DE LA RECHERCHE À L'INDUSTRIE

Stability Analysis and Control of Grids with High Renewable Energy Penetration

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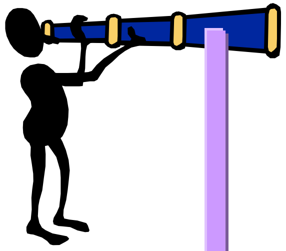
PLAN



I. Introduction

1. Context
2. Categories of Power System Stability

II. Methodologies

1. Methodology for Assessing the Impact of RES on Power System Stability
2. Simulation Results of Power System Performance

III. Solutions

1. Grid Stability under Fault Ride-Through (FRT) Conditions
2. Optimization of System Components
3. Incorporation of HVDC
4. Stochastic Analysis of Power System Stability

IV. Conclusions and perspectives

Plan

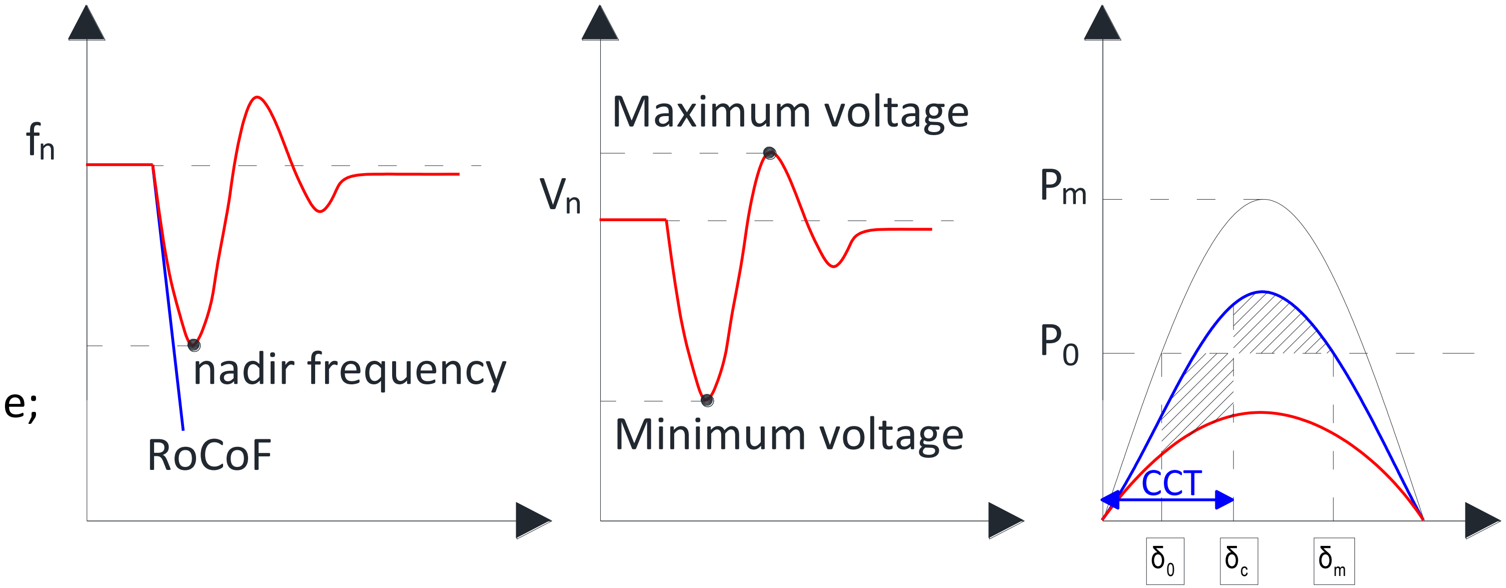
Assessment of RES impact on grid stability

❑ How to examine the impact of RES on power system stability?

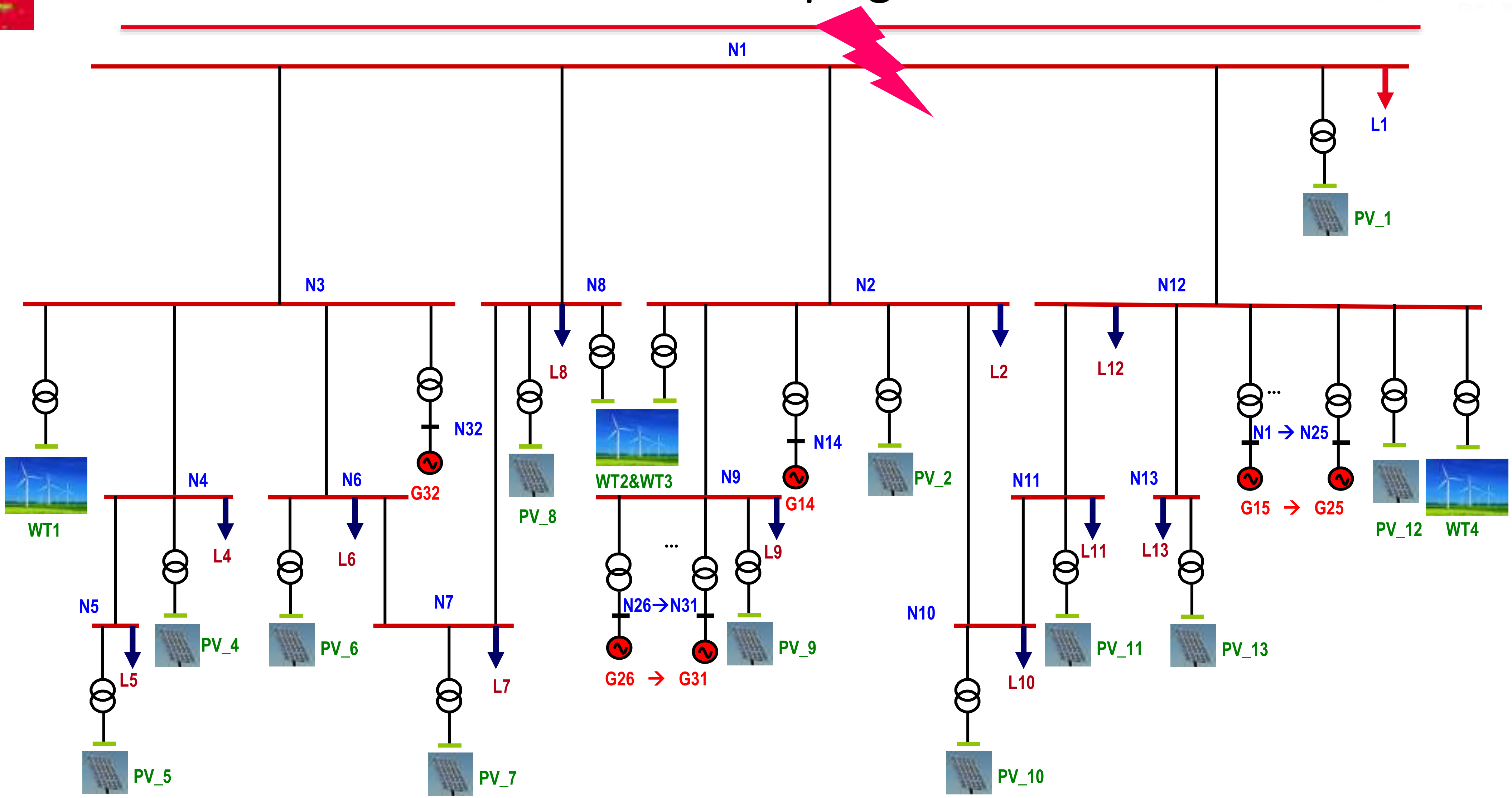
- Modelling: PV, WT, BESS, SM, grid;
- Establishing different scenarios (% Penetration of RES);
- Disturbances: a three-phase short circuit & generator outage;
- Dynamic simulation

❑ Indicators?

- Nadir frequency;
- Rate of Change of Frequency (RoCoF);
- Voltages (V_{mim}, V_{max});
- Critical Clearing Time (CCT) for Rotor angle;
- Short circuit current magnitude.



Guadeloupe grid

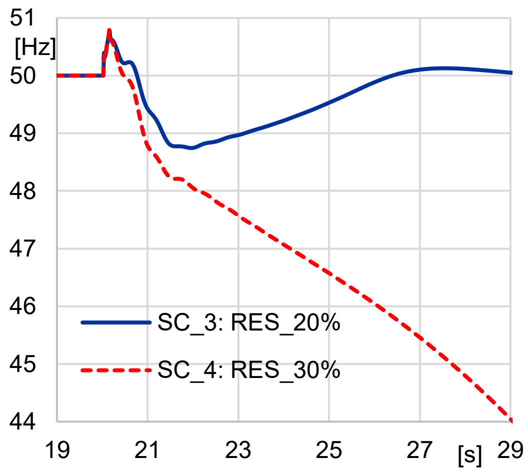


- Island grid (63kV, 20kV; 5.5kV);
- 12 PVs; 2 WT type 3; 2 WT type 4; 18 SMs (S_G = 582.7MVA); 12 loads (S_{load} = 253MVA).

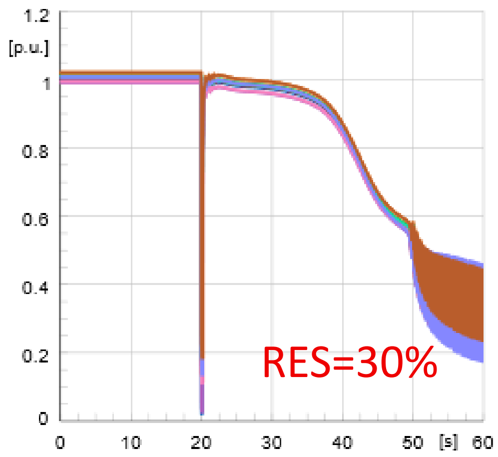
Simulation Results of Power System Performance

- A three-phase short circuit

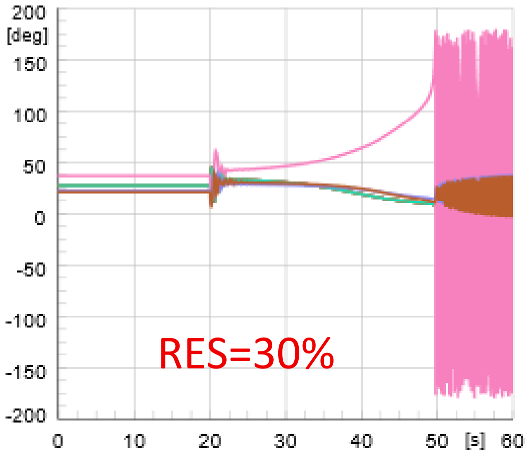
Frequency variation



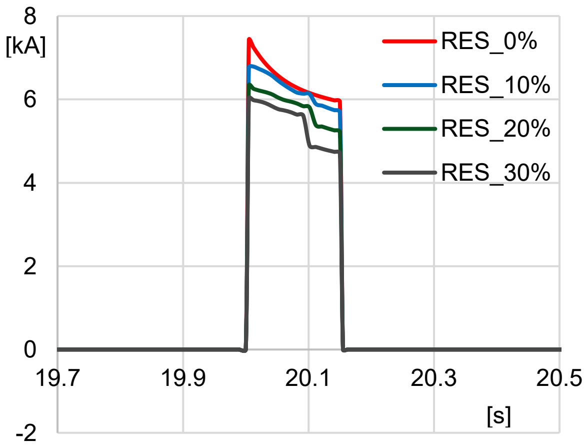
Voltage variation



Rotor angle variation



Short circuit current magnitude



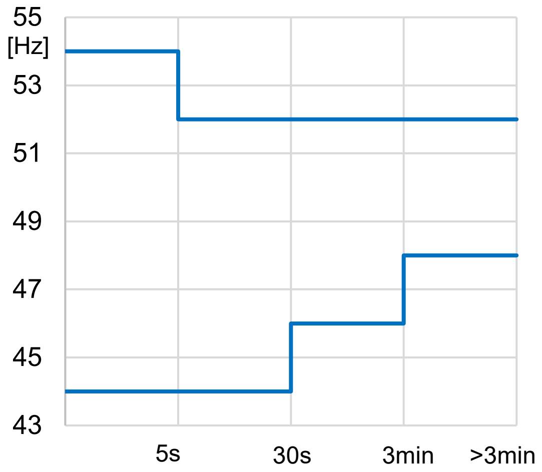
	RES = 0 %	RES = 10 %	RES = 20%	RES = 30%
H_{sys} (s)	4.27	4.01	3.54	2.89
RoCoF (Hz/s)	1.23	1.38	1.87	Unstable
Nadir frequency (Hz)	49.74	49.12	48.74	Unstable
CCT (s)	2.7	1.8	1.7	0.1
I_{sc_N1} (kA)	7.43	6.79	6.34	6.03

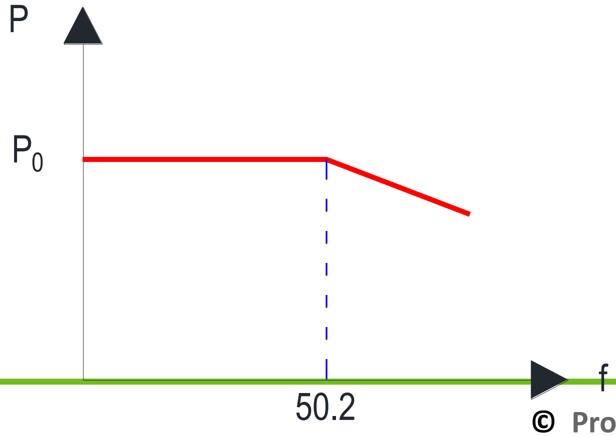
Plan

Solutions: FRT

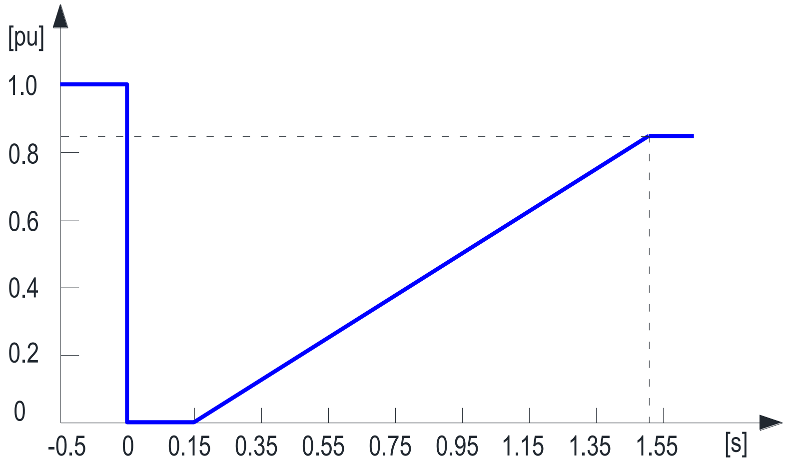
- ❑ **Why should we apply FRT requirement?** Grid Code Requirements
- ❑ **What is FRT (Fault Ride Through) requirement?**

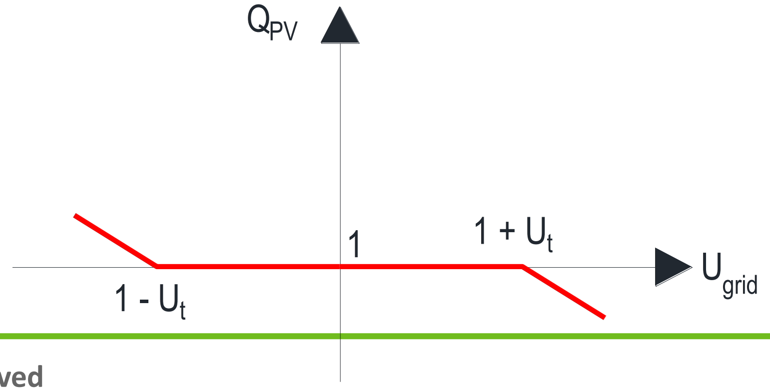
FRT in frequency





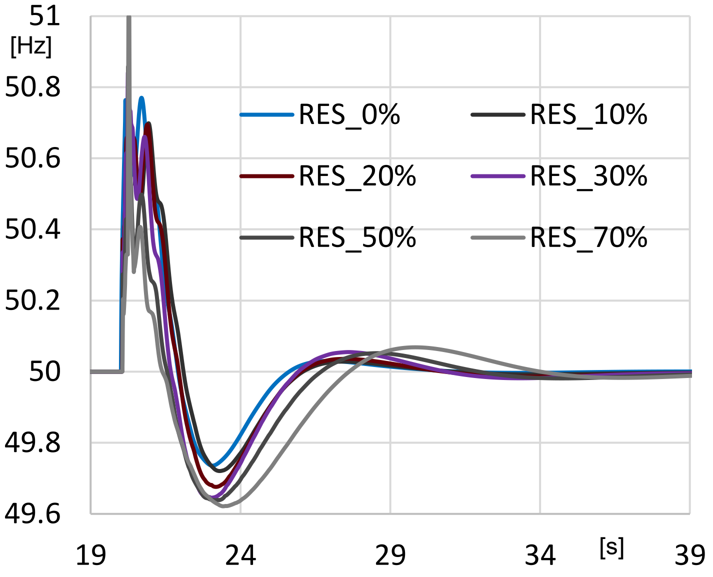
LVRT for grids





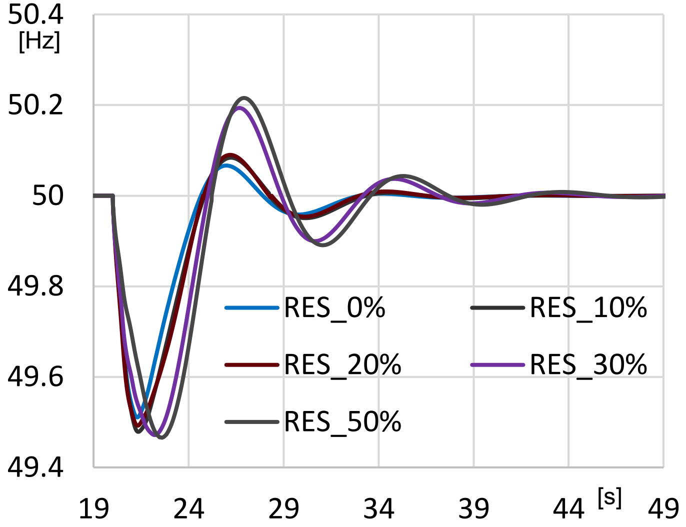
Solutions: FRT

Frequency variation after a three-phase short circuit

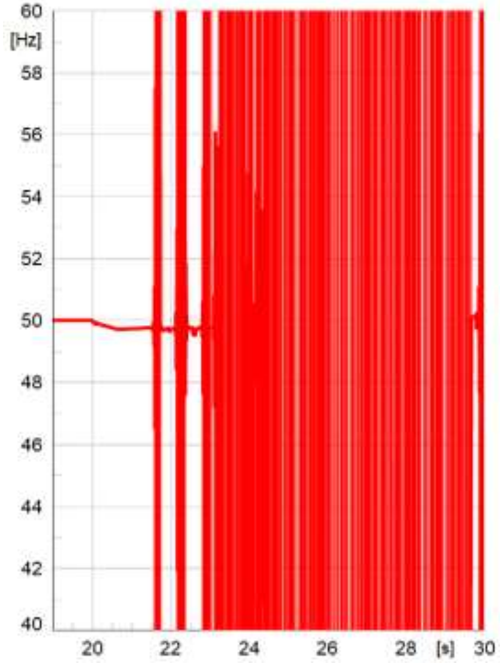


Frequency variation after generator outage

RES = 0% - 50%



RES = 70%



❑ **FRT requirement:**

🡅 RES limitation from 30% to 70%.

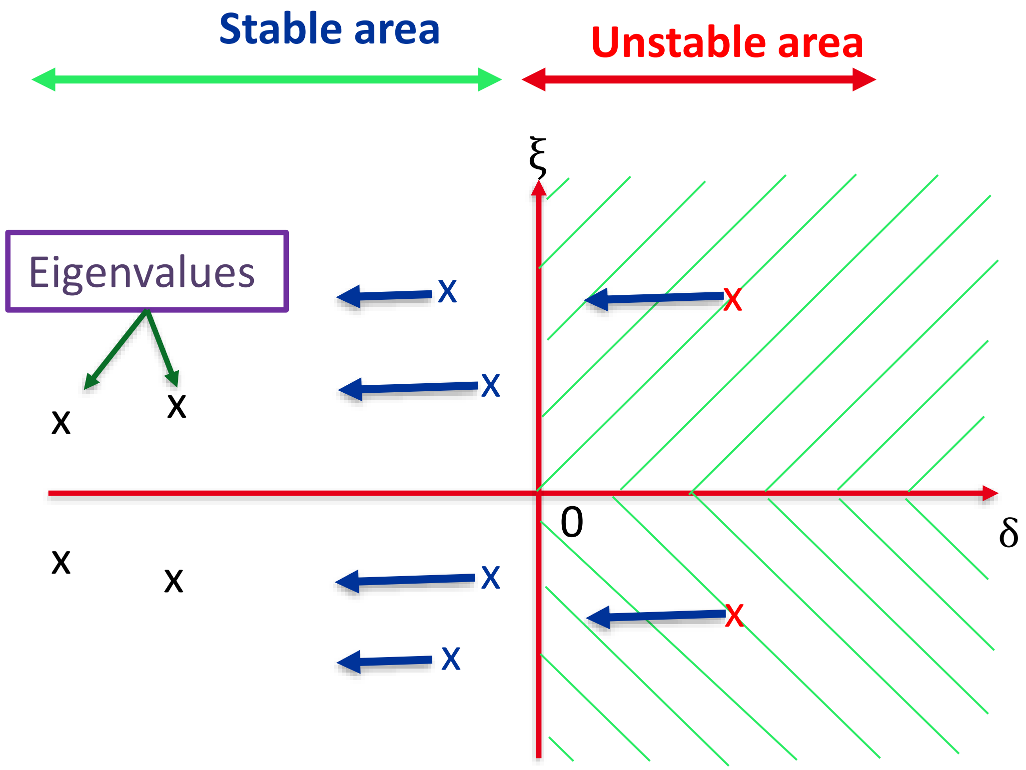
Solutions: Optimization of System Components

❑ Methodology

- Linearize a power system around an operating point:

$$\Delta\dot{x} = A\Delta x + B\Delta y$$
$$y = C\Delta x + D\Delta u$$

  - The system is stable: all real part of eigenvalues of A < 0;
  - Changing parameters of BESS & PSS can change the real part of the eigenvalues of A.

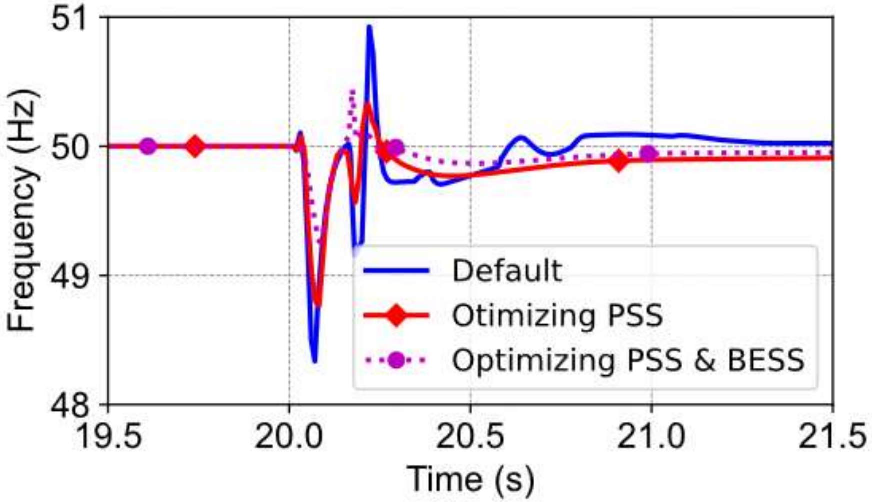


❑ Applying PSO algorithm to determine optimized parameters of system components:

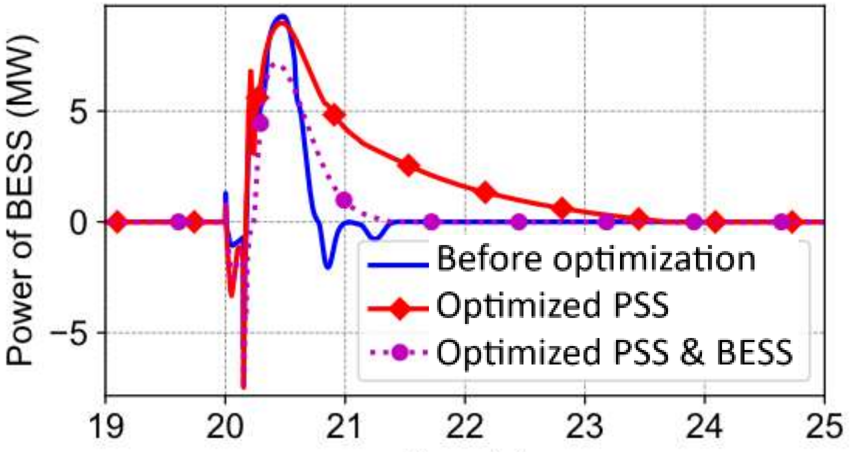
- Effectiveness in Nonlinear and Multi-dimensional Problems;
- Simplicity and Ease of Implementation;
- High Convergence Speed;

Solutions: Optimization of System Components

Frequency variation

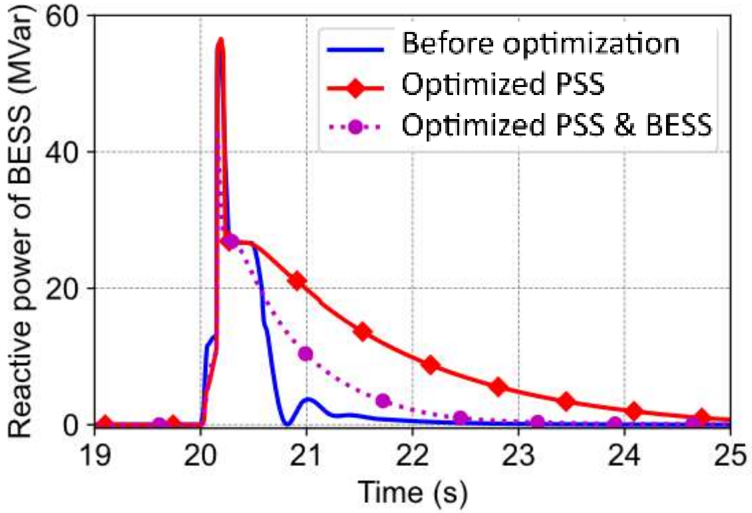


Active power of BESS variation

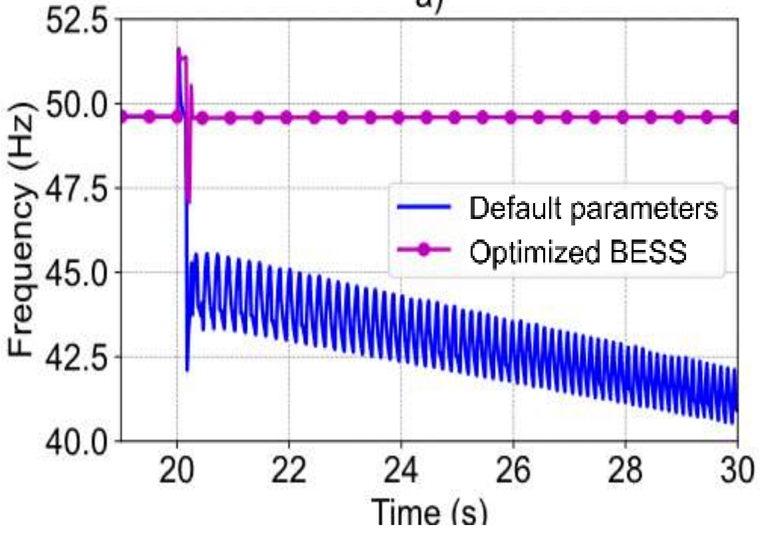


a)

Reactive power of BESS variation



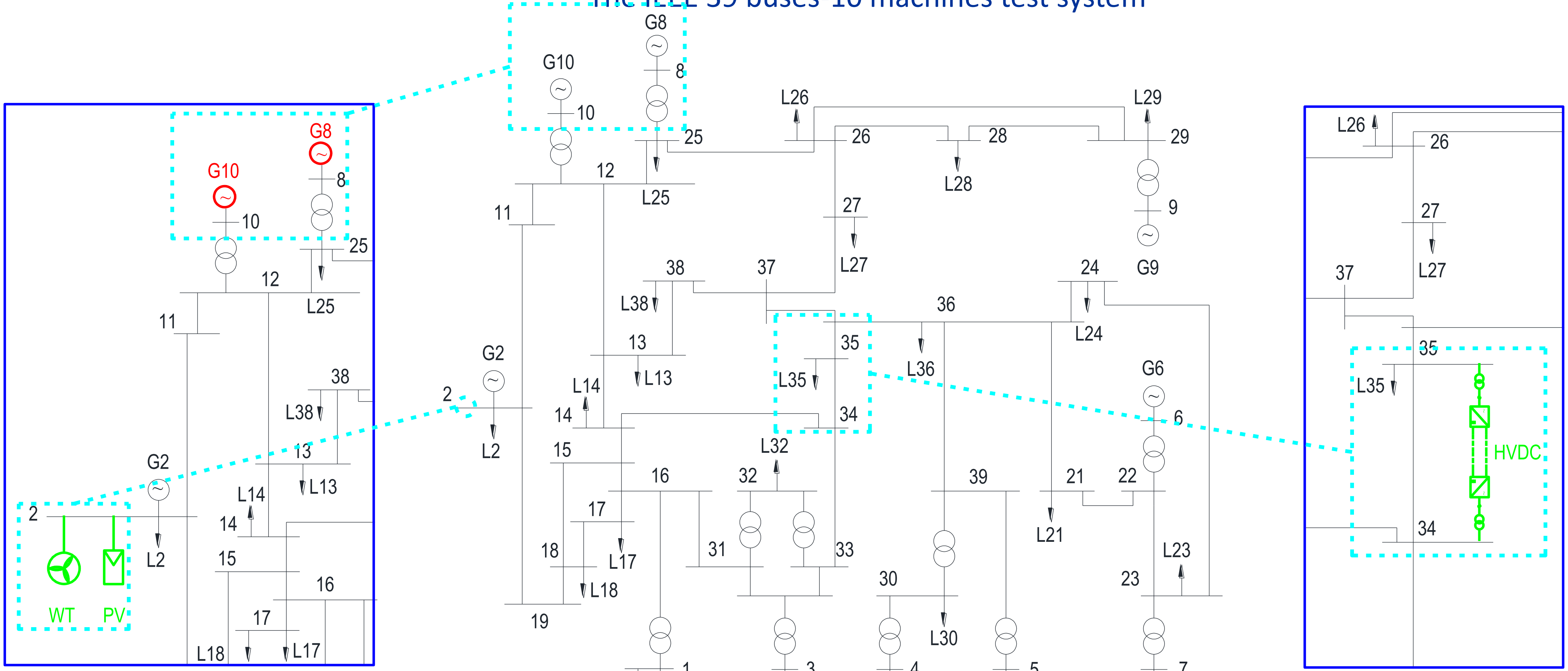
- Enhance stability;
- Lower installed capacity of BESS,
- Avoid oscillation and a collapse in the grid.



Frequency variation – special parameters of BESS

Solution: Incorporation of HVDC

The IEEE 39 buses-10 machines test system



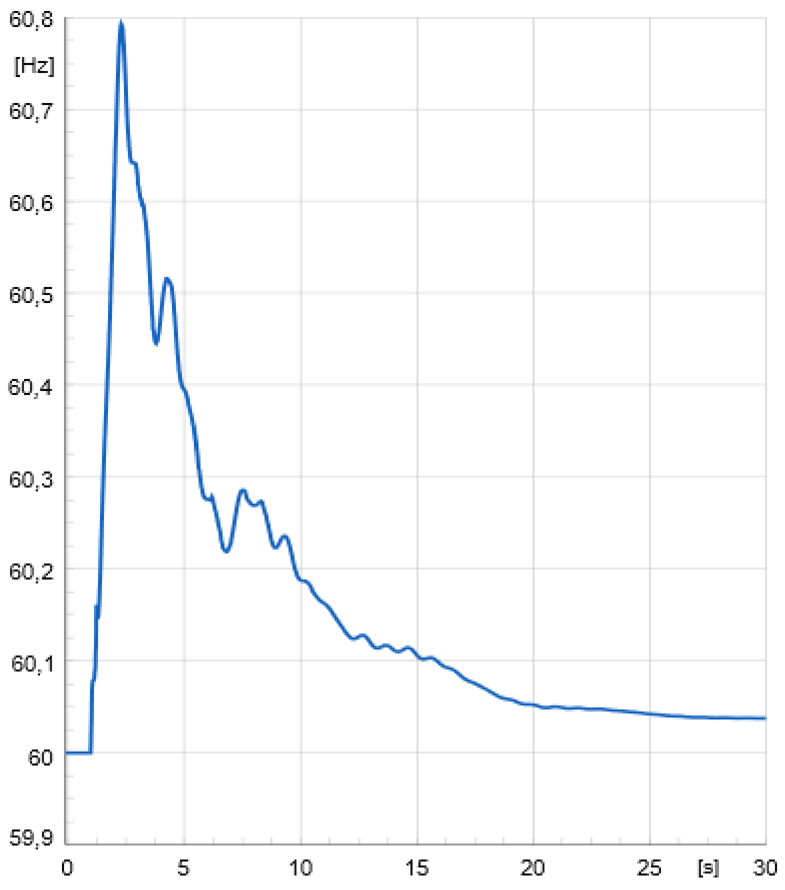
Incorporating RES (Case 2)

Original power system

Incorporating HVDC (Case 3 & 4)

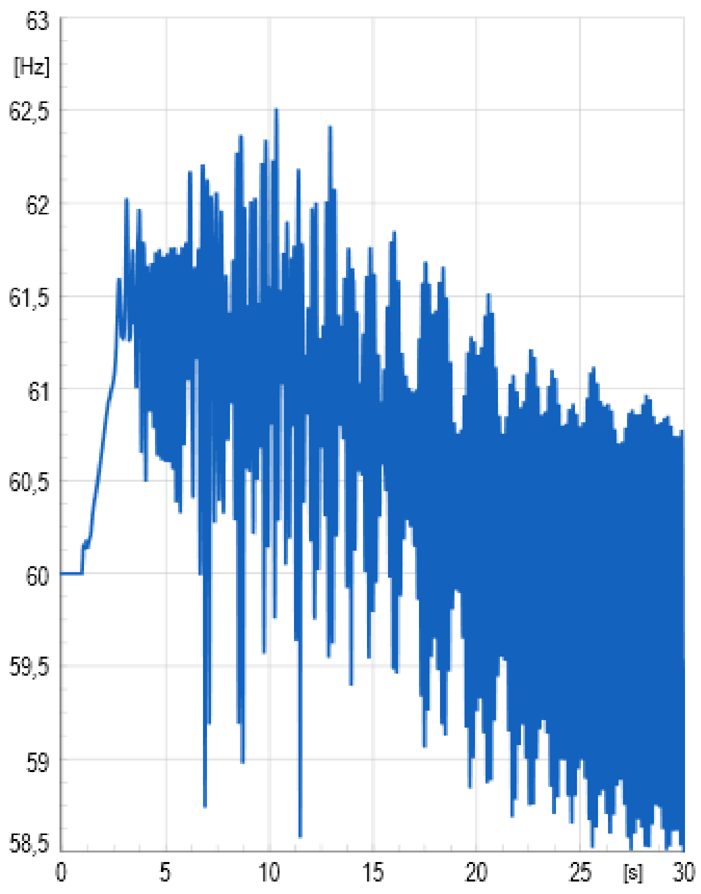
Solution: Incorporation of HVDC

Frequency variation: Without RES



- Stable

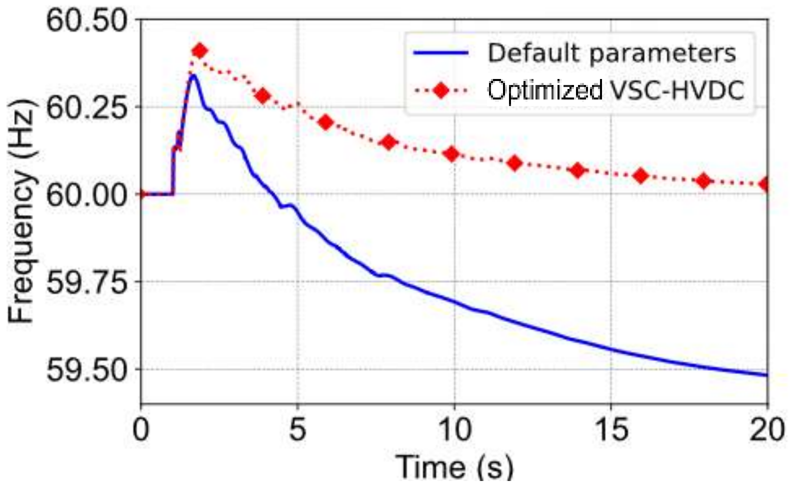
Frequency variation: With RES



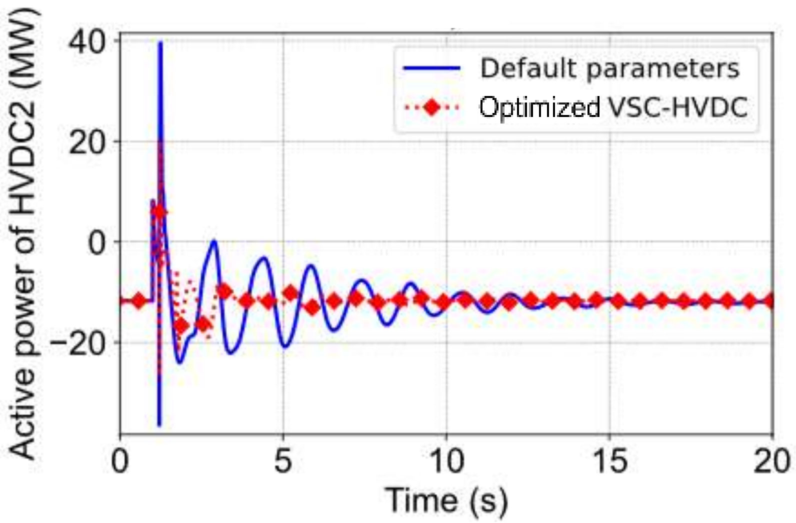
- Unstable

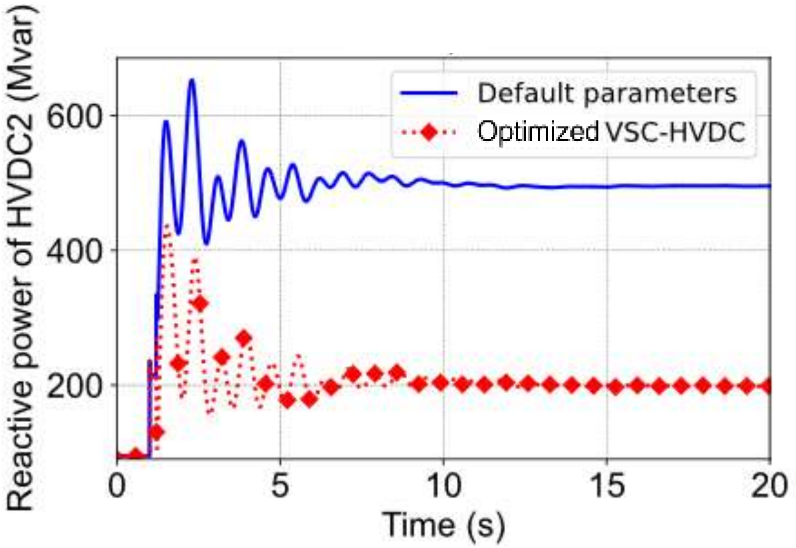
Solution: Incorporation of HVDC

Frequency variation: RES&HVDC



Power transmitted through HVDC: RES & HVDC

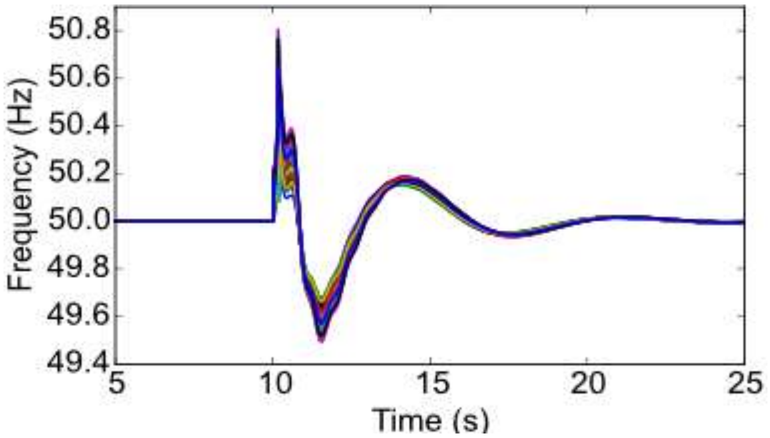




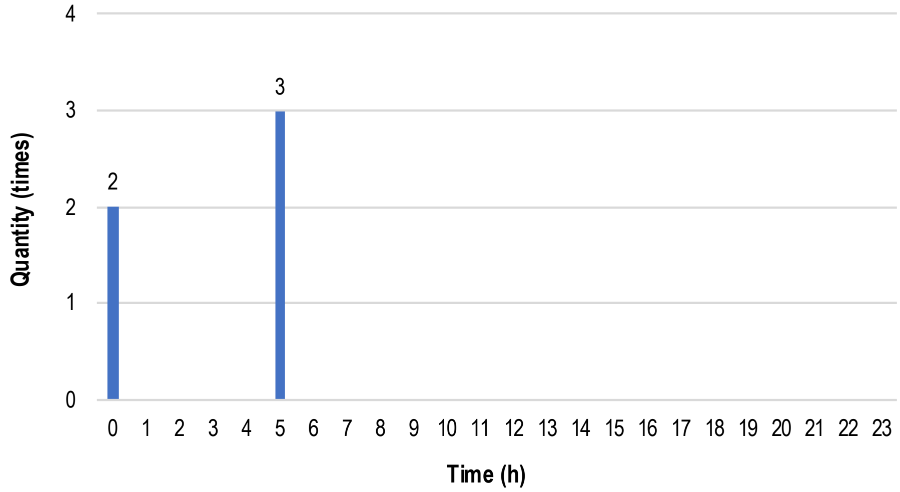
- RES has negative impact on stability.
- HVDC can improve stability.
- Optimized parameters of VSC-HVDC: better stability, lower capacity of VSC-HVDC system

Solution: Stochastic study

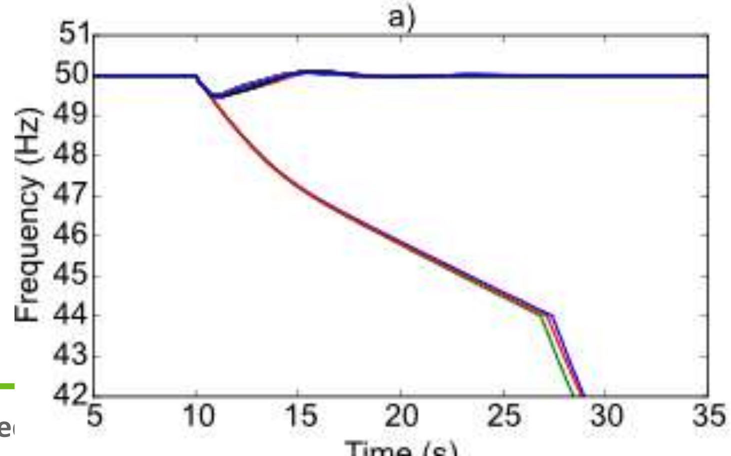
Frequency variation after a three-phase short circuit



Distribution of the number of instabilities in case of generator outage



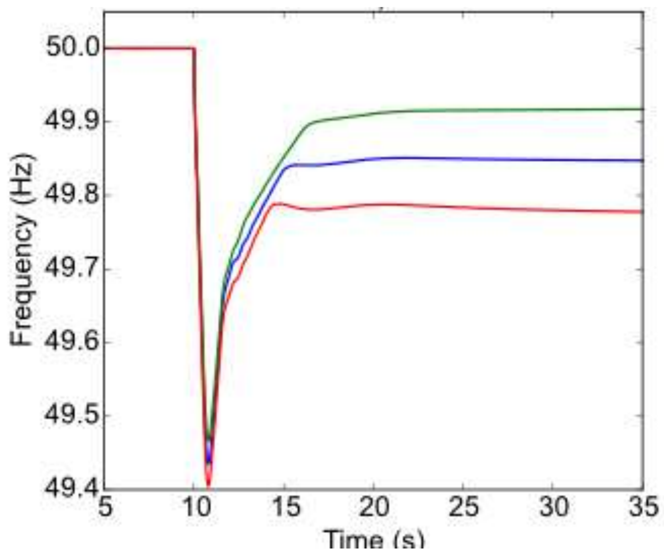
Frequency variation after generator outage



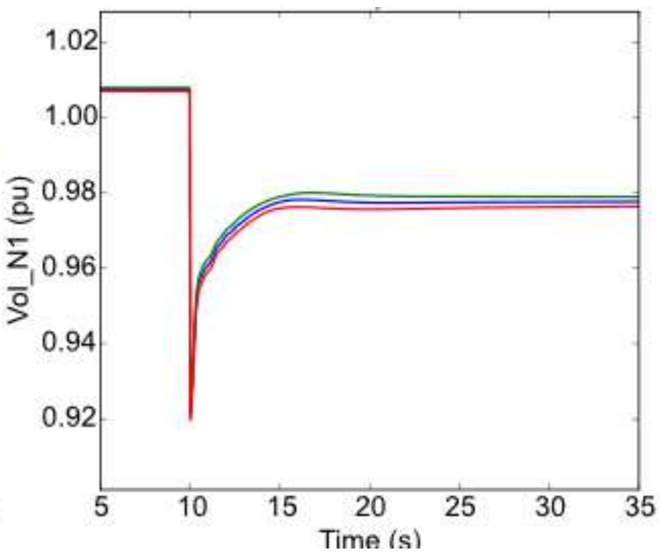
Time period	Sim order	Working SGs
0.00am ÷ 1.00am	27	G21; G22; G31; G32
	63	G21; G22; G31; G32
5.00am ÷ 6.00am	38	G21; G22; G31; G32
	73	G21; G22; G31; G32
	59	G21; G22; G31; G32

Solution: Stochastic study

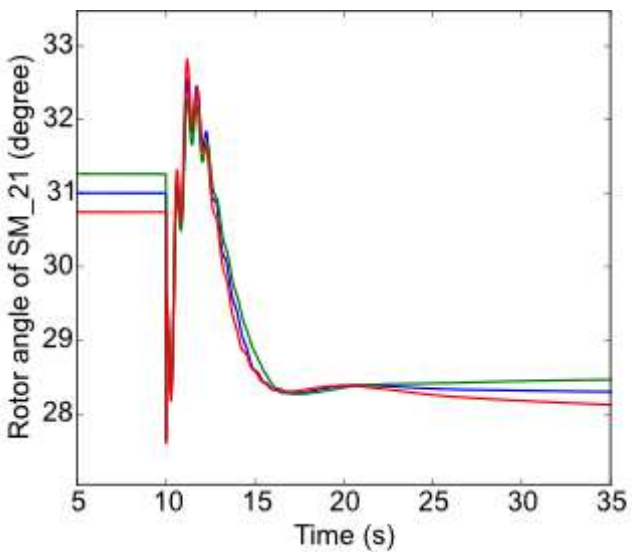
Time period	Sim order	Required power of BESS (MVA)
0.00am ÷ 1.00am	27	5.00
	63	5.00
5.00am ÷ 6.00am	59	5.00
	73	5.00
	38	5.00



Frequency variation in extreme cases



Voltage variation extreme cases



Rotor angle of G21 variation

Plan

Conclusions

- ❑ **Challenges of RES Integration:** Reduction of system inertia, nadir frequency, short-circuit magnitude, CCT while increase RoCoF.
- ❑ **FRT:** Keeps RES units connected during faults, RES penetration can increase from 30% to 70%.
- ❑ **BESS solution**:
  - Enhance stability.
  - Optimising can reduce BESS oversizing while enhancing stability.
  - The best solution: Optimizing all components in the power system.
- ❑ **VSC-HVDC**:
  - Prevents fault propagation across the grid so improve stability of the grid.
  - Optimizing VSC-HVDC can enhance stability and lower its installed capacity.

Perspectives

- **Enhancing Stability with BESS :** Compare with other methods such as: intelligent control, adaptive droop control, robust droop control, VSG.
- **Optimization of Component Parameters Using PSO** : Compare PSO algorithm with other classes of optimization methods (e.g., Model Predictive Control (MPC), Machine learning).
- **Optimizing the Number, Location, and Capacity of BESS and VSC-HVDC Systems.**
- **Converter-driven and Resonance Stability.**
- **Stability of AC-DC Hybrid Grids, DC grids.**
- **Load shedding.**

THANK YOU FOR YOUR ATTENTION

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