EMT System Modelling

ELECTRANIX
SPECIALISTS IN POWER SYSTEM STUDIES

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

System Model Construction and Quality Assurance

Consider:

1. How big?
2. What detailed models to include?
3. How to construct the model?
4. Can we validate it?

Keep in mind:

- Practical vs Accurate (assumptions!)
- Data availability, timelines, budgets

https://www.iso-ne.com/static-assets/documents/2020/04/new-england-geographic-diagram-transmission-planning.pdf

Kept System Selection

- Not feasible to include full interconnect
- What are you looking for? Fast phenomena -> small system, slow phenomena -> larger system
- Selecting is part science, part art! Mix and match as appropriate…

Too Small ⟷ Too Big

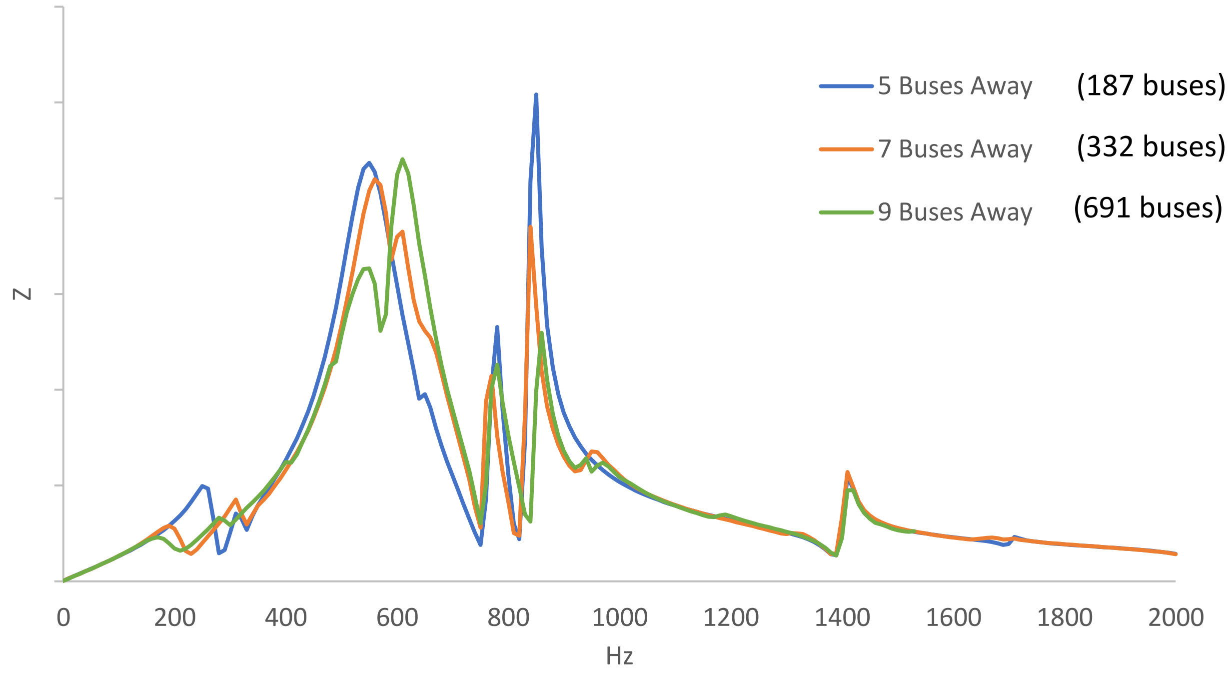
-Missing key device dynamics (machines, HVDC, etc.)
-Network Equivalents having outsized impact on dynamics
-System capacitance cancelled-out in equivalent

-Dynamics de-coupled by strong bus? ("boundary of strength")
-Frequency response?
-Keep distribution?
Engineering judgement & experience!

-Slow simulation
-Modelling burden
-less "usable" model

Kept System Selection: Frequency Response

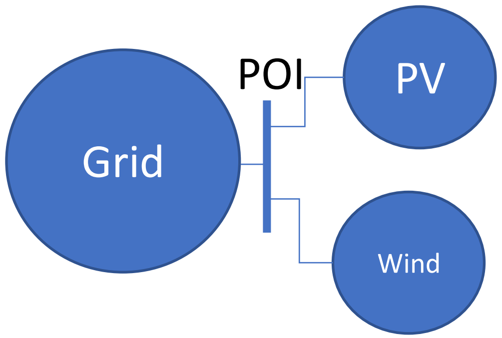
- Ideally, model a large enough system to get a valid electro-magnetic response from system
- Shunt capacitors and long transmission lines dominate the electrical frequency response (remainder is inductive)



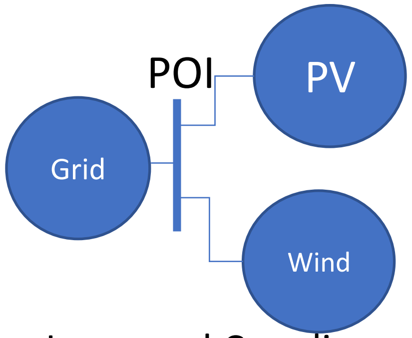
Detailed Models to Include: Nearby IBRs

Impact of Nearby Inverter-Based Resources

- Wind plants, solar plants, STATCOMs, SVCs, HVDC
- Interaction risk is strongly dependent on controls & tuning
- Screening methods are limited, but coupling between inverters (and risk of interaction) is stronger on weak grids
- Unable to assess interactions without EMT models



Reduced Coupling



Increased Coupling

Technical References

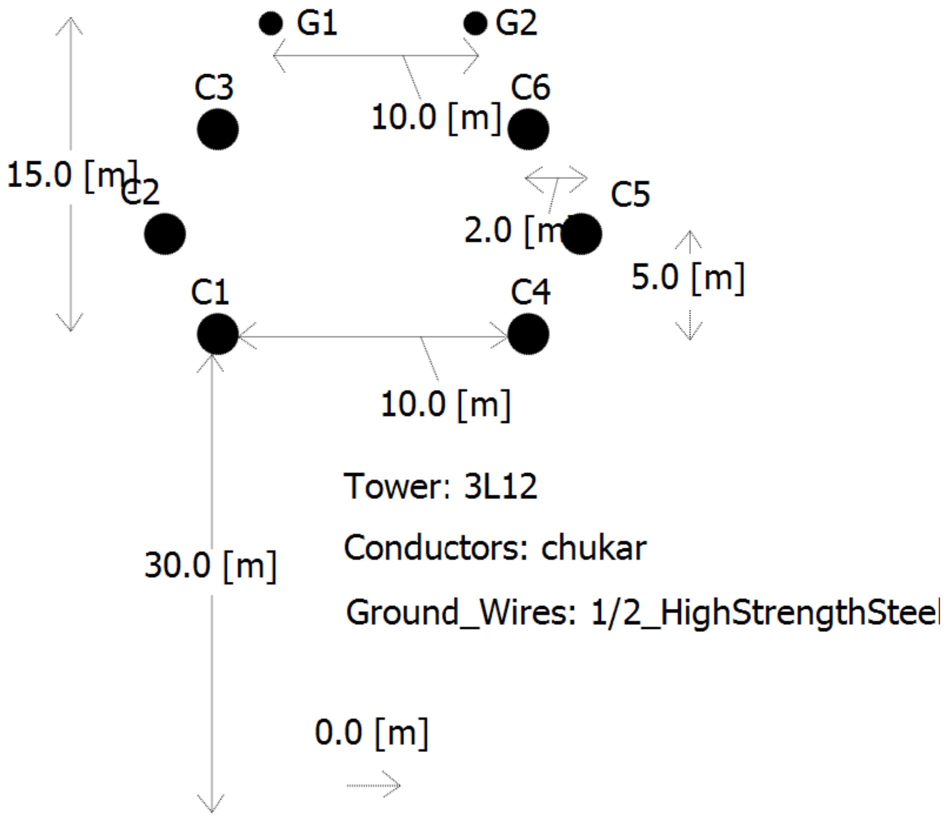
- CIGRE “Connection of Wind Farms to Weak AC Networks” B4.62, Technical Brochure 671
- ERCOT Panhandle Renewable Energy Zone Study Report

Detailed Models to Include: Transmission Lines

- "Detailed" relative to loadflow-derived data
- Where does it matter?
  - "focus area" vs boundary region
- Transmission lines: Pi-section vs Bergeron vs frequency dependent, mutual coupling
- Transformers: Winding Configuration, Saturation, multi-limb vs 3-phase bank
- Loads: ZIP vs CLOD / CMLD style vs non-generic
- non-IBR generation: standard library models

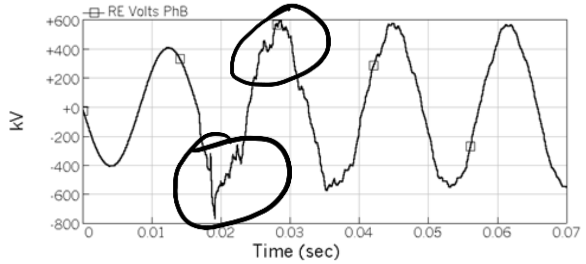
Detailed Models to Include: Transmission Lines

- Load-flow derived models
  - select based on simulation timestep and travel time
  - Travel time > Time Step: Bergeron Traveling Wave Model
  - Travel time < Time Step: Coupled PI Model
- Detailed T-lines:
  - More modelling detail needed
  - Conductor type, tower geometry, sag, grounding, bundling, etc.

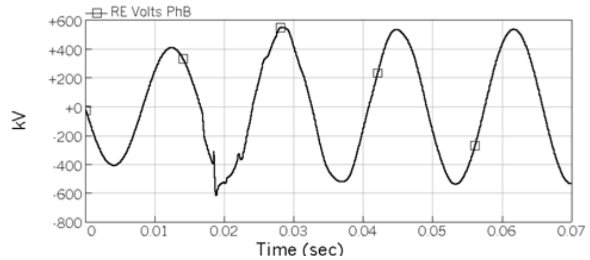


Detailed Models to Include: Transmission Lines

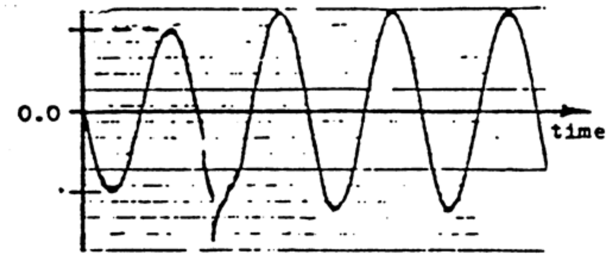
Bergeron model



Frequency dependent (phase) model

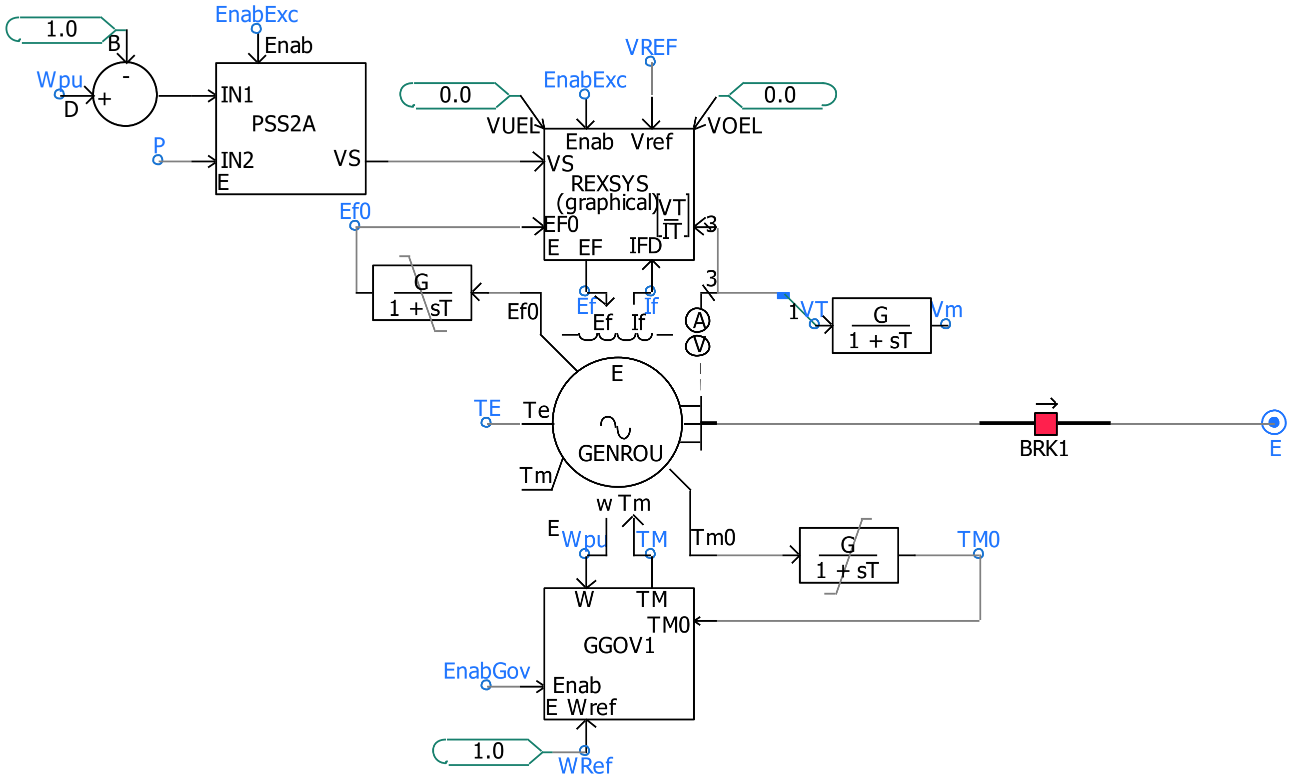


Field test measurement



Full System Model Construction
Generator Model Example

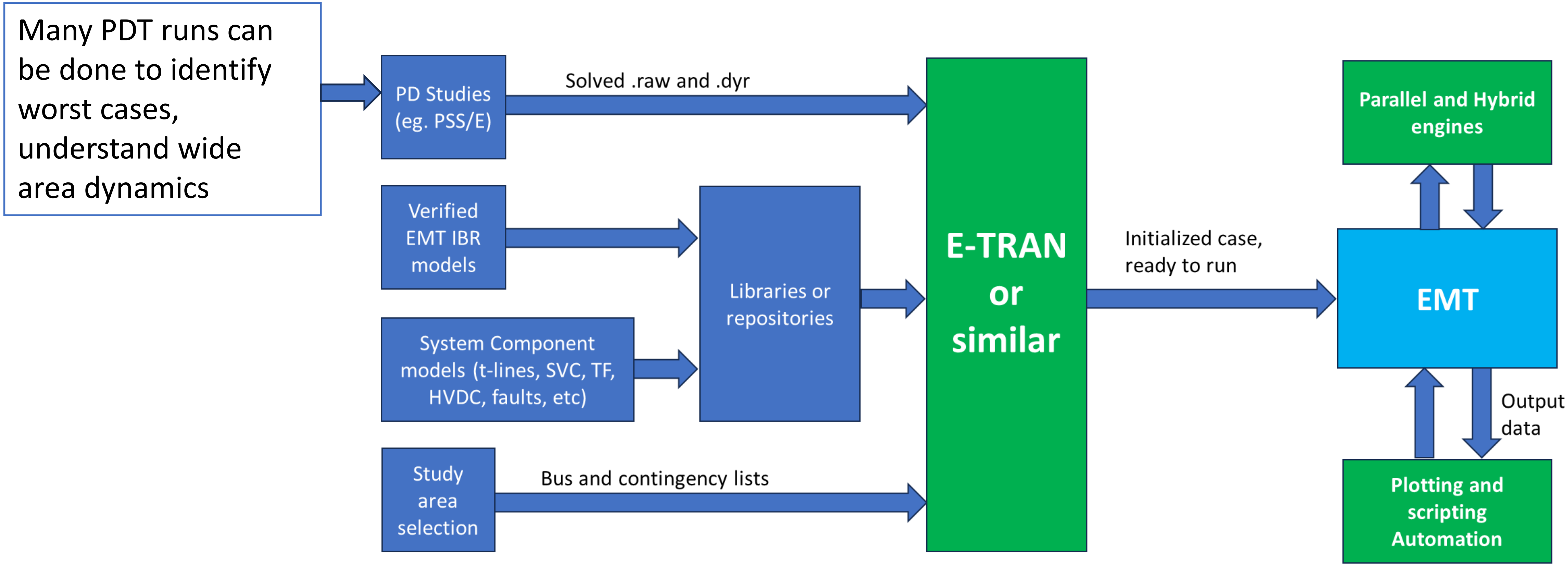
Can construct using PSPD machine dynamic data:



EMT Studies – Building System Model

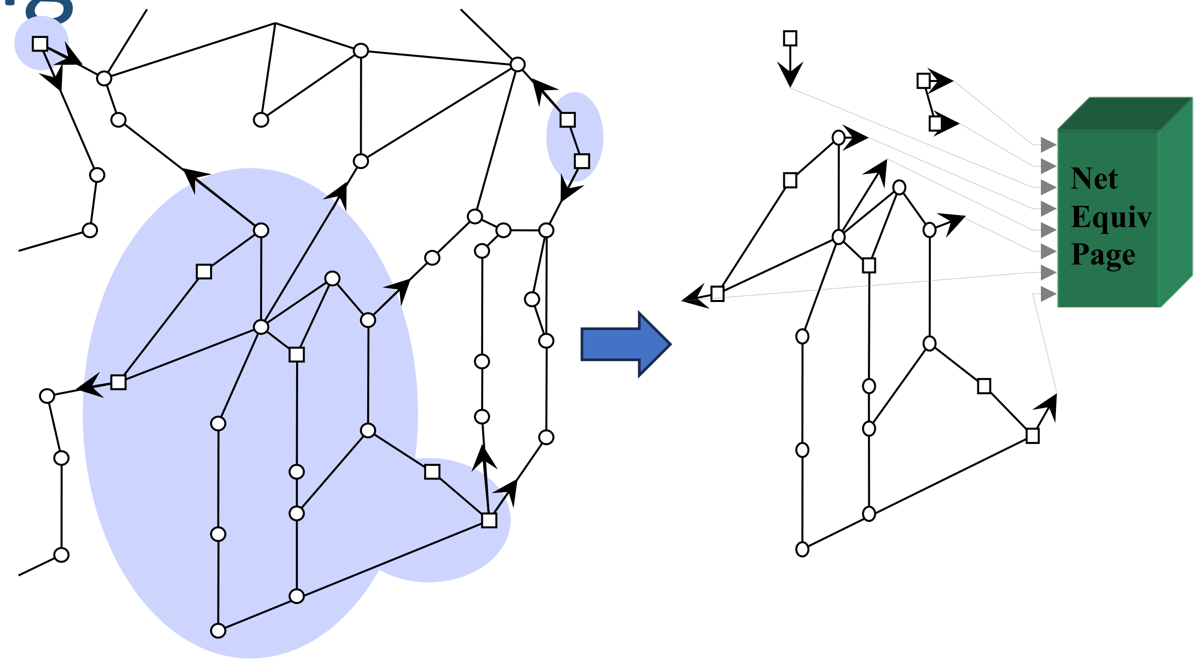
- EMT type study normally deals with relatively small or medium size power systems
- Main challenges of building system models for large systems:
  - Large amount of data entry (model building) is a challenge and time-consuming
  - Easy to make errors
  - Difficult to select appropriate kept and equivalent subsystems
  - Difficult to use available load flow type data (PSS/E, PSLF and etc) maintained by most power utilities

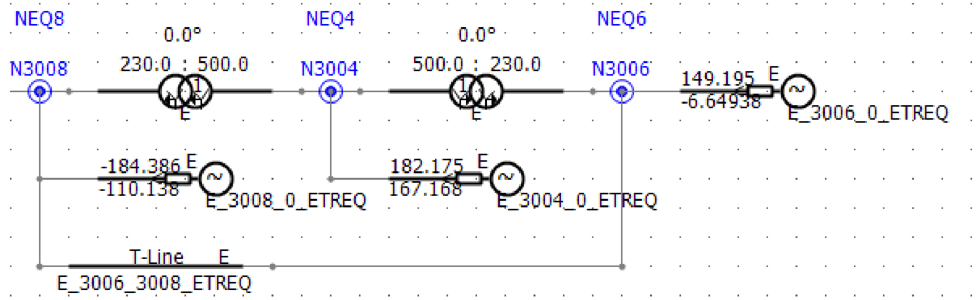
System Model Construction (Electranix Approach)

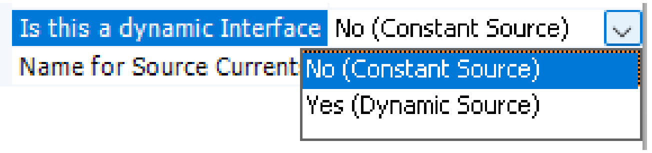


Full System Model Construction
External System Modelling

- External network typically modelled as NxN admittance matrix with voltage sources behind impedance at N boundary points
- Voltage source can be passive, (fixed magnitude and angle), or dynamic (co-simulation)
- Custom network equivalents which imitate machine dynamics of external system also possible, but not easy







Full System Model Construction Checking Accuracy

- How do we know the model is right?
- Steady state benchmark against loadflow solution
  - Should be very close. Precise alignment is possible
- Short-circuit benchmark
  - Beware of differences in IBR current contributions
- Dynamic benchmark against transient stability
  - Best used to check local electro-mechanical response (inter-area modes may be missing in EMT)
  - Won't match if individual models (especially IBR) are not well benchmarked
  - Consider inherent differences between tools
- Frequency Response Comparisons
- Field validation
  - High speed recordings needed