User Spotlight Series 2.0: Q&A Document

Episode 3 – March 23, 2022

<u>"Development of a Digital Twin Simulation Wind Turbine and Power Plant Controller Model in RSCAD, Based on Microsoft Windows Dynamic-Link Library Code Integration by Using IntervalZero"</u>

Answers provided by RTDS Technologies and Vestas Wind Systems

Q: When comparing PSCAD results against RSCAD results some of the (very small) differences are presumably due to the different ways the converters are modelled and not all due to the fact that the controller is being executed on a DLL, correct?

A: The small difference is likely due to slight modelling differences which could be resolved with further effort. The same controller code was used for PSCAD and RSCAD for those results – the only difference was that a DLL file was used for PSCAD and LIB file was used for RSCAD. Additionally, there might be slight differences in the way of simulating/modelling the passive components of the grid equivalent in the case setup.

Q: Does the DLL modelling approach used by Vestas support only EMT type simulations? (e.g. including switching mode of power electronics) Or is it also possible to use the same DLL model to run average simulations (e.g. to simulate power electronic components at a potentially larger time step)?

A: The Vestas DLL model supports both detailed IGBT model switching and Average EMT source modelling. The main difference between 2 will be the required time step of the simulation. However, user is not free to select one or the other without Vestas guidance/approval.

Q: What is the interface between the RTDS Simulator and Windows/RTX based on, and how do you ensure the interface/communication is in real-time? Is the interface/communication latency tested before simulation? Could you guide us letting us know any corrections one needs to do in the control model to accommodate latencies in the interface/communication?

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A: The interface is via UDP. The loopback time of UDP is around 20 usec. The project was using a time step of 100 usec, so the communcation delays from UDP are acceptable.

Q: Usually PSCAD models and associated DLL are developed some time ahead of factory testing and commissioning. Use of this software in the loop approach provides new flexibility to combine in-development projects and commissioned projects into the same simulation environment to examine their interaction. Do you see this approach being used further in future projects that are staged/complex in design?

A: Indeed. Electrical simulation models have different maturity and stages, from prior the actual product built to the product commissioning and certification. In a new product, control code is developed ahead the final product, with this approach model can follow the exact same maturity as the product. From its design to its validation. It is the only way to de-risk projects' commissioning.

Q: In applying your control code to a real time environment where real time signals are sampled/filtered and there are latencies in communication and response, did you encounter any new challenges in interfacing the code developed offline to the real-time? Aso beyond the user needs, do you see benefits from having these models available; e.g. control transition design?

A: The main challenges in integrating the DLL into the real-time environment are related to computational power and memory that are required to run the code in real time. Some others are more into the performance of the model, related to library components that are not identical between the offline and real-time environments. On top of this, the real controllers have a discrete timestep that you need to adapt somehow when running a real-time simulation with a specific timestep. So, there are multiple challenges here. But a hybrid approach, using both software- and hardware-in-the-loop, will be very beneficial for grid operators in order to understand and tackle/mitigate some control interactions, such as weak grid situations, power oscillation damping, sub synchronous resonance. Using this hybrid approach, you could have a neighboring plant represented in the simulation, with a different vendor's hardware connected in the loop.

Q: What is the time step for execution of the DLL model?

A: The timestep could be variable and will depend on the number of instances and computational power memory. For this project, we have used a timestep of 100 microseconds.

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Q: What does 'UMF' stand for?

A: It is an internal Vestas term that stands for Unified Model Framework.

Q: Can I ask if the real time model is running on a standard desktop PC or dedicated controller hardware that you would typically see in a turbine?

A: For the SIL integration, the controller code is running on a standard PC with higher specs. 10 GEN Intel running on 7 cores at 3.6 Ghz.

Q: What is the benefit to having these DLL based models available with the RTDS if you already had this option with PSCAD?

A: The real-time model allows for hardware-in-the-loop (HiL) testing. A hybrid SiL and HiL approach will extend the capabilities of grid operators to assess potential grid connection issues using real controllers from different OEMs.

Q: Do you see use of these software in the loop models in real time having the potential to improve the functionality and detail in offline EMT models – given you can validate them and their functions in real time and in re-play of those real-world conditions?

A: Indeed. This is an additional tool to validate the offline EMT model. As an example, this is the approach being taken by CEPRI in China, where vendors are required to provide both a software- and hardware-in-the-loop models. This will be a great approach in the future for validation in situations where measurements are too limited/restricted.

Q: Is it possible to run the DLL on an FPGA?

A: DLL and LIB files need to run on a Windows OS. Some FPGAs include an arm processor which can be used for this purpose. In these cases, the code can be compiled to a ".a" or ".so" file and then run on the FPGA's arm processor.

Q: Please give a comparison between two solutions for modeling: modeling based on real-time SiL/HiL and modeling based on an offline model program (like PSSE/EMTP…).

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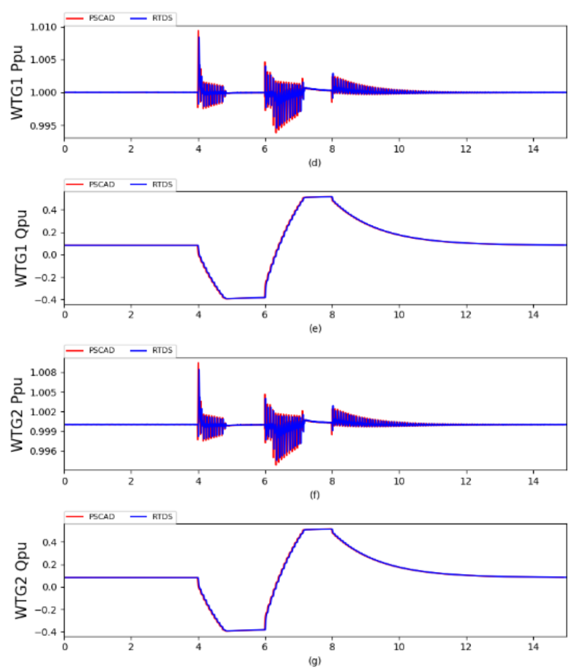
A: In terms of modelling approach/power system solution, the comparison here depends on the particular offline program. PSCAD, for example, performs offline electromagnetic transient (EMT) simulation, which will yield very similar results to the RTDS Simulator (real-time EMT simulation). PSS/E is based on a load flow analysis which can be useful for transmission planning but does not provide the level of detail available in real-time or offline EMT simulations. SiL/HiL testing is only possible with real-time simulation which uses dedicated processing hardware instead of a standard PC. HiL testing gives insight into the actual behavior of a device as well as the interoperability of multiples devices connected to a specific network.

Q: On Slide 9, the Case 3 plot (showing the Q ramping) indicates spikes in the RSCAD results, What is the reason for these spikes?

A: Vestas – This was a mistake when extracting the plots for the presentation. It was a bug fixed during the implementation of the model and the latest results does are not showing such spike.



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Q: There are several processes on the highest priority in kernel. WTG DLL model after setting the highest priority called at each step of model simulation is set in queue of system processes. It means that some of the steps can have a pretty big delay which influences the quality of the simulation. What time step can you achieve in the DLL-model in Windows system?

A: The UDP communication has a loopback of around 20 microseconds, so this will impact the minimum time step supported. Likely the time step should be limited to 50 microseconds. WIth Interval Zero, the windows OS will not interfere with the cores that are allocated for the DLL integration.

Q: Is each step calculation triggered by Windows system interrupt service controlled by system clock?

A: On the Interval Zero side, the turbine code is triggered when it receives data from NovaCor. There is a little jitter from timestep to timestep, and jitter can increase with more instances of the WTG. A single instance has a full loopback delay of around 26 microseconds. With 4 instances, the loopback increased to around 42 microseconds. This would also be heavily dependent on the PC hardware specs.

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“Development of a Co-Simulation Test Bench for Power System Studies with HIL and PHIL”

Answers provided by RTDS Technologies and Friedrich-Alexander-Universität and the Karlsruher Institut für Technologie

Q: Could you please give some pointers on how you would ensure overall stability of the distributed RT simulation in presence of a two-digit ms delay, especially when doing HIL?

A: In general, it’s a good idea to choose a coupling point that isn’t too close to the events of interest, especially to the hardware that you want to connect in the loop. For HIL, the distributed coupling is usually not a good solution, as has a very limited bandwidth. Furthermore, you would usually try to handle faults in one local system in order to keep the whole system stable.

Q: Have you thought about doing a frequency domain sweep and understanding across that frequency dependent network transfer impedance and current control resonance of inverters what frequency of interaction may exist- then selecting points of co-simulation interface where the latency will not affect that interaction frequency behaviour?

A: We have not taken this into account yet, but it is a very good idea and we will look into it.

Q: I am familiar with the VILLASnode from ACS – great initiative! I am just curious on the recent contributions compared to the work done some years ago. Could you please point me to the differences or incremental developments from the teams involved?

A: I am not familiar with the state of VILLAS from a few years back, but I think the general implementation pretty much stayed the same. Improvements that I recognized during our usage (in the last 2 years) were mainly in documentation, configuration, and platform compatibility.

Q: How much is the usual latency from VILLASnode + the distance between K and E?

A: Around 10 ms total latency.

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Q: What is the fidelity of the distributed real time simulations? Have the results been compared to a simulation performed in one location using one simulator or even offline EMT simulation?

A: We did not validate it in this case. However, we have done another study on exactly this topic. Essentially the results indicated that it's a bad idea to have fast dynamics near the coupling point, but for events further from the coupling point, results correlated well. (https://ieeexplore.ieee.org/document/9621665)

Q: In the co-simulation environment – are you modelling wide area control optimisation, and if so, do you then adjust the latency within communications to offset real-time delays or are they not sufficiently sizeable to worry about this?

A: We are not modelling wide area control within the distributed simulation.

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