Electranix Advanced Simulation Lab (EASL)

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1. Background

The penetration of IBR (Inverter Based Resources) such as wind/solar (as well as HVDC, SVC, STATCOM, Battery Energy Storage (BES) etc.) is accelerating rapidly worldwide. This is often accompanied by retirement of conventional coal-fired synchronous generators and other sources of inertia and system strength. This results in a lowering of the SCMVA (Short Circuit MVA) and SCR (Short Circuit Ratio or related WSCR/CSCR etc.) - i.e., the system is becoming weaker, and devices with complex controls and protection are now commonplace.

Accompanying the increase of complexity in the grid, is a corresponding increase in the complexity of power system simulation. Traditional RMS tools (i.e., transient stability tools like PSS/E, PSLF, DigSilent) are still used for full-system analysis, but do not have the accuracy or capability of modeling some grids, and are rapidly accompanied by EMT tools (i.e., PSCAD). Tools like E-TRAN are used to convert powerflow and transient stability models into PSCAD and maintain databases of EMT models that are aligned with the RMS base cases.

Several grid characteristics trigger the need for EMT analysis, including:

- Weak systems.
- Systems with numerous IBRs close to each other.
- Systems with high transient over-voltages or sustained under-voltages.
- The need to verify ride-through (i.e., testing protection and controls).
- Projects near series capacitors (and associated SSCI/SSTI/SSR and ride-through concerns).
- Harmonic concerns.

EMT simulation models for IBRs are now almost 100% based on the real-code approach (i.e., OEMs compile their source code from the field firmware to a DLL and call this from PSCAD) [1]. The controls and protection are virtually identical to what is running in real hardware, complete with every gain, controller and protection settings, sample times etc. This level of modeling is important for many of the above studies - a joint working group between IEEE [2] and CIGRE [3] is setup to standardize a method of interfacing to the real-code via DLLs (so the models can be used in any simulation tool).

It is now also common that other advanced EMT simulation techniques are used - this adds capability, but also extra complexity and software licenses. This includes:

- Parallel processing (to increase the speed of the simulations).

- Hybrid or co-simulations (i.e., running RMS and EMT tools in the same simulation) to interface between different simulation tools.
- Scripting and automation.
- Automatic processing of plots and creation of results tables/spreadsheets.

This complexity (and need for real-code models) has created a new problem – confidentiality. In many cases, the OEMs are not able to run full grid PSCAD models because they are not able to obtain models from other competitors/suppliers.

Electranix has >20 engineers who do this type of work every day and offer training and setup services. This paper describes the Electranix Advanced Simulation Lab (EASL), which solves the fundamental problem of sharing confidential models and offers a ready to use lab for advanced simulation studies.

Example cases where EASL has been deployed are presented at the end of this paper.

2. NDA Issues

The use of real-code brings clear accuracy advantages, but also brings privacy/software security concerns - NDAs (non-disclosure agreements) are required for many of the real-code models. Although the source code is not visible in the delivered models (i.e., DLLs are in a binary format) the concern is that the model could be reverse-engineered or probed to understand its capabilities. NDAs are sometimes avoided if the models are sent to utilities (who could have model requirements without the use of NDA restrictions) but are often required by consultants or others who require access to the models.

The impact is felt most by developers and OEMs, as one OEM often will not allow its models to be used by other OEMs/competitors. This means that a wind turbine supplier will not be able to perform adequate studies if there is nearby equipment from other suppliers - or similarly a multi-terminal HVDC link using equipment from 2 or more suppliers cannot be studied adequately. They can be blind, and unable to tune/adjust their controls for optimum behaviour.

One common workaround is that a third party (consultant or utility study engineer) can perform all simulations, can generate traces/plots from each project and send them to each OEM separately. This process is sometimes workable, but can be time-consuming and in-efficient, as there are communication delays (via email etc), size restrictions on transfers and other limitations. In some cases, the OEM may be able to determine the cause of the problem by looking at traces, suggest setting/controller changes, and finally forward these back to the simulation operator for testing. Due to time zone and other challenges, this often results in a turn-around time of 1 case per day (compared to running many iterations/tests in a single day if access to the full model was possible) or may not work at all.

3. Computer Hardware and Software Setup Concerns

Developing a computer and environment suitable for power system simulation is not trivial. Large companies are reluctant to customize a computer for individual users (and prefer to copy/paste OS images, complete with a standard but limited set of software). There are inherent complexities in IT setup - security, firewalls, anti-virus software etc. that may all require setup/customization. The simulation tools also often have requirements for compilers (Fortran or C) - older models (that use static linking of .lib or .obj files) are famous for IT requirements of certain combinations of C and/or Fortran compilers (and environment variable setup for PATH, LIB and INCLUDE etc.). Similarly, 32-bit vs 64-bit support varies between tools and models.

Another hurdle is that is now becoming commonplace to require cyber-insurance to protect the IP (Intellectual Property) of others and to protect against fraud, ransomware attacks etc. Security audits shall be implemented.

Even the computer hardware itself may be a limiting factor (some simulations now require multiple multi-core computers to run simulations with >100 processes!).

Software licenses can also be challenging and expensive (some licensing schemes are certificate based so help in this regard, but setup and maintenance is still required). Annual maintenance fees and initial licensing costs can be expensive. Licenses for PSCAD, PSS/E or PSLF, hybrid interface options, E-TRAN, parallel processing, compilers etc. may all be required for some large/complex simulations (in addition to the expertise to use/run these tools!).

4. The EASL

The Electranix Advanced Simulation Lab (EASL) allows OEMs and other users to participate in simulations via secure means, while preserving confidentiality of the models. It achieves the following:

- Allows OEMs and others to run complex simulations that include confidential models.
- Offers fast computer hardware suitable for large/parallel processing simulations.
- Offers a complete simulation platform, where all hardware, IT/setup etc. are all setup (and includes technical support and licenses for all required simulation tools).
- Offers simulation setup and training services (to create system models, integrate multiple models into a single or parallel simulation case, setup faults, contingencies and monitoring etc.).

Figure 1 below shows the EASL setup - it uses a combination of custom hardware and software. Physical computer hardware is in a DMZ (a De-Militarized Zone) for physical separation from other LAN resources. Virtual computers are setup for multiple OS and user-accounts. We use custom-built 64/32 thread/core, using liquid cooling and over-clocked for best but stable performance (see Figure 2).

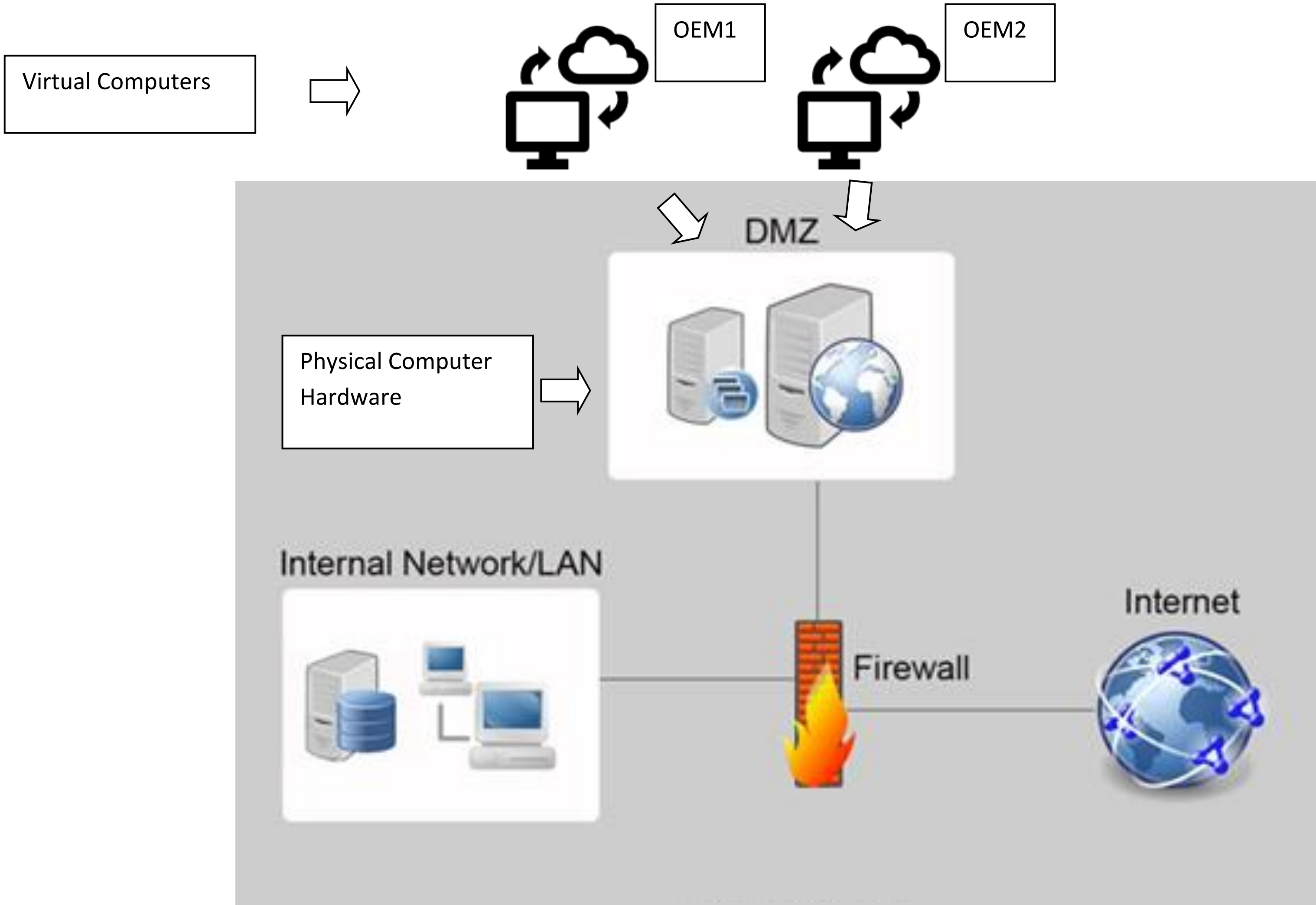

Figure 1 The EASL (Electranix Advanced Simulation Lab)

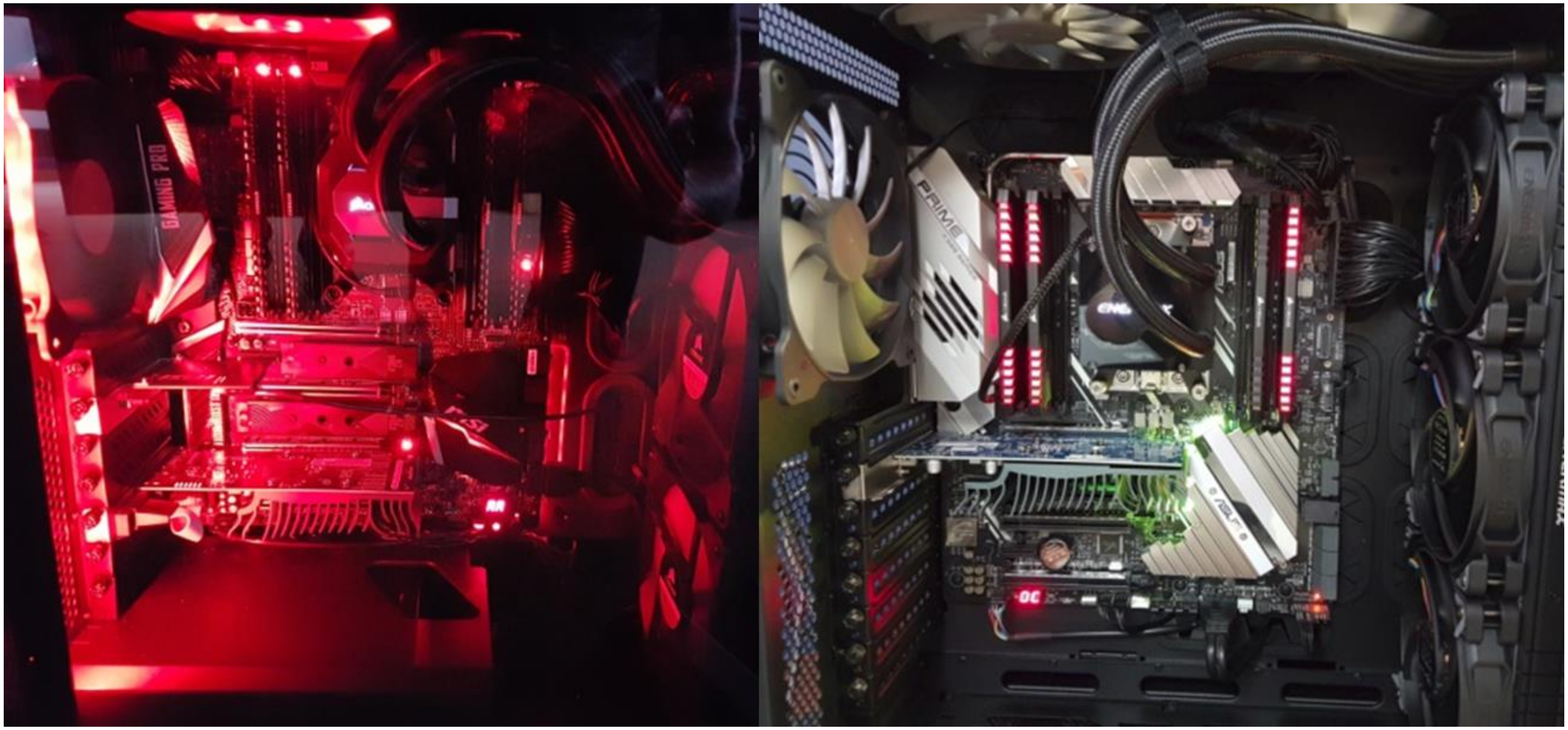

Figure 2 Custom Built “ThreadRipper” PC Hardware

Virtual machines/computers (VMs) on one or more hardware computers (extremely large cases with >32 complex models may require more than one computer) are setup to provide a separate operating system (OS) and set of accounts/files for each user - each uses a standard Microsoft windows OS, secure file storage, user access, network security, and anti-virus.

Each VM is setup with all required power system software licenses including:

- PSCAD (any version, can mix/match)
- PSS/E (any version, can mix/match)
- PSLF
- DigSilent
- E-TRAN
- Parallel processing (E-TRAN Plus for PSCAD or ENI)
- Hybrid interfaces (PSCAD to PSS/E, PSCAD to PSLF, and others under development)

Remote desktops are setup with encrypted virtual private network (VPN) access to securely allow remote users to login to each VM - the VM user has Internet access (through secure firewalls), file upload/download capability, as well as email access (through internet browsers).

More important than the physical computer, OS, or simulation software setup, is the engineering expertise at Electranix in using these tools. The EASL can include services to build simulation models of complete areas, setup faults/disturbances, monitoring etc. – i.e., ready for original equipment manufacturers (OEM)s or others to step in and perform their work.

5. Example Cases

A common application is to allow an OEM to run simulations of large/complex grid models, but due to NDA and other restrictions, they cannot receive the complete case (as it contains models from other suppliers for example).

An OEM first requires a username and password to access the EASL. We pre-setup the system so when the user starts their main simulation case, the E-TRAN Auto-launch component triggers the start of the confidential/slave cases. This is done via a custom client/server messaging program - it allows the user to see the status of the remote/slave cases, and to stop the cases prematurely if required. This allows the user to start the slave cases using the same PSCAD options as the main case (i.e., to start from a data file or snapshot, perform multiple runs etc.).

One example case where this has been applied involved a weak network that had 3 large wind farms (from 2 OEMs) - the system would run correctly if two of the wind farms were operating, but with 3 farms operating and under a network fault condition and recovery to a weakened network, oscillations developed between the farms (i.e., a weak system instability problem). Attempts were made to resolve the issue by conventional means (i.e., sending plots/traces) but the OEM of the new wind farm required the ability to run the overall model (which was not possible by conventional means due to NDA restrictions from the other OEM) to perform control optimization.

We setup all three wind farms on the EASL, with 2 of the wind farms placed in the private/confidential side of the lab, and the third wind farm accessible remotely from the wind turbine OEM. The OEM was able to login to the VM, upload/modify/tune/adjust its wind farm controls, start/stop the entire simulation etc. They only had access to measurements/traces in its local wind farm. The OEM was able to resolve the problem by controller tuning, documented the changes made, then left the updated models on the EASL (so the remainder of the study could be completed by Electranix).

A similar example would be how to handle combinations of solar/BES/wind, or large-scale wide area weak system instabilities (affected by equipment from many suppliers).

Similarly, a multi-terminal HVDC link with equipment from many suppliers could be studied - this could be in the form of 2 or more identical/parallel EASL setups (so each OEM can run cases independently) - a model revision tracking system is used so after one OEM updates its model/control/protection settings, the model revision is incremented and the model is shared with the other EASL setups (to keep all models in sync, but still allow each OEM to test independently).

6. Conclusions

This whitepaper outlines the Electranix Advanced Simulation Lab (EASL) - this is a service offered by Electranix to provide access to simulation tools, fast/parallel processing computer hardware, IT, technical support, and training, based on the years of power systems and simulation experience of the Electranix engineering team.

7. References

[1] Recommended PSCAD model requirements Rev. 10 by Isaacs, A., Unruh L. & Irwin, G. (2021, February 03).

[2] IEEE Working Group "Use of Real-Code in EMT Models for Power System Analysis".

[3] Cigre B4.82 "Guidelines for Use of Real-Code in EMT Models for HVDC, FACTS and Inverter based generators in Power Systems Analysis".