ESIG Webinar: EMT Modeling and Simulation – Who Needs an EMT Model for Doing Stability Studies?	
Question	**Answer**
If bandwidth of PDT is up to 10Hz, how come oscillation with frequency less than 10 Hz was not captured in PDT simulation in slide 15?	The phenomenon shown has an absolute dominant frequency of slightly less than 10 Hz rather than having a bandwidth of 10 Hz. The absolute frequency and bandwidth are two different things. As discussed PDT tools are not capable of representing harmonics and inter-harmonics, e.g. an absolute frequency of around 10 Hz compared to the network fundamental frequency of 50 Hz or 60 Hz.
Simulation time is a concern for large VLSI circuits as well in Cadence/Spectre. Are there techniques that are useful for IC sim that is useful in EMT sims?	Dividing the network model to several parts and assigning each to one CPU core, and assigning each IBR model to one CPU core are the commonly used methods for wide-area EMT modelling. Efficient use of the CPU is cirtical for both VLSI and wide-area EMT network modelling. As such techniques aiming to reduce the size of the matrix and make more efficient calculations, e.g. partionining, will apply to both applications, and can be learned and applied from one application to another.
Is it possible to develop real-code models that can work both in EMT and phasor domain, of course with disabling fast controls for phasor simulations?	Yes, it is possible provided that it is supported by IBR OEMs.
In your vision and from a stability point of view., can we have a 100% renewable based power systems?	Yes, provided that sufficient synchronous condensers/ pumped hydro storage systems, and grid-forming inverters are installed. Also note that correct operation of protection systems might be the binding factor rather than stability issues. This could require changes in existing protection philosophies/relays. Also as discussed answering such questions will require conducing wide-area EMT studies. The outcome of these studies could indicate the need for changing the parameters/control system designs of some of the inverter-based resources, or looking at system technical needs afresh rather than replicating the current power system technical requirements.
Do you know the difference between EMT studies in PS CAD and Power Factory? Is there a major difference?	The main consideration is whether OEMs of various types of IBRs will provide user-written models in these two tools and other EMT types tools.

The NEMO EMT model with 3000 nodes a 30 seconds simulation takes 3 hours. Such computation time might not be acceptable even for long-term planning studies?	With recent version of the EMT tool used in Australia the simulation time is approaching one hour for ~30 seconds simulation. The use of cloud computing will further assist. It is correct that running thousands of studies is not still practical in EMT. It was for this reason that we discussed in the webinar the role of screening methods in shortlisting the most important scenarios that need to be studied in detail rather than studying several hundred or thousand of scenarios.
How the frequency control can be coordinated between the two types of resources (inverter based and synchronous)?	Synchronous generators are most suitable for providing the inertia response and slow frequency control, i.e. several seconds to minutes range. IBRs are most capable in providing FFR, i.e. sub-second frequency response. The coordination can be performed this way as two generation technologies come with complementary capabilities with regard to the frequency control. Grid-forming IBR can provide both inertia and fast frequency response. However, all IBRs are current limited devices and it might not be best to always use grid-forming inverters to provide virtual inertia.
Are the harmonics provided in IEC 61400-21 reports for WTG accurate enough? Do EMT studies performed before connection harmonic wise reflect real operation?	One of the min influential factors is the grid background harmonic and its variable nature. This cannot be captured in the type of reports provided by the OEMs. Also harmonic emissions can vary as function of the network short circuit ratio. EMT models can be used for harmonic studies in theory. However, most models provided by OEMs do not include the PWM switching logic which is the key contributor to harmonics. This is because the EMT models accounting for harmonic response of the IBR are even significantly slower than the EMT dynamic models. Also if EMT models are used for harmonics studies, all these models should include the PWM switching rather than just some of them. For these reasons whilst it is theoritically possible to use EMT models for harmonic studies, their application for system wide harmonic studies have been very limited to date.
Is there a need to model specific protection schemes (distance relays, oc relays, etc.)? Or specifying the normal or delayed clearing time is sufficient?	It is becoming more important to model some of the protection systems especially impedance based relays in power system dynamic simulation. This is because low network fault level might mean that the relay will operate where it should not or does not operate where it should. Also relays sensitive to or relaying on negative-sequence current could be impacted due to high IBR penetration.

You mentioned black start in response to another question. Can you explain any special considerations you might need when study a black start in an EMT study?	Please refer to the paper entitled ''Tools and Techniques for System Restoration'' published in CIGRE Science and Engineering Journal, issue 20, February 2021.
Lack of good load models either in phasor or EMT make both methods to be not very accurate so maybe better to stay in phasor?	The WECC/NERC load models are equally good for EMT or PDT models. As discussed if say 20-30% of the total generation is distributed IBR such as rooftop PV, then dynamic modelling of these distributed IBR will become important to the same level of details commonly used for grid-scale IBRs. This may not be possible with PDT tools. Also while load models are important, they don't generally influence the interaction between the control systems of multiple IBRs which as discussed it is generally studied with EMT tools.
why do you use RMS not EMT in the text part I the previous slide?	The term RMS is a sub-set of what we are talking about. Phasors have magnitude and phase angle not just the magnitude.
Could you please tell us something more about the spike in the PDT model? This is something we are seeing now in our simulations with high IBR penetration	Usually these are caused by abnormal behaviour of integrators in PI controllers. They often occur when the fault clears and as the voltage is recovering to the pre-fault value. Anti-wind-up control of integrators will certainly help. Many different and sometimes complementary approaches have been applied by various OEMs.
Is PMU principal similar to the phasor domain modelling?	PMUs are actual hardwares capturing the magnitude and phase angle of a given quantity, e.g. voltage. They can provide excellent information for validating power system models after a natural system disturbance occurs. However, PMU is not a modelling tool by itself unlike the PDT or EMT tools for example, but more of an enabler for more gaining more confidence in the accuracy of the overall power system simulation models.
What publicly available resource(s) would you recommend for a primer on the basics of real RL circuits and EMT stability modeling?	Technical Brochure for CIGRE WG C4.56 will be published in the next 3 months or so. Also CIGRE 2021 Workshop entitled: ''EMT analysis for large-scale system impact studies in power systems having a high penetration of inverter connected generation''. With regard to the books on electrical transient analysis, suggest the books by Greenwood or Das.

What are preferred techniques to avoid post-fault voltage spikes in PDT models?	Anti-wind-up control of integrators will certainly help. Many different and sometimes complementary approaches have been applied by various OEMs. 1) Initialising the controller integral to a desired value, for instance to the value before the fault 2) Disabling the integral function until the process has entered the controllable region 3) Preventing the integral term from accumulating above or below pre-determined bounds 4) Back-calculating the integral term to constrain the process output within feasible bounds

