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Developments of the Cyber Physical Security CPS Platform: CR-DES project: D2.1

Cyber security environment at FREESI lab

School of Technology and Innovation:

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Abstract

Today's energy grid is becoming more 'intelligent' and increasing in complexity that composed of electrical power system and information communications technology (ICT) infrastructure i.e. The energy grid is becoming more vulnerable to cybersecurity threats by expanding the attack surface. Therefore, cyber security environment at FREESI lab is developed to simulate/test the energy system in different circumstances based on "What if scenario" to measure and improve energy system resilience. The development process of the cyber security environment at FREESI lab simulation platform is explained systematically in this document. The document is intended to be self-experienced/ to serve as an example to help other users to configure, simulate and run their own projects in the future. By following up the development and configuration procedure, other users will able to develop adequate knowledge to undertake the platform development tasks and settle the troubleshooting issues, in which that accelerate the research, education and developments activities in FREESI lab.

Keywords

Cyber Physical System (CPS), FREESI, EXata, HYPERSIM, Real-time simulator





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Introduction

Today's energy grid is becoming more 'intelligent' and increasing in complexity that composed of electrical power system and information communications technology (ICT) infrastructure i.e. The energy grid is becoming more vulnerable to cybersecurity threats by expanding the attack surface. The objective of this document is to explain systematically the development of the cyber security environment at FREESI lab simulation platform. The document is intended to be self-experienced/ to serve as an example to help other users to configure, simulate and run their own projects in the future. The development of the Simulation Platform task start by purchasing the state-of-the-art real-time simulator. The real-time simulator was delivered by Opal RT Europe France branch. It reached Vaasa University at 24. September 2020. The real-time simulator is consist of hardware and software in which that include an innovative solution for cyber physical system CPS. The CPS solution is a combination of two software, Exata communication emulation tool and HYPERSIM power system simulation tool. These tools are integrated and internally connected, doing so both tools are running in parallel on the real-time simulator hardware. This CPS tool plays a key role on reducing cost, offering a complete solution for cybersecurity assessment.

The CPS solution can be used to investigate how the network responds to different attack vectors "What if scenario", while a power system simulation is running in real-time and monitoring all the power system parameters. In addition, visualization to gain valuable insight into the network dynamics, including how malware spreads within the network. These include;

- 1. The hop-by-hop path taken by an attack packet from an attacker to a victim
- 2. Key statistics which are updated dynamically, including memory and CPU utilization at devices (which are often impacted by cyber-attacks)
- 3. Cyber assurance state of a node in the network, i.e., whether the node has been compromised and the degree to which it is compromised
- Post-simulation, statistical data collected during the simulation (for example, number of suspicious traffic packets, number of packets blocked at a firewall,





number of services compromised, etc.) can be analyzed to help identify potential issues and the effectiveness of counter-measures

5. Effectiveness of mitigation strategies: The models can be used to run multiple what-if scenarios with different network configurations and attack patterns to assess the effectiveness of different counter-measures





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1 Development of the CPS platform

1.1 Checking the real-time simulator package

First of all checking the delivered real-time simulator package is one of our concern. The package should include the items that we ordered based on the official quotation and compare it with the system summary documentation delivered with the package as illustrated in Figure 1. Figure 1 is showing a diagram of the layout for the delivered system. It is a top view and is meant to show the component placement and interconnection. The "Empty" boxes are the free available slots in the motherboard that can be used to install the analog/digital input/output cards. These cards can be used to facilitate the connection of the real-time simulator to external intelligent electronic devices (IEDs) based hardware in the loop (HIL), controller hardware in the loop (CHIL), power hardware in the loop (PHIL) etc.



System #1 (OPT901579)

Figure 1. Block diagram of the delivered system

Unpacking for the delivered package had been video recorded and photographed in the presence of two persons from computer science department. The first looking, that illustrated in Figures 2 and 3, the system is physically fine.







Figure 2. The delivered package OP5700 Real-Time Simulator



Figure 3. OP5700 Real-Time Simulator System





1.2 General overview of the real-time simulator

The OP5700 is a complete simulation system operating with Virtex-7 FPGA platforms. It is designed to be used either as a desktop (or shelf top) or as a more traditional rack-mount. It contains a powerful Target Computer and a signal conditioning stage. The design makes it easier to use with standard connectors (DB37, RJ45 and mini-BNC) without the need for input/output adaptors and allows quick connections for monitoring. In its standard configuration, the lower part of the chassis contains a powerful target computer that can be added to a network of simulators or can act as a standalone.

1.3 List of delivered system

The system serial number is OPT901579 (OP5700 Real-time simulator) and the target include the features listed in Table 1.

| Items | Quantity | Description |
|------------------|----------|--|
| Operating System | 1 | CentOS-opal-v0.38 |
| Chassis Type | 1 | OP5700 |
| CPU | 1 | Intel Xeon E5, 8Cores, 3.2 GHz, 20M Cache |
| Total Core # | 8 | |
| Memory | 2 | 8 GB |
| Motherboard | - | X10DRL-I Supermicro Motherboard Dual Intel® Xeon® |
| | | (E5) processor |
| IP Address | | 192.168.5.171 (eth 0) |
| | | see Figure 4 for Ethernet port identifications |
| AC Input | | 100-240V, 60-50Hz |
| FPGA Board Index | | 00 |

Table 1.List of features

1.4 Connection of the OP5700 real-time simulator

Next step, is to connect the OP5700 real time simulator to University communication network. This task needs to configure the front panel "eth0" adapter to be registered with the Vaasa University communication network based on the physical adapter MAC address: MAC: 3C:EC:EF:6A:85:98 and IP address:193.166.118.100

Contact by emails to the University IT group had been made to register the system to the University network, and now it is registered, so whenever we connect the system to the network the University network Dynamic Host Configuration Protocol (DHCP) will recognize it.





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1.5 First starting of the real time simulator

At this point, first starting up of the real time simulator needs to connect the target to the University communication network via RJ45 and power supply cables. In order to facilitate the starting up procedure mouse, keyboard and desktop screen also had been connected to the target. The power button is turned ON, the real time simulator start up, Linux CentOS kernel start the checking process of the all installed drivers, cards etc. The checking steps show the GREEN "OK" at the desktop screen, then the Desktop icons appear. At this context, it clarifies that the operating system, drivers, cards etc. are installed/operate correctly and the first checking, testing for the delivered real time simulator had been accomplished successfully.





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2 Tasks based on WP2

2.1 Task (T2.1) Installation and commissioning of software, device drivers on the host computer and on the real time simulator.

2.1.1 Download the needed software

The first step in this task is to download the needed software from the provider's webpage and repository, below is the list of the software and the download locations;

1. Download the last version of the HYPERSIM 2020,2,0,078 from Opal RT

Download Page

- Download the latest version of the Exata Cps 1.0 from the repository ftp://ftp.opal-rt.com/products/HYPERSIM / username: client password: opal102
- 3. Download MobaXterm for open the SSH connection to the target or any other open SSH software.
- Download the Cygwin with openssh package and follow the instructions at this link https://www.cygwin.com/

2.1.2 Installations on the HOST PC

2.1.2.1 Installations of the HYPERSIM software on the HOST PC

The second step is the installations, starting with the HYPERSIM software. Before starting the installation, please see the HYPERSIM host PC requirements at the HYPERSIM installation guide and be shore that you PC pass these requirements. If your PC pass the requirements, installation start by executing the setup.exe file "OPAL RT_HYPERSIM _2020.2.exe", double clicking on it and follow the installation instruction. It is highly recommended that the directory of the HYPERSIM installation folder to be located at the C:\opal rt folder to limit the software errors.





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2.1.2.2 Installation of the Exata software,

Execute the setup.exe file by double clicking on the exata-cps-1.0-windows-installer-64bit.exe file, follow the installation instruction and keep the offered default options. This will install the software on the following directory, C:\Program Files\Scalable\exatacps\1.0.

2.1.2.3 Installation of the MobaXtrem software.

This software is free of charge and it is available at the MobaXtrem webpage https://mobaxterm.mobatek.net/. The installation steps is easy and steps forward.

2.1.2.4 Installation of the Cygwin with openssh features.

From the available location shown above search for the setup.exe file "Install Cygwin by running setup-x86_64.exe". Run this file from the downloading directory and follow the installation instruction. Keep in mind that you need to search for the openssh package from the list of the offered packages and select it, as well as you need to select all its dependences. This will install the openssh in your host computer. This openssh connection allows opening link between your host computer and the real time simulator. Along with this link, the host computer is able to transfer the model executing code to the real time simulator.

2.1.2.5 Installation of the EXata CPS on OPAL Simulator

Copy the EXata CPS installer on the simulator using mobaXterm, make sure the execution

rights are enabled, then execute it;

```
scp exata-cps-1.0-linux-installer-64bit-centos6 root@<IP>:
ssh root@<IP>
chmod +x exata-cps-1.0-linux-installer-64bit-centos6
./exata-cps-1.0-linux-installer-64bit-centos6
```





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2.1.3 Activation of the installed software and upload their licenses

2.1.3.1 HYPERSIM software activation in HOST PC

The HYPERSIM software activation is starting by following a number of steps, below the list of these steps. It will go through the request and install the HOST licenses on the user Windows HOST PC. Within the Host Windows PC do the following steps;

 Open the HYPERSIM License Activation Tool, from the Windows startup menu chose the HYPERSIM folder "HYPERSIM R20XX.XX" and click on the "Activation HYPERSIM R20XX.XX", as illustrated in Figure 4.



Figure 4. Window startup menu

This will open the HYPERSIM license activation window as illustrated in Figure 5.







Figure 5. HYPEERSIM license activation window

2. Click on Request a new license, this will generate the Machine ID, go to the specified link and paste the Machine ID in the license request, as illustrated in Figure6.

| HYPERSIM License Request | | | _ | | \times |
|---|-------------------------------------|--------------------------------|------------------|--------------------|----------|
| | H | | | | |
| HYPERSI | M License | Reques | t | | |
| | | | | | |
| Your computer information is sl please follow the link below, fill information. | hown below. To o in the form and | complete your copy/paste yo | licens ur cor | se reque mputer | est, |
| MAC_RANK=0 INFO_TIME=06/11/2019 | | | | | |
| MAC Address=c8:5b:76:94:ab:07 HD Serial Number=2632974149 | | | | | |
| | | | | | |
| https://www.opal- | -rt.com/contact-t | echnical-supp | <u>ort/</u> | 1 | |
| | | 0 | | | |

Figure 6. HYPEERSIM license Request





3. Send this information to Opal technical support center as illustrated in Figure 7. and waiting for the Opal technical support center response by sending an email that will include the license for your machine.

PLEASE DESCRIBE YOUR PROBLEM * MAC_RANK=0 INFO_TIME=06/11/2019 MAC Address=c8:5b:76:94:ab:07 HD Serial Number=2632974149

Figure 7. Opal technical support center

4. Load a license file that had sent by the Opal technical support center as illustrated

in Figure 8.

11 HYPERSIM License Activation



HYPERSIM License Activation

You have an active license with 48 days remaining. More info



Support

Х

Figure 8. HYPEERSIM license activation window load license file

5. Navigate to the folder where you saved the license and select it (.bin or .zip) and activate it. This will open a conformation window as illustrated in Figure 9.





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11 HYPERSIM License Information

| Feature Name | Former Value | New Value |
|--|--|-----------------------|
| Expiration date | 24-12-2019 | 24-12-2019 |
| End of software maintenance | 13-05-2025 | 13-05-2025 |
| Includes HYPERSIM | Yes | Yes |
| Includes ScopeView | Yes | Yes |
| Includes TestView | Yes | Yes |
| Number of supported NRT processors | 12 | 12 |
| Number of supported RT processors | 12 | 12 |
| Number of supported single-phase buses | 100000 | 100000 |
| | | |
| Confirmation: Apply license | | |
| The license you have selected is ic Applying this new license will repl with this one. | Ientical to your active license. ace your active license file Yes No | Activate Save to File |

License Information

Figure 9. HYPEERSIM license information window

6. Close the Activation Tool you can now open HYPERSIM 20XX.XX software

2.1.3.2 HYPERSIM software activation in the real time simulator TARGET

The HYPERSIM software activation at the target is starting by following a number of steps. The list of these steps will go through the request and install the TARGET licenses on the real-time simulator. Within the Host Windows PC that connected to the TARGET via "eth0" do the following steps.

 Open the last version of the HYPERSIM 2020.2.0.078. Go to the HYPERSIM Tab > Tools > Target Manager within the HYPERSIM opened window as illustrated in Figure 10.





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Figure 10. HYPEERSIM software window

2. In order to connect the HOST PC to the TARGET, from the target manger pop-up window click on the + sign on the right and type the TARGET IP address, (This IP address is provided in the System Description Document pdf provided with the Simulator) as illustrated in Figure 11.

| Targets | Targets | | | | | | |
|---|----------------|-------------------------|--------|-----------------------|-----------------|-------------------|--------|
| localhost | Last refresh: | 2010-11-06 12:00:54 723 | | | | c E | |
| 192.108.11.215 Default Code Generation | cuserencian | 2015 11 00 12:05:54:725 | | | | | Add.pc |
| Denant code deneration | Name / IP | Description | Active | Architecture | Current Version | License (days) | |
| | localhost | | ~ | Windows | R2019.2.0.o48 | 48 | |
| | 192.168.11.215 | Obyrne | ~ | linux-rhel5-32-opalrt | R2019.2.0.o48 | 50 | |
| | | | | | | | |
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Figure 11. HYPEERSIM TARGET connect

3. Expand the list of the TARGET by clicking the arrow beside the IP address of the Target on the left, select "Versions" from the list, make sure that the versions match. If the current version is not match, please consult the "this KB Article". Click refresh to see all available versions as illustrated in Figure 12.





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| 🔢 Target Manager | | - 🗆 X |
|---|---|--------------------------|
| 🔻 🗬 Targets | Target Versions - 192.168.11.215 | 15 |
| Uccalhost 192.168.11.215 | Versions Log | |
| 📕 Code Generation | Local running version: R2019.2.0.048 | 1 |
| 별 Versions | Last refresh: 2019-11-06 12:10:28.12 (target is running the same version) | |
| Advanced | | |
| License | | |
| Uefault Code Generation | Installed versions | * 4 0 |
| | Name Location | Refresh versions in list |

Figure 12. HYPEERSIM target manager window

 You can change the HYPERSIM version by right-clicking on the desired version and selecting "Use this version as server on target". Versions should match as illustrated in Figure 13.

| Versions Log Local running version: R2019.2.0.0 Last refresh: 2019-11-06 | 48 | | | |
|--|--|--|---|--|
| Local running version: R2019.2.0.0 Last refresh: 2019-11-06 | 48 | | | |
| Last refresh: 2019-11-06 | | | | 1 |
| | 13:03:21.926 (target i | s running the same version) | | |
| | | | | |
| | | | | |
| Installed versions | | | * | 6 (|
| Name | | Location | | Date |
| R2019.2.0.048 | · · · · · | /ssr/hypersim_R2019.2.0.o48 | 2019-10 | 1-16 15:36 |
| R6.2.2.o888 | ersion from target | /ssr/hypersim-target_R6.2.2.o888 | 2018-12 | -18 10:32 |
| R6.1.3.o698 | as server on target | ssr/hypersim-target_R6.1.3.o698 | 2018-03 | -09 17:28 |
| R6.1.3.o698 | /export/local | l/ssr/hypersim_R6.1.3.o698 | 2018-03 | -09 17:30 |
| R6.0.11.o505 | /export/local | l/ssr/hypersim_R6.0.11.o505 | 2019-10 | -17 17:11 |
| R2019.1.1.o34 | /export/local | l/ssr/hypersim-target_R2019.1.1.o34 | 2019-07 | -04 15:39 |
| R2019.1.1.o34 | /export/local | l/ssr/hypersim_R2019.1.1.o34 | 2019-07 | -04 15:39 |
| | | | | |
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| | | | | |
| | | | | |
| < [| | | 1 | |
| | Installed versions Name R2019.2.0.048 Uninstall this version R6.2.2.0888 Use this version R6.1.3.0698 Use this version R6.1.3.0698 Use this version R6.0.11.0505 R2019.1.1.034 R2019.1.1.034 Image: Control of the second secon | Installed versions Name R6.2.2.0888 Uninstall this version from target R6.1.3.0698 Jest version as server on target R6.1.3.0698 /export/loca R6.1.1.0505 /export/loca R2019.1.1.034 /export/loca R2019.1.1.034 /export/loca R2019.1.1.034 /export/loca | Name Location R2019.2.0.o48 Uninstall this version from target /ssr/hypersim_R2019.2.0.o48 R6.2.2.0888 Uninstall this version from target /ssr/hypersim-target_R6.2.2.0888 R6.1.3.0698 Use this version as server on target /ssr/hypersim-target_R6.1.3.0698 R6.1.3.0698 /export/local/ssr/hypersim_R6.1.1.0505 R2019.1.1.034 /export/local/ssr/hypersim_R2019.1.1.034 R2019.1.1.034 /export/local/ssr/hypersim_R2019.1.1.034 R2019.1.1.034 /export/local/ssr/hypersim_R2019.1.1.034 R2019.1.1.034 /export/local/ssr/hypersim_R2019.1.1.034 | Installed versions Image: Control of the second secon |

Figure 13. HYPEERSIM updating version within the target

5. In order to request license for your TARGET, go to License from the list, click on the i (blue circle) on the right, copy the Machine ID and click the envelope. This





will bring you to Opal RT Website to create a Support Ticket (Case) to which the requested license will send by email that include the license file as illustrated in Figure 14.

| Targets | Target License - 192.168.11.215 | | |
|-------------------------|---|--|--------------------------|
| Jocalhost | 192.168.11.215 Log | | |
| 192.168.11.215 | | | |
| I Code Generation | For requesting a new license, please join the machine information below. | | |
| ≣_ Versions | MAC_RANK=0 | | |
| Advanced | MAC Address=0C:C4:7A:00:38Ï41 | | |
| Default Code Generation | HD Serial Number=SATA_Samsung_SSD_840S1ANNSADB62906Z | | |
| Delauti Code Generation | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | | | |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE | RSIMTARGET_PF000-000-S01_DEMO_2019-12-26_1 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE | RSIMTARGET_PF000-000-S01_DEMO_2019-12-26_12 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version | RSIMTARGET_PF000-000-S01_DEMO_2019-12-26_13 Value 2019.2 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation | CRSIMTARGET_PF000-000-S01_DEMO_2019-12-26_13 Value 2019.2 12 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation Activated cores for non-real-time simulation | ERSIMTARGET_PF000-000-S01_DEMO_2019-12-26_12 2019.2 12 12 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation Activated cores for non real-time simulation Activated 1-phase nodes | ERSIMTARGET_PF000-000-S01_DEMO_2019-12-26_12 2019.2 12 12 100000 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HVPE Description Software Version Activated Cores for neal-time simulation Activated cores for non real-time simulation Activated 1-phase nodes Activated MMC valves on FPGA | ERSIMTARGET_PF000-000-S01_DEMO_2019-12-26_12 2019.2 12 12 10 10000 36 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation Activated cores for non real-time simulation Activated Ores on PGA Activated MMC valves on FPGA Activated MMC cells per valve on FPGA | RSIMTARGET_PF000-000-S01_DEMO_2019-12-26_12 2019.2 12 12 12 100000 36 1600 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation Activated cores for non real-time simulation Activated orDes nodes Activated MMC valves on FPGA Activated MMC valve on tPGA Activated MMC valve controllers on FPGA | Value 2019.2 12 12 12 10000 36 16000 36 36 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation Activated cores for non real-time simulation Activated orNC valves on FPGA Activated MMC valves on FPGA Activated MMC valve controllers on FPGA External time synchronization with the Spectracom card using IRIG-B or | RSIMTARGET_PF000-00-S01_DEMO_2019-12-26_13 2019.2 12 12 12 12 100000 36 10000 100 | 23456.bin (expires in 50 |
| | License File: /export/local/ssr/hyconfig/OPALLICENSE_201902791_HYPE Description Software Version Activated cores for real-time simulation Activated cores for non real-time simulation Activated Orner PGA Activated MMC valves on FPGA Activated MMC valve controllers on FPGA External time synchronization with the Spectracom card using IRIG-B or | Value Value 2019.2 12 12 12 100000 36 1600 36 10PS true | 23456.bin (expires in 50 |

Figure 14. HYPEERSIM request license window

6. Paste the Machine ID in this box based on created support Ticket (Case) as illus-

trated in to Figure 15.

PLEASE DESCRIBE YOUR PROBLEM *

MAC_RANK=0 INFO_TIME=06/11/2019 MAC Address=0C:C4:7A:00:3B:41 HD Serial Number=SATA_Samsung_SSD_840S1ANNSADB62906Z

Figure 15. Opal RT Ticket (Case)

 Once you have received the license from Support (.zip file), save it to your files and navigate to it via the folder icon in HYPERSIM. Then click the UP arrow to apply the license as illustrated in Figure 16.





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| Remaining days Software Version | 50 2019 2 | 50 | | â |
|---|--------------|--------|--|-----|
| Software Version | 2010.2 | | | |
| | 2015/2 | 2019.2 | | |
| Activated cores for real-time simulation | 12 | 12 | | |
| Activated cores for non real-time simulation | 12 | 12 | | |
| Activated 1-phase nodes | 100000 | 100000 | | |
| Activated MMC valves on FPGA | 36 | 36 | | |
| Activated MMC cells per valve on FPGA | 1600 | 1600 | | |
| Activated MMC valve controllers on FPGA | 36 | 36 | | 201 |
| external time synchronization with the Spect. | true | true | | |
| PTP master with the Spectracom card | true | true | | |
| PTP slave with the Spectracom card | true | true | | |
| external time synchronization (IRIG-B, 1 PPS, | true | true | | |
| Activated I/O data points for Ethernet-base | 1000 | 1000 | | |
| EC 61850 GOOSE publishing | true | true | | |
| EC 61850 GOOSE subscribing | true | true | | |
| EC 61850 Sampled Values publishing | true | true | | ~ |

Figure 16. HYPEERSIM install license window

8. You might see this Window pop up, click OK, at this point you will be ready to use the simulator as illustrated in Figure 17.

| Information Dialog | _ | | × |
|--|---|---|---|
| Message | | | i |
| Osbin file successfully installed. Proceeding to bin file installation. | | | |
| | | 9 | K |

Figure 17. HYPEERSIM confirmation window





2.1.3.3 Scalable EXATA software activation in HOST PC

After EXata is installed in the HOST PC, activation is required to run the EXata software. The first time you launch EXata CPS, the SCALABLE license application will open. There are two options to request the license for the windows computer:

- A. Activating using the license using internet (if you have internet access)
- B. Activating the license manually (if you do not have internet access)

Opal RT delivered the system document file that include the Scalable EXata licenses as illustrated in Figure 18.

| License Type | GUI | Target |
|-----------------|---------------------------------|------------------------------|
| End-User | Tero Vartiainen / Mike Mekkanen | Tero Vartiainen |
| Entitlement | 23e2-a217-1715-c41f-5b17-db7 | 23e2-a217-1715-c41f-5b17-db1 |
| Act ID | 23e2-a217-1715-c41f-5b17-daf | 23e2-a217-1715-c41f-5b17-db0 |
| Expiration Date | 2021-07-09 | 2021-07-09 |

Figure 18. EXata licenses delivered with the system documentation

Therefore, at first option A. was chosen to activate the EXata license using the internet. The Node-Locked License requires an internet connection. If you have an activation ID, select the first option "automatic activation, return and repair" and input the Activation ID, then click on Activate as illustrated in Figure 19.

| le-locked License | Client-Server License | Delete License | Output | | | | | | | |
|--|--|---|--|--|--|--|---|--|----------------|----------|
| Automatic Activ | ation, Return and Repair | | | | | | | | | |
| o activate or return utton. | your license via the Inter | net, enter your Activ | vation ID and | d click on the Activate | or Return button. T | o repair your license | e, enter your Actival | tion ID and click o | n the Rep | air |
| tivation ID: | | | | | | | Activate | e Return | Re | pair |
| Manual Activati | on | | | | | | | | | |
| Generate Requ | est File | | | | | | | | | |
| | | | | | | | | | | |
| Generate a reque will send you a res | st file by specifying the loc sponse file. NOTE: You mu | ation and name of the st have write access | to the direct | le and then dicking or tory where you want | the Generate File b to create the reques | utton. Send the rea t file. | uest file to license@ | scalable-network | s.com. SC | ALABLE |
| | | | | | | | | | | |
| | | | | | | | | | | |
| Request File: | | | | | | | | | | |
| Request Hie: | | | | | | | | | Gener | ate File |
| Request File: | | | | | | | | | Gener | ate File |
| Process Respo | nse File | | | | | | | | Gener | ate File |
| Process Respon | nse File | | | | | | | | Gener | ate File |
| Process Respon | nse File se by specifying the location | on and name of the re | esponse file | sent by SCALABLE ar | nd clicking on the Prov | cess File Button. | | | Gener | ate File |
| Process Respon | nse File se by specifying the location | on and name of the re | esponse file : | sent by SCALABLE ar | d dicking on the Pro | cess File Button. | | | Gener | ate File |
| Process Respondent Activate the licens | nse File se by specifying the locatio | on and name of the re | esponse file : | sent by SCALABLE an | id dicking on the Pro | cess File Button. | | | Gener | ate File |
| Process Respondent Activate the license Response File: | nse File se by specifying the locatio | on and name of the re | esponse file : | sent by SCALABLE ar | id clicking on the Pro | cess File Button. | | | Gener | ate File |
| Process Response File: | nse File se by specifying the locatio | on and name of the r | esponse file : | sent by SCALABLE ar | d clicking on the Pro | cess File Button. | | | Gener | ate File |
| Process Respondent Activate the licent Response File: | nse File se by specifying the locatio | on and name of the n | esponse file : | sent by SCALABLE an | d clicking on the Pro | cess File Button. | | | Gener | ate File |
| Process Respon Activate the licens Response File: | nse File se by specifying the location annually, enter the Activation be-networks.com. SCALA | on and name of the re ion ID and generate Ion ID and generate | esponse file : a return file ise as return | sent by SCALABLE ar by specifying the loci | id clicking on the Prov ation and name of the | ess File Button. | en clicking on the Get | serate File buttor = the return file. | Gener Proce | ate File |
| Process Respon Activate the licens Response File: | nse File se by specifying the location annually, enter the Activat bie-networks.com. SCALA | on and name of the re ion ID and generate SLE will mark the licen | esponse file : a return file ise as return | sent by SCALABLE an by specifying the loci led. NOTE: You must | id clicking on the Prov ation and name of th have write access to | cess File Button. e return file and the the directory wher | en dicking on the Gea | herate File buttor E the return file. | Proce | ate File |
| Process Respon Activate the licent Response File: Manual Return return a license to license @scala | nse File se by specifying the locatio namually, enter the Activat be-networks.com. SCALAI | on and name of the re ion ID and generate SLE will mark the licen | esponse file : a return file ise as return | sent by SCALABLE ar by specifying the loc by NOTE: You must | Id clicking on the Prov ation and name of the have write access to | e return file and the the directory when | in dicking on the Ge | herate File buttor the return file. | Proce | ate File |
| Activate the license Response File: Manual Return or return a license m e to license discala | nse File se by specifying the location annually, enter the Activation be-networks.com. SCALAI | on and name of the n ion ID and generate SLE will mark the licen | esponse file a return file se as return | sent by SCALABLE ar by specifying the loci led. NOTE: You must | id clicking on the Pro- ation and name of th have write access to | cess File Button. e return file and the the directory wher | en didding on the Ger e you want to create | herate File buttor be return file. | Gener Proce | ate File |
| Process Respon Activate the licent Response File: Manual Return return a license me to license Biscala ctivation ID: | nse File se by specifying the location annually, enter the Activat ble networks.com. SCALA | on and name of the re ion ID and generate LE will mark the licen | esponse file : a return file ise as return | sent by SCALABLE ar by specifying the loci led. NOTE: You must | id clicking on the Prov ation and name of the have write access to | ereturn file and the the directory when | en dicking on the Ger e you want to create | herate File buttor the return file. | Gener Proce | ate File |

Figure 19. EXata licenses automatic activation

If Option A not working to activate the EXata software over the internet server, we need to activated manually, by choosing option B.





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Next Option B. activating the license manually, to do so we need to create a request file and send it to Opal technical support center. The procedure is described below,

 From the Scalable license application Window select manual activation. Specify a name and location for the request file. The default name of the generated file is "GenReqForNodeLockedLicense.xml" and the default location is INSTALL_DIR/license_dir/windows-x64/application (for Windows) and click on Generate File. The Request File contains information about the machine on which you want to activate the license. OPAL-RT will send you a response file, which you will need to activate your license as illustrated in Figure 20.

| | | | | | | | | | | - | |
|---|---|--|--|---|---|--|-----------------|------------------------------------|------------------------------------|-----------------|-------------|
| de-locked License | Client-Server License | Delete License | Output | | | | | | | | |
| Automatic Activa | ation, Return and Repair | | | | | | | | | | |
| 'o activate or return outton. | your license via the Inte | rnet, enter your Acti | vation ID and | lick on the Activat | te or Return butto | on. To repair you | r license, ente | r your Activatio | n ID and click | on the F | Repair |
| ctivation ID: | | | | | | | | Activate | Return | | Repair |
| Manual Activatio | n | | | | | | | | | | |
| . Generate Requ | est File | | | | | | | | | | |
| Generate a reques will send you a res | t file by specifying the lo ponse file. NOTE: You mu | cation and name of t ust have write access | he request file s to the directo | and then clicking o ry where you wan | on the Generate F It to create the re | File button. Send | the request fi | e to <u>license@s</u> o | alable-netwo | <u>ks.com</u> . | SCALABL |
| Request File: | | | | | | | | | | | |
| | | | | | | | | | | Ge | enerate Fil |
| | | | | | | | | | | _ | |
| | | | | | | | | | | | |
| . Process Respon | ise File | | | | | | | | | | |
| Activate the license | i se File e by specifying the locati | on and name of the | response file s | ot by SCALABLE a | and clicking on the | Process File But | ton. | | | | |
| Activate the license | ise File | on and name of the | response file s | nt by SCALABLE a | and dicking on the | e Process File But | ton. | | | | 1 |
| Activate the license Response File: | i se File e by specifying the locati | on and name of the | response file s | nt by SCALABLE a | and clicking on the | e Process File But | ton. | | | | |
| Activate the license Response File: | ise File e by specifying the locati | ion and name of the | response file s | nt by SCALABLE a | and clicking on the | Process File But | ton. | | | Pi | |
| Activate the license Response File: | ise File e by specifying the locati | on and name of the r | response file s | nt by SCALABLE a | and clicking on the | Process File But | ton. | | | P | |
| Process Respon Activate the license Response File: Manual Return - oreturn a license m e to license @scalab | ese File e by specifying the location anually, enter the Activa le-networks.com. SCALA | on and name of the interview of the inte | e a return file b | nt by SCALABLE a | and dicking on the | of the return file | and then didd | ng on the Gene vant to create | rate File butte | Pron. Send | rocess File |
| Process Respon Activate the licens Response File: Manual Return - return a license m to license Biscalab trivation ID: | e by specifying the locati e by specifying the locati anually, enter the Activa de-networks.com. SCALA | on and name of the r tion ID and generate BLE will mark the lice | e a return file b nse as returne | nt by SCALABLE a | and clicking on the cation and name t have write acce | of the return file ss to the director | and then dick | ng on the Gene vant to create | rate File butte the return file | Province Send | rocess File |
| Process Respon Activate the licens Response File: Manual Return - oreturn a license m le to license @scalab ctivation ID: conse File | e by specifying the locati e by specifying the locati specific terms of the location anually, enter the Activa ie-networks.com. SCALA | on and name of the i | e a return file b nse as returne | nt by SCALABLE a | and clicking on the cation and name (t have write acce | of the return file | and then dick | ng on the Gene vant to create | rate File butt | Pi on. Send | rocess File |
| Process Respon Activate the licens Response File: Manual Return - oreturn a license m to license Bscalab ctivation ID: eturn File: | e by specifying the locati e by specifying the locati anually, enter the Activa ie networks.com. SCALA | on and name of the i | e a return file s | nt by SCALABLE a | and clicking on the cation and name t t have write acce | of the return file | and then click | ng on the Gene vant to create | rate File butts | Pan. Send | the retur |
| Process Respon Activate the licens Response File: Manual Return - oreturn a license m le to license @scalab ctivation ID: eturn File: | e by specifying the locati e by specifying the locati anually, enter the Activa ie networks.com. SCALA | on and name of the i | response file s : a return file b nse as returne | nt by SCALABLE a | and clicking on the cation and name t have write acce | e Process File But | and then click | ng on the Gene want to create t | rate File butt | Pr on. Send | d the retur |

Figure 20. EXata licenses manually activation

- 2. Create Ticket to Opal technical support center that include the generated file. OPAL-RT will send you a Response File by email. Save this file on your system.
- In the License Application, specify the name and location of the Response File. Click on Process File. This will activate the Scalable EXata license as illustrated in Figure 20.





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2.1.3.4 Scalable EXata CPS Activation on OPAL RT Simulator

To activate EXata CPS on your target, you will need to create a Request File and send it to our support team. The Request File contains information about the machine on which you want to activate the license. OPAL-RT technical center will send the Response File, which you will need to activate your license. The procedure is described below;

1. Start an SSH session with the simulator, change directory to /opt/Scalable/exata-cps/1.0/license_dir/linux-x64/application/ by using this command,

cd /opt/Scalable/exata-cps/1.0/license_dir/linux-x64/application/

2. Generate a Request File by typing the following command;

./NodeLockedLicense -g [<generated-file-name>]

If <generated-file-name> is included, a file called <generated-file-name> will be generated. (You can specify the directory in which the file is to be created by including the path in <generated-file-name>.). While if <generated-filename> is not included, a file called GenReqForNodeLockedLicense.xml is generated in the current directory.

- 3. Create a Ticket to the Opal technical support center that include the generated file. OPAL-RT will send you a Response File by email. Save this file on your system.
- Still in the directory /opt/Scalable/exata-cps/1.0/license_dir/linux-x64/application/, process the Response File by typing the following command;

./NodeLockedLicense -p <received-file-name>

Where <received-file-name> is the name of the Response File (including the path) sent by OPAL-RT. This will activate your license

2.2 Task (T2.2) Simulation platform test runs

At this point, after all the needed software are installed and activated. Based on this task testing for the simulation system platform need to be done in order to decide that both software are working properly. Opal RT delivered with the HYPERSIM software number of examples. Firstly the user needs to go to the "Open an Example File tab" search for





the "Transmission" expanded by clicking the left arrow and double clicking at the "HVAC_500kV_6Bus.ecf" file to open the example. This step will open the HYPERSIM software GUI and load the example. Within the HYPERSIM GUI there is a tab, "HVAC_500kV_6Bus.ecf" which is the power system model and loaded automatically see Figure 21.



Figure 21. HYPERSIM HVAC_500kV_6Bus example

In order to be shore that the HYPERSIM software is installed at the HOST PC correctly, the user needs to run the model at first offline within the HOST PC. Go to HYPERSIM at the menu tool bar, assign the Target to localhost and click Ok, then click on start this will run the simulation on your HOST PC in which that indicate that the HYPERSIM software is installed correctly as illustrated in Figure 22.





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| Hit Simulation Settings - HVAC_500 | DKV_6Bus.ecf | - | | × |
|------------------------------------|--|---|-------|-----|
| General Target Advanced | | | | |
| Target Configuration | | | | - î |
| 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\210b3b71b7015abd111054ca66b4354 | | C | 4 |
| Enable simulation logging | Perform load flow and set initial conditions at simulation st | | | |
| Nonlinear elements iterative metho | bd | | | |
| Activate iterative method | Maximum iterations 5 Apply to all nonlinear elements | | | ~ |
| Tasks Manager | Ok Apply Revert | | Cance | I |

Figure 22. HYPERSIM simulation setting



Figure 23. HYPERSIM simulation is running offline

The execution time is shown on the output tab and it is for this model equal to 50.00 μs as illustrated in Figure 23.

In addition, Scopeveiw can be opened from the upper left side button to monitoring in real time all the model physical parameters, as illustrated in Figure 24.





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Figure 24. HYPERSIM ScopeView

In order to stop the running model the user need to click the red square button to stop it.

2.3 Task (T2.3) Integration of different systems (eg distributed generation, access control, market, society, big data) into a single real-time simulation model and testing of reliability and security of telecommunication links

This wide concept role needs to run two models in parallel at the target. One based on the HYPERSIM software and the second based on the EXata software. At HYPERSIM, the power system components are modeled and simulated while at EXata the communication system components/cybersecurity are modeled and emulated. Based on our request Opal RT had delivered a real time "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" testing model that consist from both the HYPERSIM and EXata models linked internally via virtual adapters.





To open this model go to the "Open an Example File tab" from the HYPERSIM GUI, search for the "Cyber-Physical" expanded by clicking the left arrow and double clicking at the "Cyber_Physical_Micrgrid.ecf" file to open the example. This step will open the HYPER-SIM software GUI and load the example. Within the HYPERSIM GUI there is two tabs, "Cyber_Physical_Micrgrid.ecf1" and "Cyber_Physical_Micrgrid.ecf2" which are loaded automatically. The first "Cyber_Physical_Micrgrid.ecf1" file is the power system model as illustrated in Figure 25.



Figure 25. HYPERSIM power system model

While the second "Cyber_Physical_Micrgrid.ecf2" file is the communication and control model, as illustrated in Figure 26.



Figure 26. HYPERSIM connection system model





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However, at this point still, the EXata software is not open yet; the user needs to go to the upper left side (HYPERSIM GUI) and click the green square button. The EXata software needs the administrative privilege to start. After EXata software is starting the EXata GUI will open as illustrated in Figure 27.



Figure 27. EXata GUI

To open the associated EXata model, go to the File at the menu bar and click it. Then from the open down list chose open File, search for the EXata CPS folder at the example "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" directory which usually located at the C: drive/Opal rt/work space. You find a file name is "Cyber Physical Microgrid.config" double click on it to open the EXata model, as illustrated in Figure 28.







Figure 28. EXata GUI "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" model

This EXata communication emulation model describes the communication links between all the simulated electrical grid components that connected to the control units based on IEC61850 GOOSE more details about the model in D2.2.





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3 Troubleshooting and problem solving

3.1 Troubleshooting within the Installation and commissioning of software and device drivers.

3.1.1 HYPESIM installation troubleshooting

3.1.1.1 Installation of the HYPESIM software

From the delivered CD drive installation of HYPERSIM is not working as expected since it will install older version that is not "compatible" with EXata software. It needs more manually steps to commission both software to run smoothly. This happen to us for the first installation. Then the support Opal center recommend to install HYPERSIM 2020.2.0.078, that we need to downloaded from the Opal web page as described in T2.1.

3.1.1.2 Activation of HYPESIM error

EKSIM

Activation of HYPERSIM software from the delivered license is not working as illustrated in Figure 29.

| Home HYPERSIM | | | |
|--|---|---|-------------------|
| perView Target Manager peView Preferences tview Exata-CPS Tools Import/Exp | vork Network U/Os |) Topology Analysis Report 🔯 Set Initial Conditions 🧠 Netlist 🗰 Disable Breakers/Faults Load Flow 👔 Task Manager Network | Map Generate Code |
| | Invalid license Error You have selected a license intended for another computer, it | t cannot be used. | |
| SIM Ks RMI server registered. ing Hykorks RPC server [0x3fffa025] tering Hykorks [/Hypersim/yp_mmekka/Hyk ks RPC server running. icting to HyCoreServer on: localhost - / ks registered. ks initialization completed! | orks-1] to HyCore Hypersim/HyCore | | |

Figure 29. Activation of HYPERSIM software error





Request file will be made and send to the Opal support center/ wait for the response file to activate the HYPESIM software,

3.1.1.3 Error running example model in HYPERSIM

For the first running of one example from the available examples with the HYPERSIM software, offline an error has raised as illustrated in Figure 30.



Figure 30. HYPERSIM software error

Fixing the problem based support center;

This error is mainly caused by oversized model that requires time to generate the codes. To resolve this problem I suggest some actions to apply :

- Go to Hypersim preferences and change the value of long operations timeout as shown in the picture below:
- Change the compiler used to compile the C code by following this Knowledge base :

https://www.opal-rt.com/support-knowledge-base/?article=AA-01468





3.1.1.4 EXata license issue

Asking about the EXata license is it permanent as we ordered. The answer of the support center,

Exata License is actually permanent. However the way Scalable Technologies manages the licenses is to renew the license yearly.

Indeed, before the expiration date, OPAL-RT on your behalf sends a reminder to SCALA-BLE to ensure you have your license on time.

3.1.1.5 Other issue with the EXata license

The support center answer;

Normally, The EXata License (for the target) comes preinstalled in the simulator. Did you check if the license is already installed on your Target ? for this you can just do the following :

- Connect to the simulator using MobaXterm.

- Type the following commands:

cd /opt/Scalable/exata-cps/1.0/license_dir/linux-x64/application/

./NodeLockedLicense -v

The option -v is to see the content of the license.

However, the GUI license needs to be downloaded and activated by the user. For this I'll use your generated file, in order to request the response file from SCALABLE.

Once I have it from SCALABLE I'll send it to you immediately in order to activate your Exata GUI.

EXata is installed/ activated and checked at the target as illustrated in Figure 31.

| Last lagin: Wed Sep 30 13:37:51 2020 from 103.166.118.44 froet@MTServer =J# cd /opt/Scalable/execta-cps/10/license_dir/lin froet@MTServer applicationJ# /NodeLockedLicense v | ux-x64/application/ |
|--|---|
| Trust Flags: FULLY TRUSTED Fulfillment Type: Publisher Activation Situs: Trust The The Trust State of The | Rectangular Salp |
| Expiration date: 00-301-2021 Fosture line(s): Inf science info(s): INT science info(s): INCREMENT 24FC Cor4 File 6007 0A0A A001 7015 02CE 5C72 0BFA 0CF0 5 INCREMENT 24FC Cor4 File 6007 0A0A A001 7015 02CE 5C72 0BFA 0CF0 5 INCREMENT additional-connections 10000 scalable 2021.0700 0-Jul-2 INCREMENT 0A1A File 10500 0000 1000 scalable 2021.0700 0-Jul-2 INCREMENT 0A1A File 10500 0000 1000 scalable 2021.0700 0-Jul-201 INCREMENT 0A1A File 10500 0203 7140 85C7 FF02 A046 318C 8384 0805 C3CE INCREMENT scenario_player full scalable 2021.0700 0-Jul-2021 I 15 INCREMENT Licenserpoil(scenario)5 scalable 2021.0700 0-Jul-2021 I 15 INCREMENT Licenserpoil(scenario)5 scalable 2021.0700 0-Jul-2021 I 15 | sep-2020 START=10-jul-2020 ONE_TS_OK SIGN="000C 10C7 FC9D F 4D3 05AF 3FFB C10B E504" 6211 15SUED=0-sep-2020 START=10-jul-2020 ONE_TS_OK SIGN="0 7FA 233 15TART=10-101-2020 ONE 5_D0 SIGN="0071 BIA1 8048 06F6 F731 A21C A5F0 BC1C" SUED=0-sep-2020 SIART=10-jul-2020 ONE_TS_OK SIGN="02F6 FD13 UCD=0-sep-2020 SIART=10-jul-2020 ONE_TS_OK SIGN="02F6 FD13 |
| 4471 821C 2088 986C 926E 9594 A019 85C9 5500 9976 3886 F2E0 58FF HCGEMERE Feat pricesome full solar 108 1020 5700 9976 3886 F2E0 58FF HCGEMERE Feat pricesome full solar 108 1020 10706 F101 2472 10015 INCREMENT cyber-full scalable 2021,0709 9-jul-2021 I ISSUED=0-sep 2114 3649 2328 2687 3849 A086 E500 928 7E88 D0C1 E517 IEF5 E901 INCREMENT extat-full scalable 2021,0709 9-jul-2021 I ISSUED=0-sep 8E39 DE33 3118 6070 43CD D048 B103 90C9 5A19 A796 58F9 4358 BC48 | DUPE F84C 1922 AABC F0AB 1500" DIPARAM - 4522 AABC F0AB 1500" DIPARAM - 4528 STATE 100 µCK-80 DIPARAM - 4528 STATE 100 µCK-80 -2020 START=10-jul-2020 ONE_TS_OK SIGN="027E A020 048B EE74 E818 2080 4420 07EE" -2020 START=10-jul-2020 ONE_TS_OK SIGN="0340 23AC 35CD 4F89 8010 A0E4 BA92 CCCC" |
| [root@RTServer application]# 📕 | |

Figure 31. EXata licenses at the TARGET is activated





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3.2 Troubleshooting based on running "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" example task.

The fully functional setup for the HYPERSIM and EXata on an OPAL-RT Simulator, it needs more steps. These steps are not step forward and need more attention and manually executing a number of predefined scripts to make both software compatible to be running together in parallel at the target and share data over the assigned virtual adapters

3.2.1 The example it consists from more than 200 active simulated nodes

First issues at this example it consists from more than 200 active simulated nodes, however in our HYPERSIM license we have less number of active nodes than this number of nodes. In our system, there are five active cores, every core able to simulate 30 nodes; also, some of these active cores are dedicated for the EXata emulation (2 cores) and HYPERSIM (2 cores). At this point the first running of the example it rise an error as illustrated in Figure 32.



Figure 33. HYPERSIM error based number of nodes





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In order to solve this issue, contact to the Opal RT technical support center was made asking for extending the ability of our system to simulate and run the "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" example. Demo license from Opal RT support center had been offered which is valid until 6.Desember.2020. With this demo license the user will able to simulate 1000000 active nodes, as illustrated in Figure 34 and 35.



Figure 34. HYPERSIM number of nodes before extending







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Figure 35. HYPERSIM number of nodes after extending

In future, we need either to develop our model based on the HYPERSIM license 30 available active node, our buy/extend our system active cores/nodes.

3.2.2 Can't create the directory at the real time simulator

The first running of the demo example in real time raise an error "can't create the directory...", as illustrated in Figure 36.



Figure 36. HYPERSIM no access to the target





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This error needs more steps to execute manually in order to solve these issues. The first thinking is to ask Opal RT to arrange webinar to solve these issues. Based on making a contact to the Opal technical support center, we agree to arrange a "fixing real time running issues webinar". Within this webinar, we try to fix all the real time running issues via remote desktop control connection. The first problem see above, is the missing connection between the HOST PC running HYPERSIM software and the real time simulator, because the HYPERSIM use a special kind of connection protocol (SMB) to transfer files to the target which is by default is disabled by Windows and need to be enabled, as illustrated in Figure 37.



Figure 37. Adding Windows features

This step will download/install new features to Windows and user need to restart the HOST PC to activate the installed features.

At this point , in order to check that the connection is fixed between the HOST PC and the TARGET open the file explorer and type the target IP address "193.166.118.100" it





will open the "hyppub" directory on the target in which is used for transferring the generated code from the HOST PC to the TARGET as illustrated in Figure 38.

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Figure 38. Opining connection from HOST PC to the TARGET

3.2.3 Ruining demo example in real time

The first running of the demo example in real time, it raise an error. The error is based on the using of a compiler by HYPERSIM which is not compatible, because there is no Intel licenses. In order to solve this issue it needs to change the used compiler from "opicc" to "opgcc", as illustrated in Figures 39 - 41.

| Concess Builder | history | | |
|--|-------------------|---|-------------------|
| HYPERSIM Error | | | × |
| An error occured while executing 'startsim' | | | $\mathbf{\times}$ |
| Error | | | |
| 7. yoptymilelycompliers_and_iloranes_zoro.il.io/ilindx/bin/ilitelo4/ | anc | | ~ |
| Please visit http://software.intel.com/sites/support/ if you require techn | nical assistance. | | |
| icc: error #10052: could not checkout FLEXIm license | | | 0 |
| gmake: *** [/obj/T_Bus6x.o] Error 1 | | | |
| Error: A license for Comp-CL could not be obtained (-1,359,2). | | | |
| Is your license file in the right location and readable? | | | |
| The location of your license file should be specified via | | | |
| the \$INTEL_LICENSE_FILE environment variable. | | | |
| License file(s) used were (in this order): | | | |
| 1. Trusted Storage | | | |
| ** 2. /opt/intel/compilers and libraries 2016.1.150/linux/licenses | | | ~ |
| | | - | |
| | | | d3 |
| | | | |

Figure 39. Error based on the used opicc compiler by HYPERSIM





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| Targets | Advanced - 193,166,118 | 100 | | | |
|---------------|--|--|-------|-----------------|-------|
| ▼ 🖳 localhost | Real-time / Offline (RTA) | | | | |
| E Advanced | Compilation | | | | |
| | C flags Make command Make mask Compiler Linker Python command Server | /usr/bin/gmake -j10 gmake opicc I opicc CP /usr/bin/python | | | |
| | ▼ Task Mapping | | | | |
| | Communication overhead | 4.0e-6 | | | |
| | I/O overhead | 2.0e-6 | | | |
| | Processor performance | 20 | | | |
| L | Default | | Apply | M ^{°e} | evert |

Figure 40. opicc compiler used by HYPERSIM before

| Targets | Advanced - 193.166.118 | .100 | | | | |
|---|--|--|-------|-----------------|-----|--|
| localhost | Real-time / Offline (RTA) | | | | | |
| E Advanced | ▼ Compilation | | | _ | | |
| A License J 193.166.118.100 Code Generation Versions Advanced Diagnostic License Default Code Generation | C flags Make command Make mask Compiler Linker Python command Server | /usr/bin/gmake -j10 gmake opgcc I opgcc /usr/bin/ _{P2} mon | | | | |
| | Task Mapping | | | | | |
| | Communication overhead | 4.0e-6 | | | | |
| | Processor performance | 20 | | | | |
| | Default | | Apply | M ²⁶ | eve | |

Figure 41. opgcc compiler used by HYPERSIM after





3.2.4 Configure EXata software to be compatible with the HYPERSIM

The next step is to configure the EXata software to be compatible with the HYPERSIM. At first the user need to open Cygwin terminal is administrator and change the directory

to EXata installation folder and executing below commands,

cd "c:\Program Files\Scalable\exata-cps\bin

chmod +x exata.remot.sh

chmod +x setupRemoteExec.sh

./setupRemoteExec.sh root@193.166.118.100

After executing, the setupRemoteExec.sh as illustrated above it is expected that the open ssh link based remote connection between the HOST PC to the target will not ask for the root password to allow the ssh connection. However, if the user try the ssh connection as root@193.166.118 and click enter it is still asking for the root passward, as illustrated in Figure 42.



Figure 42. Cygwin openssh connection

To fix this issue the user need to change command line within the setupRemoteExec.sh script as illustrated in Figure 43,





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Figure 43. setupRemoteExec.sh script before change



Figure 44. setupRemoteExec.sh script after change

These steps also did not fix the problem, the user need to open MobaXterm software and change to the folder /root/ssh within the target as illustrated in Figure 45.





| 193 | .166.118.100 (root) | V convor | Tools Game | s Sottings Mac | ros Hel | 0 | and the second | | | | | | | | | | - | | × |
|---|--|------------|--------------------------------|---|-----------------------|----------|---|--|-------------------|--|---|--|--|--|------------------------------------|---------|----------------|------------------|-------------|
| Session | Servers Tools | Games | Sessions V | new Split N | Y AultiExec | Tunnelir | ig Packages | settings | (?) Help | | | | | | | | | X X server | (U) Exit |
| Quick | connect | | | | | | * S | 2. 193.166 | 5, 118, 10 | 10 (root) | | × | 5 | | | | | | 0 |
| * /roi | 🛓 🚹 🕑 🍋 📗 N/.ssh/ | 0 A I | 2. 🖩 | | 1 39 | 0 | Desktop Document Download | s s | | | | | | | | | | | ^ |
| Sftp A Macros 4 Tools + Session | Name Im. 2 authorized, keys 2 authorized, keys 2 authorized, keys 2 known_hosts | | Size (KB) | Last modified 2020-10-06 2 2020-10-06 2 2020-09-12 1 | Owner root root | > | exata-cp HYPERSIM install. install. Music opal-hyp opal-hyp Pictures Public Template vethscri Videos Iroot@RT LSB Vers raphics- iroot@BT | s-1.0-0 _Releas log log.sys 2.6.32- ersim_a ersim_t s pt.sh Server ion: 4.0-amd Server | <pre>~]# 1</pre> | <pre>-instal tes_202 el6ost. s-sa64- ller-sa t-2020. lsb_rel se-4.0- raphics uname</pre> | Lter-641 20.2.pdf .netns.: -2-2.x86 a-2020.: .2.0.079 lease -amd64:1 s-4.0-nd | bit-cer f 2.x86_(6_64.rp 2.0.07 9-1.x8(base-4. oarch: | 54.rpm 54.rpm 9-1.x86 5_64.CE .0-noar printin | _64.CEN NTOS.rpr ch:core g-4.0-ar | TOS.rpm m -4.0-am md64:pr | nd64:co | re-4. -4.0- | 0-noar noarch | ch:g |
| | | 🜉 Re | emote monito v terminal fol | ring Ider | | | Linux RT x86_64 G [root@RT | Server NU/Linu Server | 3.12 ix ~]# | . 26 - opa | alrt #9 | SMP A | M | 29 10:4 | 5:24 EC | OT 2015 | x86_ | 64 x86 | _64 |
| UNRE | SISTERED VERSION | N - Please | e support Mobi | aXterm by subscri | bing to th | ne profe | ssional edition | n here: ht | ttps://n | nobaxtern | m.mobatek | k.net | | | | | | | |

Figure 45. MobaXterm connecting to the TARGET

The idea is to eliminate the requested password and allow the Cygwin to access the TARGET without limitation, this problem need to solve see Figure 46.



Figure 46. MobaXterm connecting to the TARGET





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3.2.5 Cygwin installation features

At this point, checking Cygwin installation features, therefore we decided to reinstall again and in C: drive, as illustrated in Figures 47-49.

| | | Browse |
|--|--|---|
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| s. Cygwin Menu Entries, a Only select this if you lac | nd impo k Admini | rtant strator |
| | | |
| | s. Cygwin Menu Entries, a Only select this if you lac | s. Cygwin Menu Entries. and impo Only select this if you lack Admini |

Figure 47. Cygwin installation

| Cygwin Setup - Select Local Package Directory | - 0 | ~ |
|--|----------|---|
| Select Local Package Directory Select a directory where you want Setup to store the installation files it do The directory will be created if it does not already exist. | wnloads. | 2 |
| Local Package Directory | | |
| Cţ\temp | Browse | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |
| | | |

Figure 48. Cygwin installation steps





| iew Full V Search ssh | Clear | | | | | ОКеер | Best | OSync | Te |
|------------------------------|-------------|----------|--------------|--------|---|-------|------|-------|----|
| Package | Current New | Sro | ? Categories | Size | Description | | | | |
| autossh | Skip | - | Net | 24k | Automatically restart SSH sessions and tunnels | | | | |
| jnome-ssh-askpass | Skip | | GNOME | 6k | GTK+ passphrase grabber for ssh-add | | | | |
| gnome-ssh-askpass-debuginfo | Skip | - | Debug | 26k | Debug info for gnome-ssh-askpass | | | | |
| sshaskpass | Skip | - | KDE | 23k | KDE passphrase dialog for ssh-add | | | | |
| sshaskpass-debuginfo | Skip | • | Debug | 152k | Debug info for ksshaskpass | | | | |
| bssh-common | Skip | • | Net | 16k | SSH implementation library | | | | |
| ibssh-debuginfo | Skip | • | Debug | 597k | Debug info for libssh | | | | |
| ibssh-devel | Skip | • | Net | 36k | SSH implementation library | | | | |
| bssh2-debuginfo | Skip | - | Debug | 274k | Debug info for libssh2 | | | | |
| bssh2-devel | Skip | - | Net | 104k | SSH2 protocol library | | | | |
| bssh2_1 | Skip | - | Net | 113k | SSH2 protocol library | | | | |
| ibssh4 | Skip | - | Net | 155k | SSH implementation library | | | | |
| kqt-openssh-askpass | Skip | - | X11 | 16k | LXQt SSH password dialog | | | | |
| qt-openssh-askpass-debuginfo | Skip | ~ | Debug | 334k | Debug info for lxqt-openssh-askpass | | | | |
| ningw64-i686-libssh2 | Skip | - | Devel | 152k | SSH2 protocol library for Win32 toolchain | | | | |
| ningw64-x86_64-libssh2 | Skip | - | Devel | 159k | SSH2 protocol library for Win64 toolchain | | | | - |
| openssh | Skip | | Net | 863k | The OpenSSH server and client programs | | | | |
| openssh-debuginfo | Skip | ' | Jninstall | 2.319k | Debug info for openssh | | | | |
| ish-pageant | Skip | · · · | Skip | 22k | SSH agent for Cygwin/MSYS that links to PuTTY's Pageant | | | | |
| sh-pageant-debuginfo | Skip | 1 1 | 3.1p1-1 | 30k | Debug info for ssh-pageant | | | | |
| shpass | Skip | 1 | 201-1 | 15k | Non-interactive SSH password provider | | | | |
| shpass-debuginfo | Skip | 1 | 2-1.1 | 46k | Debug info for sshpass | | | | |
| | | | s.201-1 | | | | | | |
| | | | | | | | | | |
| | | | M CP | | | | | | |
| | | | | | | | | | |
| | | | | | | | | | |

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Figure 49. Cygwin installation steps

After the reinstallation of the Cygwin with the associated "openssh", is finished then the user needs to redo the above steps again (execution of the remote setup scripts) as illustrated in Figure 50.



Figure 50. Cygwin execution scripts





At this point the connection via the openssh is allowed without requested password between the Cygwin at HOSTPC and the Target, as illustrated in Figure 51.

| root@RTServer:~ | an ti | | × |
|---|---|-----------------------------------|------------|
| LUW-CND6190MVJ+yp_mmekka@LUW-CND6190MVJ /cygdrive/c/Program Fil -cps/1.0/bin \$./setupRemoteExec.sh root@193.166.118.100 exata SSH remote execution setup Configuring security settings to root@193.166.118.100 to requir h this client | es/Sca e no pa | lable/e assword | xata Î |
| The authenticity of host '193.166.118.100 (193.166.118.100)' ca d. RSA key fingerprint is SHA256:2nJemr1tfV+23GEy4Dqe+h61FL1DHNXT6 Are you sure you want to continue connecting (yes/no/[fingerpri Warning: Permanently added '193.166.118.100' (RSA) to the list root@193.166.118.100's password: mkdir: cannot create directory `/root/.ssh': File exists Done | n't be +9TOk/2 nt])? y of know | establ «Plc. /es wn host | ishe s. |
| LUW-CND6190MVJ+yp_mmekka@LUW-CND6190MVJ /cygdrive/c/Program Fil -cps/1.0/bin \$ ssh root@193.166.118.100 Last login: Tue Oct 6 15:00:08 2020 from 193.166.118.76 [root@RTServer ~]# [root@RTServer ~]# [root@RTServer ~]# | es/Sca | lable/e | xata ~ |

Figure 51. Cygwin openssh connection

3.2.6 Finalized EXata software configuration

The EXata software configuration need to be finalized by interring the information at the

"Run setting" window as illustrated in Figure 52.





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Figure 52. EXata configuration

The next step is to run EXata software with a simple model and check the output tab if there is any error showing up. After running the model no errors raises in which indicates that the EXata software is configured and run correctly, as illustrated in Figure 53.



Figure 53. EXata GUI with running model





At this point, the EXata-CPS and HYPERSIM platforms are developed and running on OPAL-RT target in parallel/real-time.

Conclusions

The development of future cyber physical security CPS at FREESI lab research/education environment based innovative solution/real-time simulator is outlined. The development work of the CPS at FREESI lab has resulted in a high flexibility/quality practical testing lab environment that has been tested and validated by "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" testing model that consist from both the HYPERSIM and EXata models linked internally via virtual adapters (Section 2.3). Troubleshooting/problem solving and conclusion of the development of future cyber physical security CPS at FREESI lab research/education environment are given in (Section 3). BY following up the outlined configuration/testing procedure, other users will able to develop adequate knowledge to undertake the platform development tasks and settle the troubleshooting issues, in which that accelerate the research, education and developments activities in CPS environment at FREESI lab.





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References

- [1] Opal RT HYPERSIM installation guide
- [2] Scalable EXata installation guide







