Umbrella Project

Possible future strategies to limit the extent and impact of major system disturbances

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Polskie Sieci Elektroenergetyczne Operator S.A.

APG AUSTRIAN POWER GRID WE KEEP IT GOING

amprion

FGH Forschungsgemeinschaft für Elektrische Anlagen und Stromwirtschaft e.V.

swissgrid

TRANSNET BW

ČEPS, a.s.

IAEW Institut für Elektrische Anlagen und Energiewirtschaft Univ.-Prof. Dr.-Ing. Albert Moser

RWTH AACHEN UNIVERSITY

EWL

TU Delft Delft University of Technology

ELES ELEKTRO-SLOVENIJA, d.o.o.

ETH Eidgenössische Technische Hochschule Zürich Swiss Federal Institute of Technology Zurich

tennet Taking power further

TU Graz Graz University of Technology

Outline

Umbrella Project

- Introduction
- Risk-based Security Assessment
- Methods for Risk-based Security Assessment
- Umbrella Project
- Summary

Introduction

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- Definition of Power System Security:

> *Security of a power system refers to the degree of **RISK** in its ability to survive imminent disturbances (contingencies) without interruption of customer service. [Kundur et al.]*

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  - Increased uncertainty due to intraday trading and infeed from renewable energy sources
  - High, fluctuating cross-border flows

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- N-1 criterion reaching its limits due to
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  - high, fluctuating cross-border flows

How to extend/supplement the N-1 criterion with security assessment that can account for these uncertainties?

Objective

Develop strategies to keep system secure while facilitating market operation and integration of renewable energy

Proposed method:

Risk-based security assessment

Risk-based Security Assessment

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Risk = probability · severity

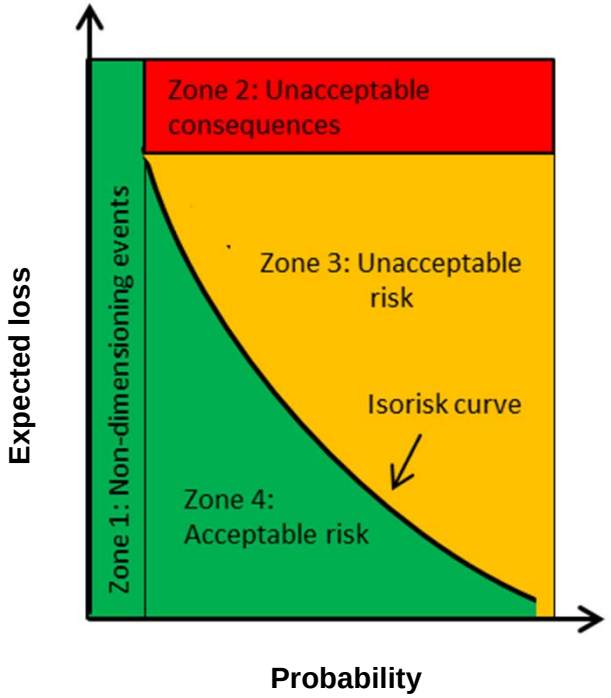

Figure 1: Risk zones in operation based on different risk levels. [UCTE OH]

Risk-based Security Assessment

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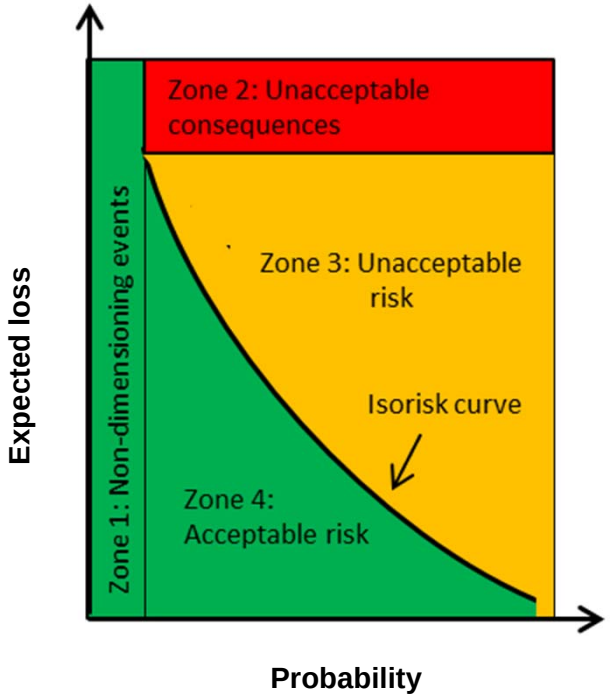
Risk = probability · severity

- Advantages
  - Quantitative formulation of risk
  - Explicit formulation of acceptable risk level
  - Direct trade-off between security and cost
  - Incorporation of different sources of uncertainty

- Challenges
  - Modeling (e.g. definition of outage probability and severity)
  - Computational requirements
  - Visualization (for interpretation in control center applications)



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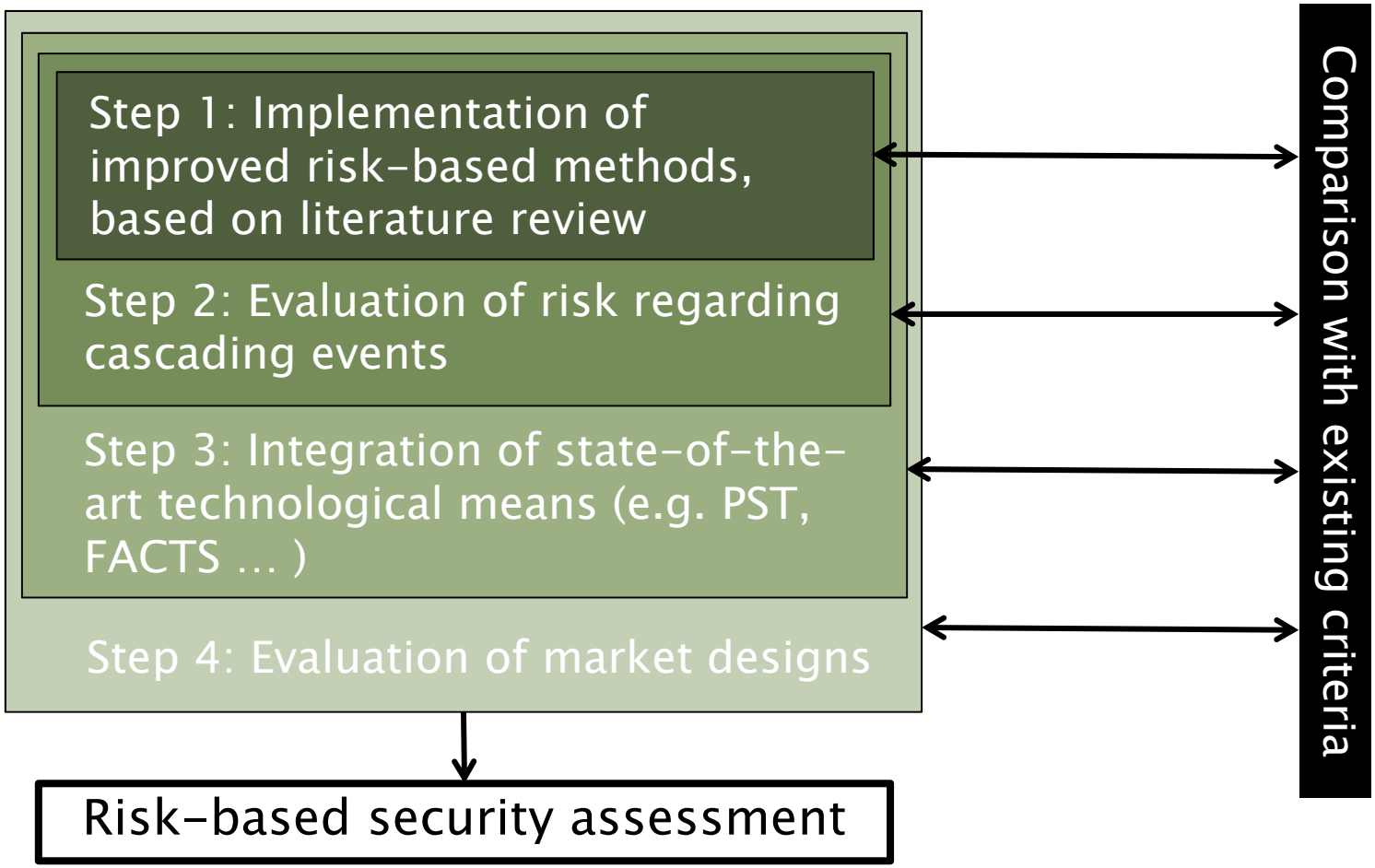
Steps and Outcomes



Methods for Risk-based Security Assessment

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I. Monte Carlo Approach

[D.S. Kirschen, D. Jayaweera, 2007]

II. Multiobjective Optimization

[F. Xiao, J. McCalley, 2009]

III. N-1 security with probabilistic guarantees

[M. Vrakopoulou et al., 2012]

Methods for Risk-based Security Assessment

Umbrella Project

I. Monte Carlo Approach

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- Increased understanding of risk in different operating conditions

II. Multiobjective Optimization

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III. N-1 security with probabilistic guarantees

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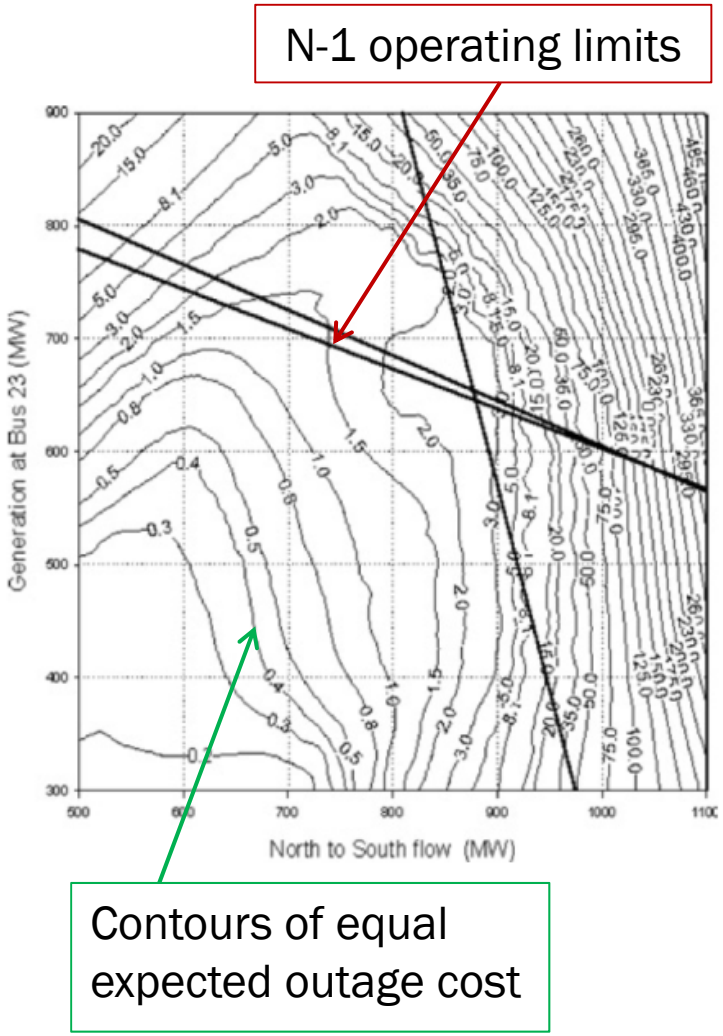

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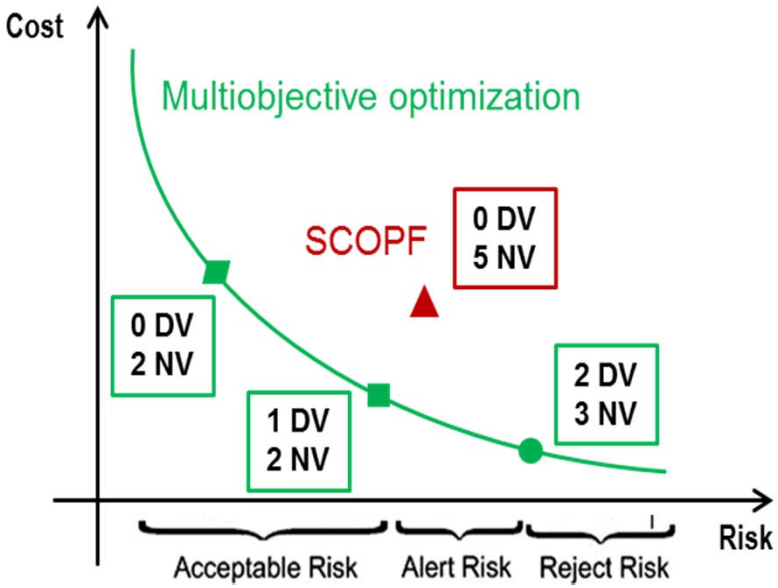
- Lower risk level at lower cost
- Optimize risk level, but allow for deterministic violations



DV: Deterministic violation
NV: Near violation

III. N-1 security with probabilistic guarantees

[M. Vrakopoulou et al., 2012]

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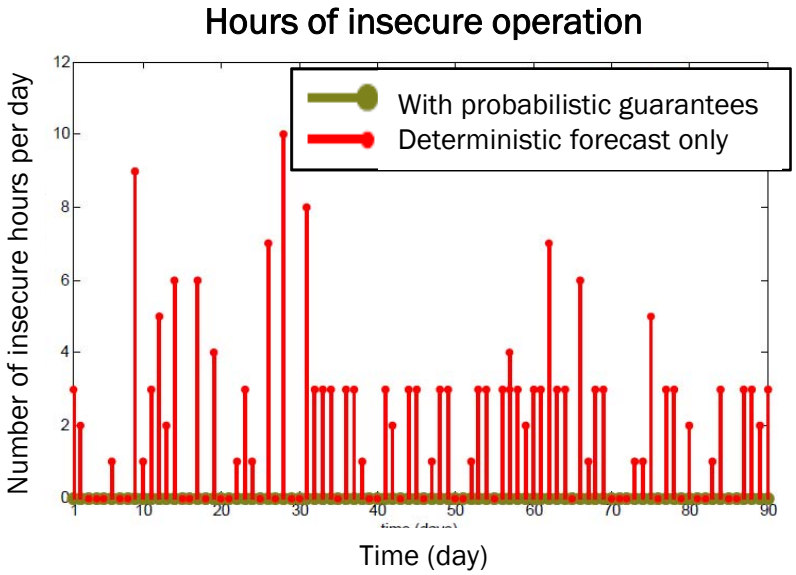
- Guarantees that operation is N-1 secure with probability of at least 1-ϵ
- Reduce hours of insecure operation by accounting for uncertainty



Conclusions

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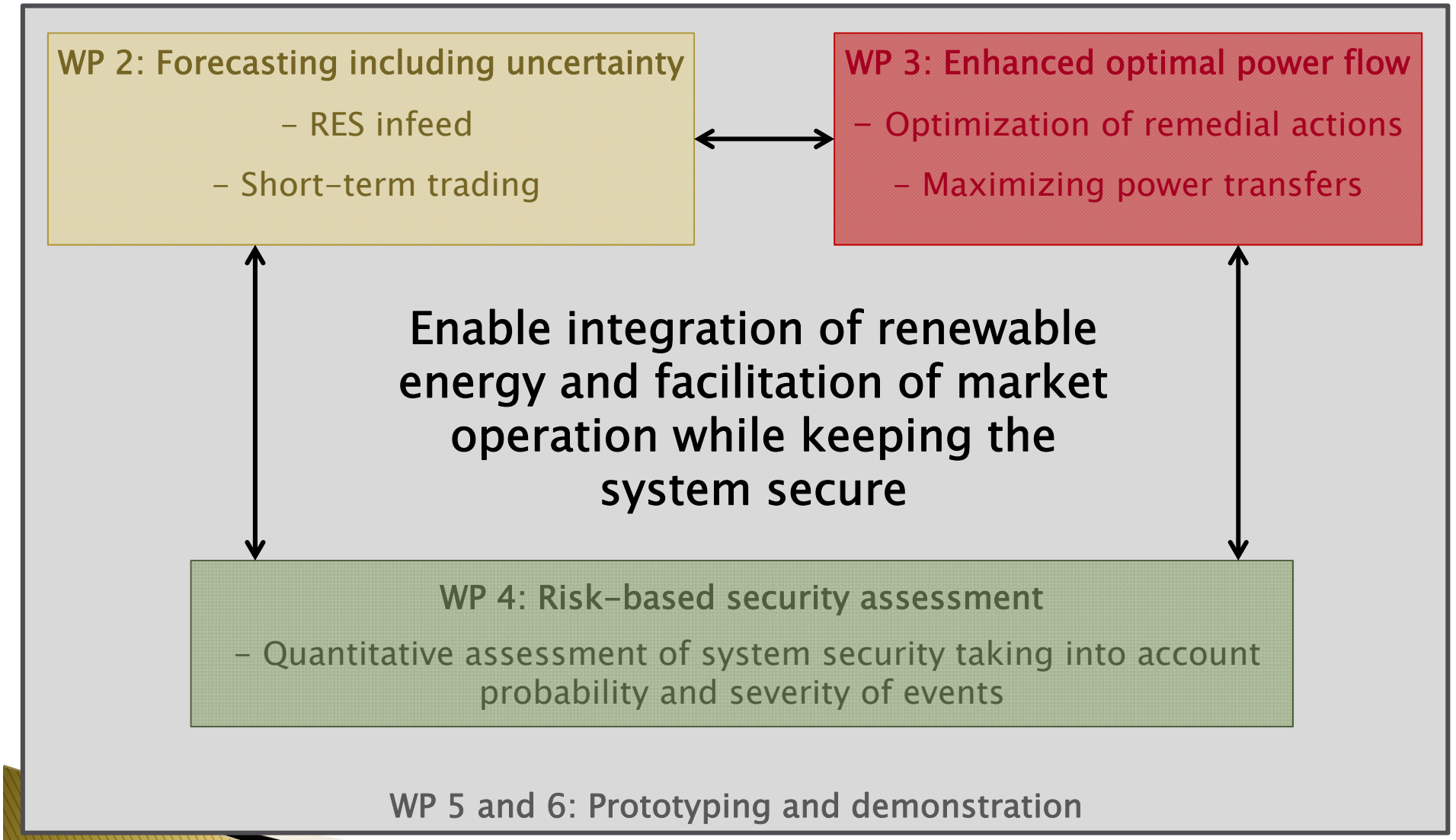
- Risk-based security assessment
  - Supplements N-1 criterion
  - Accounts for both probability and impact of contingencies
  - Allows for quantitative assessment of system security
  - Additional information can be used to mitigate risk and optimize power transits
  - Different state-of-the-art technological means (FACTS, phase-shifting transformers, thermal line ratings, reactive power support etc.) can be used to enhance system security.
- Challenges include
  - Modeling of uncertainties and severity of contingencies
  - Formulation of a large-scale, tractable problem

UMBRELLA View



UMBRELLA Summary

- New situation in transmission grid operation
  - Growing utilization and rising uncertainty
  - Additional operational degrees of freedom (FACTS, PST, …)
- UMBRELLA toolbox
  - Forecasts including uncertainty
  - Enhanced optimization algorithms
  - Risk-based security assessment

UMBRELLA Summary

- New situation in transmission grid operation
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Early identification of critical system states

Maximize power transits and limit impact of disturbances

Thank you for your attention!

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Sources:

IEEE/CIGRE Joint Task Force on Stability Terms and Definitions, Kundur, P. et al, «Definition and Classification of Power System Stability», IEEE Transactions on Power Systems, Vol. 2, No. 2, May 2004

UCTE Operation Handbook, https://www.entsoe.eu/resources/publications/system-operations/operation-handbook/

Kirschen, D. and Jayaweera, D.: «Comparison of risk-based and deterministic security assessments», IET Generation, Transmission and Distribution, 2007, 1, (4)

Xiao, F. and McCalley, D.: «Power System Risk Assessment and Control in a Multiobjective Framework», IEEE Transactions on Power Systems, Vol.24, No. 1, February 2009

Vrakopoulou, M., Margellos, K., Lygeros, J., Andersson, G.: «Probabilistic guarantees for the N-1 security of systems with wind power generation», PMAPS 2012, June 10-14, Istanbul