Discussion on Validation

Topic Change

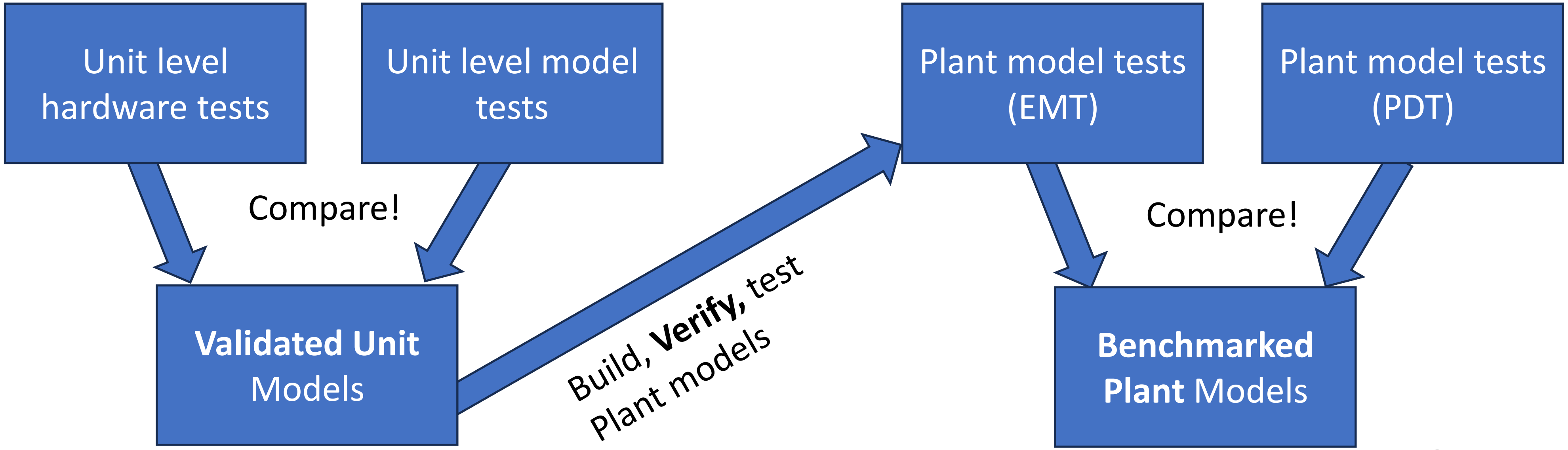
Disclaimer!!

- I have experiences and opinions which may differ from others (especially in the 2800 drafting groups)!!
- **Where the following slides are good, then I am representing the SG3 leadership team. Where the following slides are wrong or bad, I am representing myself!! ☺**

Acknowledgement: Much hard work and discussion from members of 2800.2 drafting team. In particular, manufacturer teams helped us a lot!

Definitions:

- **model validation:** The process of comparing measurements with simulation results for the assessment of whether a model response sufficiently mimics the measured response.
- **model benchmarking:** the process of comparing simulation results from two models for the assessment whether a response from one model sufficiently mimics the response from the other model for the same disturbance and external power system conditions
- **model verification:** The process of checking documents and files or equipment and respective settings (e.g., controls & protection), and comparing them to model parameters or model structure.



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Why do we care?

- Reliability!
  - Studies accurately predict system performance
    - (verified) Plant models accurately represent what is constructed and how it is configured
      - (validated) Unit equipment models accurately represent the controls and protection functions…

IEEE 2800-2022 requires validation!!

Per IEEE 2800 Clause 12 (Test and verification requirements), *the original equipment manufacturer (OEM) shall perform IBR unit level testing and testing of the supplemental IBR device equipment*. The details of these equipment-level type tests to be performed are listed in clause 5.

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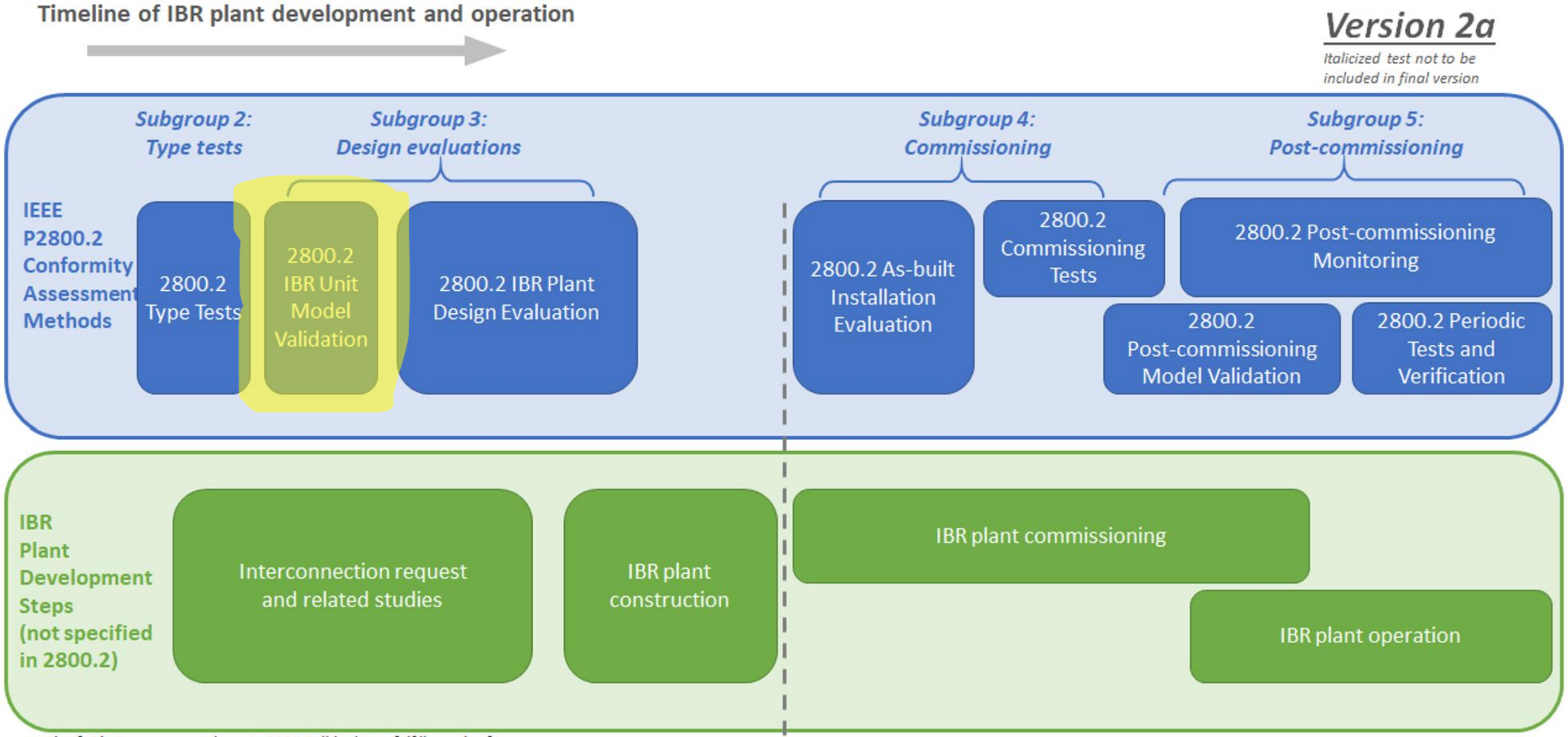
Where does validation sit in the process?



- *Clarify that some procedures in 2800.2 (blue) can fulfill needs of interconnection process (green)*
- *How do 2800.2 procedures relate to NERC Mod 26, 27? Potentially one work effort can satisfy some reqs of 2800 and Mod 26/27. No need to create extra work. Wait till Mod 26/27 published to specifically address*
- *This is a general version of the process. Variations may occur in the field.*

Stage gate: All plant components installed

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What validation test sets are being proposed?

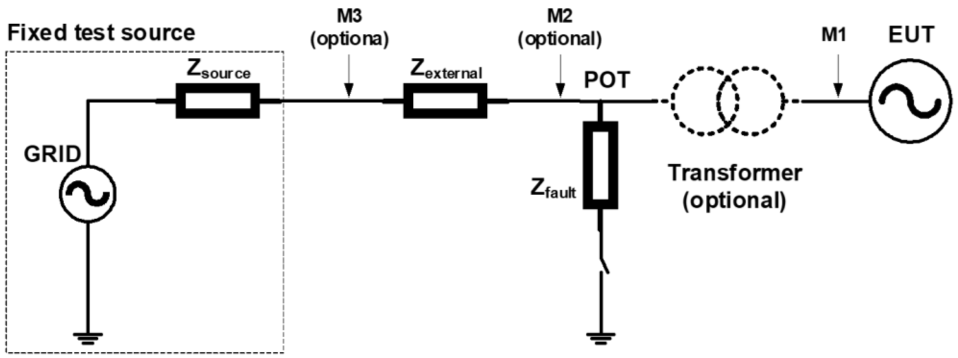

Figure 16—Test circuit for method 1

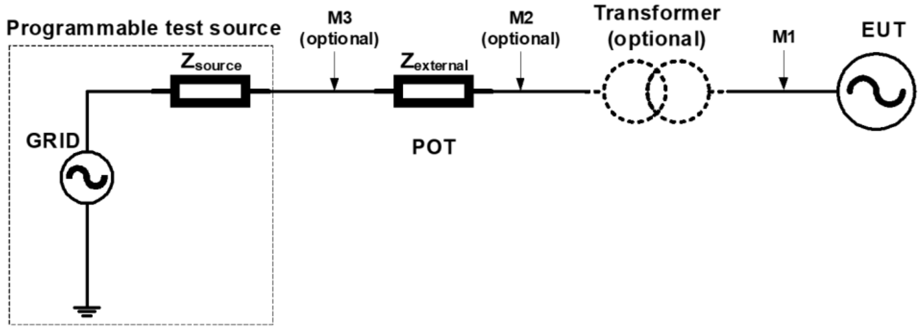

Figure 17—Test circuit for method 2

- Method 3: Control Hardware In the Loop (CHIL)
  - Connect control hardware to real-time EMT simulator test benches

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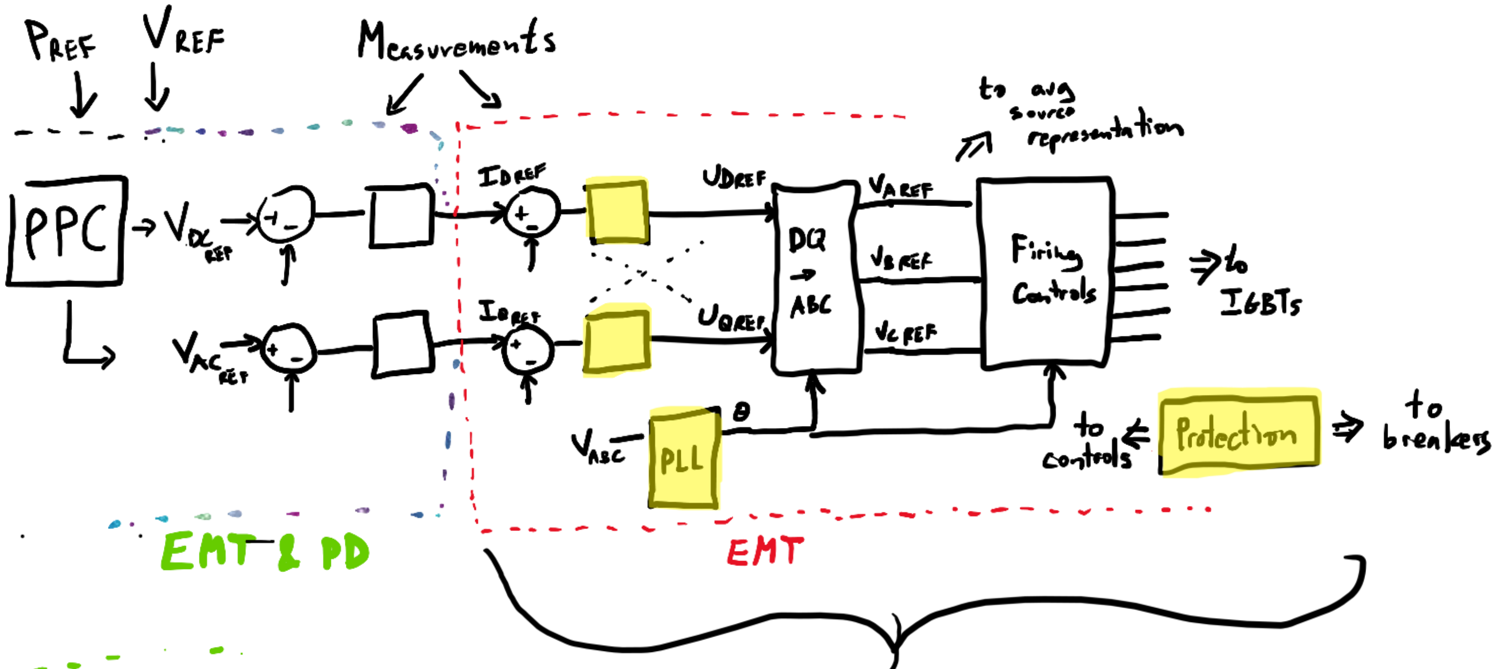
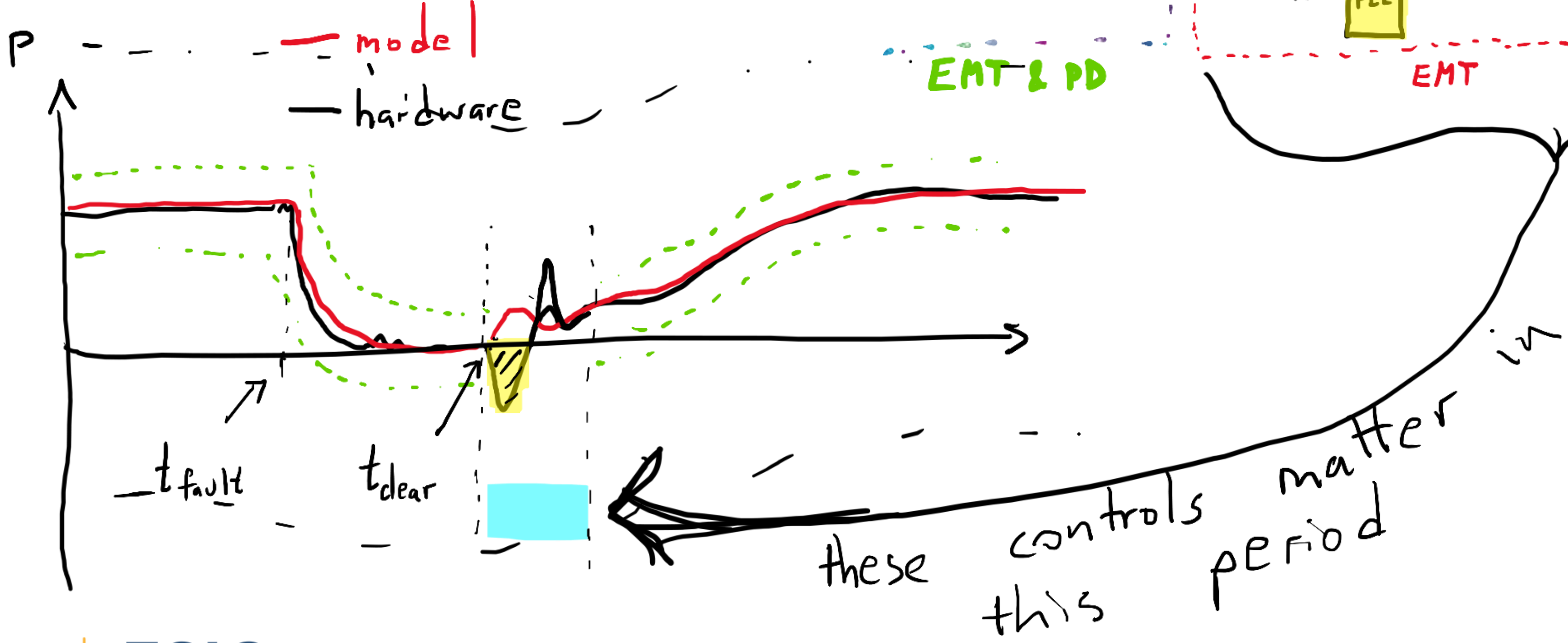
What will be validated?
(models compared against type tests)

1. Voltage and reactive power control modes – Clause 5.7.4
2. Primary Frequency response – Clause 5.9.4
3. Fast Frequency response – Clause 5.9.4
4. Voltage disturbance ride through – Clause 5.11.4 to 5.11.8
5. Frequency disturbance ride through – Clause 5.13
6. Limitation of overvoltage over one fundamental frequency period – Clause 5.14.4
7. PPC Testing – Clause 5.17
8. Frequency Scanning
9. Protections – Clause 5.15
   a. Frequency protection
   b. ROCOF protection
   c. Voltage protection
   d. AC overcurrent protection
   e. Unintentional islanding protection

Unit Validation challenge!





Note that hardware and model may both “ride-through” in Validation testing, but accuracy and correctness is needed in each aspect to ensure confidence in ride-through behaviour in plant and system contexts.

What gets in the way of close comparisons?

- Insufficient care in modeling practice.
  - Developing good EMT modeling practice takes time and a strong investment in modeling by OEMs.
  - “real code” techniques and appropriate processes are needed

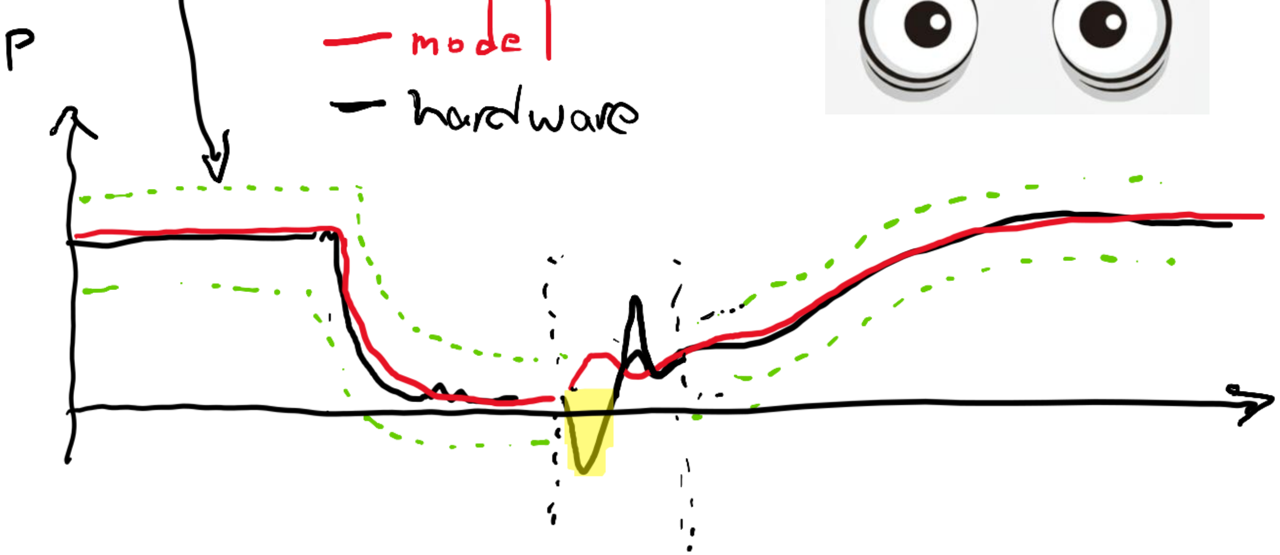
- Uncertainties in test system conditions (for example)
  - Nonlinearities (eg. Transformers)
  - Point-on-wave impacts
  - Measurement error
  - Simulation artifacts

Quantitative and Qualitative

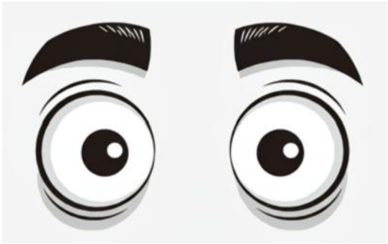
- Huge point of discussion in 2800.2… possibly the most contentious part of the entire standard. A few discussions were *lengthy.*
  - Where should the quantitative bands be drawn?
  - “Should we even use quantitative metrics at all?”

Which is best? ☺

Quantitative



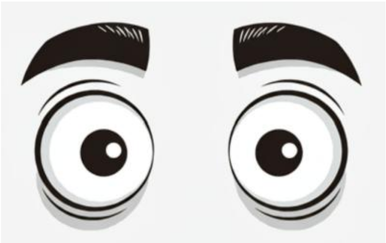
Qualitative



Quantitative: Pros and Cons

- Pros:
  - Can standardize model quality to a degree. Repeatable, transparent outcomes are desirable.
  - Can automate the evaluation
  - Can theoretically be performed with little experience
- Cons:
  - **False "pass":** If bands are too wide, serious errors in modeling can be sent through as validated models.
  - **False "fail":** If bands are too narrow, legitimate differences may be flagged as errors and delay and headache is introduced.
  - Can theoretically be performed with little experience

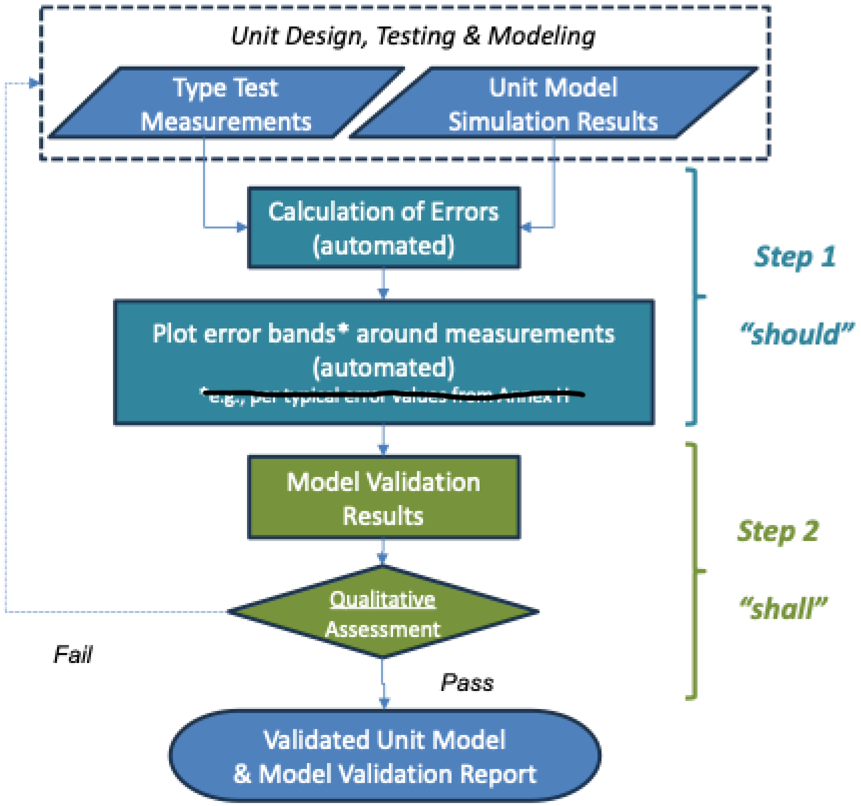
Qualitative: Pros and Cons



- Pros:
  - Experienced engineers can sufficiently evaluate whether the model is suited for purpose, and ask questions appropriately
  - When done well, effectively identifies important errors in models
- Cons:
  - There may not be enough "experienced engineers" to do this correctly at scale.
  - You can't get help from automation tools. Large amounts of data can make any engineer's eyes glaze over, regardless of experience.
  - Without standardization, opinions will differ on what is "acceptable"

(My) recommended approach:

- OEM (could be other parties) writes a "validation report" that includes:
  - Use quantitative comparison as guidance to identify regions that lie outside appropriate error bands
  - Engineering review and discussion of comparisons which lie outside error bands
  - Qualitative comparison using expert engineers
- Recipient or users of unit level models should review the validation report and accept, reject, or ask questions as appropriate.



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Example quantitative bands (removed from current draft)

[Table X] – Permissible maximum errors when EUT is type tested by P-HIL testing method

Case description	Time window	Positive- and negative-sequence values							
		Active power		Reactive power		Active current		Reactive current	
		Transient	Quasi steady state	Transient	Quasi steady state	Transient	Quasi steady state	Transient	Quasi steady state
Case dependent information such as pre-fault voltage, test equipment settings such as short circuit impedance if used, etc.	Pre-fault	n/a	0.05	n/a	0.05	n/a	0.05	n/a	0.05
	Fault	0.2	0.15	0.2	0.15	0.2	0.15	0.2	0.15
	Post-fault	0.2	0.15	0.2	0.15	0.2	0.15	0.2	0.15

[Table Y] – Permissible maximum error when EUT is type tested in field

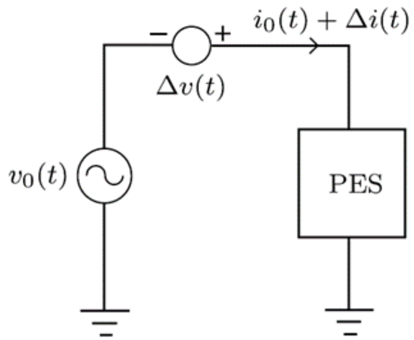
Case description	Time window	Positive- and negative-sequence values							
		Active power		Reactive power		Active current		Reactive current	
		Transient	Quasi steady state	Transient	Quasi steady state	Transient	Quasi steady state	Transient	Quasi steady state
Case dependent information such as pre-fault voltage, estimated grid Impedance, grid operating condition, etc.	Pre-fault	n/a	0.05	n/a	0.05	n/a	0.05	n/a	0.05
	Fault	0.2	0.15	0.2	0.15	0.2	0.15	0.2	0.15
	Post-fault	0.2	0.15	0.2	0.15	0.2	0.15	0.2	0.15

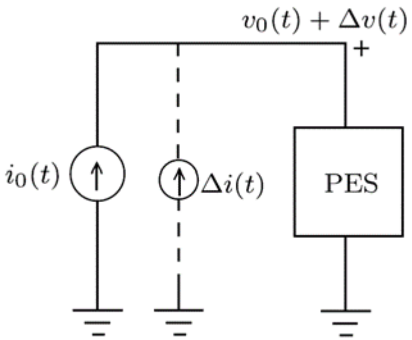
[Table Z] – Permissible maximum error when EUT is type tested by C-HIL testing method

Case description	Time window	Positive- and negative-sequence values							
		Active power		Reactive power		Active current		Reactive current	
		Transient	Quasi steady state	Transient	Quasi steady state	Transient	Quasi steady state	Transient	Quasi steady state
Case dependent information such as pre-fault voltage, test equipment settings such as short circuit impedance if used, etc.	Pre-fault	n/a	0.05	n/a	0.05	n/a	0.05	n/a	0.05
	Fault	0.1	0.05	0.1	0.05	0.1	0.05	0.1	0.05
	Post-fault	0.1	0.05	0.1	0.05	0.1	0.05	0.1	0.05

Frequency Scans!!

- Variation of converter impedance characteristics with frequency is widely used in real studies, and happens to provide a good representation of the small signal control characteristics!
- We can use this for model validation!





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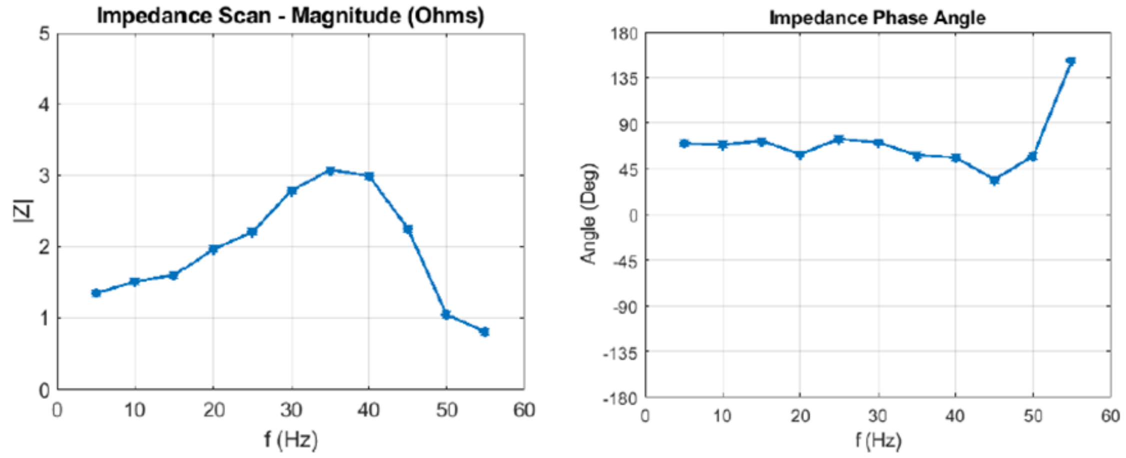
PSCAD Results



HiL-RTS Results