# Overview of Electromagnetic Transient Model Requirements for Inverter-Based Resources

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## 1. Research Background and Objectives

As the proportion of inverter-based resources (IBRs) in power systems rapidly increases, these resources reduce the overall system inertia due to their lack of inherent inertia, negatively affect traditional protection schemes because of their unique fault current characteristics, and can cause sub-synchronous and low-frequency oscillations resulting from interactions between their controllers and the power network. To accurately analyze and predict system behavior following the integration of IBRs, electromagnetic transient (EMT) simulation has become an indispensable analytical tool. However, practical challenges remain with current EMT models, including complex model structures, insufficient model quality and information, and confidentiality constraints. Therefore, establishing clear and rigorous requirements for EMT models can help standardize simulation practices. This research systematically presents the development and validation process of EMT models for IBRs, providing an overview of model requirements specifications, model verification, model quality testing, and validation methods.

## 2. Research Results

### (1) Development and Verification Process of EMT Model for IBRs (Figure 1)

The process begins with the original equipment manufacturer (OEM) leading the equipment model development phase. An EMT model is built based on the inverter's actual circuitry, control, and protection systems. This model is then validated using the results of type testing. Subsequently, the plant owner utilizes these validated equipment models to develop and assemble a plant-level EMT model.

Once the plant-level EMT model is completed, it is submitted to the utility and enters the model quality testing phase. A system impact study is then conducted to assess the potential impacts of the proposed inverter plant on the power system. When all the above steps are completed and the results meet the required specifications, construction and grid connection of the new IBR plant can begin.

After the plant is built, commissioning tests are conducted. At this phase, the plant-level model is validated by comparing simulated results with field measurement data. If the simulated performance does not match the performance observed during an event, the plant owner should provide an updated model in accordance with the utility's specifications and timeline.

### (2) EMT model Requirements Specification for IBRs

During the development phase of equipment and plant models, it is essential to define EMT model requirements in advance to ensure models are fully functional and of high quality. Currently, international power industries mainly use PSCAD as the simulation tool for EMT model development, with relevant standards and guidelines issued by

organizations such as Electranix and ERCOT (North America), AEMO (Australia), NESO (the UK), and IEEE 2800.

The requirements for IBR EMT models can generally be summarized into the following four categories:

A.  Model Accuracy: Whether the model can realistically reflect the behavior of the actual equipment to ensure accurate representation.

B.  Model Usability: The model must be easy to use and robust, allowing for convenient practical applications and parameter adjustments.

C.  Model Efficiency: The model must comply with software and version-related specifications to ensure computational efficiency.

D.  Model Documentation Requirements: OEMs and plant owners should provide complete model documentation and user manuals.

(3) Model Verification, Model Quality Test, and Model Validation

In the model requirements section, the characteristics that a model must possess are typically specified through textual descriptions. Therefore, verifying, validating, and ensuring model quality are critical. The following explains the key contents illustrated in Figure 1.

A.  Model Verification: Model verification primarily focuses on reviewing relevant documentation, equipment settings, model parameters, and structure. The parameters, such as electrical parameters, control gains, and protection settings, must remain consistent with those of the actual deployed system.

B.  Model Quality Testing: Model Quality Testing (MQT), also referred to as Model Quality Assessment (MQA) or Dynamic Model Acceptance Testing (DMAT), aims to ensure that the submitted model meets quality standards. A series of basic simulation tests, including typical test cases, is conducted using a specific architecture, such as the single-machine infinite-bus test configuration shown in Figure 2.

C.  Model Validation: At the equipment or unit level, model validation is typically performed in conjunction with type testing. These tests apply specific disturbances to the equipment under controlled conditions, such as voltage dips, frequency deviations, or other dynamic events, and record the resulting responses. The measured data are then compared with the outputs of the EMT simulation model to confirm the accuracy of the model parameters and control and protection logic.
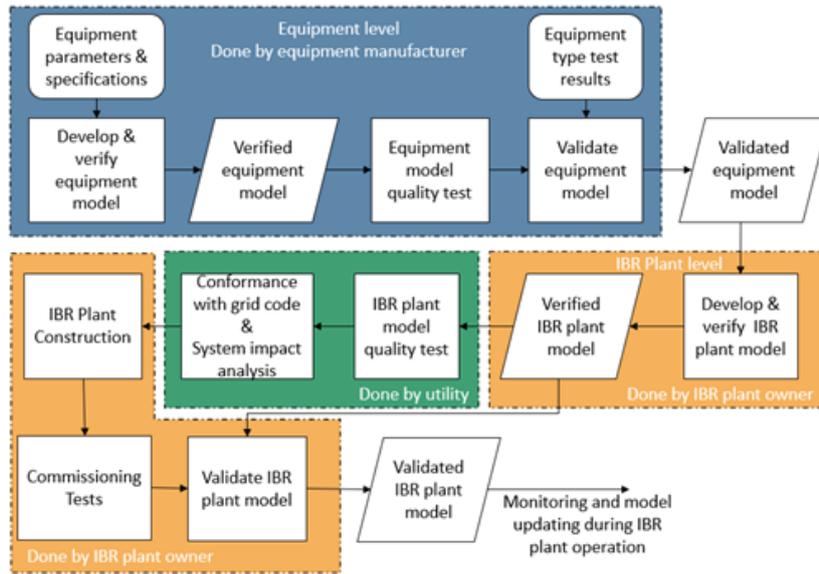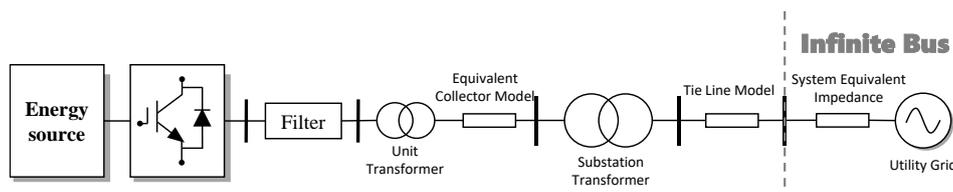
Source: Drawn by authors

Figure 1. Development and verification process of electromagnetic transient model for inverter-based resources

## 3. Conclusion

International experience indicates that the absence of rigorous model requirements, multi-level checking, and validation procedures compromises the reliability of system analysis and decision-making. Therefore, this research recommends that utilities establish a unified, mandatory EMT model management framework that encompasses model requirements, quality testing, version control, documentation transparency, and continuous monitoring mechanisms during operation. Furthermore, technical collaboration should be encouraged among OEMs, project developers (or plant owners), and utilities to balance the protection of commercial confidentiality with model transparency. Continuous collection of operational data should also be utilized for dynamic model updates and revalidation.



Source: Drawn by authors

Figure 2.    Single Machine Infinite Bus (SMIB) architecture