

GRID EMT

SIMULATION INITIATIVE

Industry Current State-of-the-art Parallelism Practices in Large Scale EMT Simulation of Power Grids

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Motivation

- Need for large scale EMT studies is driven by the newer needs of the Power Electronics (PE) dominated modern power systems:

Table 2: Classification of frequency ranges

Group	frequency range for representation	shape designation	representation mainly for
I	0.1 Hz - 3 kHz	Low frequency oscillations	Temporary overvoltages
II	50/60 Hz - 20 kHz	Slow front surges	Switching overvoltages
III	10 kHz - 3 MHz	Fast front surges	Lightning overvoltages
IV	100 kHz - 50 MHz	Very fast front surges	Restrike overvoltages

Source*

- Modern SSO Phenomena (SSCI, SSTI)
- High penetrations of inverter-based generation
- Weak grid interactions
- Transient stability and dynamics of inverter-based generation
(Reliability concerns)
- Large scale EMT dynamic studies are performed to capture the phenomenon resulting in low frequency oscillations and slow front surges such as Temporary over voltage and switching over voltages
- The EMT simulation time step for these types of studies are typically between 10 to 20 micro secs

Source*: Guidelines for Representation of Network Elements when Calculating Transients: Cigre Working Group 02 (Internal Overvoltages of Study Committee 33 Overvoltage and Insulation Coordination)



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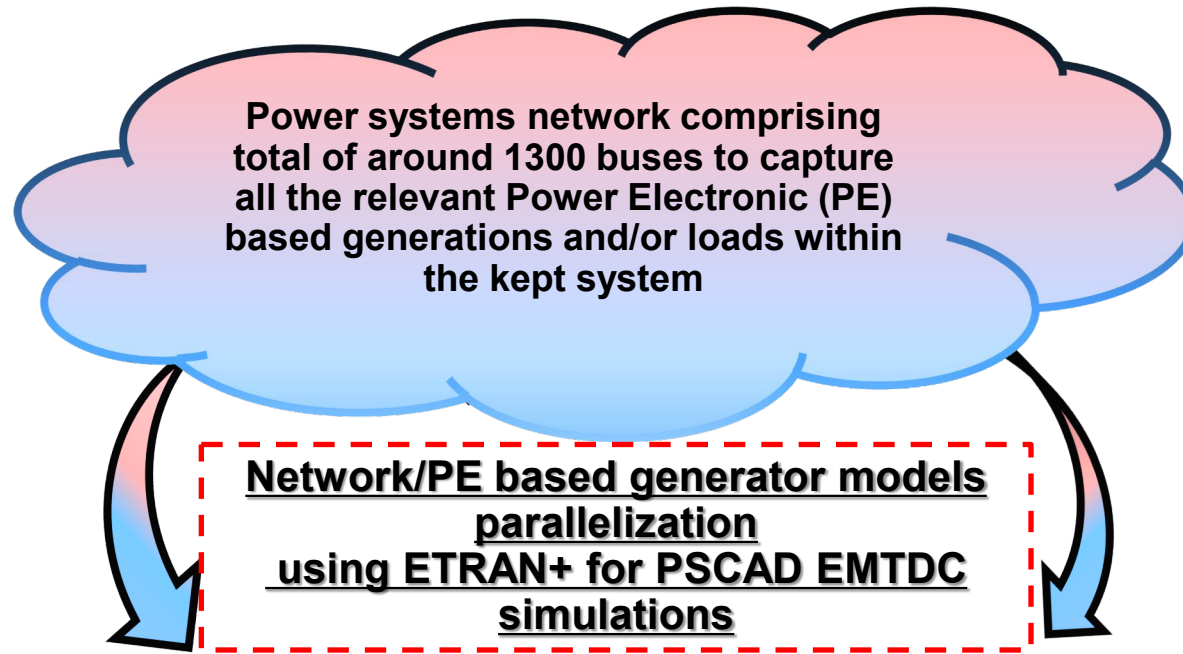
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Problem Statement

- Large scale EMT Dynamic Study is a complex and advanced study that comprises of the following different steps:
 - EMT Model Sizing and Validation (Use of Interaction factors and Frequency Scan Techniques)
 - Decision on which Distributed Energy Resources (DERs) to model (DER evaluation process): applicable only to the system with large penetration of DERs
 - Network model splitting to achieve faster simulation time (Each case split can run on one CPU Core)
 - Substitution library model creation/validation of each project (Inverter based resources, IBRs) including DERs if applicable included in the reduced study model (UDMs can be utilized and can run on separate cores)
 - Inclusion of the PE based project/s under study including all the surrounding projects in close electrical proximity
 - Contingency substitution library creation and validation
 - Perform the system impact study for each of the selected contingency
 - Post process the response of all the IBR projects included in the study (DERs if applicable)



Problem Statement (Contd.)



Around 300 Total power electronics based generation in distribution (Around 45 UDMs and rest generic models)

12 Total power electronics based generation in transmission (UDMs) Aggregated plant models

- Our experience on factors affecting total computational time
 - **Size of the grid**
 - **Number of static elements**
 - **Number of dynamic elements (generic or UDMs)**
 - **Type of studies**
 - **Available CPU cores**



Approach

Step 1: Defining the reduced system buslist

- Define the original system buslist using the methodology based on hybrid method using the interaction factor calculation and frequency scan technique
- The reduced system buslist will capture all the PE based generators with high weighted interaction factor that carries the possible risk of control interactions and instability
- The frequency scan technique ensures that the frequency characteristics of the full system is captured in the reduced system
- The size of the reduced buslist is generally 800 -1300 buses depending on the location of the projects in the study area
- **If this entire network is run as a single EMT (PSCAD) case, the simulation would be extremely slow (10-12 hrs of computational time for one scenario)**

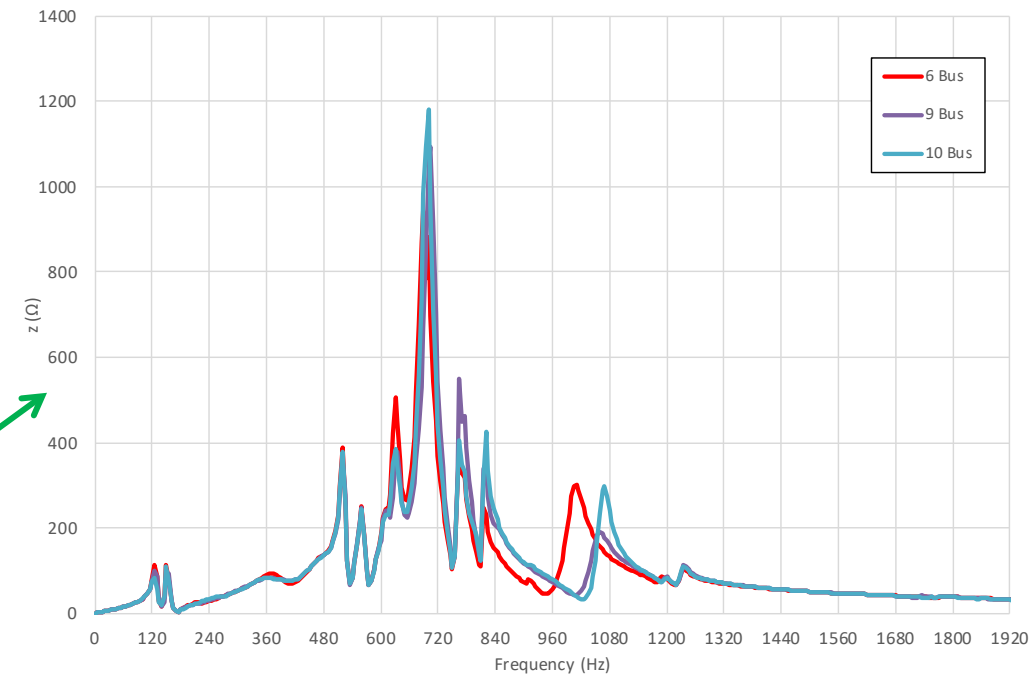


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Approach

Buslist definition: Electromagnetic Sizing



Approach

Step 2: Splitting the large network buslist into smaller buslists

- The total reduced buslist is reduced on to smaller buslists of 200-300 buses each
- E-TRAN (developed by Electranix) is utilized to create the reduced network equivalent in PSCAD
- E-TRAN is a tool that is capable of translating PSS/E power flow files (.raw, .dyr and .seq) into PSCAD .pscx files based on the defined total buslist or multiple subset buslists
- It creates the network equivalent around the boundary of the provided buslist with the accurate power flow results as compared to the full PSS/E case



Approach

Step 2: Splitting the large network buslist into smaller buslists

- E-TRAN generates a complex admittance (Y) matrix for the entire system (PSS/E base case)
- It calculates the PQ mismatch of the entire system to see if the input .raw file is solved
- It decomposes the entire network using LDU sparse decomposition techniques to generate network equivalents
- Caution: Some conditioning of the PSS/e network data might be needed for proper translation to PSCAD case using E-TRAN

Source: <https://www.electranix.com/software/>



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Approach

Step 2: Example sample case split by E-TRAN (PSS/E Example Case: savnw.raw)

File Options Help

E-Tran Case Input/Output Files Circuit Options Advanced PSCAD Options ETran Plus Conversion

PSS/E Input

PSS/E loadflow (.raw) file: C:\Users\SXAO4\Desktop\ETRAN_Example\savnw.raw

PSS/E loadflow file format: ☐ v26 ☐ v29 ☐ v30 ☐ v31 ☐ v32 ☐ v33 ☐ v34 ☒ v35

☒ Use high precision .rawpr file (automatically converts .raw files)

☒ Use PSS/E Dynamics (.dyr) files: C:\Users\SXAO4\Desktop\ETRAN_Example\savnw.dyr

☐ Use PSS/E Sequence (.seq) file:

☐ Use PSS/E Location (.loc) file:

PSCAD Output

PSCAD output version: ☐ v4.5+ ☒ v5.0

PSCAD output File: C:\Users\SXAO4\Desktop\ETRAN_Example\CaseA.pscx

☐ Use PSCAD substitution libraries:

☐ Additional dependencies (.obj, .lib):

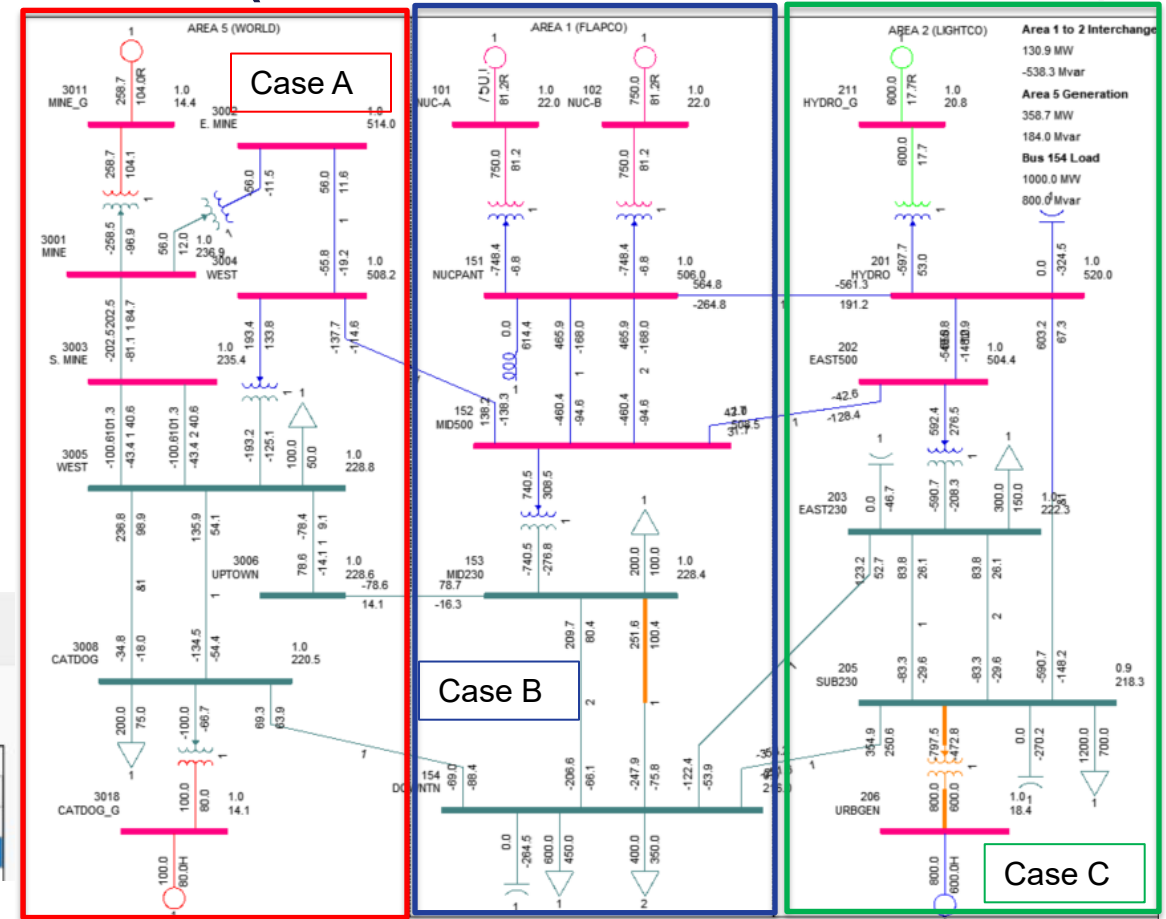
File Options Help

E-Tran Case Input/Output Files Circuit Options Advanced PSCAD Options ETran Plus Conversion

☒ Split this network into multiple cases

Enter list of parallel subcases with the list of busses to carve out of the kept system:

Case Name	Bus List
Case_B	101 102 151 152 153 154
Case_C	201 202 203 205 206 211



Challenges

Step 2: Splitting the large network buslist into smaller buslists

- Splitting of the large buslist into smaller buslists is an iterative process in E-TRAN and considers the engineering judgement about the location of the case splits.
- Example 1: If the split buslist is incomplete such as missing some buses or if two split systems have some duplicate buses, E-TRAN cannot create the split cases, and it can be hard to debug this issue. So, defining the split system's buslist is a meticulous task.
- Example 2: If the split buslist is provided such that a single plant is split across multiple split cases, it might result in issues while using the substitution library that is described next.

Source: <https://www.electranix.com/software/>



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Step 3: Substitution library of the PE based devices

- The E-TRAN translated power flow data is not detailed as needed for the Electromagnetic Transients (EMT) studies. Detailed models can be substituted on to the powerflow model created:
 - Transmission line data, RXB from powerflow are translated as simple PI and Bergeron line models and might not be detailed enough for certain types of EMT studies in which frequency dependent effects across the entire frequency spectrum is required
 - Transformer data in the powerflow model do not contain the saturation or non-linearity information that will be required in the EMT studies
 - Synchronous Generators should be represented with detailed DQ synchronous machine models with exciter, governor, multi-mass model and/or stabilizer data and so on
 - Power electronic devices (HVDC, FACTS, IBRs, SVCs, etc) should be represented in detail using the vendor supplied models of these equipment.
- The substitution library in E-TRAN can substitute the needed components in the power flow model with the detailed/user-defined model so that the resulting case can be used for detailed EMT study



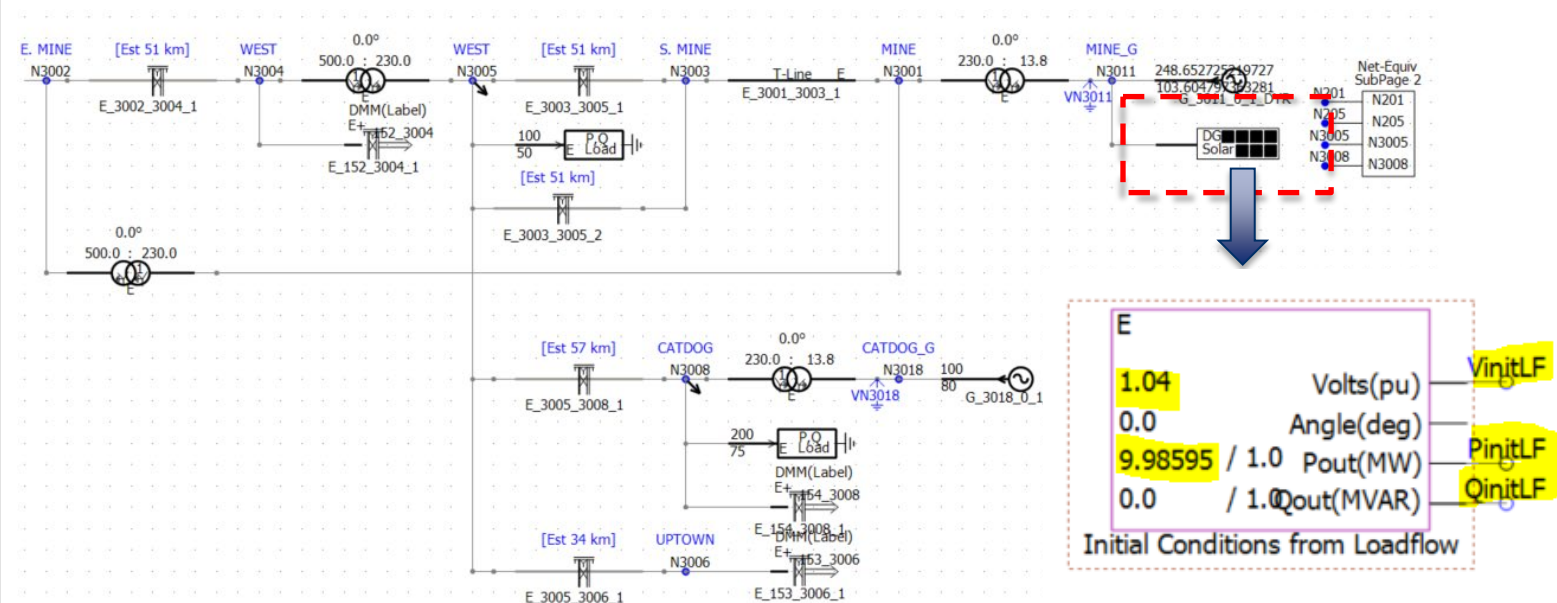
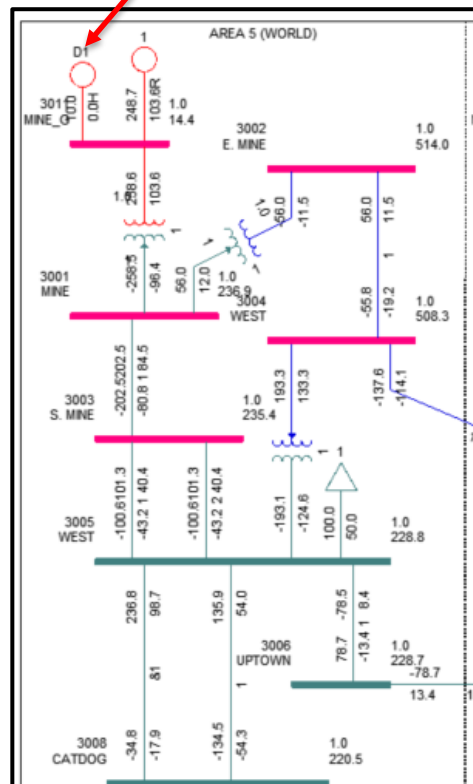
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Approach

Step 3: Example: Substitution of ETRAN generic DER model

10 MW DER D1 added at Bus 3011 Case A for demonstration



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Step 4: Simulation Parallelization

- E-TRAN Plus for PSCAD is utilized to perform parallel simulations after previous steps are complete
- E-TRAN Plus comprises of a set of models that allow large PSCAD cases to be split up and run using Parallel processing on multiple cores (1 computer) or on multiple computers
- It helps to run the large scale EMT study such that:
 - Large PSCAD case can be split up into multiple cases that can run on many CPU cores or multiple computers
 - It allows each split subsystem/process to be built with a different PSCAD version or different version of Intel Fortran Compilers or at different time step than the time step of the main case
 - The results of the split case with UDM models (PE based devices) are identical as that from the original full PSCAD case
- The large PSCAD case can be broken up electrically using the following two ways:
 - Split across the Bergeron traveling wave transmission line or cable (traveling time should be greater than time-step used)
 - Split across any transformer location (using the ETRAN scaling transformer model)



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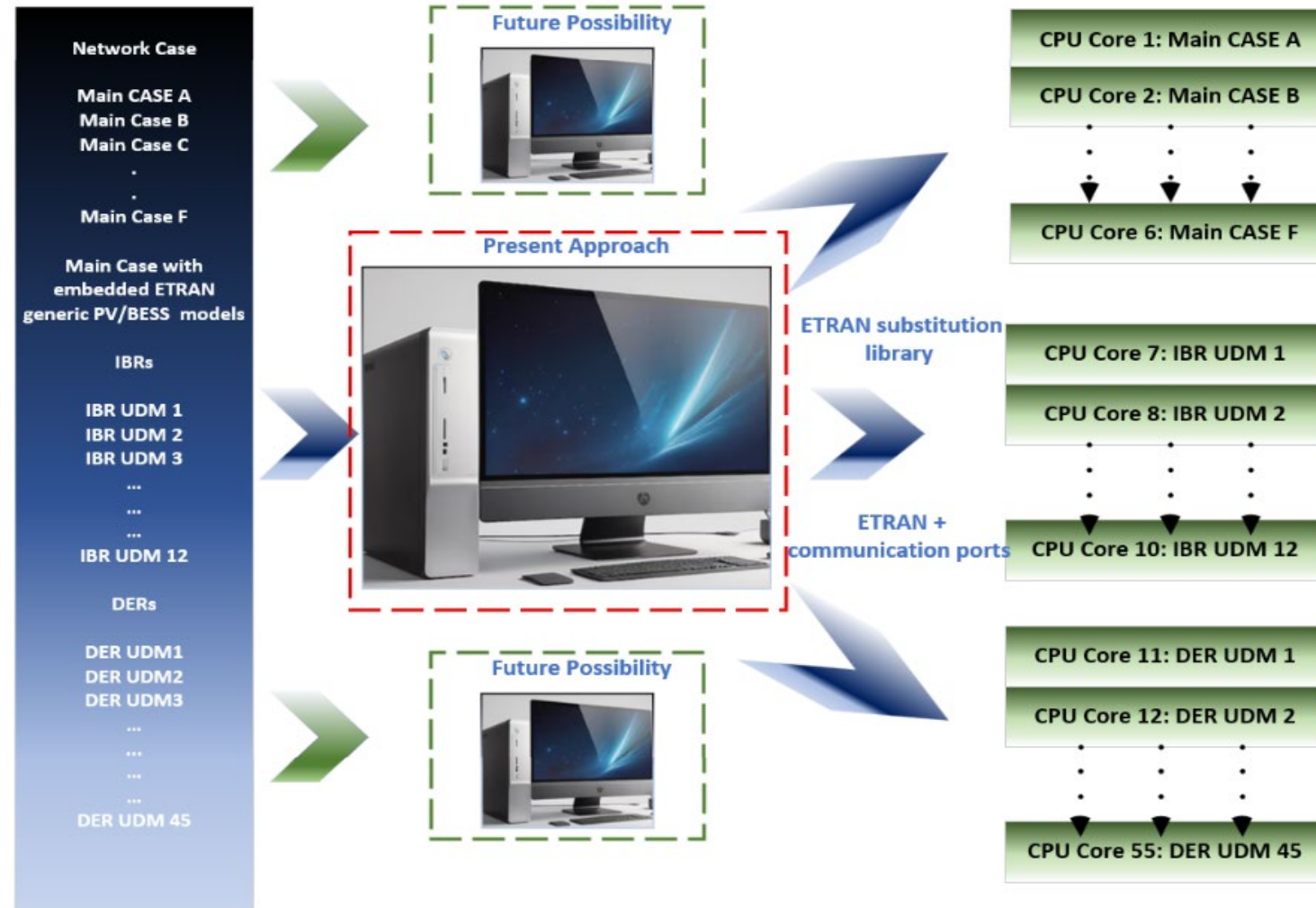
Overall Approach

- **Variables:**

- Number of split Network Cases
- Number of PE based devices (IBR) User Defined Models (UDM)
 - (DER generic/ UDMs

- **Constraints:**

- Number of CPUs available
- Number of CPU cores available
- CPU hardware configurations



Results/Observations

Scenario/ Tool Version	System Size	Total PE Devices (IBR UDMs)	Total PE Devices (DER Generic/ UDMs)	Total Simulation Time for 60 secs Dynamic EMT Study per contingency
1) PSCAD V4.6.3, ETRAN V5	~900 buses (Without network splitting)	12 (running in individual CPU cores)	None	~10-12 hrs
2) PSCAD V5.0.2, ETRAN V6	~1300 buses (With network splitting)	12 (running in individual CPU cores)	~300 Generic DERs (PE based devices) 40 DER UDMs	~12 hrs
3) PSCAD V5.1, ETRAN V7	~1300 buses (With network splitting)	12 (running in individual CPU cores)	~300 Generic DERs (PE based devices) 45 DER UDMs	~6 hrs



Overall Challenges

- Several steps involved in the simulation parallelization makes it time-consuming
- Computational Challenges (Hardware structure: number of cores, clock speed, RAM memory and total data storage)
- Extensive computational hours for large scale EMT studies even with parallelization method
- The inclusion of newer large AI and computational load models to the large EMT simulation will make the overall parallelization process and study even more tedious and time consuming
- Large volume of data to be post processed to understand the results:
 - Debugging a large EMT model for ongoing issues
 - Delay in decision making process resulted by the delay in understanding the reliability impacts of the PE based devices



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Conclusions/Next Steps

- The combined capabilities of PSCAD/EMTDC, E-TRAN and E-TRAN Plus for PSCAD are utilized to achieve large scale EMT simulation parallelization for with satisfactory results
- The power system network is reasonably sized without losing the needed fidelity
- The network model simulation timestep is increased to a reasonable number between 10 and 20 microsec without losing fidelity required by the study
- A combination of generic and UDMs dynamic models is used without compromising the validity of the study conclusions

Next Steps:

- Research and testing on utilizing multiple CPUs for simulation parallelization
- Reduce the total simulation time with reasonable accurate results



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Thank You!

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