

Use of RTDS in R&D of Wide Area Early-Warning and Early-Prevention Systems

IEEE SGSM 2021: Panel Session 1



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Future challenges / problems to address in R&D

Ensuring Secure Operation of Sustainable Electric Power Systems

- **Future visions:** a society with minimal dependency of fossil fuels
 - Requires power production to be mainly based on renewable energy sources (RES)
 - Production becomes subject to prevailing weather conditions (fluctuations) behind inverters

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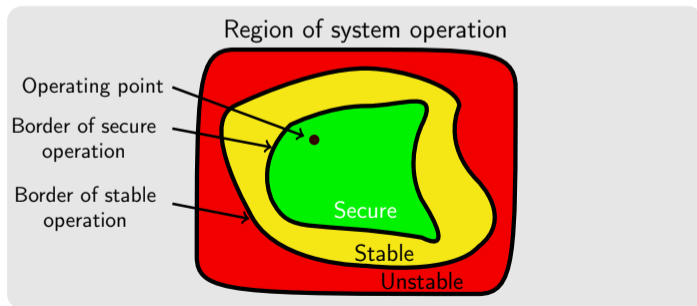
- Are existing approaches for stability and security assessment sufficient for ensuring satisfying operation of such systems?

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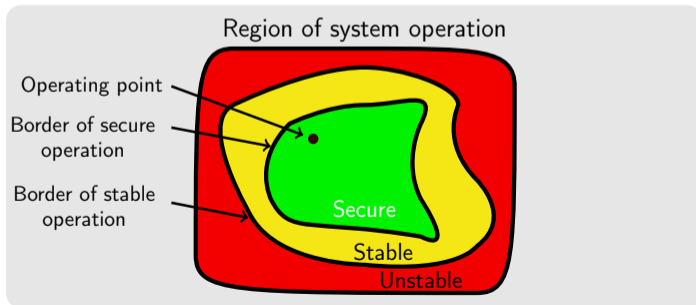
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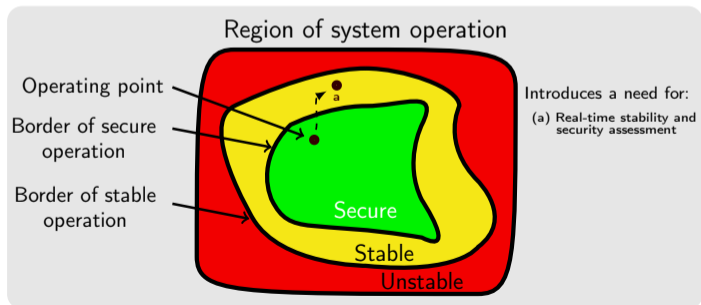
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 - Time consuming \Rightarrow Insufficient



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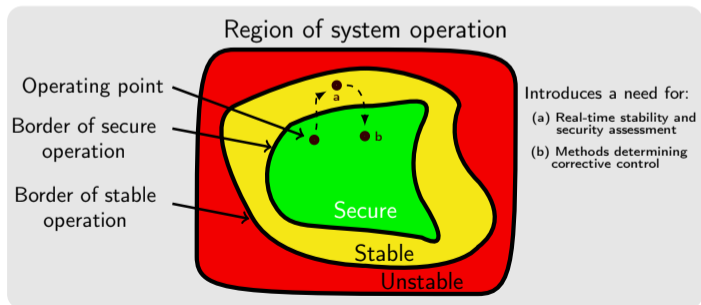
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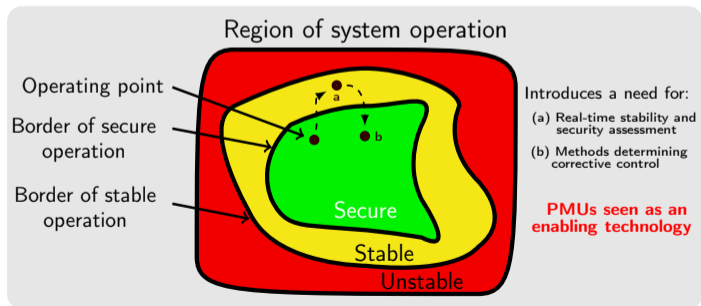
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Envisioned approach to address the R&D challenges

The overall R&D challenge

Ensuring secure operation of future power systems with heavily fluctuating operating point

The envisioned approach: Online operational tool for real-time assessment & countermeasures

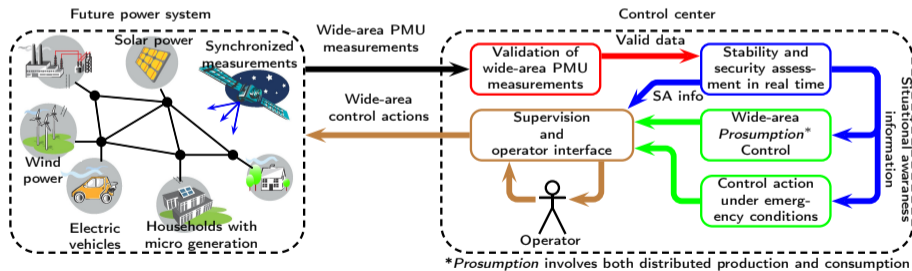
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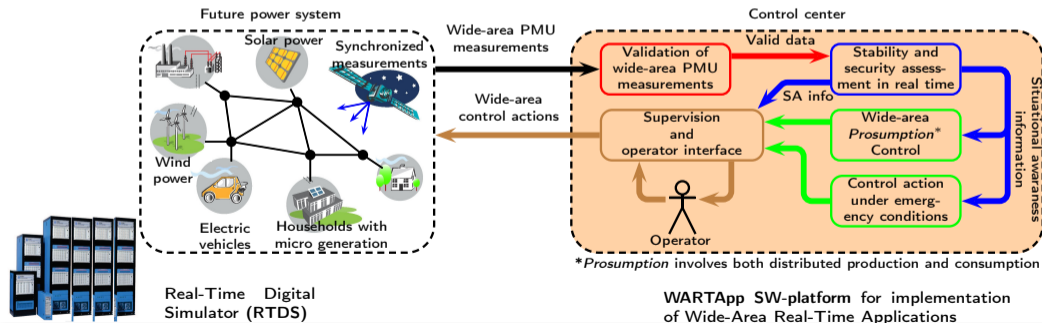


Envisioned approach to address the R&D challenges

The overall R&D challenge

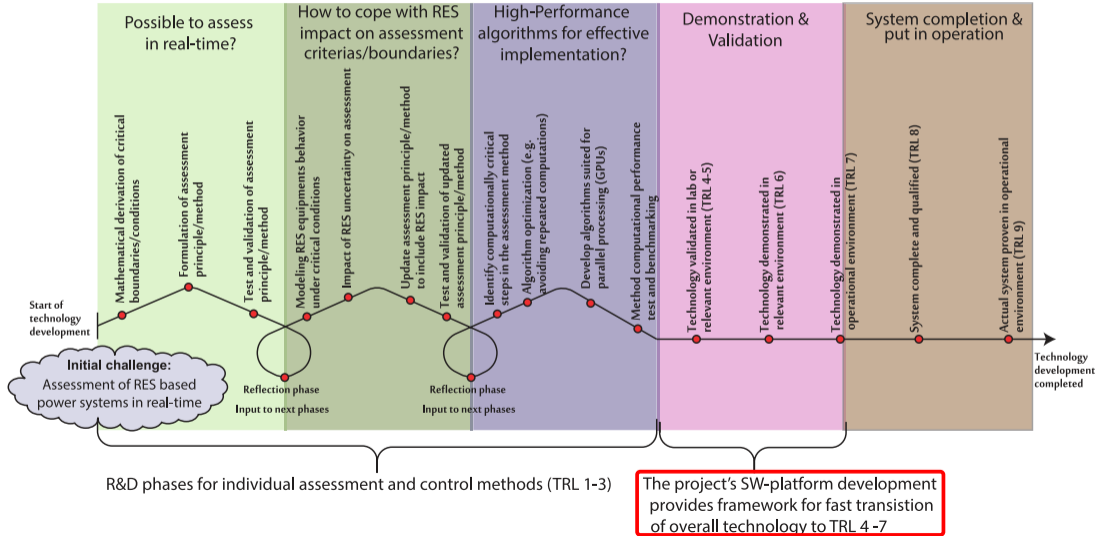
Ensuring secure operation of future power systems with heavily fluctuating operating point

The envisioned approach: Online operational tool for real-time assessment & countermeasures



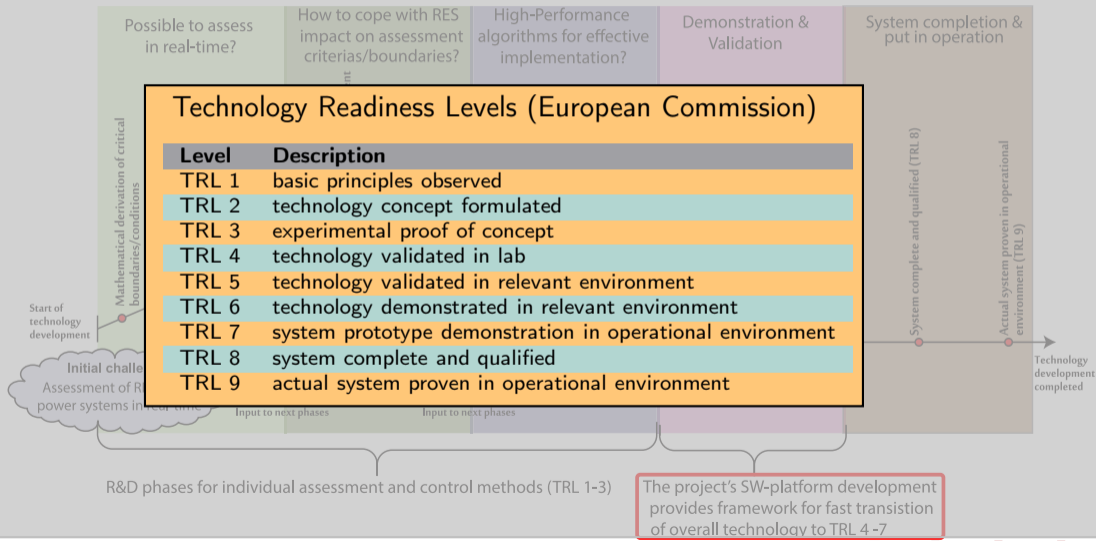
RTDS + WARTApp: Fast track from Research to Online Demonstration

Envisioned Technology Development Process for new Methods/Approaches



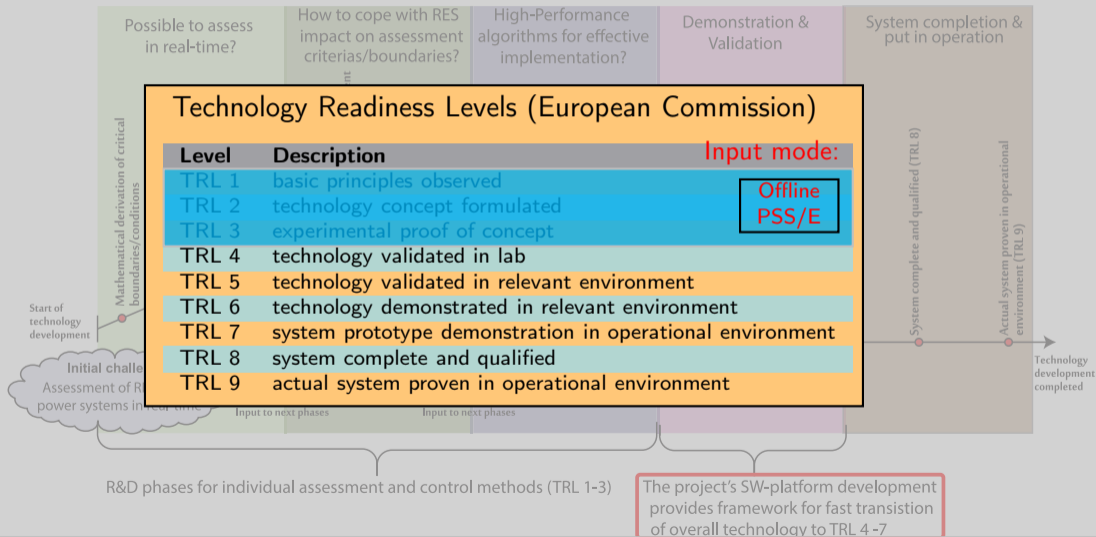
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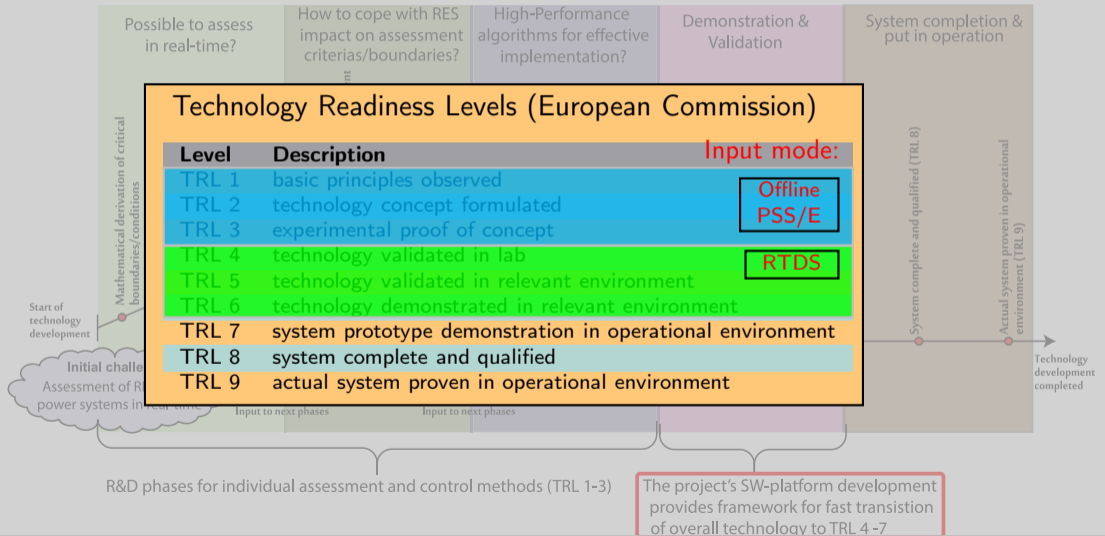
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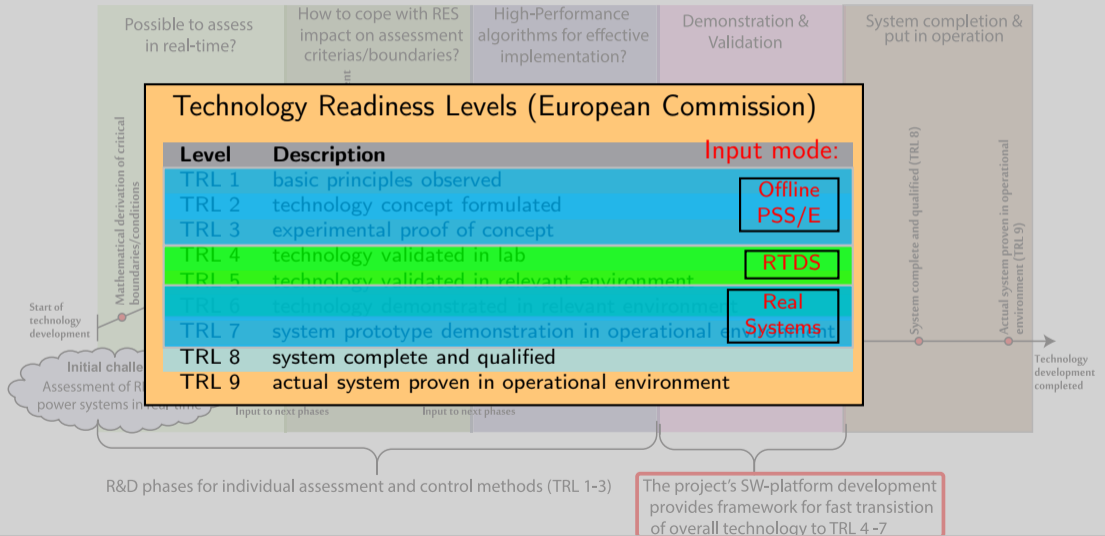
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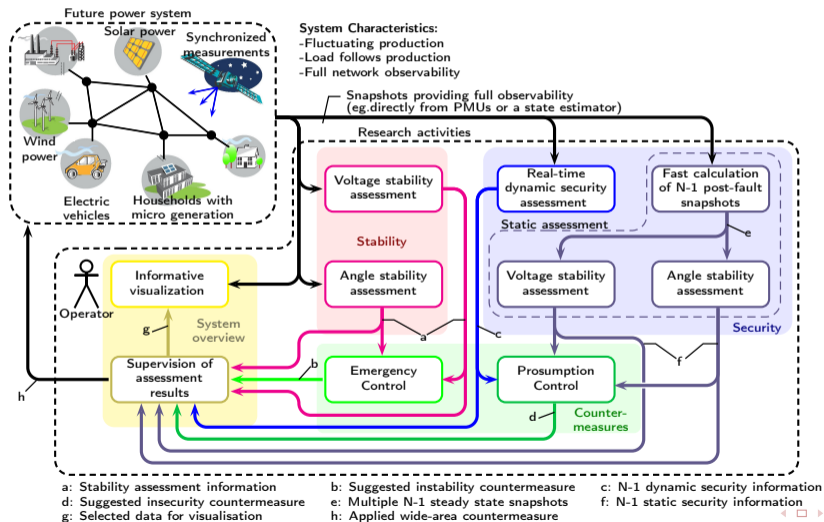


RTDS + WARTApp: Fast track from Research to Online Demonstration

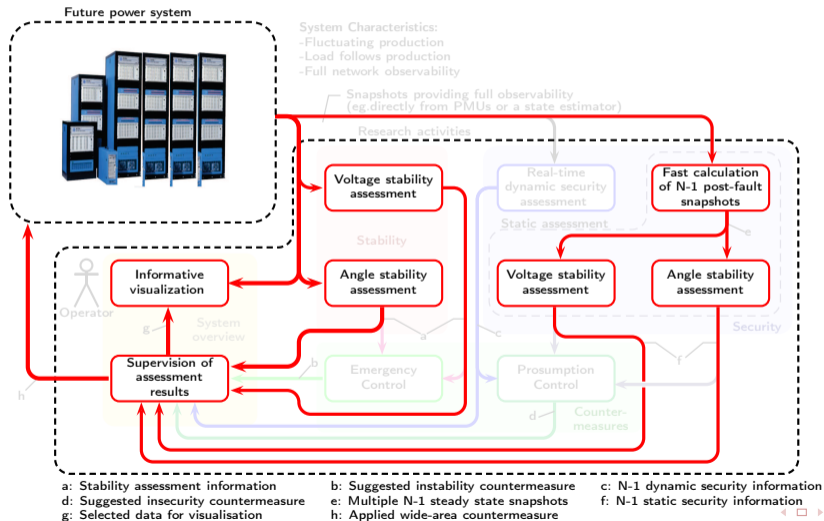
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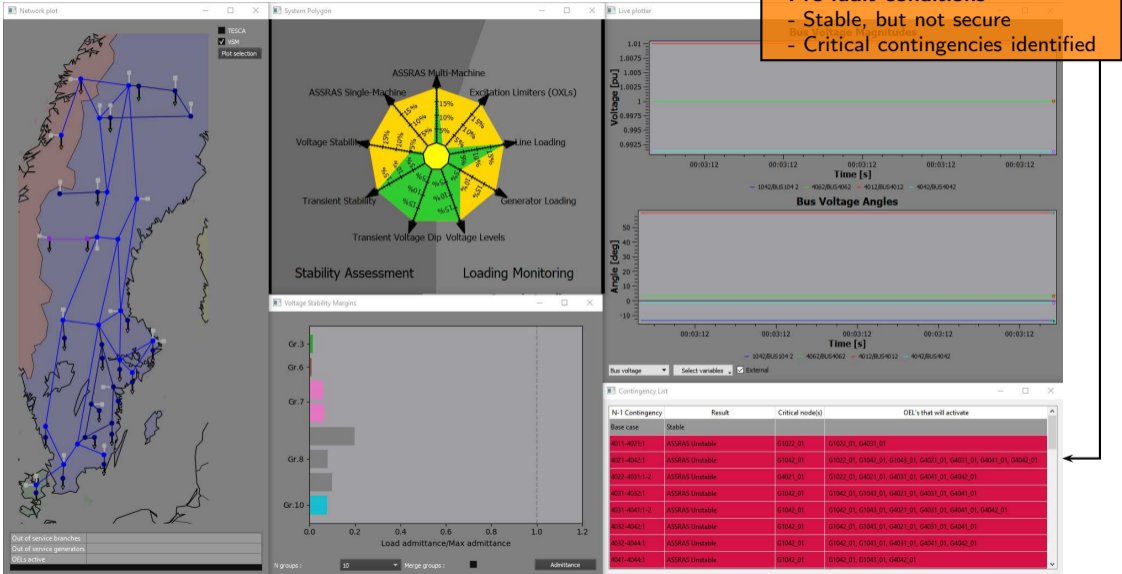
Demonstration: Early-Warning & Early-Prevention



Demonstration: Early-Warning & Early-Prevention



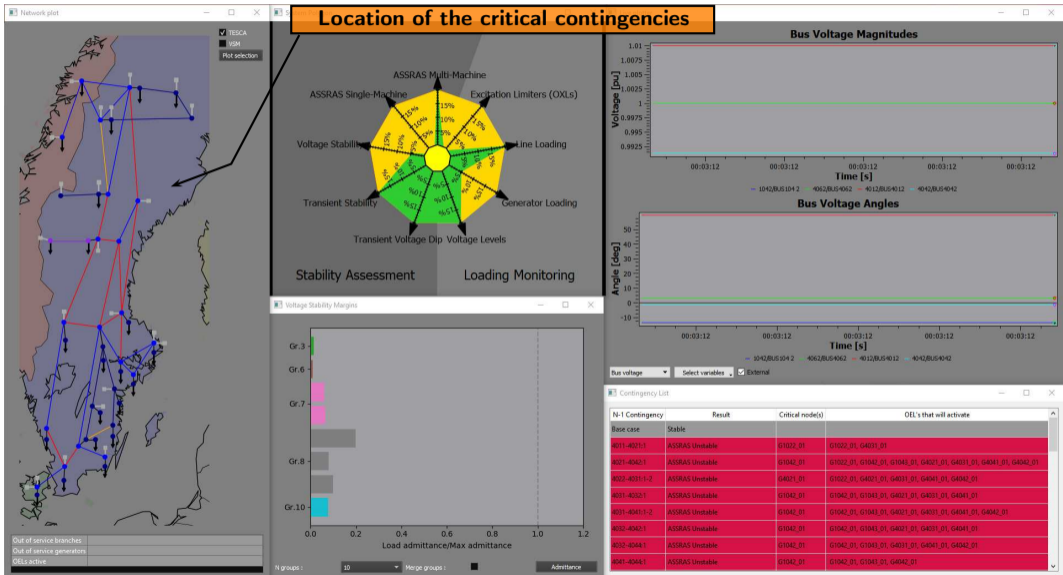
Play Video (use these slides as backup)



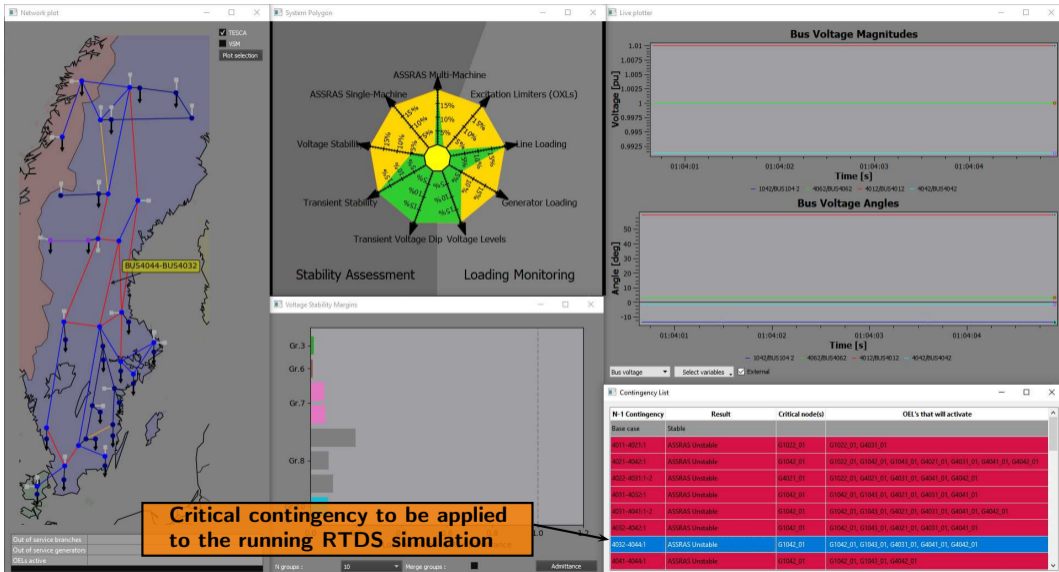
Pre-fault conditions

- Stable, but not secure
- Critical contingencies identified

Play Video (use these slides as backup)



Play Video (use these slides as backup)



Critical contingency to be applied to the running RTDS simulation

Play Video (use these slides as backup)

1st OXL activated

Network plot

TESCA
 WSM
 Plot selection

Out of service branches: #032-#04#1
 Out of service generators: G4042_01
 OEL's active: G4042_01

System Polygon

Stability Assessment Loading Monitoring

ASSRAS Multi-Machine: 15%
 ASSRAS Single-Machine: 10%
 Excitation Limiters (OXLs): 15%
 Line Loading: 10%
 Generator Loading: 10%
 Voltage Levels: 10%
 Voltage Stability: 10%
 Transient Voltage Dip: 10%
 Transient Stability: 10%

Live plot

Bus Voltage Magnitudes

Bus Voltage Angles

Time [s]

Bus voltage Select variables External

Voltage Stability Margins

Group	Margin
Gr.2	~0.18
Gr.3	~0.12
Gr.5	~0.10
Gr.7	~0.08
Gr.9	~0.05

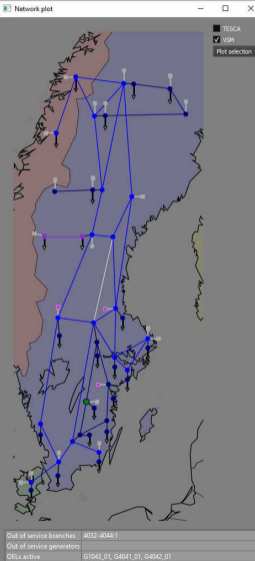
N groups: 10 Merge groups: Admittance

Contingency List

N-1 Contingency	Result	Critical node(s)	OEL's that will activate
Base case	ASSRAS Unstable	G1042_01	G1042_01, G1043_01, G4041_01
1011-1013:1-2	No convergence		
1012-1014:1-2	No convergence		
1013-1014:1-2	No convergence		
1021-1022:1-2	No convergence		
1041-1043:1-2	No convergence		
1041-1043:1-2	No convergence		
1042-1044:1-2	No convergence		
1042-1045:1	No convergence		

Play Video (use these slides as backup)

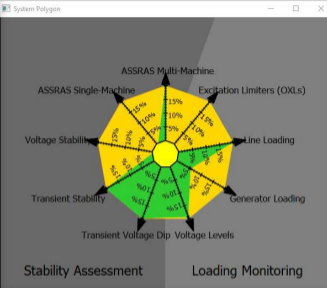
Just before 2nd OXL



Network plot

TESCA
 VSM
 Plot selection

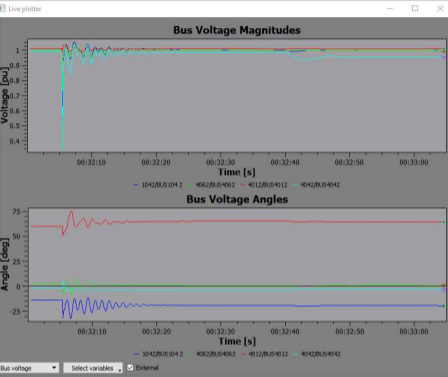
Out of service branches: #032-404#1
 Out of service generators:
 OEL's active: G1042_01, G4041_01, G4042_01



System Polygon

Stability Assessment Loading Monitoring

ASSRAS Multi-Machine
 ASSRAS Single-Machine
 Voltage Stability
 Transient Stability
 Transient Voltage Dip
 Voltage Levels
 Excitation Limiters (OXLs)
 Line Loading
 Generator Loading



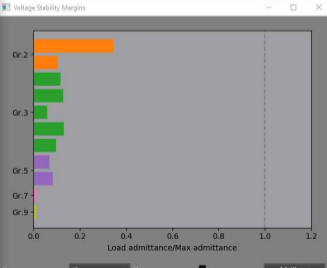
Live plotter

Bus Voltage Magnitudes

Bus Voltage Angles

Time [s]

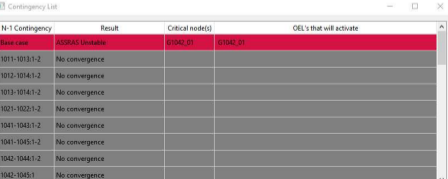
Bus voltage: Select variables External



Voltage Stability Margins

Load admittance/Max admittance

N groups: 10 Merge groups: Admittance



Contingency List

N-1 Contingency	Result	Critical node(s)	OEL's that will activate
Base case	ASSRAS Unstable	G1042_01	G1042_01
1011-1013:1-2	No convergence		
1012-1014:1-2	No convergence		
1013-1014:1-2	No convergence		
1021-1022:1-2	No convergence		
1041-1043:1-2	No convergence		
1041-1045:1-2	No convergence		
1042-1044:1-2	No convergence		
1042-1045:1	No convergence		

Play Video (use these slides as backup)

2nd OXL activated

Network plot

TESCA
 VSM
 Plot selection

Out of service branches: #032-#046.1
 Out of service generators: G1042_01, G1043_01, G4001_01, G4042_01
 OEL's active: G1042_01, G1043_01, G4001_01, G4042_01

System Polygon

ASSRAS Multi-Machine
 ASSRAS Single-Machine
 Voltage Stability
 Transient Stability
 Transient Voltage Dip
 Voltage Levels
 Excitation Limiters (OXLs)
 Line Loading
 Generator Loading

Stability Assessment Loading Monitoring

Live plotter

Bus Voltage Magnitudes

Bus Voltage Angles

Time [s]

Bus voltage Select variables External

Voltage Stability Margins

Group	Load admittance/Max admittance
Gr.1	1.042
Gr.2	~0.35
Gr.3	~0.15
Gr.5	~0.1
Gr.7	~0.15
Gr.9	~0.05

N groups: 10 Merge groups: Admittance

Contingency List

N-1 Contingency	Result	Critical node(s)	OEL's that will activate
Base case	Stable		
1041-1045:1-2	ASSRAS Unstable	G1042_01	
1042-1046:1-2	ASSRAS Unstable	G1042_01	
1042-1045:1	ASSRAS Unstable	G1042_01	
1043-1046:1-2	ASSRAS Unstable	G1042_01	
2031-2032:1-2	ASSRAS Unstable	G1042_01	G4001_01
4011-4012:1	ASSRAS Unstable	G1042_01	G4001_01
4011-4021:1	ASSRAS Unstable	G1042_01	G1022_01, G4001_01
4011-4022:1	ASSRAS Unstable	G1042_01	G4021_01

Play Video (use these slides as backup)

3rd OXL activated

Network plot

TESCA
WSM
Plot selection

Out of service branches: 4032-4044.1
Out of service generators: G1042_01, G1043_01, G4031_01, G4041_01, G4042_01
OELs active

System Polygon

Stability Assessment: ASSRAS Multi-Machine, ASSRAS Single-Machine, Voltage Stability, Transient Stability, Transient Voltage Dip, Voltage Levels

Loading Monitoring: Excitation Limiters (OXLs), Line Loading, Generator Loading

Live plotter

Bus Voltage Magnitudes

Bus Voltage Angles

Time [s]

Angle [deg]

Bus voltage: 1042,BUS104.2, 4062,BUS4062, 4012,BUS4012, 4042,BUS4042

Voltage Stability Margins

Group	Margin
Gr.1	1042 ΔP7.88%
Gr.2	~0.7
Gr.3	~0.65
Gr.5	~0.2
Gr.7	~0.15
Gr.9	~0.05

Load admittance/Max admittance

Contingency List

N-1 Contingency	Result	Critical node(s)	OEL's that will activate
Base case	ASSRAS Unstable	G1042_01	
1011-1013:1-2	No convergence		
1012-1014:1-2	No convergence		
1013-1014:1-2	No convergence		
1021-1022:1-2	No convergence		
1041-1043:1-2	No convergence		
1041-1045:1-2	No convergence		
1042-1044:1-2	No convergence		
1042-1045:1	No convergence		

Play Video (use these slides as backup)

Voltage instability detected

Network plot

TESCA
WSM
Plot selection

Out of service branches: 4032-4046.1
Out of service generators: 61042_01, 61043_01, 64031_01, 64041_01, 64042_01
OEL's active:

System Polygon

ASSRAS Multi-Machine
ASSRAS Single-Machine
Voltage Stability
Transient Stability
Transient Voltage Dip
Voltage Levels
Excitation Limiters (OXLs)
Line Loading
Generator Loading

Stability Assessment Loading Monitoring

Live plotter

Bus Voltage Magnitudes

Bus Voltage Angles

Time [s]

Bus voltage Select variables External

Voltage Stability Margins

Group	DP Value
Gr.1	1042 ΔP -0.22%
Gr.2	ΔP 15.01%
Gr.3	ΔP 17.60%
Gr.4	ΔP 19.97%
Gr.5	
Gr.7	
Gr.9	

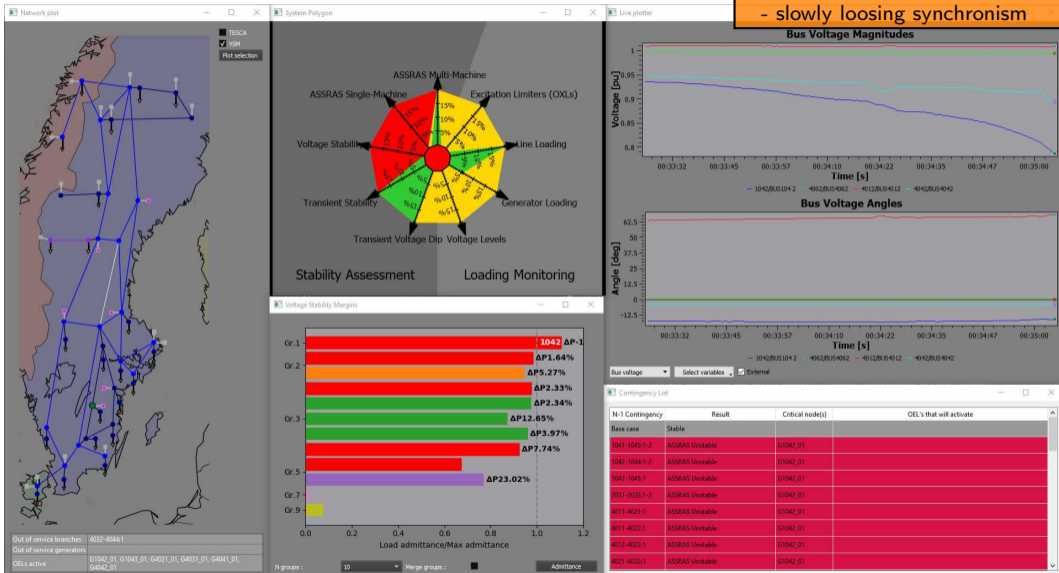
Load admittance/Max admittance

N groups: 10 Merge groups: Admittance

Contingency List

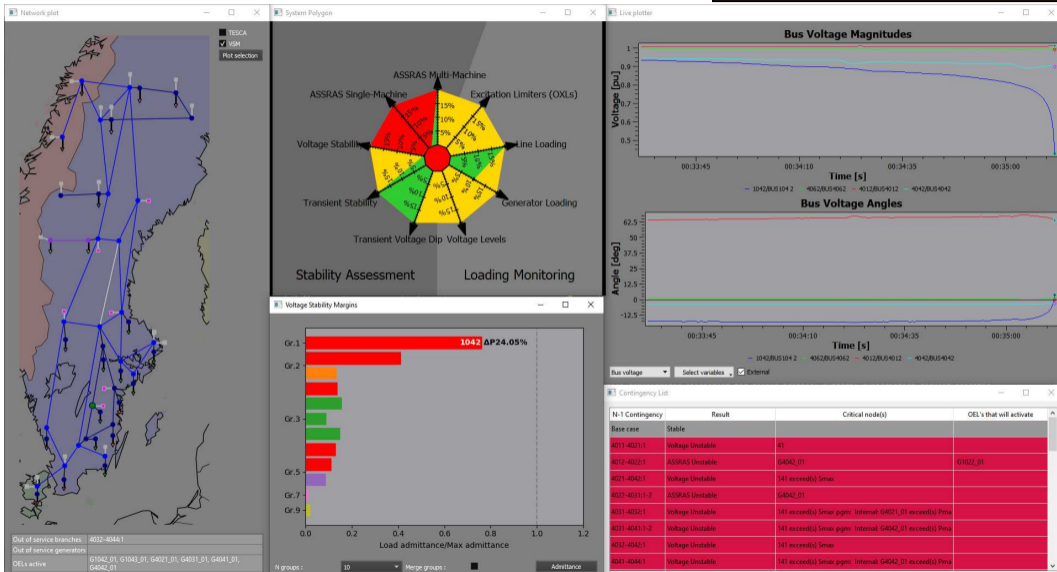
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Base case	ASSRAS Unstable	61042_01	
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1013-1014:1-2	No convergence		
1021-1022:1-2	No convergence		
1041-1043:1-2	No convergence		
1041-1045:1-2	No convergence		
1042-1044:1-2	No convergence		
1042-1045:1	No convergence		

Play Video (use these slides as backup)



Play Video (use these slides as backup)

Collapse in voltage - blackout



Out of service branches: 4032-4044:1
 Out of service generators: G1042_01, G1043_01, G4021_01, G4021_01, G4041_01, G4042_01
 OELs active:

Bus voltage Select variables External

N-1 Contingency	Result	Critical node(s)	OEL's that will activate
Base case	Stable		
4011-4021:1	Voltage Unstable	41	
4012-4022:1	ASSRAS Unstable	G4042_01	G1022_01
4021-4042:1	Voltage Unstable	141 exceed(s) Smax	
4022-4031:1-2	ASSRAS Unstable	G4042_01	
4031-4032:1	Voltage Unstable	141 exceed(s) Smax pgrm; Internal; G4021_01 exceed(s) Pmax	
4031-4041:1-2	Voltage Unstable	141 exceed(s) Smax pgrm; Internal; G4042_01 exceed(s) Pmax	
4032-4042:1	Voltage Unstable	141 exceed(s) Smax	
4041-4044:1	Voltage Unstable	141 exceed(s) Smax pgrm; Internal; G4042_01 exceed(s) Pmax	