Model Demonstration and Training

New Providence, Eleuthera & Exuma Islands

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11.05.2023

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Based in Darmstadt, Germany

Services by Energynautics

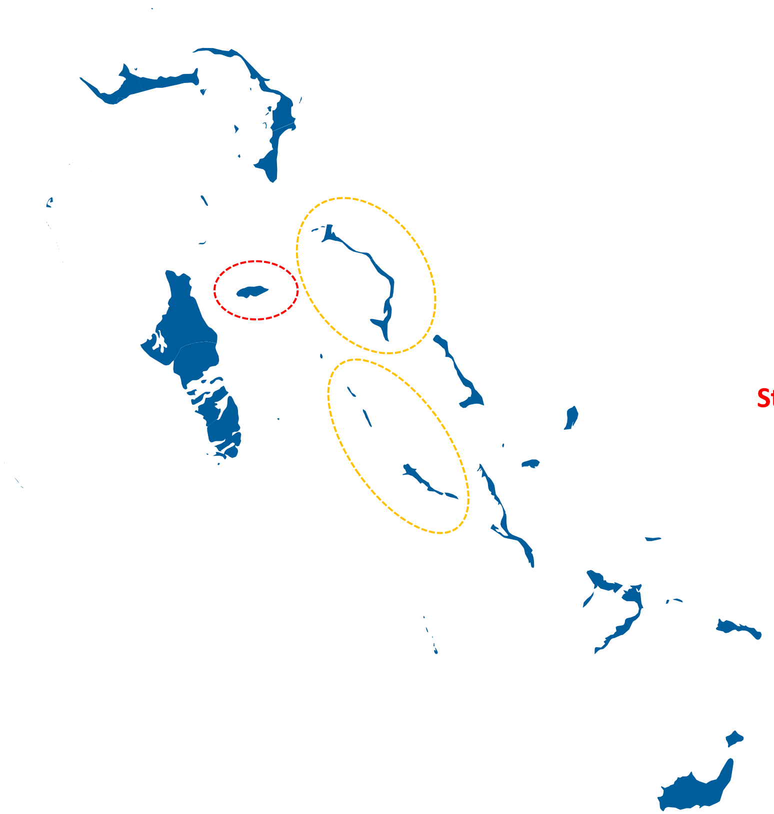
- Grid Studies
- Smart Grid Development
- Power Generating Unit Modelling
- Grid Code Development
- Measurement Campaigns
- Capacity Building
- Conference Planning

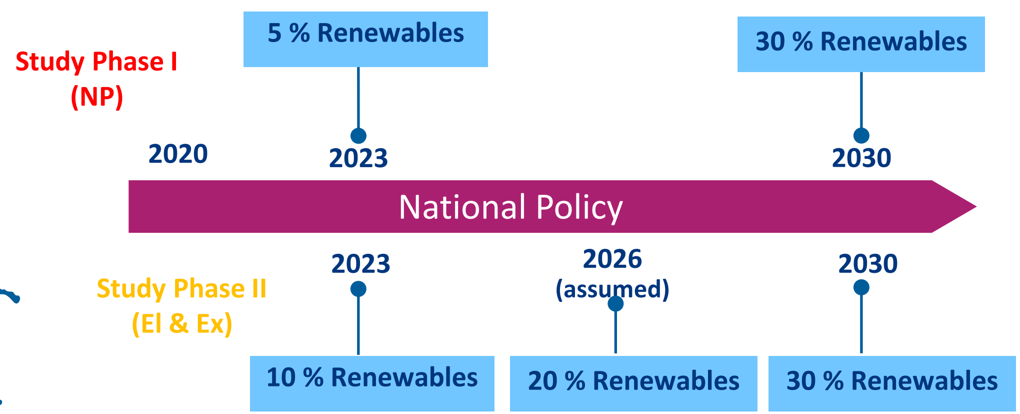
AGENDA

- Project Objective
- Methodology and Case Matrix
- Power System Model Development
- Intro to ETAP
- Study Organization
- Load Flow
- Transient Stability

Project Objective

Energynautics was commissioned to undertake a power system stability study for islands in Bahamas – New Providence, Eleuthera and Exuma to assess their future readiness for renewable integration





% as part of annual electricity mix

Methodology (Phase I)

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Data Collection and Analysis

Energy resources, renewable targets, existing SLD, expansion plans, unit parameters, cost and merit order

Capacity optimization in HOMER

Estimating best mix of generating capacities to meet the targets and choosing scenarios for analysis

Modelling in ETAP

Updating the SLD with current state, incorporating future expansions, selecting appropriate dynamic models, setting the cases

Stability analysis in ETAP

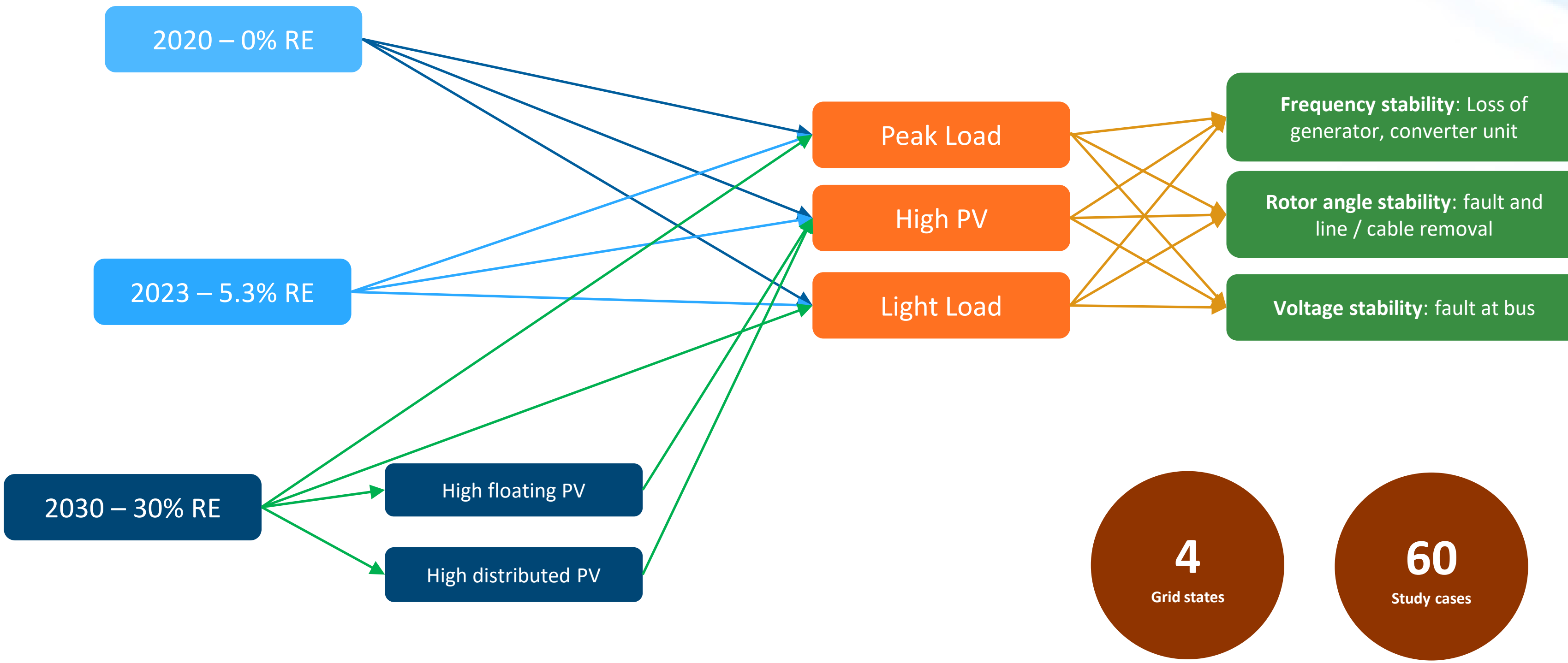
Generator dispatch, reserves, voltage violations, steady state simulations, contingency analysis

Scenario	Cases	PV instantaneous penetration
2020 (0% RE)	Peak Load (evening) High PV (mid-day) Light Load (night)	0 % 0 % 0 %
2023 (5.3% RE)	Peak Load High PV Light Load	10 % (BESS) 30 % 0 %
2030 (30% RE)	Peak Load High Floating PV High Distributed PV Light Load	8 % (BESS) 75 % 75 % 0 %

Possible Pathways

Selected Cases

Case Matrix (Phase I)



Power System Development

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Study Phase I (NP)

	2020	2023	2030
Synchronous Generator	**480 MW** 20 Generators	**500 MW** 26 Generators	**500 MW** 26 Generators
Commercial PV	**0.9 MW** 1 PV	**25 MW** 16 PVs	**115 MW / 55 MW** 16 PVs
Residential PV	0	0	**90 MW / 30 MW** 16 PVs
Utility PV	0	**30 MW** 1 plant	**30 MW / 150 MW** 1 plant
Battery	0	**25 MW** 1 BESS	**25 MW** 1 BESS

Study Phase II (Exuma)

	2023	2026	2030
Synchronous Generator	**(17.6 + 6) MW** 4 main + 6 ren.	**(17.6 + 6) MW** 4 main + 6 ren.	**(17.6 + 6) MW** 4 main + 6 ren.
Commercial PV	**4 MW** 3 PVs	**6 MW** 4 PVs	**9 MW** 4 PVs
Residential PV	0	**3 MW** 3 PVs	**6 MW** 3 PVs
Battery	**2 MW** 1 BESS	**2 MW** 1 BESS	**3 MW** 1 BESS

Study Phase II (Eleuthera)

	2023	2026	2030
Synchronous Generator	**30.7 MW** 10 Generators	**30.7 MW** 10 Generators	**30.7 MW** 10 Generators
Commercial PV	**6 MW** 4 PVs	**10 MW** 4 PVs	**16 MW** 4 PVs
Residential PV	0	**4 MW** 4 PVs	**8 MW** 4 PVs
Battery	0	**2 MW** 1 BESS	**4 MW** 1 BESS

ETAP Topics

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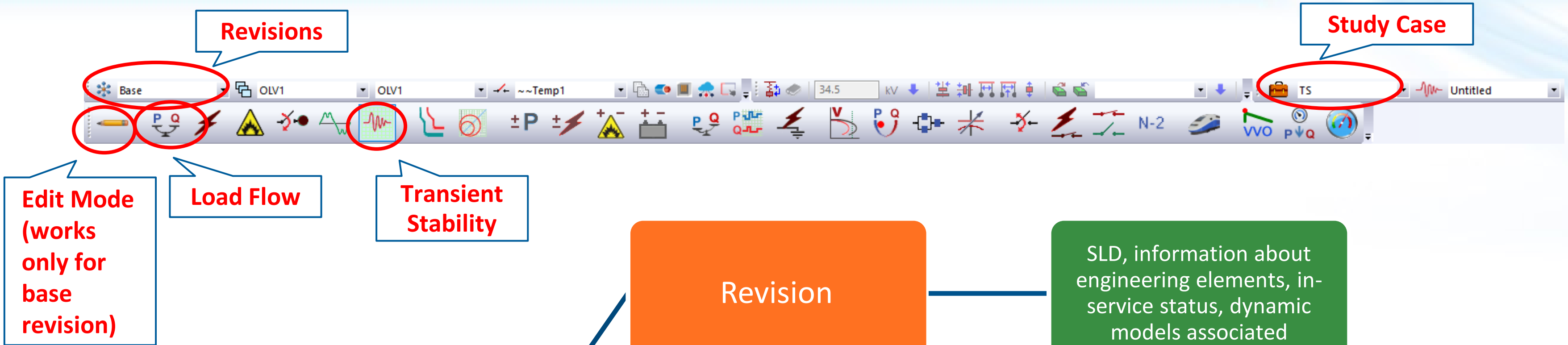
Static Simulations

- Model Organization
- Running Load Flow
- Power Flow Results
- Changing Power Flow Model

Dynamic Simulations

- Running dynamic simulations
- Simulation Results
- Changing models

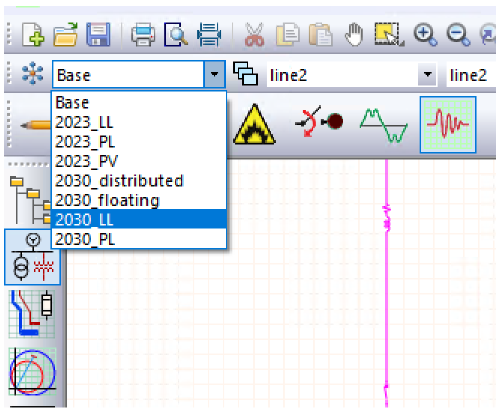
Introduction to ETAP: Interface



- **Scenario**
  - **Revision** — SLD, information about engineering elements, in-service status, dynamic models associated
  - **Configuration** — Switch configuration, generator control mode
  - **Study Case** — Load./gen. categories, Load scaling, Simulation length, time step, plotting elements, Contingencies

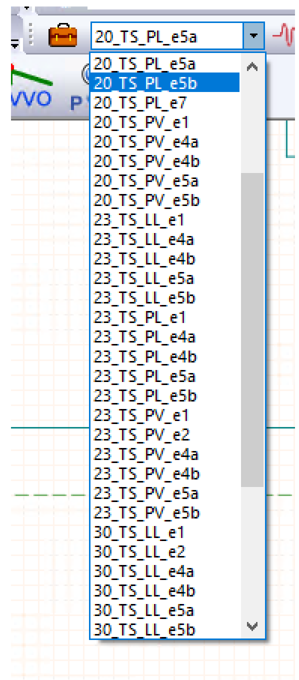
Introduction to ETAP: NP Example

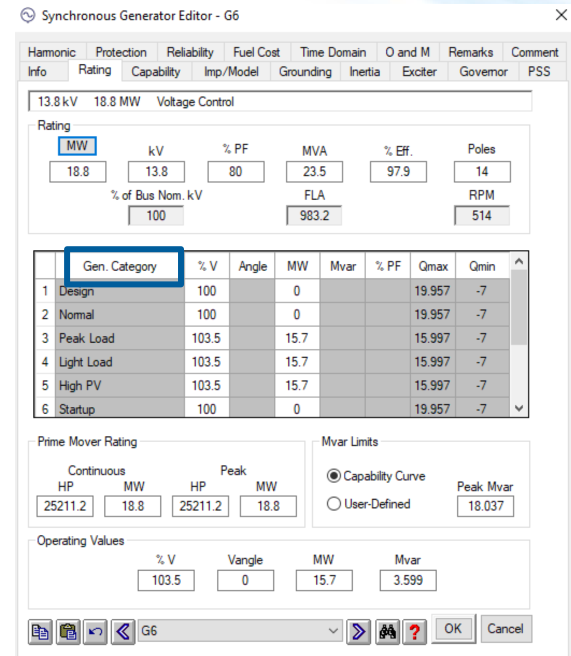
Revision



- No two revisions can be activated at same time
- Out of service for an element a revision

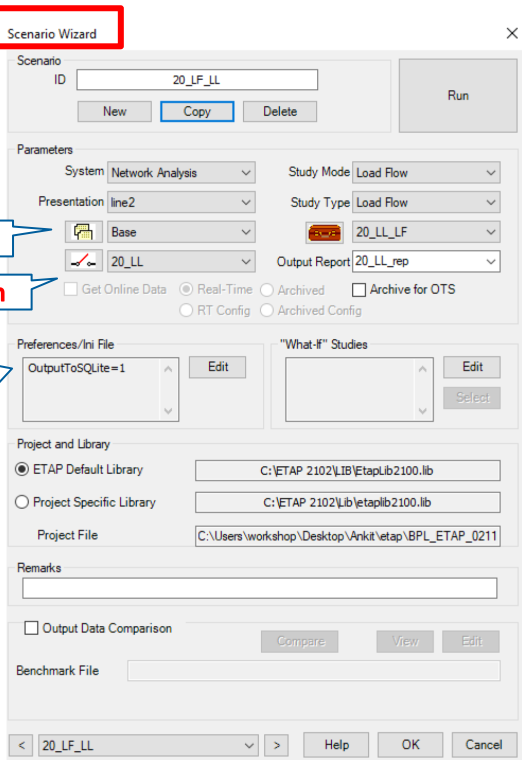
Study Case





Load flow and transient stability study cases differ!

Intro to ETAP: Wizards



Revision

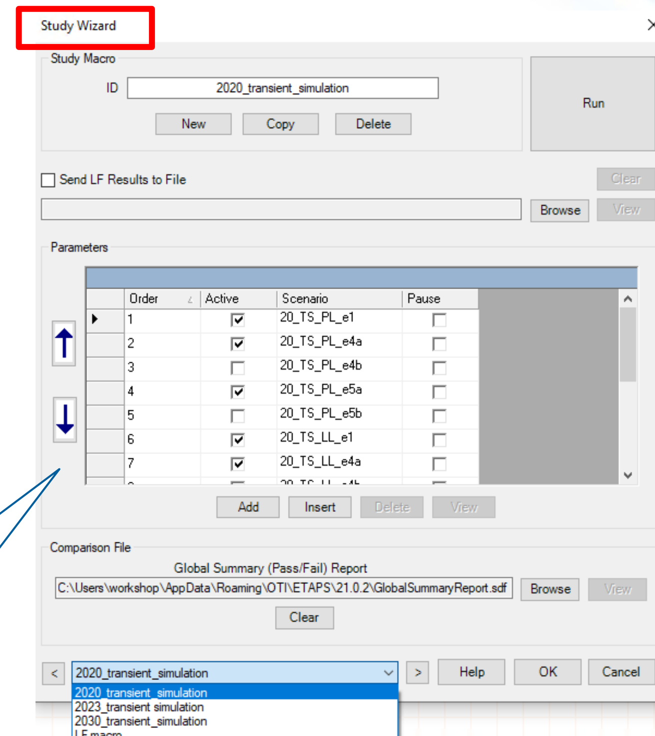
Configuration

To export data in SQLite db file

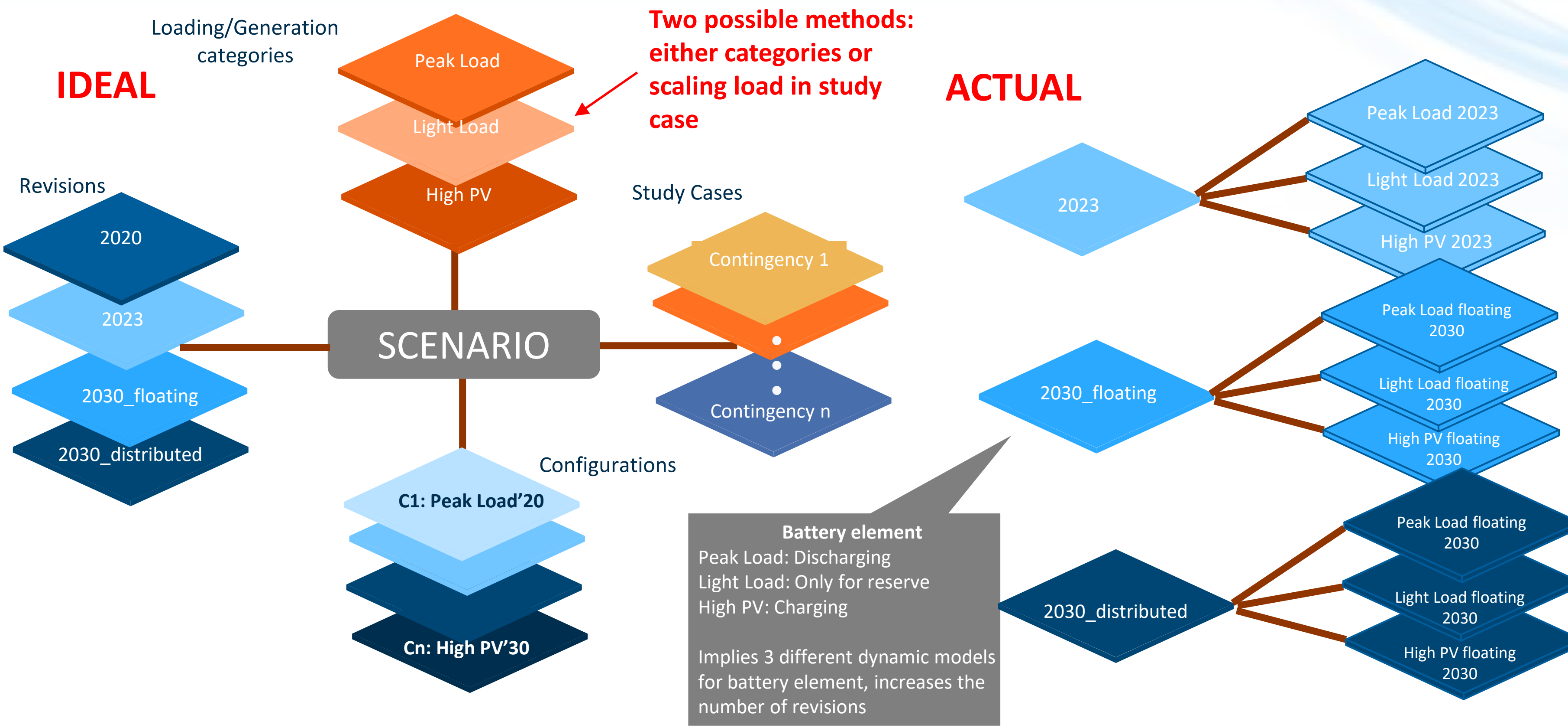
Study Case

Name of report/db file

Batch running simulations via Study and Project Wizard



Study organization



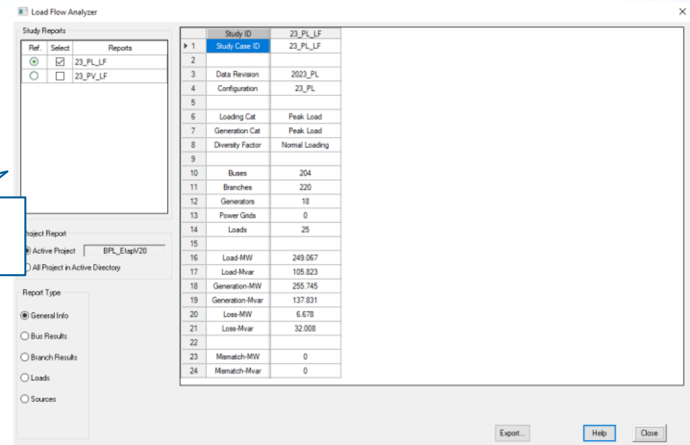
Load Flow

Running Load Flow

Activating alert window

Report Manager

Load Flow Analyser



Case names as per report names

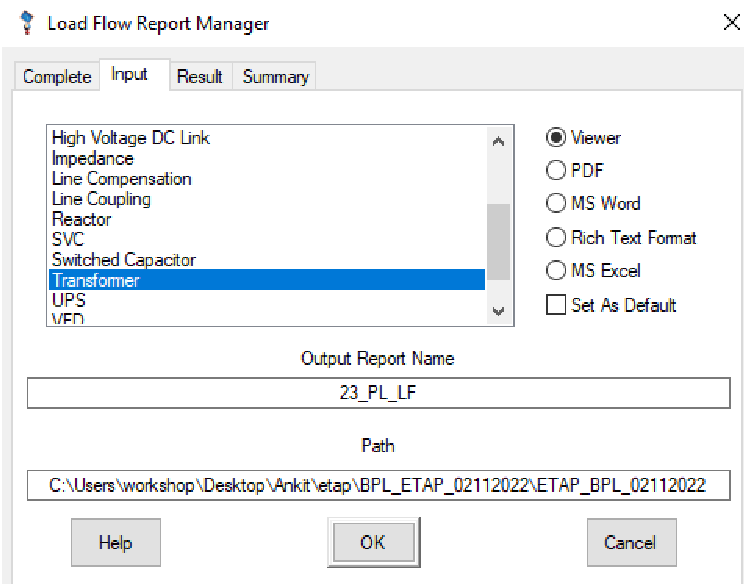
Load flow analyser

Provides overview of results for buses, branches, sources, loads

	ID	MW	Mvar	% PF	% Generation
1	BESS_system	25	7.5	95.78	100
2	G1	15.7	45.692	32.5	83.5
3	G2	15.7	0.0366	100	83.5
4	G3	15.7	0.0366	100	83.5
5	G4	15.7	0.0366	100	83.5
6	G5	15.7	0.0366	100	83.5
7	G6	15.7	0.0366	100	83.5
8	G7	15.7	0.0366	100	83.5
9	G8	9.823	6.538	83.25	52.2
10	G9	9.823	6.538	83.25	52.2
11	G10	15.7	6.538	92.32	83.5
12	G11	15.7	6.538	92.32	83.5
13	G12	15.7	6.538	92.32	83.5
14	G13	15.7	6.538	92.32	83.5
15	GT1R	22	32.893	55.59	63.8
16	SUN01	4.1	3.075	80	100
17	SUN02	4.1	3.075	80	100

Source load flow results

Load flow reports



2-Winding Transformer Input Data

Transformer		Rating					Z Variation			% Tap Setting		Adjusted	Phase Shift	
ID	Phase	MVA	Prim. kV	Sec. kV	% Z1	X1/R1	+ 5%	- 5%	% Tol.	Prim.	Sec.	% Z	Type	Angle
ALB1-T1	3-Phase	15.000	33.000	11.000	8.26	18.60	0	0	0	0	0	8.2600	Dyn	0.000
ALB1-T2	3-Phase	15.000	33.000	11.000	8.23	18.60	0	0	0	0	0	8.2300	Dyn	0.000
BESS01-TX	3-Phase	31.000	33.000	13.800	9.70	20.00	0	0	0	0	0	9.7000	YNd	0.000
DA9-XF	3-Phase	35.000	34.500	11.000	10.16	13.00	0	0	0	0	0	10.1600	YNd	0.000
DA10-XF	3-Phase	35.000	34.500	11.000	10.20	13.00	0	0	0	0	0	10.2000	YNd	0.000
DA12-XF	3-Phase	42.000	34.500	11.000	8.84	29.50	0	0	0	0	0	8.8400	YNd	0.000

LOAD FLOW REPORT

Bus		Voltage		Generation		Load		Load Flow					XFMR
ID	kV	% Mag.	Ang.	MW	Mvar	MW	Mvar	ID	MW	Mvar	Amp	%PF	%Tap
1 VENETW	33.000	93.732	-9.2	0.000	0.000	1.503	0.640	VENETW-T1_Bus	0.000	0.000	0.0	0.0	
								VENETW-T1_Bus2	0.000	0.000	0.0	0.0	
								703 WIND33B	-1.503	-0.640	30.5	92.0	
301 CPPS SUBB-A	33.000	102.091	-3.9	0.000	0.000	11.892	5.066	Bus40	-32.548	-10.222	584.6	95.4	
								Bus48	-32.548	-10.222	584.6	95.4	
								Bus49	-44.367	-15.253	804.0	94.6	
								Bus47	-27.384	-10.831	504.7	93.0	
								Bus50	-27.384	-10.831	504.7	93.0	

Transient Stability

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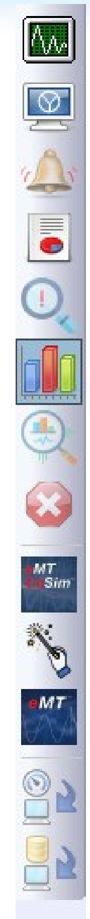
Why needed?: Concerned with studying the system response to severe transient disturbances such as fault on transmission facilities, loss of generation or loss of load. Dynamic RMS simulations are conducted for each event to assess **frequency stability, dynamic voltage stability and rotor angle stability**

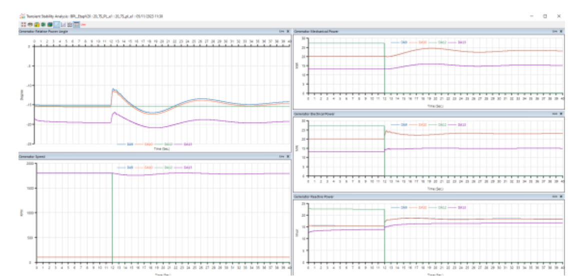
Choosing Dynamic Models: appropriate model with the right functionalities for these components. IEEE standards for choosing excitation, governor models, WECC2/IEC for renewables

Setting right parameters for models: Realistic set of parameters to mimic the actual component response, validation necessary!



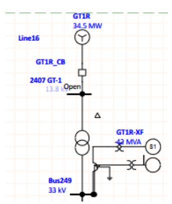
Running transient simulations

For plotting the results, can also be plotted in SLD directly



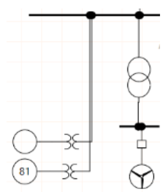
ETAP UDM Models in Use

Synchronous generator



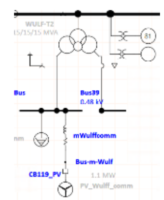
Governor: GGOV1, DEGOV1
Exciter: AC4A, AC7B, AC8B

Residential PV



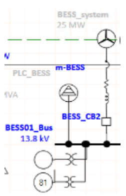
Unit: PVD1

Commercial and Utility PV



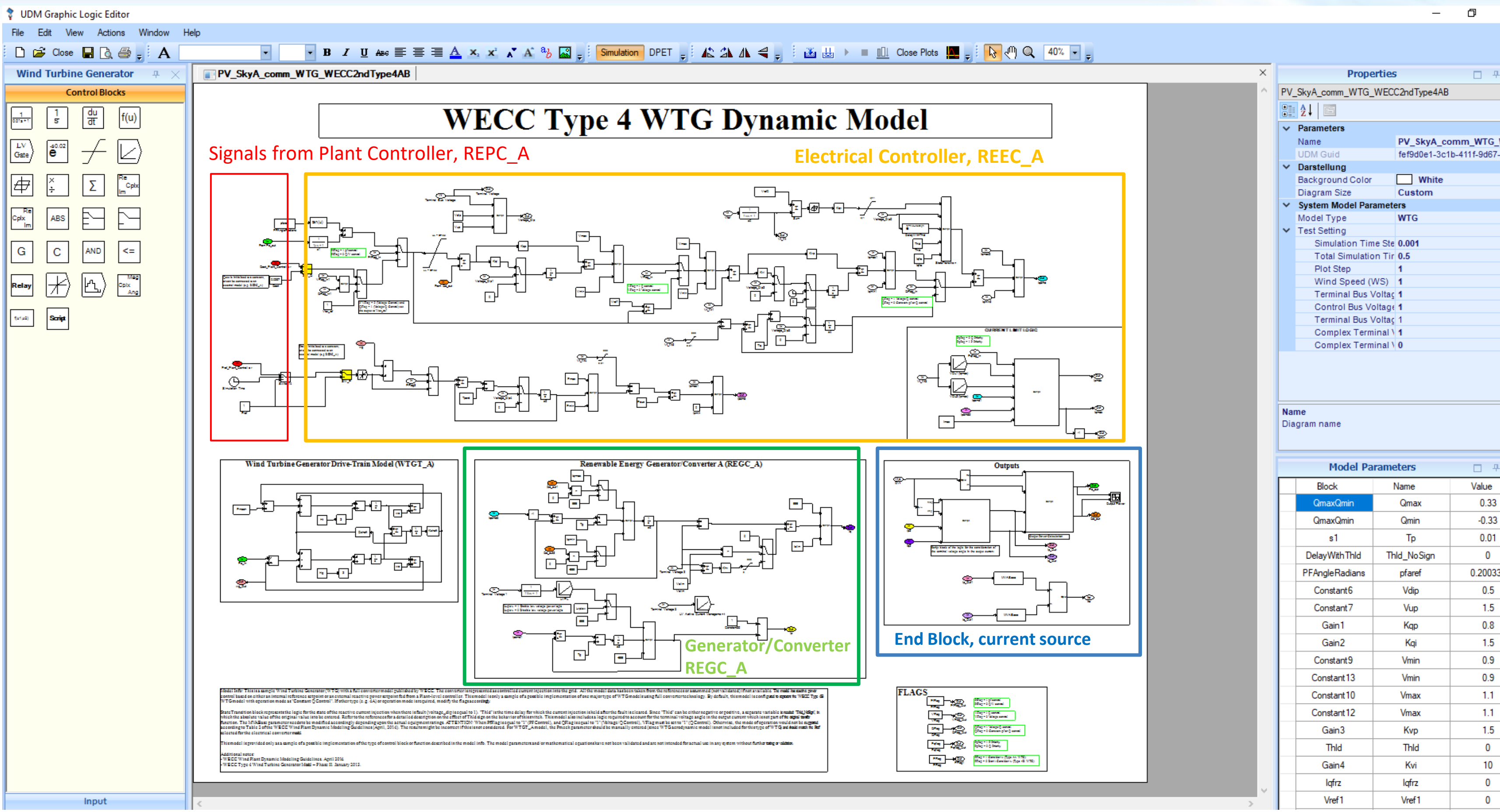
Unit: WECC2ndType4AB
Plant: REPC_A

Battery



Model: BESS_Model
Plant: REPC_A

UDM Model Structure



UDM models vs built-in?

- Built-in WECC models are 1st generation models
- Control behavior of built-in models cannot be altered – grid code dependent
- UDM models allow for easy debuggability and allow plotting options for internal control signals
- Plant controller can be used to set reference set-points for multiple UDM models
- Reference set-point changes possible during the simulation

Example Stability Results (2020)

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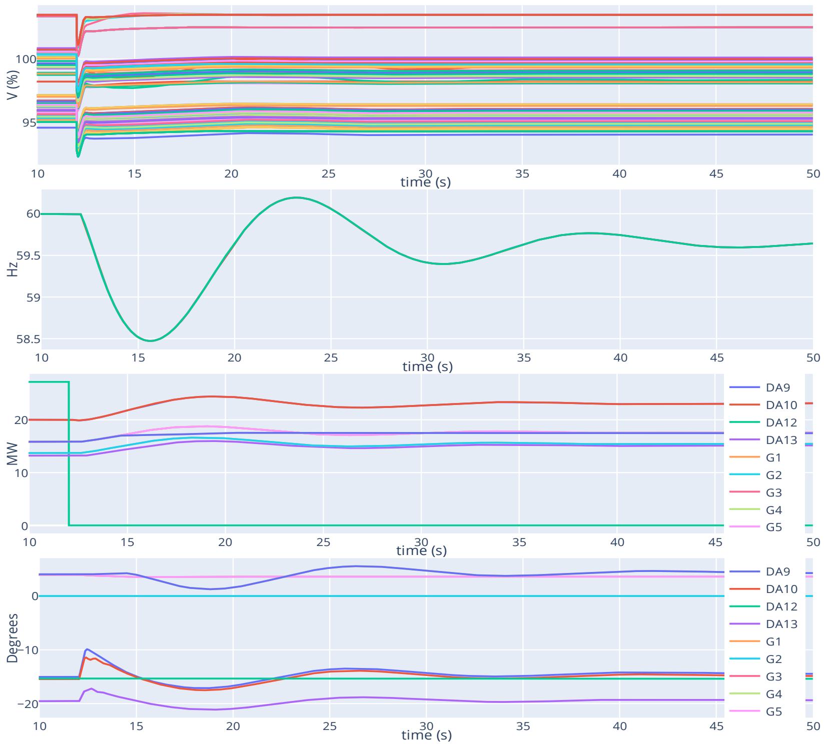


No secondary reserve

Secondary reserve wasn't modelled. Governor droop acts in to stabilize frequency after the event

Loss of DA12

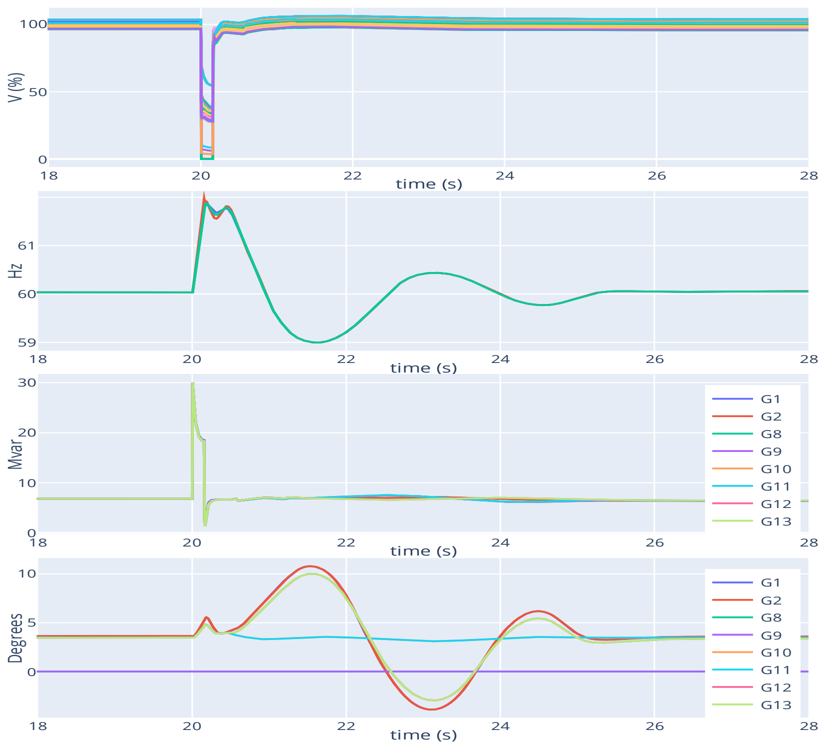
Outage of generator DA12 producing 25 MW power. Plots show mechanical power of remaining generators

System Details

Scenario: Peak Load
Total Generation: 245 MW
Renewables: 0.9 MW

System reaches a stable state with no frequency or voltage violations after the event. Protection limits not triggered.

Example Stability Results (2023)



Fault and loss of line

A low voltage fault is followed by removal of 132 kV line.

Relative Rotor Angles

Plots show no angular instability

System Details

Scenario: High PV
Total Generation: 175 MW
Renewables: 58 MW
Battery: -25 MW (Charging)

Example Stability Results PV (2023)

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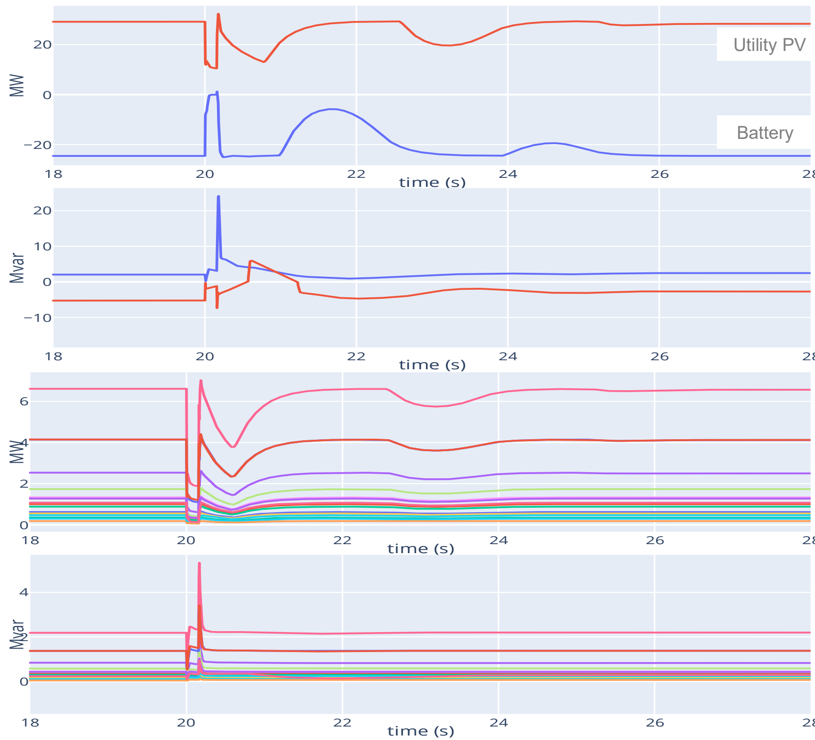
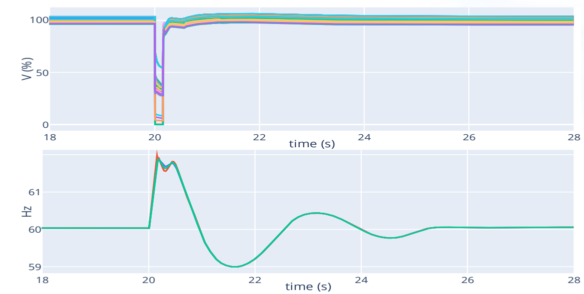


Utility PV and Battery Plot. Battery is charging before the event

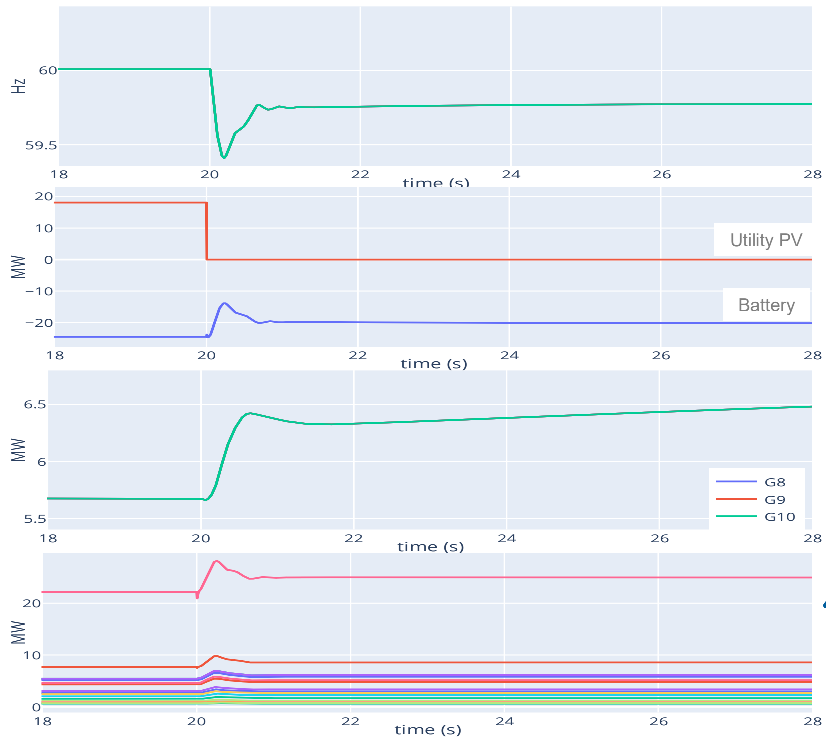
Commercial PVs active and reactive power. The PVs provide both frequency and fault ride-through support



Bus voltage and frequency profiles

System reaches stable state, no frequency or voltage violations. Converter units contribute to fault support.

Example Stability Results (2030) (distributed)



Loss of Utility PV
Outage of a converter-based unit, frequency droop support from battery

Derated to 60%
The commercial PVs were derated to 60%, capacity available for reserve

System Details

Scenario: High PV
Total Generation: 193 MW
Total Renewables: 157 MW
Res. PV: 82 MW (no derating)
Comm. PV: 57 MW (60 % derated)
Utility PV: 18 MW (60 % derated)
Battery: 25 MW (Charging)

Bus voltage profiles

System reaches stable state, converter units contributed to fast frequency recovery.

What worked and what can be improved in ETAP!

UDM Models

- Wide variety of UDM Models available for renewables, synchronous generators

Multi-dimensional Database Structure

- Easy to organize such studies

Macro Wizards

- Simple to reload and batch run simulations

SQLite Database and Python Integration

- Automation helps to rerun and analyze such studies

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Model Initialization

- UDM Models for REs don't start from set-points, convergence issues for derating - workarounds

Load flow not linked to UDMs

- Increases no. of models as each UDM models needs different ref. set-points

Handling Large Number of Models

- Difficult to change parameters / block diagram for large no. of similar models, no scope for experimentation

Element Out of service

- High effort to put element out of service, done via CBs in same revision, problem if dynamic models involved

Our Recommendations

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Transient Stability Analysis

- **Component and control parameters info.**: Accurate knowledge of system components needed – generator, lines, transformers
- **Need for validation:** Basic validation for major components and overall system needed to represent actual system behaviour
- **For system reliability, planning future expansions:** With system snapshots for different loading, accurate dynamic models - a contingency analysis can help identify critical assets
- **Developed model of NP and Eleuthera and Exuma Islands** can serve as a template to see how such studies are performed

Model requirements for unit connection

- New converter-based plants should supply **unit and plant models** before interconnection
- For larger units, the **system response should be studied** with and w/o unit

Switch to ETAP v22

- **New features:** Dynamic models for inverters, load scenario in wizard, data manager
- **Grid forming inverters** can now be modelled

Photo Credits

Synchronous generator: smalllike / Noun Project

Battery: Designing Hub / Noun Project

Utility PV: Eliricon / Noun Project

Commercial PV: Cipto Nur Khoir / Noun Project

Residential PV: Laymik / Noun Project

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