An Open-Source Implementation of WECC Battery Energy Storage Systems Models for Power System Stability Studies

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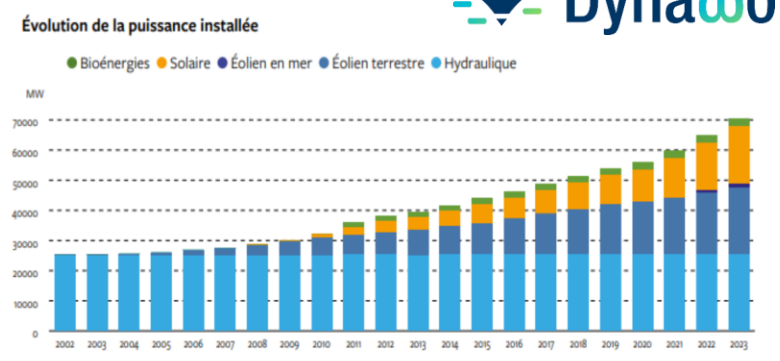
Context

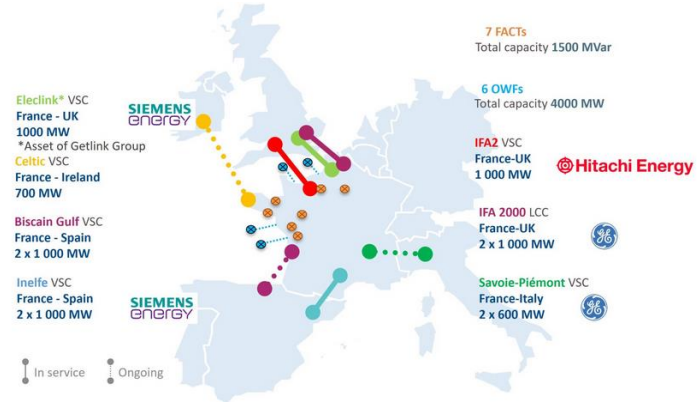
Context

An ongoing switch from a centralized physically-driven system to a decentralized numerically-driven system...

- Massive penetration of Power Electronic based components – Renewable Energy Sources, storage
- Increase of the global electrical demand – electrolyzers, data centers, electric vehicules.
- Large development of the interconnections – in particular HVDC links.



Installed power of RES *[Source : RTE]*



HVDC interconnections *[Source : RTE international]*

Transmission System Operator

Mission of RTE remains the same:

- Non-discriminatory and transparent access to the electricity grid
- Safe operation and maintenance of the system
- Grid infrastructure development

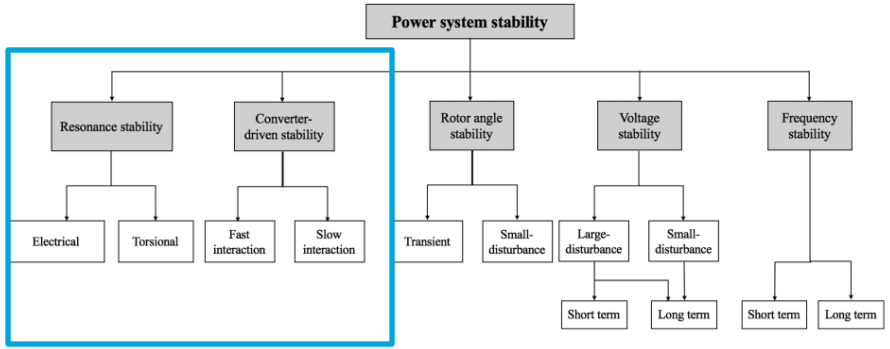
Ensuring stable and secure operations is done by verifying **adequacy** and **stability** of the electrical transmission system :
Acceptable steady state and Dynamic stability following a perturbation.

This is ensured by time-domain simulations.

It is important to have models that represent all the components of the grid, for accurate simulations.

Stability phenomena

- Traditional power system stability phenomena effected by the power-electronics-based components.
- New stability power system phenomena related to the power-electronics based components connected to the grid.



Classification of power system stability [Source : Hatziargyriou, Nikos, et al. "Definition and classification of power system stability–revisited & extended." *IEEE Transactions on Power Systems* 36.4 (2020): 3271-3281.]

➡ Conduct accurate and fast simulations at different time frames in a robust manner, while being able to correctly model the existing components.

➡ Standard generic models (WECC, IEC) can be accurate enough (limiting the number of models to be implemented)

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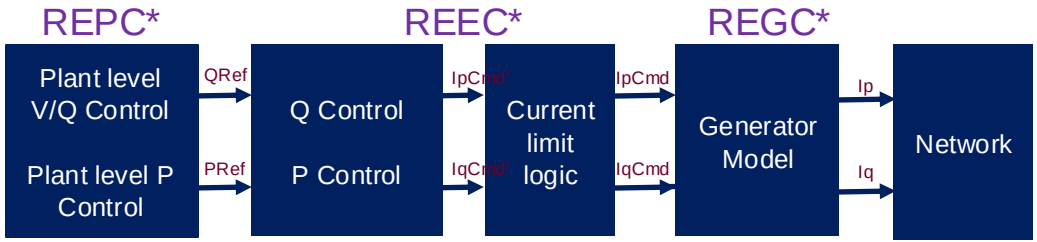
Standard Models

Standard Models – WECC models

Western Electricity Coordinating Council

- Evolving at a quite fast pace and used in the US
- Propose models for :
  - Photovoltaics plants
  - Battery Energy Storage Systems (BESS)
  - Wind power plants

By combining Power Plant Controllers, Converter Electrical Control and Generator/Converter models
+ mechanical models for Wind plant type 3



Scheme of how modules are connected (not all connections are represented)

Table 4-11
Models that can be used for modeling each type of IBR plant. Note, only ONE model should be chosen in each category.

Model Name	Wind Plant Type 3	Wind Plant Type 4	PV Plant	BESS Plant
Category 1 - Generator/Converter Model				
REGC_A	√	√	√	√
REGC_B	√	√	√	√
REGC_C	√	√	√	√
Category 2 - Converter Electrical Controls				
REEC_A	√	√	√	
REEC_C				√
REEC_D	√	√	√	√
Category 3 - Power Plant Controller				
REPC_A	√	√	√	√
REPC_C	√	√	√	√
Category 4 - Aero-Dynamics				
WTGA_A	√			
Category 5 - Torque Controller				
WTGQ_A	√			
Category 6 - Pitch Controller				
WTGP_A	√			
WTGP_B	√			
Category 7 - Drive Train Shaft Dynamics				
WTGT_A	√			
WTGT_B		√ (optional)		
Category 8 - Auxilliary/Supplemental Controls				
WTGWGO_A		√ (optional)		
WTGIBFFR_A	√ (optional)	√ (optional)		

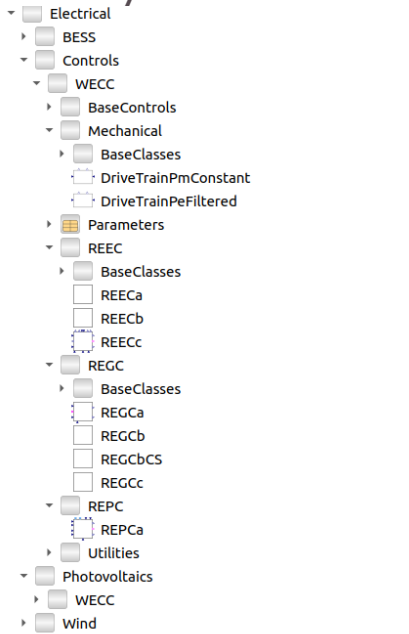
Model combination [Source : EPRI Model User Guide for Generic Renewable Energy System Models 3002027129 –2023]

http://dynawo.org – rte-dynawo@rte-france.com

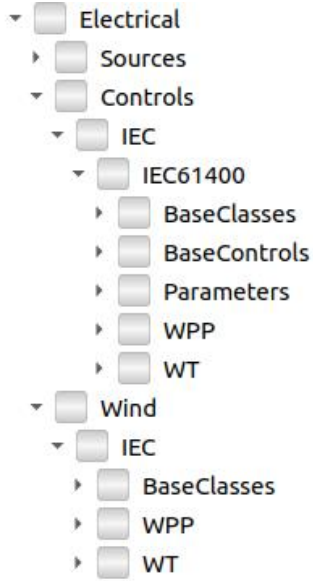
Standard Models – Modelica Implementation

Both WECC and IEC models are available in Dynawo Modelica library

1. Keep identical structures compared to the one proposed by the standard
2. Easy to create different final models using sub-blocks
3. Enable to have access to the implementation choices and to highlight ambiguities in the standard and their documentation
4. Validated against reference signals / other implementations



WECC in Dynawo Modelica Library

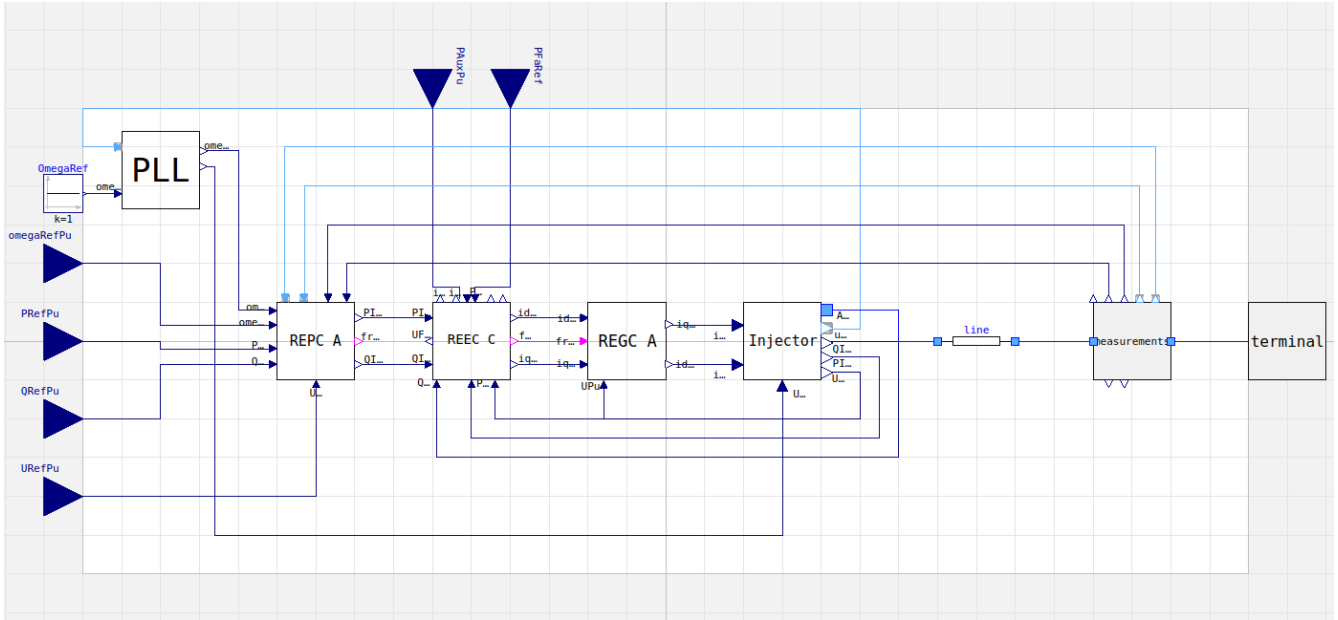


IEC in Dynawo Modelica Librar

03

Implementing the BESS model

Implementation of WECC Battery Energy Storage Systems



Combination of REPC-A, REEC-C and REGC-A

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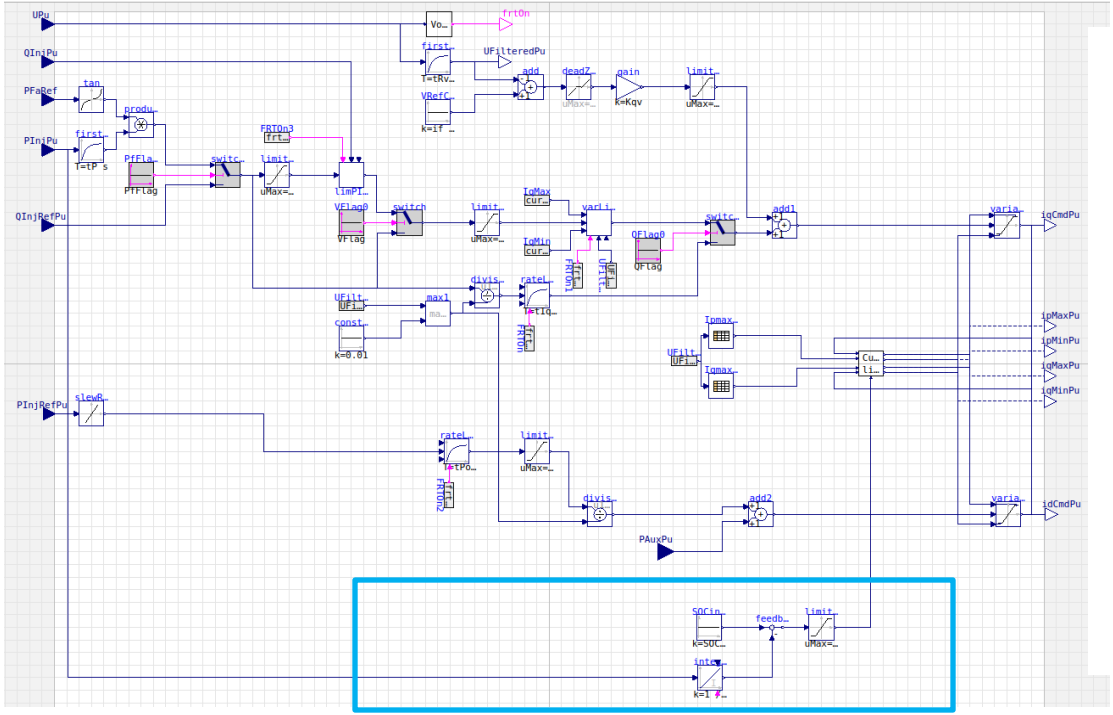
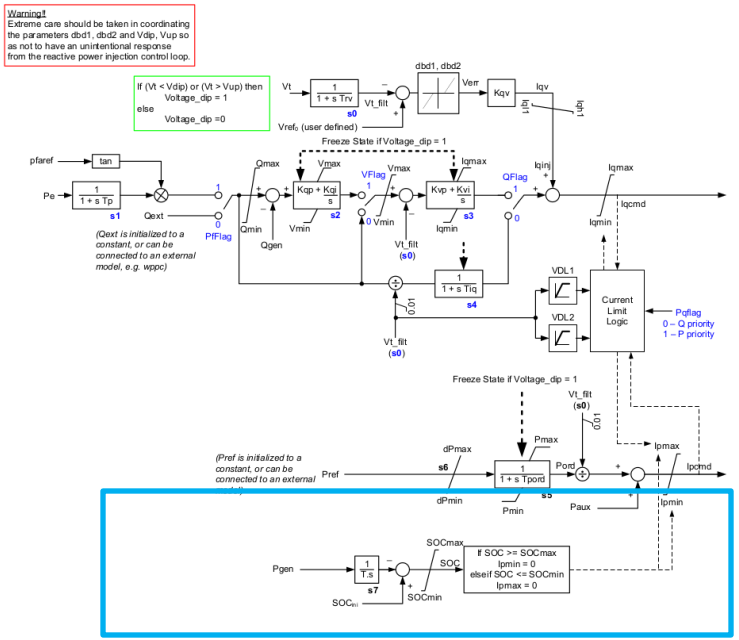
Electrical control model- REEC-C

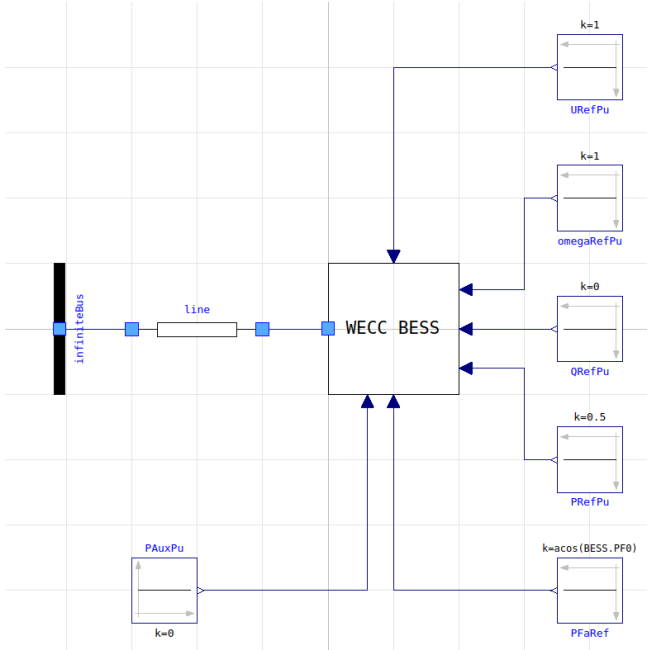




REEC-C enables a negative active current, representing battery behavior to absorb energy

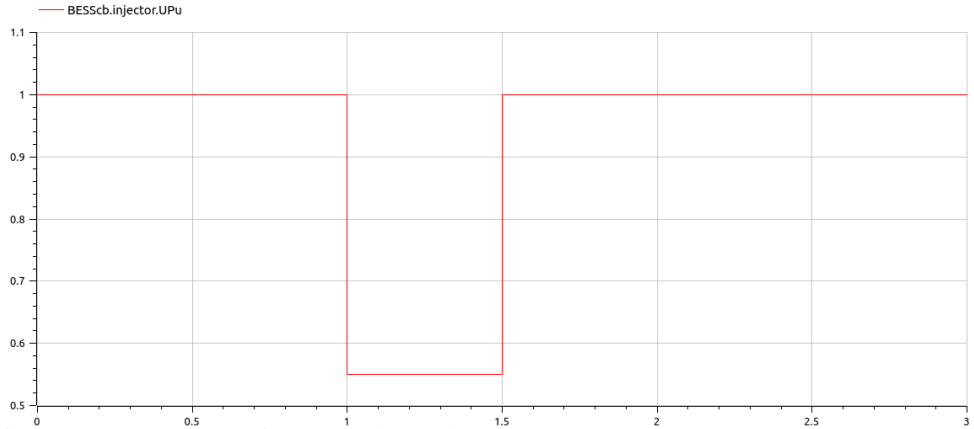
REEC-C model [Source : EPRI Model User Guide for Generic Renewable Energy System Models 3002027129 –2023]

Implementing the test case in Dynaωo Modelica library

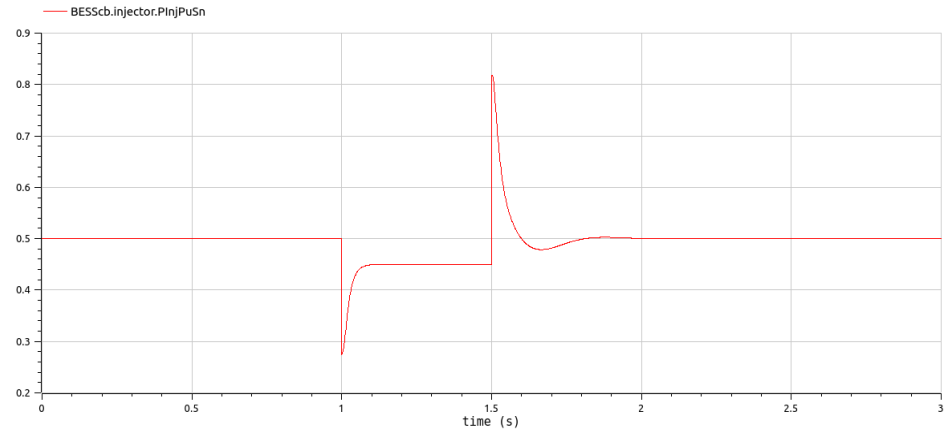


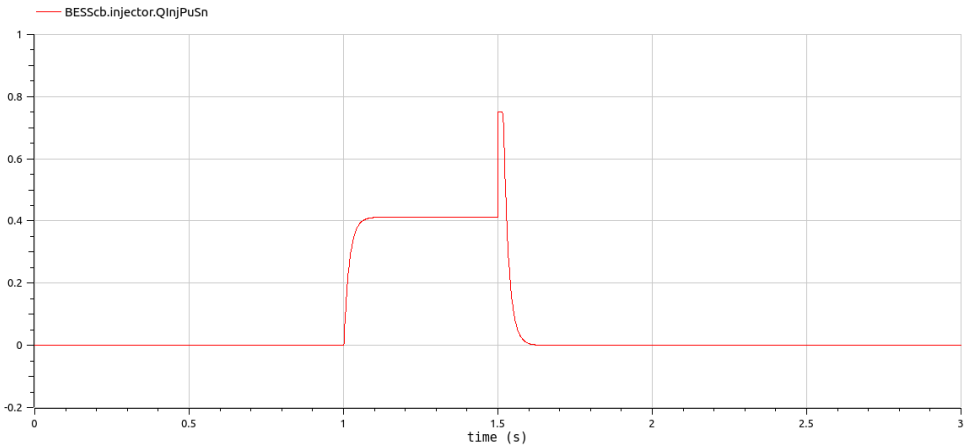
This example and the data are inspired by the article [P. Pourbeik and J. K. Petter, "Modeling and validation ofbattery energy storage systems using simple generic modelsfor power system stability studies", CIGRE Science and Engineering, October 2017, pp. 63-72.]

At t = 1 s, a fault at the infinite bus is simulated



Results





Validations were done by comparing visually to the results found in [P. Pourbeik and J. K. Petter, "Modeling and validation ofbattery energy storage systems using simple generic modelsfor power system stability studies", CIGRE Science and Engineering, October 2017, pp. 63-72.]

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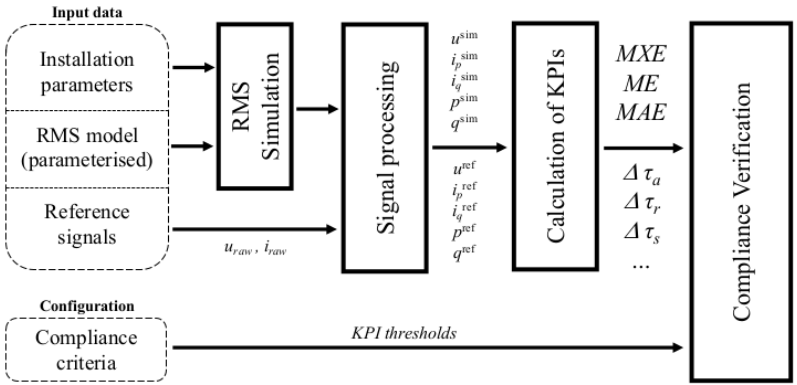
Model Quality

Model quality – An open-source RMS Model validation tool

RMS models developed in Dynaωo Modelica Library and simulation done with Dynaωo



Overview of the RMS model validation tool processes
[Source : *An open-source tool for the validation of power park modules generic models, JL Marin et al, CIGRE 2024]*

A tool for automating the verification of dynamic grid compliance requirements for solar, wind, and storage farms (Power Park Modules - PPM) as well as synchronous machines (SM), including:

- validation of RMS models (a.k.a. *"phasor models"*) for PPM
- verification of electric performance requirements for both PPM and SM

05

Conclusions

Conclusions

- Standard generic models are enough for stability simulations and representation of the component (balance between precision and performance of the tool)
- Possible open-source implementation for standard generic models
- Update the models when improvements are available to match the real behavior of the power electronics system

Q & A

GitHub page : https://dynawo.github.io/
GitHub repository : https://github.com/dynawo/dynawo
Contact us :rte-dynawo@rte-france.com