EE 552, Spring 2024,
Homework Assignment #3

In this assignment, you will work with a power grid testbed model, and your goal is to conduct a Loss-of-Load Expectation (LOLE) study to determine a minimum planning reserve margin (PRM) necessary for maintaining a system with a LOLE of less than 0.1 days/yr. To conduct this study effectively, you will utilize the commercial software application GE-MARS to compute reliability indices for the power grid. Please follow the steps outlined below to complete this assignment. We begin by providing some overview information about GE-MARS.

OVERVIEW INFORMATION

The EE 552 notes "Reliability.pdf," also called Module U21.5, contain some overview information about GE-MARS that you should read. We provide some additional information here, obtained from a slide deck developed by GE called "GE MARS". There are 685 slides in this slide deck.

Unlike the so-called analytical method (convolution), GE-MARS is sequential (also known as chronological) with respect to loading conditions, i.e., it evaluates one time period (e.g., hour) at a time, accounting for events which are dependent on past events. GE-MARS also uses Monte-Carlo (MC) simulation (otherwise known as stochastic simulation) to establish the generation available to supply the load within those operating conditions. It does this by taking random samples of various operating conditions (e.g., the state of a generation unit). It repeats this randon sampling over and over again (as N→infinity), computing the reliability indices that result, according to

$$Loss\ of\ Load\ Probability\ (LOLP) = \lim_{N \to \infty} \frac{1}{N} \sum_N Loss\ of\ Load$$

where we see that the LOLP is the limit as the number of random samples, N, approach infinity of the sum of the loss of load events in each sample divided by the number of outages. If the number of samples is sufficiently large, the simulation method should converge to a value very near to the value obtained via the analytic method. Then, the expected value of the reliability indices, i.e., loss of load probability (LOLP), loss of load expectation (LOLE), and loss of energy expectation (LOEE) can be computed as

$$\bar{I} = \frac{1}{N} \sum_{i=1}^{N} I_i$$

It is also possible to obtain the standard error of simulated reliability indices.

The essence of MC simulation is contained in three steps:
Step 1: Generate a uniform random number, U, in the range 0→1, for each random variable in the system.
Step 2: If U_i< forced outage rated for generator G_i, the generator is unavailable based for that time period.
Step 3: If Load > Generation, a loss of load has occurred for that time period.

A. Review the system description as follows:

The system is composed of nine local balancing authorities distributed among three pools. The high-level diagram is shown in Figure 1.
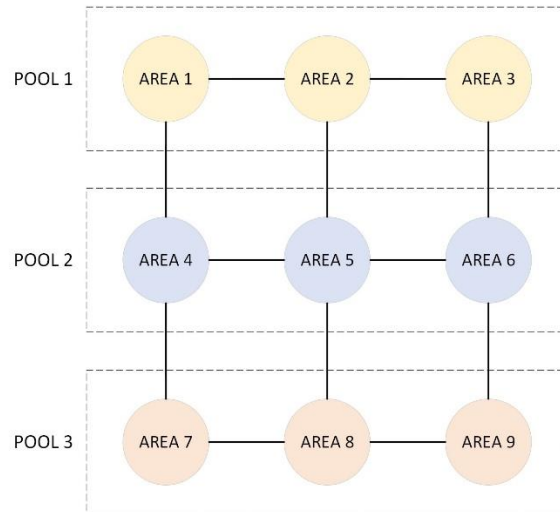

Figure 1. Diagram of the system.

Using GE-MARS, you will compute reliability indices for 2024. The provided material contains information on the following system's components that you will need to model the system and complete the study. There are five prepared files, as follows:

- *01-System_Topology.xlsx*
- *2006LoadShapes.xlsx*
- *02-Load_Forecast.xlsx*
- *03-Thermal_Units.xlsx*
- *04-Transmission.xlsx*

These five files are provided for you on the website, and they are further explained below. You are encouraged to open each file and inspect it.

- **System topology**: MARS calculates reliability indices on pool, area, and area group levels. The *"01-System_Topology.xlsx"* file defines the nine areas and pools you will consider for the study.
- **Load:** Information related to system's demand behavior is composed of two types of data:
  I. Load shapes: load shapes must be included for all areas in the system. The *"2006LoadShapes.xlsx"* file contains hourly load data collected for all areas in the year 2006.
  II. Load forecast: Through the *"02-Load_Forecast.xlsx"* file, MARS will adjust the annual peak load (MW) and energy (MWh).
- **Generation:** Even though multiple types of generators can be modeled in MARS, this study will only consider thermal units to keep the system relatively simple. The file *"03-Thermal_Units.xlsx"* contains two sheets with the following information:
  I. Thermal Defaults: This tab has default parameters set by unit summary type, including forced outage rate (FOR), number of transitions, and planned outage rate.
  II. Thermal Units: All existing thermal units are in this tab. For each unit, data includes type, area, installation date, retirement date, summer capacity, and winter capacity.

- **Transmission interconnections:** Transmission interfaces are defined between areas. The "*04-Transmission.xlsx*" file has two sheets. The "Transmission Interface" tab defines 12 transmission interfaces, as shown in Figure 1. The "Transmission Limits" tab sets positive and negative transmission limits. Notice that ratings change over time, representing transmission expansion investments.

B. Access the software:
1. Log onto VDI (https://etg.ece.iastate.edu/vdi/) - Use the EE server
2. Launch "GE MAPS & MARS"
3. Configure the Software
   a. Navigate to "General" and click on "Options"
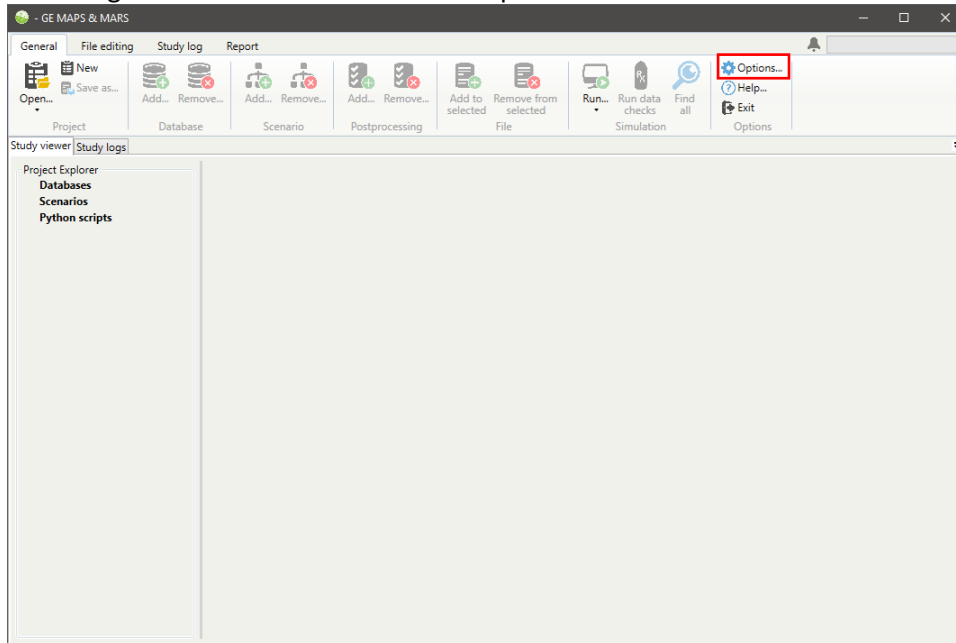
   b. In the Options dialog box, under the General tab, enter (or browse for) "C:\Program Files (x86)\GE MAPS & MARS\License key – 2024\MARS-LIC" for the MARS license file.
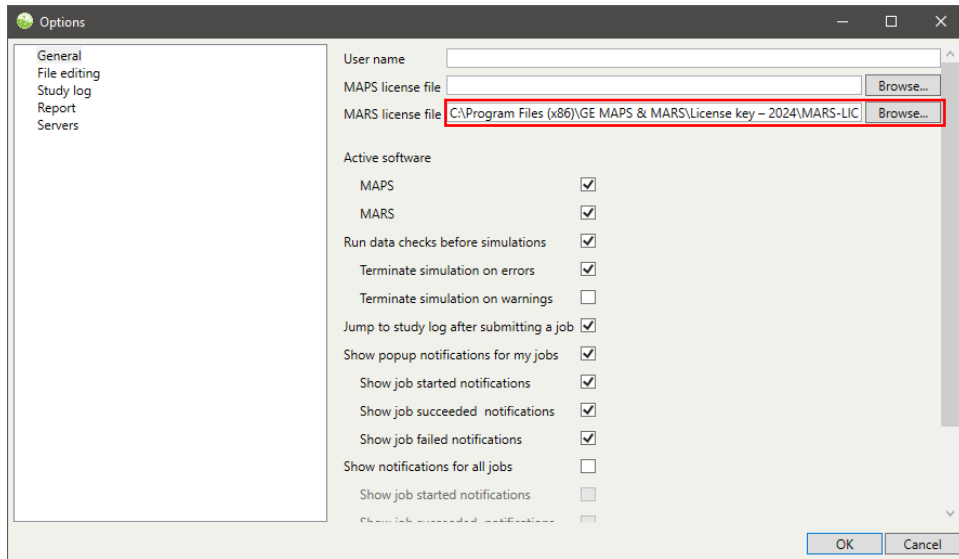
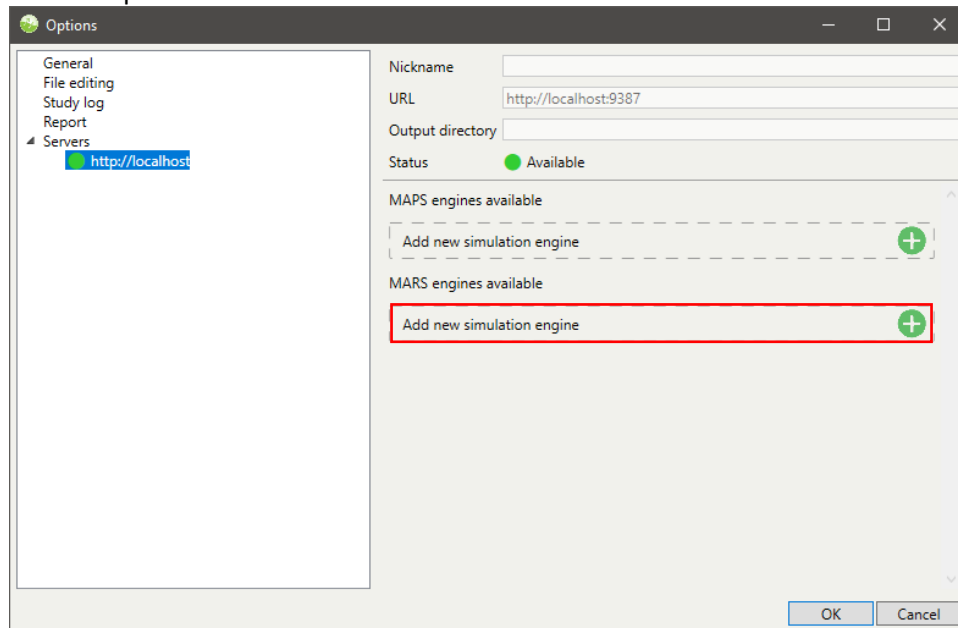c. In the same dialog box, select the Servers tab and click "Add new server"
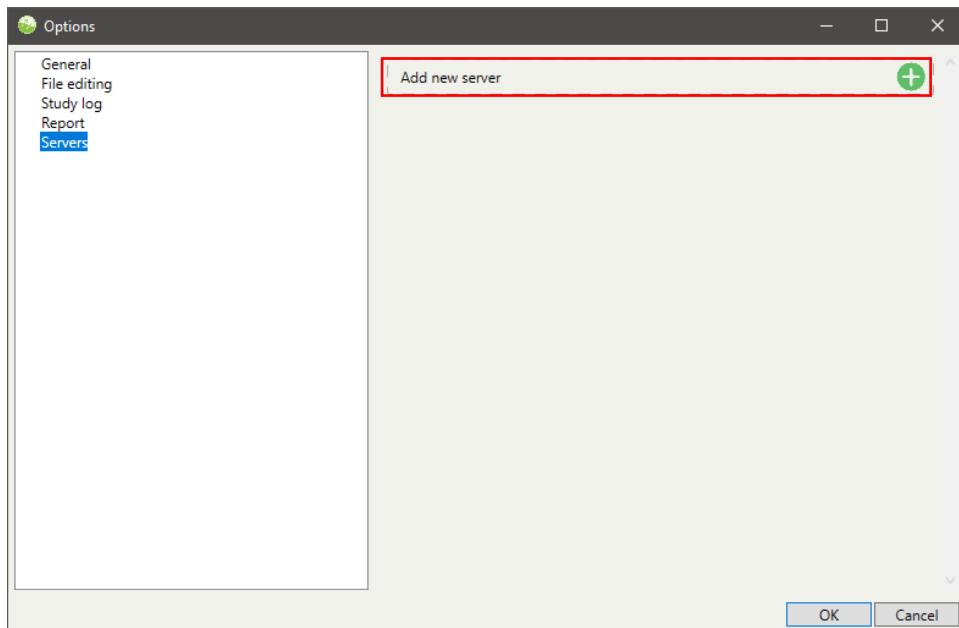
d. Use "C:\\Temp" as the Output directory for MARS to save results, and use "C:\ProgramData\GE\snappy_services" for the binary directory.
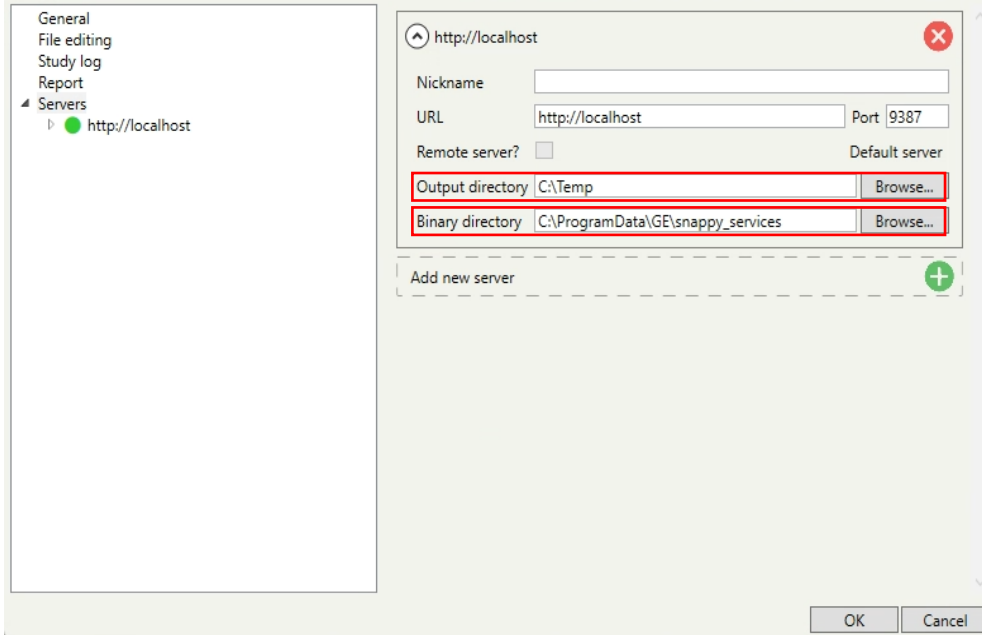
e. Select the new server in the left panel, and click "Add new simulation engine" under "MARS engines available".
Enter "C:\Program Files (x86)\GE MAPS & MARS\Binaries\MARS-4.12.2091-win64.zip" in the Open File window and select OK.

C. Now, you are ready to use the software. You will take the following steps:

1. Create a new project file and database	5. Thermal units
2. Add program options to the database	6. Transmission interconnection
3. System Topology Definition	7. Run simulation
4. Demand modeling	8. Results review

After completing these steps, you will need to answer some questions in Section D. Turn in your answers.

1. **Create a new project file and database:**

1.1. Open the GE-MARS user interface.

1.2. In the "General" ribbon, click on "New" to create a new project file, choose a file name for it, and save it in the "U:" drive or on your personal computer.
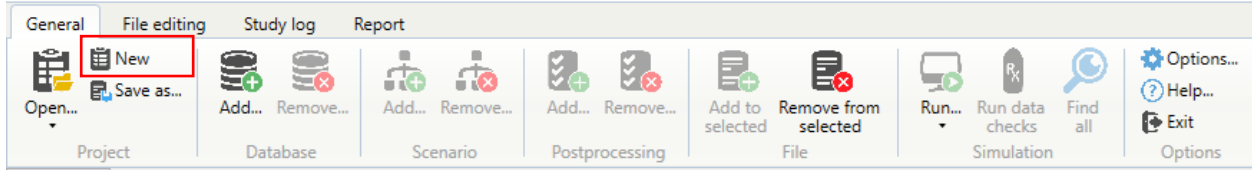
1.3. In the "General" ribbon, click on "Add…" to create a new database in the project.
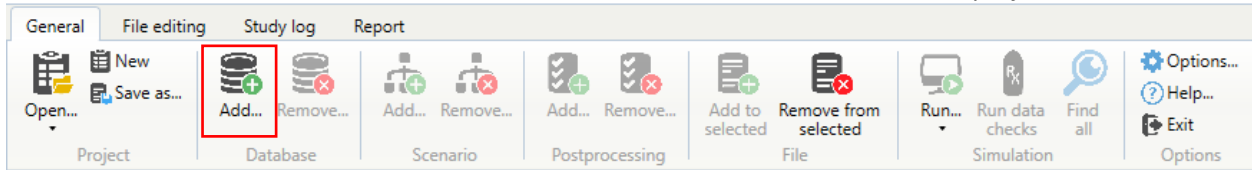
1.4. In the simulation options, enter the following information:

|	
Database Name = EE552 System	MARS version = 4.12.2091
Simulation type = GE MARS	Start Replication = 1
First run year = 2024	Minimum Replications = 100
Last run year = 2030	Maximum Replications = 8,000
Year of database = 2006	Convergence Tolerance = 0.05
Cores to use = 1	
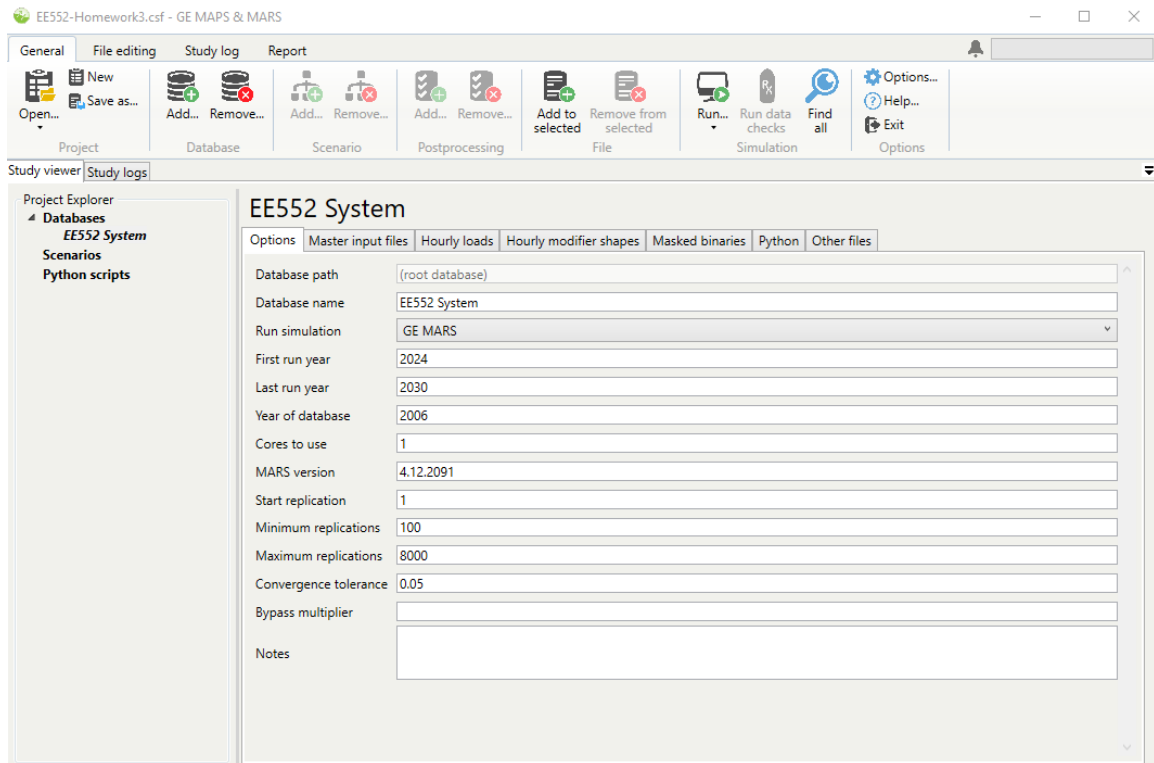
2. Add program options to the database:

2.1. In the "General" ribbon – click on "Add new MIF" on the "Master Input Files" tab of the Study viewer.
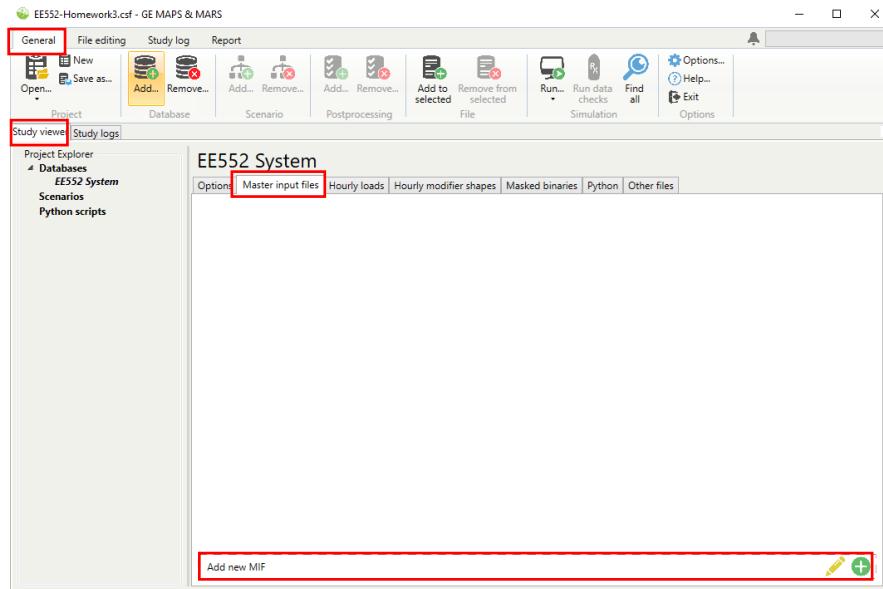
2.2. Select the "*00-MARS_Options.mif*" file in the provided materials.
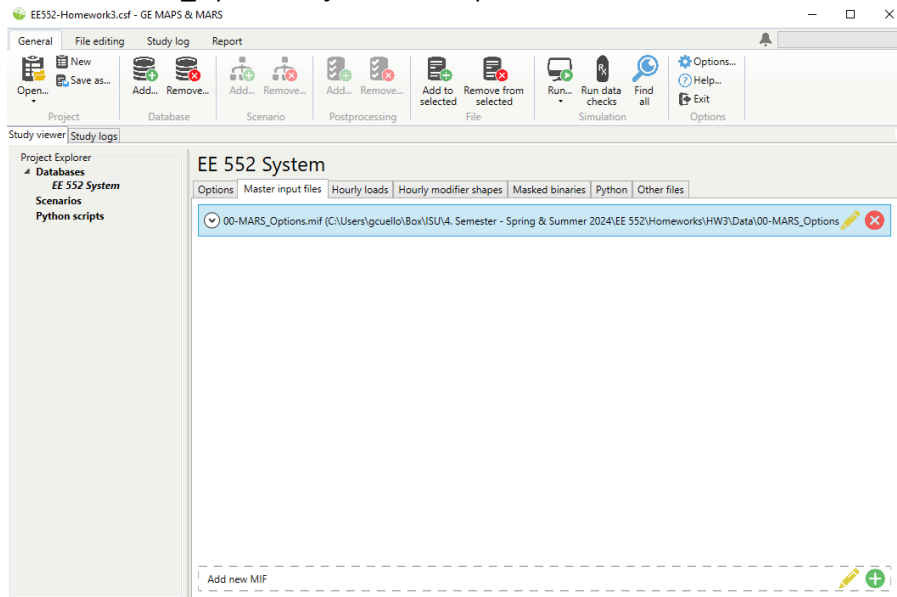
3. System Topology Definition:

    3.1. In the "General" ribbon – click on "Add new MIF" on the "Master Input Files" tab of the Study viewer, as in step 2.1.

    3.2. Create a new MIF in the database named "*01-System_Topology.mif*" and save it in your folder.

    3.3. Click the edit icon on that file in the Study viewer, or double-click on the file.
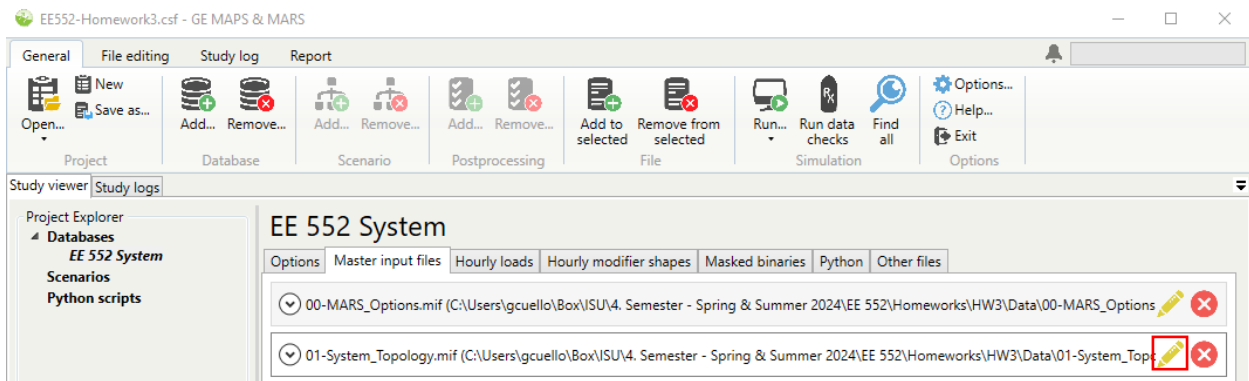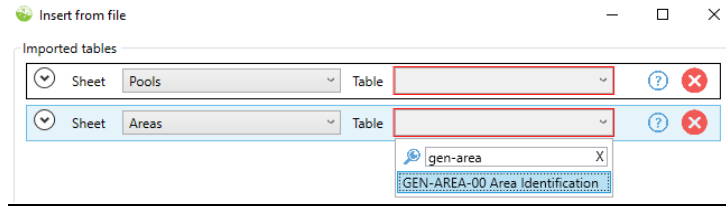

    3.4. Insert a table from a file by right-clicking anywhere in the editor and selecting "Insert" and "Insert table from file."
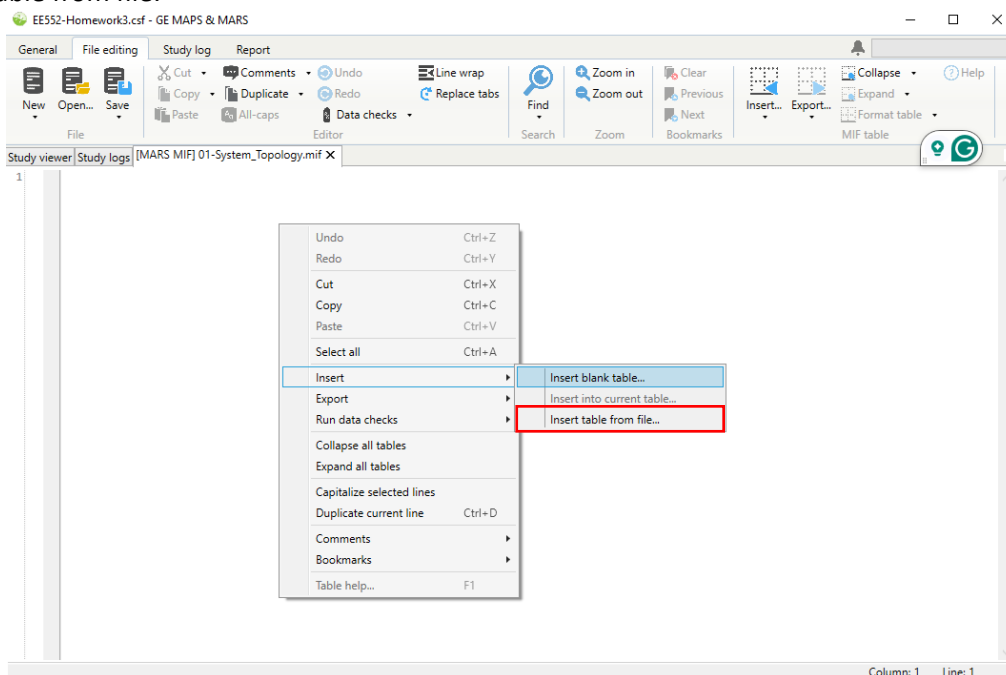

    3.5. Navigate to the "*01-System_Topology.xlsx*" file in the provided materials.

    3.6. Search for GEN-POOL-00 in the table dropdown for the "Pools" sheet.
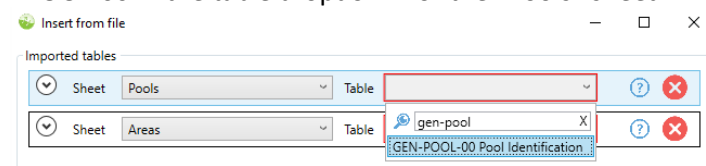
3.7. Search for GEN-AREA-00 in the table dropdown for the "Areas" sheet.

3.8. Make sure the columns from the file are mapped to the appropriate fields for the table. If your file column names match the table fields, this mapping will be done automatically. Click OK and save the file.
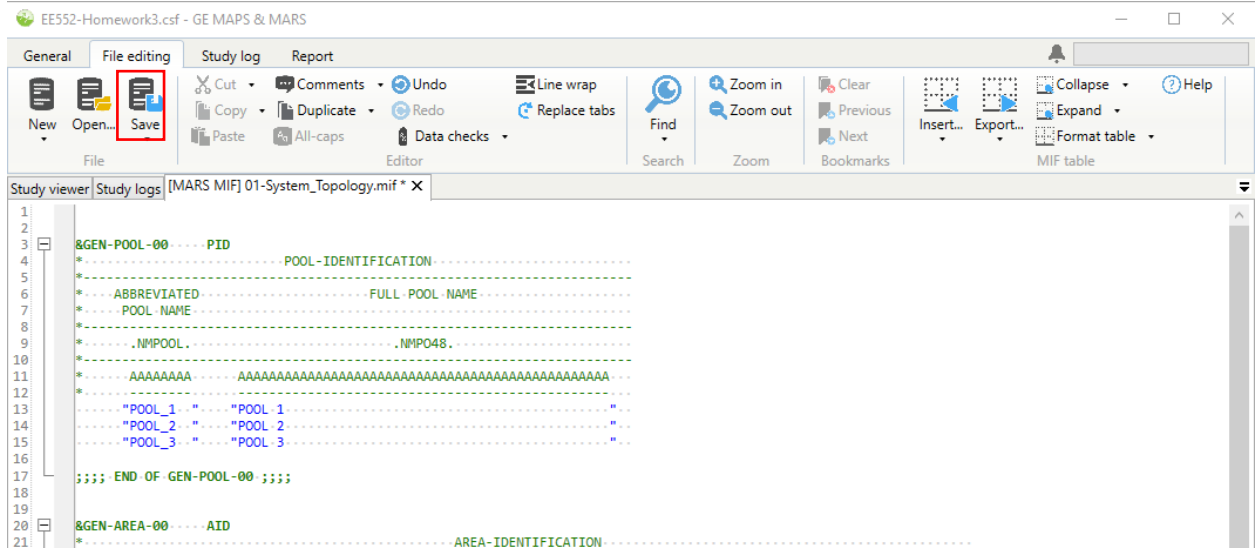
3.9. Having defined individual areas and pools, the next step is to establish an area group comprising all areas to represent the entire system. This will enable us to calculate the system's reliability indices. To define an area group, at the bottom of "01-System_Topology.mif," right-click anywhere in the editor and select "Insert" and "Insert blank table."
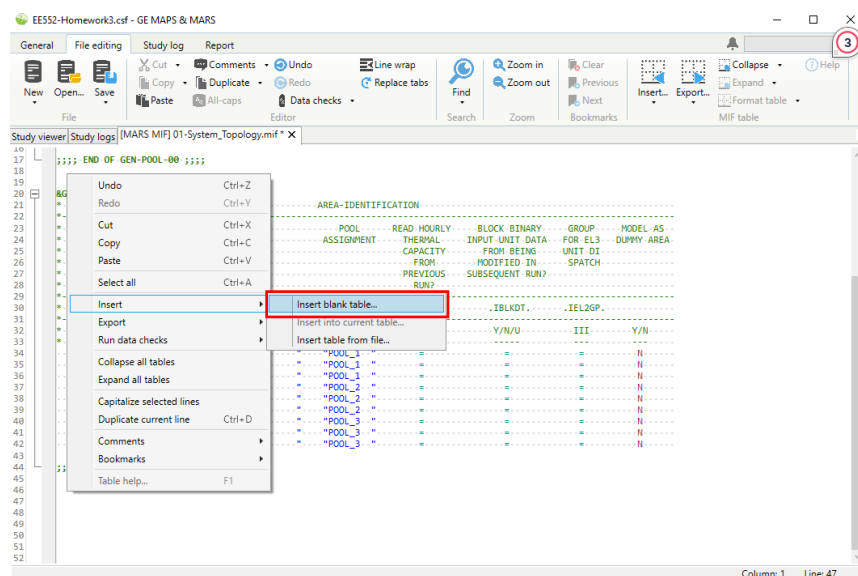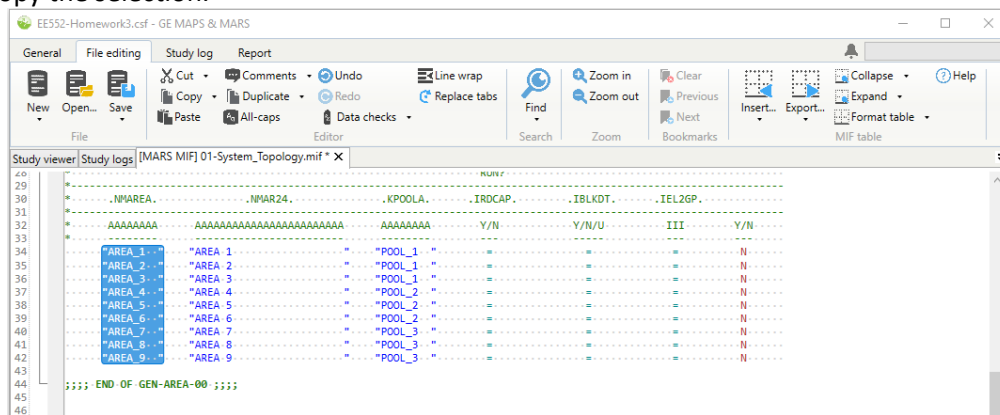
3.10.   Search and select "GEN-ARGP-00". Click OK. Then, name the area group "ALLAREAS" and give it the long name "ALL AREAS."

3.11.   Press and hold Alt (Block Selection) and select all areas from the GEN-AREA-00 table. Copy the selection.

3.12.   Add some blank lines after the "ALLAREAS" line and paste the selection into the GEN-ARGP-00 table. Then, press and hold Alt and click/drag the cursor to create a multiline cursor before all area names (left image). Type "+" (right image).

3.13. Select "Format table" and then save the file.
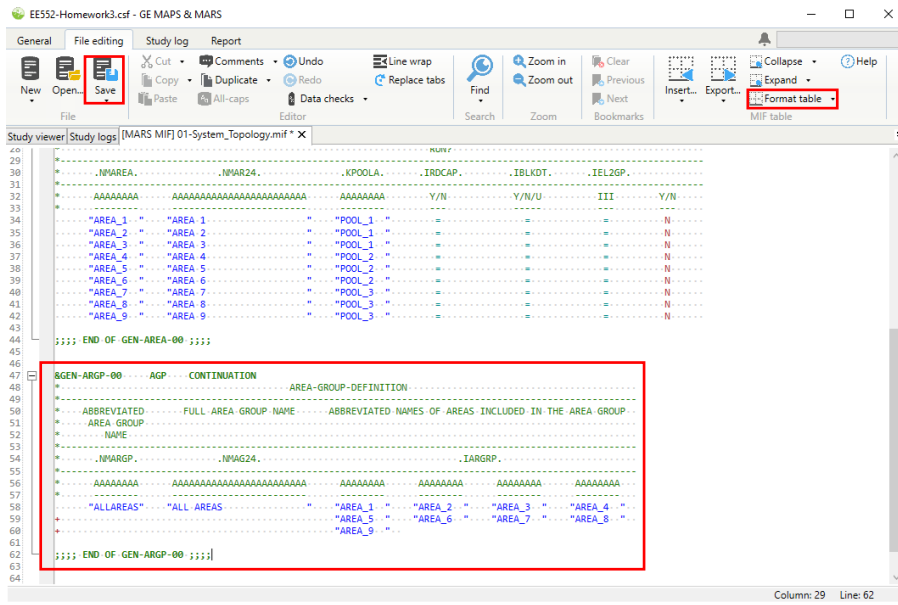
4. **Demand modeling:**

4.1. In the "General" ribbon – click on "Add new load file" on the "Hourly loads" tab of the Study viewer.

4.2. Add the file named "*2006LoadShapes.csv*".

4.3. In the "General" ribbon – click on "Add new MIF" on the "Master Input Files" tab of the Study viewer, as in step 2.1.

4.4. Create a new MIF in the database named "*02-Load_Forecast.mif*" and save it in your folder.
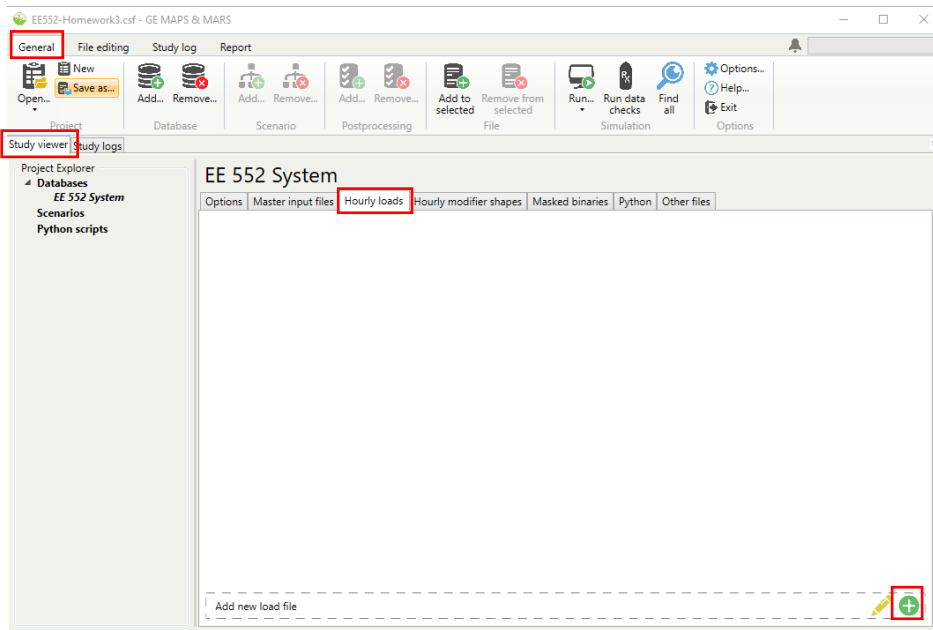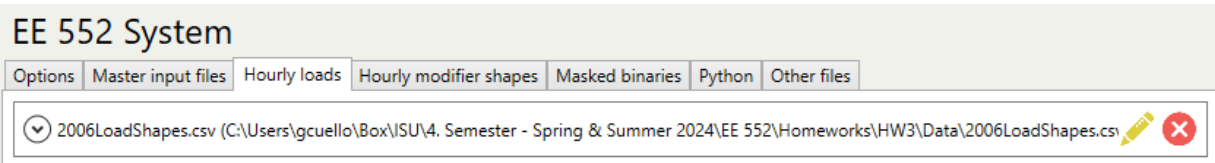
4.5. Click the edit icon on that file in the Study viewer, or double-click on the file.

4.6. Insert a table from a file by right-clicking anywhere in the editor and selecting "Insert" and "Insert table from file."

4.7. Open the "*02-Load_Forecast.xlsx*" file and search for LOD-DATA-01 in the table dropdown for the "Load Forecast" sheet.

4.8. Make sure the columns from the file are mapped to the appropriate fields for the table. If your file column names match the table fields, this mapping will be done automatically. Click OK. Save the file.
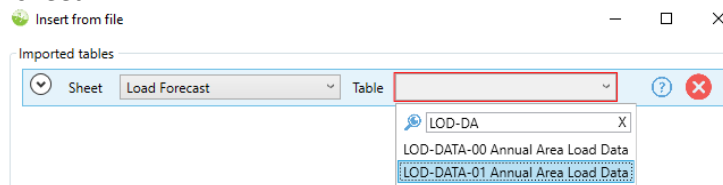
5. Thermal Units:

5.1. In the "General" ribbon – click on "Add new MIF" on the "Master Input Files" tab of the Study viewer, as in step 2.1.

5.2. Create a new MIF in the database named "*03-Thermal_Units.mif*" and save it in your folder.

5.3. Click the edit icon on that file in the Study viewer, or double-click on the file.

5.4. Insert a table from a file by right-clicking anywhere in the editor and selecting "Insert" and "Insert table from file."
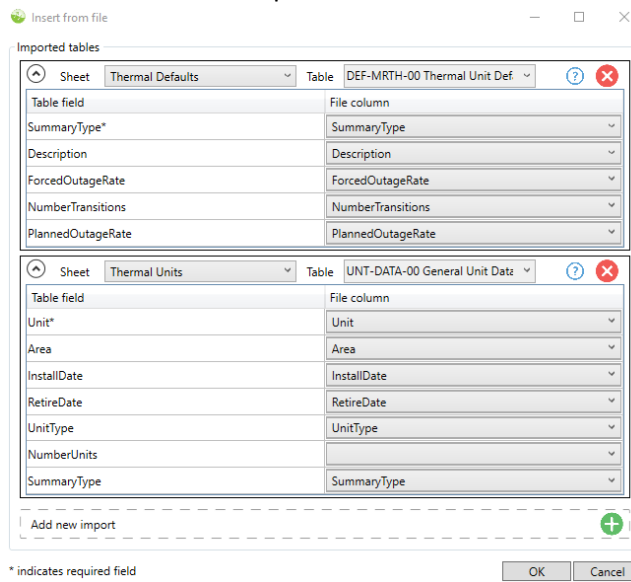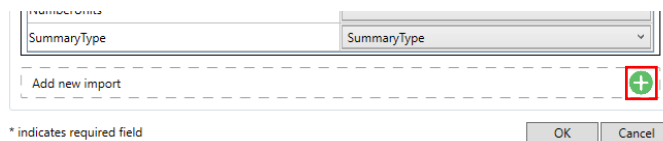
5.5. Open the "*03-Thermal_Units.xlsx*" file in the provided materials.

5.6. Search for DEF-MRTH-00 in the table dropdown for the "Thermal Defaults" sheet.

5.7. Search for UNT-DATA-00 in the table dropdown for the "Thermal Units" sheet.

5.8. Click on "Add a new import."

5.9. Select the "Thermal Units" sheet. Search for UNT-MXCP-00. Map the "Winter Capacity" column from the Excel sheet to the capacity field in the table. Click OK.
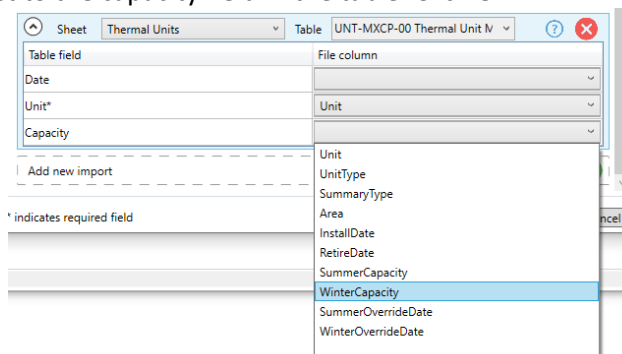
5.10.　　To specify the thermal unit capacity during summer and winter, with the cursor in the UNT-MXCP-00 table, right-click and select "Insert" and "Insert into current table." Open the *"03-Thermal_Units.xlsx"* file. Select the "Thermal Units" sheet and "insert rows into table at the end." Map the Date field to the "SummerOverrideDate" column and the Capacity field to the "SummerCapacity" column. Click OK.

5.11.　　Repeat step 5.10., mapping the Date field to the "WinterOverrideDate" column and the Capacity field to the "WinterCapacity" column. Save the file.

6. Transmission Interconnections:

6.1. In the "General" ribbon – click on "Add new MIF" on the "Master Input Files" tab of the Study viewer, as in step 2.1.

6.2. Create a new MIF in the database named "04-Transmission.mif" and save it in your folder.

6.3. Click the edit icon on that file in the Study viewer, or double-click on the file.

6.4. Insert a table from a file by right-clicking anywhere in the editor and selecting "Insert" and "Insert table from file".

6.5. Open the "*04-Transmission.xlsx*" file in the provided materials.

6.6. Search for INF-DATA-00 in the table dropdown for the "Transmission Interfaces" sheet.

6.7. Search for INF-TRLM-00 in the table dropdown for the "Transmission Limits" sheet.
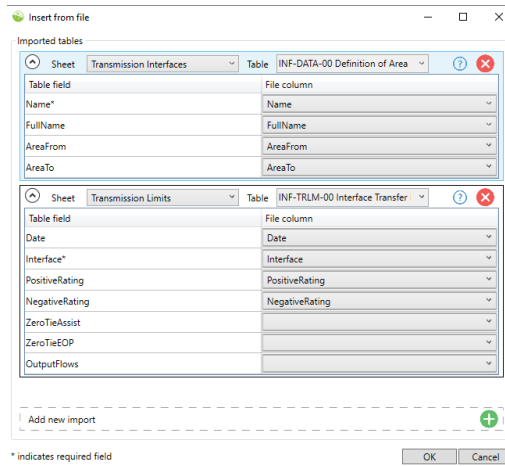
6.8. Click OK and save the file.

7. **Run Simulation:**

7.1. In the "General" ribbon, click on "Run."
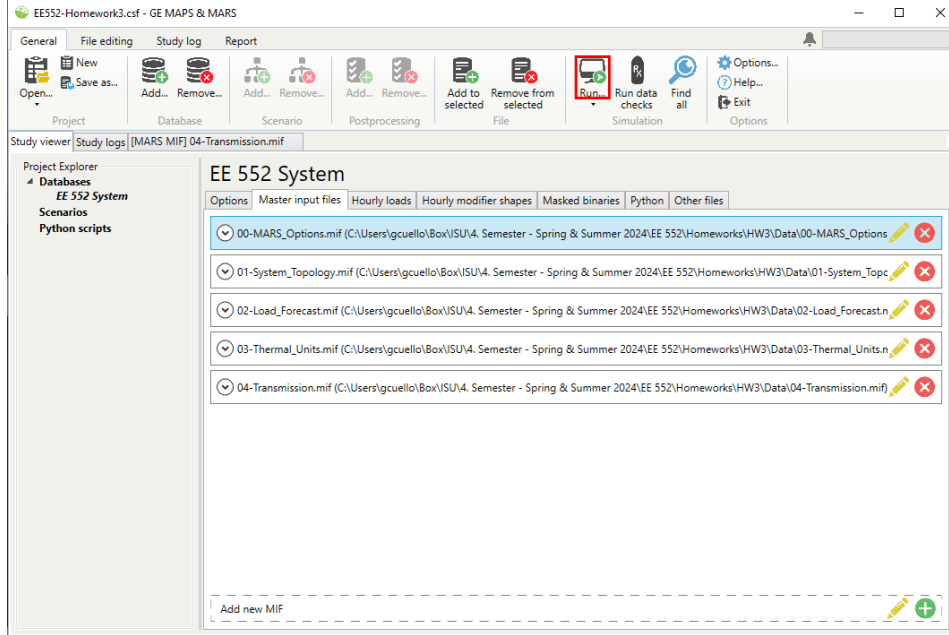
7.2. The run dialog will open with a variety of run configuration options. Select only the year 2024. Click on "Run".
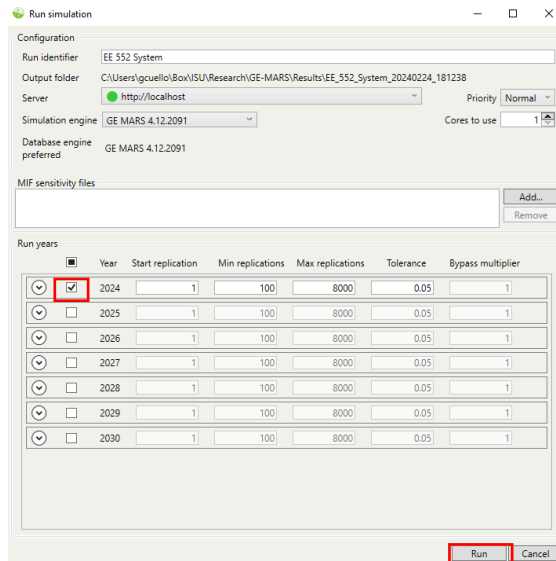
8. Results Review:

8.1. Check the "study log" tab to see that the run is actually running. Selecting the job shows more details.
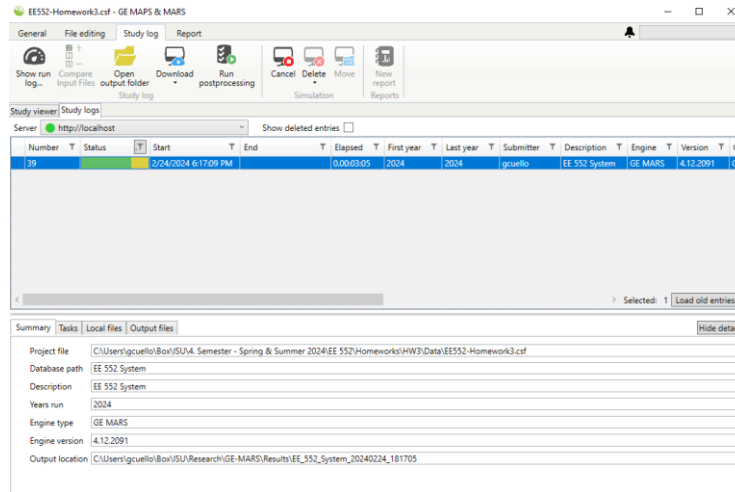
8.2. You can view the progress of each task in the job by selecting the "tasks" subtab.
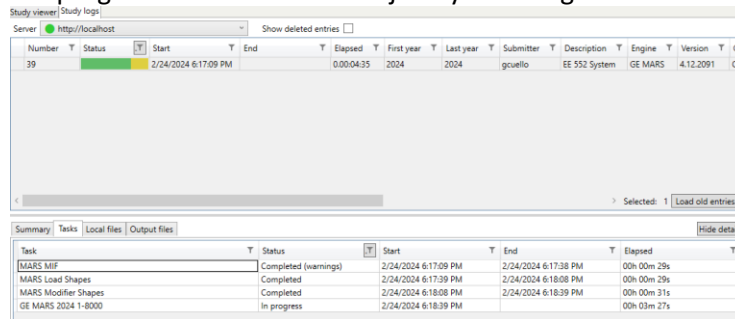
8.3. Once the simulation is complete, select the job and click on "Open output folder" in the "Study log" ribbon.
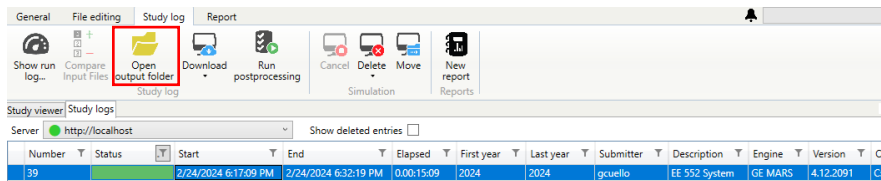
8.4. In the folder named "2024", you will find all output files described in the table below. You can open these files in a text editor.

File	Description
mars-2024.ot06	• Program dimension summary • List of errors and warnings
mars-2024.ot07	• Monthly load model statistics by area, pool, and area group • Weekly maintenance summaries by unit • Maintenance start and end dates and types listed for each unit • Weekly reserve summaries by area, pool, and system • Thermal capacity, capacity state, planned and forced outages • Interface ratings and capacity states
mars-2024.ot08	• Weekly and monthly reliability indices
mars-2024.ot09	Annual output summaries showing the following reliability indices by area, pool, and area group: • Daily LOLE (days/year) • Hourly LOLE (hours/year) • LOEE (MWh/year) • Frequency (outages/year) • Duration (hours/outage) Annual summaries of Interface flows.

Notice that file "mars-2024.ot09" contains the annual reliability indices, which are essential for this study. Please ensure to give special attention to this file throughout the analysis.

Note: Since the output files were saved in the "C:\\Temp" folder, move these to a non-volatile location. For instance, create a folder in "U:\" called "GE-MARS Results" and save them for security.

D. Answer the following questions:

- Question 1: Complete the table below using data from the year 2024 provided in the *"03-Thermal_Units.xlsx"* and the *"02-Load_Forecast.xlsx"* file.

Pool	Area	Annual Peak Load (MW)	Summer Capacity (MW)	Reserve (%)
Pool 1	Area 1			
	Area 2			
	Area 3			
Pool 2	Area 4			
	Area 5			
	Area 6			
Pool 3	Area 7			
	Area 8			
	Area 9			
Total				

- Question 2: After finishing the simulation processes in Section C, complete the table below using the output file "*mars-2024.ot09*".

Calculated Indices For 2024								
	Isolated				Interconnected			
Area or Pool	LOLE (days/yr)	LOEE (MWh/yr)	Frequency (outg/yr)	Duration (hrs/outg)	LOLE (days/yr)	LOEE (MWh/yr)	Frequency (outg/yr)	Duration (hrs/outg)
Area_1								
Area_2								
Area_3								
Area_4								
Area_5								
Area_6								
Area_7								
Area_8								
Area_9								
Pool_1								
Pool_2								
Pool_3								
AllAreas								

- Question 3: Is there a relationship between reserve (%) and isolated LOLE of each area, based on the information provided in Questions 1 and 2? If no relationship exists, please explain why.

- Question 4: To ensure sufficient resources to guarantee a continuous electricity supply, ISO/RTOs conduct annual LOLE studies to determine a planning reserve margin (% percentage of installed capacity available above the system coincident peak) that would result in a system experiencing less than one-day loss of load event every ten years (0.1 days/yr). Reviewing the table below, you should realize that the system (ALLAREAS) interconnected LOLE is greater than 0.1 days/yr. Your assignment is to determine a minimum system-wide planning reserve margin (PRM) required to meet an interconnected system LOLE of 0.1 days/yr. To proceed, adjust the system's generation, considering the following:

- Generation allocation: Initial results indicate variations in reliability among different areas in an isolated scenario. These areas could serve as suitable locations for allocating new generation.
- Unit Type: Once the allocation is decided, choose the appropriate unit type based on the data provided in the "Thermal Defaults" sheet of the "*03-Thermal_Units.xlsx*" file.
- Number of units and capacity: Note that the number of units and their capacities can significantly impact results. For instance, installing one X-type unit with a capacity of 200 MW differs from installing four X-type units with capacities of 50 MW each.

The steps for adjusting the generation and verifying the LOLE are as follows:

Step 1) Adjusting Generation:

You have two options for this:

Option A:
- Navigate to the "Master input files" tab.
- Click the edit icon on the "03-Thermal_Units.mif" file.
- Add the new generation units in the UNT-DATA-00 (General Unit Data) table.

Option B:
- Open the "Thermal Units" sheet in the "*03-Thermal_Units.xlsx*" file.
- Add the new generation units.
- Return to the "Master input files" tab.
- Click the edit icon on the "03-Thermal_Units.mif" file or double-click on the file.
- Right-click anywhere, select all and delete.
- Enter the new data in your modified generation file, following steps 5.4 to 5.11 of the simulation process outlined in Section C.

Note: The name of the new generating units should not exceed eight characters. As the installation date, enter 01/01/2024, and depending on the unit type you have selected, assume a retirement date.

Step 2) Rerun the Simulation:

Follow steps 8.1 to 8.4 of the simulation process in Section C.

Step 3) Verify the System Interconnected LOLE:
- If the LOLE is between 0.08 and 0.1 days/yr, the adjustment is sufficient, and you can stop.
- If the LOLE is not within this range, return to Step 1 and repeat the process.

You should develop a report containing the following information:

1. An "Executive Summary" briefly (1 paragraph) describing the study's objectives and significant conclusions.

2. An "Introduction" describing the problem, the objective of the study, and the report's structure.

3. A "Methodology" section describing the approach taken and the tool used.

4. A "Results" section, which provides an overview of the generation added (location, unit type, and capacity) to meet a LOLE of 0.1 days/yr. This section should include tables, as in questions 2 and 3, showing new values of the modified power system to meet the resource adequacy goal.

5. A "Conclusions" section that identifies the significant conclusions concerning the study's objective, including the required system's PRM and comments on any other observations made related to additional actions that can take place to improve the system's adequacy.