Novel Solutions for Transmission Controllability and Expansion Planning in Colombia and Brazil

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PSR

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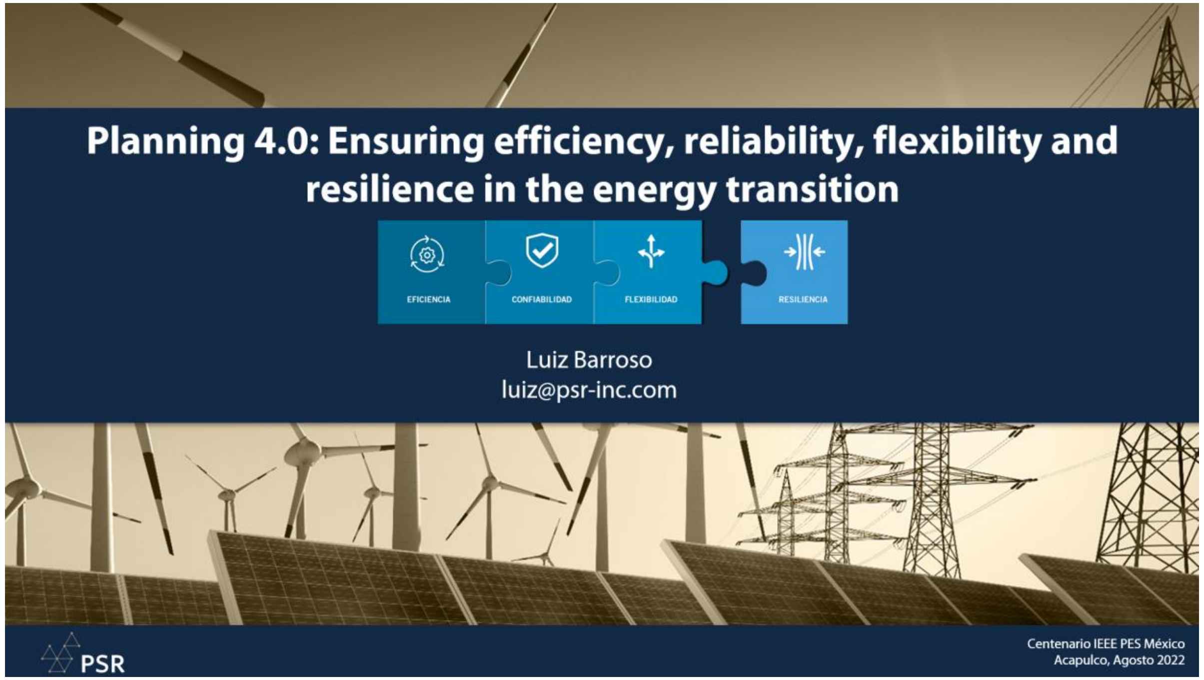
Introduction

Novel Solutions for Capacity Expansion Planning

- **Planning 1.0**: economic efficiency + energy policy guidelines
  - BAU: Business as Usual
  - Minimize expected total costs (investment + expected value of the operating costs) under uncertainty (variability of hydro, wind, solar, biomass production, and demand)
- **Planning 2.0**: (1.0) + reliability & resource adequacy
  - Security of supply considering the “known unknowns” (equipment failure, composite generation and transmission reliability)
- **Planning 3.0**: (2.0) + co-optimization with flexibility (= dynamic probabilistic reserve)
  - Contemplating: intermittency of renewables, demand fluctuations and failure of the largest generating unit
  - Considers that reserve requirements vary over time ➔ better dimensioned requirements and, consequently, the costs for the provision of these services are optimized
- **Planning 4.0**: (3.0) + resilience
  - Feasible supply considering the “unknown unknowns” (stochastic models are not suitable for extreme events)
  - Application examples: Geopolitical disruptions of fuel supply, very severe droughts, wind disruptions, effects of climate changes, etc.

Novel Solutions for Capacity Expansion Planning



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ENERGY REPORT PSR

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EFFICIENCY RELIABILITY FLEXIBILITY RESILIENCE

RESILIENCE: THE NEW ELEMENT OF ENERGY PLANNING

OPINION 2

The objective of this Editorial is to illustrate the incorporation of resilience in energy planning methodologies through two case studies with computational models developed by PSR: (i) an earthquake-resilient infrastructure planning for the Government of Chile; and (ii) the resilient generation expansion planning, in the case of Costa Rica.

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G&T Expansion Planning

G&T Expansion Planning

Decision-making under Uncertainty using Different Multistage Stochastic Optimization Approaches

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PES GM 2017

Panel:
Transmission Planning for Non-Synchronous Variable Resources

July 18th 2017

IEEE PES Power & Energy Society | IEEE

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http : //www.cigre.org

Study Committee C1
PS2 – New System Solutions and Planning Techniques

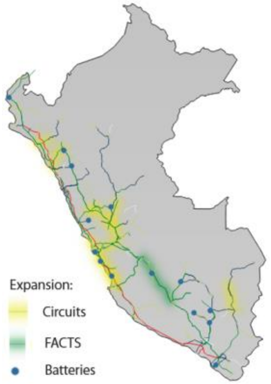
CIGRE 2014

FACTS and D-FACTS: The Operational Flexibility Demanded by the Transmission Expansion Planning Task with Increasing RES

R. C. Perez*, G. C. Oliveira, M. V. Pereira, D. M. Falcão, F. Kreikebaum, S. M. Ramsay
PSR PSR PSR UFRJ SWG SWG
Brazil and USA

SUMMARY

There are sever
reasons include
different dispat
biomass, wind
transmission sys



COPPE UFRJ
Instituto Alberto Luiz Coimbra de Pós-Graduação e Pesquisa de Engenharia

POWER FLOW CONTROLLABILITY AND FLEXIBILITY IN THE TRANSMISSION EXPANSION PLANNING PROBLEM: A MIXED-INTEGER LINEAR PROGRAMMING APPROACH

Ricardo Cunha Perez

Novel Solutions for Transmission Controllability and Expansion

Process Flow

SDDP
- Stochastic operating policy calculation and dispatch simulation

OptGen
- Transmission Expansion planning
- Power transfer capacity increase between areas

OptFlow
- AC OPF for VaR expansion planning
- Voltage control

Organon
- Dynamic stability assessment

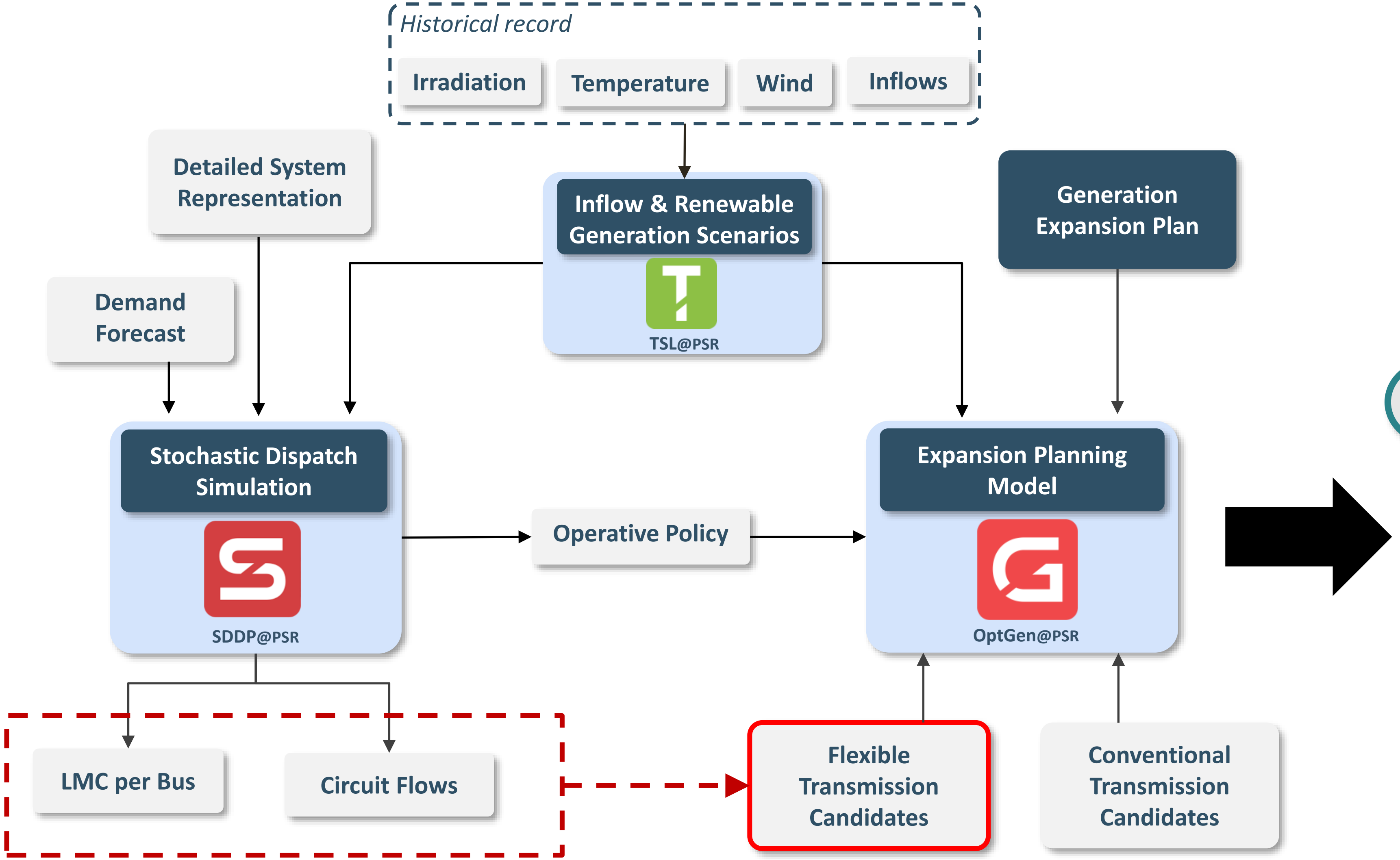
1 — Linearized Power Flow

2 — AC OPF

3 — Stability Analysis

In this presentation we will focus on Part 1

1 Flexible Expansion Planning Methodology – Part 1



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Optimal expansion in transmission capacity

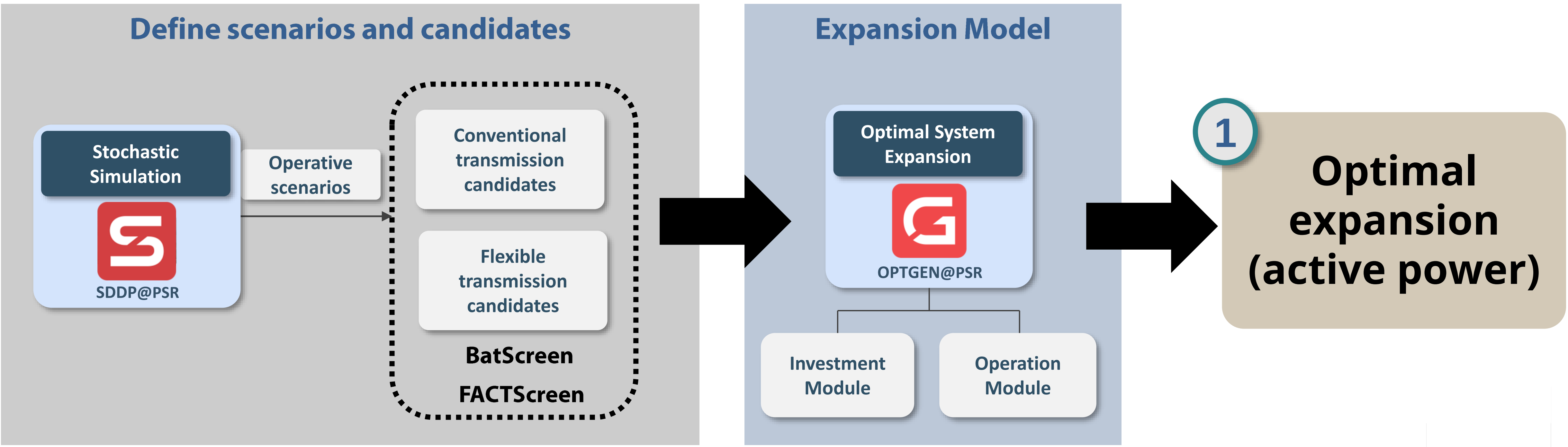
Flexible Expansion Planning Methodology – Part 1

- **Transmission reinforcements:**
  - Power transfer capacity increase between areas
  - Series compensation FACTS devices are contemplated (active power flow control through equivalent impedance variation)
- **Expansion Candidates:**
  - Transmission line / transformer (conventional)
  - Phase-shifter (conventional)
  - TSSC, TCSC, SSSC (flexible technology)
  - D-FACTs (flexible technology)
  - Flexibility Aggregators at the Distribution Level
  - Dynamic Line Rating (DLR)
  - Battery

	Active Power Control	Voltage Control	Reactive Power Control	Frequency Control	Subsync. Resonance Control
SVC		X	X		
STATCOM		X	X		
TSSC	X				
TCSC	X				X
SSSC	X		X		X
UPFC	X	X	X		
LCC-HVDC	X			X	X
VSC-HVDC	X	X	X	X	X
Battery	X	X	X	X	

For FACTS and Batteries, we use screening models to reduce the number of candidates

1 Methodology for optimal transmission expansion

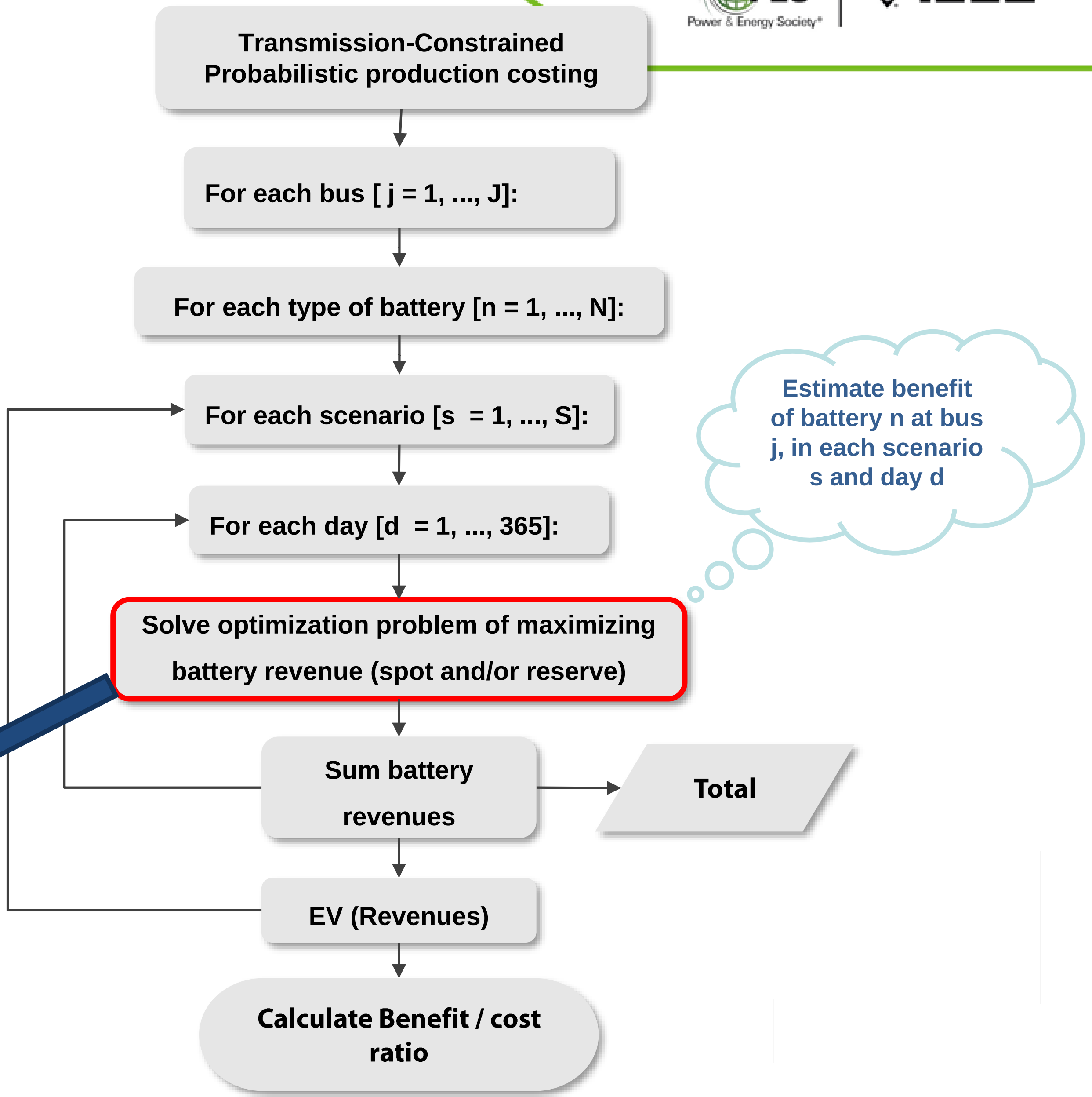


Optimal siting & sizing of batteries

Step 1 – BATSCREEN
Screening of battery candidates

Optimization Problem

- Objective Function: $R^{ns}_{jd} = \text{Max} \sum_{\tau=1}^{24} \pi^{s}_{jd\tau} \cdot g^{s}_{jd\tau}$
- Subject to:
  - Energy balance equation ⟶ $e^{s}_{jd,\tau+1} = e^{s}_{jd\tau} - g^{s}_{jd\tau}$
  - Storage constraint ⟶ $0 \le e^{s}_{jd,\tau+1} \le \bar{e}^{s}_{jd\tau}$
  - Generation constraint ⟶ $\underline{g}_n \le g^{s}_{jd\tau} \le \overline{g}_n$

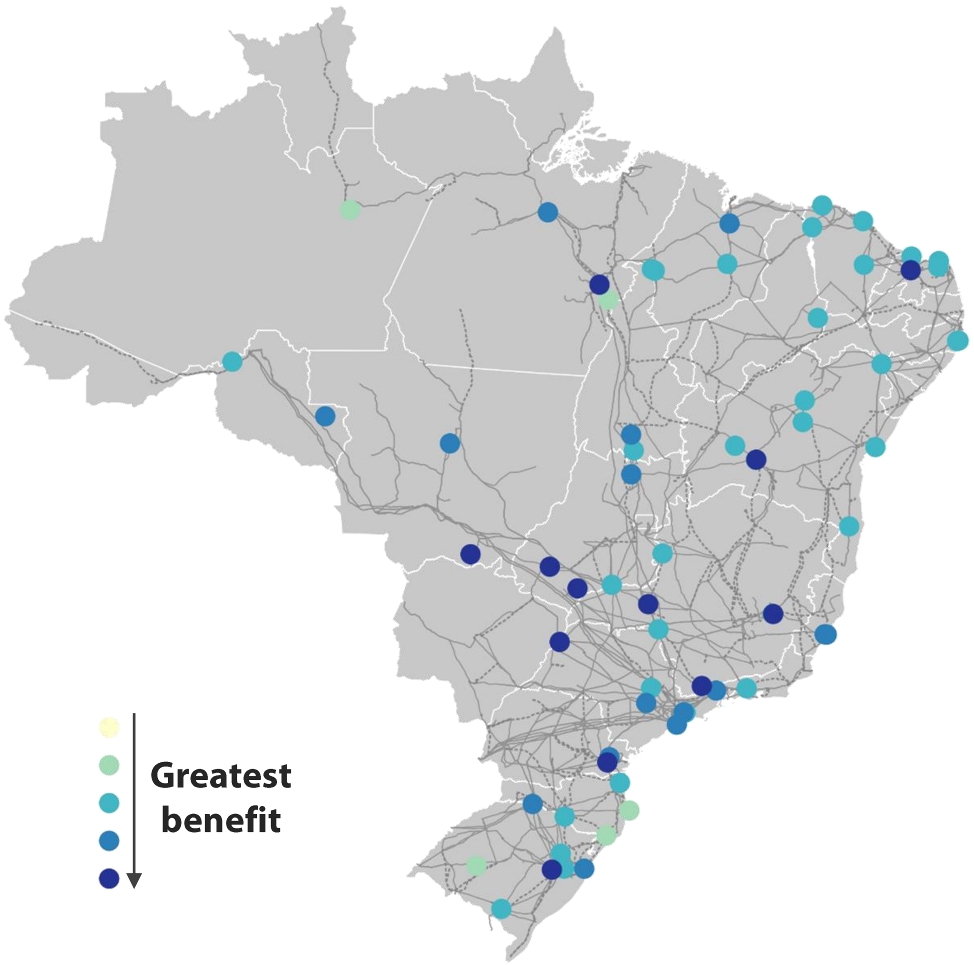


Battery siting and sizing – Step 2

- 80 candidate batteries

Best sites:

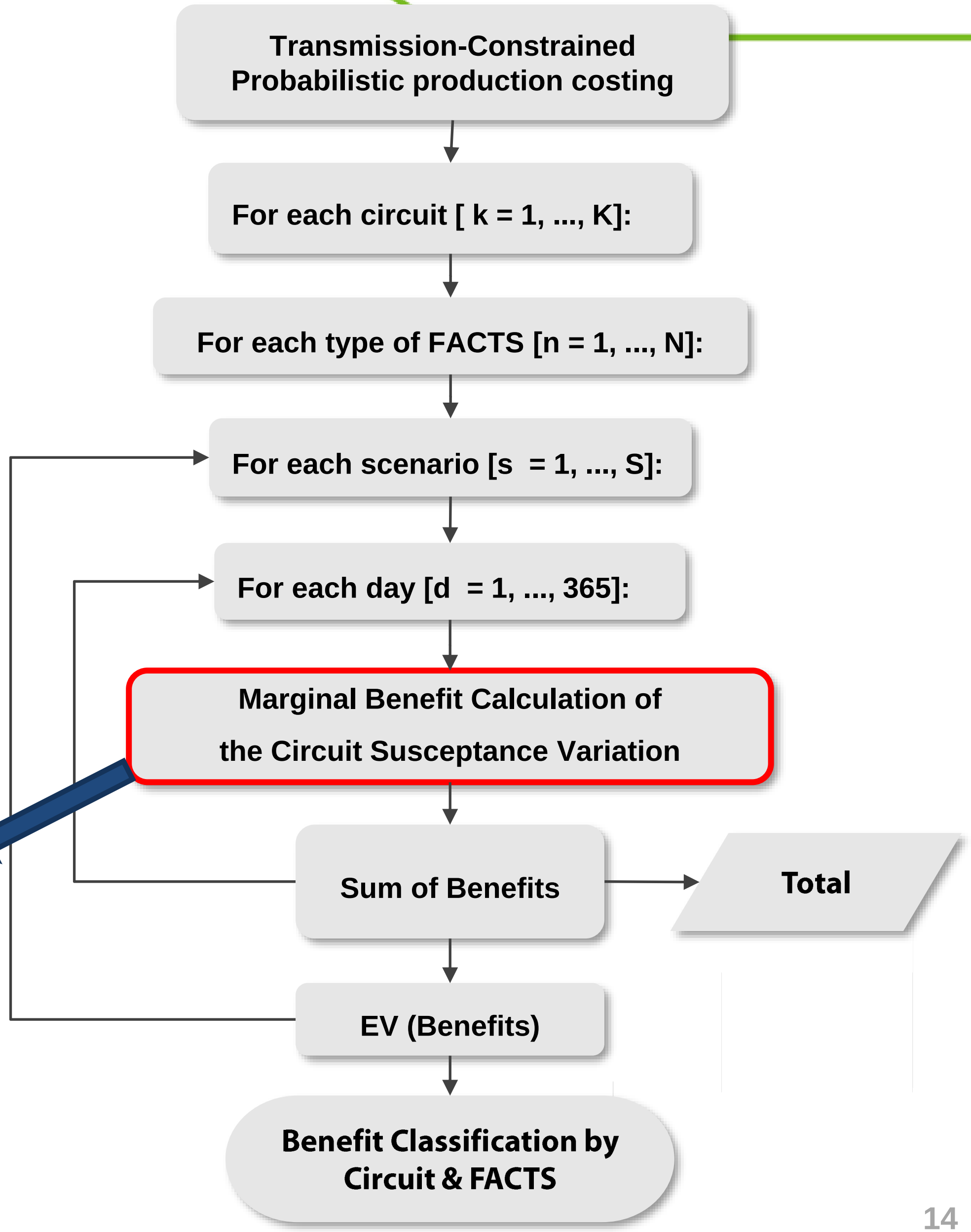
- Areas with higher demand
- Areas with concentrated VRE resources
  - Bahia
  - Coast of Northeast region
- Regional tie-lines
  - North-South
  - Northeast-Southeast



A similar procedure is used for the siting of FACTs candidates (FACTSCREEN)

Optimal siting & sizing of series comp. FACTS

Step 2 – FACTSCREEN
Screening of FACTS candidates



Given the solution of the dispatch problem:

$z(\gamma) = Min \sum_i c_i \times g_i$

s.a. **Multipliers**

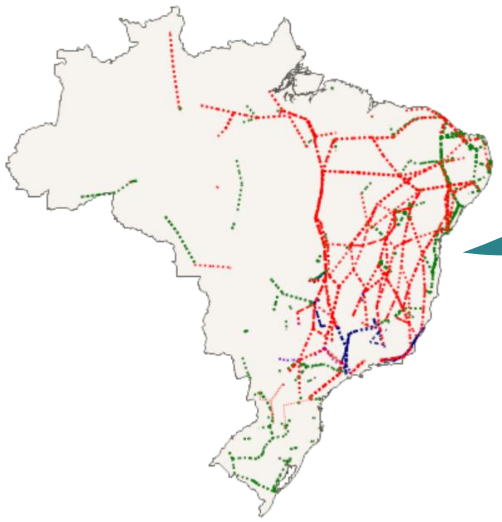
$Sf + g = D$	π
$f_{i,j} - \gamma_{i,j} \times (\theta_i - \theta_j) = 0$	$\pi_{\gamma,i,j}$
$\lvert f \rvert \leq \bar{f}$	$\pi_{\bar{f}}$

Sensitivity of the variation in the LMC in relation to the variation in the susceptance of the circuit:

$$\frac{\partial z(\gamma)}{\partial \gamma_{i,j}} = -\pi_{\gamma,i,j} \times \left(-(\theta_i - \theta_j)\right)$$

Comparison of Conventional versus Flexible Expansion

Candidates



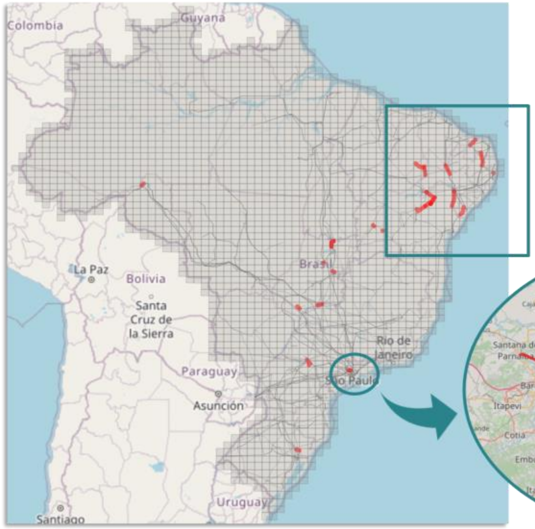
Conventional

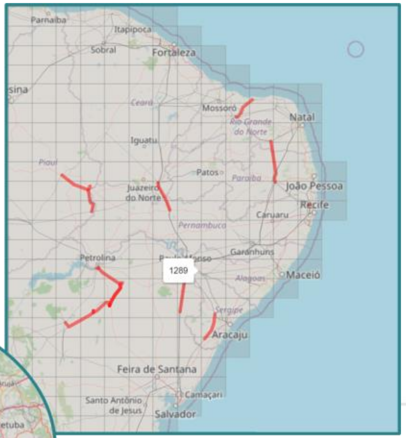
Reduction in operating + investment costs

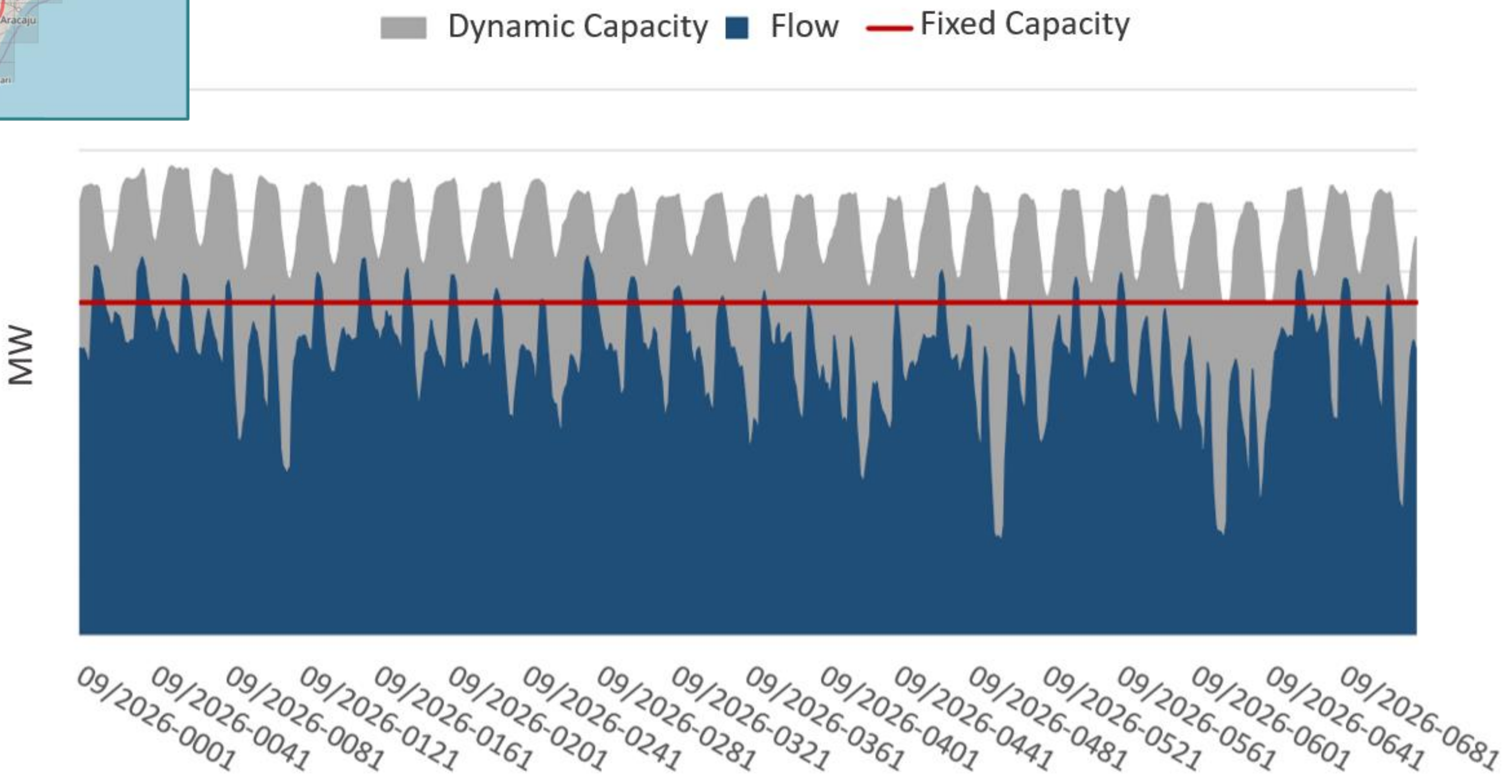
Flexible

Comparison of Conventional versus Flexible Expansion

Example of the effects related to Dynamic Line Rating (DLR)







2 Flexible Expansion Planning Methodology – Part 2

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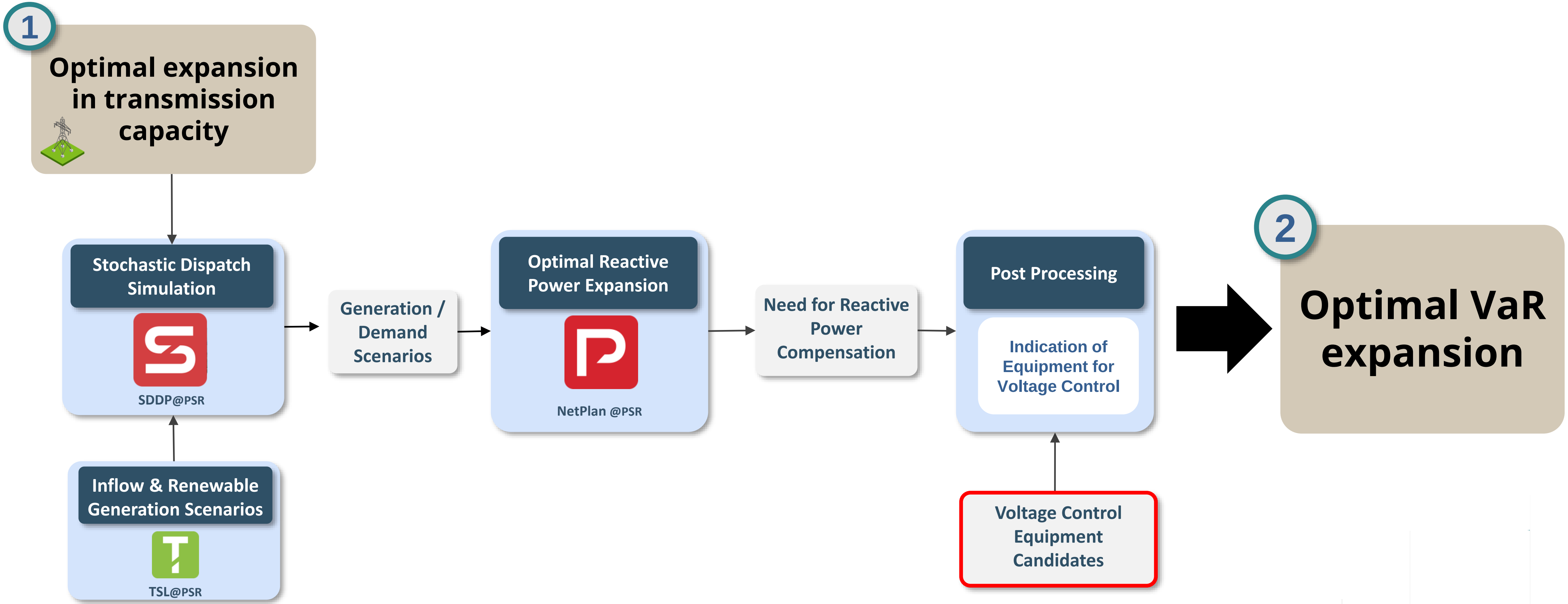
2 Flexible Expansion Planning Methodology – Part 2



Flexible Expansion Planning Methodology – Part 2

- **Expansion Candidates:**
  - SVC (flexible technology)
  - STATCOM (flexible technology)
  - UPFC (flexible technology)

	Active Power Control	Voltage Control	Reactive Power Control	Frequency Control	Subsync. Resonance Control
SVC		X	X		
STATCOM		X	X		
TSSC	X				
TCSC	X				X
SSSC	X		X		X
UPFC	X	X	X		
LCC-HVDC	X			X	X
VSC-HVDC	X	X	X	X	X
Battery	X	X	X	X	

3 Flexible Expansion Planning Methodology – Part 3

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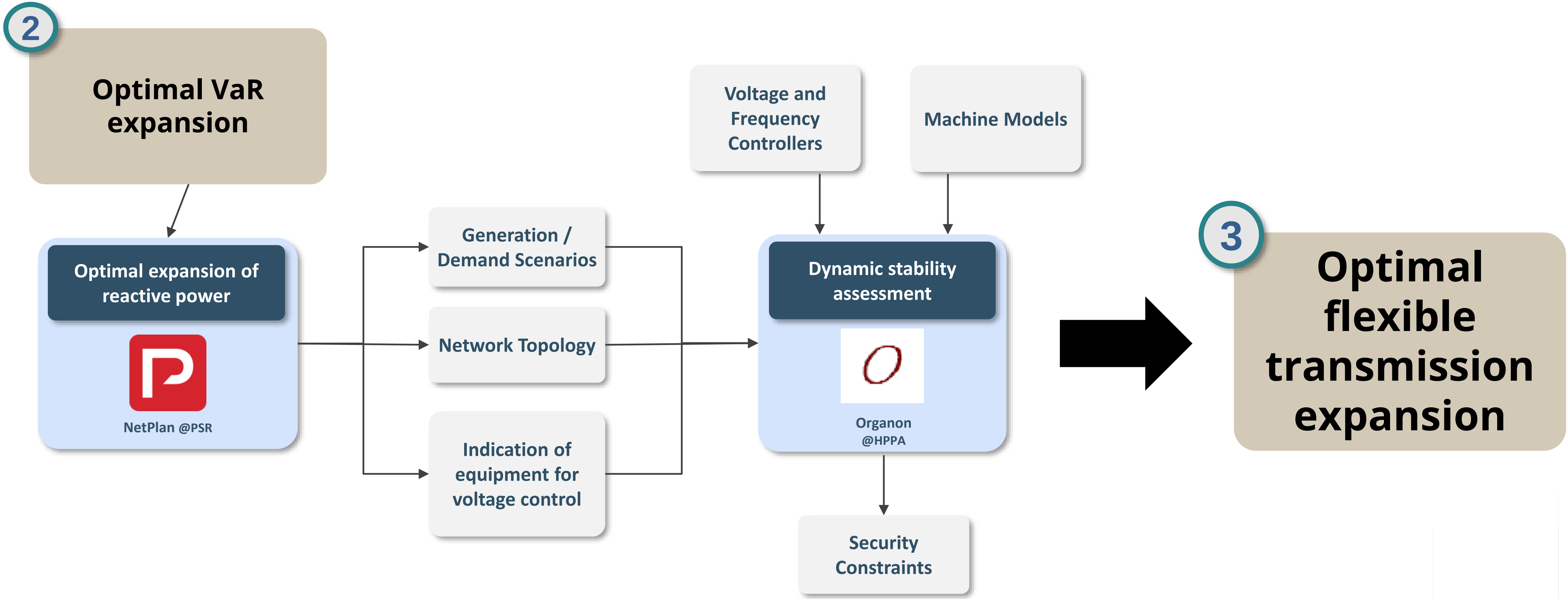
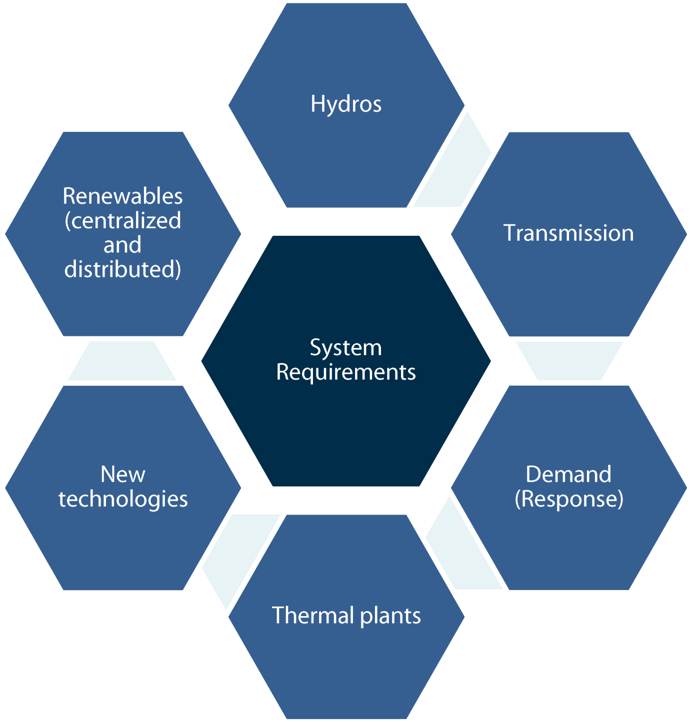
3 Flexible Expansion Planning Methodology – Part 3

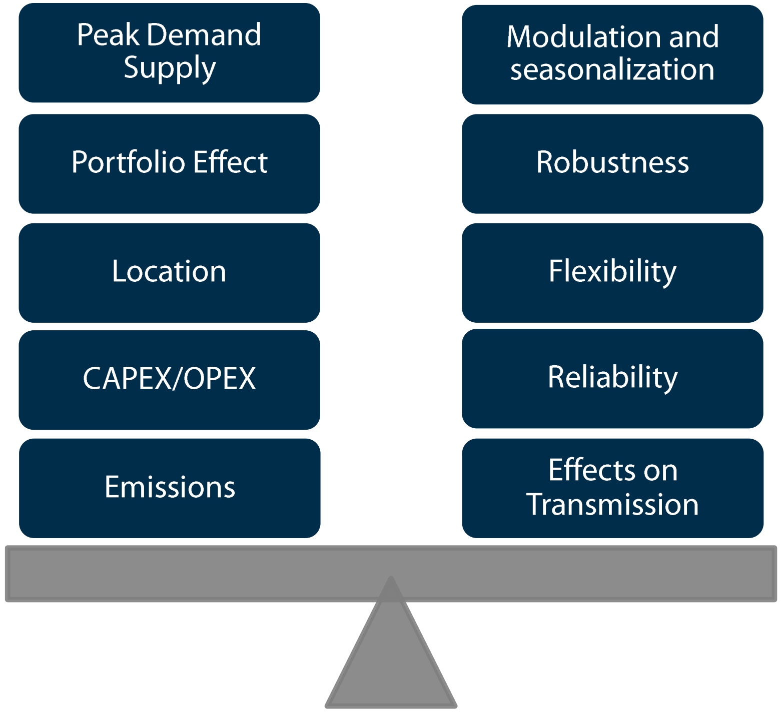


Conclusions

Conclusions

- Each technology is a piece of the "puzzle" of the energy transition / decarbonization process
- Flexibility resources for the transmission network include FACTs, batteries, DLR and flexibility aggregators
- The proposed planning scheme allows economic valuation of transmission flexibility that is vital for high penetration of intermittent renewables





Energy Report as Bonus

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Planning transmission for a net zero future

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Questions? Thanks!

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