Modeling Renewables as IBR Penetration Rises

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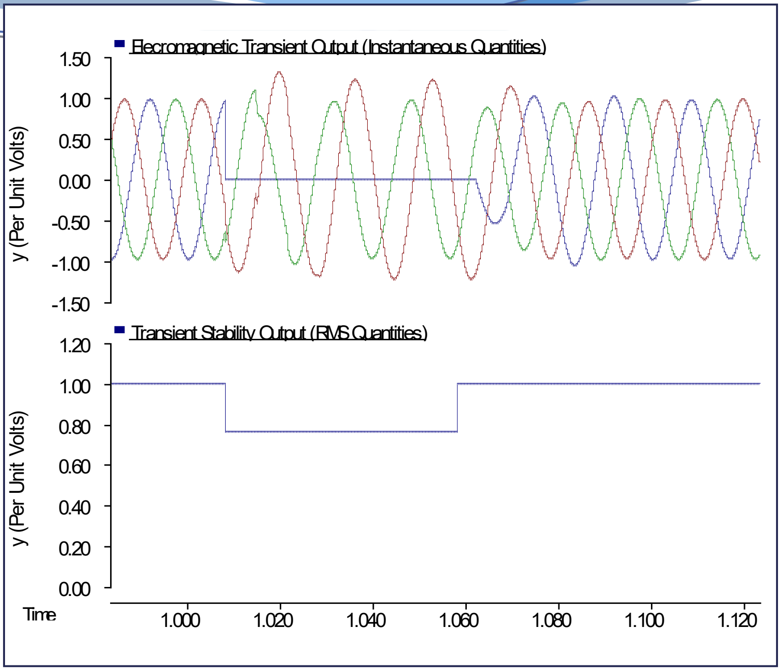
Overview: Too many topics…

- What is EMT? What is it good for?
- Screening Approaches
- Strategies to verify EMT and RMS model quality
- Study Techniques and Tools
- Potential limits to IBR penetration

What is EMT?



- Power-flow and transient stability programs iteratively solve a systems of equations in the RMS 50/60 Hz phasor domain
- Electromagnetic Transient (EMT) software solves systems of differential equations which describe the three-phase electrical network in the time domain.
- This allows EMT simulations to represent the power system behavior at all frequencies, limited only by the period of time between solutions (simulation time-step). Every individual instantaneous phase quantity is represented, allowing unbalanced faults, harmonics, transients and other effects to be modeled.

- A few software brands (alphabetical order): ATP, DigSilent (EMT mode), EMTP-RV, PSCAD/EMTDC

Where might you use EMT today?

- Classical studies are still done:
  - Lightning evaluation
  - TOV/TRV/Insulation coordination
  - Switching/line energization
  - Transformer energization
  - Harmonic analysis
  - Sub-Synchronous Resonance (SSR)
  - HVDC/FACTS control design and analysis

Some newer applications for EMT…

- Weak interconnections
- Very high renewable penetration
- Regions with high chance of power electronic device interactions (eg. dynamic performance, FRT tests, etc)
- SSO phenomena (SSR, SSCI, SSTI, SSTA)
- Black start analysis
- Detailed fault current / protection analysis.
- Model Validation
- Support for Factory Acceptance Testing

A few notes on Screening…
When should you do EMT studies?

Screening Approaches

Weak grid/High Penetration metrics:

- Weak grid studies are more common now.
- Looking for ride-through failure, control instability, device interactions
- Engineers continue to misunderstand SCR based metrics. Key points to understand:
  - There is no single threshold which is "weak", particularly when there is more than one plant close together
  - SCR metrics become more and more problematic the more plants are included, and the larger the network being studied. For some systems, they are completely inappropriate!

SCR Metric

- SCR is the most basic and easily applied metric to determine relative system strength.
  - Calculations should be applied after worst realistic contingency
  - Assume no contribution from nearby IBR

$$SCR_{POI} = \frac{SCMVA_{POI}}{MW_{VER}}$$

  - Doesn't account for load
  - If there are multiple IBR plants, SCR doesn't work well

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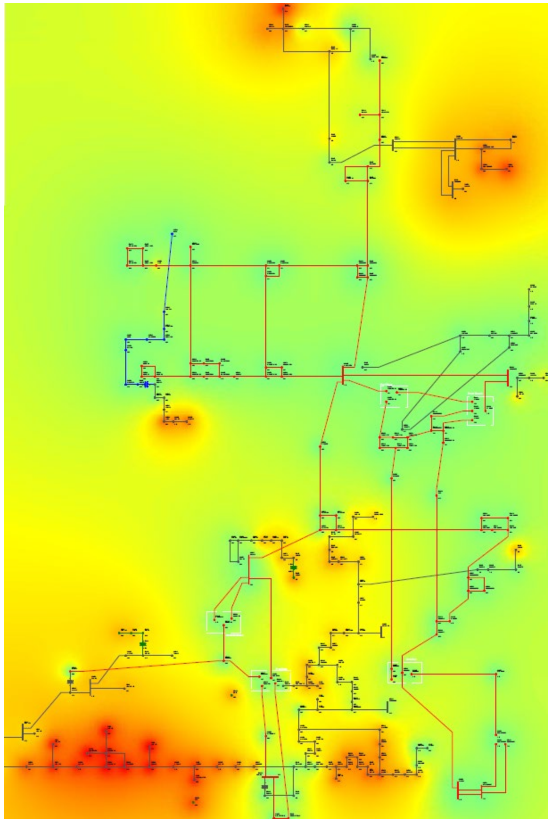
Screening Approaches

- WSCR and CSCR can be used for multiple IBR plants
  - Requires well-delineated renewable regions with low load
  - Acceptable threshold is system dependent
- IPSCR can be used for screening wider areas
  - New metric, good for very wide area screening
  - Requires more experience and validation
- **Weak grid issues are system and equipment specific and it is difficult to define a "minimum system strength" criteria that can be applied uniformly.**
- **Threshold selection involves detailed study first!!**



Strategies to verify EMT and RMS model quality

If you are doing EMT system studies, you need good IBR models!

- IBR model adequacy should be tested against quality criteria:
- Criteria examples:
  - Electranix PSCAD model submission guidelines V6
  - Electranix Model Compliance Checklist (NEW, being tested…)
  - ERCOT PSCAD Model Submittal Guidelines (Draft Jan 2018)
  - ISONE Planning Procedure PP5-6
  - NERC IRPTF guideline for IBR connections
  - IEEE 2800 draft wording on model requirements
  - New ATC model submission criteria
  - Many AEMO (Australia) requirements
- Adequacy tests include a statement of compliance, visual inspection, review of supplied documentation, and actual spot-testing in PSCAD.

Strategies to verify model quality: Benchmark RMS against EMT

- Provides check on parameters, adds to validation not covered by MOD-27, and identifies shortcomings in *both* models.
- Note: Overly stringent benchmarking requirements can be self-defeating!
  - Can be expensive and time consuming
  - If modeling experts and OEMs are overwhelmed, the care in modeling declines and then you're worse off!
  - Needs compromise to accommodate existing resources.
- Note: Overly relaxed benchmarking requirements (or no benchmarking requirements) can result in bad models, leading to reliability risks and study churn.

What is the consequence of accepting poor quality models?

- You will waste expensive and time-consuming EMT study effort.
- You will get behind on meeting your tariff study timeline requirements
- You may never get another chance to ask for better models!
- You may spend a lot of effort mitigating threats which are not real.
- You may ultimately miss reliability threats

(Potential dumpster fire)

(Aside)

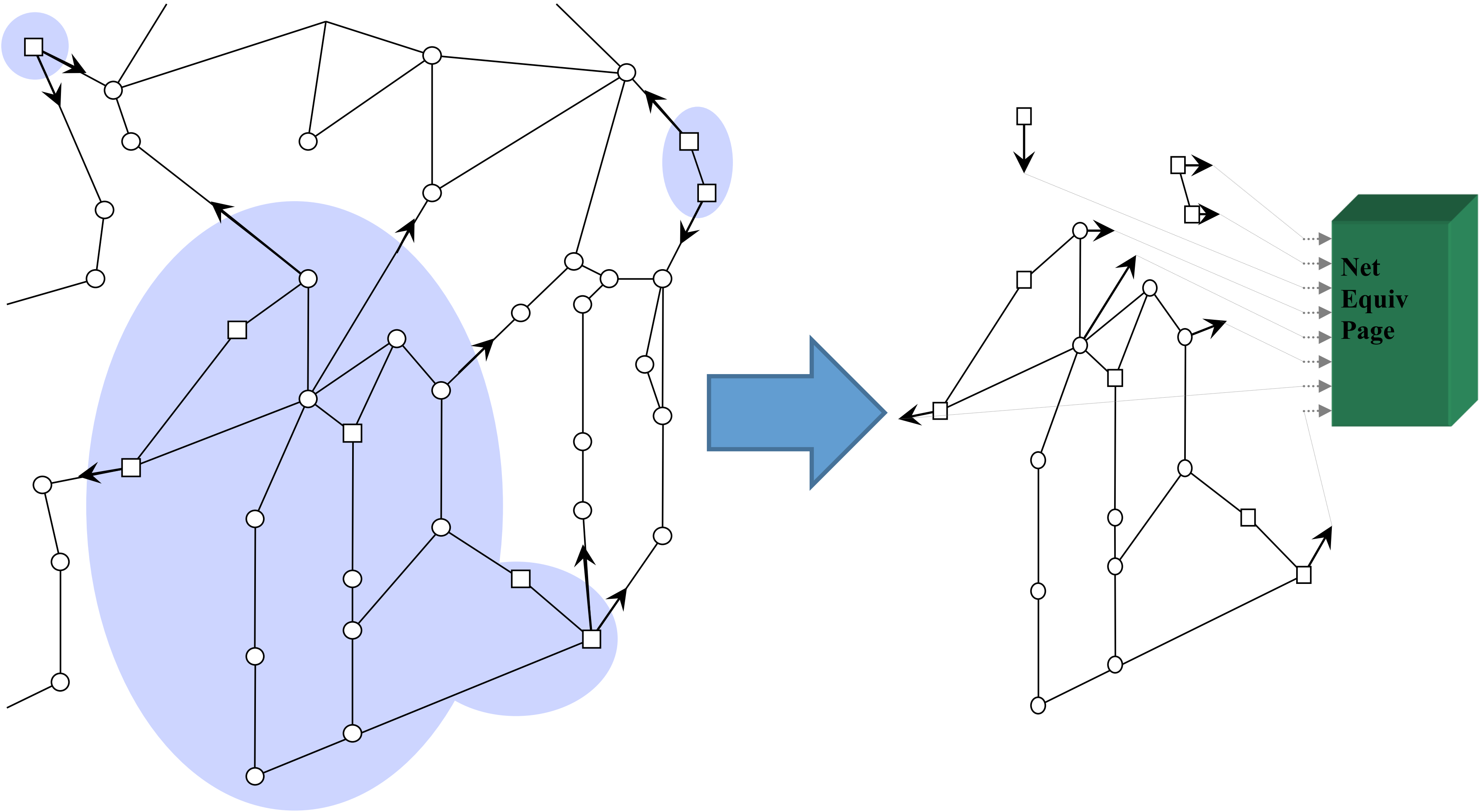
If you're doing EMT system studies, you also need good EMT system models with appropriate size and detail!

Long term: Model Standardization

- DLL common modelling standards
  - Existing IEC-61400-27-1 standard
  - New IEEE PES Task Force "Use of Real-Code in EMT Models for Power Systems" (this task force is organized under the AMPS (Analytical Methods for Power Systems) Committee, and TASS (Transient Analysis and Simulation) working group.
  - Cigre C4.82 Working Group "Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis"

Study Techniques and Tools

Step 3: System Model Development



System Model Development

- For the “kept” network, the E-Tran tool (= PTI data conversion module) will:
  - Initialize all voltages, angles, taps, switched shunts, etc to solved values.
  - Create Bergeron or PI section line models where only simple R,X,B data is available
  - Use generic .dyr machine data where available (including generators, exciters, governors, CLOD, and other)
  - Create multi-port passive system equivalents at the boundaries of the “kept” network.
  - Add fault and line monitoring automation to the case for the case as required.
  - Replace powerflow data with the detailed data in the library (IBRs, lines, loads, faults, SVCs, HVDC, SPS, etc)

Data management

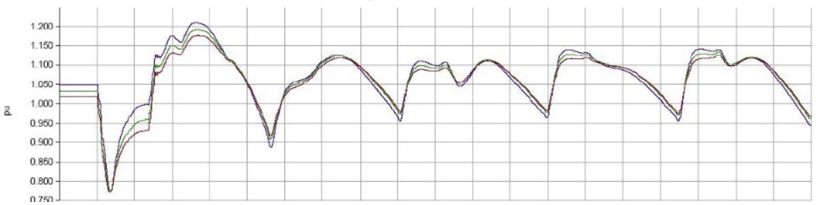
Model library development:

- Some interconnections have developed their EMT data libraries and automation to a degree that the interconnection EMT study cycle is very fast (as short as 1 month beginning to end), depending on requirements.

Simulation and Analysis

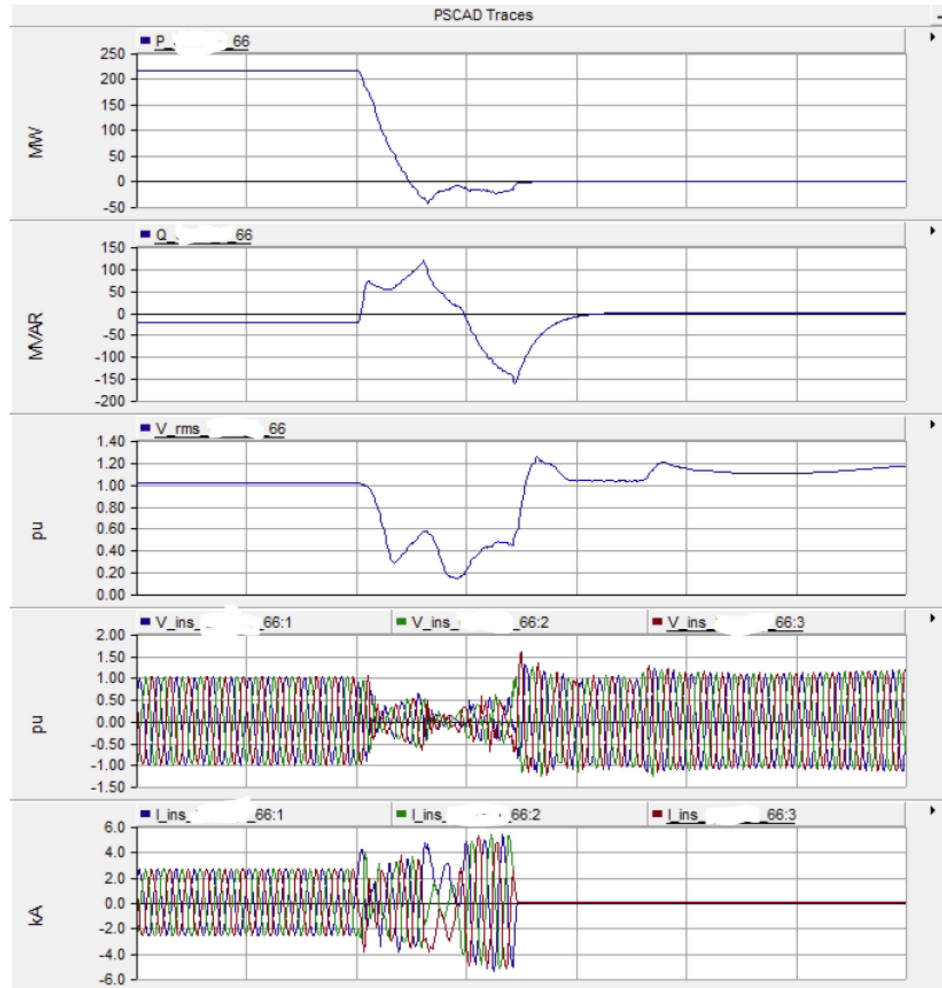
System Performance:

- Eg: interactions between different controls, or between a control system and the bulk system



(Plot is system voltage, 6 cycles per division)

Eg: TOV/FRT Failure ->



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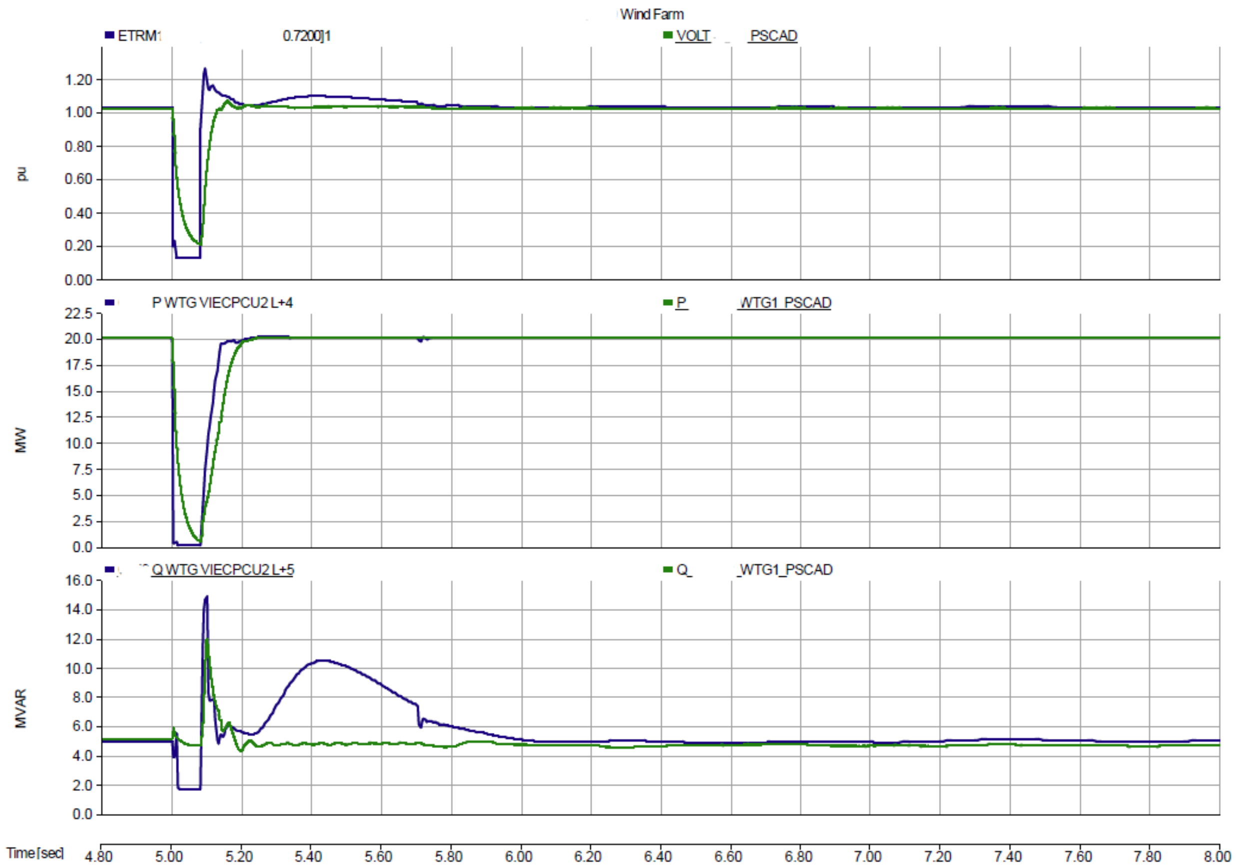
Simulation and Analysis

Validation:



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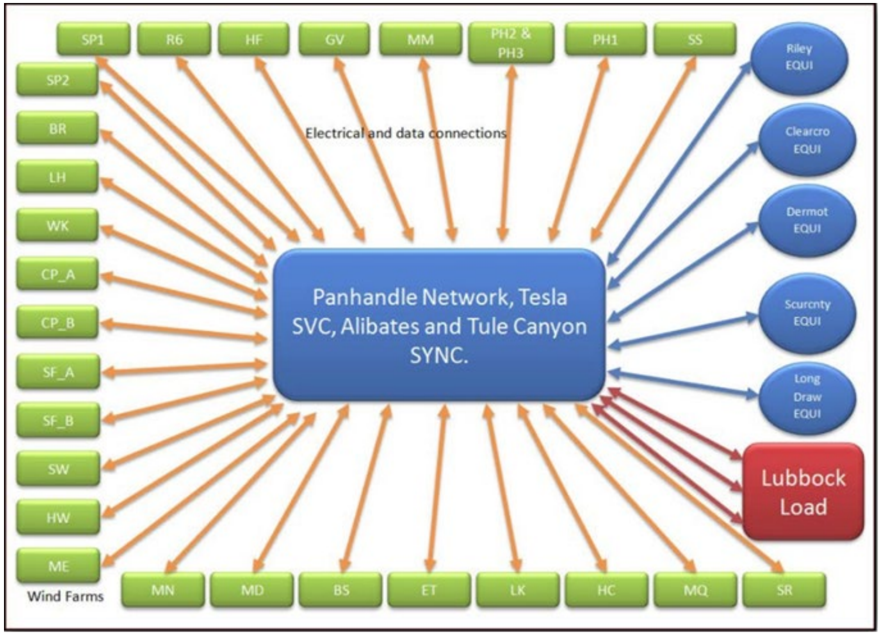
As models get bigger, more tools are required!

Parallelization and co-simulation tools:

- E-Tran Plus for PSCAD - parallel simulation for:
  - Speed
  - Overcoming compatibility errors (eg. FORTRAN, timesteps, conflict between models, multiple instances)
- PSCAD ENI: parallel simulation built-in to PSCAD
- E-Tran Plus for PSS/E (= PTI Co-simulation module): hybrid simulation between transient stability and EMT



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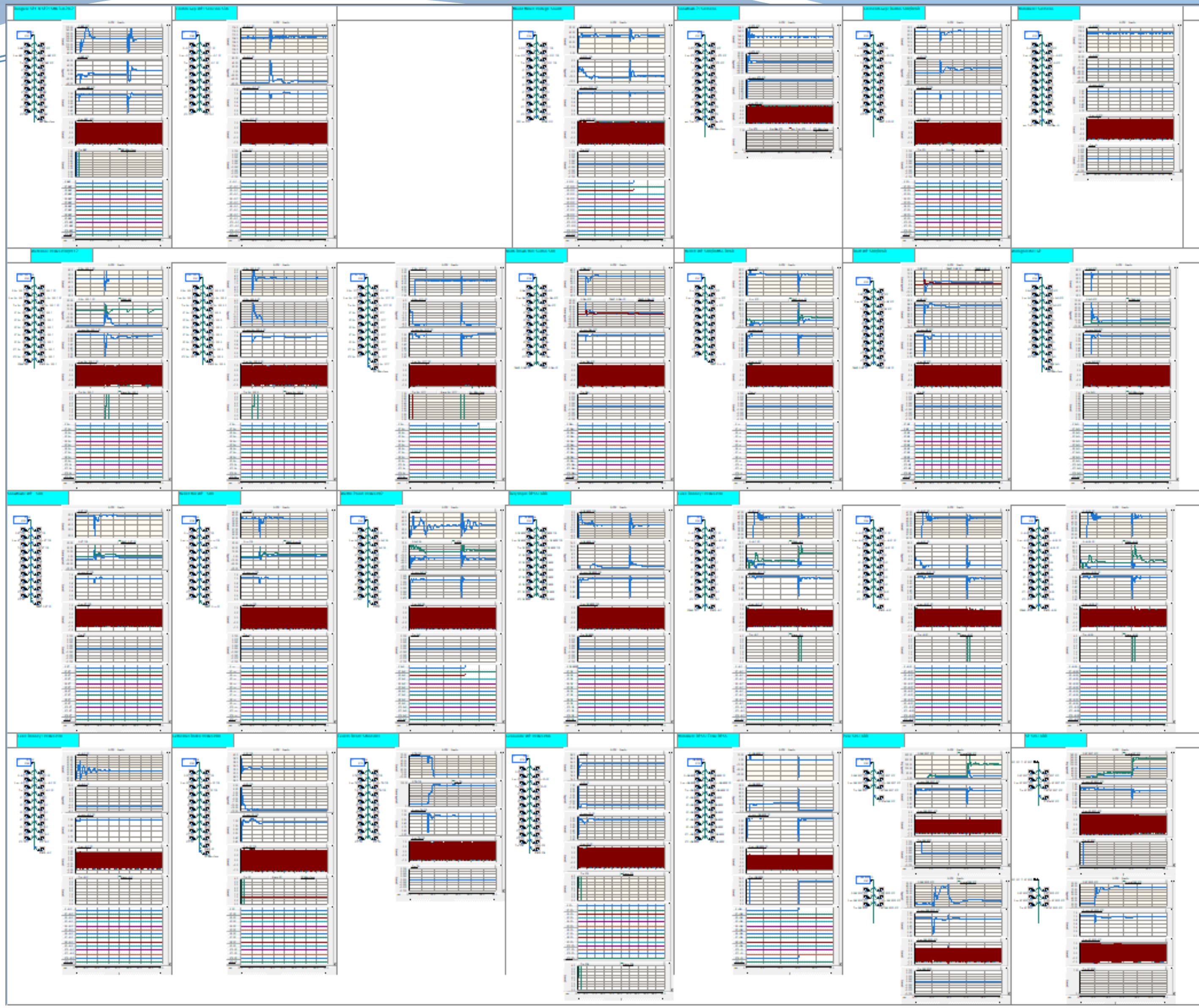

Simulation and Analysis

- Massive amount of output makes *engineering* challenging. There are many things to see…
- We use sensitive high level pass-fail criteria, then dig deeper when something fails. We test for:
  - Ride-through failure, momentary cessation
  - Voltage recovery and stability
  - Very high or extended transient voltages
  - High or low steady state voltages
  - Undamped oscillations in P, Q, V
  - Harmonic content
  - Loss of synchronism or slipped poles
- Custom software is used to help evaluate and summarize key output, and then engineers can zoom in to key issues as required.

Example summary tables…

	WF1	WF2	WF3	WF4	WF5	WF6	WF7	WF8	WF9	WF10	WF11	WF12	WF13	WF14	WF15	WF16	WF17	WF18	WF19	WF20	WF21	WF22	WF24	WF27	WF28
Fault 1																									
Fault 2																									
Fault 3																									
Fault 4																									
Fault 5																									
Fault 6																									
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Fault 31																									

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Example individual fault table…

	Pass 1	Pass 2	Pass 3	Pass 4	Pass 5	Pass 6	Pass 7	Pass 8	Pass 9	Pass 10	Pass 11	Pass 12	Pass 13
WF1													
WF2													
WF3													
WF4													
WF5													
WF6													
WF7													
WF8													
WF9													
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WF24													
WF27													
WF28													

Fancy tools don't equal good decisions!

- Beware precision without accuracy
- Don't be afraid to use judgement!

What about the Future?

Potential limits to IBR penetration

- Should politicians "Do MORE!!"?

- Can we get to 100% renewables? Yes! But…
  - What would happen if we suddenly retired all oil, gas, and coal based generation?
  - There is a technology gap, not just a money/policy gap.
  - There is a path forward, but it isn't easy, and it isn't ready yet.

Nevermind the politicians… what should we be doing?

- What is our role between now and 100% renewables?
  - Continue to develop our simulation capabilities
  - "Grid-forming" (Grid-firming?) will require a big industry/research push. We need to understand how to specify this so we can close the technology gap.
  - Batteries can play a big role, but we need to uncap their technology potential.
  - We need to keep our minds open, but also push back on bad policy (Ethics, and engineering judgement)

Nevermind the politicians... what should we be doing?

- What is our role between now and 100% renewables?
  - Study timeframes are decreasing, and complexity is increasing.
  - Engineers are stressed (on both TSO/ISO and GO sides) We should be investing in engineering (human) resources. Value what we have, and prioritize power systems engineering in our organizations.

Questions?