Mike Mekkanen

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
4. 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.

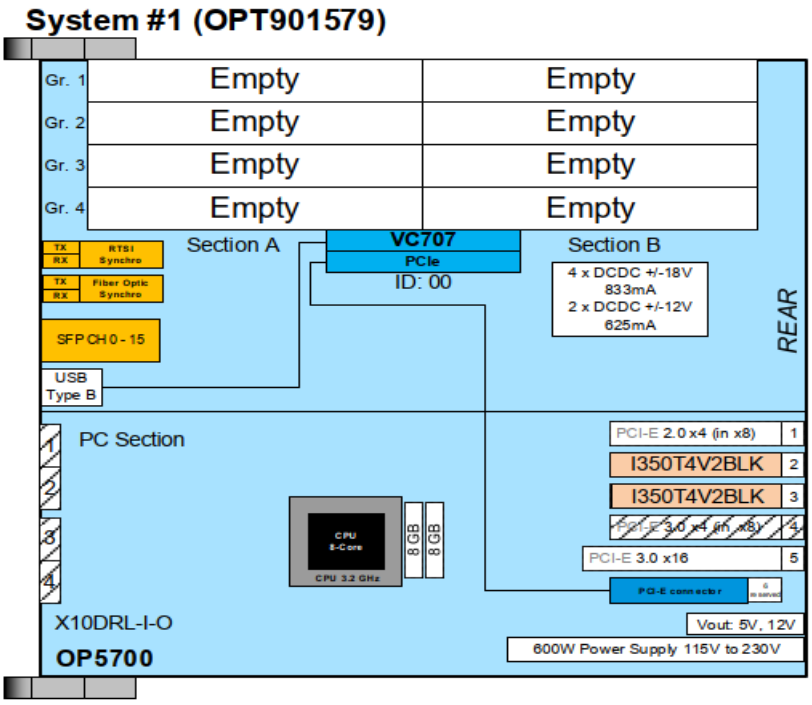

Figure 1. Block diagram of the delivered system

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.

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Figure 2. The delivered package OP5700 Real-Time Simulator

Figure 3. OP5700 Real-Time Simulator System

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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.

Table 1. List of features

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

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.

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,o78 from Opal RT **Download Page**
2. 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.
4. 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.

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\exata-cps\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
```

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;

1. 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.

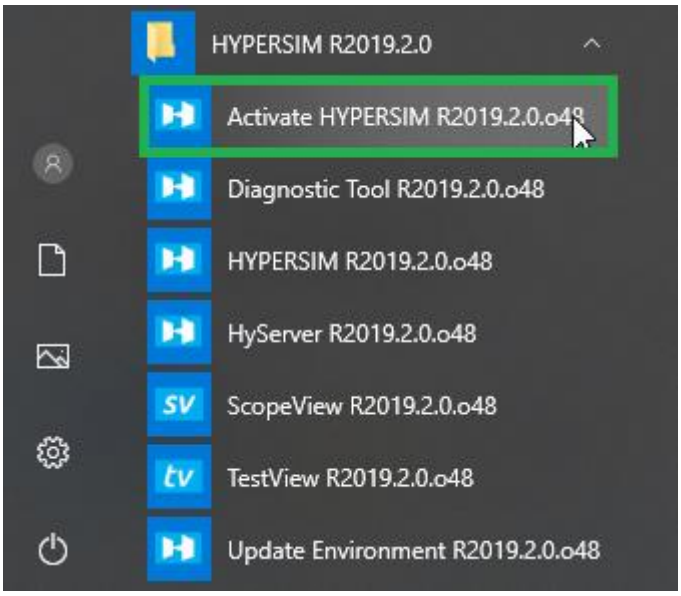

Figure 4. Window startup menu

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

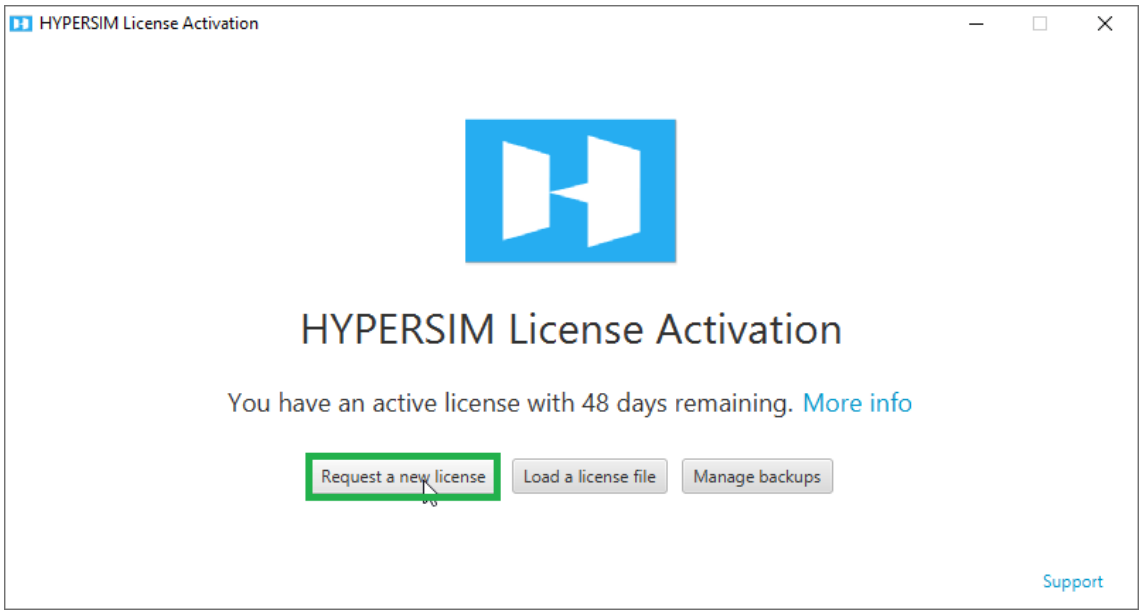

Figure 5. HYPEERSIM license activation window

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.

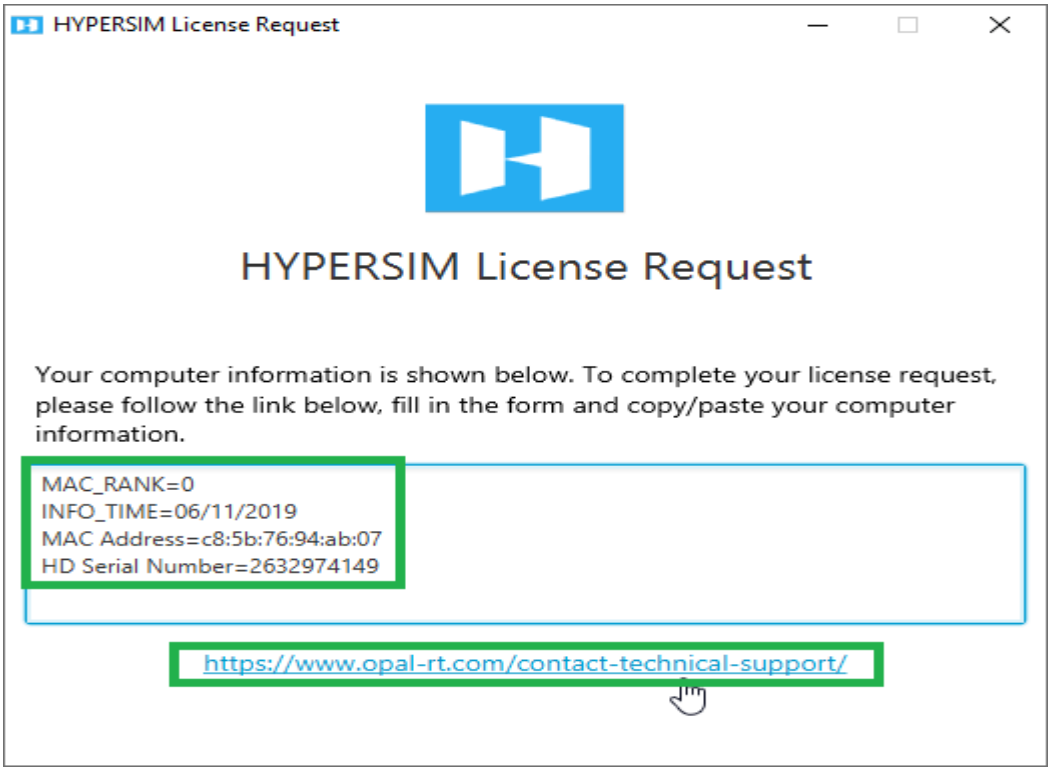

Figure 6. HYPEERSIM license Request

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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.

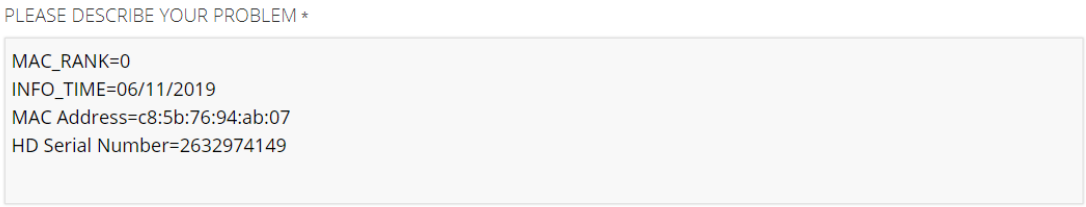

Figure 7. Opal technical support center

4. Load a license file that had sent by the Opal technical support center as illustrated in Figure 8.

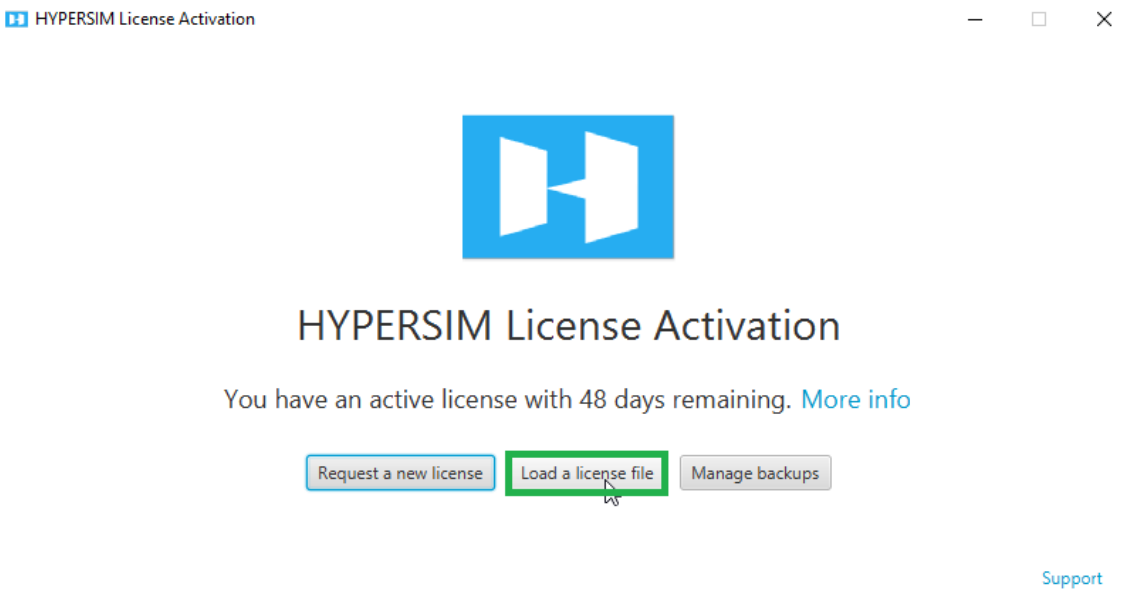

Figure 8. HYPEERSIM license activation window load license file

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.

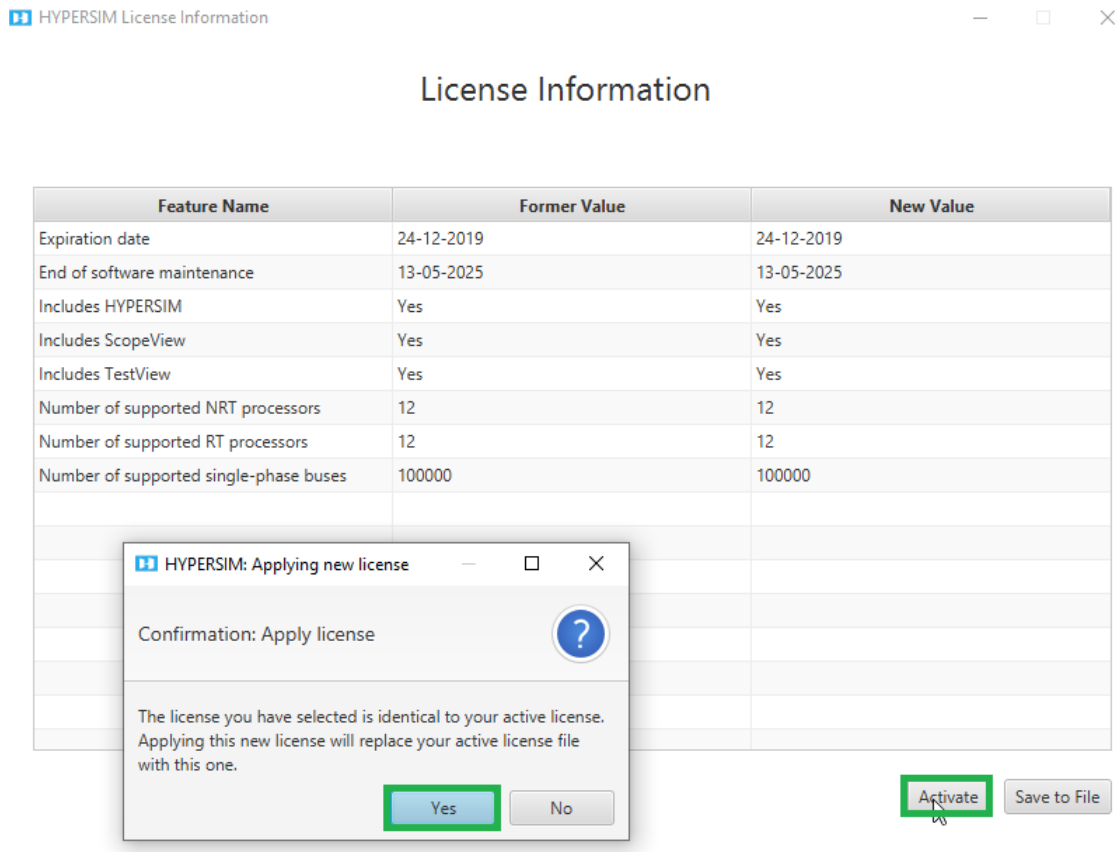

Figure 9. HYPEERSIM license information window

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.

1. Open the last version of the HYPERSIM 2020.2.0.o78. Go to the HYPERSIM Tab > Tools > Target Manager within the HYPERSIM opened window as illustrated in Figure 10.

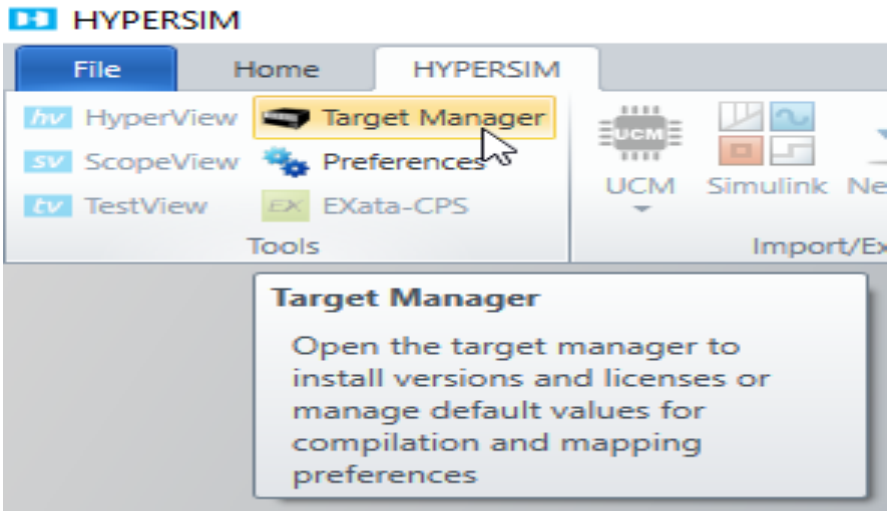

Figure 10. HYPEERSIM software window

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.

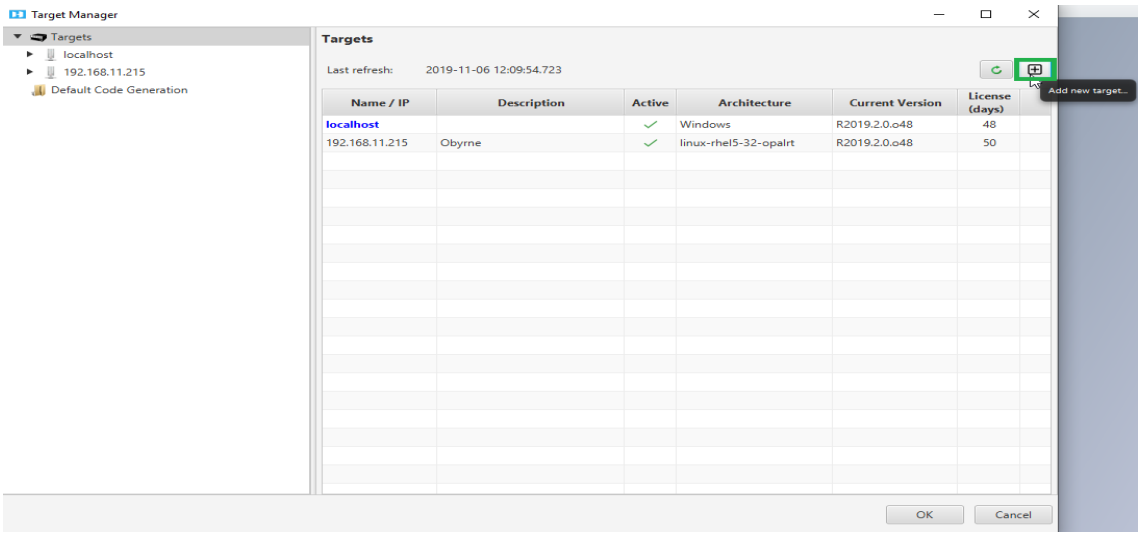

Figure 11. HYPEERSIM TARGET connect

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.

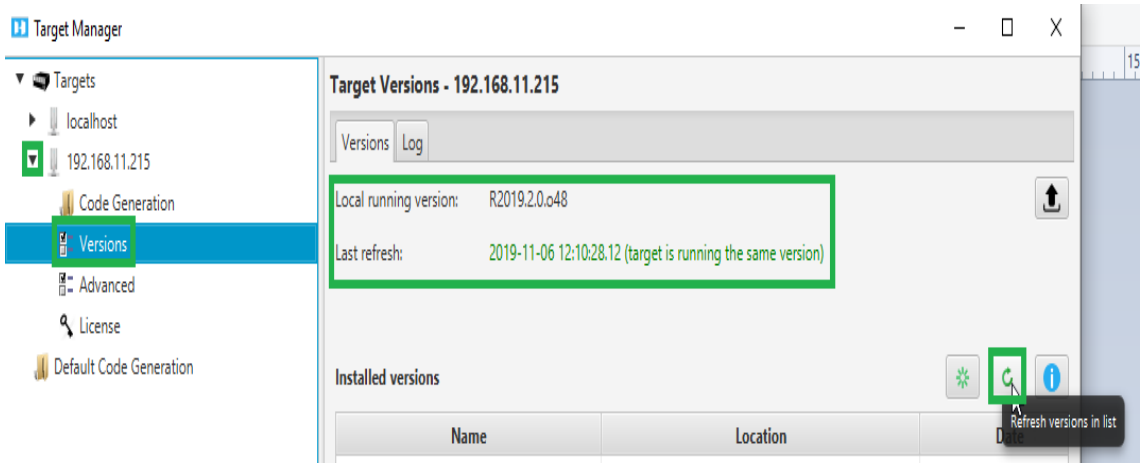

Figure 12. HYPEERSIM target manager window

4. 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.

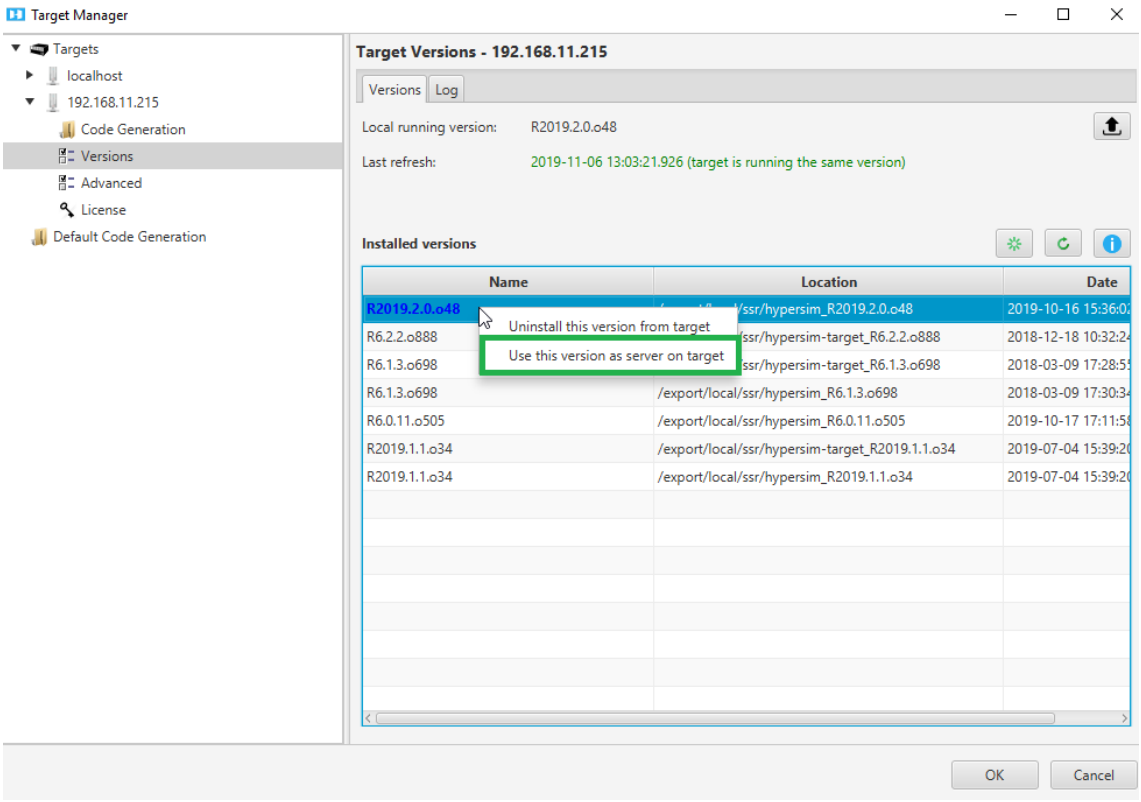

Figure 13. HYPEERSIM updating version within the target

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.

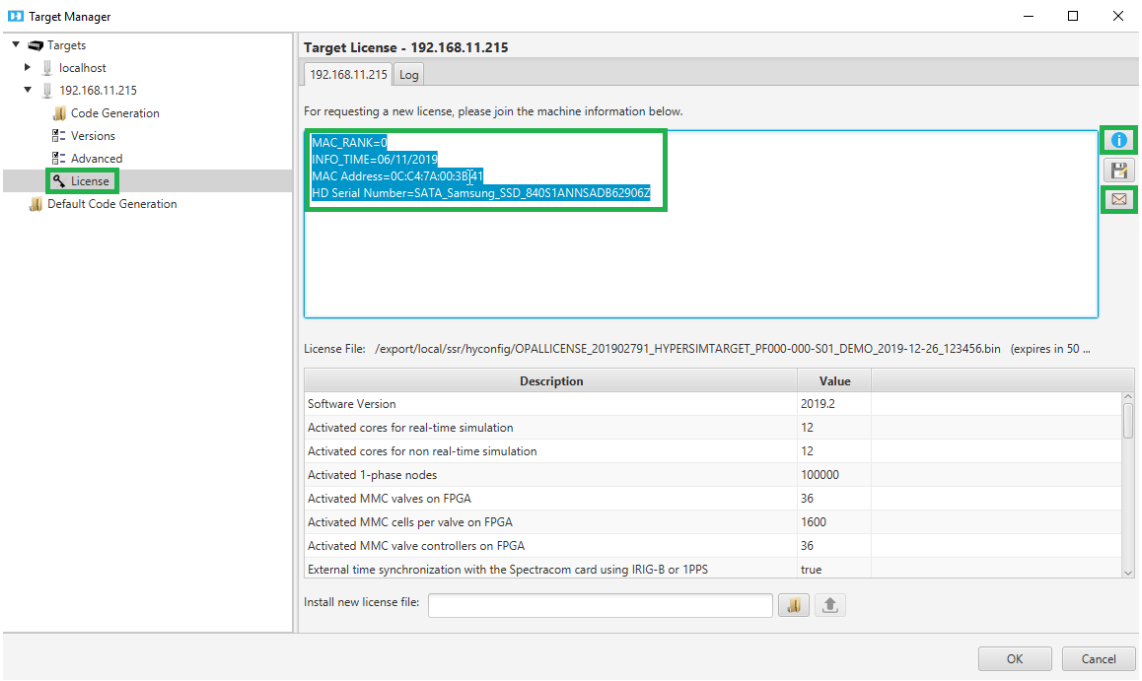

Figure 14. HYPEERSIM request license window

6. Paste the Machine ID in this box based on created support Ticket (Case) as illustrated in to Figure 15.

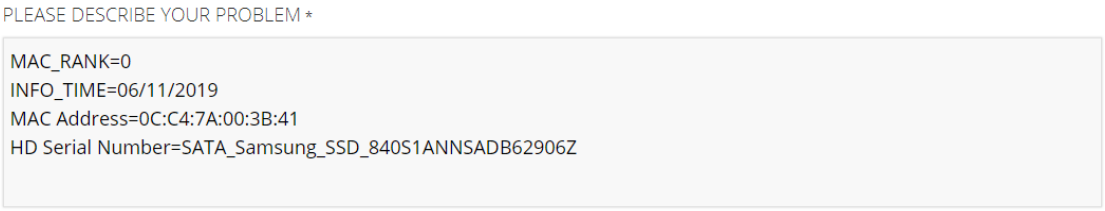

Figure 15. Opal RT Ticket (Case)

7. 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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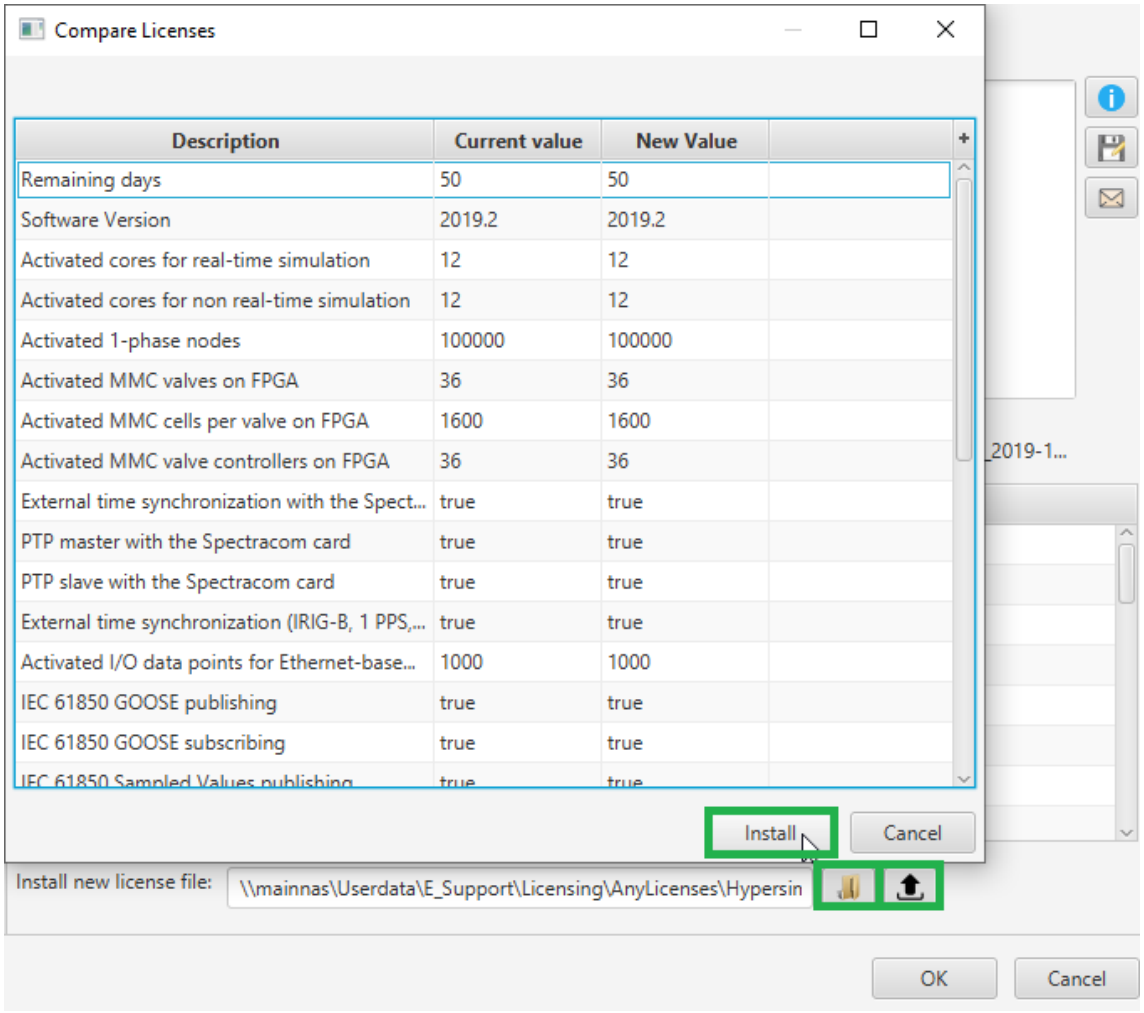

Figure 16. HYPEERSIM install license window

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.

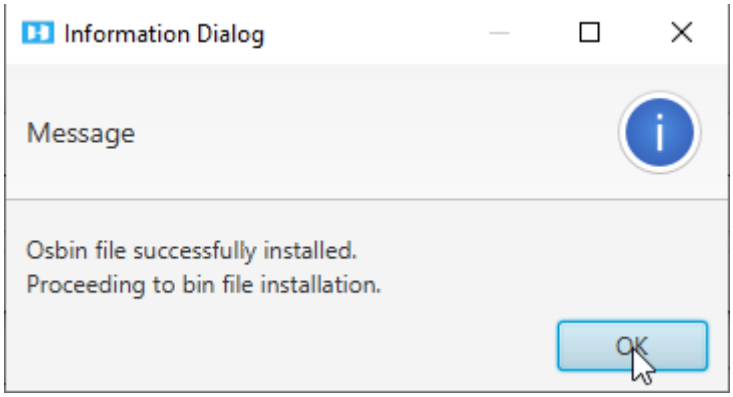

Figure 17. HYPEERSIM confirmation window

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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.

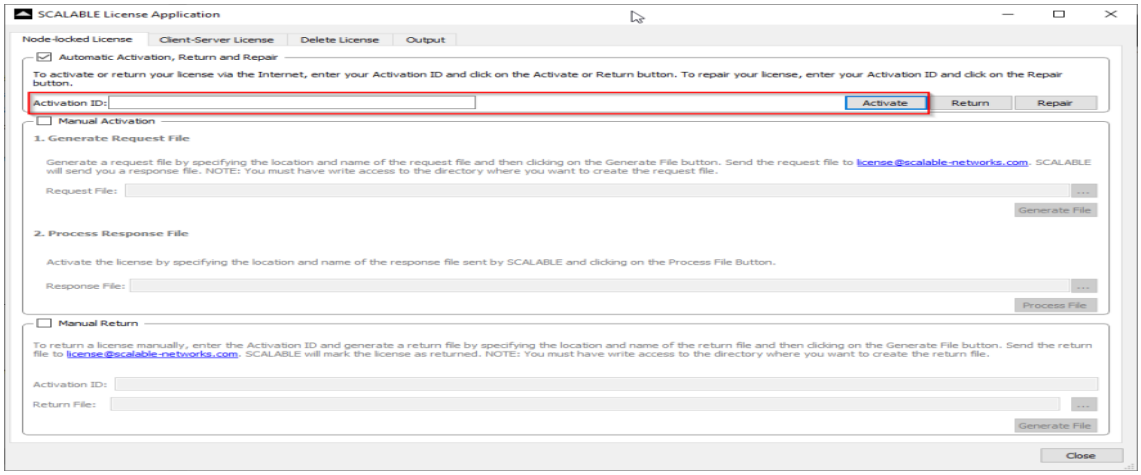

Figure 19. EXata licenses automatic activation

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

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,

1. 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.

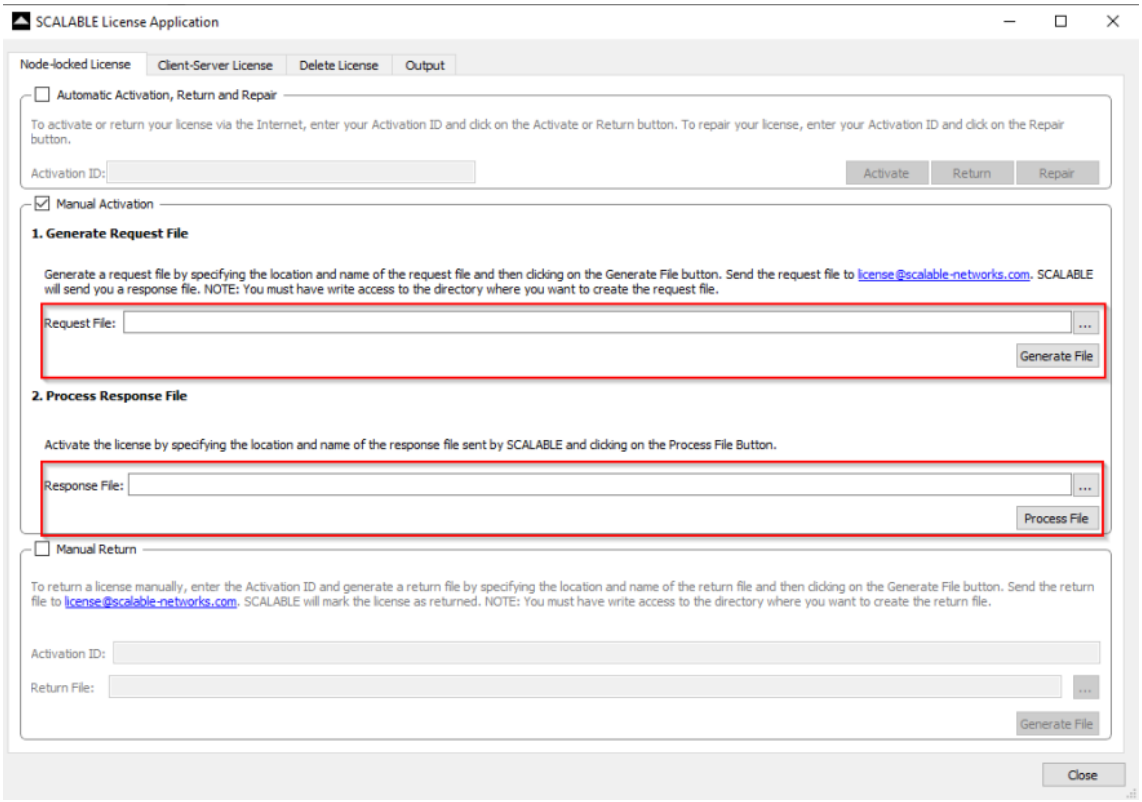

Figure 20. EXata licenses manually activation

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.
3. 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-file-name> 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.
4. 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.

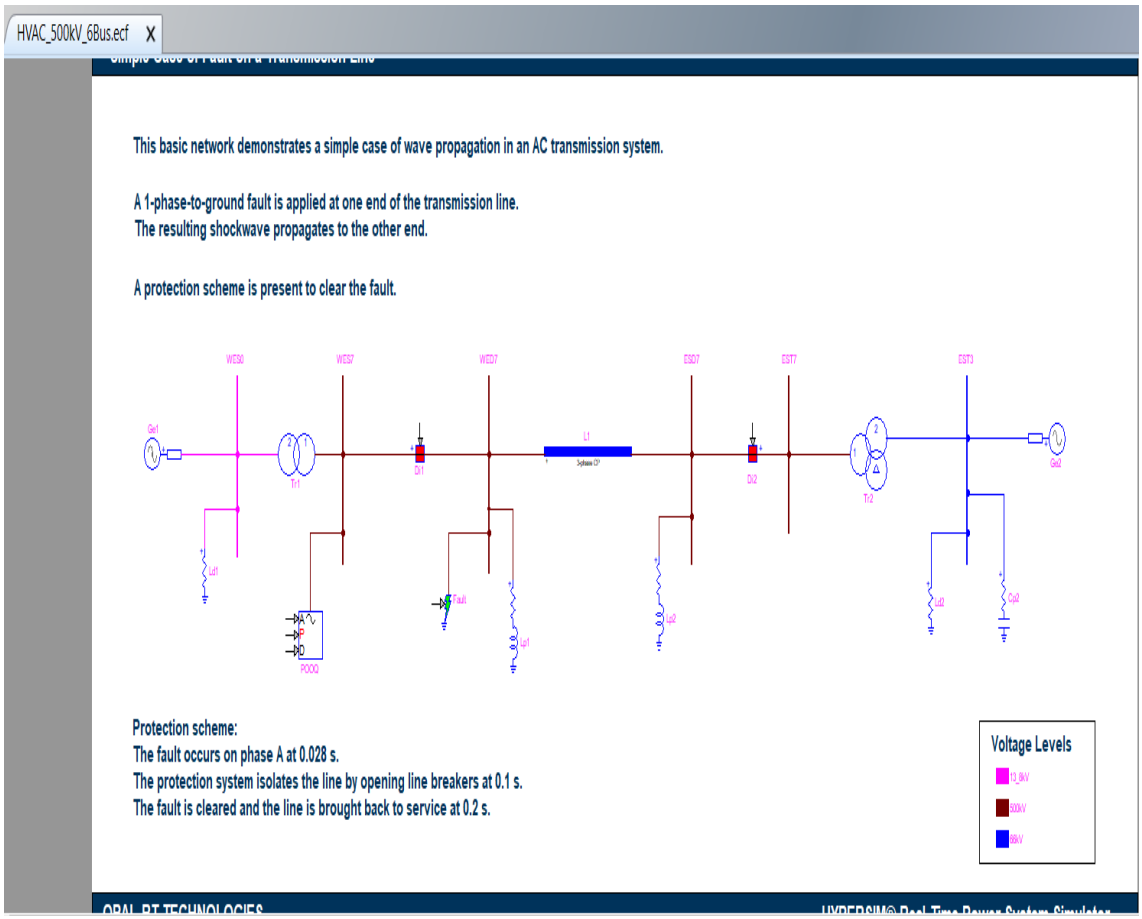

Figure 21. HYPERSIM HVAC_500kV_6Bus example

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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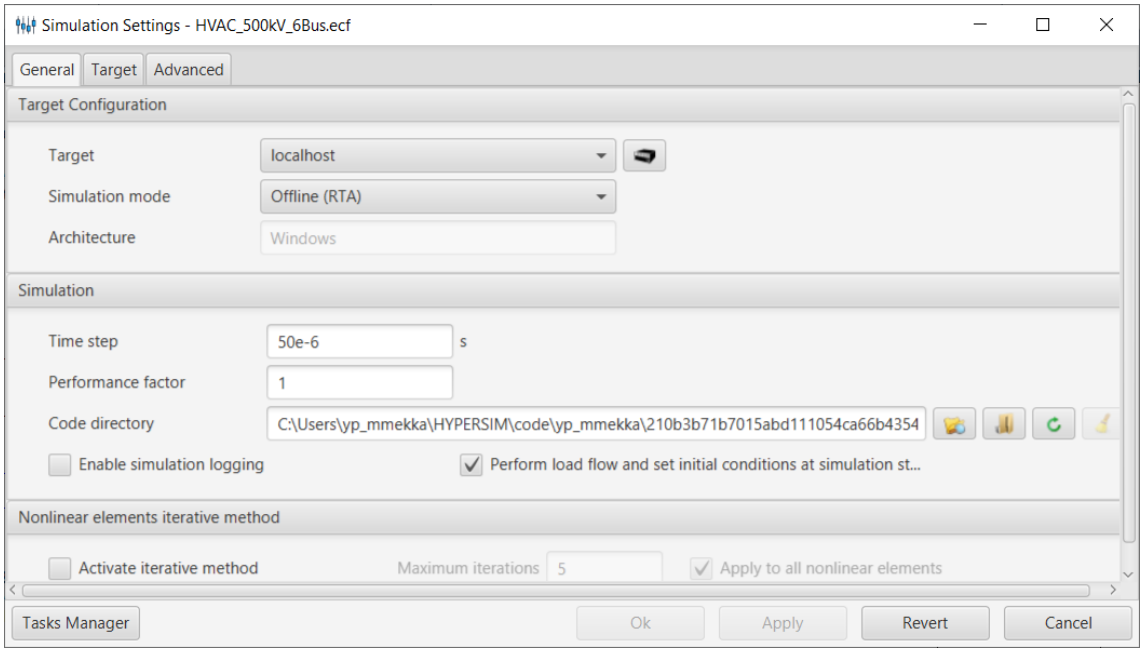

Figure 22. HYPERSIM simulation setting

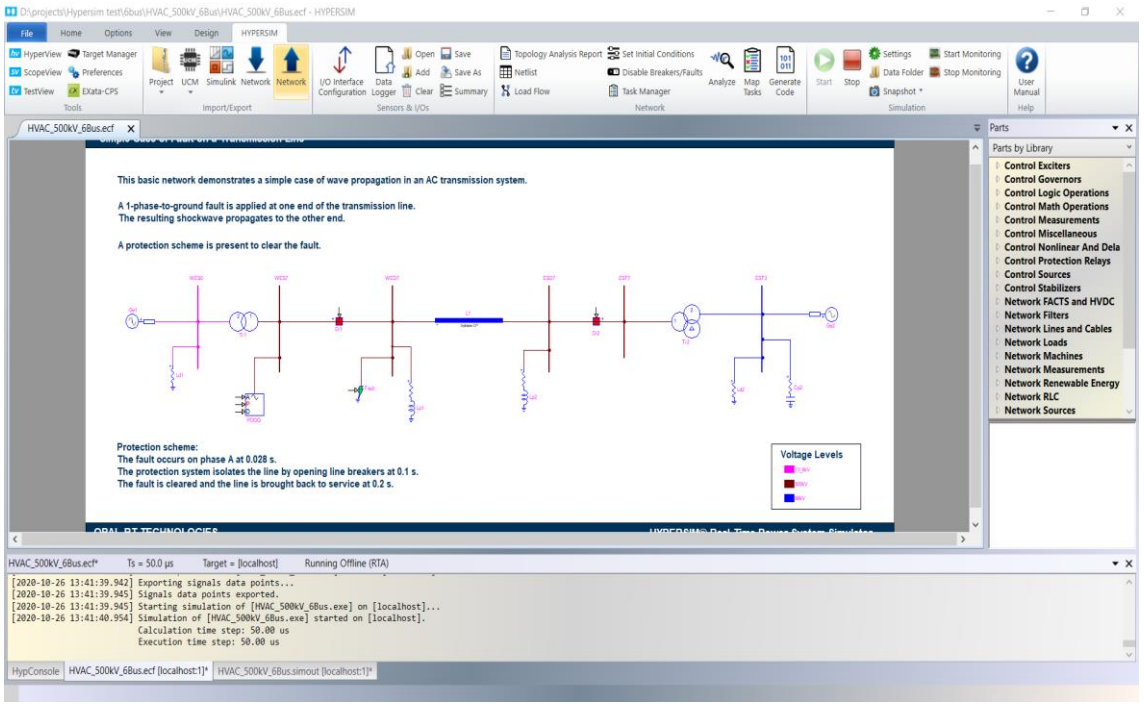

Figure 23. HYPERSIM simulation is running offline

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.

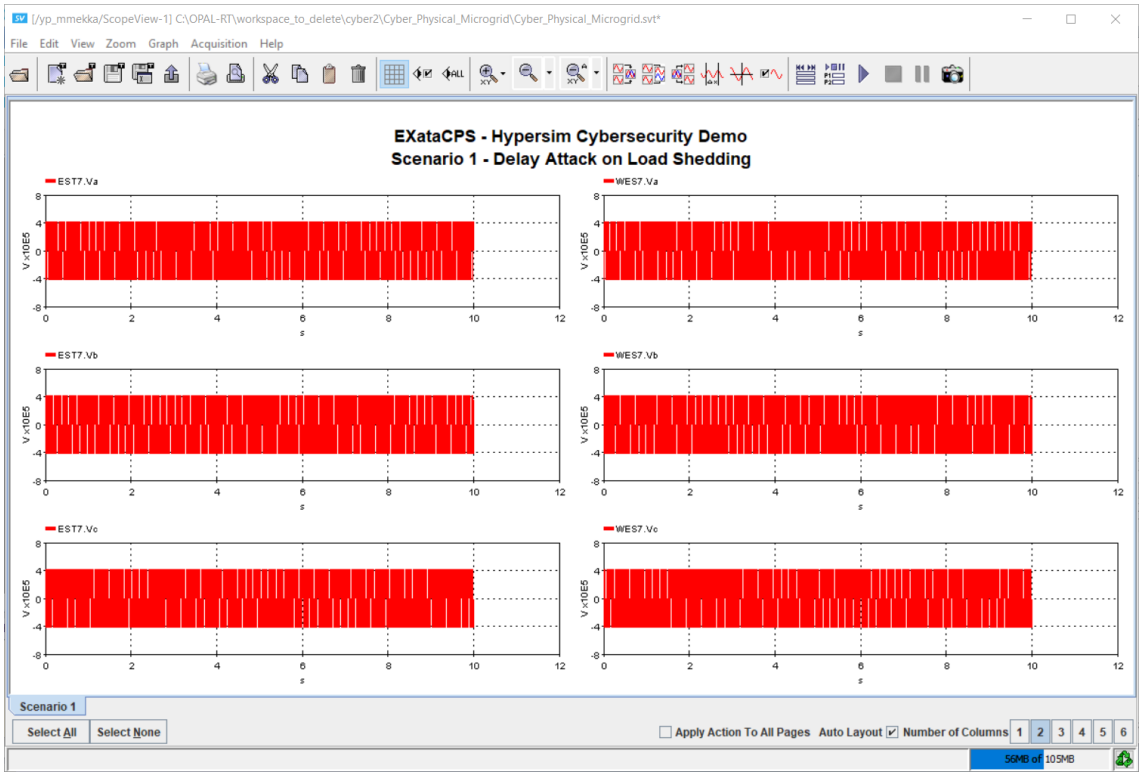

Figure 24. HYPERSIM ScopeView

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.

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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.

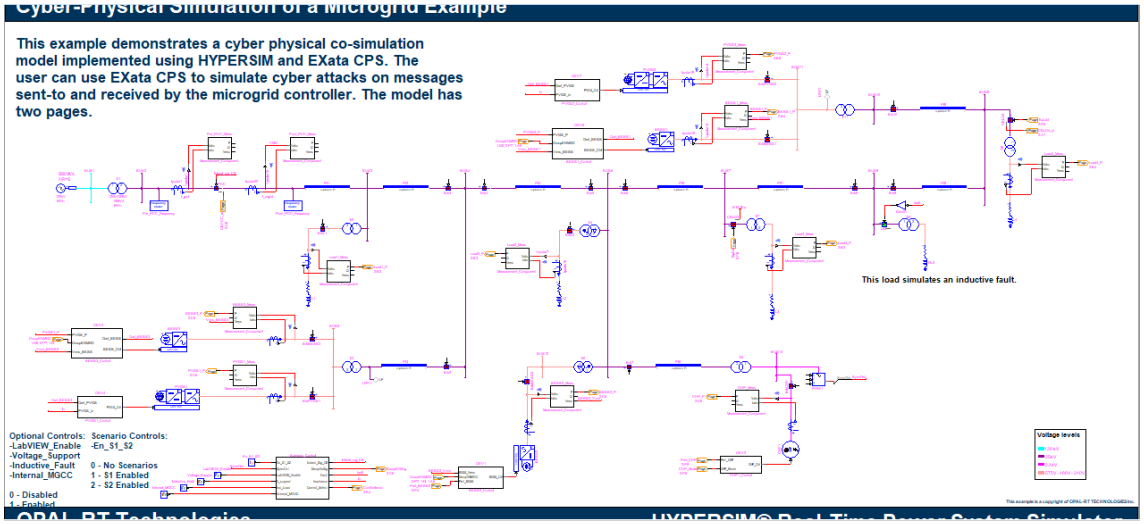

Figure 25. HYPERSIM power system model

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

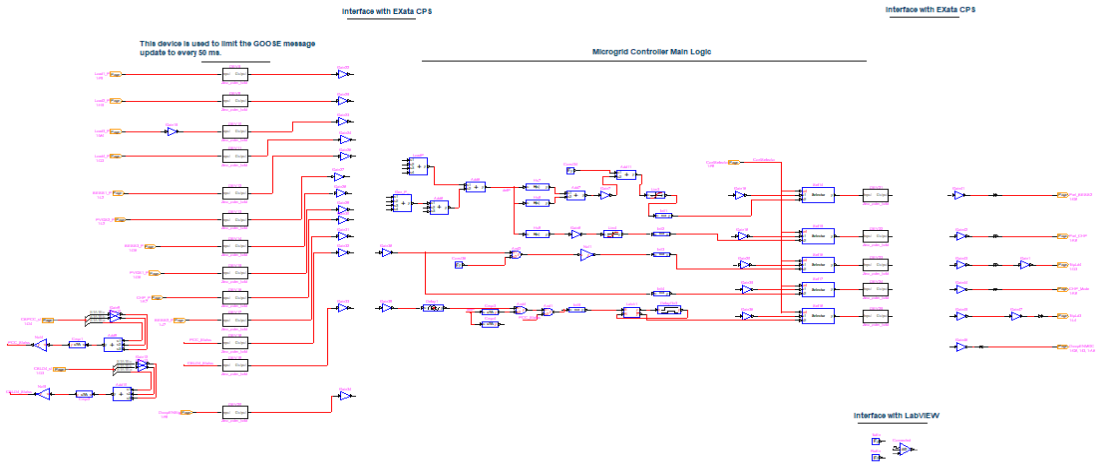

Figure 26. HYPERSIM connection system model

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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.

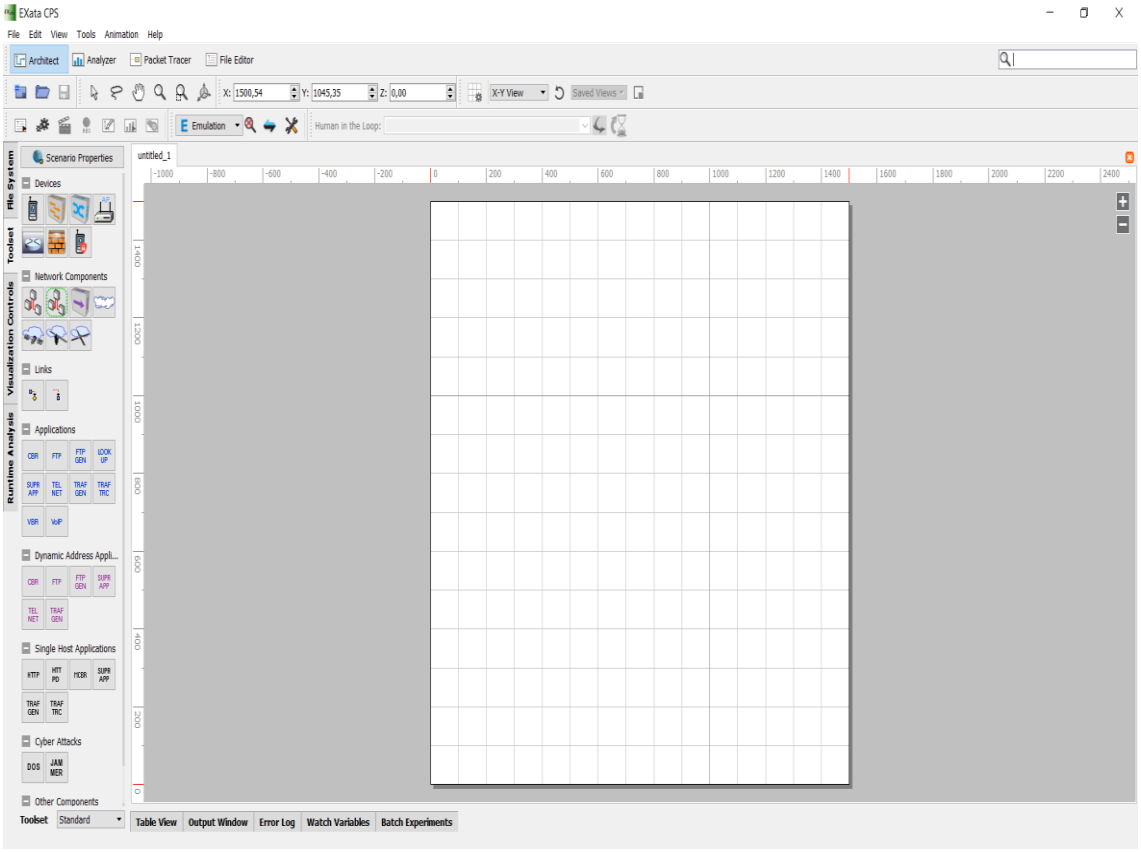

Figure 27. EXata GUI

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.

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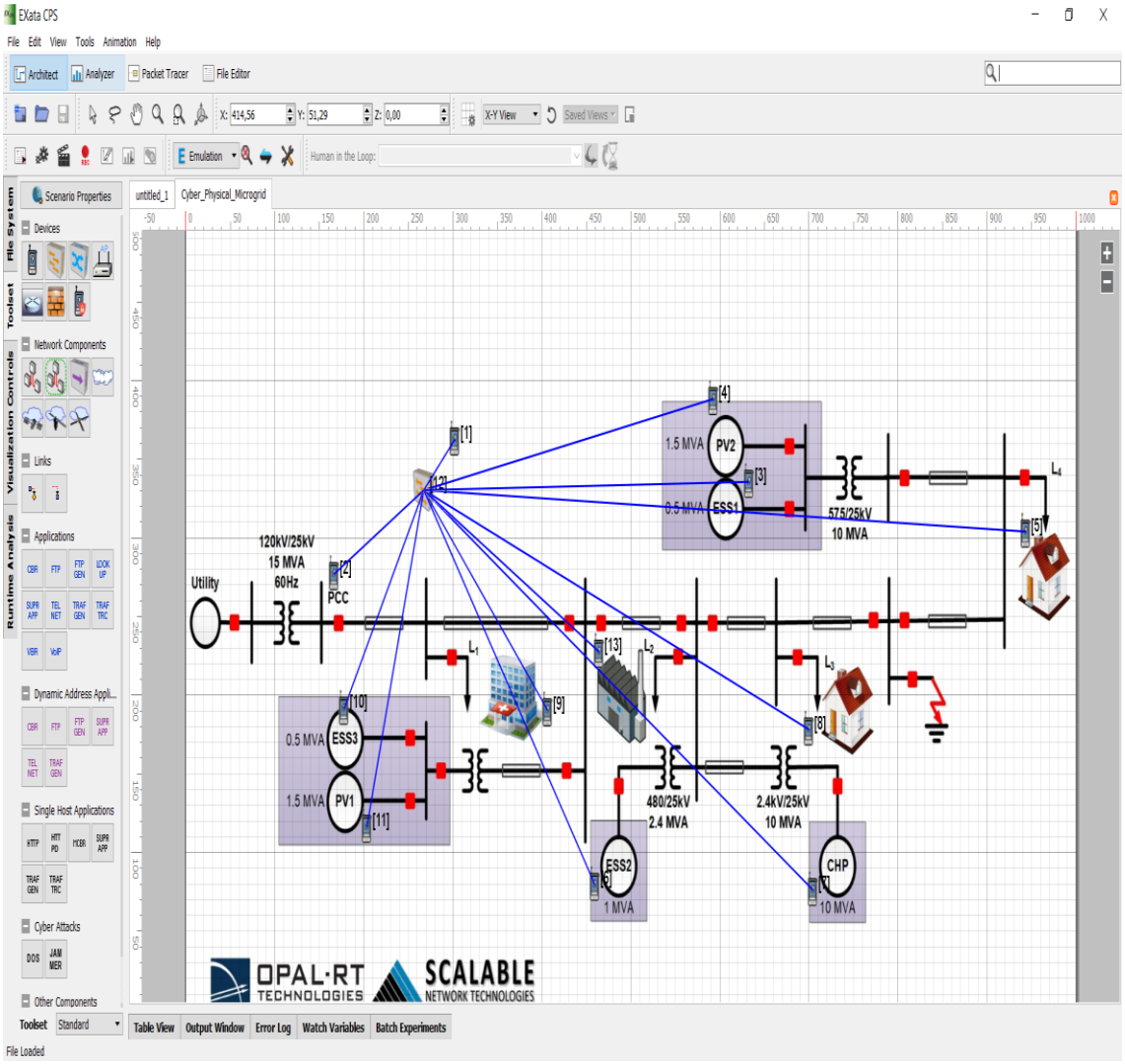

Figure 28. EXata GUI "Cyber-Physical Simulation of a Microgrid Subject to Cyber-Attacks" model

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.o78, that we need to downloaded from the Opal web page as described in T2.1.

3.1.1.2 Activation of HYPESIM error

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

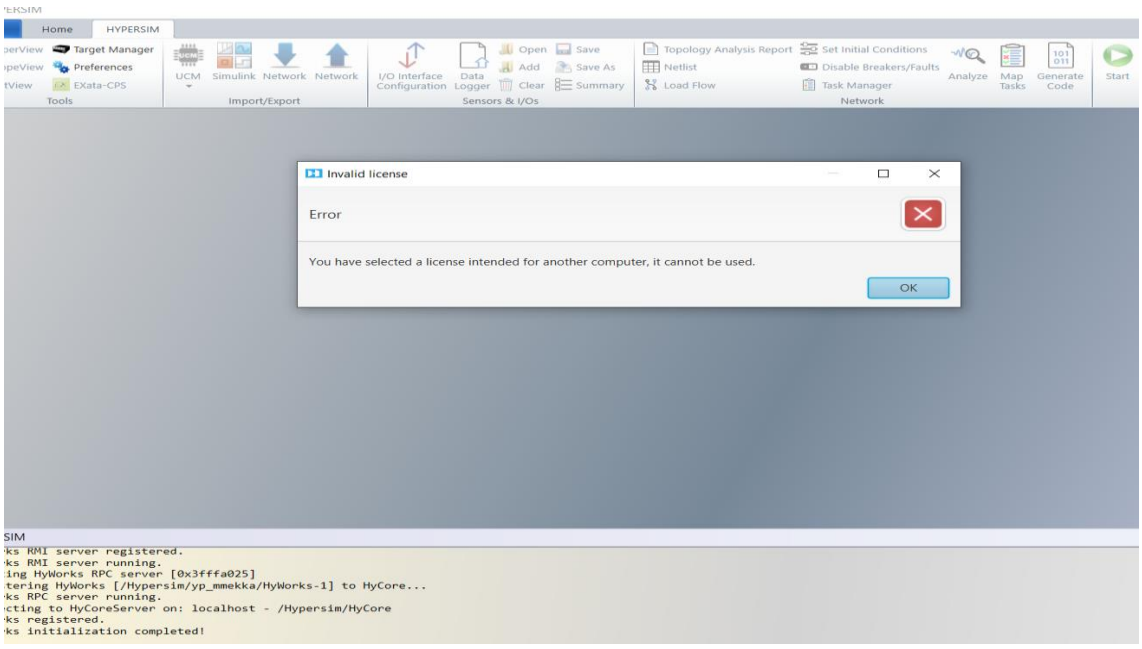

Figure 29. Activation of HYPERSIM software error

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.

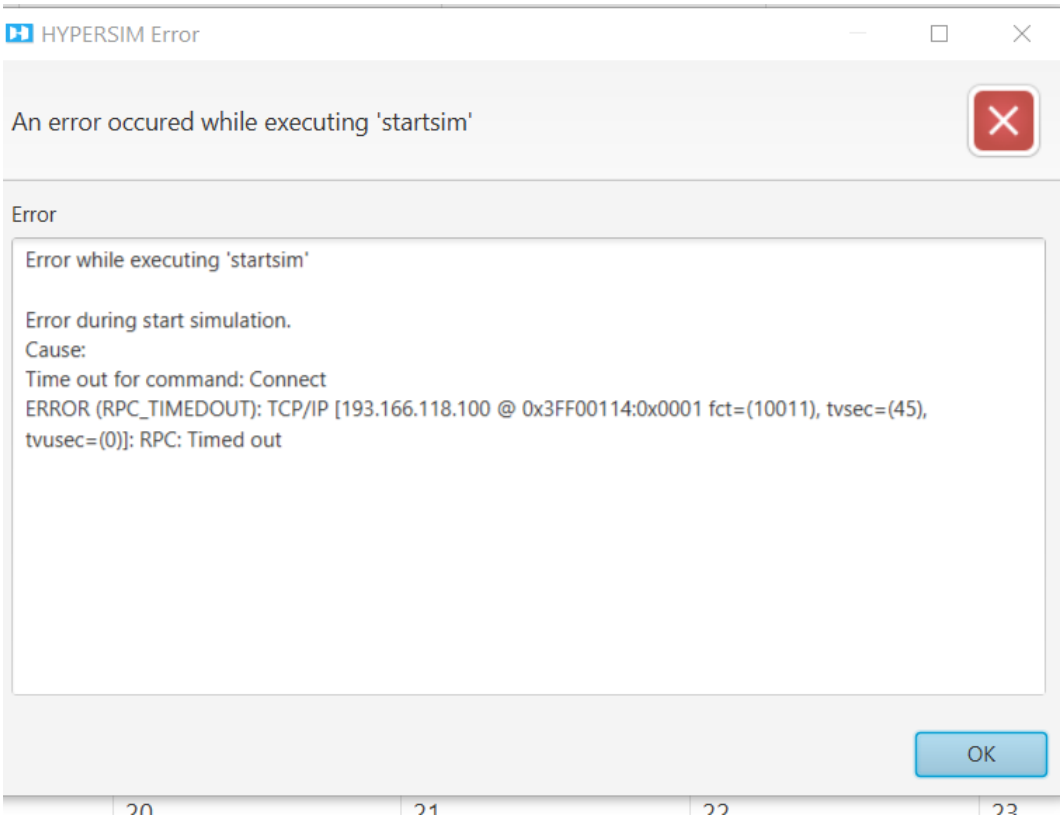

Figure 30. HYPERSIM software error

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 SCALABLE 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.

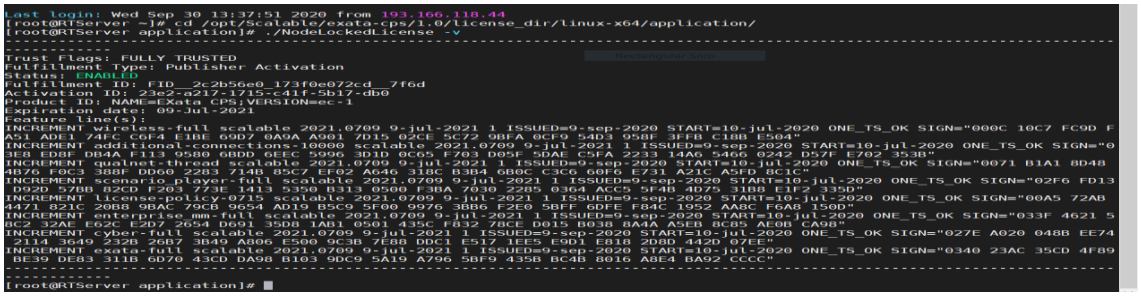

Figure 31. EXata licenses at the TARGET is activated

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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.

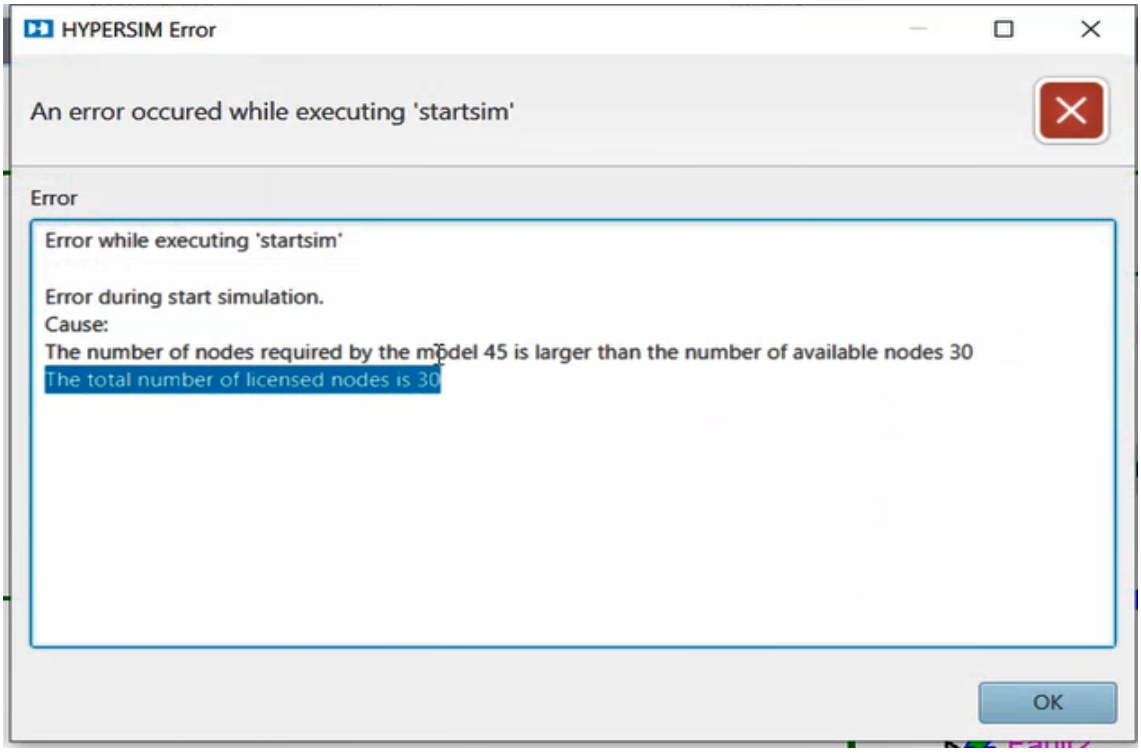

Figure 33. HYPERSIM error based number of nodes

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.

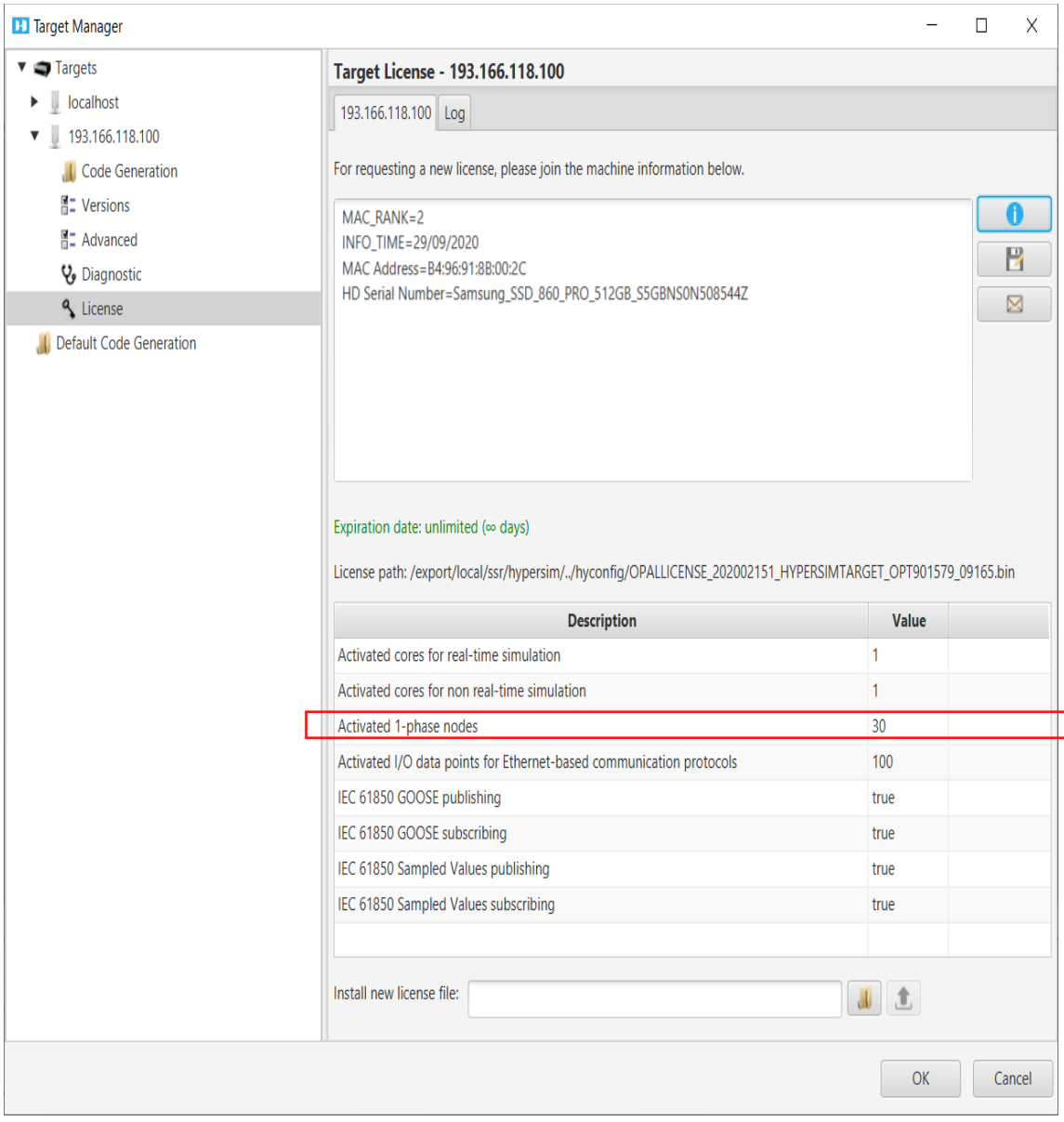

Figure 34. HYPERSIM number of nodes before extending

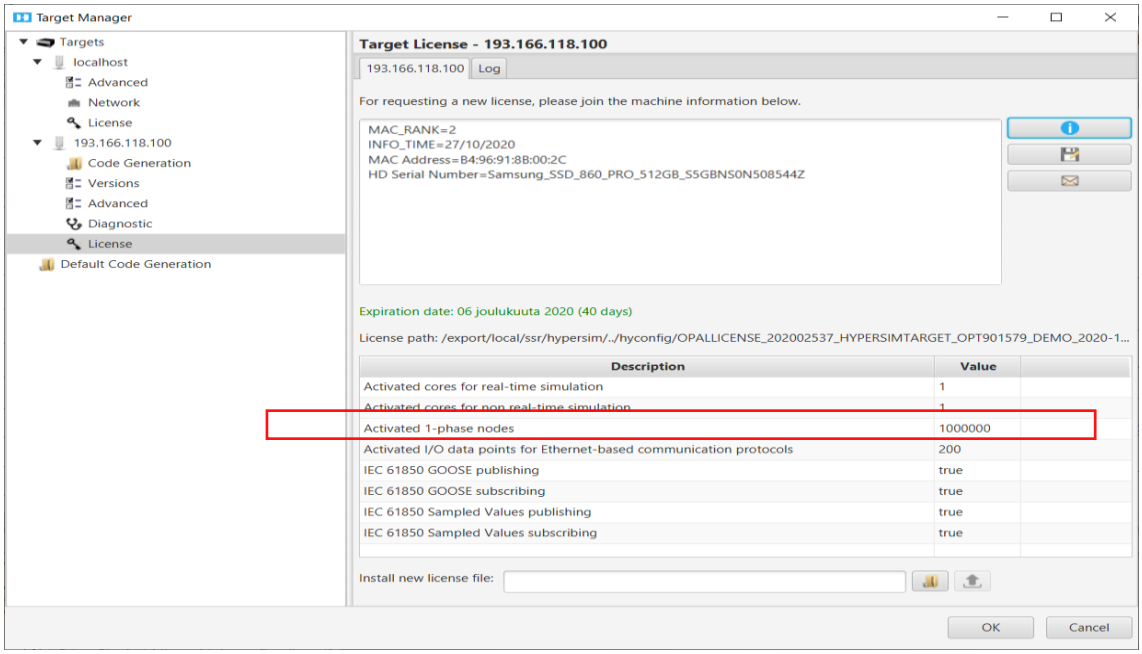

Figure 35. HYPERSIM number of nodes after extending

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.

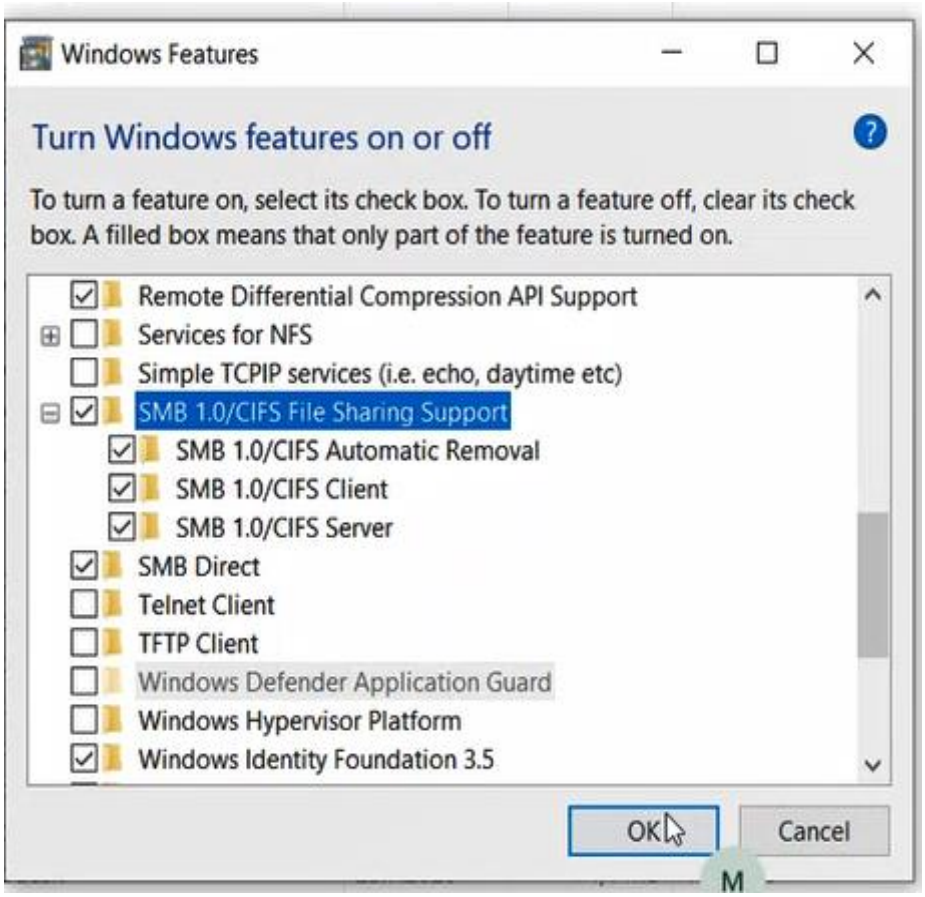

Figure 37. Adding Windows features

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.

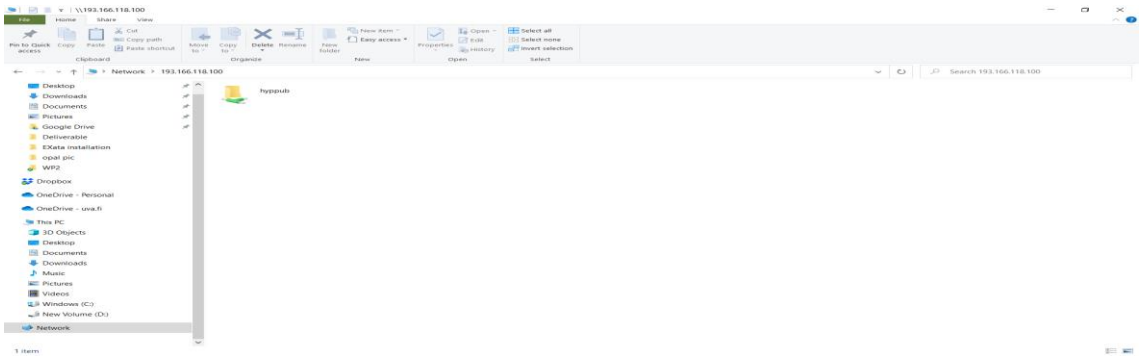

Figure 38. Opining connection from HOST PC to the TARGET

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.

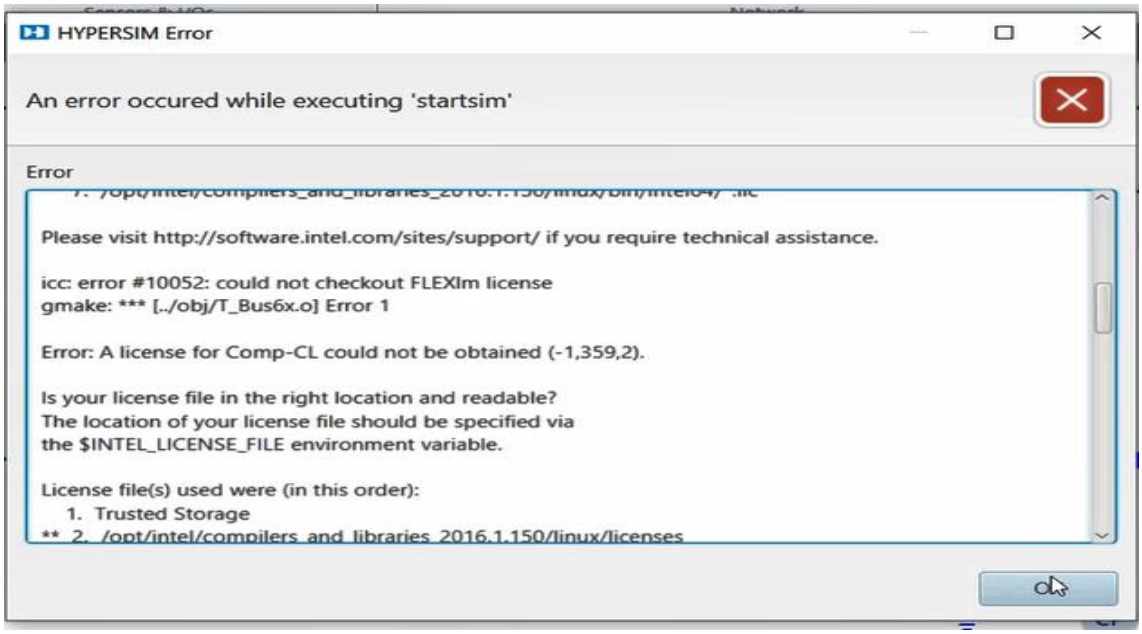

Figure 39. Error based on the used opicc compiler by HYPERSIM

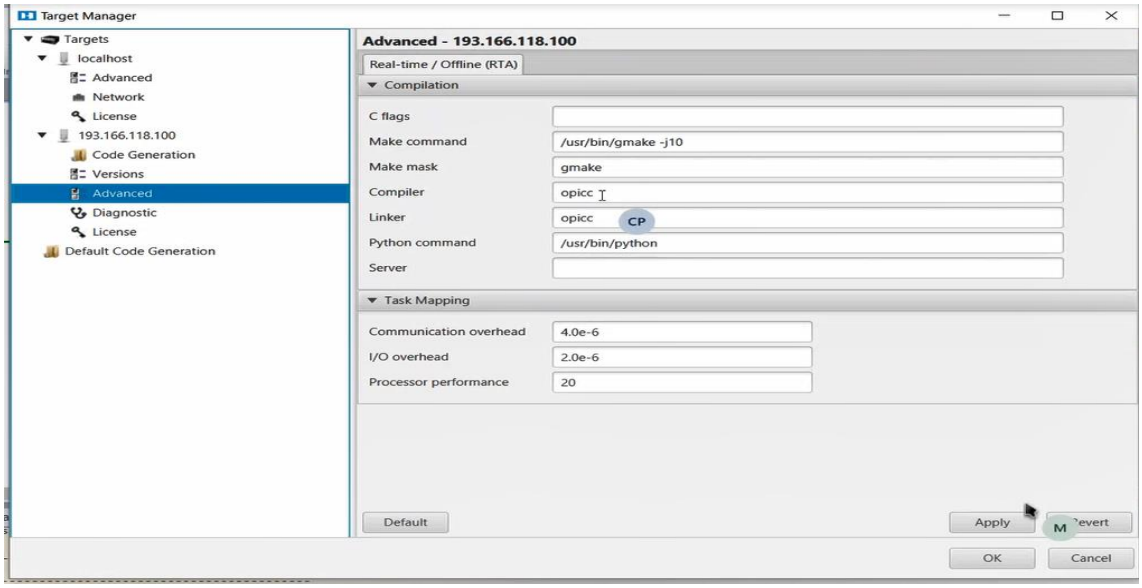

Figure 40. opicc compiler used by HYPERSIM before

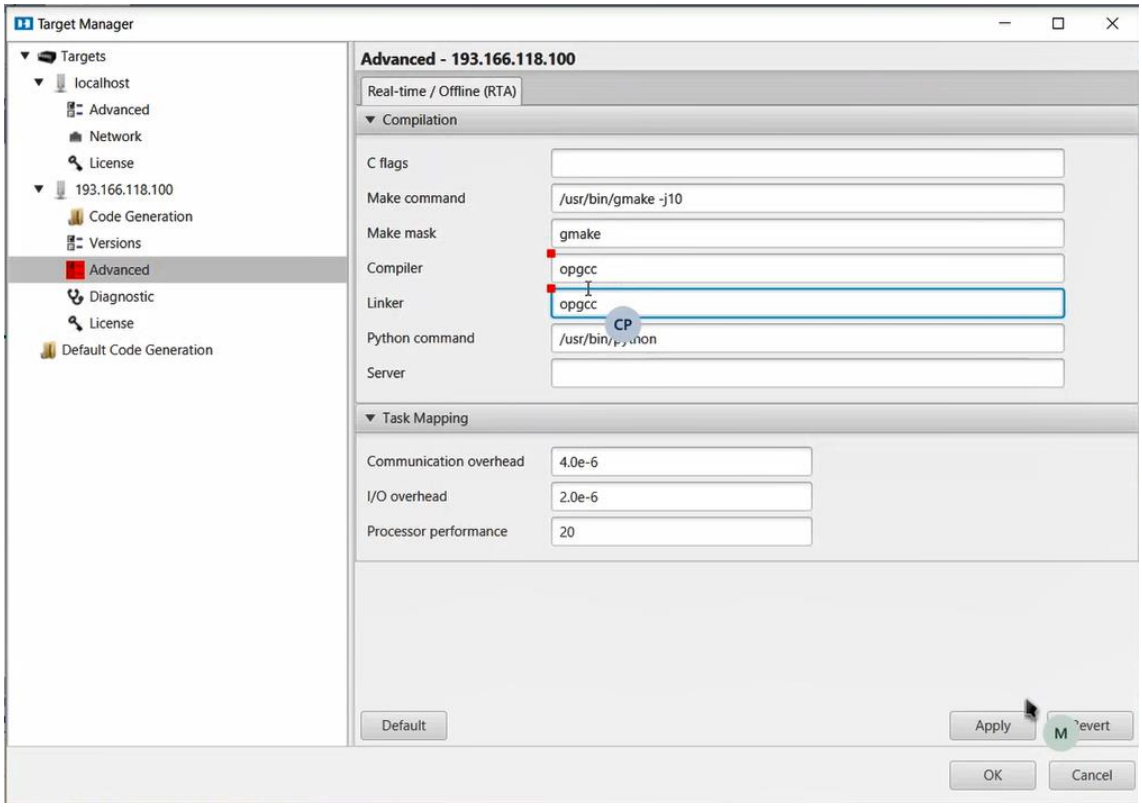

Figure 41. opgcc compiler used by HYPERSIM after

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.

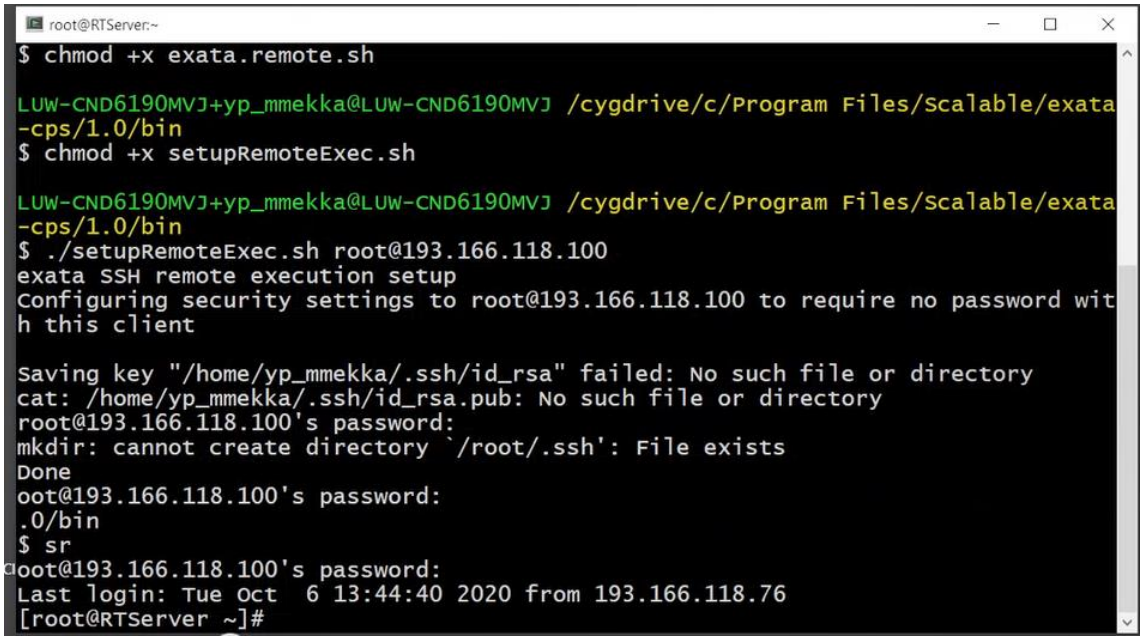

Figure 42. Cygwin openssh connection

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

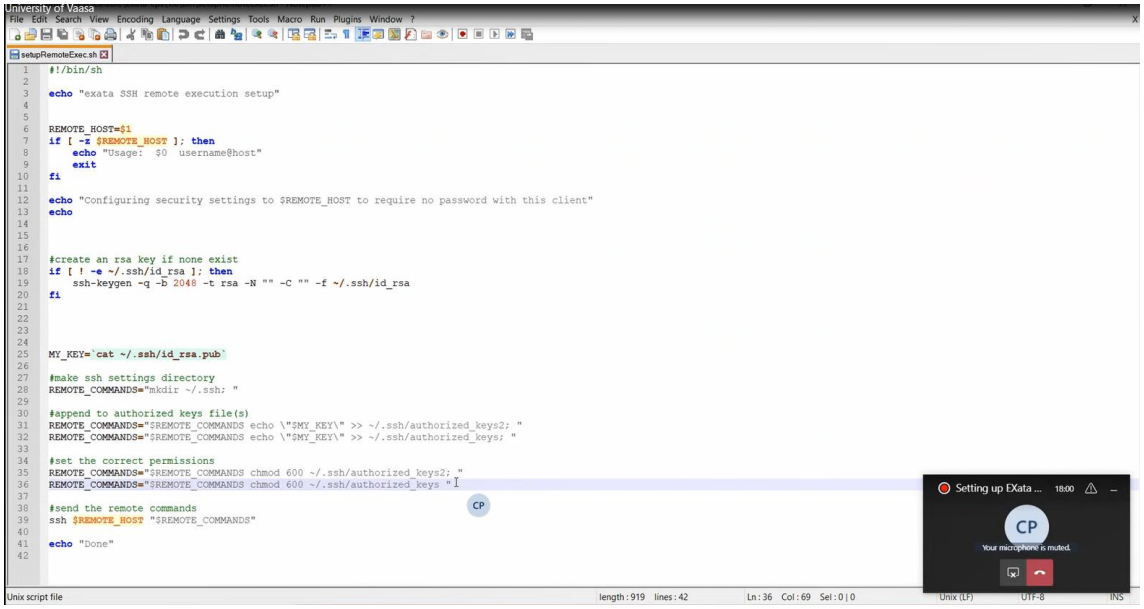

Figure 43. setupRemoteExec.sh script before change

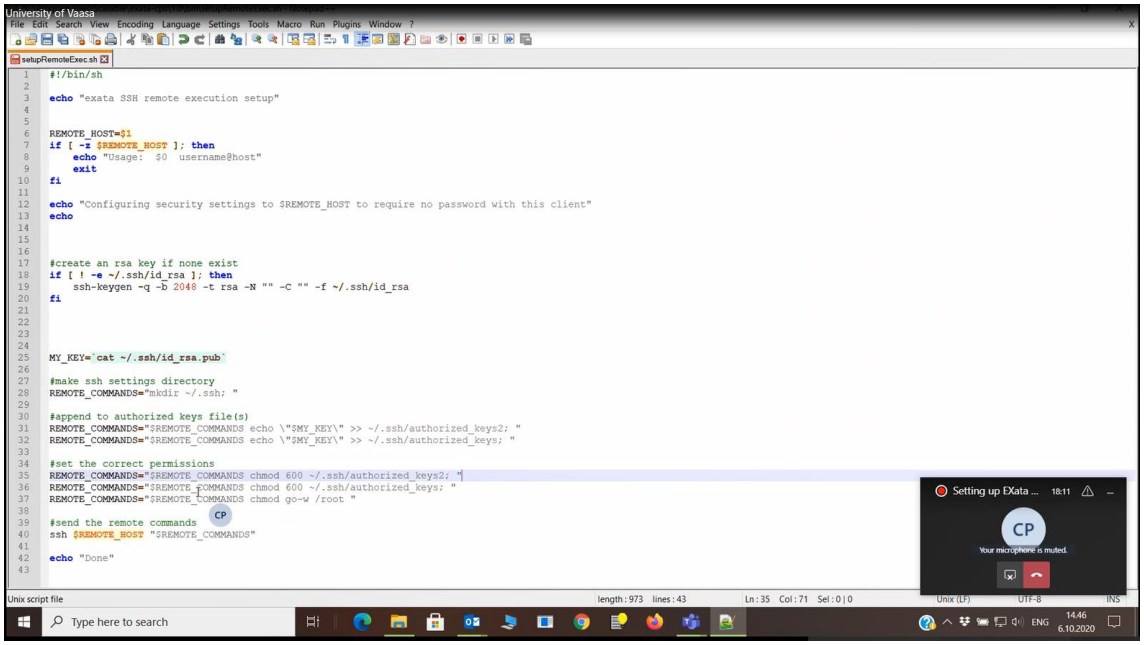

Figure 44. setupRemoteExec.sh script after change

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.

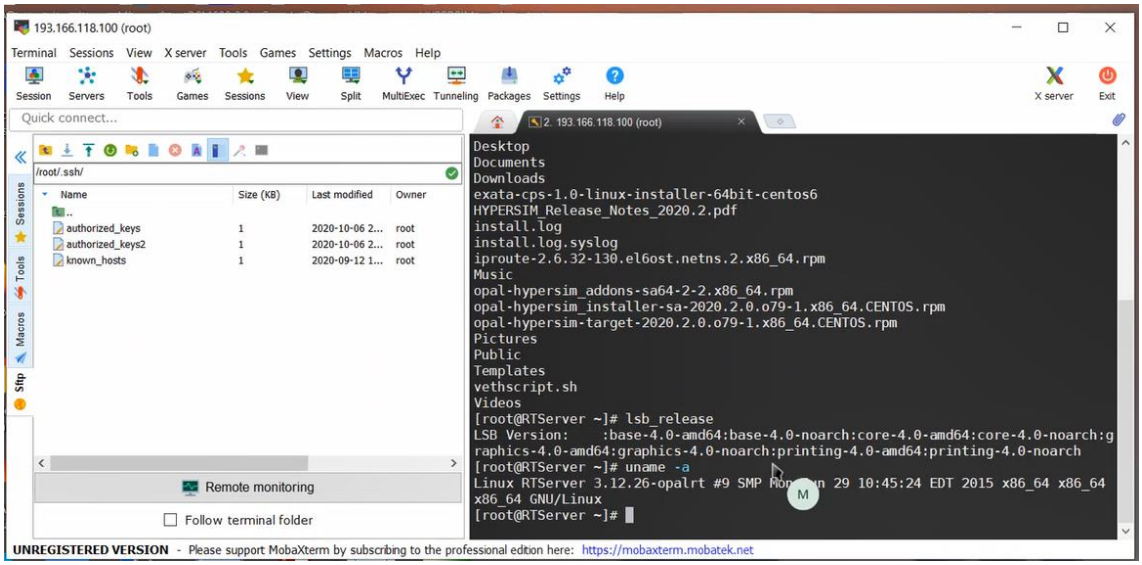

Figure 45. MobaXterm connecting to the TARGET

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.

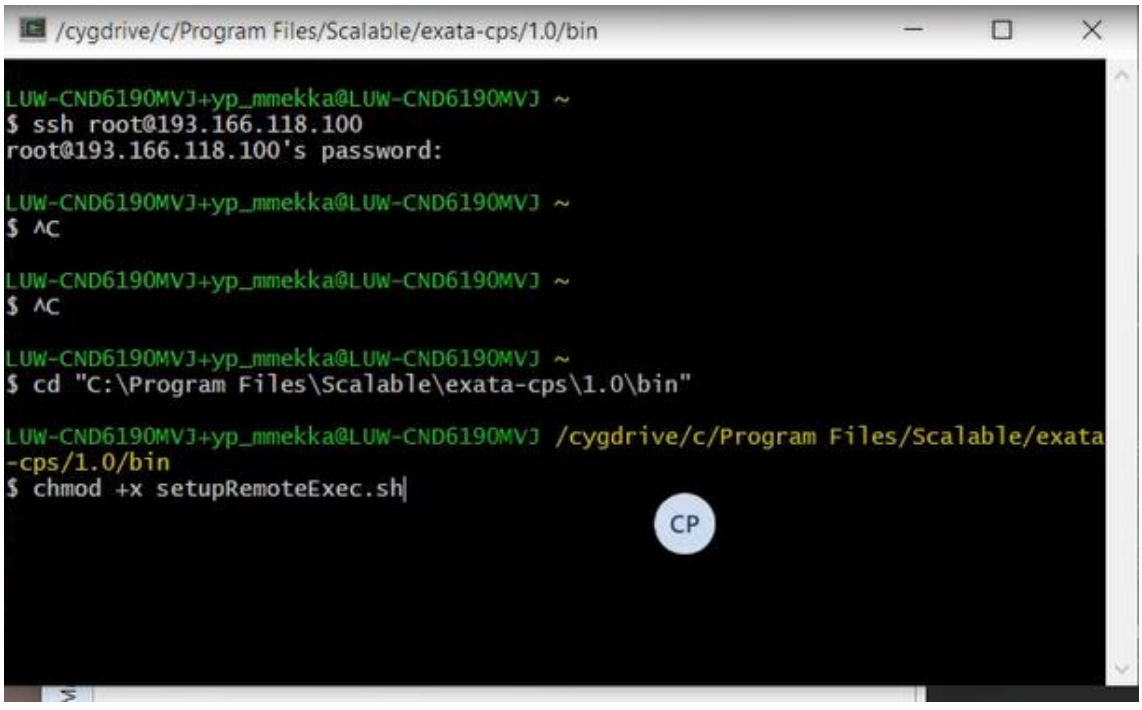

Figure 46. MobaXterm connecting to the TARGET

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.

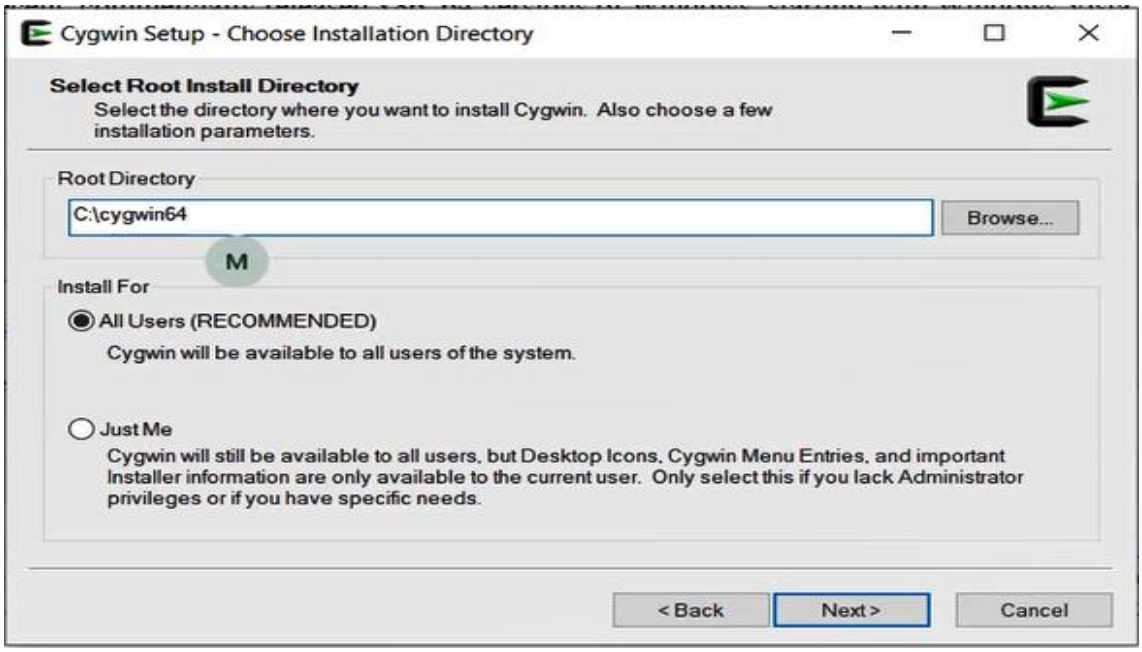

Figure 47. Cygwin installation

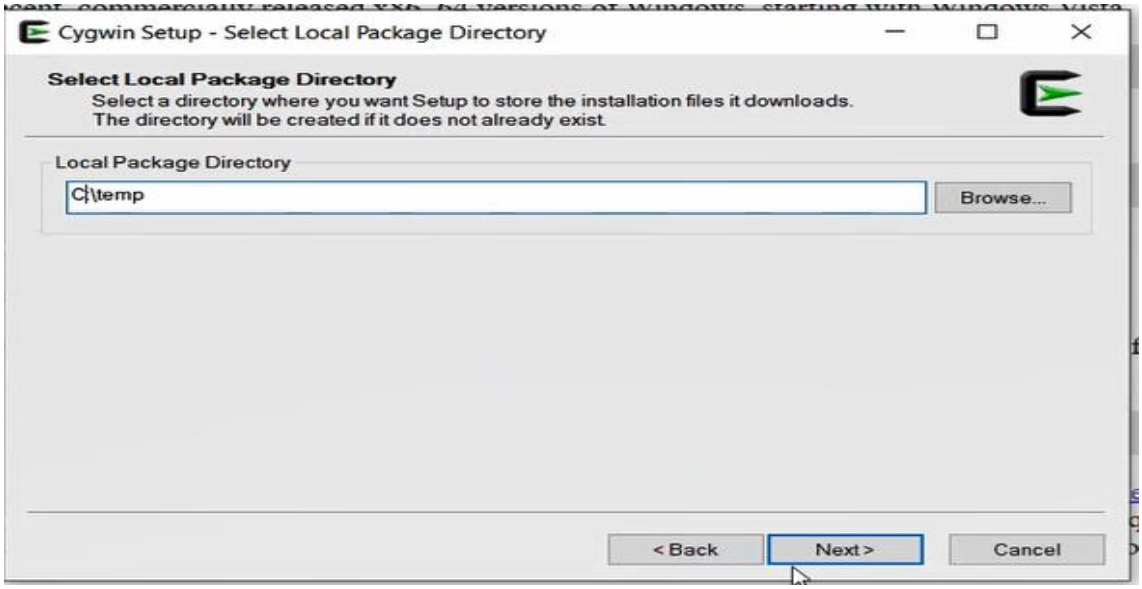

Figure 48. Cygwin installation steps

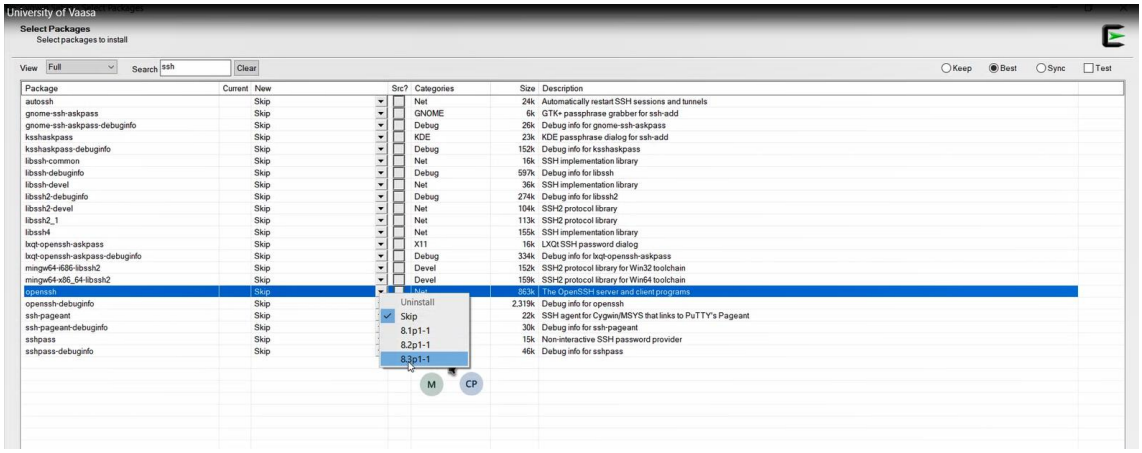

Figure 49. Cygwin installation steps

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.

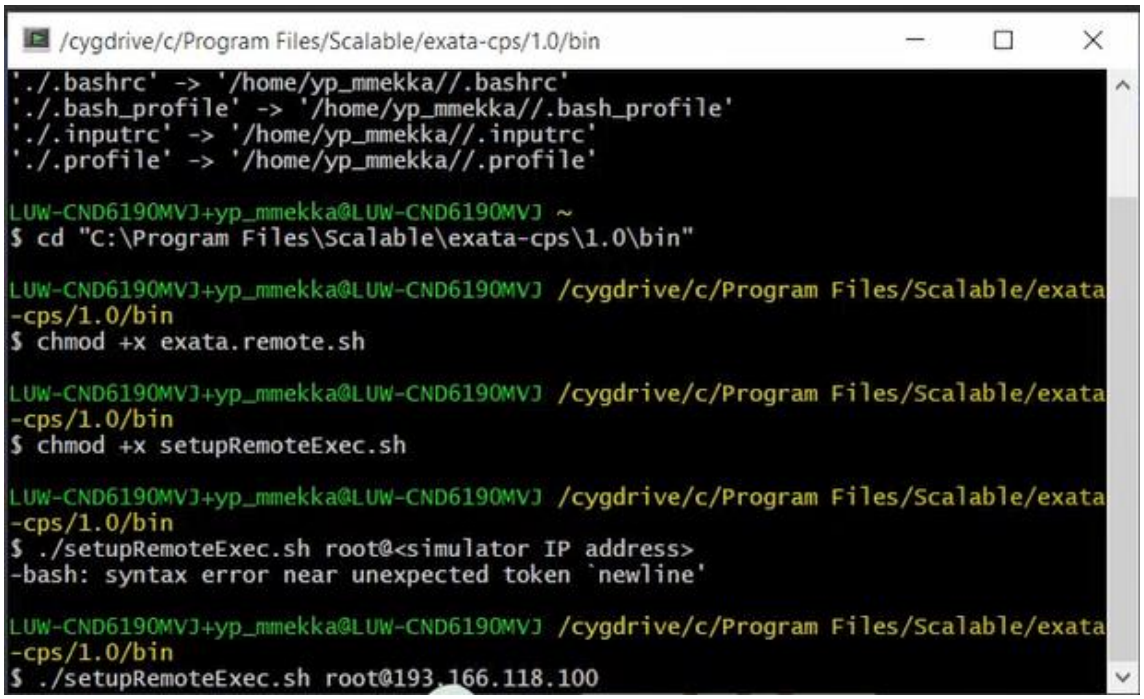

Figure 50. Cygwin execution scripts

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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.

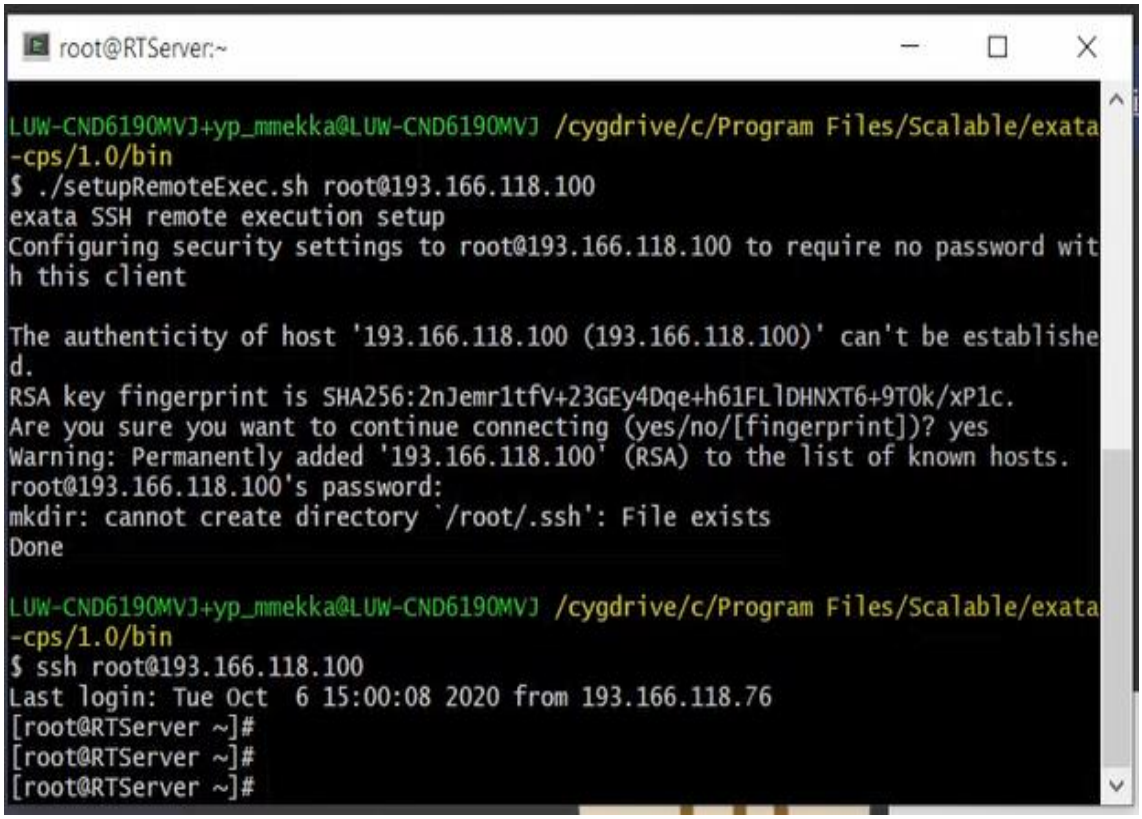

Figure 51. Cygwin openssh connection

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.

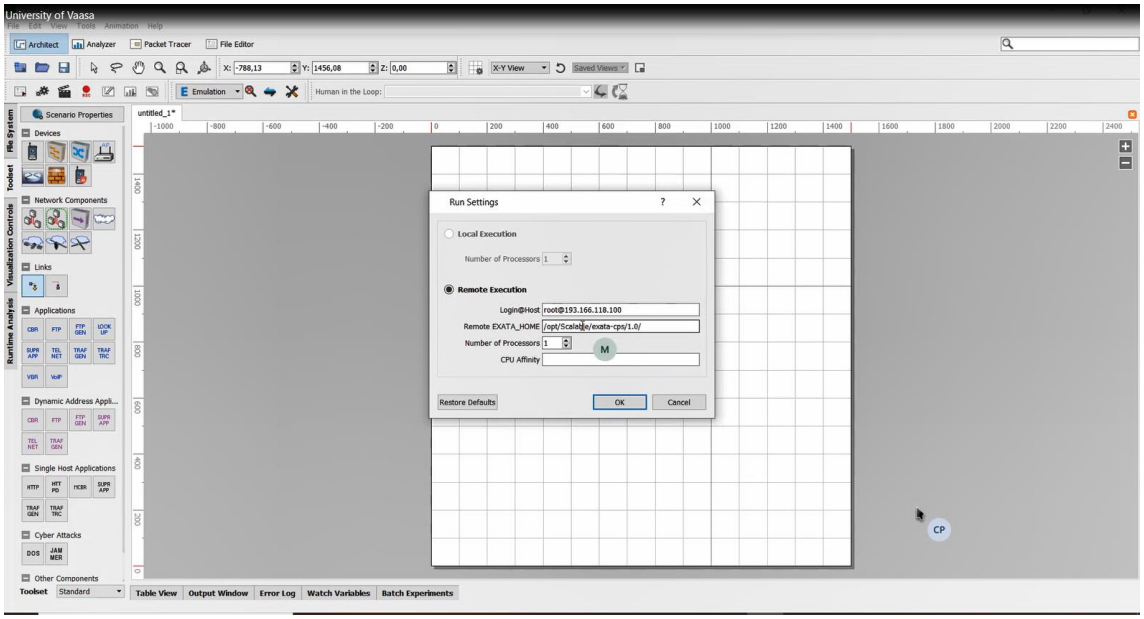

Figure 52. EXata configuration

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.

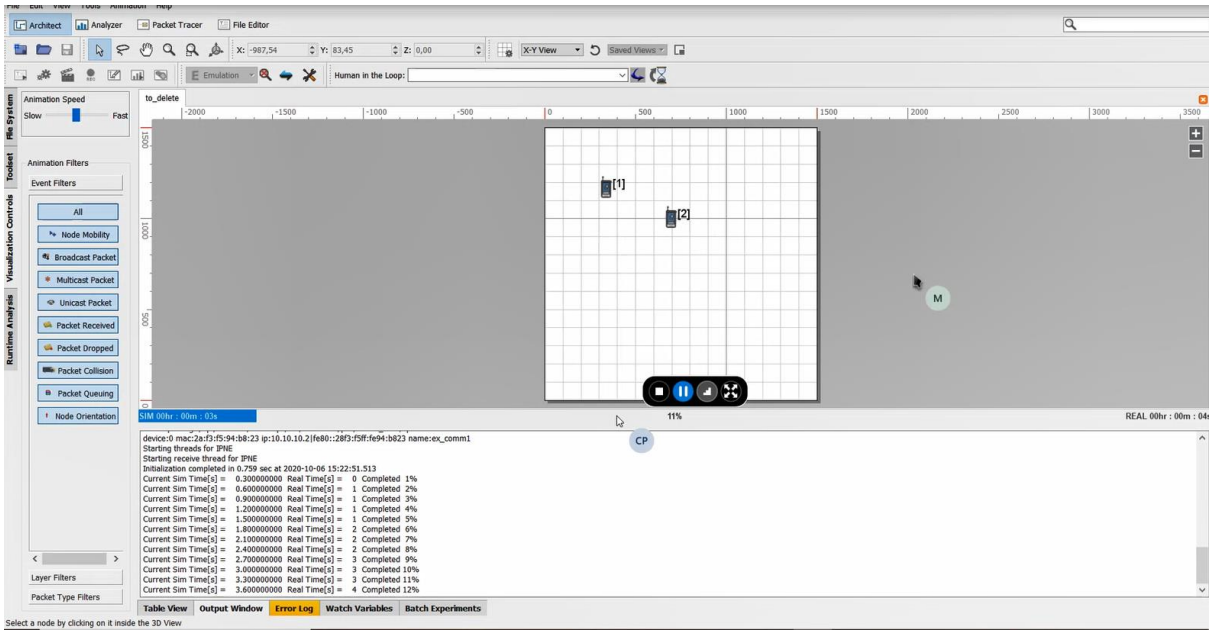

Figure 53. EXata GUI with running model

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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

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