Online Dynamic Security Assessment (DSA) Based on EMT Simulations

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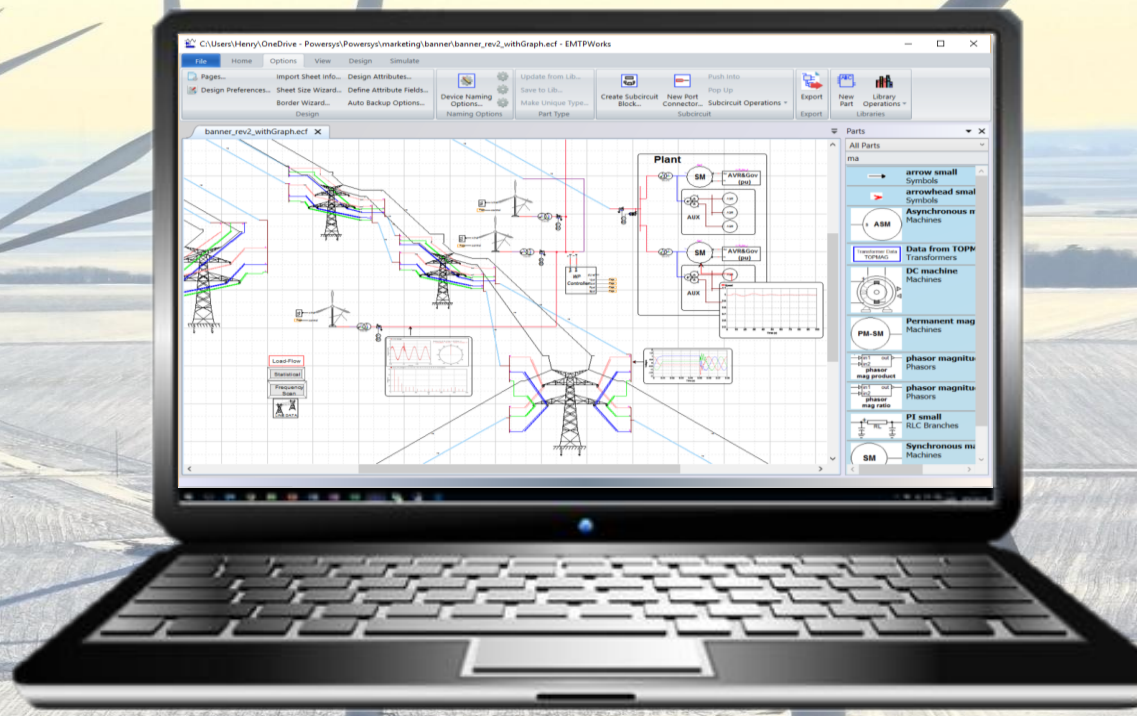
EMTP



More info

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Company introduction

- EMTP: Electromagnetic Transients Program
- EMT tool developed to handle even very-large-scale simulations
  - Uses innovative matrix solution techniques
  - Solves network equations with exceptional speed
- Allows to use large time steps (500 µs)
  - While maintaining accuracy
- Prevents numerical oscillations inherent to trapezoidal integration
  - No extraneous sawtooth jitter in waveforms
- Integrated load-flow solver
  - Allows to solve load-flow conditions in the same environment as EMT
  - Finds initial conditions and **automatically initializes EMT simulations (flat start)**

Content

- DSA tool introduction
- Operating cycle
- System overview
  - Architecture
  - Contingencies design preparation
  - DSA controller
  - Client computers
  - Hardware requirements
  - Post-processing
- Simulations/timings
- Conclusions

DSA tool introduction

➢ Dynamic Security Assessment (DSA)

- Evaluates if the grid at the current operating point remains stable after disturbances
- Run multiple simulations with different disturbances at regular time intervals
- Near-real-time process

➢ EMT-based Dynamic Security Assessment tool

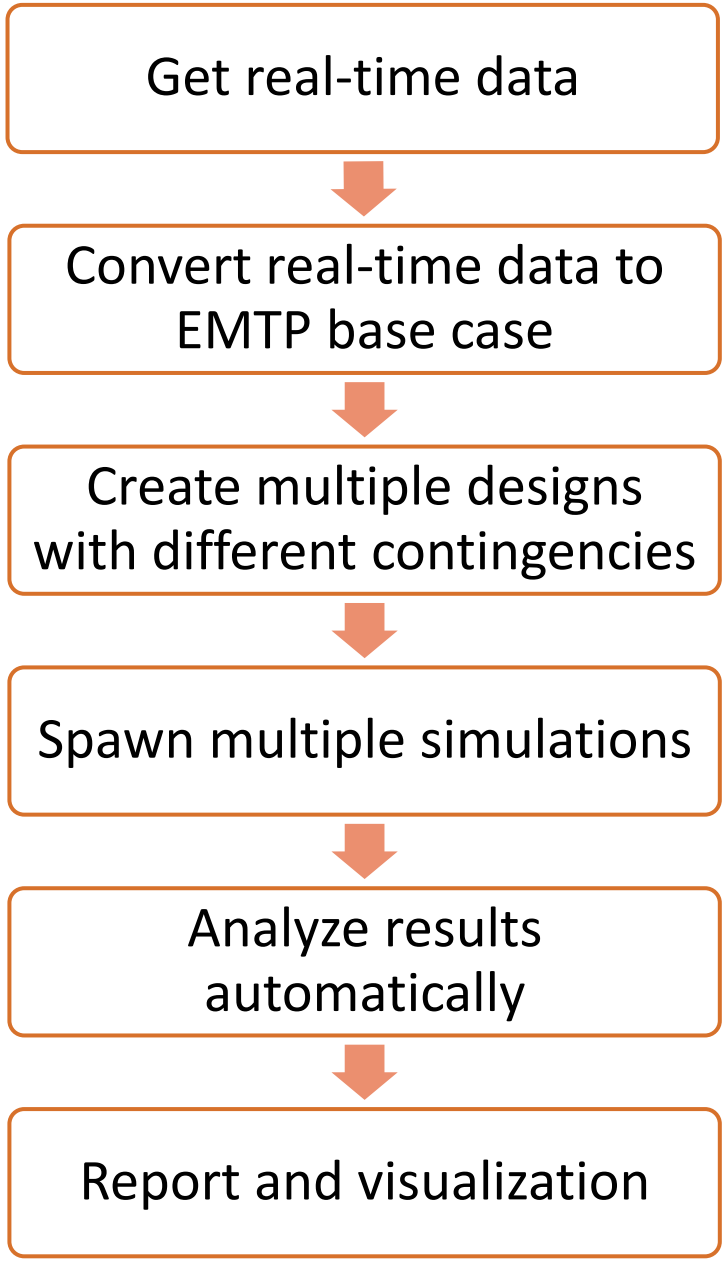
- Hardware and software architecture
- EMT simulations (high results reliability)
- Detailed models of IBRs, etc.
- Grid EMT model represents current operating conditions (“digital twin”)

➢ Intended users

- Operators in the System Operator control room (online monitoring)
- Engineers (detailed analysis)

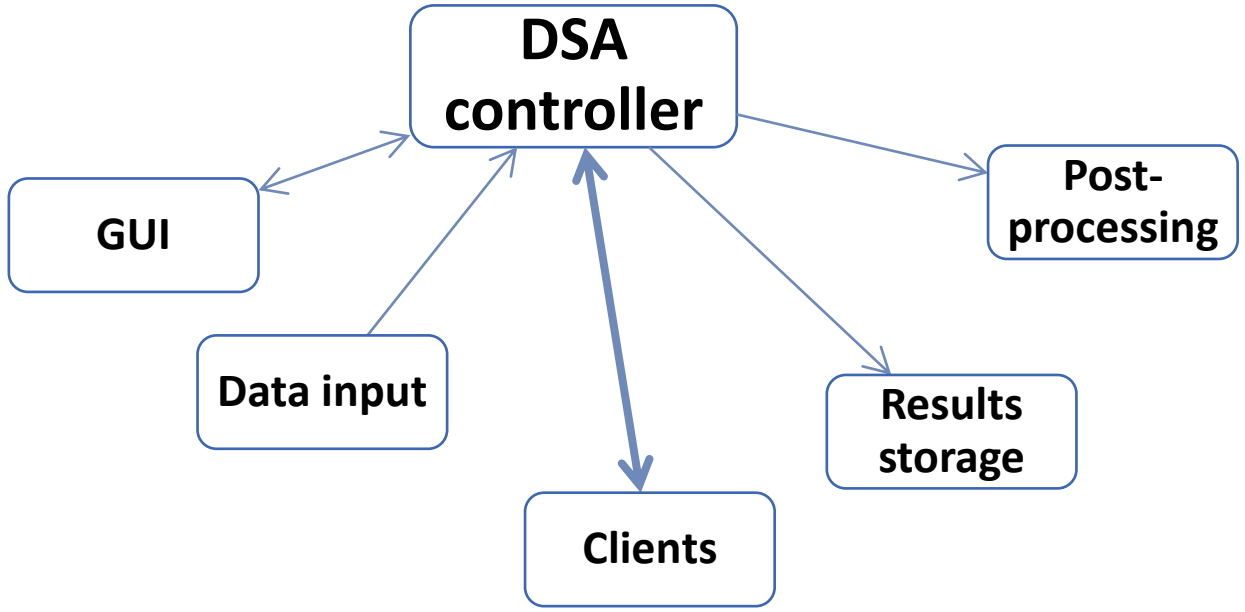
Operating cycle

- Cycle starts every 30-60 minutes
  - Real-time data about grid conditions must be ready
  - Generator setpoints, loads, …
  - From SCADA, state estimator, …
- Possibility to start the cycle manually
  - For detailed analysis by engineers



System architecture

- DSA controller
  - Interacts with users (GUI)
  - Interacts with “clients”
- Data input
  - Grid conditions (setpoints, loads, etc.)
  - Contingencies data
- Clients (computers/VMs)
  - Run simulations
- Post-processing and visualization
  - Waveform visualization
  - Report generation



Contingencies design preparation

- Multiple contingencies for each cycle
  - Faults
  - Load/generator outages
  - Setpoint changes
  - Etc.
- Level of detail for models
  - Detailed close to contingency
  - Simplified in remote zones (faster)

Contingency selection for next cycle analysis		Simplification level for remote zones			Computer			
		Detailed	Simplified	Thevenin eq	Auto assigned	Local	Remote 1	Remote 2
Cont 1	x		x		x			
Cont 2		x			x			
Cont 3	x	x			x			
Cont 4		x			x			
Cont 5	x			x	x			
Cont 6	x			x	x			

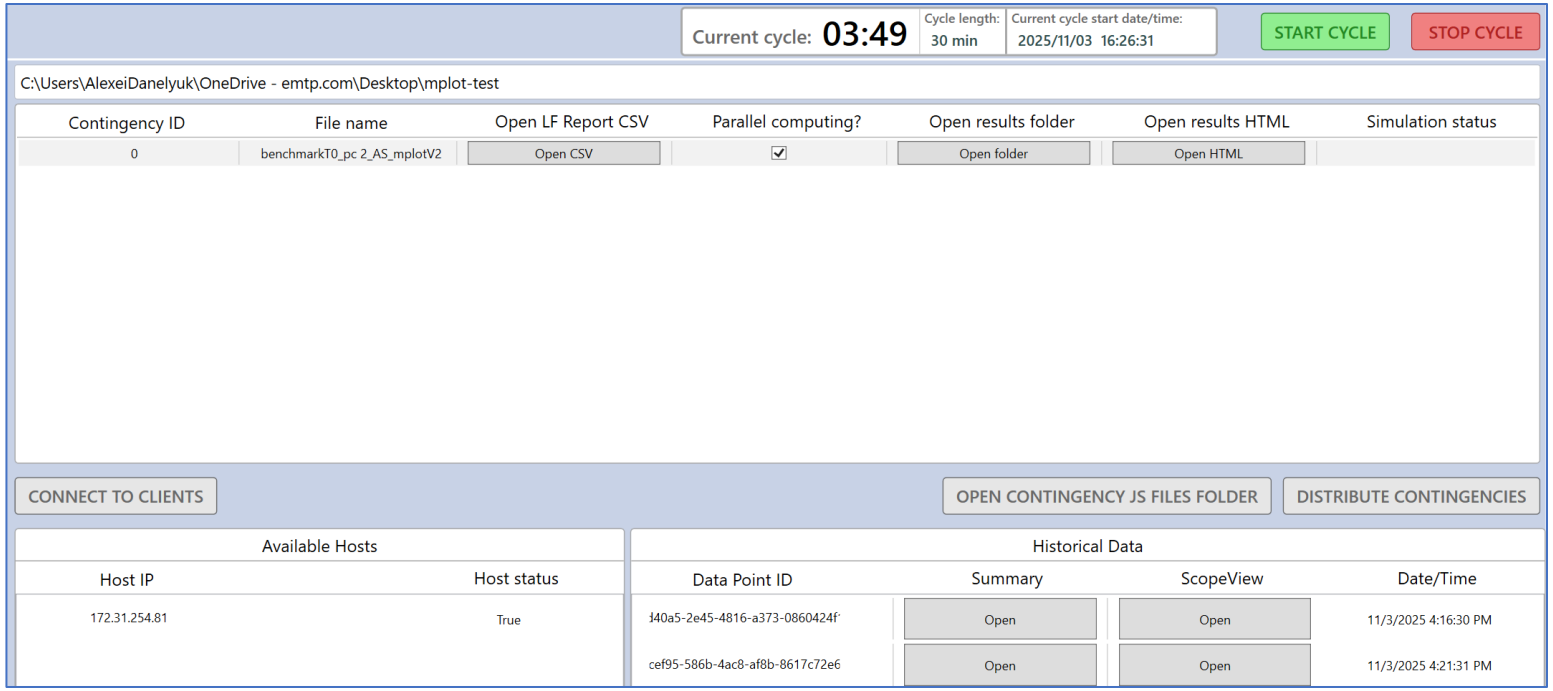
Signals selection for next cycle analysis		Limits		Post processing functions			
		Low	High	LF analysis	Oscillations	FFT	Max/min
V 1	x	0.95 pu	1.05 pu	x	x	x	
V 2		0.95 pu	1.05 pu	x	x		
F 1	x	49 Hz	51 Hz		x		x
F 2		49 Hz	51 Hz		x		x
P 1	x	-100 MW	1000 MW	x			x
P 2	x	-100 MW	1000 MW	x			x

Edit contingencies	Select and run a case	Set root folder	Time domain simulation length
	C:\offline\test.raw	C:\temp\cases	15 s

DSA controller

➢User interface

- Starts/stops DSA operation
- Tracks status, cycle progress
- Definition of contingencies
- Cycle settings



➢Archiving

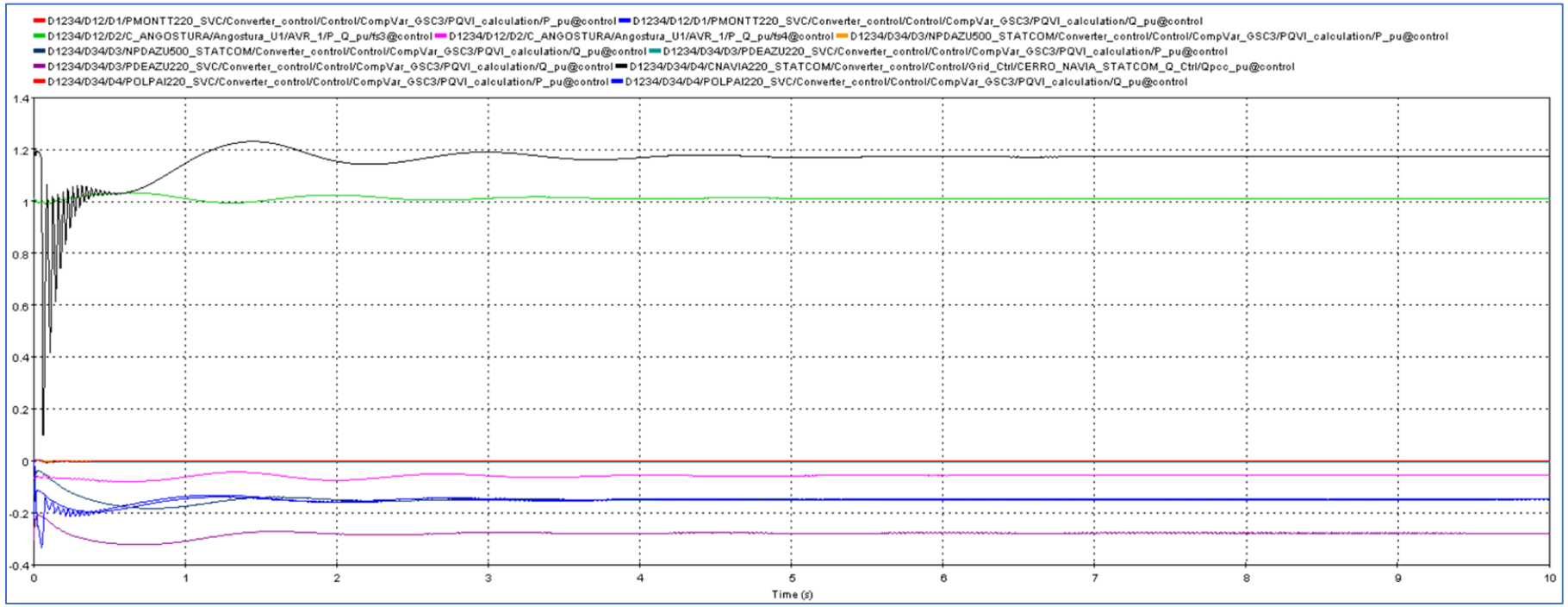
- Simulation designs
- Analysis results

➢Communication with “clients” (computers that run simulations)

- TCP/IP connection
- Sends base-case simulation design and contingencies data
- Receives simulation data

Client computers

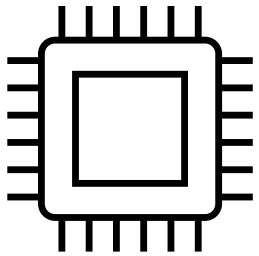
- Client computers run simulations (multiple simulations per client)
  - Apply appropriate contingency to the base-case design
  - Compute load-flow
  - Then run time-domain EMT simulation (initialized from load-flow results)
  - Send load-flow phasors and time-domain waveforms to the DSA controller



Hardware requirements

- Required hardware for client computers depends on:
  - Number of simulated contingencies
  - Number of parallel regions per simulation
  - RAM per parallel region

- Example
  - 10 contingencies × no parallelization => 10 cores (single computer may be sufficient)
  - 50 contingencies × 8 parallel regions => 400 cores (multiple computers required)



Post-processing

➢Analyze results automatically

- Load-flow phasors
- Time-domain waveforms
- Limits for current/power/voltage

➢Report generation

- Overall status, failed tests, …
- Grid stability, oscillations, …
- Export to a specific format

➢Results visualization

- Templates

LF bus voltage	Value	Limits		Pass/fail
		Low	High	
BUS1	1.01 pu	0.95 pu	1.05 pu	Pass
BUS2	0.98 pu	0.95 pu	1.05 pu	Pass
BUS3	1.1 pu	0.95 pu	1.05 pu	Fail

LF transmitted power	Value	Limits		Pass/fail
		Low	High	
BUS1 – BUS2	1000 MW	-100 MW	1050 MW	Pass
BUS2 – BUS3	5500 MW	-100 MW	1050 MW	Fail
BUS3 – BUS1	-300 MW	-1000 MW	1050 MW	Pass

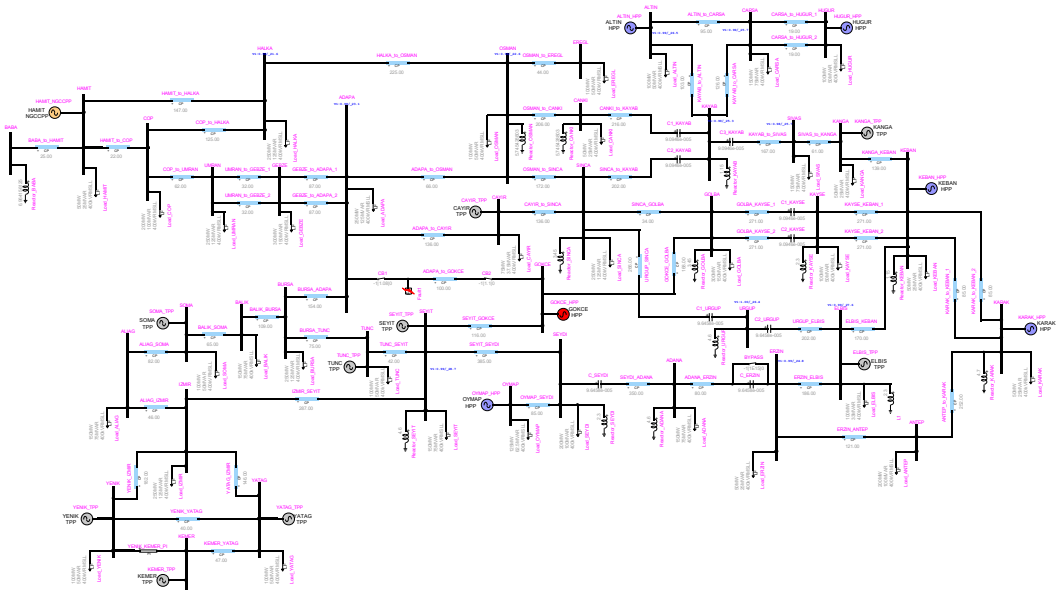
TD bus voltage	Oscillations	FFT	Max/min limit violation
BUS1	No oscillations	No harmonics	Pass
BUS2	1 Hz, damping 0.5	No harmonics	Pass
BUS3	2 Hz, damping 0.6	No harmonics	Fail

Load selected cycle data

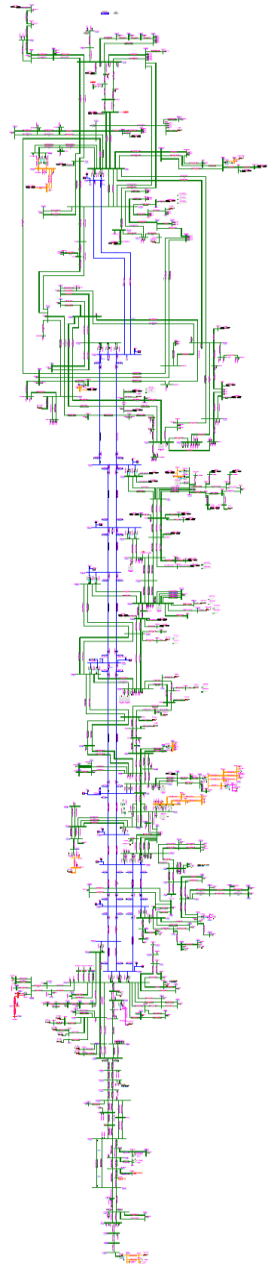
C:\temp\cases\previous case

Test cases

- Turkish grid
  - >400 nodes
  - >2000 control blocks



- Chilean grid
  - >8000 nodes
  - >80,000 control blocks



Timings

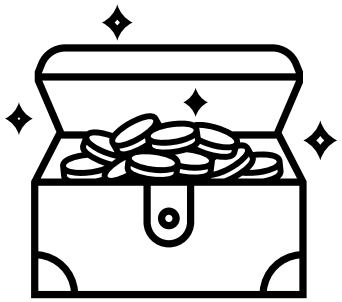
➢2 cases:

- Turkish grid (>400 nodes, >2000 control blocks), 3s
- Chilean grid (>8000 nodes, >80,000 control blocks), 10s

Metrics	Turkish grid	Chilean grid
Send base-case design to clients	4 s	9 s
Start EMT simulation software (EMTP)	27 s	26 s
Load-flow solution	1 s	43 s
Time-domain simulation	1 core: 8 s	1 core: 7526 s (125 min) 8 cores: 718 s (12 min)

Conclusions

- DSA tool allows to assess grid reliability and security
  - In near-real-time
  - Can be used by operators and engineers
- Based on EMT simulations
  - Wide-area grid with detailed IBR models
- Hardware selection depends on required contingencies
  - More contingencies => more computing power required => more investments
- Target cycle time: 30 minutes
  - Achievable with parallelization



- Thank you for your attention!

- Questions?