



# CIGRE Reference Paper : The need for enhanced power system modelling techniques and simulation tools

**B. BADRZADEH, C4.56 Convenor (AU) and Z. EMIN, SC C4 Chair (GB)**

---

The transition to a clean energy future requires thorough understanding of increasingly complex interactions between conventional generation, network equipment, variable renewable generation technologies (centralised and distributed), and demand response. Secure and reliable operation under such complex interactions requires the use of more advanced power system modelling and simulation tools and techniques. Conventional tools and techniques are reaching their limits to support such paradigm shifts.

## Emerging types of power system simulation models

Power system simulation models can be broadly divided into static and dynamic models. Root mean square (RMS) dynamic models have been the most widely used type of dynamic models for assessing most power system technical performance issues of classical power systems, from a planning and operations perspective. These models cannot represent the sub-cycle phenomena and control systems associated with the controls of inverter-based resources.

These limitations often manifest themselves when the phenomenon of interest has a dominant frequency deviating by more than  $\pm 5$  Hz with respect to the network fundamental frequency, or when the system strength available to inverter-based resources approaches close to or drops below their withstand capability. The latter situation applies even if the dominant frequency of interest is at or near the network fundamental frequency.

Electromagnetic transient (EMT) dynamic models can fully address this limitation, however, inclusion of significantly higher level of details generally results in a higher computational burden relative to the RMS dynamic models limiting their applications. Despite this, EMT models are being increasingly used in some countries for large-scale stability studies for operating scenarios with a high penetration of inverter-based resources.

EMT models can be divided into offline and real-time models. Offline EMT models are being progressively used by network owners and system operators for large-scale power system studies and are generally available from most major Original Equipment Manufacturers (OEMs). The use of real-time EMT modelling addresses some concerns regarding the speed of simulation for offline EMT studies. However, it is understood that the required software/hardware are not supported by many OEMs. The use of hybrid dynamic simulation aiming to combine the advantages of each of the RMS and EMT simulations has been recently implemented in some commercial power system analysis tools. These include hybrid RMS and offline EMT, or RMS and real-time EMT simulation.

## Modelling tools for planning and operational studies

Power system simulation models are used in a wide range of applications including long-term planning, connection studies, operational planning and real-time operations. Despite increasing applications of EMT dynamic models, both the static types and RMS dynamic models have strong roles in some applications, and this is unlikely to change in the near future. This stems from the need for faster speed of simulation for real-time and near real-time applications, availability of accurate and adequate data when looking at several years or decades ahead, or simply the need to conduct simulation studies in other tools, for example for most power quality studies.

## Model validation

Fundamental to all types of power system modelling approaches and plant models is model validation. Gaining confidence in the accuracy of power system models is paramount as these models are heavily relied upon for the development and operation of the actual power system. Model validation provides a measure of how accurate a given model is for the intended purpose(s). Different approaches are applied depending on the stage of connection project, country specific requirements, and whether the testing is initiated by the respective OEM or transmission/independent system operators. These include staged

testing on a complete generating system, e.g. full wind or solar farm, hardware-in-the-loop simulation of individual plant such as a wind turbine or solar inverter, or leveraging on data captured during system disturbances for aspects of the dynamic model where congruence between plant and model dynamic responses may be difficult to demonstrate until a network disturbance occurs, e.g. fault ride-through function of inverter-based resources.

## **Distributed energy resources (DER) and load modelling**

As DER levels grow, their behaviour becomes increasingly significant. The control systems in inverter-based DER may have settings that cause large numbers to act in unison, and the possibility of the mass mis-operation of large numbers of devices during power system disturbances poses a serious risk to system security. State-of-the-art RMS dynamic models of the DER has been recently developed. Activities are ongoing to validate these aggregate models against measured system disturbances. Operation under low system strength conditions with reduced levels of synchronous generators and increased uptake of the inverter-based resources, would increase the need for EMT dynamics models of the DER as well as the large-scale inverter-based resources.

There has been an increasing trend in deploying inverter-based loads in the distribution system as well as the inverter-based DER, both of which share somewhat similar characteristics and pose similar challenges to power system planning and operation. The validation and potential modification of the RMS dynamic load models, and their adaptation into EMT dynamic models is therefore expected to become equally important.

## **Concluding remarks**

The transition to a clean energy future will require the use of more advanced and detailed power system models and simulation tools in order to ensure the power system can be planned and operated securely and reliably. There is increasing evidence that EMT modelling will be required when studying the impact of inverter-based resources under low system strength conditions, including scenarios with high share of inverter-based DER and loads. RMS models of inverter-based resources may be unable to reliably predict control instability. Furthermore, control interaction studies are increasingly becoming a requirement for connection of inverter-based resources in parts of the network with low levels of available system strength.

The ability to conduct EMT simulation studies for large-scale power systems is also becoming a necessity in some jurisdictions who are implementing ambitious renewable energy targets. To date, EMT analysis has not been integrated in any control room environment for real-time assessments. These types of simulations are usually significantly more computationally expensive than RMS models. To address simulation speed issues associated with EMT models, state-of-the-art solution techniques are being progressively developed by software and hardware developers.

## **Further reading**

This Reference Paper is a very short summary of a longer and wider paper prepared by a small task force made up of members from SC C4 - System Technical Performance. This paper provides an overview of commonly used and emerging power system simulation tools and techniques and their applications, ranging from real-time power system operation to long-term planning.

Readers are encouraged to reach out and read the full paper in the flagship CIGRE Science & Engineering Journal's Volume No 17, February 2020 issue ([available soon on e-cigre](#)).

**[Download this Reference Paper : Reference RP\\_308\\_1](#)**