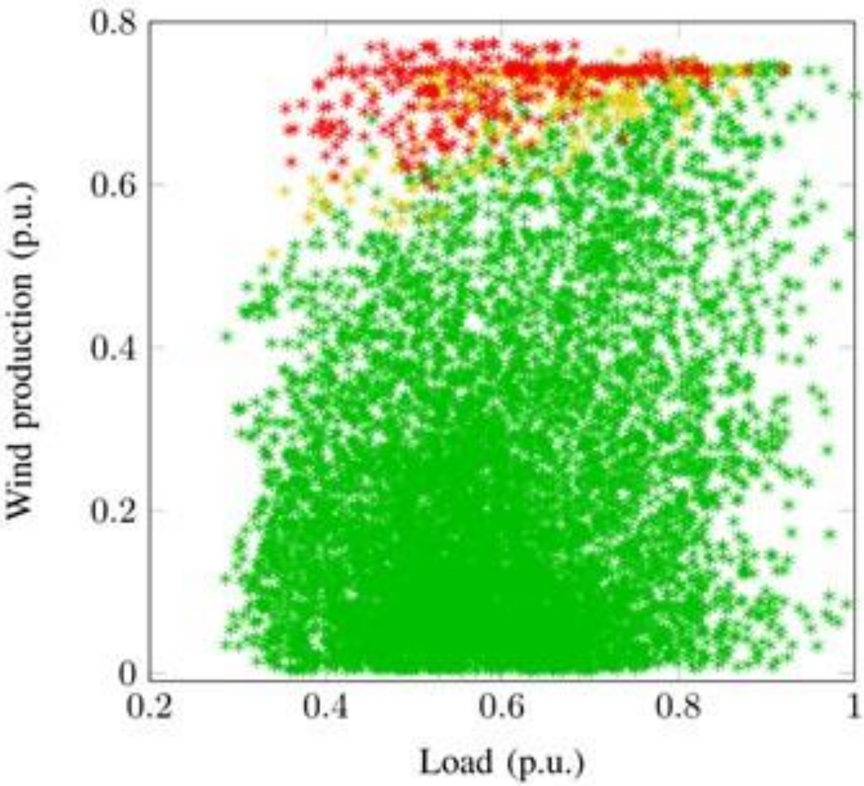
- 70 – 150 kV network
- 132 nodes and 261 branches



Generation type	Number of generators	Generation capacity(%)
Gas	22	43.8
Wind	20	30.6
Pump	4	10.7
Biogas	9	10.0
PV	95	4.7
Hydro	3	0.2

Results: operability and cost of operation





OK in N and N-1

OK in N but not in N-1

Not OK in N

Some clustering methods better than others
None catch the HILP scenarios

Peak demand is not the worst condition

Challenges

- The need for sufficient data and tools to compute accurately the system's responses to disturbances
- Limitations of modelling frameworks to capture real decisions of a transmission system operator
- Non-availability of good quality reliability data to derive probabilities of contingencies happening
- Difficulty in assessing risk posed by high impact low probability events
  - Highly sensitive to probability values
  - Widespread or long-lasting impact does not scale linearly
- Need for decision paradigms to make sense of 'macro-scenario' uncertainty

Recommendations

- For each future ‘macro-scenario’, a sufficient range of credible operating conditions should be studied.
- Modelling of system impacts should
  - represent how a system operator would dispatch the full set of controls pre-fault
  - take account of corrective actions by control equipment and the system operator.
- The quantification of impact should take account of
  - supply interruption durations
  - the spatial concentration of interruptions
  - the nature of the loads that are interrupted.
- Facilitation of maintenance should be an active consideration in system development decisions.
- Good quality data on unplanned outages should be collected by TSOs and shared with each other.