EMT Model Creation and Benchmarking

ESIG
ENERGY SYSTEMS INTEGRATION GROUP

Introduction to EMT Model Creation and Benchmarking

- Skipping model validation (for now)
  - Will cover this in the design evaluation session
- EMT model creation is a **critical starting point**
  - Some extra time and scrutiny at this point can save significant time and money later
  - This session will be **most beneficial with group discussion** so please feel free to interject
    - The real knowledge here comes from experience and peers
- Leverage experience and lessons learned from PSPD modeling
- Model **benchmarking adds extra "trust"** in the models
  - Shows that modeled representation is the "same" across simulation domains, software, and time steps
  - This session will assume we are starting with a "validated" and manufacturer-approved EMT model

Step 1: Getting *an* EMT Inverter Model

- **This is not a joke slide**
  - Procuring an EMT model can be extremely difficult
- For **transmission system operators**:
  - May not have requirements for the provision of EMT
  - Many facilities connected currently do not have an EMT model (available *or* created)
    - Very important when considering retroactive requirements
- For **developers:**
  - EMT models after commercial operation date are often expensive (for new-er equipment)
    - Service contract language can help
  - Parts of fleet may be older equipment
  - Retroactive requirements have a huge impact here
    - Can cost hundreds of thousands of dollars and up to 24 months in some cases
      - These models are often "best guesses" and may not have the accuracy of a new model/equipment pair

Step 1: Getting *an* EMT Inverter Model

- For **equipment manufacturers**:
  - There is a time cutoff where equipment and model design practices make the creation of a quality EMT model extremely difficult
  - Grid requirements (retroactive or otherwise) can create “surges” in model creation requests
  - EMT model creation for older facilities are outside of the normal business practices and often come with high prices due to the one-off nature and subject matter experts involved
- **For us all:**
  - Get an EMT model early (before COD is best)
  - Adding in modeling provisions to service contracts can help
  - Keep these thoughts in mind when discussing and creating modeling requirements

Step 1a: Getting *an* EMT Plant Controller(s) Model

- IBR facilities include power plant controllers that need to be modeled
  - Can be provided by the inverter manufacturer
  - Could be written by a third party consultant
    - These may not have actual modeling staff
      - Falls to another party to take the control philosophy and create a model
- Similar process to inverter model acquisition with some additional guiding questions:
  - Does this manufacturer make plant controllers for the region I am studying?
  - What is the *full* control capability of the facility?
    - What devices are communicating, why, and who is in charge
  - What is the communication protocol used?
    - Can these additional devices use this protocol?

Step 2: Getting The Right EMT Inverter and Plant Controller Model(s)

- **Just because the model has an EMT file extension doesn't make it the right model**
- The new paradigm involves many non-technical stakeholders
  - These stakeholders may operate in between technical experts
  - Extremely important to know exactly what you are asking for and ask it in a way that is clear
    - For those receiving requests, confirm understanding and ask follow up questions
- The right EMT model is **site-specific** (for the equipment)
  - Right technology version (and subversions)
    - Correct firmware
- Does the provided model include a site-specific plant representation? (probably not)
  - Manufacturers provide models for their equipment only
  - Some manufacturer-provided models have "generic" balance of plant representations
    - This can be extremely confusing as models change hands throughout study processes

Step 2a: Getting The Balance of Plant Data

- **Inverter models are just one piece of an EMT facility model**
  - Manufacturers often do not know nor have responsibility to build the balance of plant
  - When obtaining an EMT inverter model there is one primary stakeholder
- The balance of plant data comes from **multiple sources**
  - These sources are all working towards the same goal, often in parallel
    - Can create versioning and management of change issues – highly iterative
    - Some pieces of data may be more “final” than others
- Having a standardized checklist of required data can help during this process

Step 2b: Reviewing The Balance of Plant Data

- Similar to the inverter/dynamic models, just because a **piece of data was provided doesn't mean it is correct**
- **Guiding questions:**
  - Did I receive all of the data I asked for?
    - Checklists help – categorizing by "need" and "good to have" helps more
  - Do the values make sense?
    - This comes from engineering judgement and experience
  - Is the data dated/versioned?
    - Helps create a correct "snapshot"
  - Does the balance of plant data match what was used in the PSPD?
    - Not always applicable
  - Have I seen this data before?

Step 3: Putting Major Pieces Together

- Need to determine where the model building responsibility “ends”
  - For the plant model builder, often the point of interconnection
  - For the transmission system operator, much more difficult and study-dependent
- The balance of plant data is used to create the physical representation of the plant
  - Transformers, cables, tie line, etc.
- The inverter and plant controller models and data are connected to the balance of plant where they are designed to
  - Spot checks throughout this process are crucial for efficiency
  - ”solve” as much as possible
    - Does the result make sense?
      - Are losses in line with expectations? Etc.
  - No disturbance runs and other thoughtful checks

Step 4: Site-Specificity and Data

- Putting together the pieces of the model is (a very important) step 1
- **Parameterization** of the model is an equally important step 2
  - A correct model with wrong parameters is the wrong model
- Hinges on model **usability, fidelity, and mapping** to real-world values
- More stakeholders are involved
  - Often developers are responsible for understanding what requirements are needed at the point of interconnection
    - Voltage schedules
    - Frequency deadbands/droops
    - Protection settings
    - Enabled control modes
  - How to manage "telephone game"
  - What should be done when these values don't make sense
    - Strong foundation of engineering judgement and knowledge is necessary

Step 4a: Representing Site-Specific Controls

- Modeling complex communication systems is a **strong use case for EMT**
- EMT affords the ability to **model in detail many aspects of actual site control that is not possible (or efficient) in other domains**
  - Extremely important to request manuals and documentation from **all vendors**
    - Each vendor model likely has “nuance” that will need to be understood and implemented
- **Hierarchical controls:**
  - Main/secondary schemes
  - Mechanically switched units
  - Plant controllers and supplemental reactive devices
  - Hybrid plants
- **Real-world delays often not modeled (even in EMT):**
  - Communication delays
  - Sample time delays
  - Controller holds
- **Much more! Complexity is always increasing**

In a ”perfect world” These have parameters in the model space. In reality, these may need to be manually added.

Model Benchmarking

- **What is model benchmarking?**
  - Simply put: comparing the response of a model to another model or to the performance of the actual equipment
- **Model to measured performance:**
  - Also known as model validation and is part of the type testing process (more on model validation in the design evaluation section)
  - Shows differences between measured response and model response to the same stimulus
    - Some differences will always occur
    - Shows incorrect performance that can then be mitigated
  - **Test benches are few and in high demand**
    - Type testing is thorough but infrequent for any one piece of equipment

Model Benchmarking

Case 1 - TN1.1 - Pref

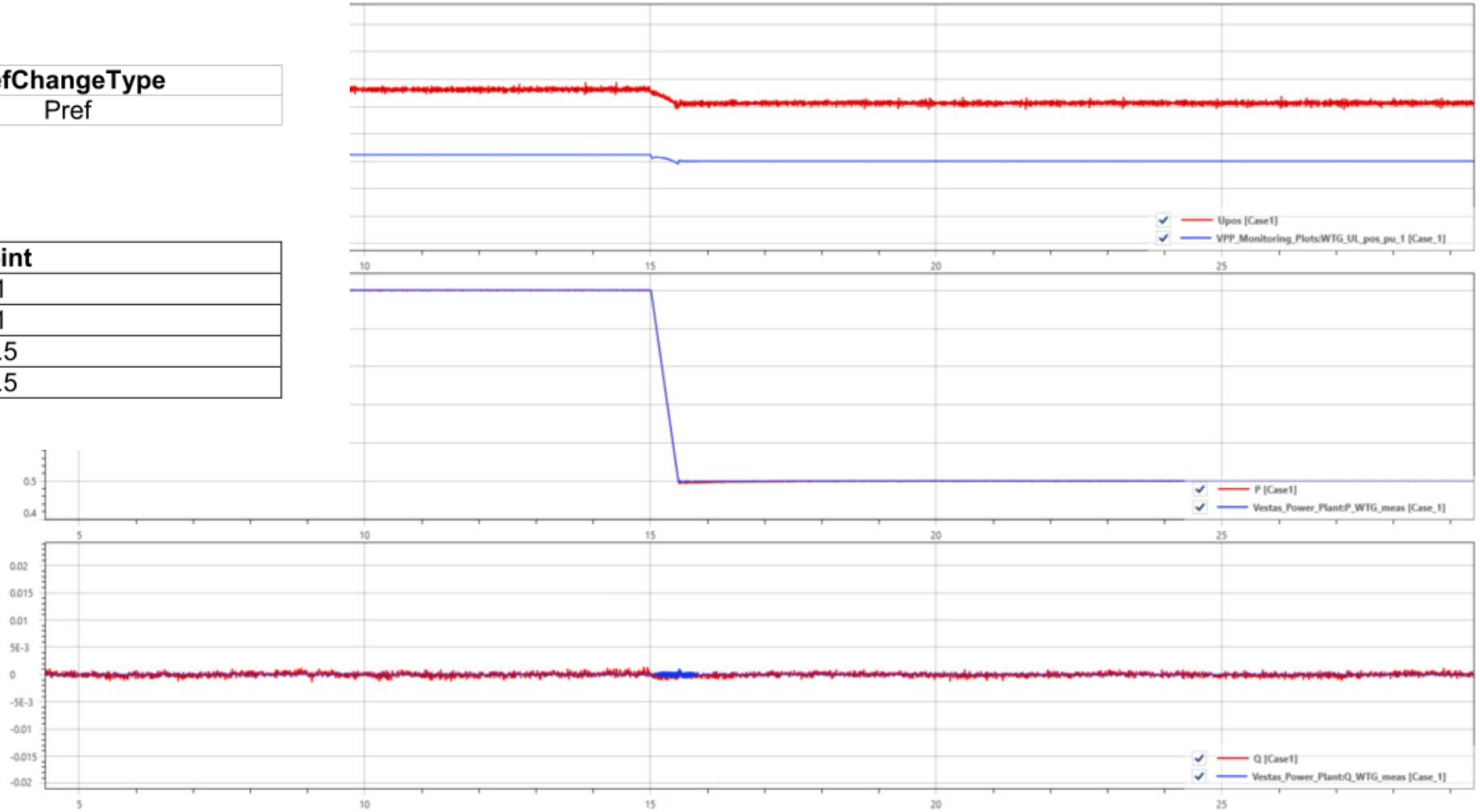
Events

Custom Input

EventType	InputType	RefChangeType
ReferenceChange	CustomInput	Pref

Point Steps Pref

Time	Point
0	1
15	1
15.001	0.5
30	0.5



Source: Vestas

Model Benchmarking

Case 2 - TN1.2 - Qref

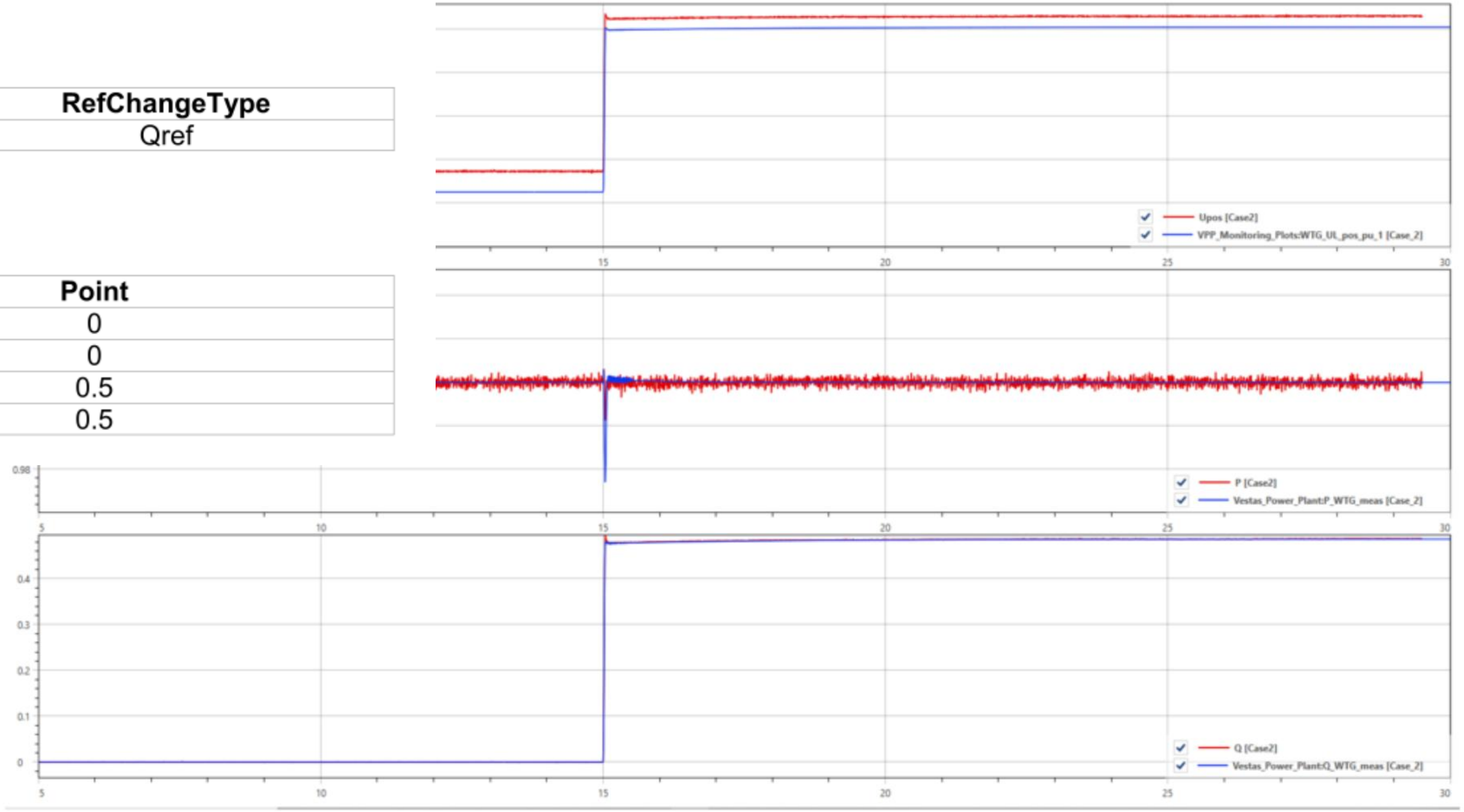
Events

Custom Input

EventType	InputType	RefChangeType
ReferenceChange	CustomInput	Qref

Point Steps Qref

Time	Point
0	0
15	0
15.001	0.5
30	0.5



Source: Vestas

Model Benchmarking

Case 11 - TN4.1 – Phase Jump +30º

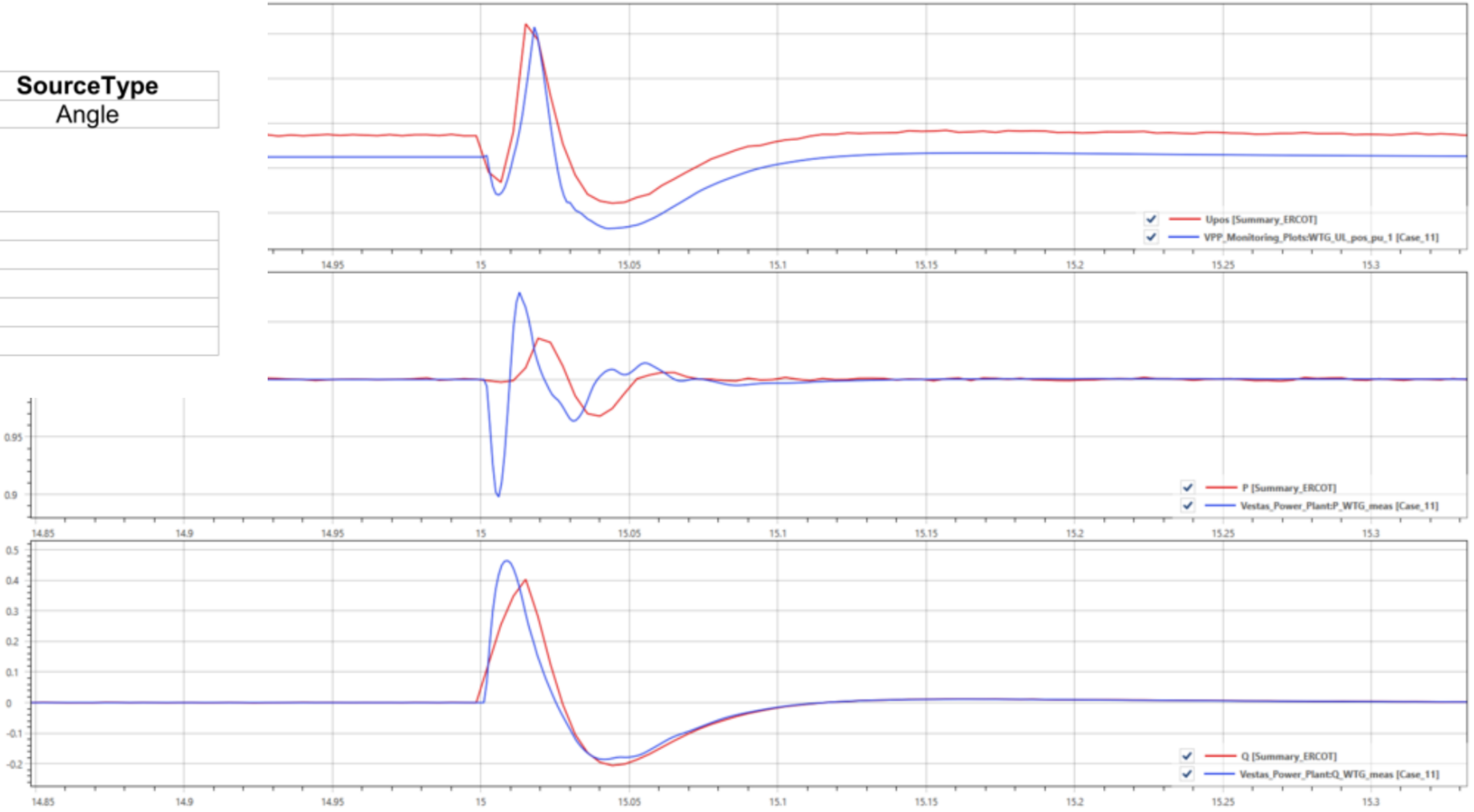
Events

Thevenin Source Change

EventType	FilePath	InputType	SourceType
TheveninSourceChange	---	CustomInput	Angle

PointSteps Angle

Time	Point
0	0
15	0
15.001	30
30	30



Source: Vestas

Benchmarking Between PSPD and EMT

- **Assumption:** The EMT model is validated by the manufacturer
  - **Pro:**
    - The manufacturer performed model validation testing
    - The manufacturer validated the model performance against the test results
    - Differences between model and measurements are explained
  - **Con:**
    - The validation was done on one specific ”platform”
    - The validation was done with one specific parameter set
- **Need:** Site-specific parameterized model in both the PSPD and EMT domains

Benchmarking Between PSPD and EMT – Inverter and Plant Controller

Will discuss model validation in more detail as part of the design evaluation session

Base Validated EMT Model

- With one parameter set on one platform

Additional Validated EMT Models

- Thorough validation of one parameter set and one platform provide trust in the model representation
- Additional parameter sets can be assumed "validated"
  - There will always be software bugs

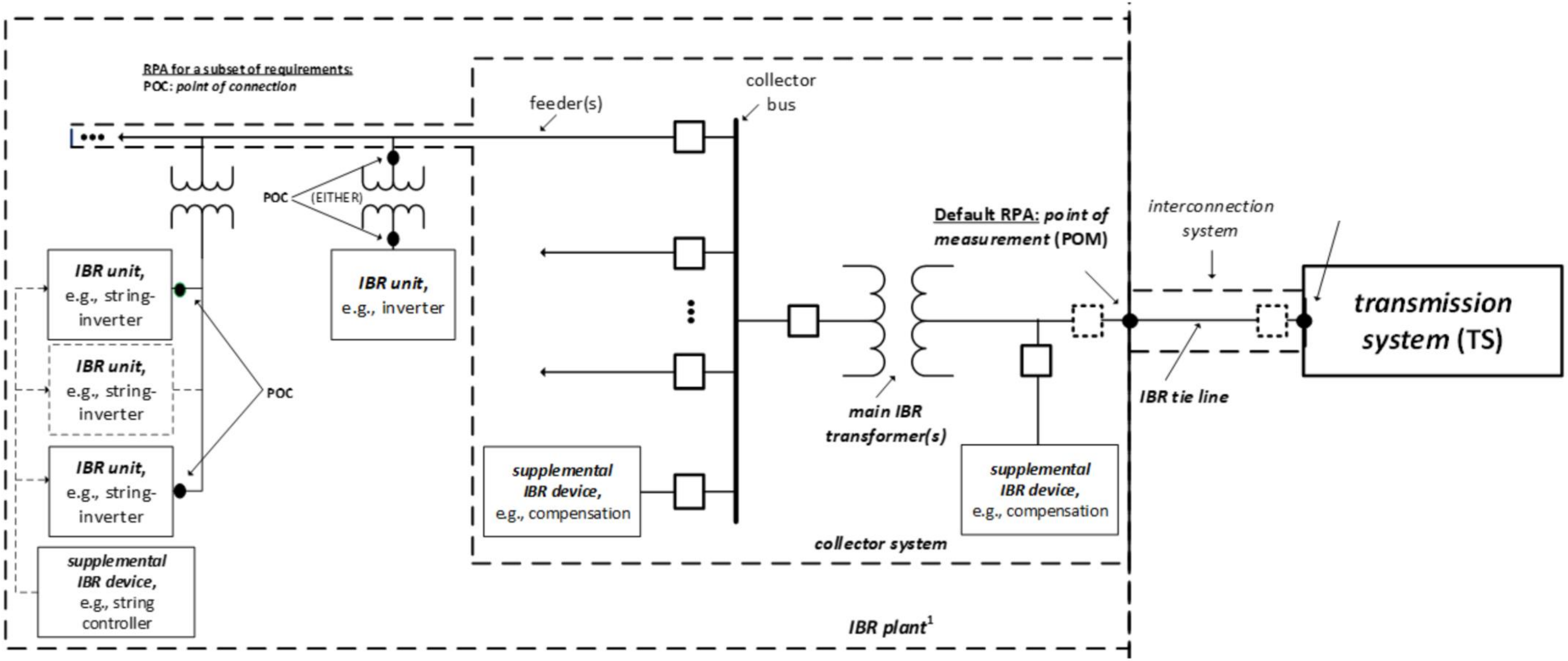
Site-specific EMT Model

- Becomes the new "source of truth" for the individual facility
- Can be used as basis for validating the PSPD model

Validated PSPD Model

- Both the PSPD and EMT model are put through thorough testing procedures
- There will be performance differences
- Differences in performance must be explained

Benchmarking Between PSPD and EMT Balance of Plant



Source: Adapted from IEEE 2800-2022

Success Story of Quality Model Practices

- Case Study: (Source Vestas)
  - IBR facility showed instability in operations that was not seen in the study space
  - Facility was immediately curtailed to ~50% output
  - Proposed solution was multiple transmission assets
- **Old paradigm:**
  - The models in the process are the best we have
  - Pay for the transmission upgrades
- **New paradigm:**
  - Leverage principles in this training
  - Perform detailed analysis with highly representative models
  - Avoid transmission upgrades, install tuned controls

Success Story of Quality Model Practices

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What Was The Problem?

A Vestas Site was curtailed and facing significant proposed transmission upgrades

Stability modelling showed severe adverse response including re-triggering of voltage ride through mode

- This caused ~20% voltage swings at the Project POI
- Grid SCR at the POI was <1.75

The proposed solutions were costly and came with significant lead times

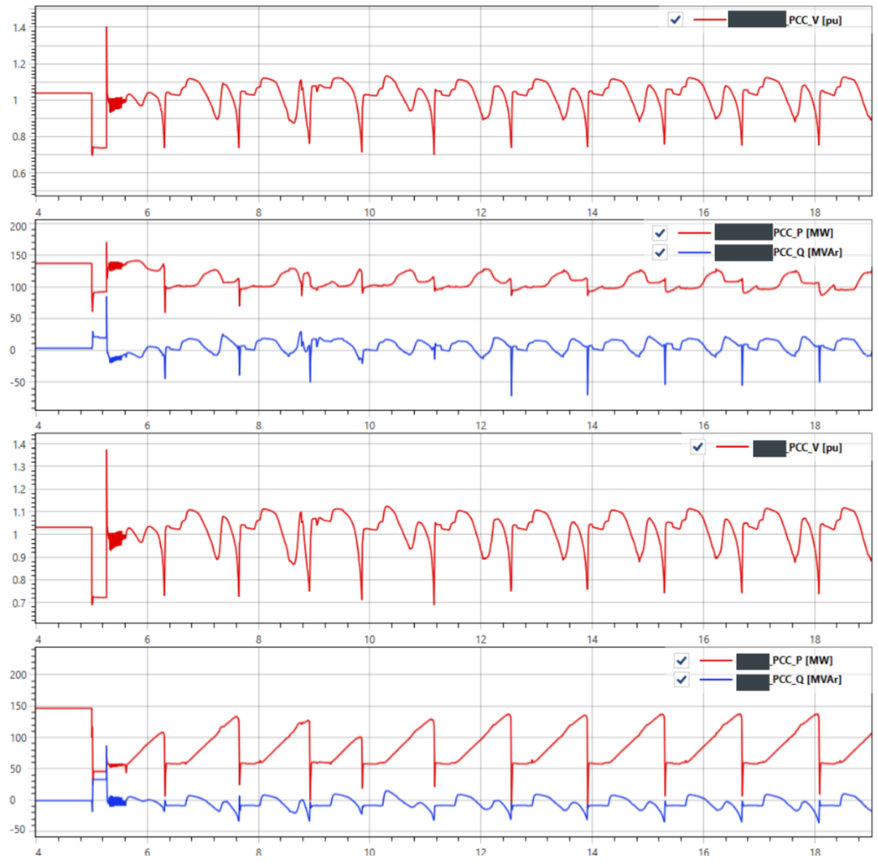
- Substation re-configuration
- New 138 kV Transmission line
- Grid Side - SVC/STATCOM/Synchronous Condenser
- Project curtailment for many prior outages

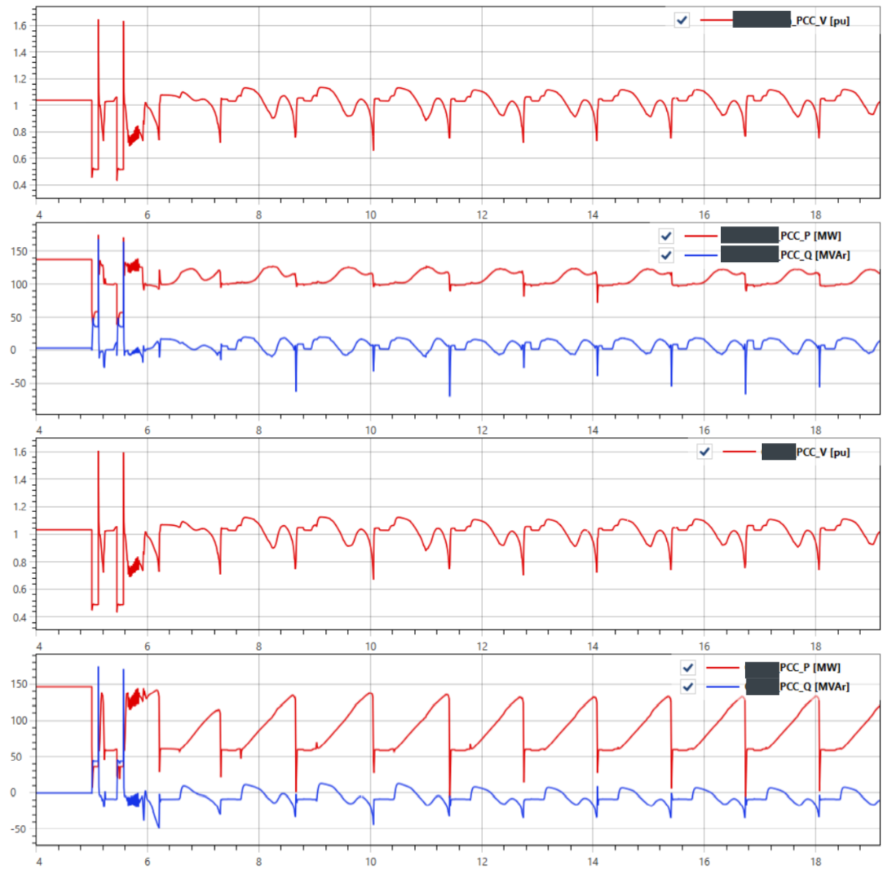
Vestas

Success Story of Quality Model Practices

Vestas Plant Results for two Severe Planning Contingencies

Both show significant retriggering and typical weak grid response





Vestas

Success Story of Quality Model Practices

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Study Groundwork and Setup

Vestas needed to work internally, with the Customer, Regional Entities, and their consultants

Work with Customer

- Several meetings with Customer to explain the situation and how site controller tuning could be an alternative solution to the transmissions upgrades

Work with Regional Entities

- Detailed collaboration to discuss the previous study process and to understand the problem grid conditions and contingencies
- Provide technical justification to re-perform two worst planning contingencies in the EMT domain with confirmation in RMS by the consultant
- Work through necessary NDA and process for proper data handling

Vestas Internal Work

- Access and download the Projects' Power Plant Controller and WTG settings
  - Create as-left models to use as tuning starting point
- Recreate a small region of the Grid in PSCAD
  - All other non-Vestas Generators were netted out
  - The fault response was benchmarked against the RMS study

Vestas

Success Story of Quality Model Practices

Vestas Internal EMT Study

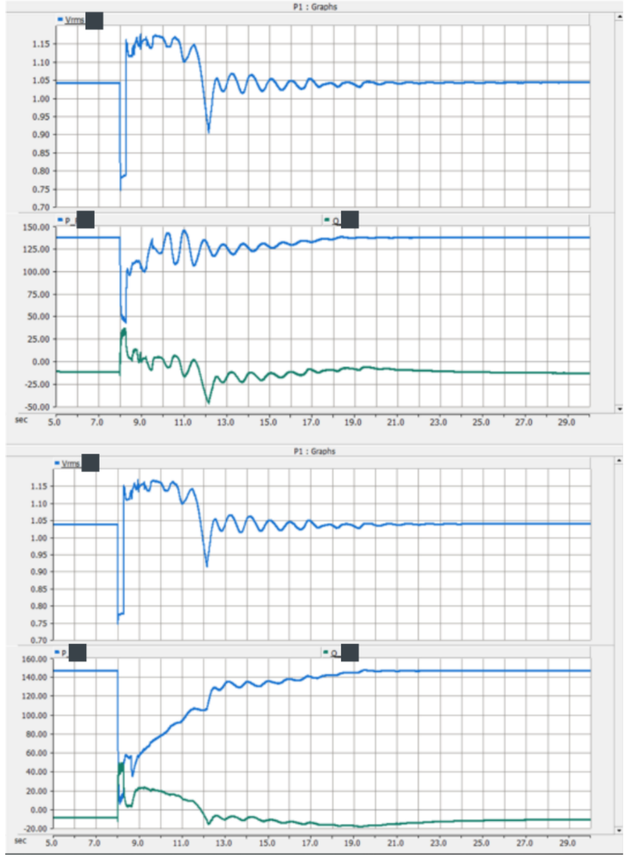
The two worst planning events were studied in the EMT domain and the Vestas controllers were tuned

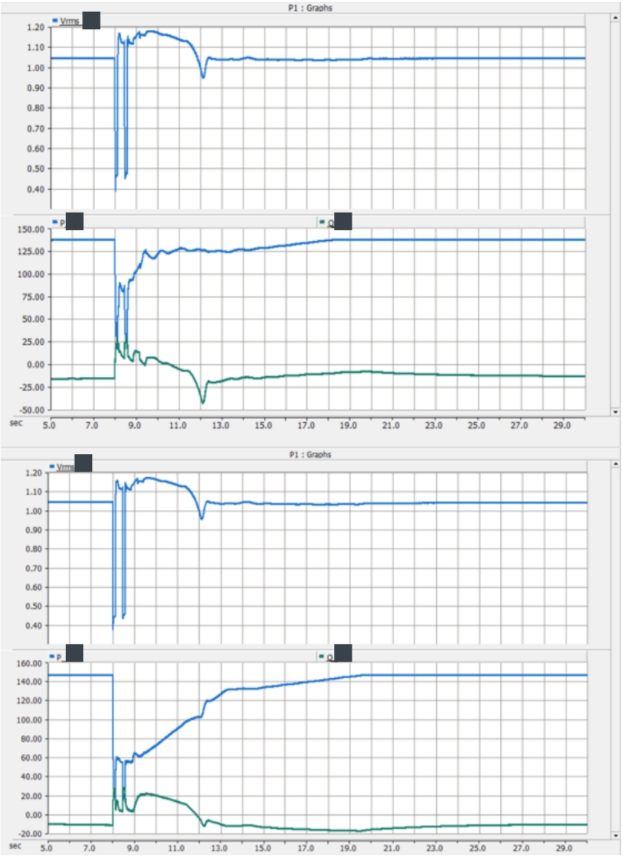
- Changes were made to both the Plants' Power Plant Controllers and WTG control parameters
- The new parameters showed stability in the EMT domain for the two worst contingencies
- Parameters from the EMT model were transferred exactly to the RMS models and these models were studied and approved for all planning contingencies under Regional Entity procedure
- In parallel, the parameters were studied internally to ensure they would not damage the WTG or reduce the WTG lifespan
- After internal and external approval of the parameters they were installed on-site with exact mapping to the studied parameters

Success Story of Quality Model Practices

Vestas Plant Results for Two Severe Planning Contingencies

Both show stable post-fault response within Regional Entity Criteria





Key Takeaways

- **"Extra" work now pays itself back later (usually)**
  - Models are the building blocks of analysis
  - Small mistakes made early on are extremely difficult to track down
    - Or worse – the mistakes give reasonable, but wrong performance
- Ensuring one thoroughly vetted "Source of truth" is critical
  - Always have a reference for expected performance
  - Enables cross-domain analysis
- While many PSPD modeling principles can inform EMT work, added details and specialized use cases underscore the importance of engineering judgement and experience
  - Also underscores the need for mentorship within organizations