Realistic modeling for Security Constrained AC Optimal Power Flow (SC-ACOPF)

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Patrick Panciatici
Scientific Advisor

Réseau de transport d’électricité

OUTLINE

- **Why realistic modeling for SC-ACOPF?**
- **SC-ACOPF ➔ multi stage process**
- **Closed loop controls in static modeling**

- **Some modeling issues**

- **Overview of 3 examples:**
  - ➔ Synchronous generators
  - ➔ HVDC links: LCC & VSC
  - ➔ Active Distribution Networks

- **Data format et data availability?**

Why realistic modeling for SC-ACOPF?

► **Find "optimal" decisions for system operation, market operation, grid maintenance and grid expansion.**

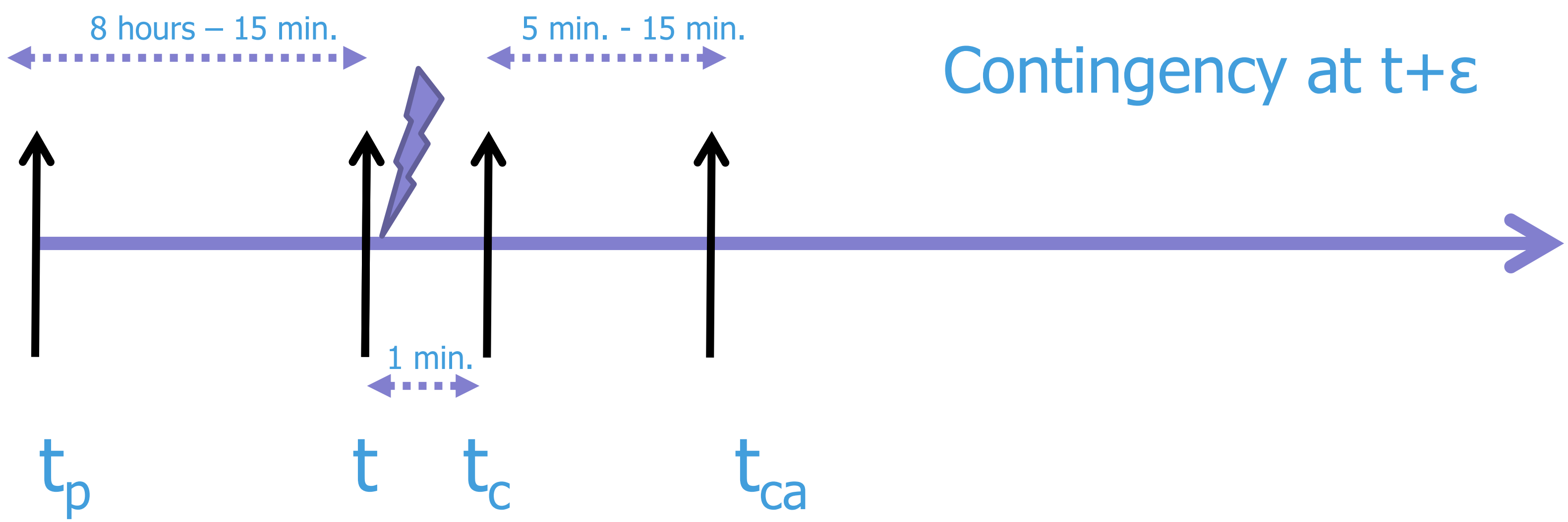
► **Definition of an acceptable risk is a prerequisite and security constrained AC OPF is mandatory.**

- In stressed conditions, optimizations based on DC approximation fail, exactly when tool should be helpful in decision making process.

► **Need for realistic modeling for reactive/voltage behaviors and corrective actions**

► **Not only for actual systems but also for future possible evolutions:** we must evaluate benefits of technological options before their implementations!

SC-ACOPF Multi stage process (Static modeling)



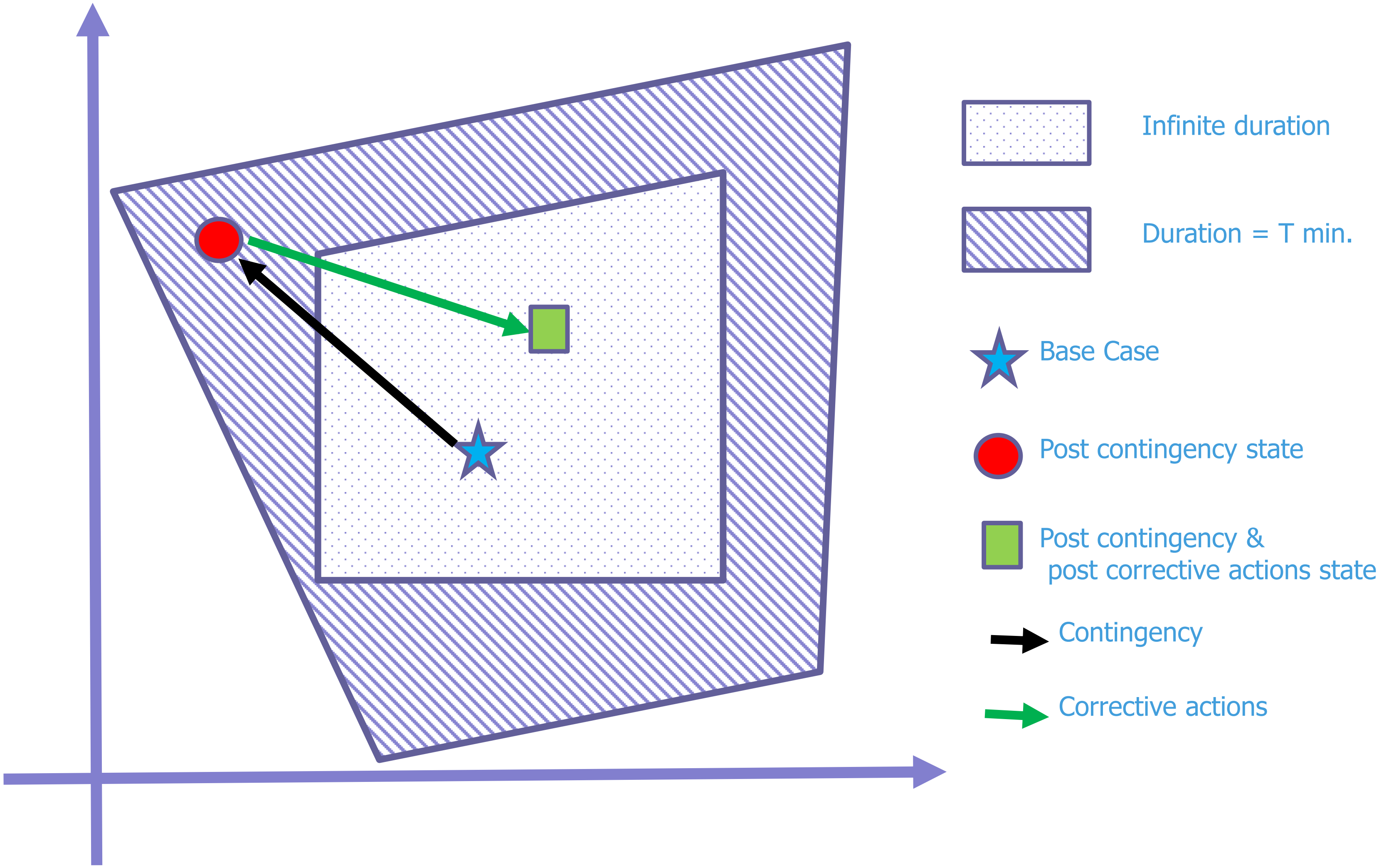
States: $X(t)$ $X(t_c)$ $X(t_{ca})$

t_p: Last time to decide preventive actions for time t

t_c: Post contingency

t_{ca}: Post contingency & corrective actions

Sequence of feasible domains (Illustration)



Abstract formulation of SC-ACOPF

$$\min_{u_p} J(x, u_p)$$

u_p*: preventive actions*

$$\begin{cases} F(x, u_p) = 0 \\ G(x, u_p) \leq 0 \end{cases}$$

➔ Base case

$k \in Set\ of\ contingencies$

$$\begin{cases} F_k(x_k, u_p) = 0 \\ G_k(x_k, u_p) \leq 0 \end{cases}$$

➔ Post contingency state

$$\begin{cases} F_k(x_k^c, u_p, u_k^c) = 0 \\ G_k(x_k^c, u_p, u_k^c) \leq 0 \\ C_k\left(x_k, x_k^c, u_p, u_k^c\right) = 0 \end{cases}$$

➔ Post contingency & corrective actions state

u^c*: simulated corrective actions*

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Final Steady state of closed loop controls in Static OPTIMIZATION PROBLEMS

► **Modeling of the final steady state of closed loop controls for the two post contingency states, simulation …**

► **The ones acting faster than 1 min. for the post contingency state:** AVR and speed generator of synchronous generators, switching of capacitor banks, HVDC links controls, ….

► **The ones which are slower than 1 min. and faster than 15 min. for post contingency & corrective actions state:** AGC, controls of PSTs, OLTC, ….

► **Controls (u) have limits ➔ The final state is not unique**

x (controlled variables) = set points or $u = u_{max}$ or $u = u_{min}$

Some Modeling Issues

- ► Generator Capability Curve ("D curve") or more (P,Q,V) 3D domain
- ► Node-Breaker modeling of Bus merging/splitting
- ► Phase Shifting Transformers: impedance depends on tap position
- ► HVDC links: Reactive/voltage modeling (LCC $\neq$ VSC)
- ► Capacitors/Reactors banks (large banks)
- ► SVC, STATCOM, variable Series Compensation ….
- ► Closed loop controls: AVR, Speed governor, AGC, …
- ► "Automatic" corrective actions:
  - ✓ RAS, SPS or simple predefined rules implemented by operators

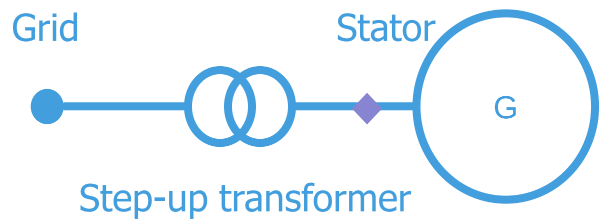
    If {some condition} then {action} …
- ► Modeling of Active Distribution Networks

Synchronous Generator (Pc , Vc)

► **Generator Capability Curve ("D curve") or more (P,Q,V) 3D domain**

✓ 3D convex domain: for a given P : (Q,V) domain, boundaries defined by a set of linear inequalities: $\alpha_l \, Q + \beta_l \, V \leq 1$

✓ Which P,Q,V? Grid or stator side? What if step-up transf. is not explicitly represented



► **AVR:** Generalization of PV ➔ PQ in Power flow

✓ Which voltage magnitude is controlled? Grid or Stator side?

✓ $V=V_c$ or (P,Q,V) is on one boundary of the domain, generally not Q=constant

► **Speed governor (primary power and frequency control)**

✓ Generalization of *"distributed slack bus"* in Power flow: P active power

✓ $P = P_c + P_r\ N$, N is scalar unique for one synchronous area but $P_{min} \leq P \leq P_{max}$

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HVDC links

► Reactive/voltage behavior very different for LCC or VSC technology

✓ VSC is similar to a synchronous generator

✓ LCC, voltage magnitude and reactive are less controllable

➔ Complex modeling generally coordination with a OLTC

➔ which “reasonable” model for ACOPF?

Constant power factor $Q = k.\ P + Q_h$ due to harmonics filters with Q_h depending on P

► Power flow control of HVDC link in // with AC power lines

✓ $P = P_c + K\ .\ (\theta_1 - \theta_2)$: Difference of voltage angles “emulation” of a AC line

► Reversal power flow for LCC

✓ Impossible to change rapidly the direction of the flows

✓ More that 1 min. corrective actions …..

Active Distribution Networks

► More and more dispersed generations (PV roof panel), Demand response programs, tomorrow storage

►The behavior seen from the transmission grid will not continue to look like even approximately to a constant P,Q load or anything like a ZIP model ….

► But it is impossible to have a detailed modelling of all the individual tiny "prosumers" in transmission grid decision making processes

►Decomposition of the total behavior between different types of fictitious aggregated components: a load, a wind farm, a PV farm and a storage device.

➔ Each of them with a specific behavior in case of voltage magnitude variation and different participation to the system balancing

Data Format & Data availability?

► The most common data formats don't support all these possible improvements.

► In the Griddata project led by U. of Michigan, we develop a new data format starting form a modeling document which propose improvements for most of these modeling issues.

► RTE can provide some realistic values for the required additional data and we are building step by step a collection of small size test cases with all the proposed improvements

THANK YOU FOR YOUR ATTENTION

patrick.panciatici@rte-france.com