# HYPERSIM and EXata - RT Simulator Guidance

**WP6 output 2: CR-DES Project**

**University of Vaasa**

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# CPS

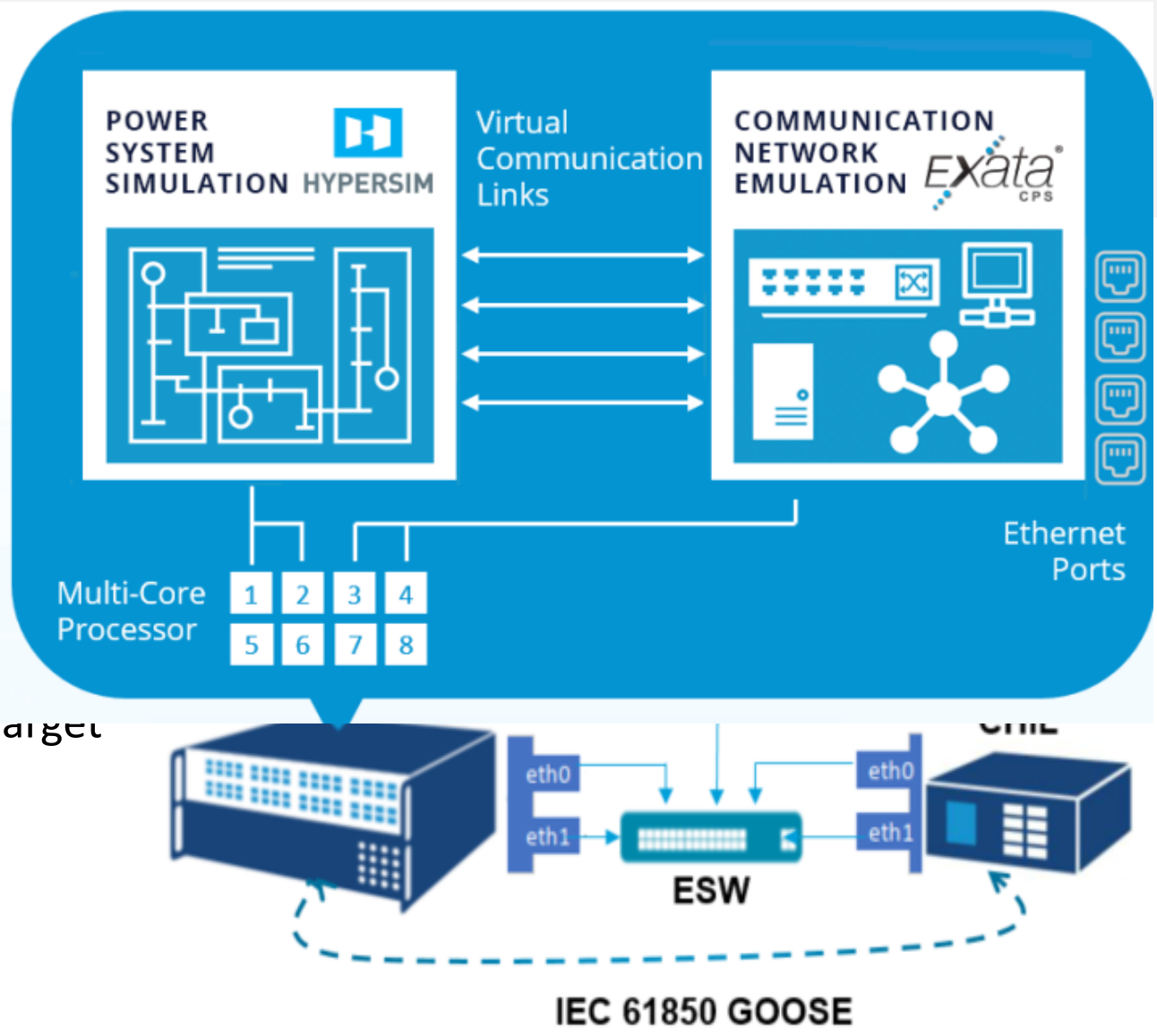
Cybersecurity and Resilie

## Host PC

- Scenario creation
- Interface Mapping
- Execution Control
- Cyber Attacks
- Animation
- Analysis / Results

## Real-Time Co-simulation Target

- Electromagnetic
- Electromechanical
- Mechanical
- Network
- Communications
- Cybersecurity



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Euroopan unioni
Euroopan aluekehitysrahasto

# CPS Platform - RT Simulator

Cybersecurity and Resilience of Digital Energy Systems (CR-DES)

## Host PC

- Scenario creation
- Interface Mapping
- Execution Control
- Cyber Attacks
- Animation
- Analysis / Results

## Real-Time Co-simulation Target

- Electromagnetic
- Electromechanical
- Mechanical
- Network
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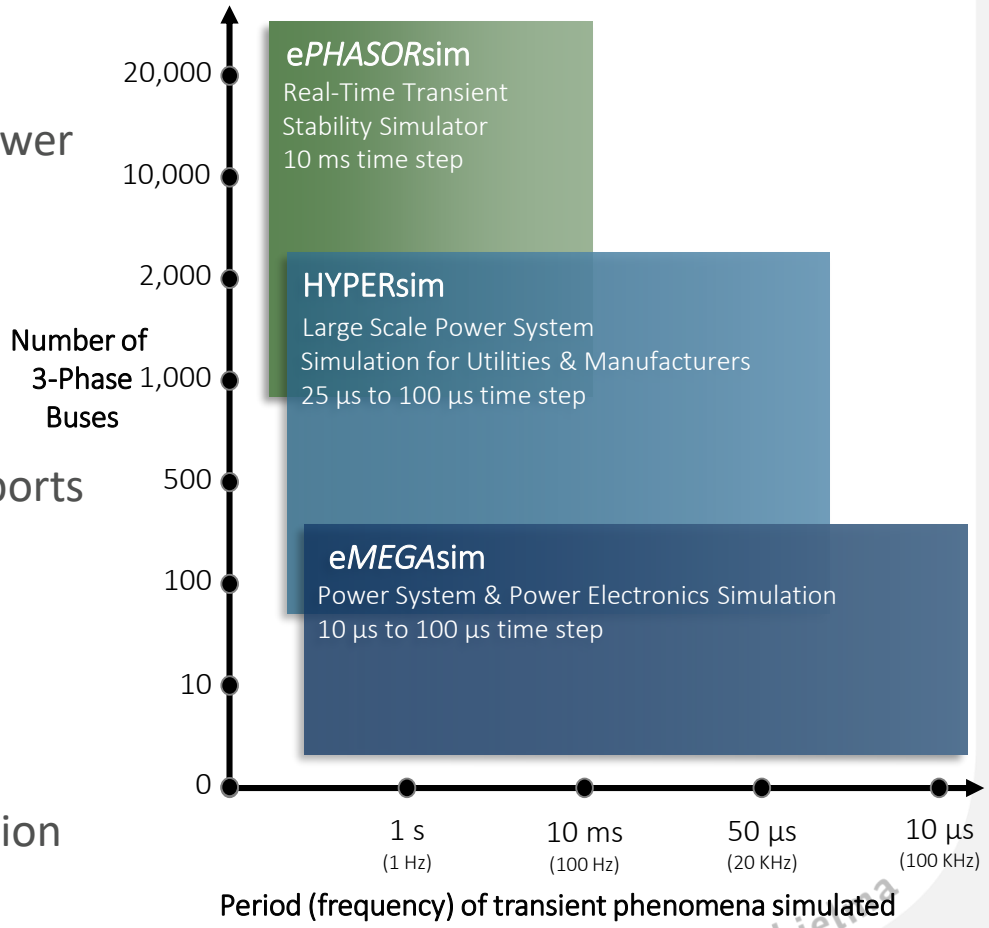
# HYPERSIM

- Windows based Detailed Large-Scale Power System software developed by Hydro-Québec (over 1000 3-phase buses) with more than 300 validated power system components and controllers
- **TestView**: Automated testing with (supports Python)
- **ScopeView**: Signal visualization, data analysis and monitoring
- **HyperView**: enables monitoring simulation performance in real-time







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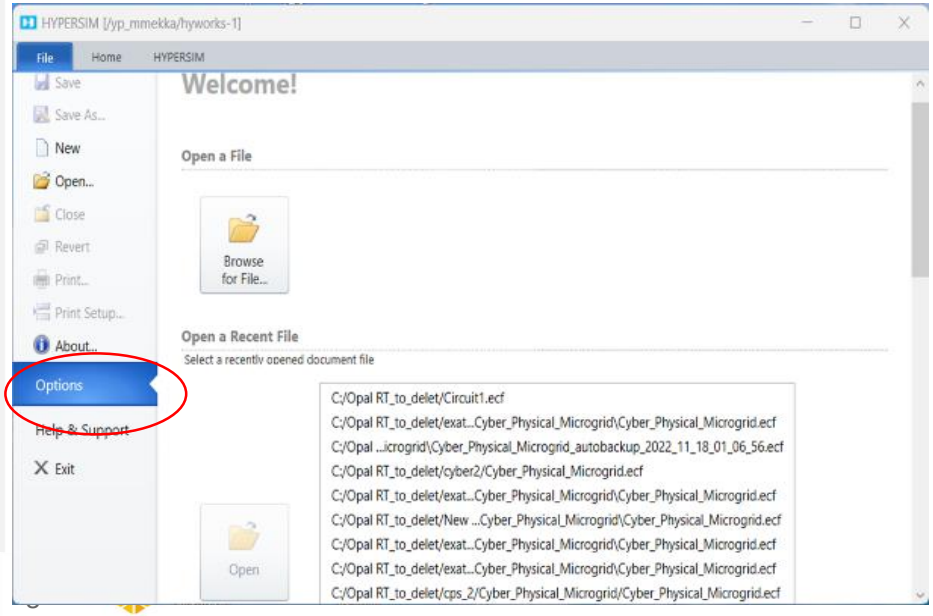
# HYPERSIM

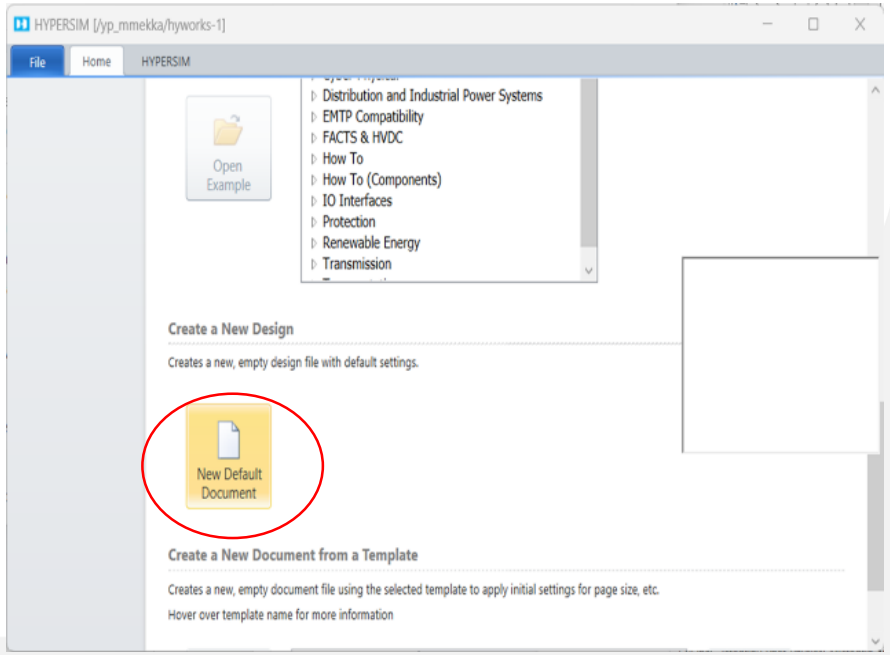
## Starting with HYPERSIM

- Right click on HYPERSIM icon, and chose the “Run as administrator”

  Step 1: the option window will pops up

  Step 2: from the option window chose “New Default Document” under “Creat New Design” section



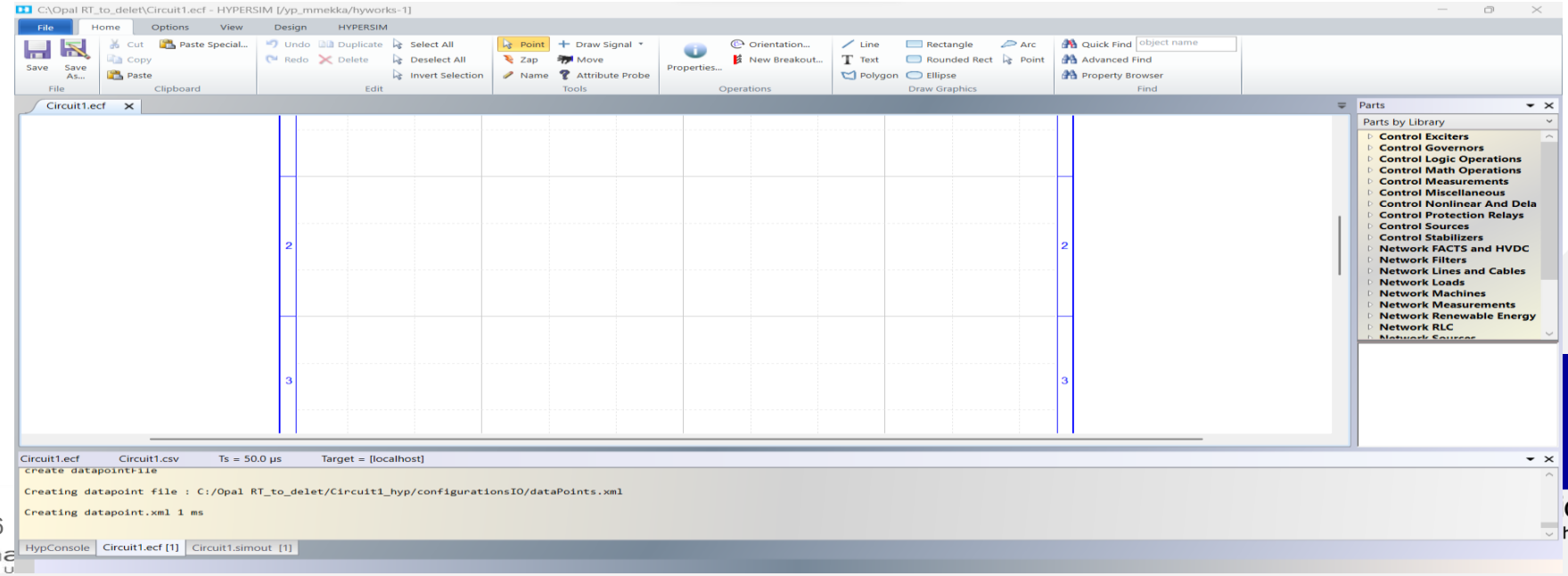
# HYPERSIM

## Starting with HYPERSIM

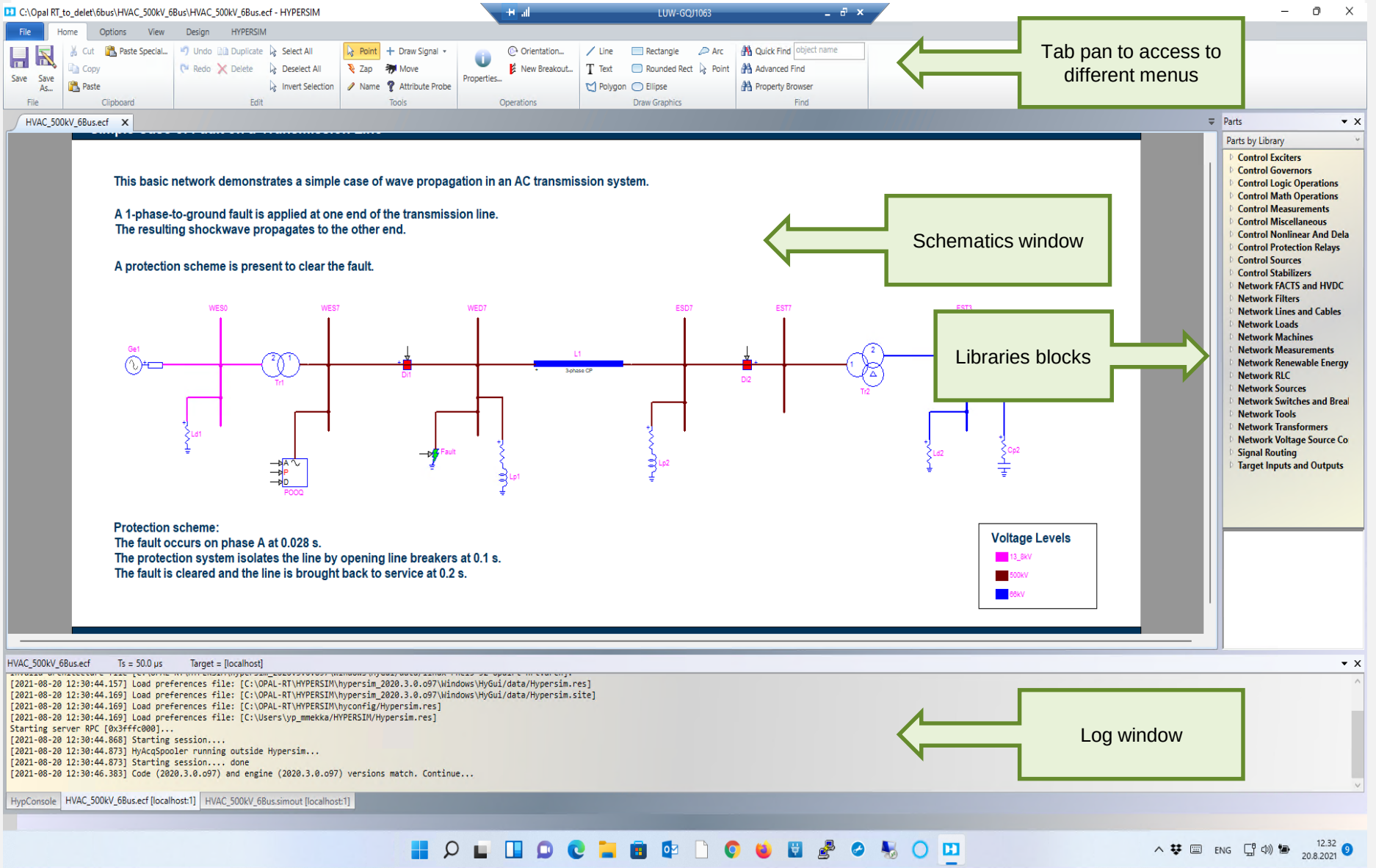
- Right click on HYPERSIM icon, and chose the “Run as administrator”

  Step 3: Saving option window pops up, name new design file and save it to the work space directory  within a predefined project folder

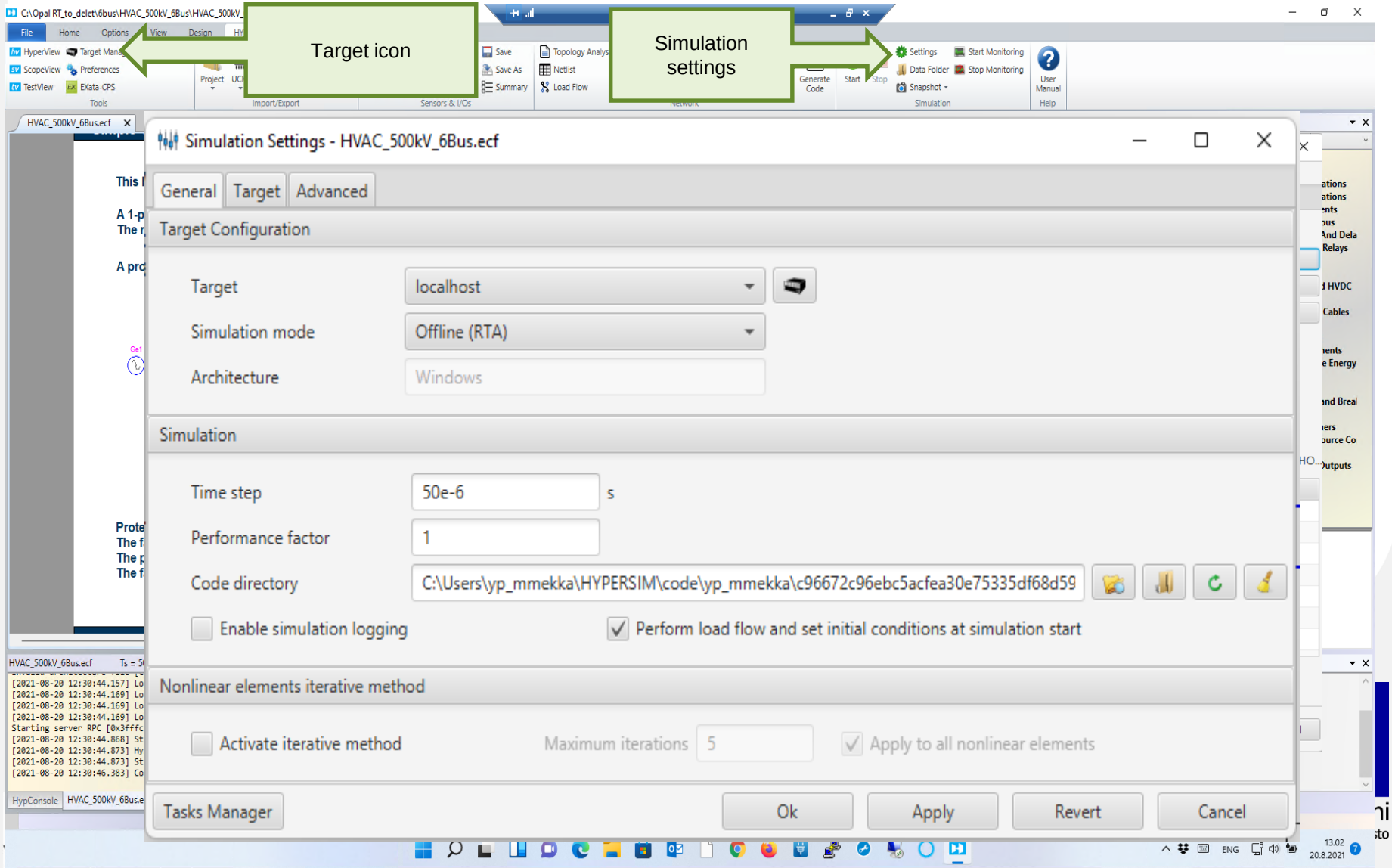
  Step 4: Full HYPERSIM GUI pops up, create new model as per guidelines provided in OPAL-RT HYPERSIM manual, also examples provided can be used as a platform to build or develop advance new model.



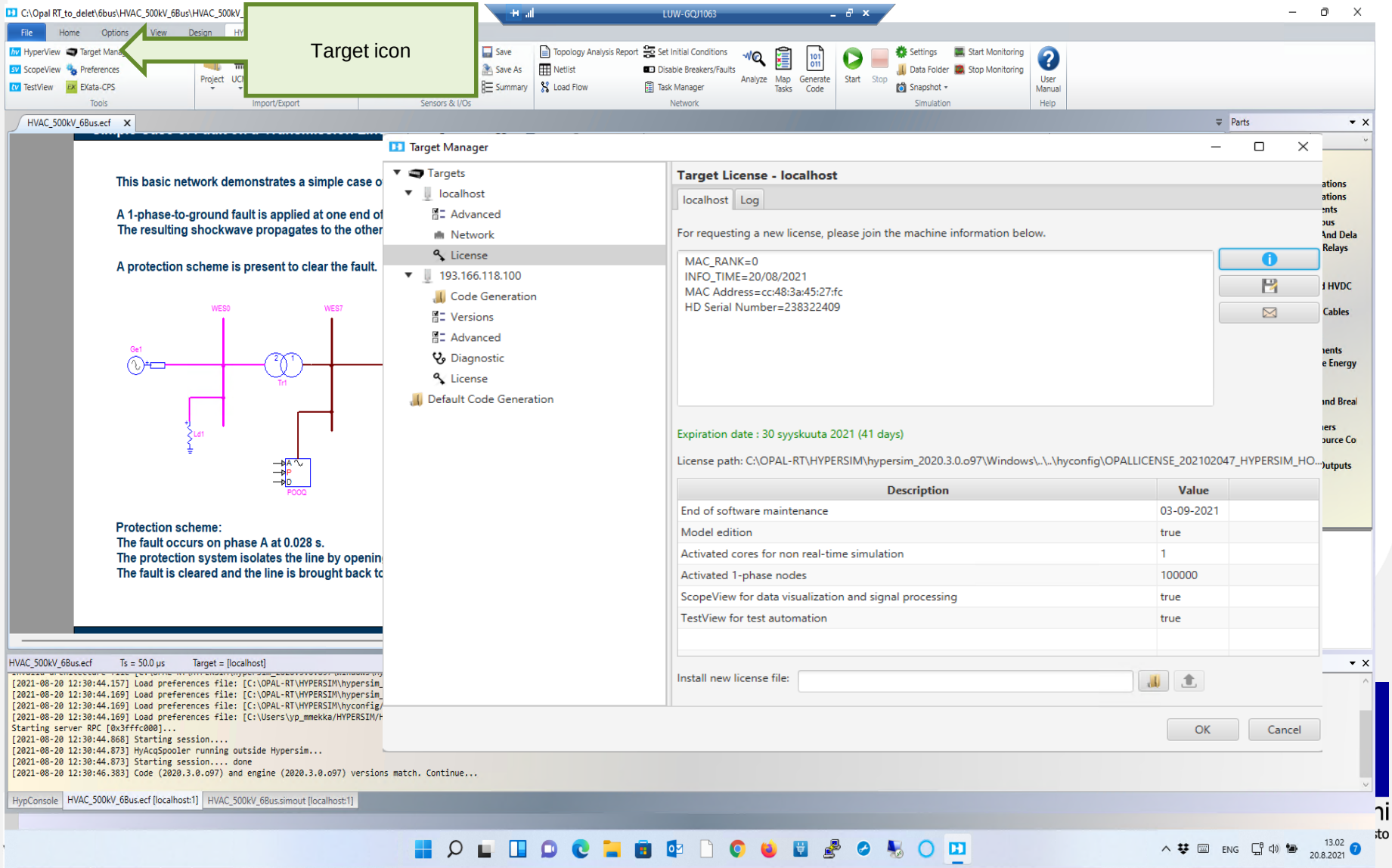
# HYPERSIM


C:\Opal RT_to_delet\6bus\HVAC_500kV_6Bus\HVAC_500kV_6Bus.ecf - HYPERSIM
LUW-GQJ1063
File
Home
Options
View
Design
HYPERSIM
Tab pan to access to different menus
HVAC_500kV_6Bus.ecf
This basic network demonstrates a simple case of wave propagation in an AC transmission system.
A 1-phase-to-ground fault is applied at one end of the transmission line.
The resulting shockwave propagates to the other end.
A protection scheme is present to clear the fault.
Schematics window
WES0
WES7
WED7
ESD7
EST7
EST3
Ge1
Tr1
Di1
L1
3-phase CP
Di2
Tr2
Ld1
Fault
Lp1
Lp2
Ld2
Cp2
POOQ
Libraries blocks
Parts
Parts by Library
Control Exciters
Control Governors
Control Logic Operations
Control Math Operations
Control Measurements
Control Miscellaneous
Control Nonlinear And Dela
Control Protection Relays
Control Sources
Control Stabilizers
Network FACTS and HVDC
Network Filters
Network Lines and Cables
Network Loads
Network Machines
Network Measurements
Network Renewable Energy
Network RLC
Network Sources
Network Switches and Breal
Network Tools
Network Transformers
Network Voltage Source Co
Signal Routing
Target Inputs and Outputs
Protection scheme:
The fault occurs on phase A at 0.028 s.
The protection system isolates the line by opening line breakers at 0.1 s.
The fault is cleared and the line is brought back to service at 0.2 s.
Voltage Levels
13.8kV
500kV
66kV
HVAC_500kV_6Bus.ecf Ts = 50.0 µs Target = [localhost]
[2021-08-20 12:30:44.157] Load preferences file: [C:\OPAL-RT\HYPERSIM\hypersim_2020.3.0.o97\Windows\HyGui/data/Hypersim.res]
[2021-08-20 12:30:44.169] Load preferences file: [C:\OPAL-RT\HYPERSIM\hypersim_2020.3.0.o97\Windows\HyGui/data/Hypersim.site]
[2021-08-20 12:30:44.169] Load preferences file: [C:\OPAL-RT\HYPERSIM\hyconfig/Hypersim.res]
[2021-08-20 12:30:44.169] Load preferences file: [C:\Users\yp_mmekka/HYPERSIM/Hypersim.res]
Starting server RPC [0x3fffc000]...
[2021-08-20 12:30:44.868] Starting session....
[2021-08-20 12:30:44.873] HyAcqSpooler running outside Hypersim...
[2021-08-20 12:30:44.873] Starting session.... done
[2021-08-20 12:30:46.383] Code (2020.3.0.o97) and engine (2020.3.0.o97) versions match. Continue...
Log window
HypConsole
HVAC_500kV_6Bus.ecf [localhost:1]
HVAC_500kV_6Bus.simout [localhost:1]

# HYPERSIM


Target icon
Simulation settings
Simulation Settings - HVAC_500kV_6Bus.ecf
General
Target
Advanced
Target Configuration
Target
localhost
Simulation mode
Offline (RTA)
Architecture
Windows
Simulation
Time step
50e-6
s
Performance factor
1
Code directory
C:\Users\yp_mmekka\HYPERSIM\code\yp_mmekka\c96672c96ebc5acfea30e75335df68d59
Enable simulation logging
Perform load flow and set initial conditions at simulation start
Nonlinear elements iterative method
Activate iterative method
Maximum iterations
5
Apply to all nonlinear elements
Tasks Manager
Ok
Apply
Revert
Cancel

# HYPERSIM


Target icon
Target Manager
Targets
localhost
Advanced
Network
License
193.166.118.100
Code Generation
Versions
Advanced
Diagnostic
License
Default Code Generation
Target License - localhost
localhost
Log
For requesting a new license, please join the machine information below.
MAC_RANK=0
INFO_TIME=20/08/2021
MAC Address=cc:48:3a:45:27:fc
HD Serial Number=238322409
Expiration date : 30 syyskuuta 2021 (41 days)
License path: C:\OPAL-RT\HYPERSIM\hypersim_2020.3.0.o97\Windows\..\..\hyconfig\OPALLICENSE_202102047_HYPERSIM_HO...
Description
Value
End of software maintenance
03-09-2021
Model edition
true
Activated cores for non real-time simulation
1
Activated 1-phase nodes
100000
ScopeView for data visualization and signal processing
true
TestView for test automation
true
Install new license file:
OK
Cancel
This basic network demonstrates a simple case o
A 1-phase-to-ground fault is applied at one end of
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Protection scheme:
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The protection system isolates the line by openin
The fault is cleared and the line is brought back to
HVAC_500kV_6Bus.ecf
Ts = 50.0 µs
Target = [localhost]
[2021-08-20 12:30:44.157] Load preferences file: [C:\OPAL-RT\HYPERSIM\hypersim_
[2021-08-20 12:30:44.169] Load preferences file: [C:\OPAL-RT\HYPERSIM\hypersim_
[2021-08-20 12:30:44.169] Load preferences file: [C:\OPAL-RT\HYPERSIM\hyconfig/
[2021-08-20 12:30:44.169] Load preferences file: [C:\Users\yp_mmekka/HYPERSIM/
Starting server RPC [0x3fffc000]...
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HVAC_500kV_6Bus.ecf [localhost:1]
HVAC_500kV_6Bus.simout [localhost:1]

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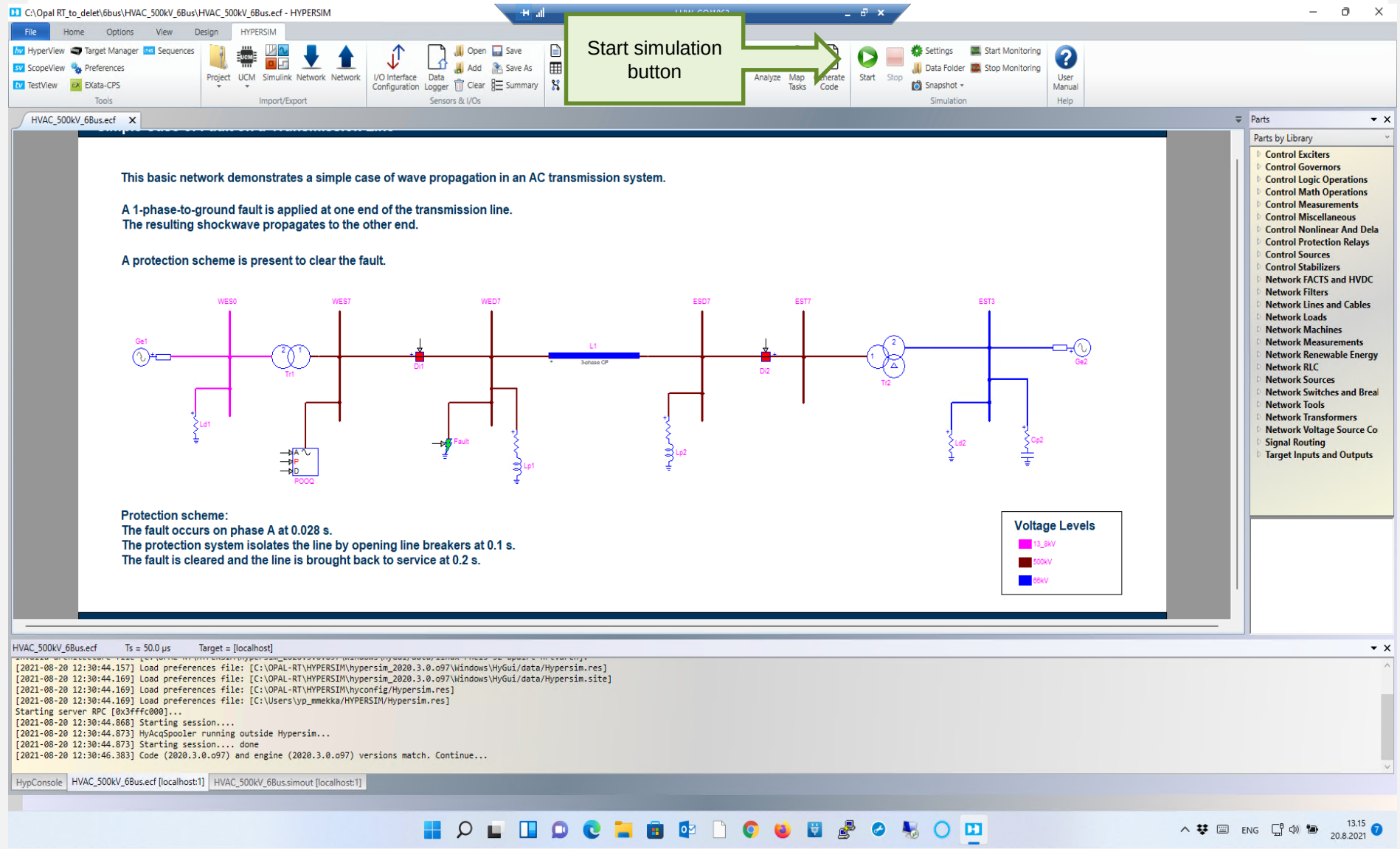
C:\Opal RT_to_delet\6bus\HVAC_500kV_6Bus\HVAC_500kV_6Bus.ecf - HYPERSIM
File
Home
Options
View
Design
HYPERSIM
Start simulation button
Start
Stop
Analyze
Map Tasks
Generate Code
Simulation
HVAC_500kV_6Bus.ecf
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WES0
WES7
WED7
ESD7
EST7
EST3
Ge1
Tr1
Di1
L1
3-phase CP
Di2
Tr2
Ge2
Ld1
Fault
Lp1
Lp2
Ld2
Cp2
POOQ
Protection scheme:
The fault occurs on phase A at 0.028 s.
The protection system isolates the line by opening line breakers at 0.1 s.
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Voltage Levels
13_8kV
500kV
66kV
Parts
Parts by Library
Control Exciters
Control Governors
Control Logic Operations
Control Math Operations
Control Measurements
Control Miscellaneous
Control Nonlinear And Dela
Control Protection Relays
Control Sources
Control Stabilizers
Network FACTS and HVDC
Network Filters
Network Lines and Cables
Network Loads
Network Machines
Network Measurements
Network Renewable Energy
Network RLC
Network Sources
Network Switches and Breal
Network Tools
Network Transformers
Network Voltage Source Co
Signal Routing
Target Inputs and Outputs
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HVAC_500kV_6Bus.ecf [localhost:1]
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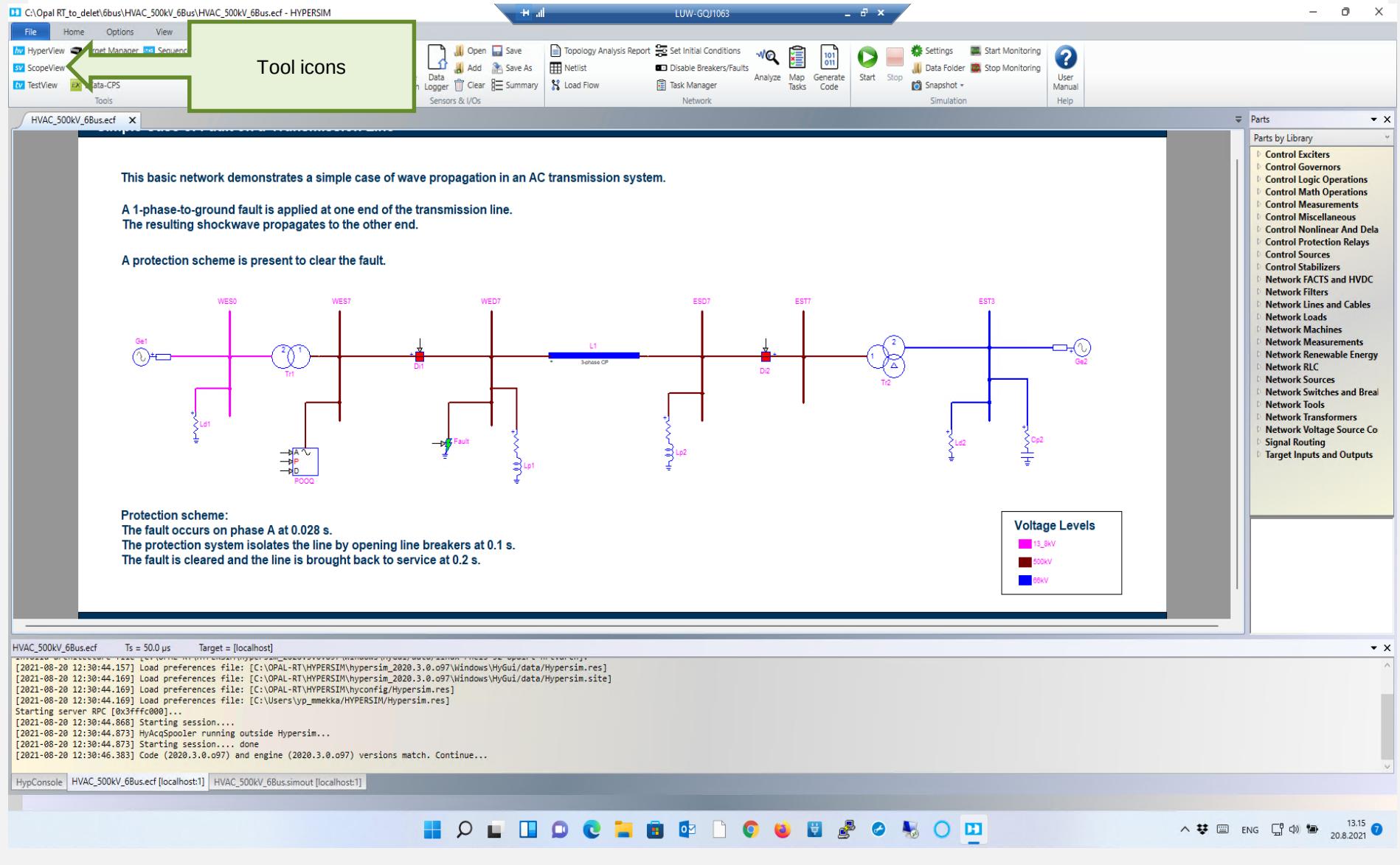
C:\Opal RT_to_delet\6bus\HVAC_500kV_6Bus\HVAC_500kV_6Bus.ecf - HYPERSIM
LUW-GOJ1063
File
Home
Options
View
HyperView
ScopeView
TestView
Tool icons
Tools
Data Logger
Open
Add
Clear
Save
Save As
Summary
Sensors & I/Os
Topology Analysis Report
Netlist
Load Flow
Set Initial Conditions
Disable Breakers/Faults
Task Manager
Network
Analyze
Map Tasks
Generate Code
Start
Stop
Settings
Data Folder
Snapshot
Start Monitoring
Stop Monitoring
Simulation
User Manual
Help
HVAC_500kV_6Bus.ecf
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ESD7
EST7
EST3
Ge1
Tr1
Di1
L1
3-phase CP
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Tr2
Ge2
Ld1
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Lp1
Lp2
Ld2
Cp2
POOQ
Protection scheme:
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Parts
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Network Tools
Network Transformers
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Signal Routing
Target Inputs and Outputs
HVAC_500kV_6Bus.ecf
Ts = 50.0 µs
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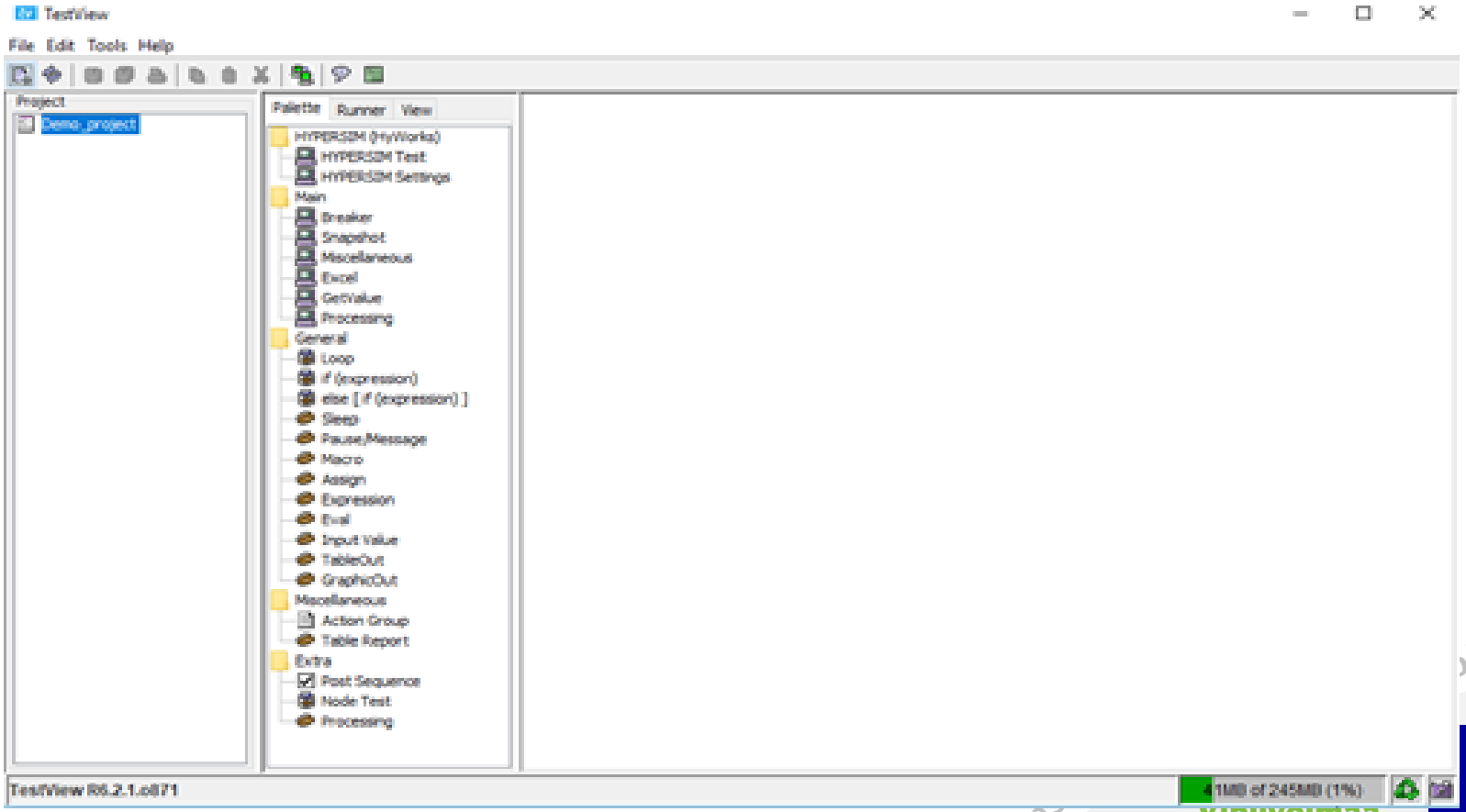
HypConsole
HVAC_500kV_6Bus.ecf [localhost:1]
HVAC_500kV_6Bus.simout [localhost:1]
ENG
13.15
20.8.2021

# HYPERSIM

- **TestView**: Automated testing with (supports Python)



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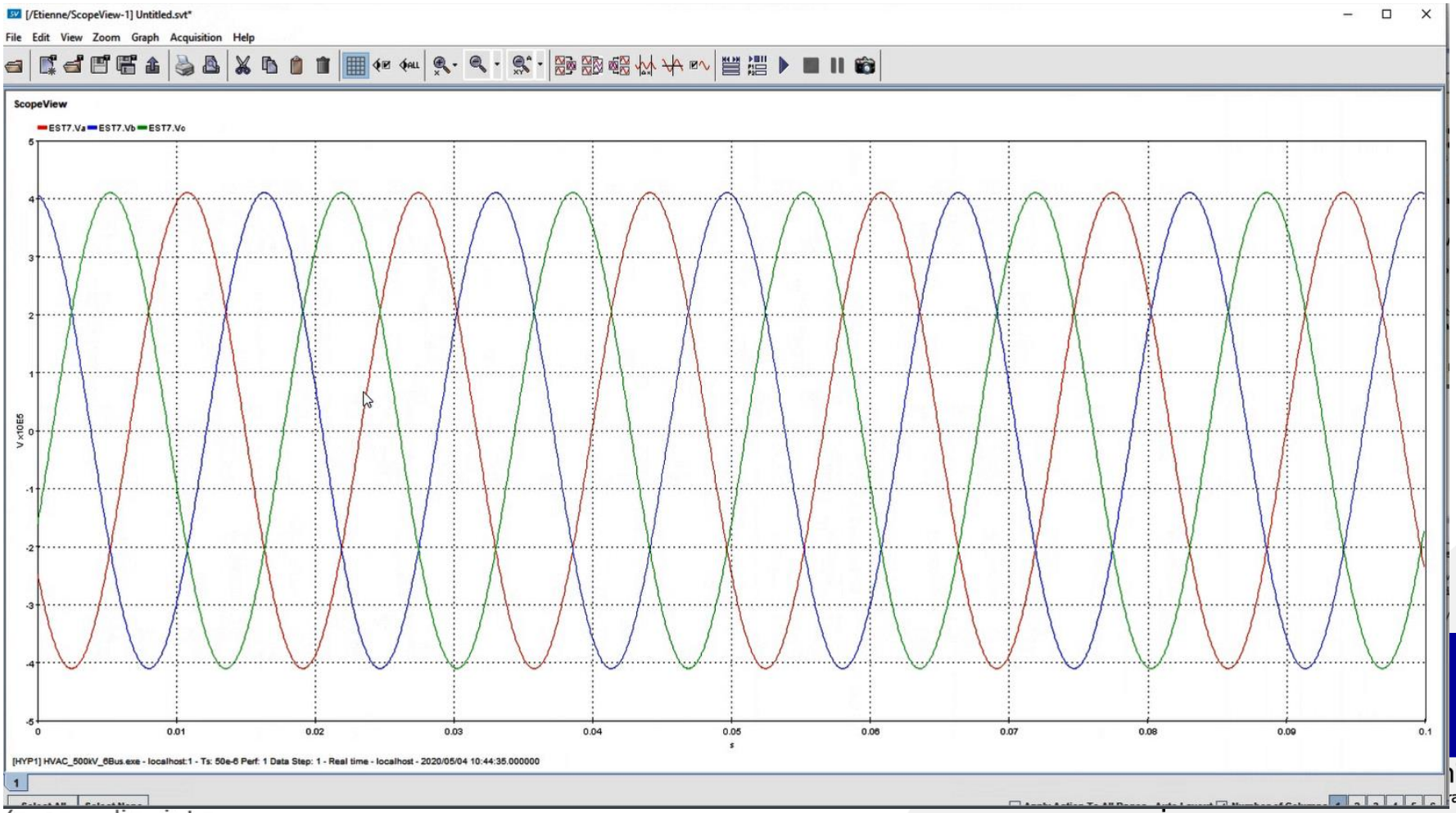
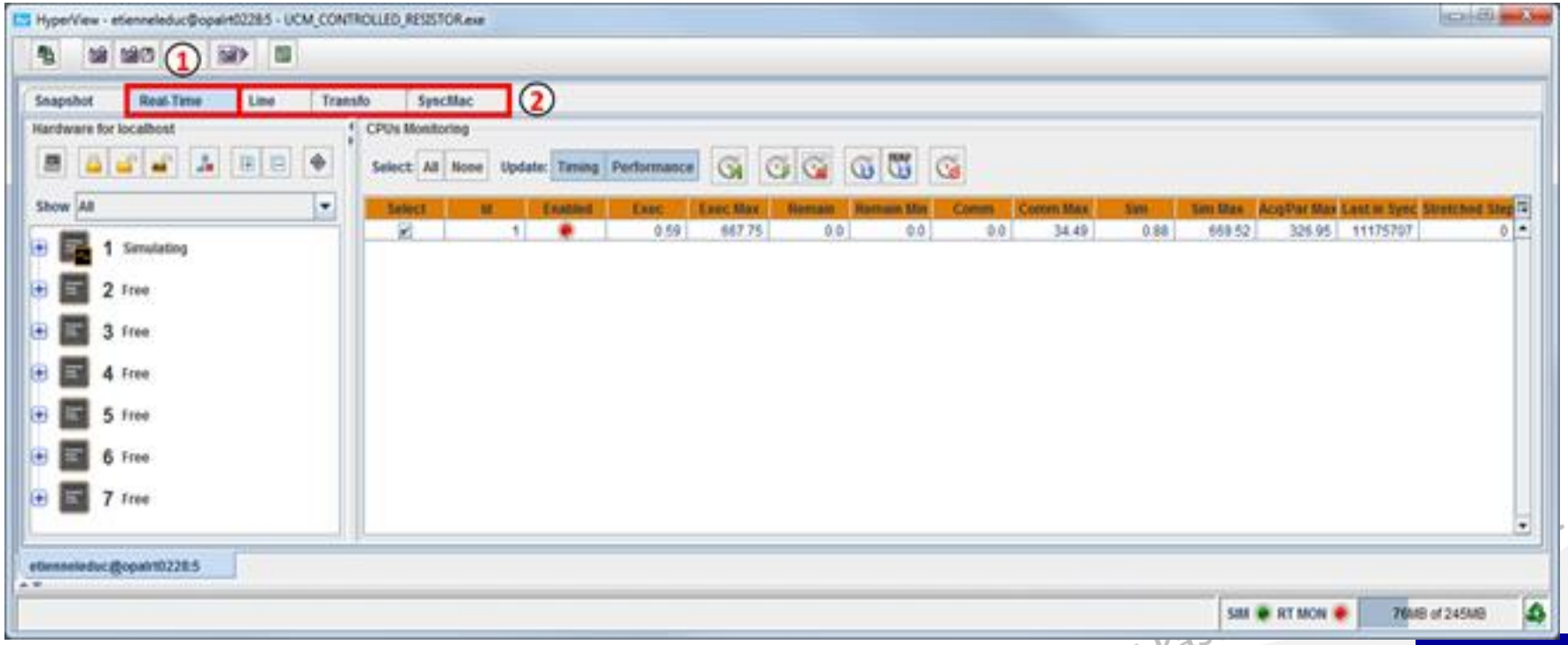
# HYPERSIM

- **ScopeView**: Signal visualization, data analysis and monitoring



# HYPERSIM

- **HyperView**: enables monitoring simulation performance in real-time



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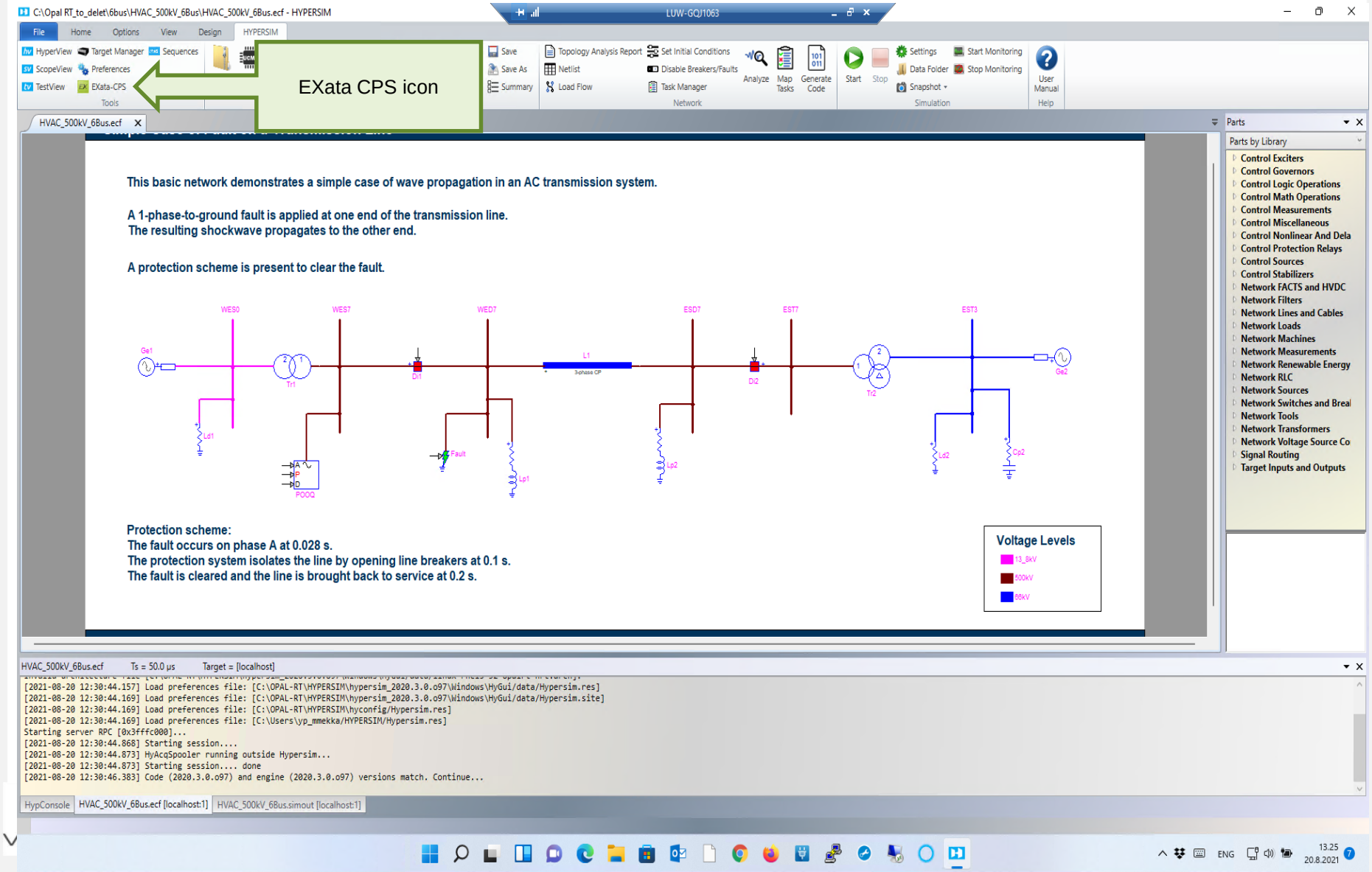
C:\Opal RT_to_delet\6bus\HVAC_500kV_6Bus\HVAC_500kV_6Bus.ecf - HYPERSIM
LUW-GQJ1063
File
Home
Options
View
Design
HYPERSIM
HyperView
Target Manager
Sequences
ScopeView
Preferences
TestView
EXata-CPS
Tools
EXata CPS icon
Save
Save As
Summary
Topology Analysis Report
Netlist
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Network
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User Manual
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Lp1
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Ld2
Cp2
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13.8kV
500kV
69kV
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Parts by Library
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Control Math Operations
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HypConsole
HVAC_500kV_6Bus.ecf [localhost:1]
HVAC_500kV_6Bus.simout [localhost:1]
ENG
13.25
20.8.2021

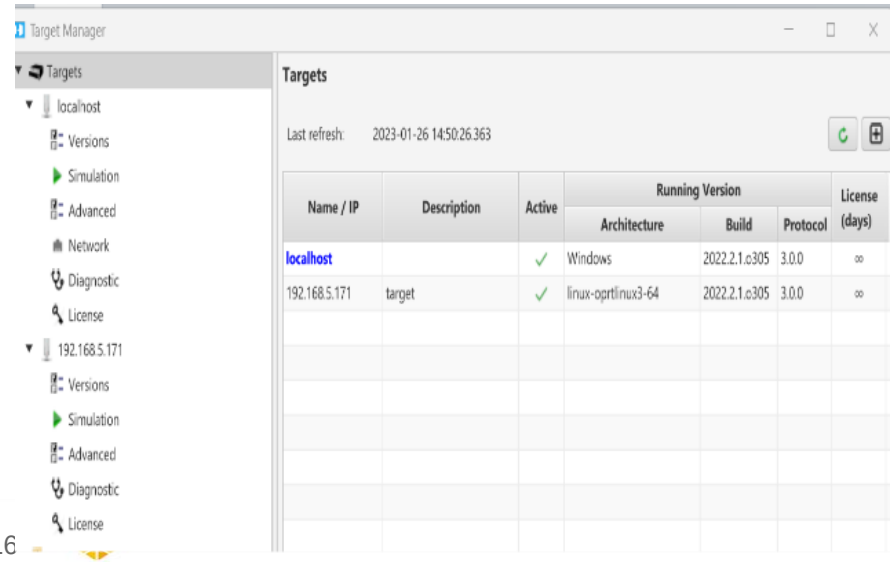
# Starting with HYPERSIM

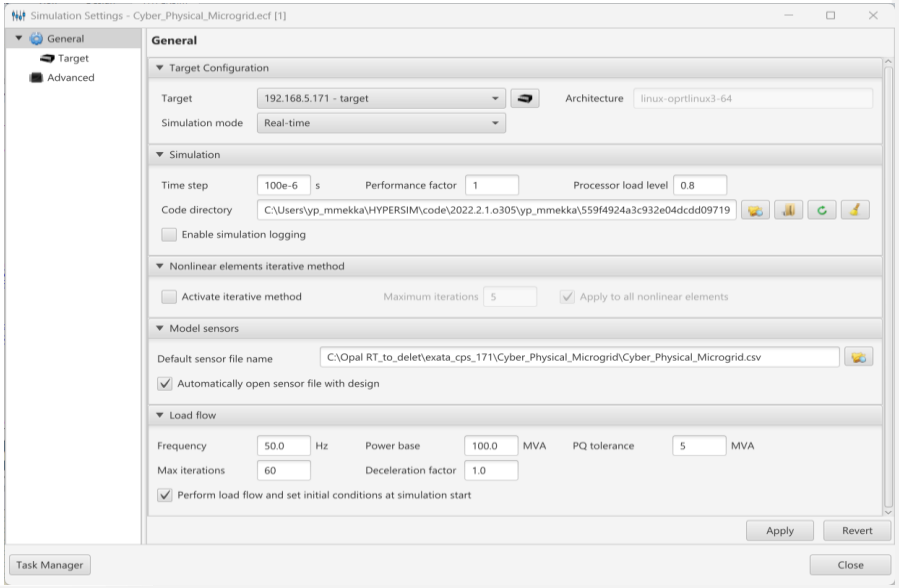
- Running the model at real-time requires the following steps

Step 1: Targets –––> click (+) sign to add target

Step 2: Add New Target –––> pops up window, define IP address for the target and name, --> ok target will appear at the target Manager window

Step 3: Simulation Settings –––> Target Configuration –––> chose the target, and at the “Simulation mode” chose “Real-time”



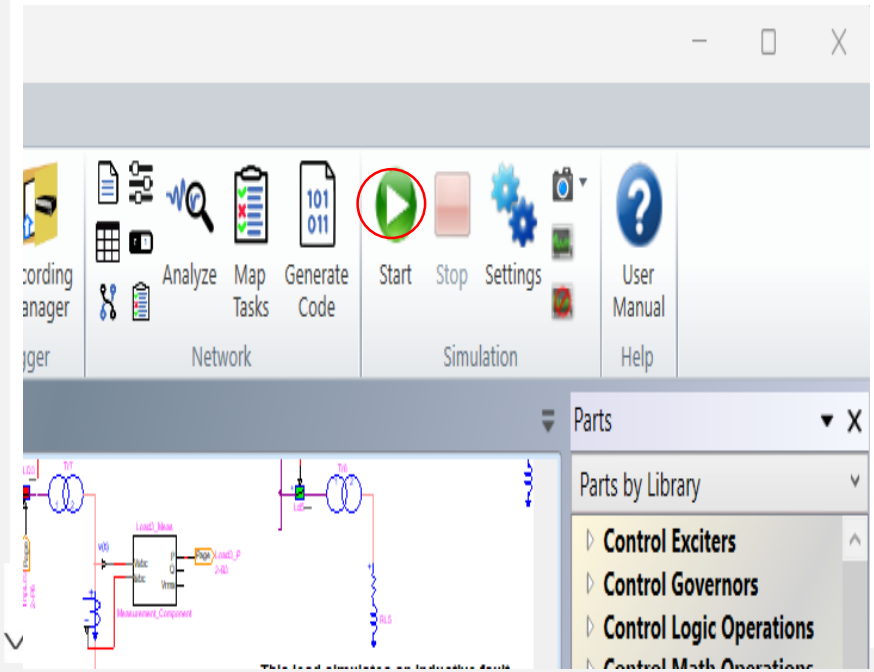



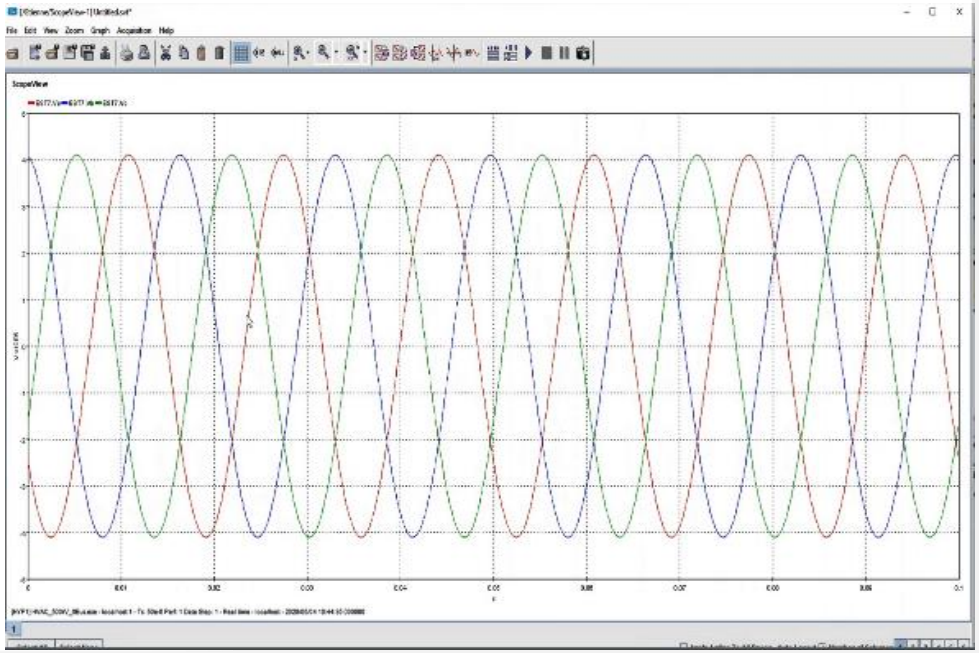
## Starting with HYPERSIM

- Running the model at real-time requires the following steps

Step 4: Start −−> the tasks are mapped automatically to the various cores, the code is compiled and the simulation starts running.

Step 5: ScopeView−−> visualize the simulation results



## SCALABLE EXata CPS

- Windows based high-fidelity network emulator/simulation, which simulates the network communications of electrical grids, attacks, defenders etc. EXata CPS is integrated with OPAL-RT's HYPERSIM real-time simulator on the same hardware to offer a complete real-time cyber-physical solution for the development, testing, and assessment of electrical grids, support 100s and 1000s of devices.

- Develop emulation/simulation models for new networking technologies. Design new communications protocol models using the OSI-style

- Connect real networks, applications, and devices with EXata emulated network

- Analyze and manage EXata virtual networks with popular, industry-standard, tools

- Develop, test and evaluate, and train users on cyber warfare and network security technologies.

## Common Attack Vectors

- Backdoors and holes in network perimeter
- Exploitation of vulnerabilities in SCADA protocols
- Communications hijacking and man-in-the-middle attacks
- Database attacks
- Bogus input data to the controller introduced by compromised sensors and/or exploited network link between the controller and the sensors
- Manipulated and misleading output data to the actuators/reactors from the controller due to compromised network link between the controller and the actuators
- Attacks on timing and synchronization

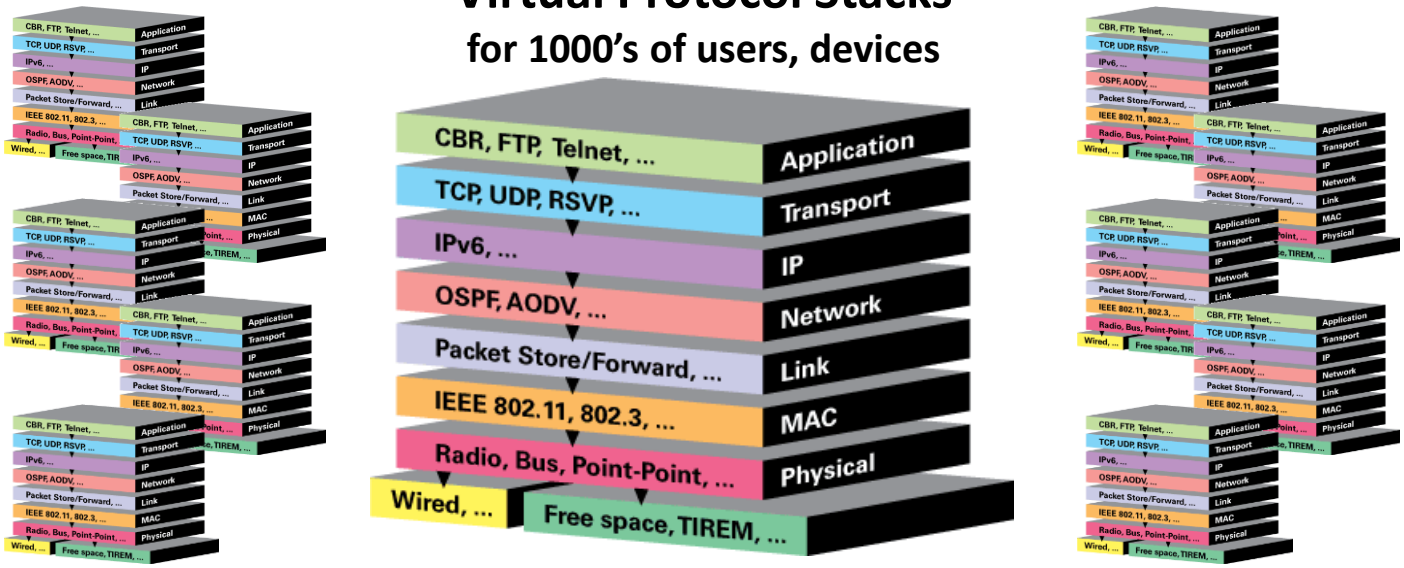
# EXata

Command-Line

GUI: Design, Visualize, Analyze

## Virtual Protocol Stacks

**for 1000's of users, devices**



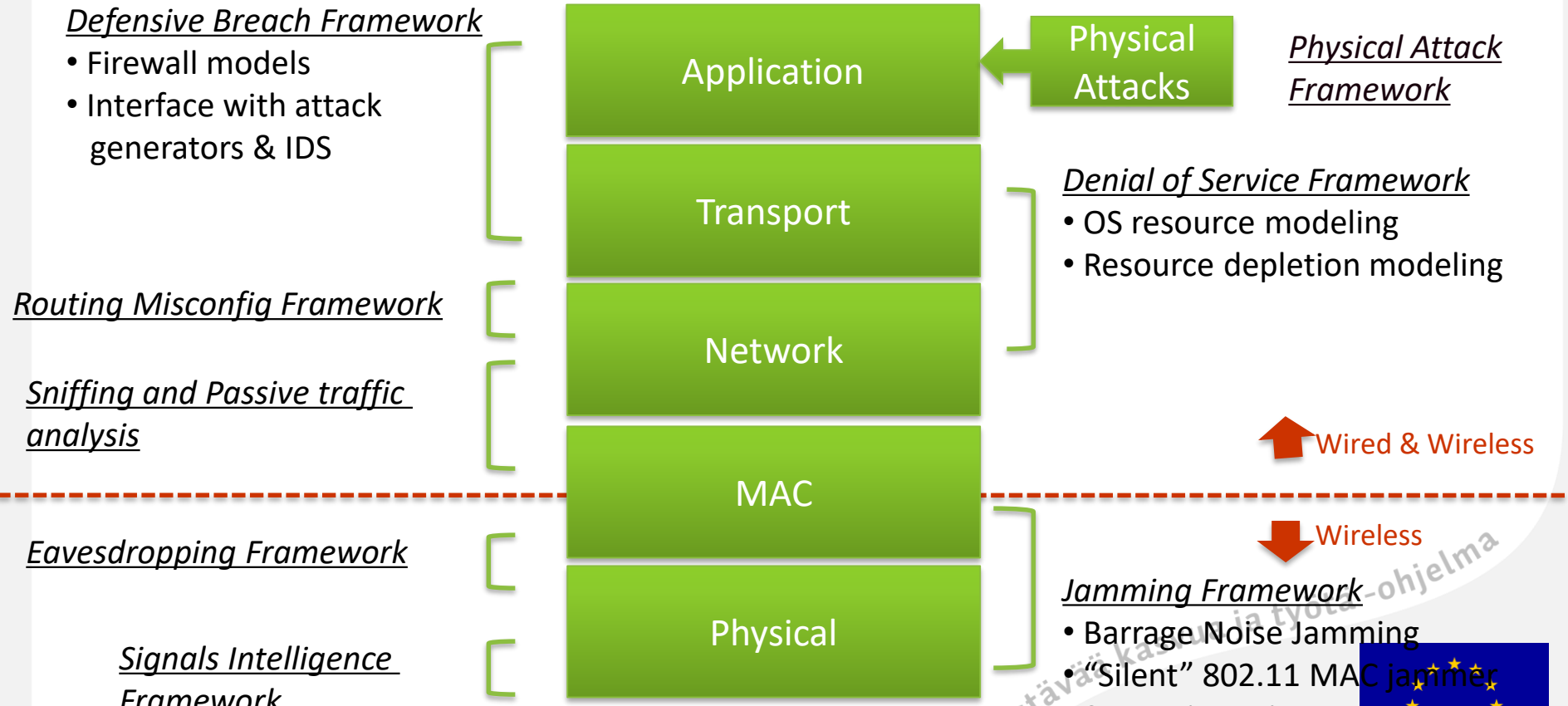

Hardware In The Loop + External Interfaces

Wireless Channel, Mobility & Terrain Models

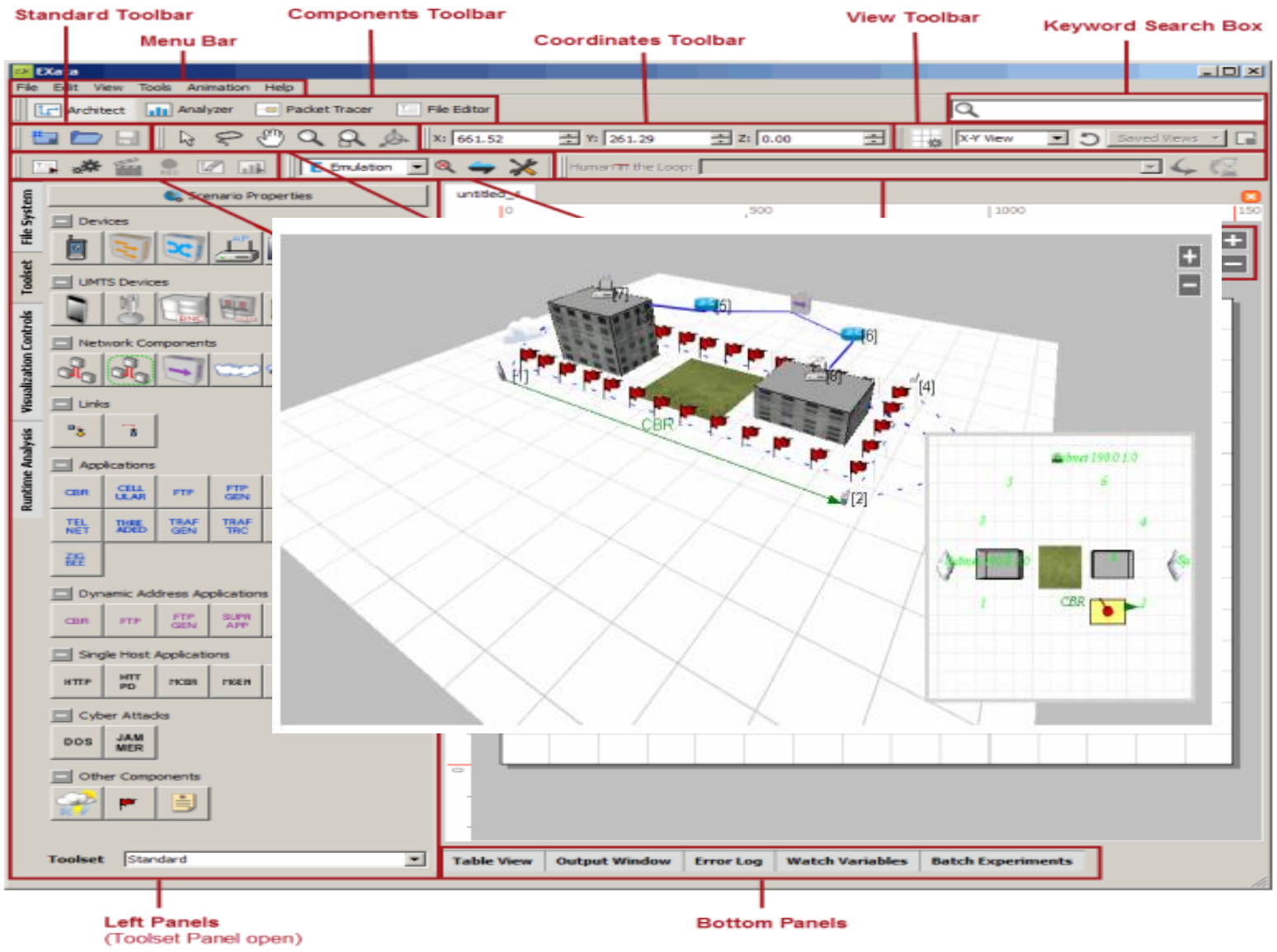
Kernel for Simulation & Emulation

Packet Sniffer + SNMP Interfaces

## Attack models encompassing the protocol stack :

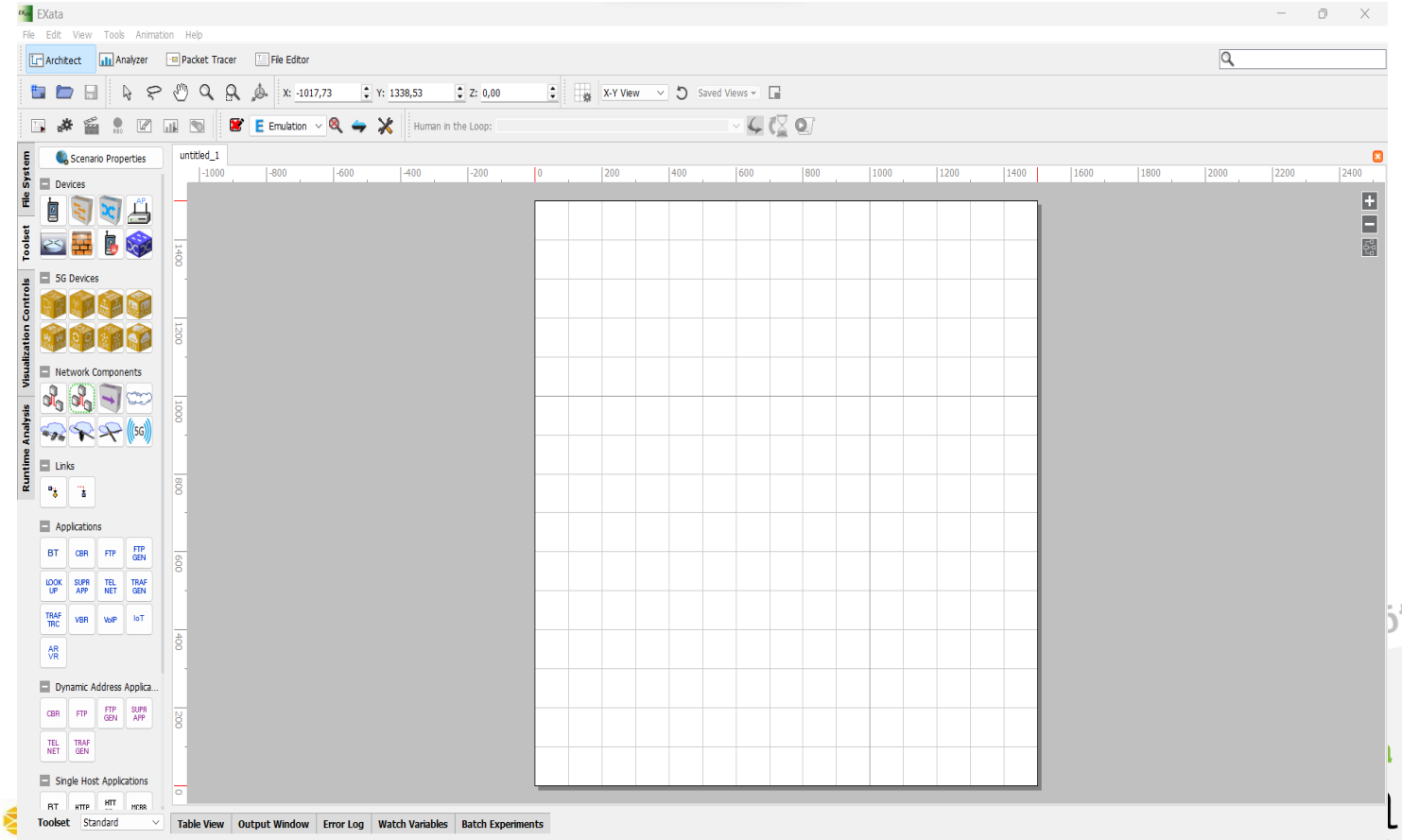


# EXata

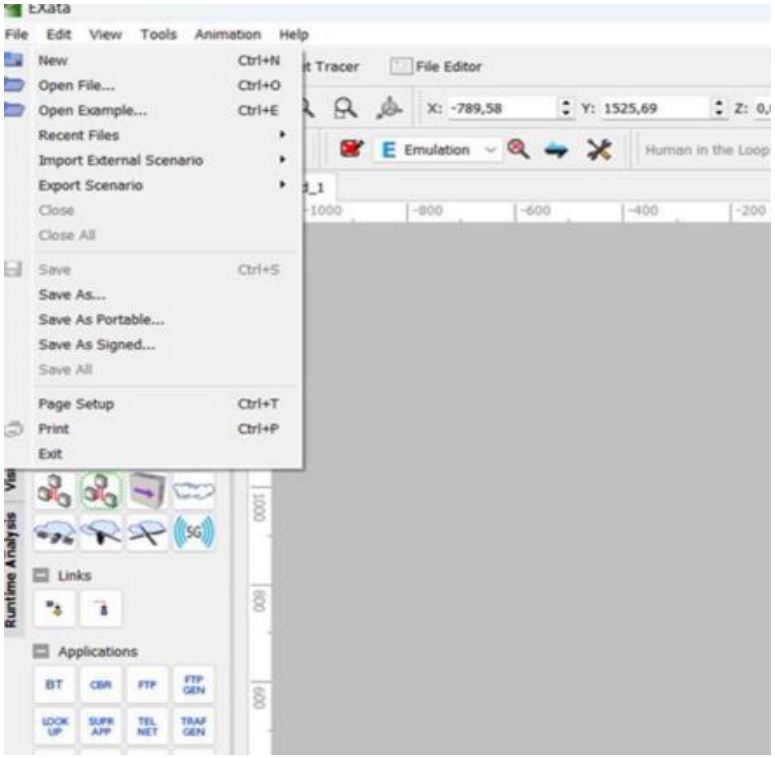

Standard Toolbar
Menu Bar
Components Toolbar
Coordinates Toolbar
View Toolbar
Keyword Search Box
File Edit View Tools Animation Help
Architect
Analyzer
Packet Tracer
File Editor
Emulation
Scenario Properties
Devices
UMTS Devices
Network Components
Links
Applications
Dynamic Address Applications
Single Host Applications
Cyber Attacks
Other Components
Toolset
Standard
File System
Toolset
Visualization Controls
Runtime Analysis
Table View
Output Window
Error Log
Watch Variables
Batch Experiments
CBR
Left Panels
(Toolset Panel open)
Bottom Panels

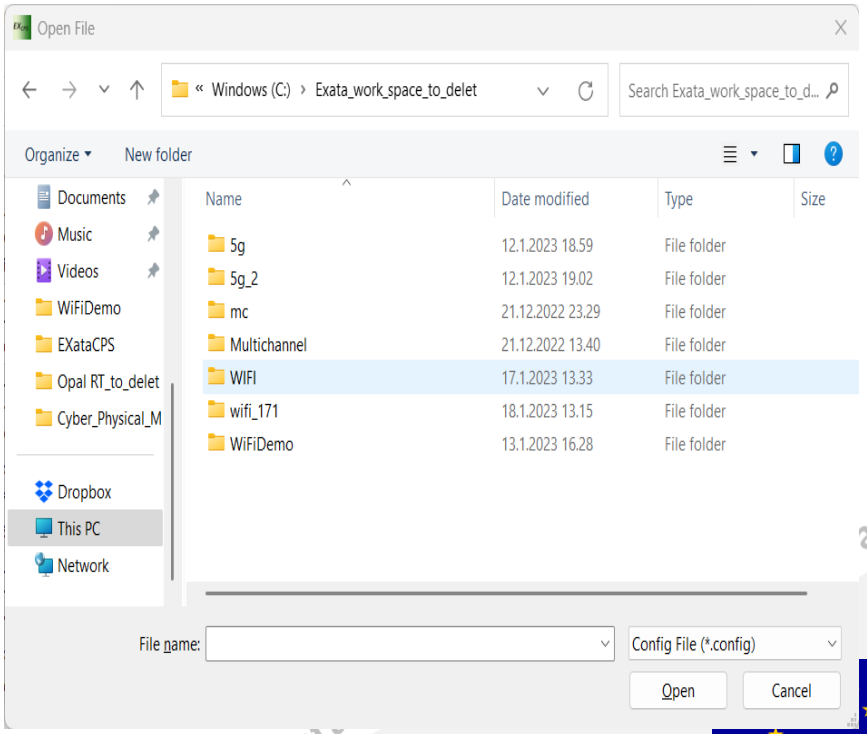
# EXata

EXataCPS GUI starting by default with new design mode



# EXataCPS GUI new design file window and file Explorer window



## EXataCPS GUI model design

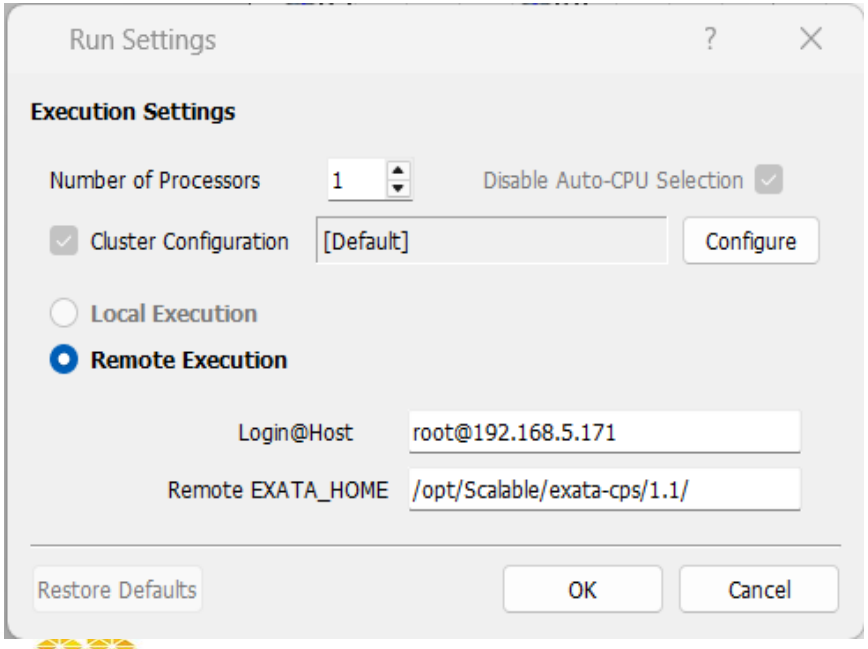
- Step 1: Click EXataCPS symbole GUI window will pops up--> do one from the following
- Step 2: File −−> New −−> new design file will open
- Step 3: File −−> Open file −−> new file Explorer window will pops up to navigate to existing design file
- Step 4: File −−> Open Example −−> a new file Explorer window will open, and the user should navigate to the SCALABLE examples folder. Other options are available under the File toolbar menu, which the user can explore.
- Step 5: after user open one from the above, at the open canvas user may create a model accordance with the guidelines provided in the SCALABLE EXataCPS "Product Tour" documents. The examples provided can also be used as a platform for developing a new model.

# EXata

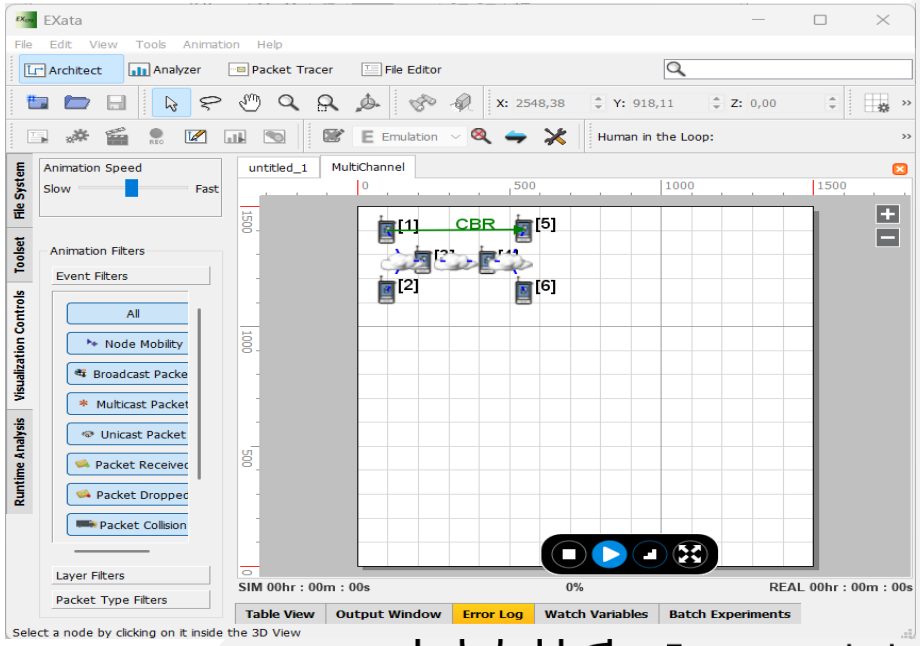
- EXataCPS GUI model execution

- To run the model in real-time after it has been built in EXataCPS, the model must be transported to the OPAL-RT real-time simulator, where initialization and execution can begin as follows

Run Settings




visualise mode



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## EXataCPS GUI model execution

- To run the model in real-time after it has been built in EXataCPS, the model must be transported to the OPAL-RT real-time simulator, where initialization and execution can begin as follows

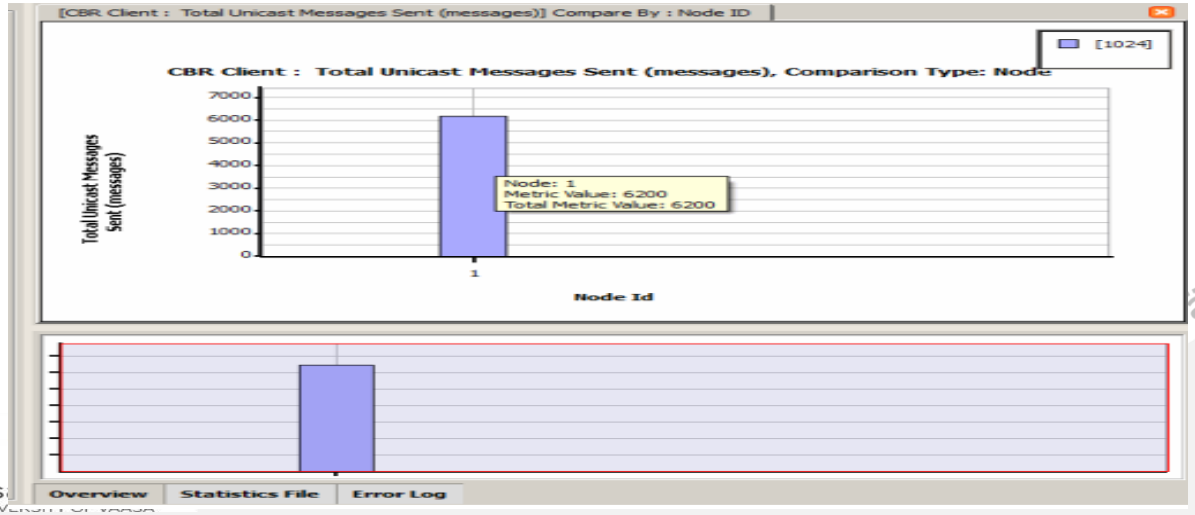
  - Step 1: click Run Settings  −−> pops up window of Run Settings, make the admin SSH access to the target and define the directory for the execution folder at the target --> ok
  - Step 2: select execution mode −−> Target Configuration −−>
  - Step 3: click  Initialize Simulation −−> pops up window, ask user to save example scenario
  - Step 4: A copy of the scenario is saved −−> the design mode will change to visualize mode

## EXataCPS GUI model execution

- To run the model in real-time after it has been built in EXataCPS, the model must be transported to the OPAL-RT real-time simulator, where initialization and execution can begin as follows

  - Step 5: Click play button  --> to run the scenario in real-time

  - Step 6: Click he Analyze Results button  --> simulation results in EXataCPS Analyzer



# Cyber Physical system security of Digital Energy Systems (CR-DES )

- Test and predict power systems and communication networks behavior under attack.
- Ability to scale to represent the entire network.
- Integration of the developed real time simulation models with equipment and power grid HIL, PHIL etc.
- Run ‘what-if’ scenarios about critical infrastructure under cyber-attack without threatening operations.
- Assess effectiveness of tools, techniques and architectures to ensure system availability.
- Measure and improve system resiliency.

Kestävää kasvua ja työtä -ohjelma
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