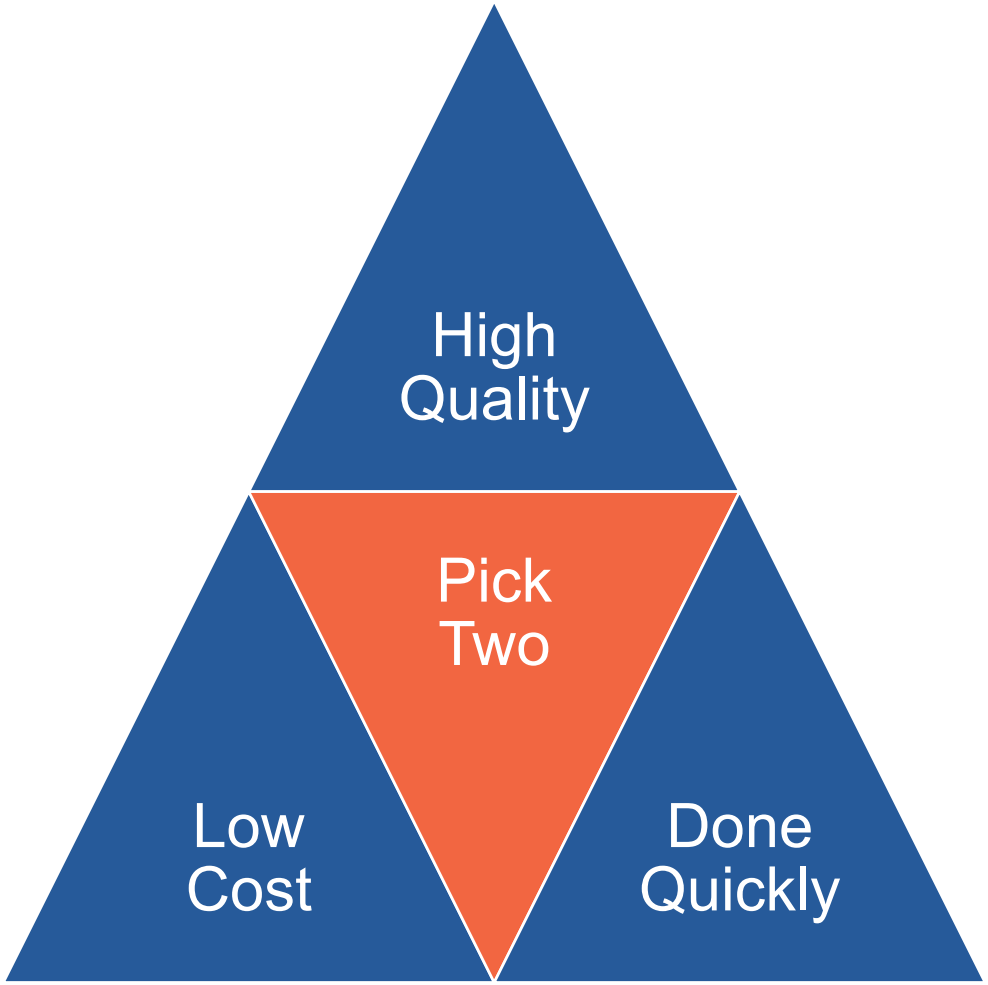
EMT Simulation Prerequisites

ESIG

ENERGY SYSTEMS INTEGRATION GROUP

EMT Simulation Key Considerations

- **EMT Simulations are:**
  - **Difficult**
    - Lack of subject matter expertise world-wide
    - Often used to solve specific problems in specialized studies
  - **Expensive**
    - Subject matter expertise is not cheap
    - EMT models may come at high costs
  - **Time consuming**
    - EMT simulations take much longer to run than PSPD and loadflow
    - Additional simulation detail requires additional data inputs



The Most Critical Prerequisite

Does this need an EMT study?

Questions to Keep in Mind

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What am I studying?

- Why am I studying it?
- Do I have sufficient experience?
- Does this need to be studied in EMT?
- Can this be studied sufficiently in another way?
- Do I have the required data?

Guiding Principles

- **EMT simulations are not needed for every analysis**
  - Numerous power systems studies can be performed in different software and with different methods
- **EMT simulations *should not be used* for every analysis (generally… for now)**
  - EMT simulations can be overly complex for some reliability needs
  - Attempting to shift paradigm from all PSPD to all EMT can impede incremental progress
- **Many of the principles of good EMT simulation practice apply also to PSPD**
  - Increasing quality, accuracy, and ability to use manufacturer-specific models can increase study accuracy without going “full EMT”
- **Any study is only as good as its inputs**
  - EMT does not automatically equate to correct or accurate
  - Proper model creation, validation, and benchmarking are necessary

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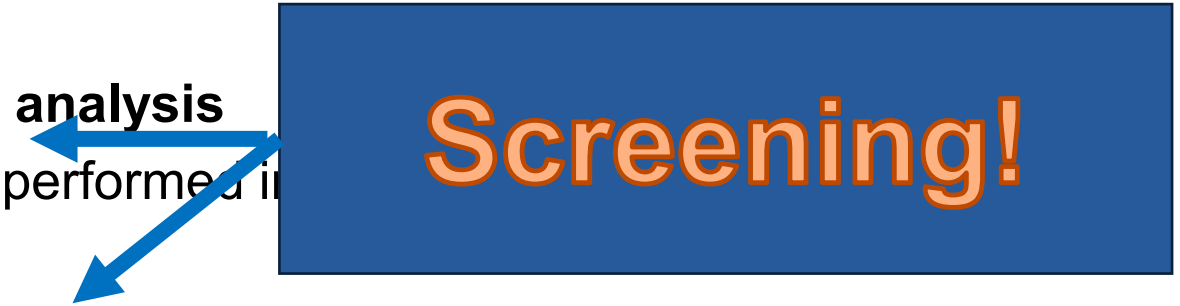


What is Screening and Why?

- **Screening (in the context of EMT):**
  - Assessing whether or not an EMT study should be performed
- **Why is screening important:**
  - Resources are limited
  - Time is limited
  - EMT is expensive
  - Some systems and topologies may not see large EMT benefit
- **Screening now may make EMT analysis easier in the future**
  - FERC Order 2023 states: “These modeling requirements include: (…) (3) a validated electromagnetic transient (EMT) model, **if the transmission provider performs an EMT study as part of the interconnection study process.”**
  - Screening for need now can inform requirements for the future

Principles of Screening

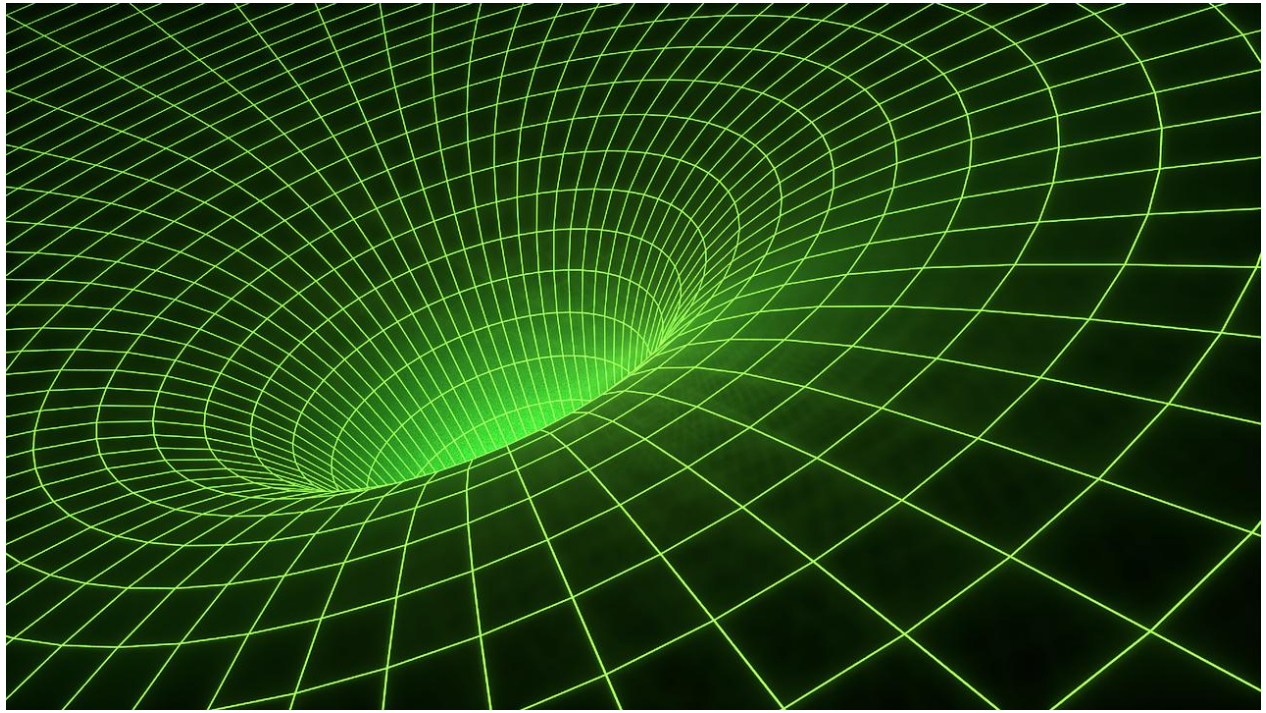
- **Screening does not need to be a detailed process, analysis, or dependent on new tools**
  - Screening *can be* as simple as asking the questions in previous slides
  - Screening *can be* as complex as new methods, tools, and processes
- **Screening should be formalized in some way**
  - Study assumptions and methods are good to have in writing
- **Considerations when performing Screening**
  - IBR penetration
  - Series compensation
  - System strength
  - Complexity of interconnecting facilities
  - Grid forming resources

Getting Started With Screening

- **Screening metrics, tools, and processes are a hot topic in industry**
  - There are many good examples from the National Labs and industry groups
  - Won't advocate for one method here
    - No one size fits all
    - This are needs further development
- **Metrics for screening need to be thoroughly understood**
  - Many metrics like short circuit ratio (SCR) are misused
  - All metrics have limitations and use cases
- **Look to peers with similar system characteristics**
  - Not every problem needs a novel solution
  - Peer-to-peer learning is critical in the grid transformation
- Andrew Isaacs presented this in ESIG's Interconnection Studies Course
  - Recording
  - Slides

So You've Decided to Perform EMT

- **Understand the problem you are solving**
  - Why does the problem exist
  - What performance is needed to be reliable
- **Understand tests needed to confirm solution**
  - Choosing proper tests and success criteria
- **Collect necessary data**
  - Managing stakeholders
- **Avoid doing "the engineer thing"**
  - What is necessary and what is nice to have



Maximizing EMT Simulation Benefit

- **Ensure the use of high quality and representative manufacturer-specific models**
  - EMT is just a simulation domain, bad models exist in all domains
  - For forward-looking and academic purposes different model types have good use cases
- **Ensure that the parameterization you study in EMT matches actual equipment**
  - A perfect EMT study with wrong parameters still results in an incorrect study
- **Ensure sufficient data is available for the study being performed**
  - If data of sufficient detail is not available, EMT simulations may not be “worth it”
- **Ensure that the submitted data is correct**
  - Can be extremely difficult to spot incorrect data
  - Comes through engineering judgement and experience
- **Leverage EMT simulations in addition to other analysis methods**
  - Performing analyses in multiple domains to maximize efficiency

Fundamentals of IBR Plant Model Construction

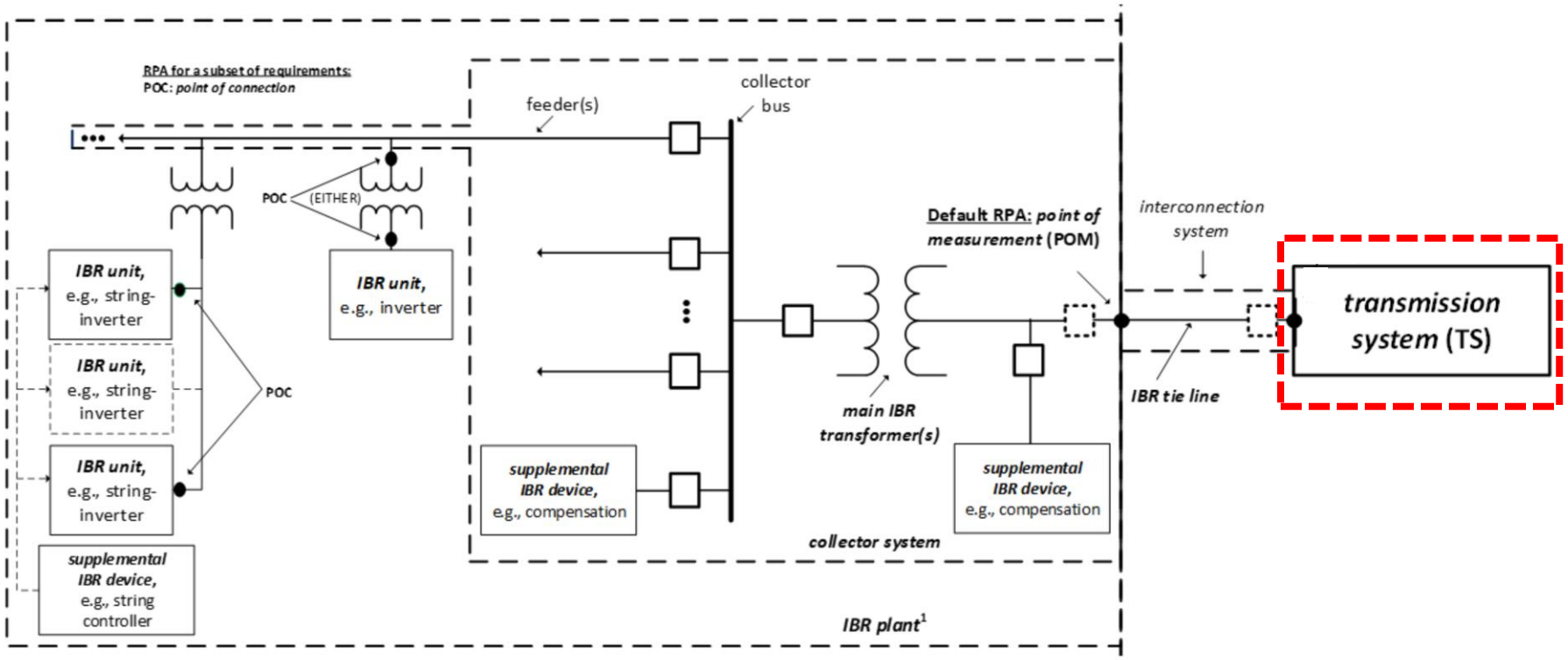
- **What is the purpose of creating IBR plant models?**
  - **At a high level:** To represent the behavior of the IBR plant during normal and abnormal conditions
    - We need to know how an IBR plant will behave under certain conditions and stimuli
  - **Digging in:** There are numerous ways to represent an IBR plant in EMT including:
    - Aggregate
    - Disaggregate
    - Generic/standard
    - Vendor-specific
  - **Key consideration:** How you represent the IBR plant in the model space should be considered based on the goals and purpose for the study work being conducted
    - **Choose two of the following:** (1) Quick study (time and computation); (2) Accuracy; (3) Cost

Introduction to Plant and Equipment Data

- **A model is only as good as the data that goes into it**
  - A study cannot provide accurate results if the model does not represent the equipment
- **Not all stakeholders involved in the data collection process are technical experts**
  - Modeling and study engineers need to know how to ask for data in the right way to get the right information
  - Engineers also need to build judgement to assess and spot check data
- **Experience in the PSPD processes is transferrable to the EMT space**
  - EMT simulation is an extension of the study process and not an entirely new concept

Components of an IBR Plant – Transmission System

You very likely will NOT get a transmission representation in the EMT domain. (There are a few exceptions)



- Equivalent networks are used in place of the transmission system
- Single machine infinite bus (SMIB) are often used
  - Can be adapted to approximate some TS conditions:
    - SCR
    - X/R ratio
    - System impedance
  - Often represented as a “test bench”

Source: Adapted from IEEE 2800-2022

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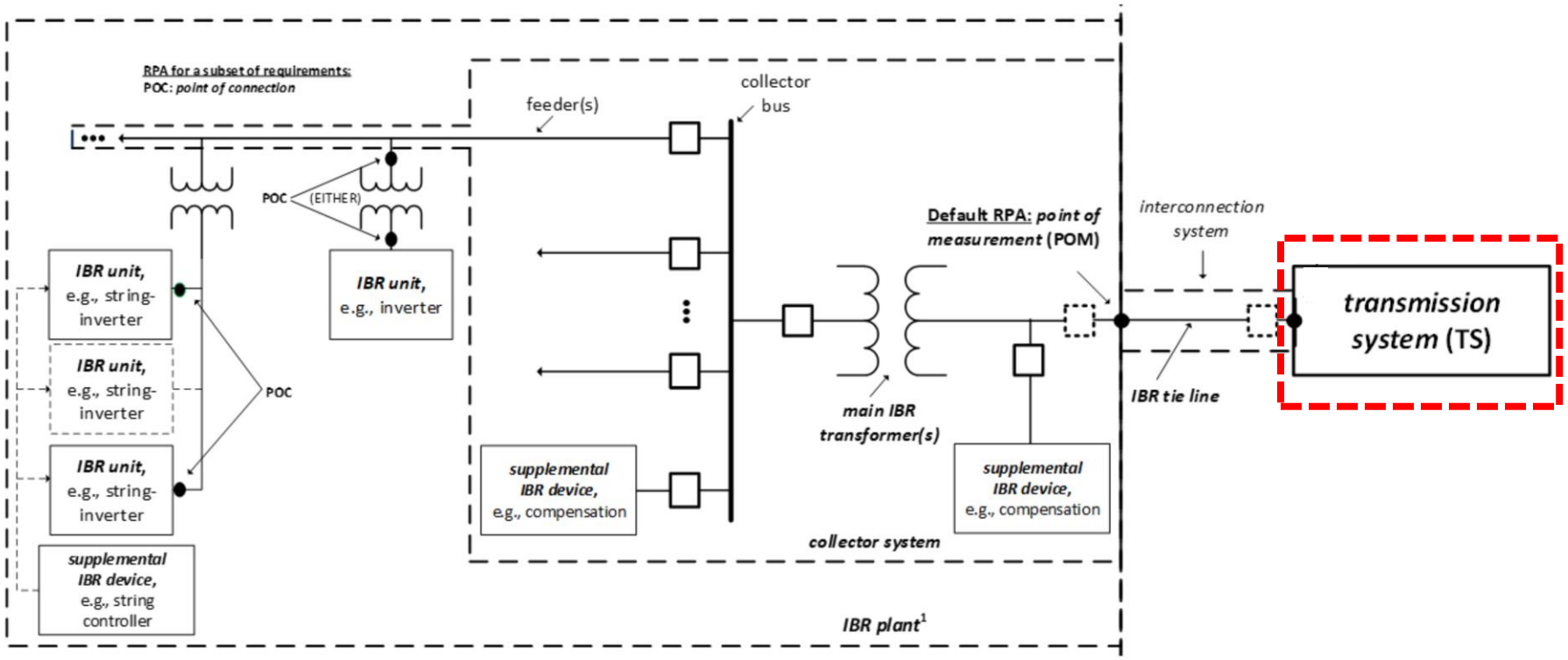
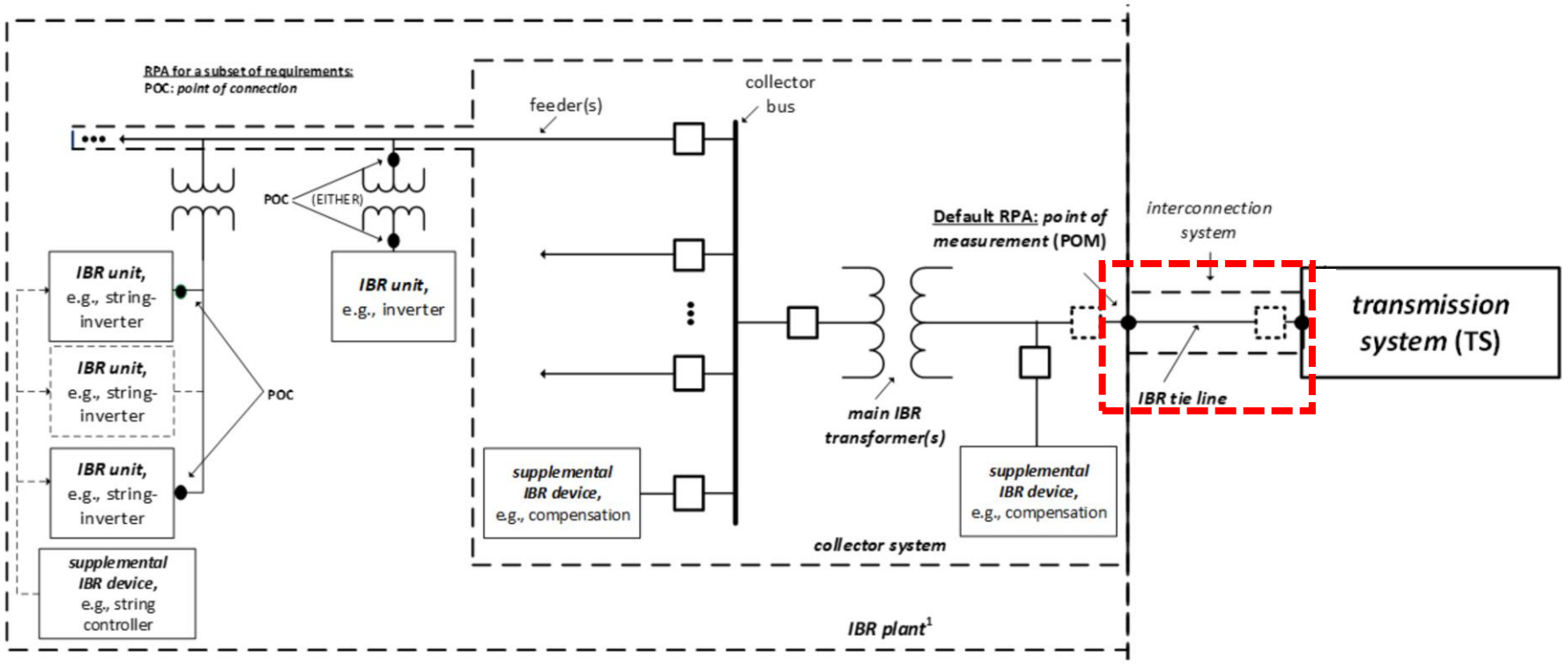


- Strong driver for the need for cross-domain simulation
  - EMT for complex plant analysis, PSPD to ”check”
- Co-simulation options exist
  - Not a perfect solution
  - Many technical and practical limitations
- Small portions of the TS may be used with equivalized boundaries

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – IBR Tie Line

IBR tie lines are often ”ignored” due to typically very short lengths

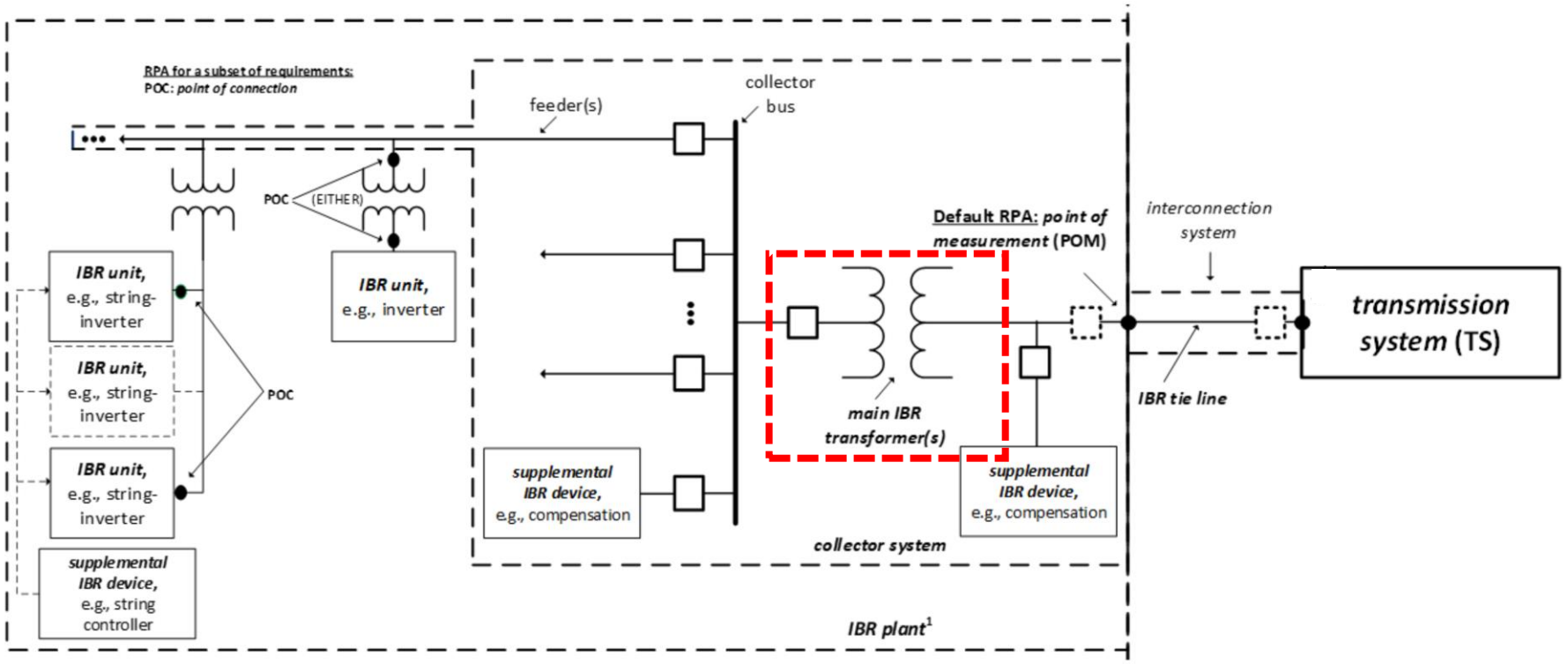


- Many IBR tie lines are extremely short (hundreds of feet) and their impedance is often not included
- Tie lines are important outside of just their impedance
  - Different regional requirements apply at sending or receiving end of tie line
  - Tie lines are often used for controller feedback in the model space
- How much detail do we need in the EMT space?

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – Main Power Transformer

Main IBR transformers: also known as main power transformers (MPT) are frequent causes of incorrect representation

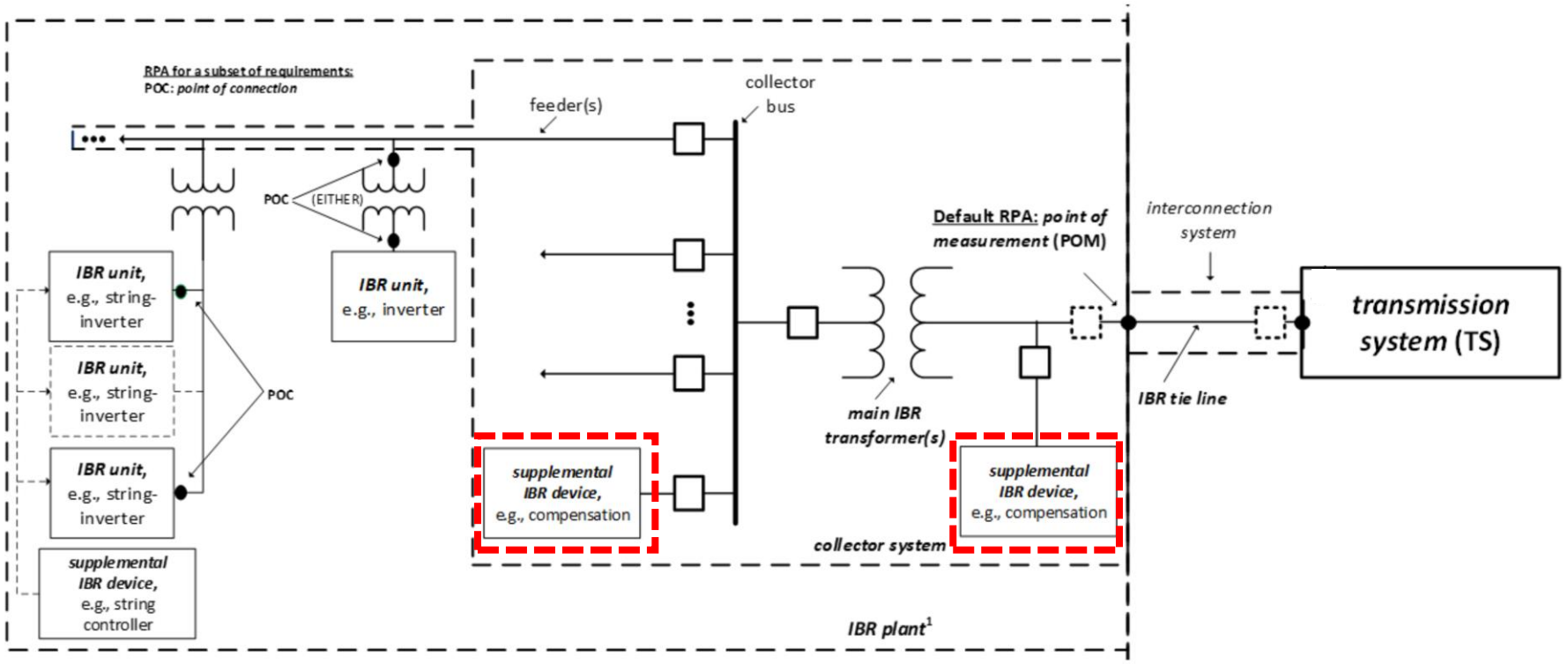


- MPT are important control devices at the IBR Plant
  - Offload tap changers
  - Onload tap changers
    - Deadbands, step size, step number
- Transformer characteristics are crucial
  - Impedance base in the software may be default or specified
  - Transformer documentation can be confusing
  - Prone to data errors when moving between software tools
  - **Some characteristics may not be in test reports**
- Simulations often are not run long enough to incorporate MPT dynamics
- **Very important to confirm parameterization between EMT, PSPD, and data sheets**

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – Supplemental Devices

Supplemental devices are often critical when representing IBR performance and capability

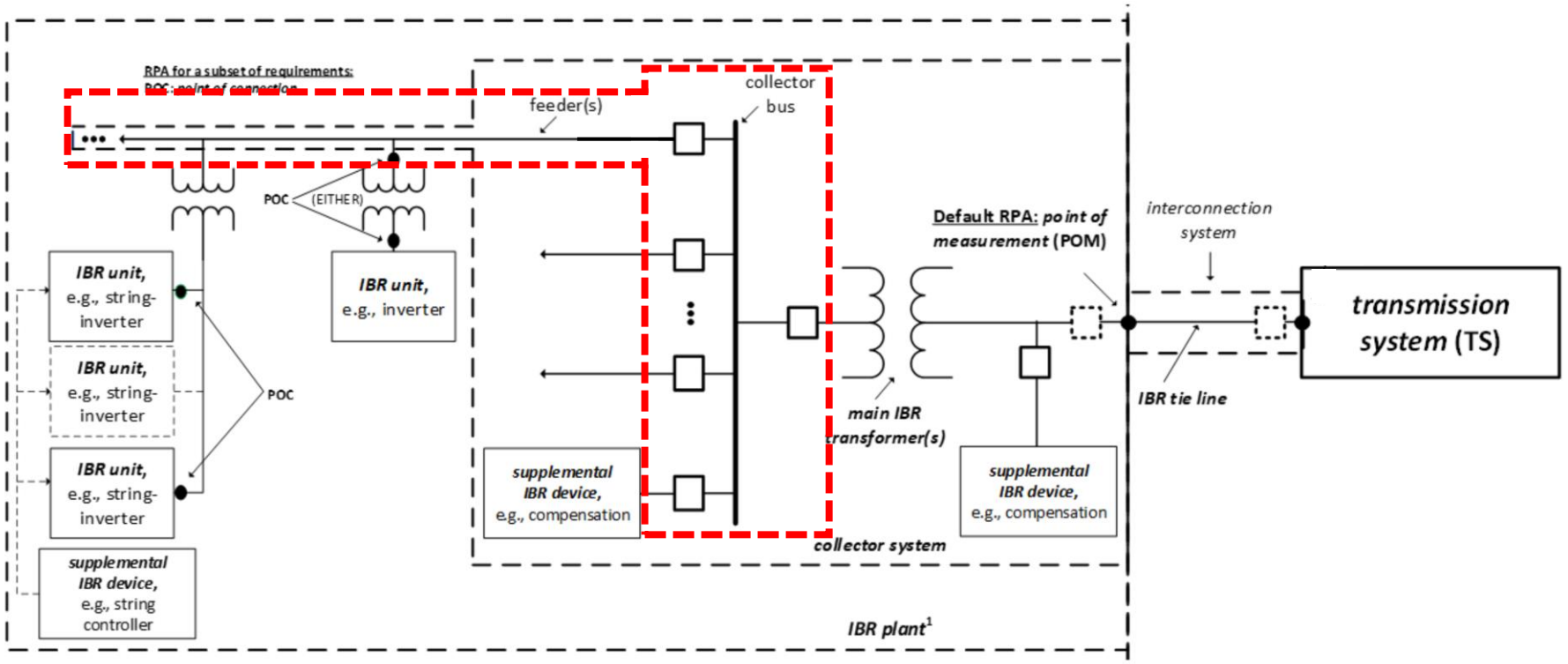


- Supplemental devices add additional capabilities to the IBR Plant design
  - Fixed shunts (capacitors or reactors)
  - Switched shunts
  - Communication devices
- Important to collect this data to maximize EMT benefits
  - Communication protocols
  - Time delays
  - Sample times
- Control hierarchy and communication
  - What is the main controller
  - Does this require additional equipment
- Managing manufacturers, consultants, and developers data security needs

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – Collector System

Collector systems vary widely among different types of IBR plants, but general layout is the same

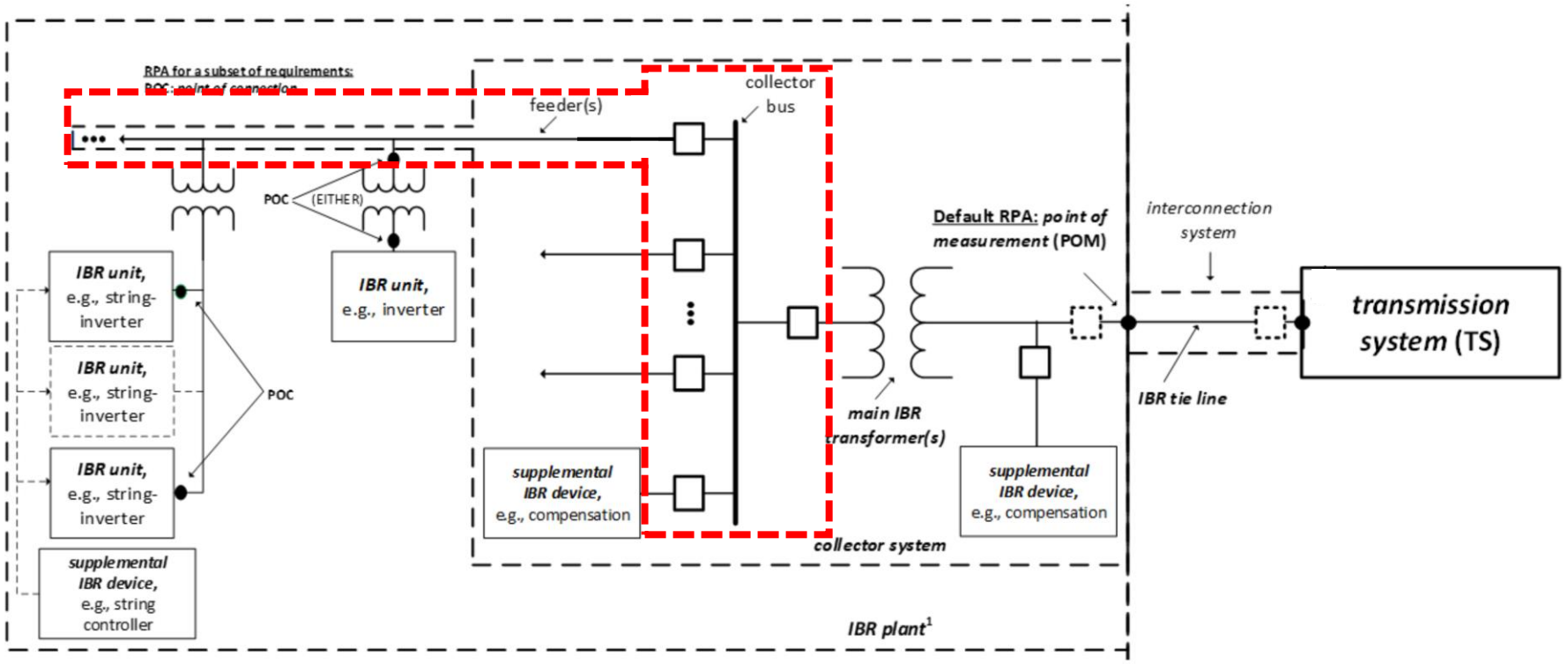


- Composed of numerous components
  - Substation collector buses
  - Cable sections and junctions
  - Protective relays
- With so many components, errors are easy to make
  - Incorrect cable types
  - Incorrect distance data
  - Problems with in-house automation and aggregation

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – Collector System

Cautionary example: Modeling lines in EMT

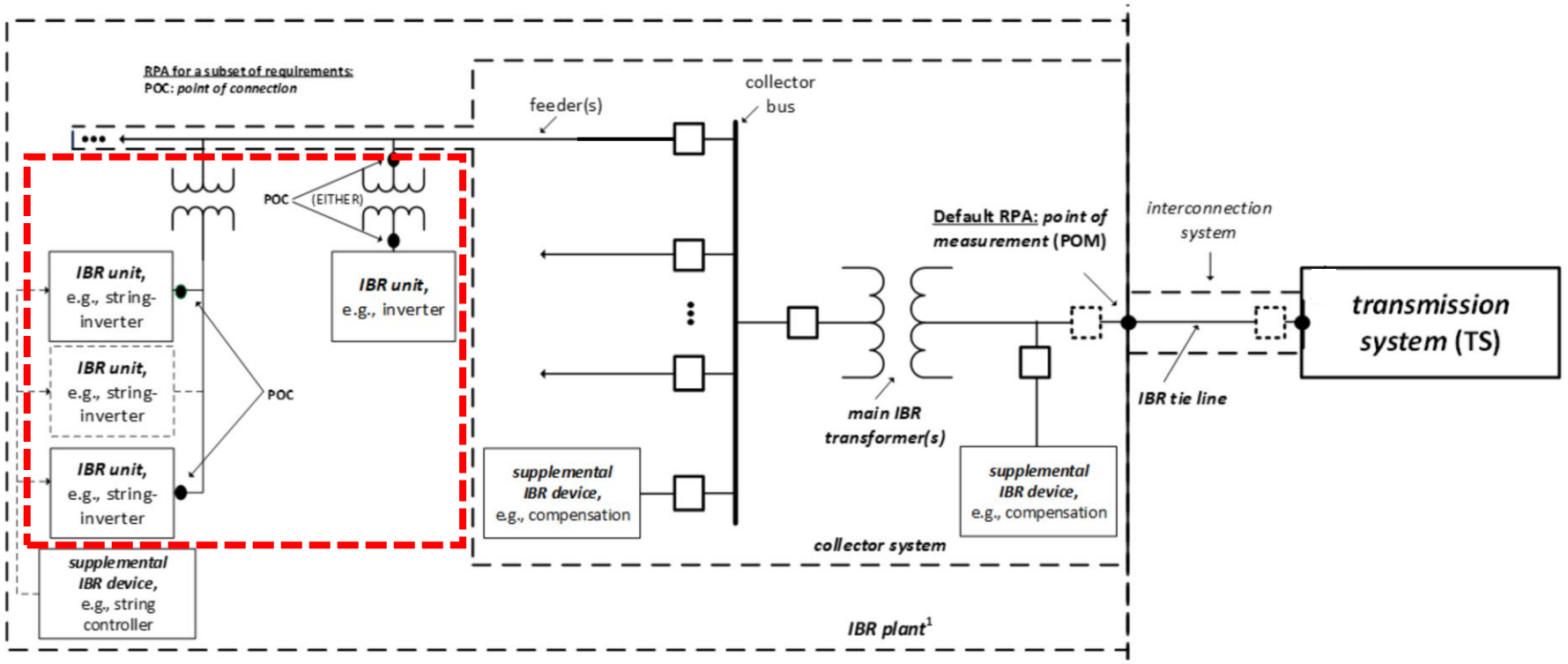


- Lumped parameter models
  - RL coupled
  - PI-section
- Distributed parameter models
  - Frequency independent
  - Frequency dependent
- **How long are collector lines typically?**
- **What phenomenon are you studying with a plant model?**

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – Inverters

Easy in the steady state, much more difficult in dynamic simulation



- **"Inverter" means OEM provided equipment**
  - Could include in inverter model and generator step-up transformer (GSU)
  - Could have this information included in one component and connect directly to collector voltage
- In steady state: inverter models are relatively simple and are comprised of easy to transpose data from the OEM
  - Represent capabilities of the inverter
  - Contain the correct data to link to dynamic models
- In dynamics:
  - Actual performance must be represented based on level of detail and type of study

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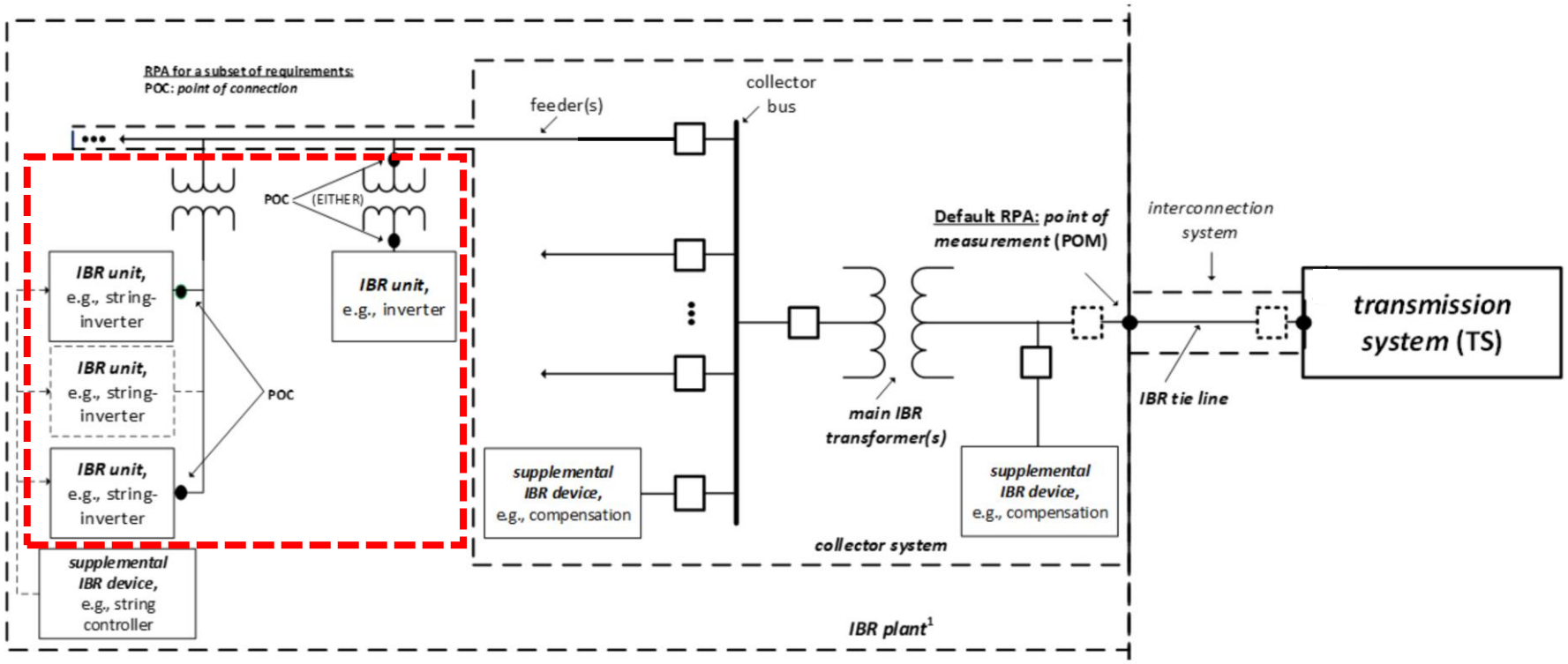
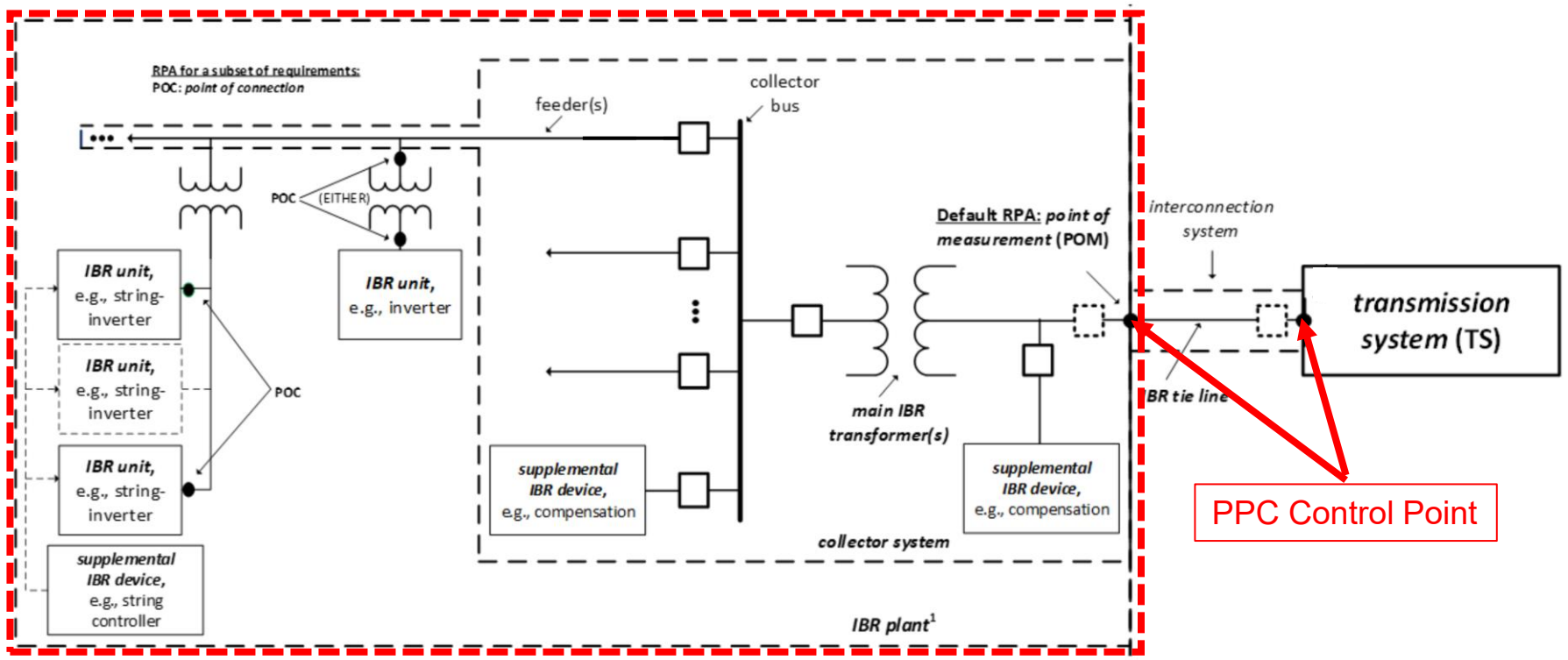


- **Important to know what has been provided in EMT**
  - Often models are provided from manufacturer with an "example" collector and parameterization
  - No two plants are identical
- **Is the model of the right equipment?**
- **Is the model the correct software version?**
- **Does the model include all manufactures as expected?**

Source: Adapted from IEEE 2800-2022

Components of an IBR Plant – Plant Controller(s)

Power plant controller(s) work to operate the IBR plant during normal operations and coordinate plant-wide performance



- Not included in steady state models
- May be standalone controller or part of multiple PPC control scheme
  - Needs to also coordinate with supplemental devices and MPT controls
  - Difficult to manage multiple OEM and control vendors
- **Critical to have high quality documentation**
  - How values are calculated
  - How to set up measurements

Source: Adapted from IEEE 2800-2022

Wrap Up and What's Coming Next

- Most important pre-requisite is **if an EMT study is needed**
  - There are many needs and use cases for EMT
    - Stakeholders need to understand their system and trends to prepare for the changing study paradigm
- EMT studies are resource intensive so it's important to maximize benefit
- Data needs (more) scrutiny

What's coming next:

- EMT model creation and model benchmarking