Design and Assessment of water-energy-food-environment Mega-Systems

Power System Modelling Interface – Step-by-step guide for introductory use

Synopsis:

This document provides step-by step instructions to access and use FutureDAMS power system modelling interface. The document first provides guidance on accessing the online interface (e.g., registering and logging to hydra.org.uk), and accessing or creating network models. A detailed description of the different functionalities offered by the interface for network modelling, inputting data and collecting outputs is then provided. Finally, selected examples are presented to demonstrate the core functionalities of the interface (and future functionalities under development), which include DC optimal power flow, AC power flow, linear estimation of technical and non-technical losses, and other features. The functionalities are demonstrated on power networks of different sizes, including illustrative examples, test networks, energy islands, interconnected systems and real networks.

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1.Accessing the online tool

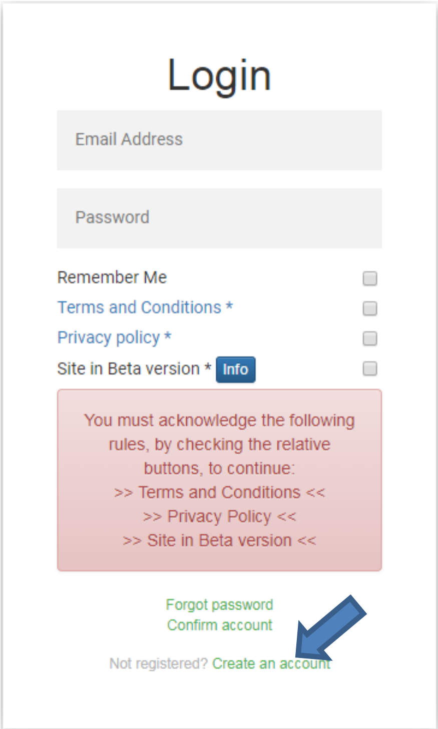
This section provides detailed instructions for accessing the online interface, as well as to navigate the dashboard and load or create examples.

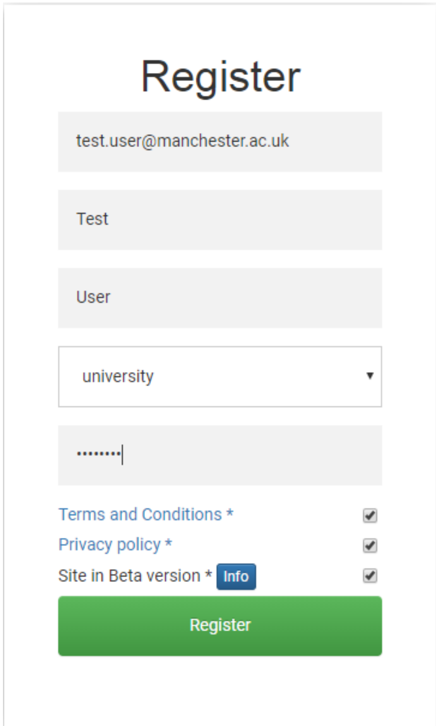
1.1.Logging to your account

To access the online tool, select your preferred browser considering that Firefox (best option) and Chrome offer the best experiences. The following link can be used to access the online tool:

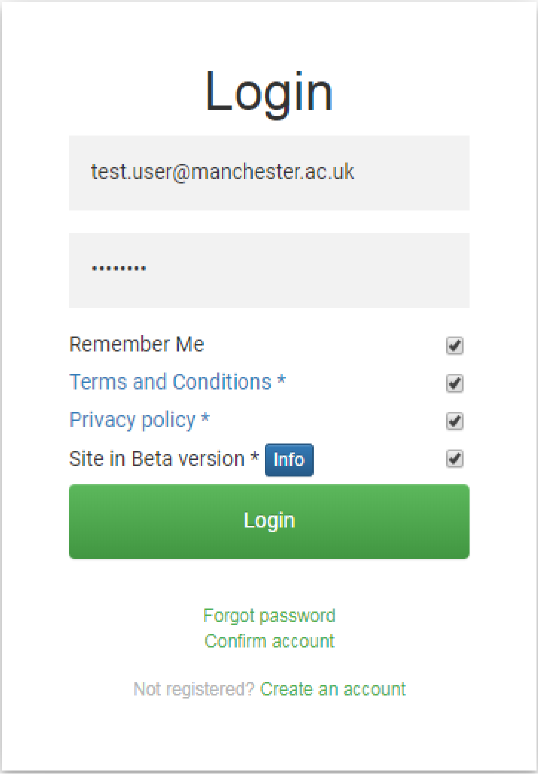
https://hydra.org.uk/login

To create a new account (e.g., for users who do not already have an account), select "Create an account" and provide the relevant information:

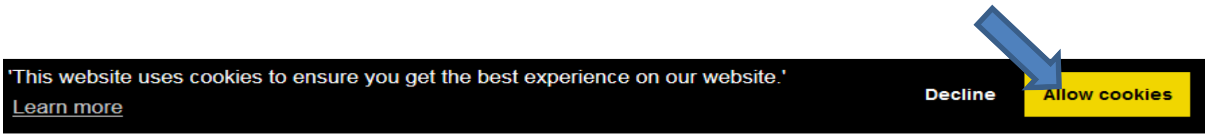




Users who already have an account (or have just created it using the instructions above) can access the modelling interface dashboard after providing the relevant email address and password, and selecting "Login":



The website may ask for cookies to be accepted; cookies must be allowed for users to access the dashboard.



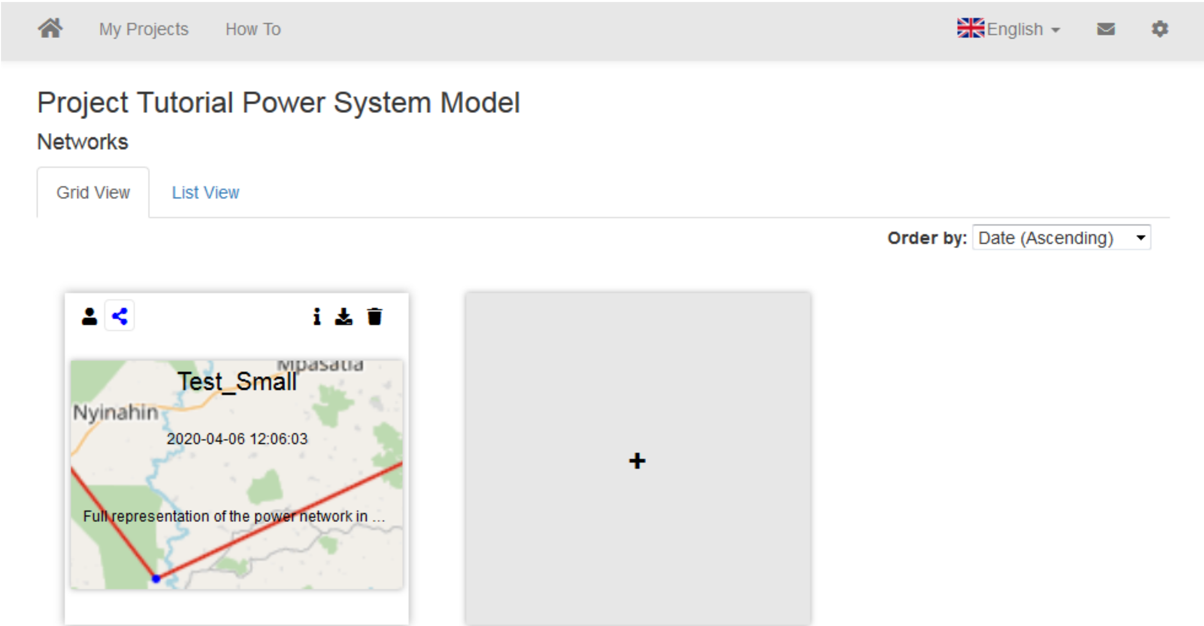
1.2.Accessing and sharing examples

There are different options to access a network model, which include contacting the network owner and providing your user name (i.e., email used to login in https://hydra.org.uk/login) or importin the network data from a json file (see Section 3.1 example on “Building a Network”). If you are participating in a tutorial and provided your email address, the models should appear in your dashboard, and you should have access to the json files.

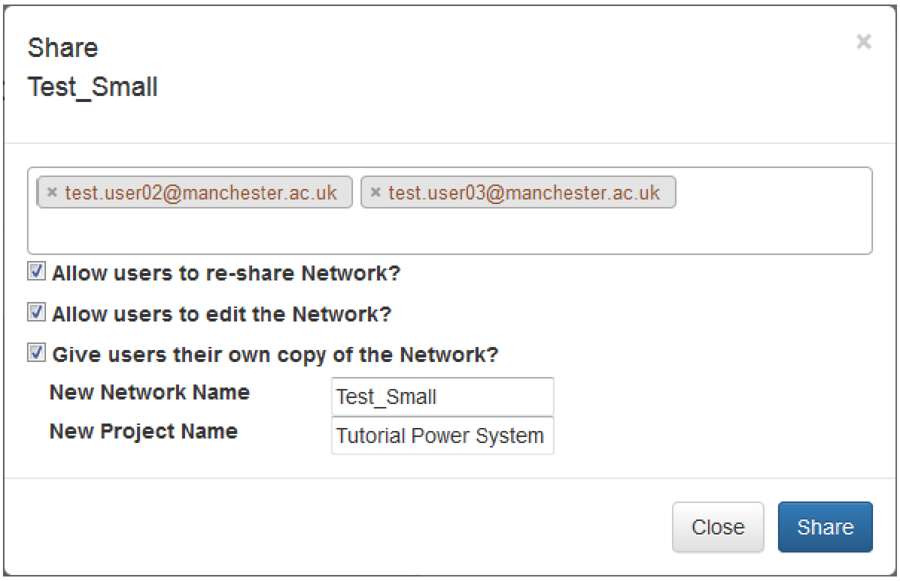
Once the network model is accessible from the dashboard, you may be granted specific rights over the model such as:

1. Right to share the network model and provide different access rights to the users you share the network model with.
2. Having a personal copy of the model which is independent (and not accessible) to other users, unless you share the model with them.
3. Right to edit the network model.

To share a network model with one or more users, the share option ( ) has to be selected.

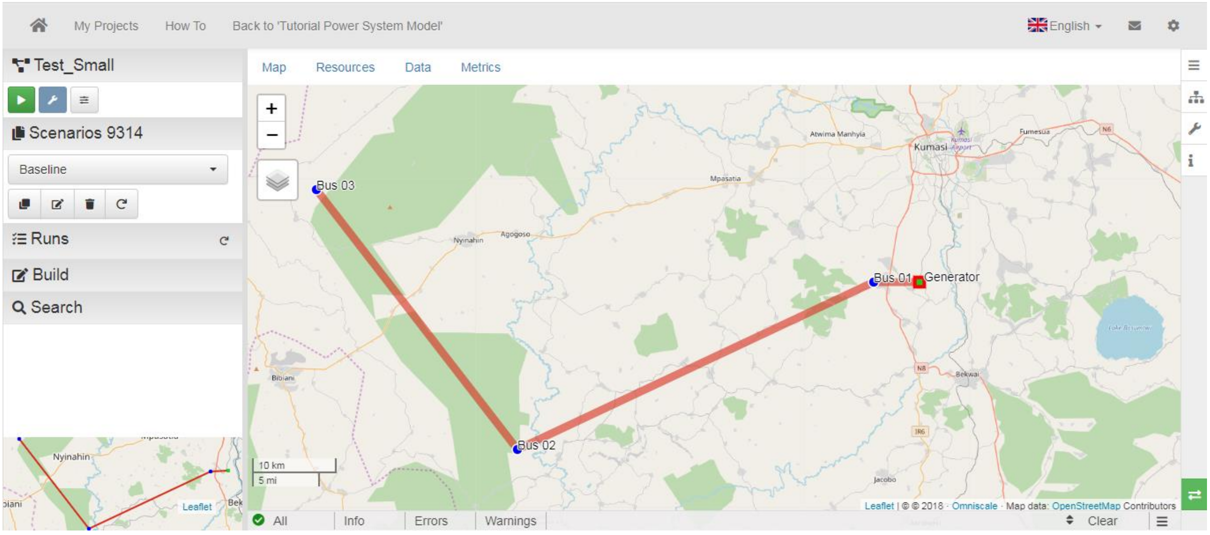


A new menu will open. Populate it by providing the accounts (emails) of the users who will have access to the network and their right over the network models.



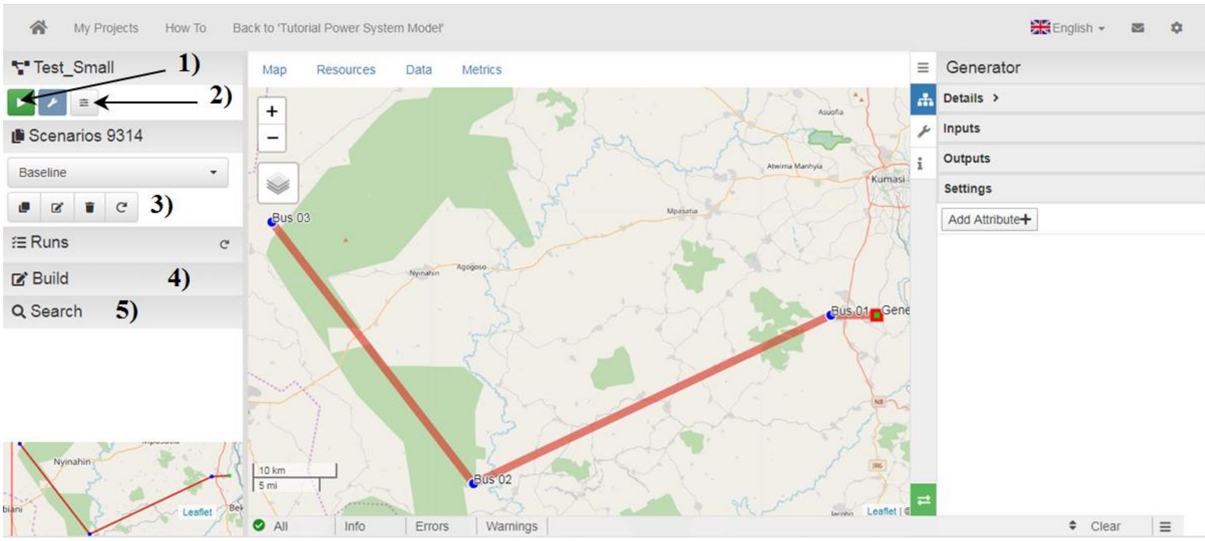
2.The modelling interface

Once an example is loaded (load "Test_Small" to follow the examples), the interface will present a series of menus used to customise the network model and input data. An example of the interface based on the "Test_Small" example is presented below.



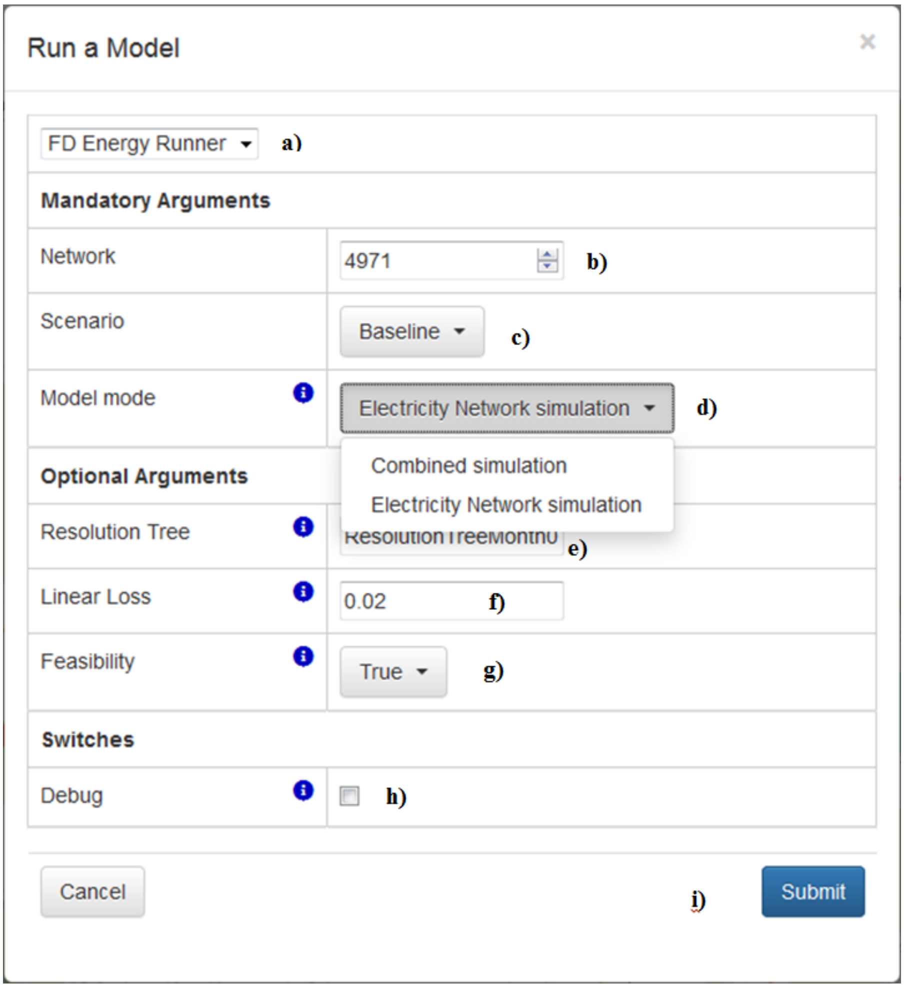
The mouse can be used to move the map, and to scroll up or down to zoom in or out, respectively. Hold the "Ctrl" key to drag and drop elements, such as generators (shown as green squares) and buses (shown as blue circles). The interface provides several menus for the use of different functionalities, such as:

1. Running the model
2. Accessing system level data
3. Creating scenarios
4. Building a network model by adding components
5. Searching for specific components and checking the list of components



2.1.Running a model

Selecting the option to run the model () opens a sub-menu that provides additional simulation settings which are depicted in the figure below



a) Engine: This will be the tool used to simulate the model. The default selection is the linear energy model ("FD Energy Runner").

b) Network: Number assigned to the power network model in the interface.
c) Scenario: Set of network characteristics and profiles considered for the study.
d) Model mode: These are the different types of studies offered by the engine. Currently, two modes are available, namely (i) "Electricity network simulation" that provides a snapshot simulation of the network conditions during a single period (this option is currently disabled) and (ii) "Combined simulation", which provides a time series analysis with a horizon and time resolution defined by the resolution tree (by default two representative days modelled with an hourly resolution).
e) Resolution tree: This is an input file (json format) which provides a definition of a time series for "Combined Simulations". By default, the "ResolutionTreeMonth01.json" file is used, which provides the assumptions to estimate the monthly performance of the power system based

on two representative days (weekday and weekend), each modelled with an hourly resolution.

f) Linear Loss: This is an optional argument currently used to calculate the power system's losses as a percentage of the total system's demand (e.g., 0.02 corresponds to 2%).

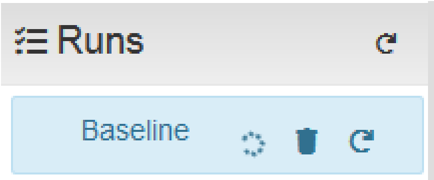
g) Feasibility: This is an optional argument to enable consideration of demand and generation curtailment. This option increases computational costs in large network models, but it can be required for the solution of the model to be feasible in some cases. Therefore this option is set to True (i.e., enabled) by default.

h) Debug: This is a switch used to enable additional model outputs used for development (e.g., debugging) purposes.

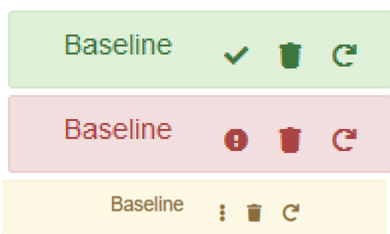
i) Submit (or cancel): Press button for submitting (or cancelling) a simulation.

It is important to note that the menus are customisable, and particularly the modes and optional arguments will be fine-tuned in consideration of the feedback provided by users.

Once a simulation is submitted, its progress will appear under the "Runs" tab.

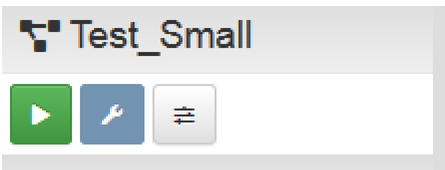


The simulation appears in blue while it is being performed and it turns green when it is successful or red if it fails (e.g., the network was not properly set up). A Yellow bar means the execution command is in the queue; refresh the page to restore the simulation.

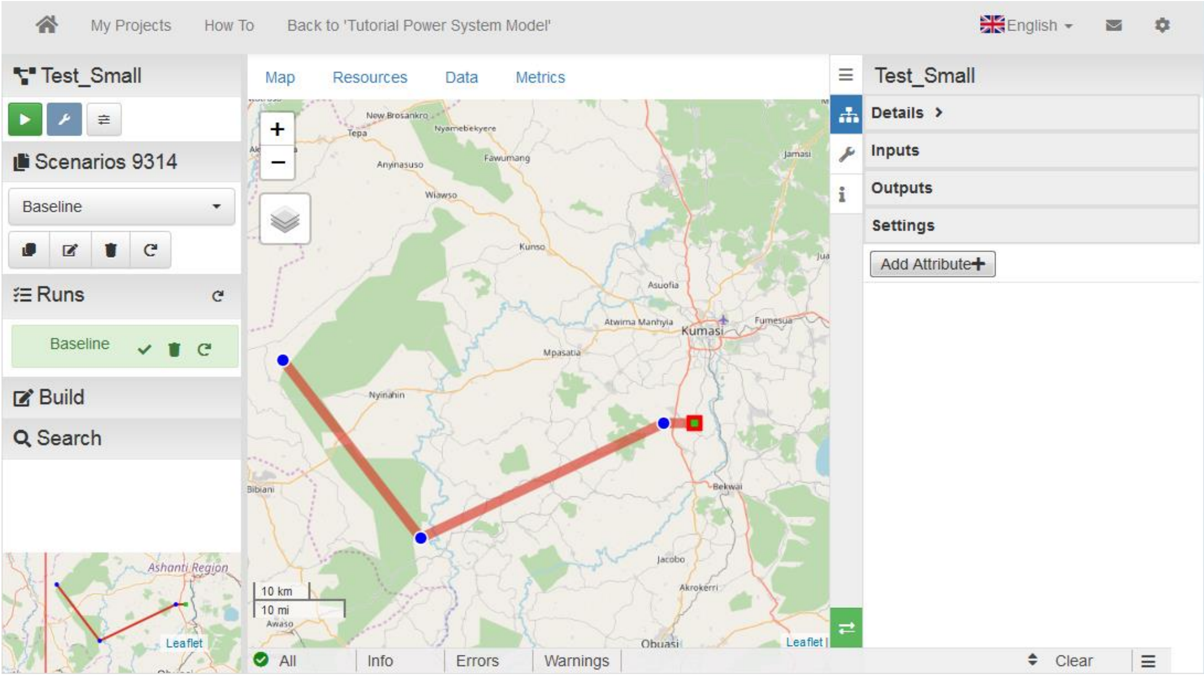


2.2.System level data

The system level data, including results from a successful network simulation, can be accessed with the  button on the top left side of the screen.

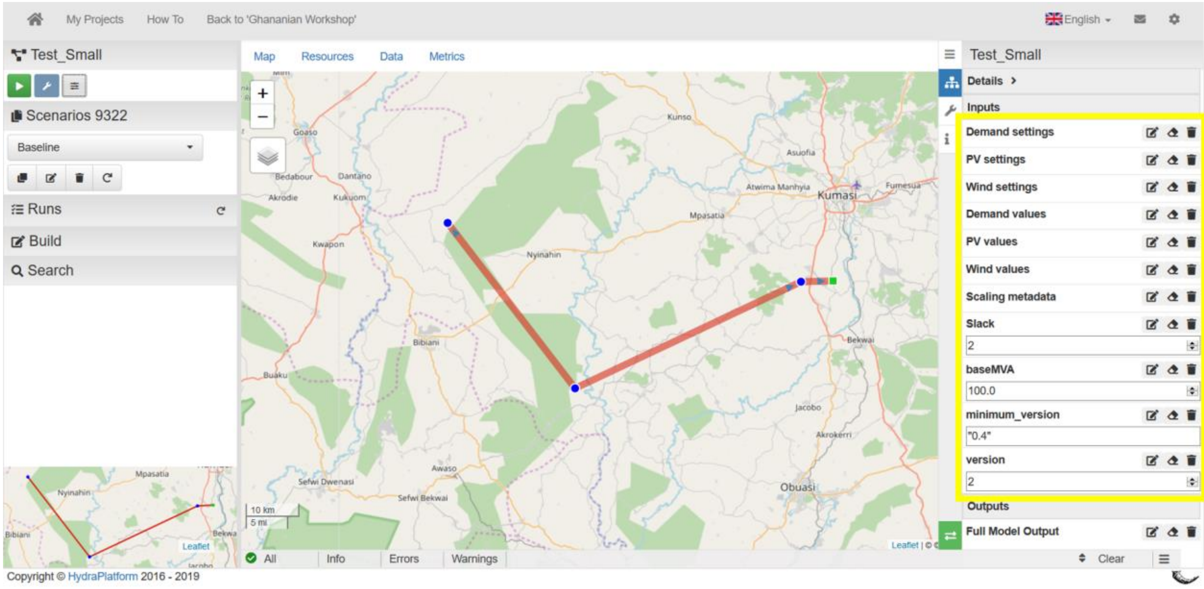


The system level inputs and outputs will appear on the right side of the screen:

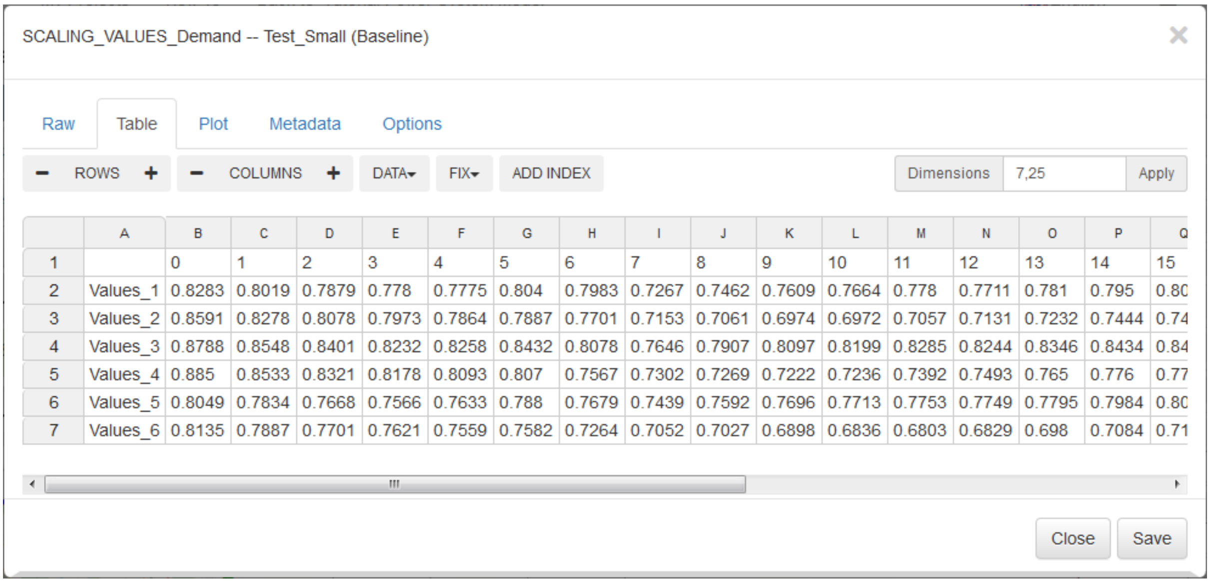


The system level data that is currently considered by the model includes:

1. Demand settings: These are the names of the different demand profiles on file, which include Winter weekday (i.e., “Values_1”), Winter weekend (i.e., “Values_2”), Shoulder weekday (i.e., “Values_3”), Shoulder weekend (i.e., “Values_4”), Summer Weekday (i.e., “Values_5”) and Summer Weekend (i.e., “Values_6”).
2. PV settings: These are the names of the different PV profiles on file, which include Winter, Shoulder and Summer.
3. Wind settings: These are the names of the different wind profiles on file, which include Winter and Summer.
4. Demand values: These are the time series corresponding to the different demand profiles.
5. PV values: These are the time series corresponding to the different PV profiles.
6. Wind values: These are the time series corresponding to the different wind profiles.
7. Scaling metadata: These are multipliers that can be used to scale up/down the different profiles.
8. Slack bus: Slack bus used for power flow calculations.
9. Base MVA: Base MVA values used for pu calculations
10. Minimum version: Minimum version of the energy engine that can be used.
11. Version: Current version of the energy engine being used.

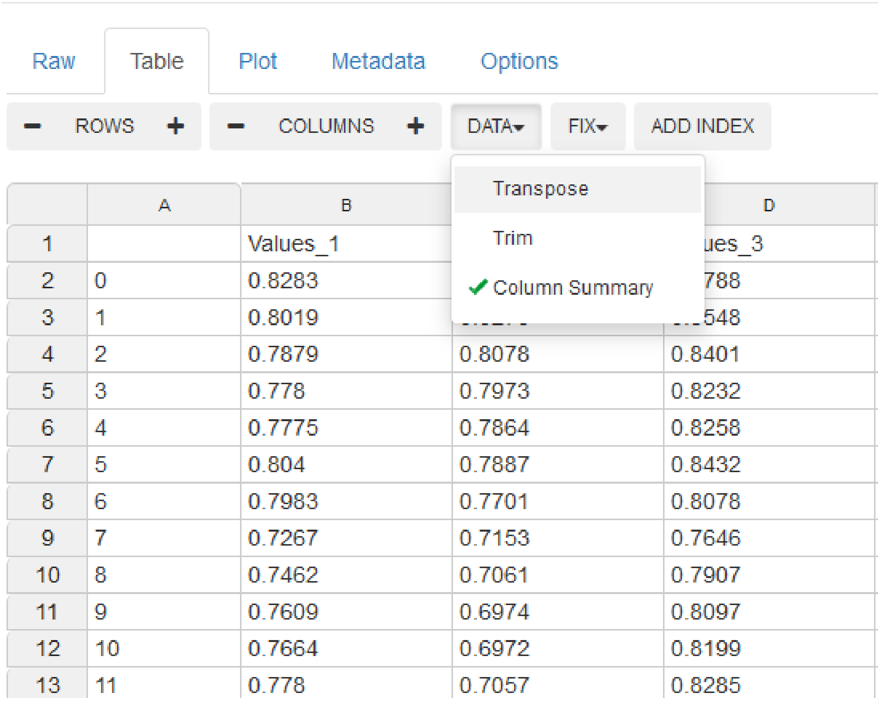


The information can be accessed, and edited with the option. An example of the "Demand values" is presented below.

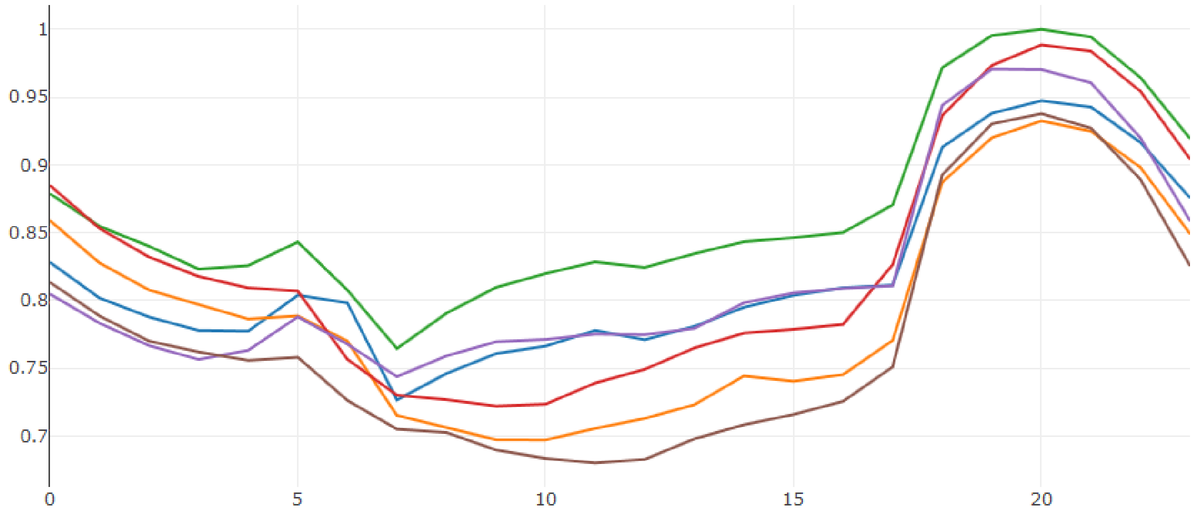


	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
1		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
2	Values_1	0.8283	0.8019	0.7879	0.778	0.7775	0.804	0.7983	0.7267	0.7462	0.7609	0.7664	0.778	0.7711	0.781	0.795	0.80
3	Values_2	0.8591	0.8278	0.8078	0.7973	0.7864	0.7887	0.7701	0.7153	0.7061	0.6974	0.6972	0.7057	0.7131	0.7232	0.7444	0.74
4	Values_3	0.8788	0.8548	0.8401	0.8232	0.8258	0.8432	0.8078	0.7646	0.7907	0.8097	0.8199	0.8285	0.8244	0.8346	0.8434	0.84
5	Values_4	0.885	0.8533	0.8321	0.8178	0.8093	0.807	0.7567	0.7302	0.7269	0.7222	0.7236	0.7392	0.7493	0.765	0.776	0.77
6	Values_5	0.8049	0.7834	0.7668	0.7566	0.7633	0.788	0.7679	0.7439	0.7592	0.7696	0.7713	0.7753	0.7749	0.7795	0.7984	0.80
7	Values_6	0.8135	0.7887	0.7701	0.7621	0.7559	0.7582	0.7264	0.7052	0.7027	0.6898	0.6836	0.6803	0.6829	0.698	0.7084	0.71

The results can also be plotted per column. In this case it is convenient to transpose the data by selecting the "Table" tab, "Data" and option to "Transpose" so that every column has a 24h profile (other time resolutions can also be used).

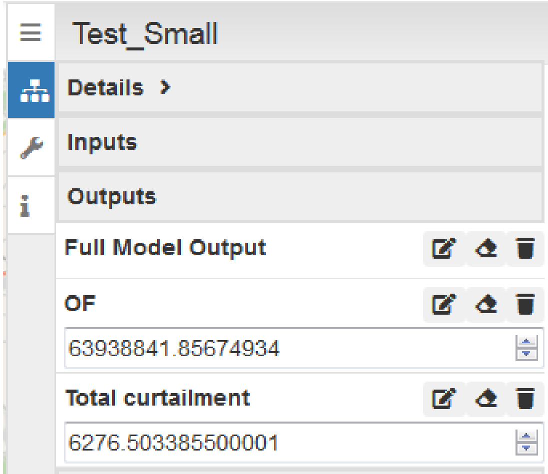


	A	B		D
1		Values_1		ues_3
2	0	0.8283		788
3	1	0.8019		548
4	2	0.7879	0.8078	0.8401
5	3	0.778	0.7973	0.8232
6	4	0.7775	0.7864	0.8258
7	5	0.804	0.7887	0.8432
8	6	0.7983	0.7701	0.8078
9	7	0.7267	0.7153	0.7646
10	8	0.7462	0.7061	0.7907
11	9	0.7609	0.6974	0.8097
12	10	0.7664	0.6972	0.8199
13	11	0.778	0.7057	0.8285



The interface also provides system level outputs, which include:

1. Full Model Output: Raw outputs including time series for the operation of each generator (e.g., generation and commitment), line (e.g., losses and flows) and buses (e.g., curtailment and voltage).
2. OF: Objective function which, by default, provides the monthly electricity costs.
3. Curtailment: By default this is the monthly load shedding.

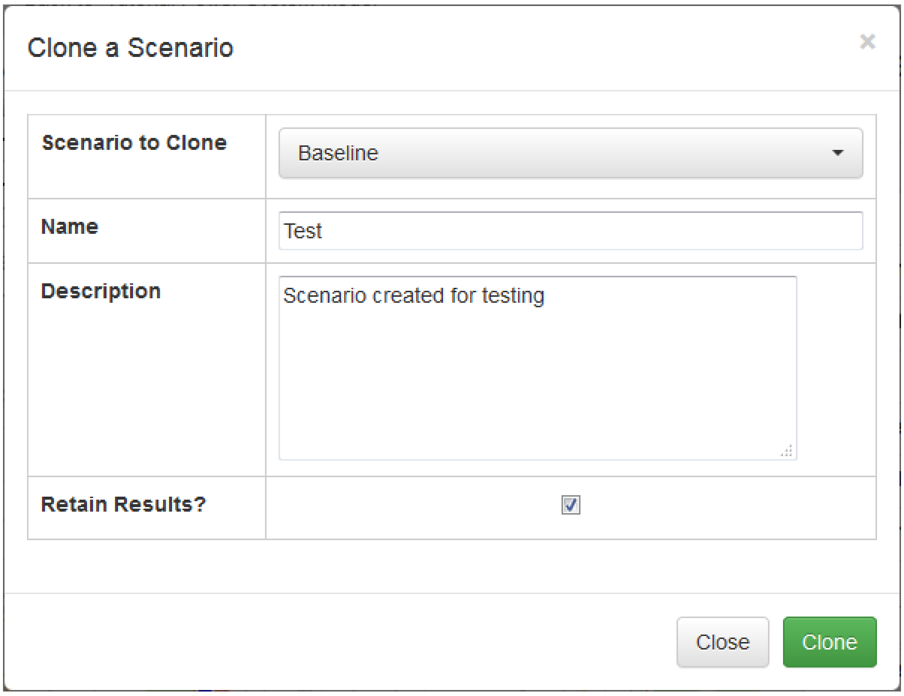


2.3.Scenarios

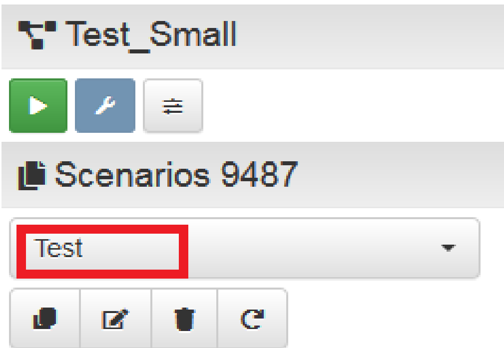
This functionality facilitates the comparison of multiple network studies within a single test network model. The various studies, which can be based on different network conditions (e.g., different demand profiles, line capacities, non-technical losses, etc.) are called scenarios.

To create a new scenario, a study must first be performed (using ). Once the study is successfully performed (green run), the settings and results of the study can be cloned into a scenario by pressing the  button. The example below clones the results from the "Baseline".

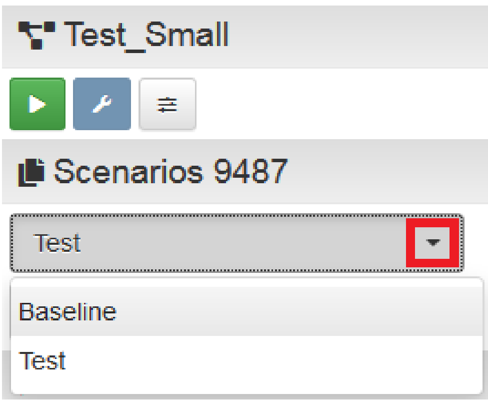
This will open the scenario submenu, where the new scenario can be given a name and description.

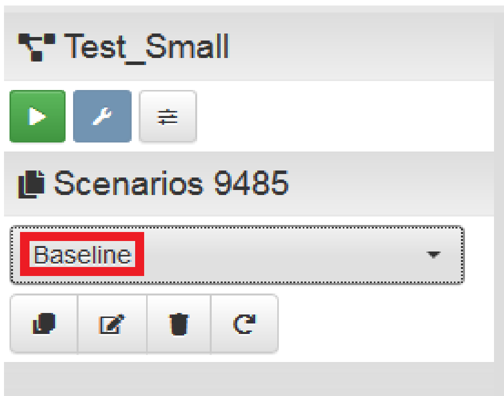


Once a scenario is created, the interface will automatically switch to the new scenario.



This allows the user to continue editing the settings of the new scenario with the caveat that any further changes will be ignored when performing a new study (pressing ). This is because the current version of the interface only uses the "Baseline" for the studies. Accordingly, it is generally recommended to manually switch back to the "Baseline" scenario.

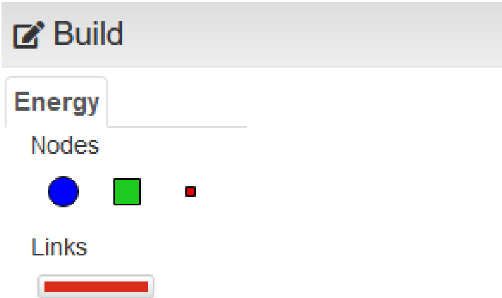




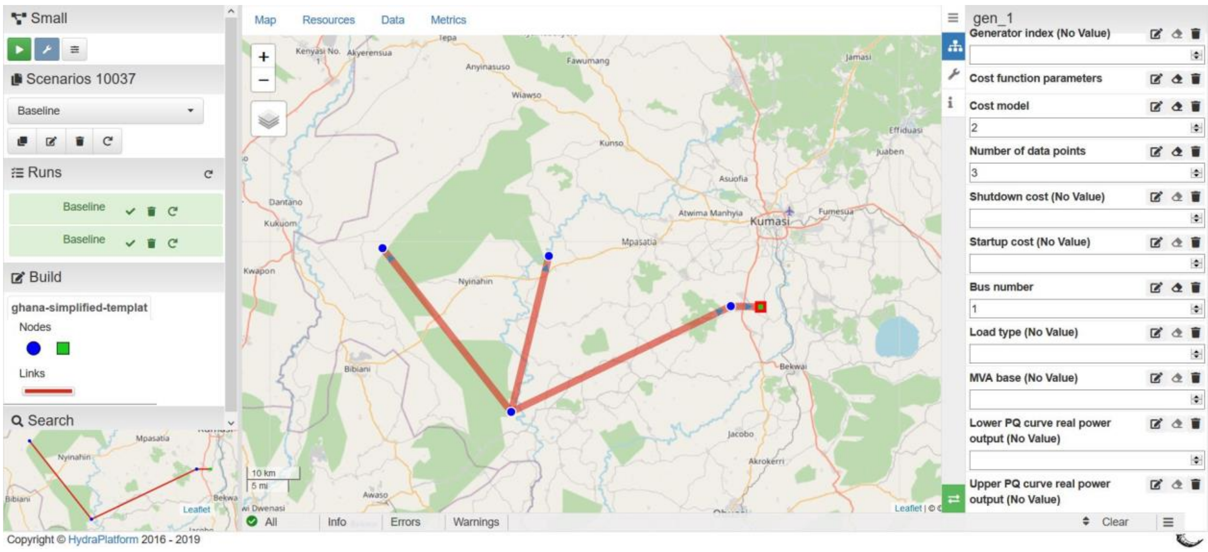
See Section 3 (Examples) below for detailed applications of this feature.

2.4. Build - Adding components

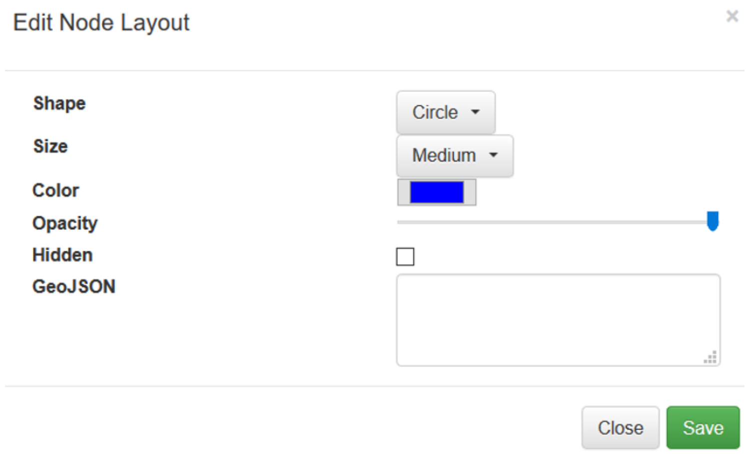
The interface provides options to introduce new components to the networks, namely buses, generators and links. Additional elements, including specialised variations of the aforementioned components can be added upon request.



The buses and generators can be dragged from the "Nodes" category within the "Build" menu to the map. The links can be added by clicking on "Links" to enable the "link mode", and then click on two elements (buses or generators) sequentially to link them. Once in the map, the elements can be moved by holding the "Ctrl" key and dragging them with the mouse. To edit the settings of each element, double click on that element or, alternatively, right click on the element and select "Edit Data". This will open the menu of the elements where the relevant inputs can be edited and the outputs can be reviewed.



In some cases, it may be useful to change the appearance of some of the components (e.g., to highlight a particularly important generator). To achieve this, right click on a "Node" or a "Link", and choose "Edit Layout", a window will pop up to allow you to modify the layout of the elements. Click "Save" to save the changes.



The main inputs that will be used in the examples below include:

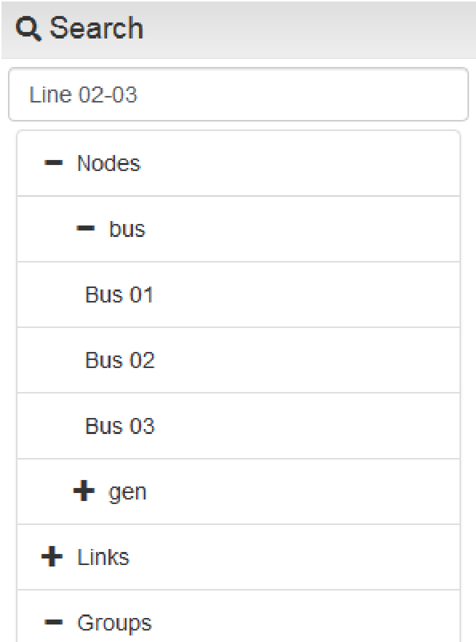
1. Buses:
    a. Bus number.
    b. Active power demand (MW).
2. Lines:
    a. Reactance (pu): Line reactance.
    b. Source bus: Bus connected at one edge (to) of the line.
    c. Destination bus: Bus connected at one edge (from) of the line.
    d. Long term rating (MVA): MVA rating of the line.
3. Generators:
    a. Bus number: Bus connected to the generator.
    b. Cost model: Option to select a piecewise (1) or a polynomial (2) generation cost curve.
    c. Number of data points: Number of components of the piecewise or polynomial approximation.
    d. Cost function parameters: Components of piecewise or polynomial function.
    e. Maximum real power output (MW): Generation capacity.

After a successful (green) run, the outputs would automatically be added to the menu under the inputs. Currently, only the following results are outputted by the interface:

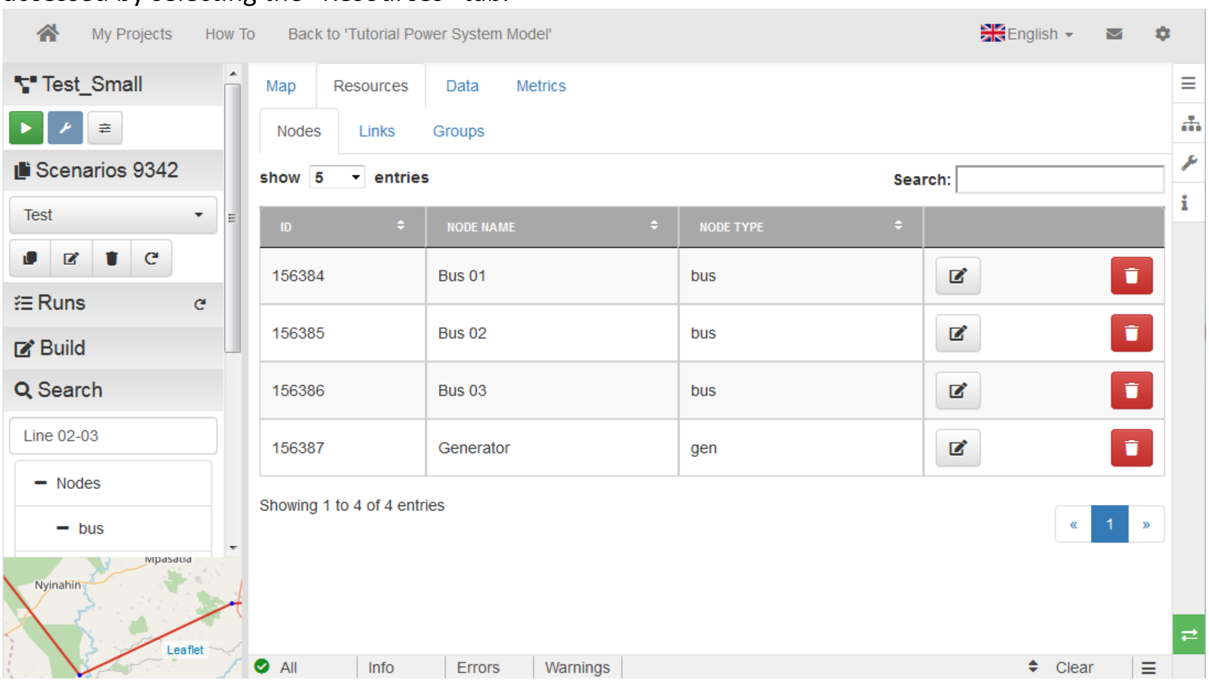
1. Bus:
    a. Voltage_Angle (radians): Voltage angle time series.
2. Line:
    a. Active power losses (MW): Power losses time series.
    b. Active power flow from source bus (MW): Power flow time series; the sign dictates the direction of the flow.
3. Generators:
    a. Status on-off (binary): Time series with the status of the generators (0:off 1:on).
    b. Active power output (MW): Power output.

2.5.Search

Locating specific network elements can become time-consuming as the size of the network and number of components increases. The search menu provides more accessible options to locate the components by presenting them in a list.



Alternatively, the list of elements, including options to edit ( ) or delete ( ) them can be accessed by selecting the "Resources" tab.



3.Examples

This section highlights some of the key functionalities of the energy model and interface, which are illustrated with several examples. The examples include:

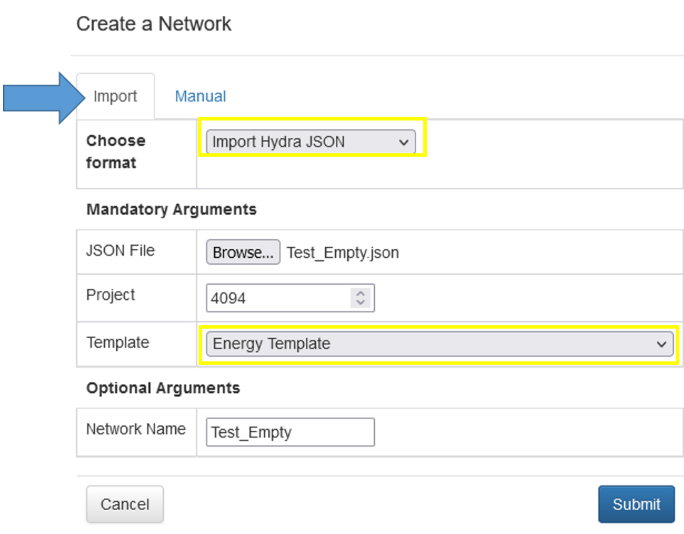
1. Building a network: Basic functionalities to build a network model and run it.
2. Editing a network: Opening an existing model, adding elements and running it.
3. Technical characteristics: Using different scenarios to explore the impacts of different network settings, including line capacity, demand profiles, and non-technical losses.
4. Energy islands: Analysis of a system comprising independent energy islands.

3.1. Building a network

This example provides step-by-step guidance to build a 3 bus network model by defining, using the interface, one generator and three nodes, and connecting them with two lines. The example also provides the instructions to run a time-series study, i.e., considering two representative days with hourly resolution. If some steps seem unclear, please revise Section 2 on “The modelling interface”.

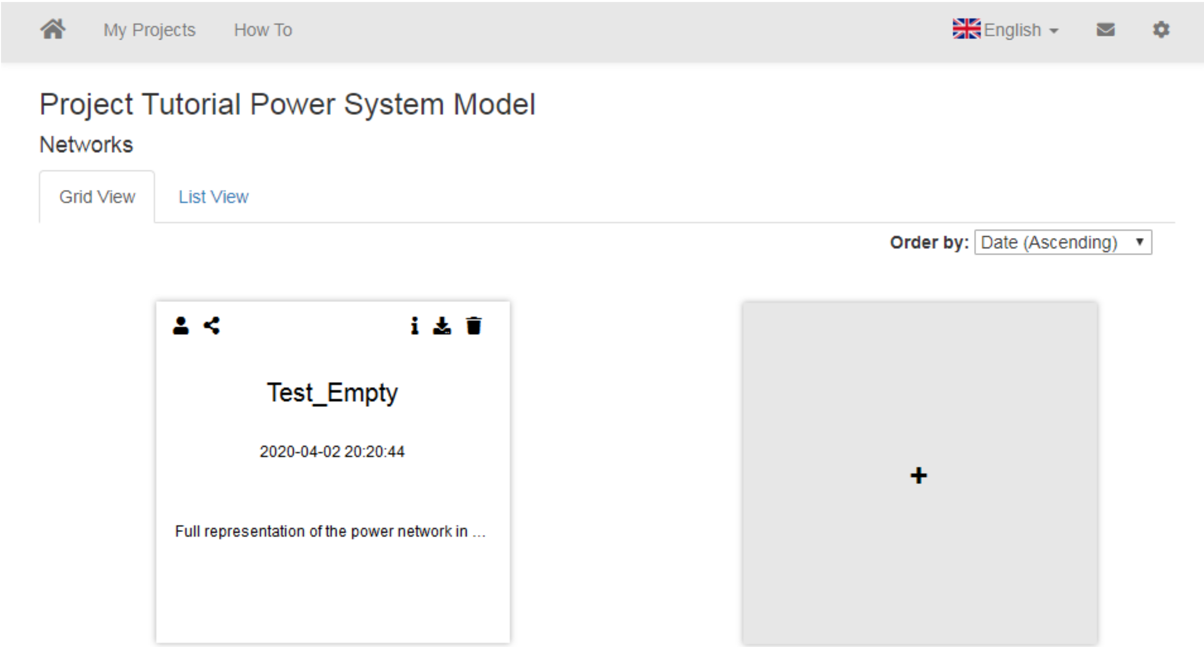
Access the modelling dashboard by login in https://hydra.org.uk/login. The “Test_Empty” network model may appear in the dashboard if the example has been shared with your account. Alternatively, if you have downloaded the relevant json file (Test_Empty.json), use the dashboard to create the example by selecting the “Create a Network Option” (i.e., large grey square with + symbol). This will open the “Create a Network” menu. This window provides the options to manually create the network or import it. Manually creating a network from scratch currently requires a large number of steps and will not be addressed in this tutorial. Instead, the basic network template, without components will be imported. So click the “Import” tap. Choose format “Import Hydra JSON” and Template “Energy Template”.

Assign a name to the network (e.g., Test_Empty) and load the json file “Test_Empty.json” from a specific location where the files were saved in your computer by clicking “Choose file”. The test comes loaded with hourly demand profiles for two representative days (weekday and weekend).

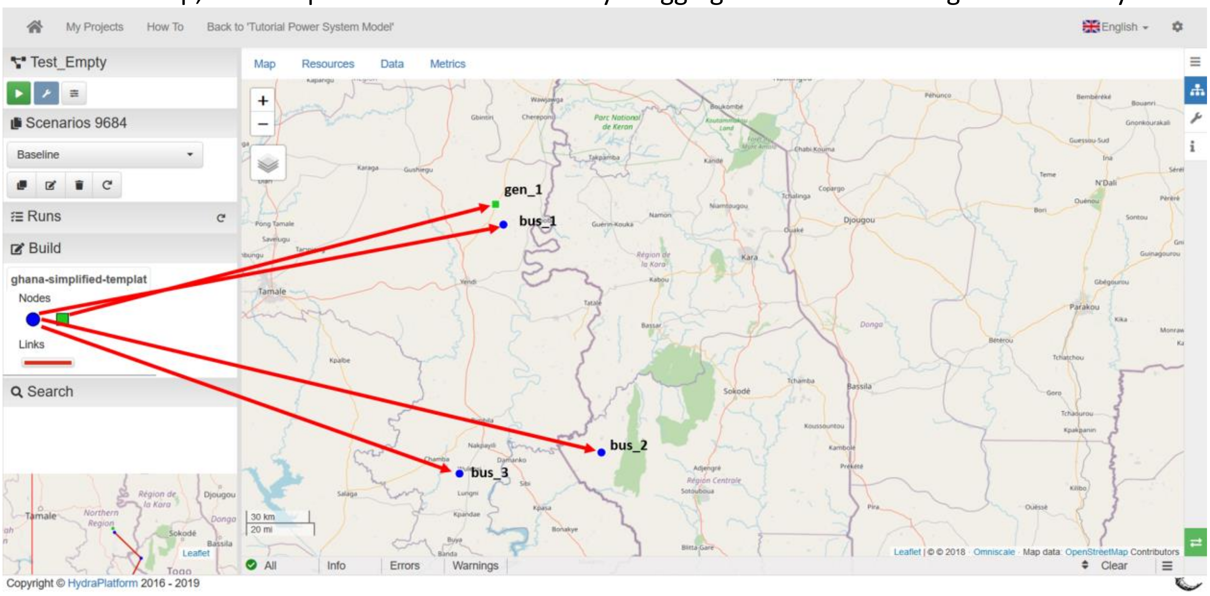


Click “Submit”.

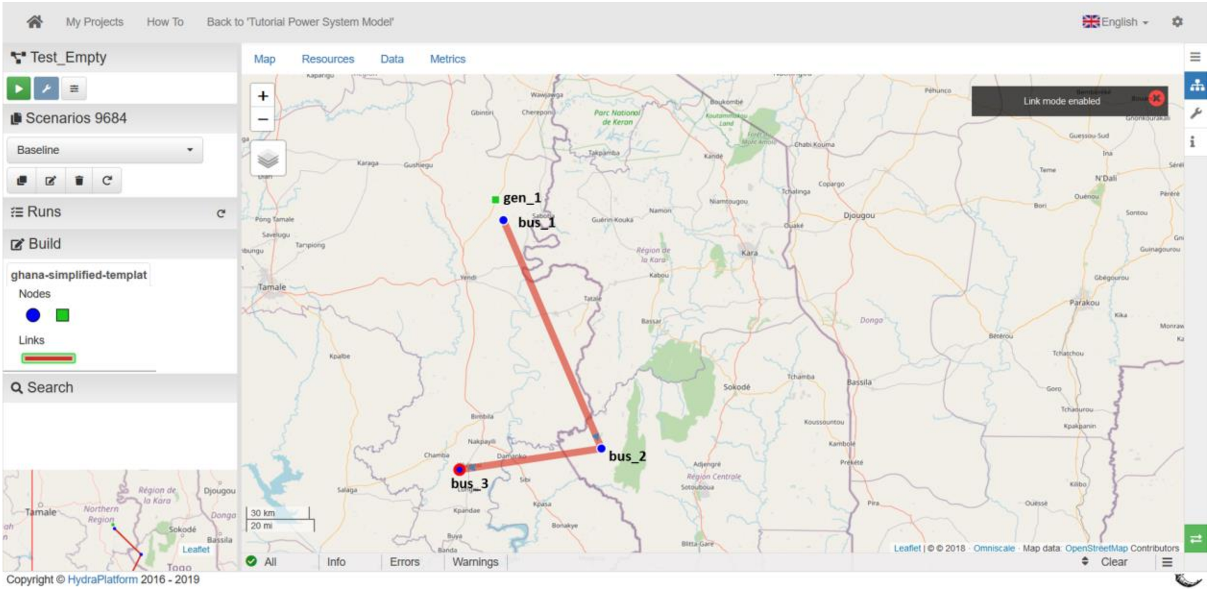
After submitting the network, the dashboard will be updated to include the new network. Click on the new network (e.g., Test_Empty) to open it in the interface.



Assuming the map is used. Zoom in to the location where the network is to be built. A three bus system will be created to demonstrate the use of different network components. To do this, take three buses ( ) and one generator ( ) from the "Build" menu and drag them to the map. Remember that, once in the map, the components can be moved by dragging them while holding the "Ctrl" key.

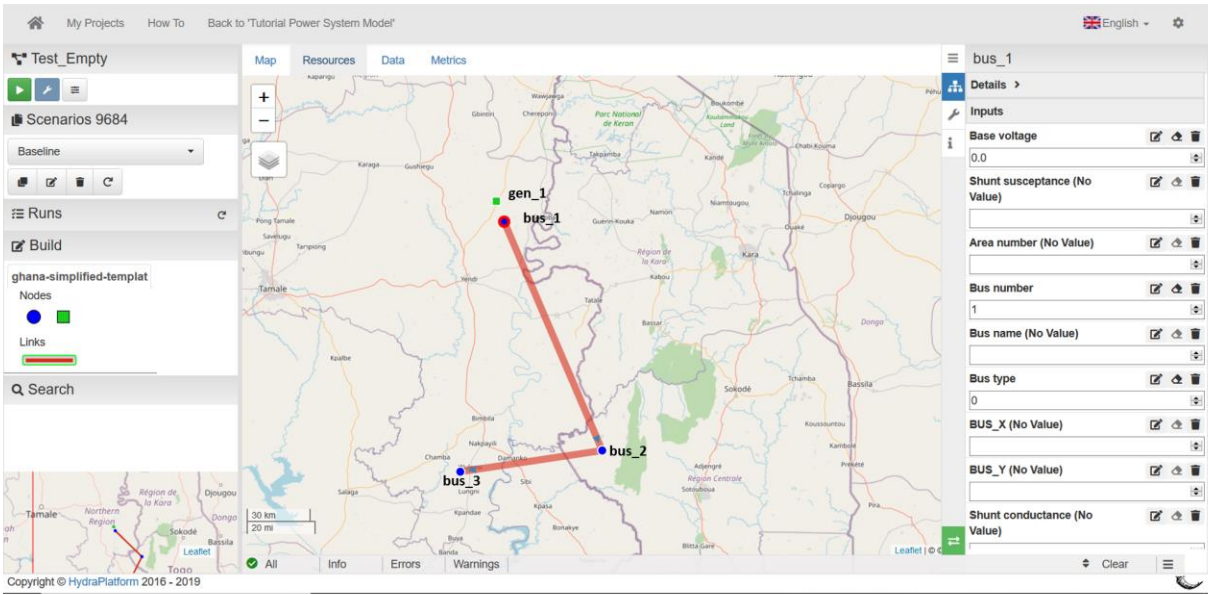


From the build menu, select Links to have the "Link mode enabled". Connect the different elements (by clicking on them) as shown in the picture below. Afterwards, select "Links" again to disable the link mode.



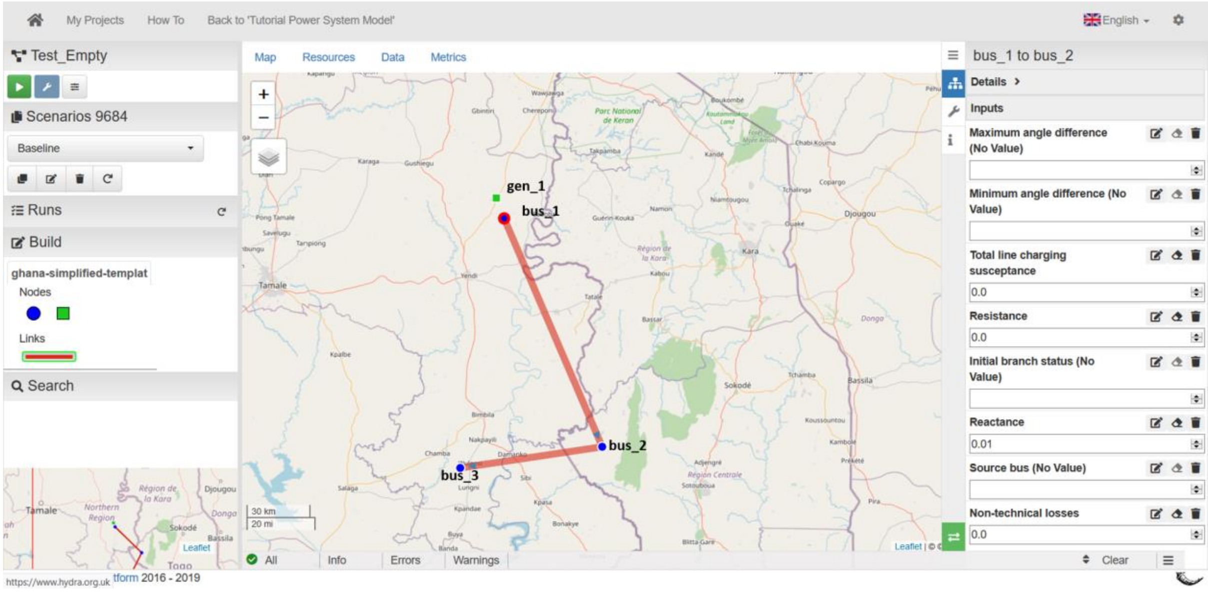
To populate each bus, double click on the bus (or right click and select "Edit Data" for the input menu to appear on the right side of the screen. The minimum information required for each bus is:

1. Bus number: In the example shown above, numbers 1, 2 and 3 are assigned to each bus respectively.
2. Active power demand (MW): In the example, assign 10 MW, 20 MW, and 30 MW to buses 1, 2 and 3, respectively.



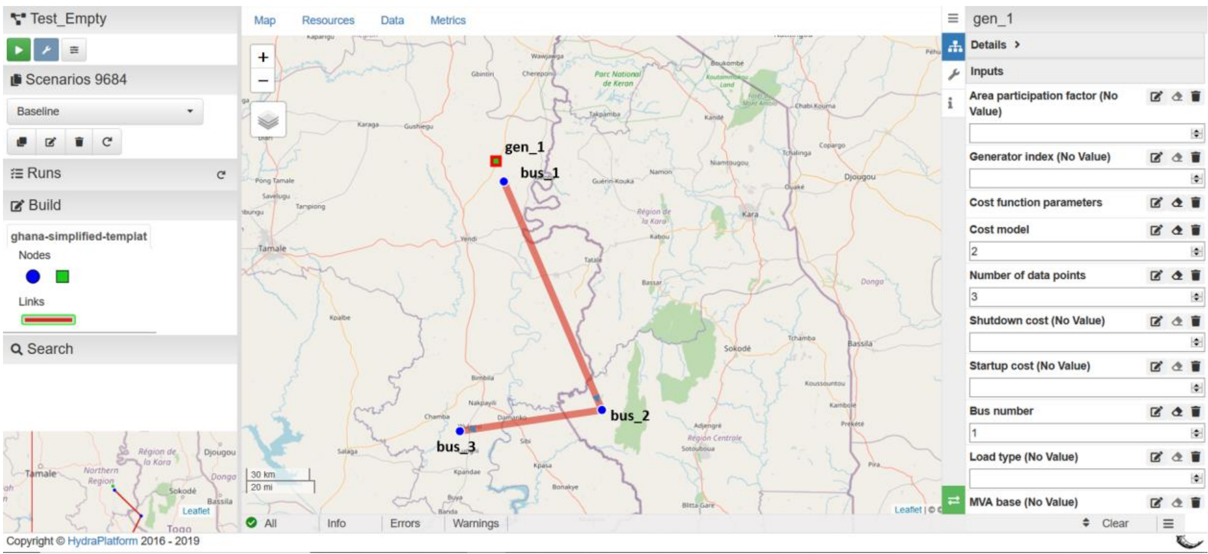
As before, to populate each line, double click (or right click and select "Edit Data") on the line to open the input menu. The minimum information required for each line is:

1. Reactance (pu): In the example, set all reactances to 0.01 pu.
2. Source bus: Bus connected at one edge (to) of the line. Set the values to 1 and 2 for the lines connecting Bus_1 to Bus_2 and Bus_2 to Bus_3, respectively.
3. Destination bus: Bus connected at one edge (from) of the line. Set the values to 2 and 3 for the lines connecting Bus_1 to Bus_2 and Bus_2 to Bus_3, respectively.
4. Long term rating (MVA): MVA rating of the line. In the example, set all ratings to 100 MVA.



Access the input menu of the generator and provide the following information:

1. Bus number: Bus connected to the generator. Set this value to 1.
2. Cost model: Option to select a piecewise (1) or a polynomial (2) generation cost curve. In the example set this option to 2 to use a polynomial model.
3. Number of data points: Number of components of the piecewise or polynomial approximation. Set this option to 3, to enable the use of three components of a quadratic generation cost function.
4. Cost function parameters: Components of piecewise or polynomial function. Click on the edit icon ( ) to access a window to provide multiple inputs. Set the values to 0.01, 20 and 0 in the first row (the table can be resized to be one row three columns).
5. Maximum real power output (MW): Generation capacity (MW). Set this value to 100
6. Minimum real power output (MW): Minimum stable generation (MW). Set this value to zero



A summary of settings for the case study are provided below:

Bus data used in the example

Bus	Bus number	Active power demand
bus_1	1	10
bus_2	2	20
bus_3	3	30

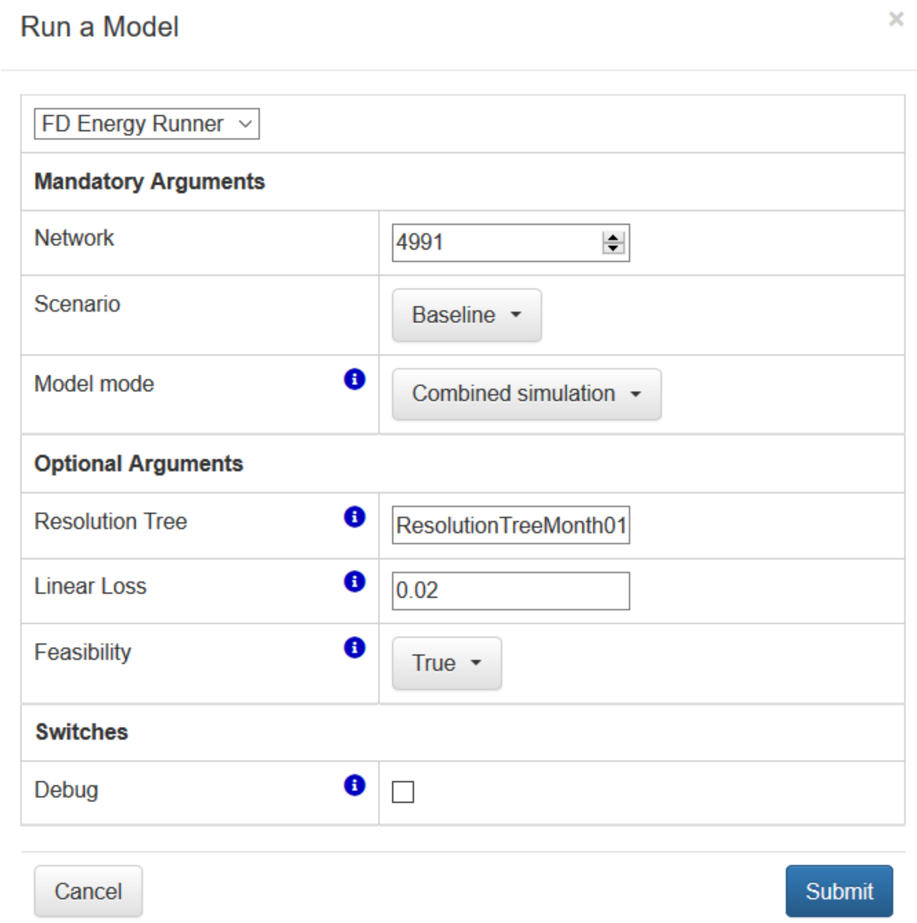
Line data used in the example

Line	Reactance	Source bus	Destination bus	Long term rating
Bus_1 to Bus_2	0.01	1	2	100
Bus_2 to Bus_3	0.01	2	3	100

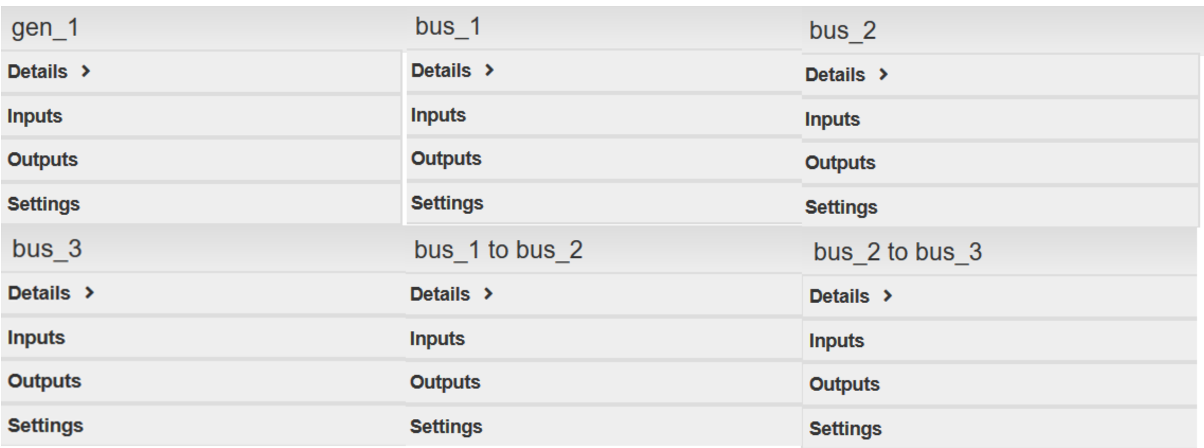
Generator data used in the example

Generator	Bus number	Cost model	Number of data points	Cost function parameters	Maximum real power output
gen_1	1	2	3	[0.01,20,0]	100

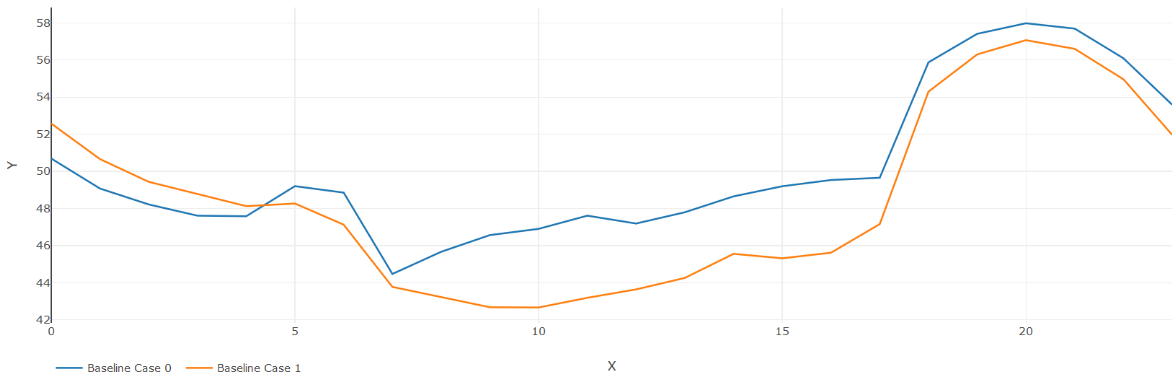
Now that the model has been setup, run the network model by selecting , and then running a time series analysis, i.e., “Combined simulation”.



Once the study is successful (green run), the outputs of the different network elements will become available.



An example of the outputs, taken as power generation (Active power outputs), for two representative days is presented below. The information, presented as figures, time series or raw data, for all elements of the network model can also be taken from the same menu.



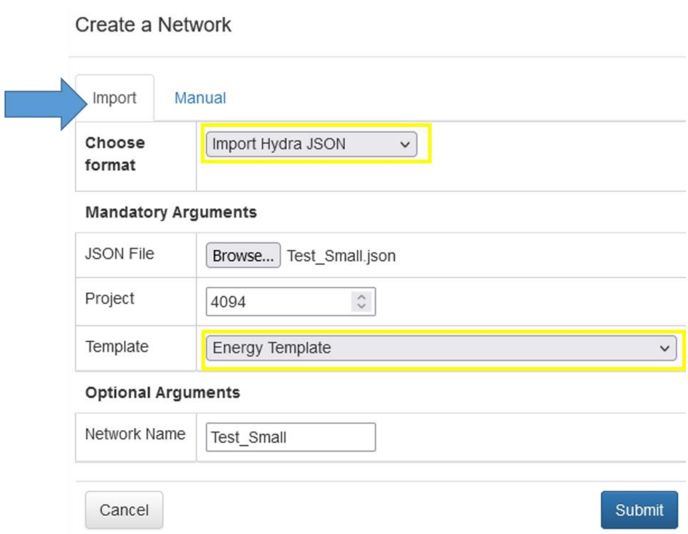
The network model developed here, called “Test_Empty_Completed”, can be accessed from the dashboard or json file

3.2.Editing a network

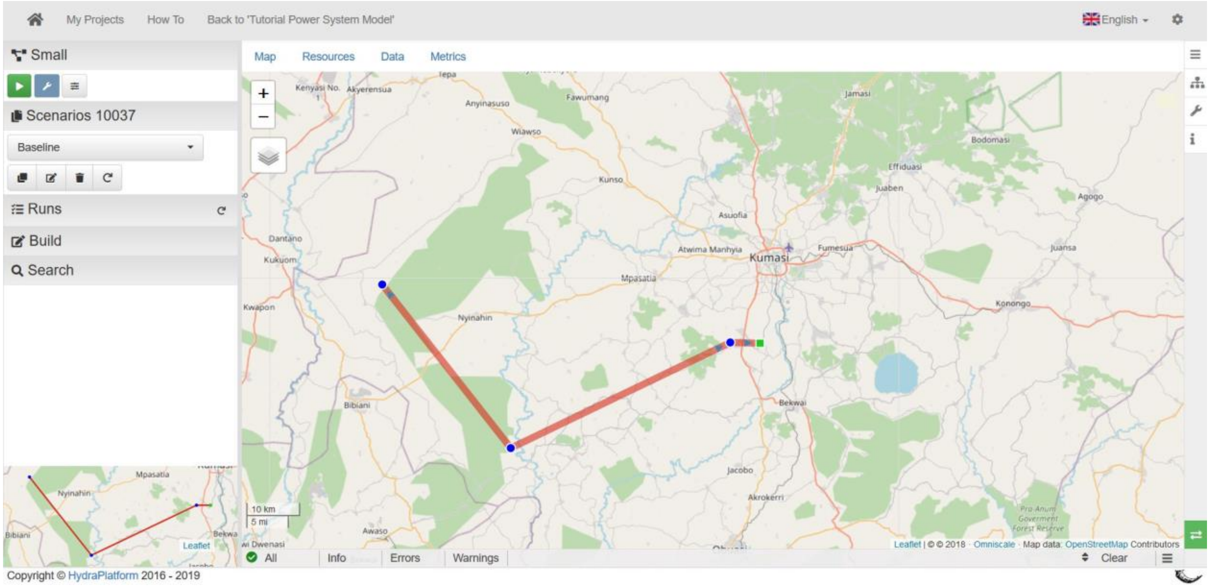
This section provides step-by-step guidance to load an illustrative 3 bus power network model. The network model file used in this example includes energy profiles for two representative days with hourly resolution. If some steps seem unclear, please revise Section 2 on “The modelling interface”.

To begin this example, access the modelling dashboard by logging in https://hydra.org.uk/login. If the “Test_Small” network model has already been shared with you, it will appear in the dashboard. In that case, select the test to open the modelling interface.

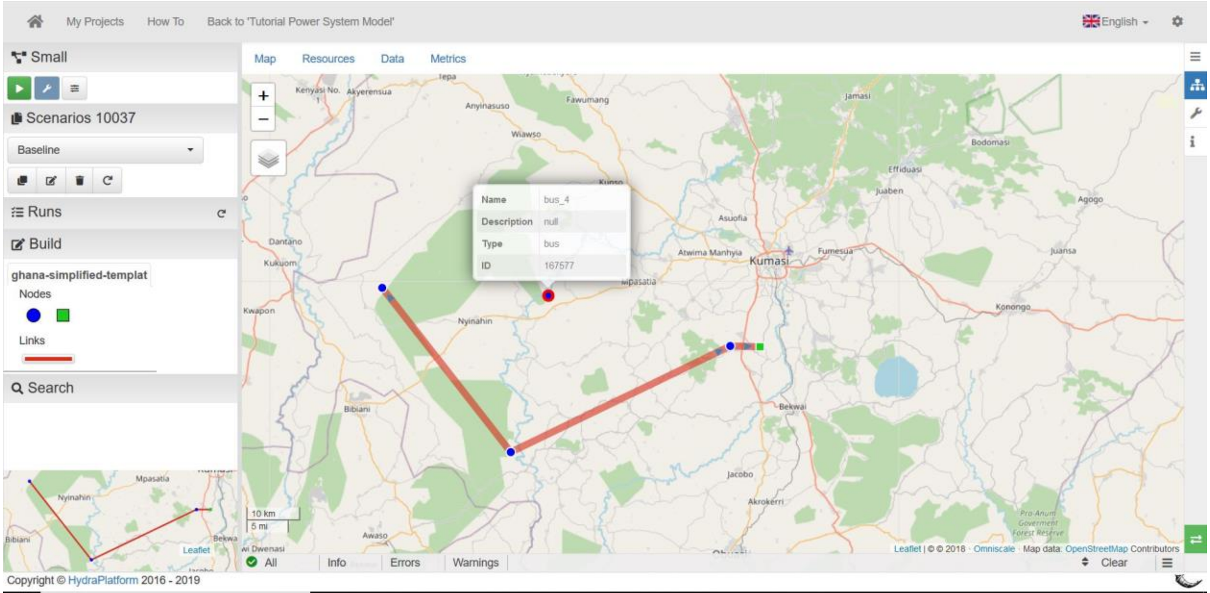
Alternatively, if you have downloaded the “Test_Small.json” file, click on the “Create a Network” option (+) to open a new menu and select the Import Tab. Create a new model named “Test_Small” and locate the “Test_Small.json” file to create the model.



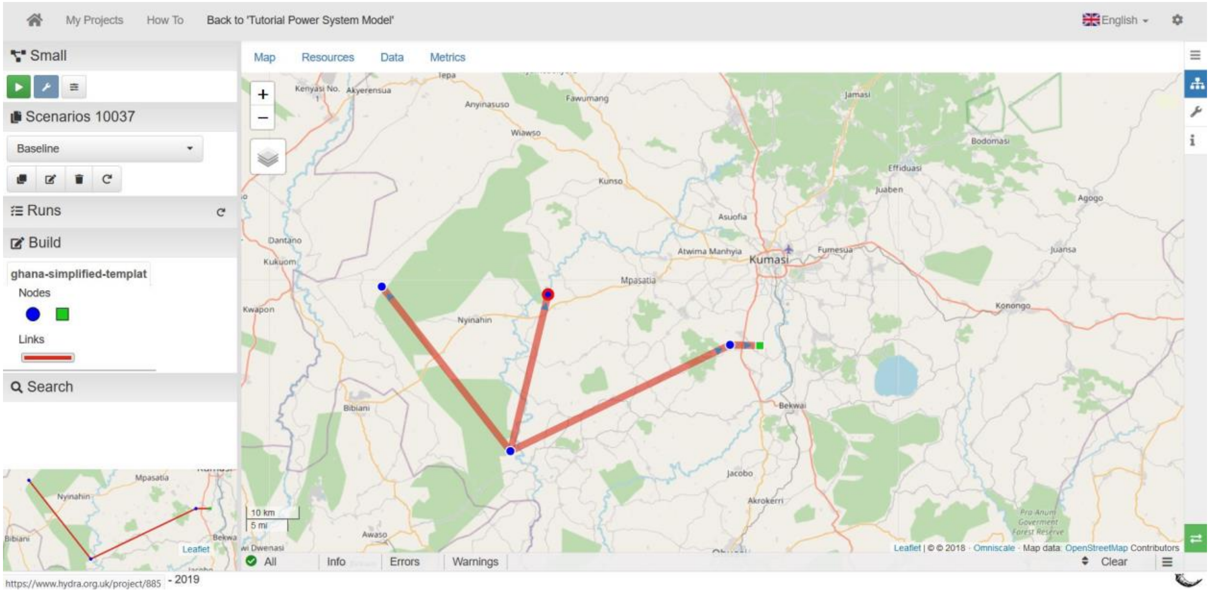
The “Test_Small” example will be created in the dashboard. Click on the example to open the modelling interface.



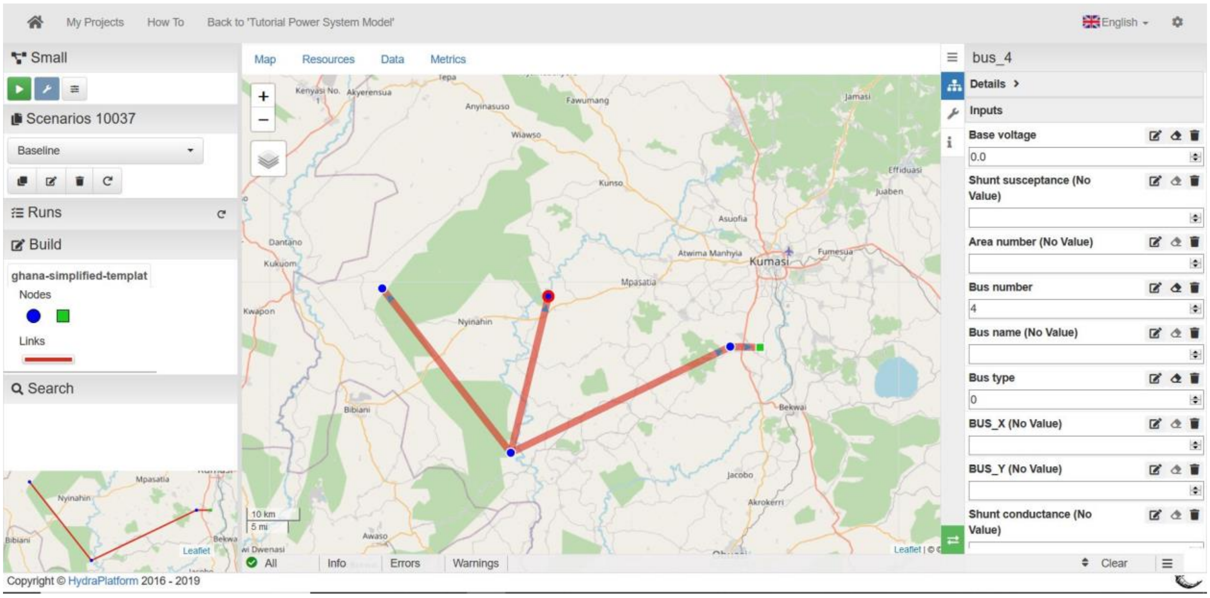
From the “Build” menu, select a node and drag it to the map



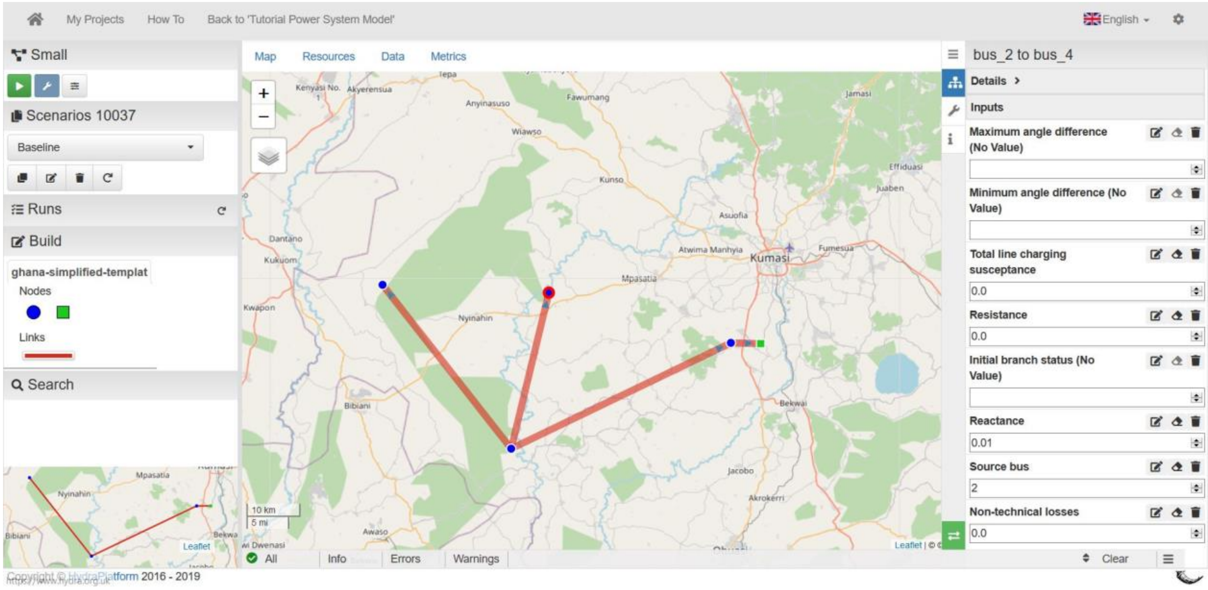
From the build menu, select Links to have the “Link mode enabled”. Select the new bus and bus 2 to connect them. Click again on “Links” to disable the link mode.



Right click on the bus and select "Edit data" to access the input menu. Define a bus number (Bus number = 4), a Load type (e.g., 0) and Active power demand (e.g., 25 MW).



Right click on the new line and select "Edit data" to access the relevant input menu. This time defines the Reactance of the line (e.g., 0.01 pu), the buses that are connected by the line (Source bus = 2, Destination bus = 4), and the capacity of the line (Long term rating = 100 MVA). The model developed until this stage, which is called "Test_Small_Completed" can be accessed from the dashboard or relevant json file.



Bus data used in the example

Bus	Bus number	Active power demand
bus_1	1	0
bus_2	2	100
bus_3	3	50
bus_4	4	25

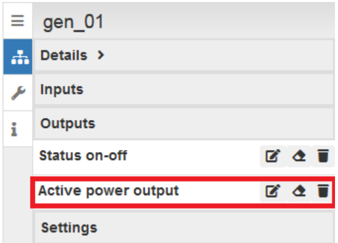
Line data used in the example

Line	Reactance	Source bus	Destination bus	Long term rating
Bus_1 to Bus_2	0.01	1	2	160
Bus_2 to Bus_3	0.01	2	3	100
Bus_2 to Bus_4	0.01	2	4	100

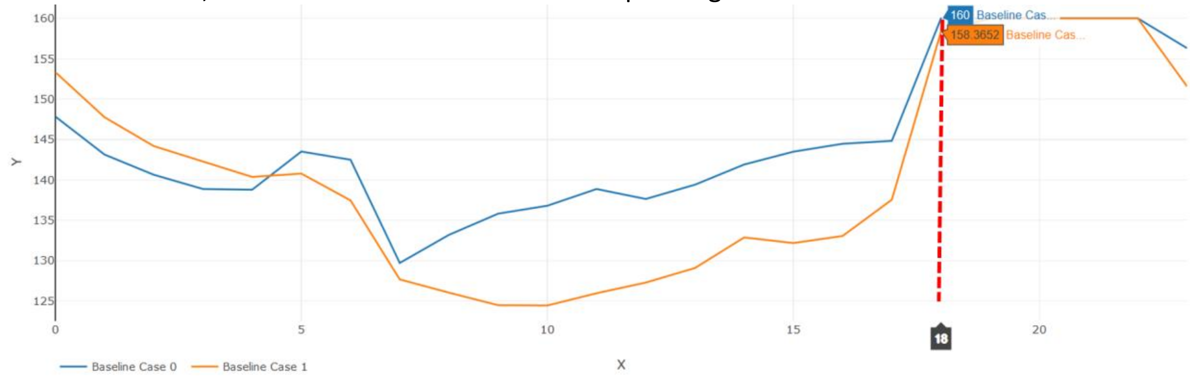
Generator data used in the example

Generator	Bus number	Cost Model	Number of data points	Cost function parameters	Maximum real power output
gen_1	1	2	3	[0.01,20,0]	400

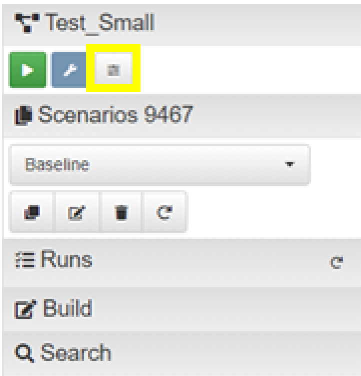
Now that the model has been setup, run the network model by selecting , and then running a time series analysis, i.e., "Combined simulation". Once the study successfully concludes (i.e., green run), access the power generation profile by double clicking on the generator and, in the menu of the generator, select Outputs, "Active power output" and click on the icon.



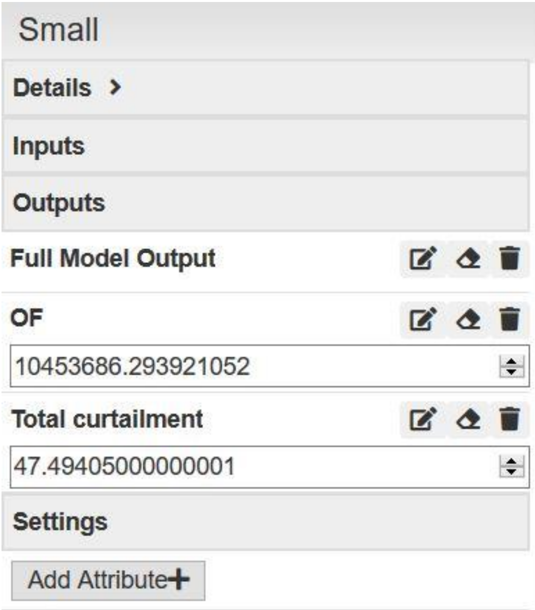
In the new menu, select the Plot tab to visualise the power generation time-series.



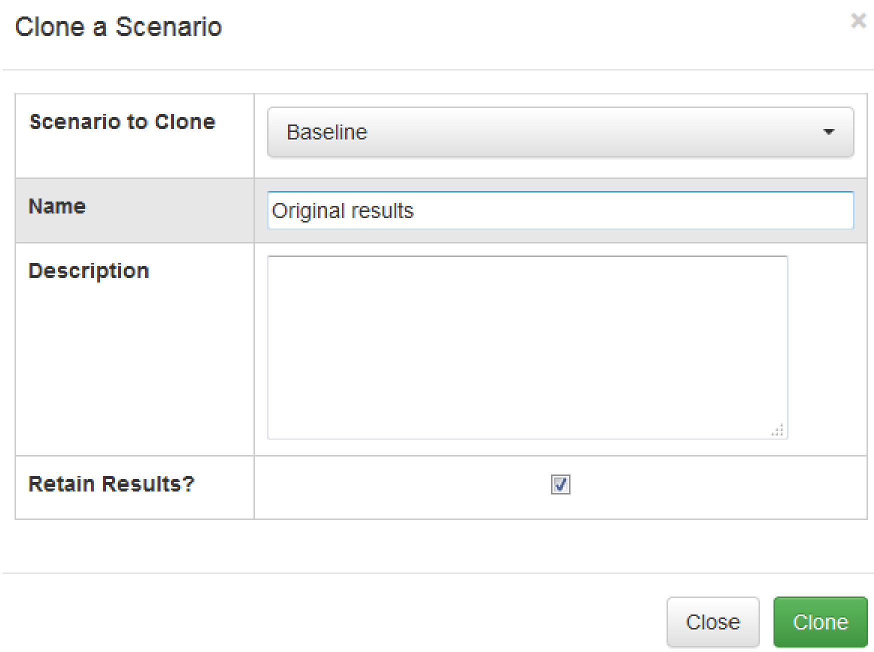
The results show that, during peak time (around 18:00h), the output of the generator is flat, which suggests that either the demand profile is flat at that time (unlikely) or part of the demand is being curtailed. The latter can be confirmed by selecting the system level data ( ) to access the monthly "Total curtailment", which is greater than zero in this case.



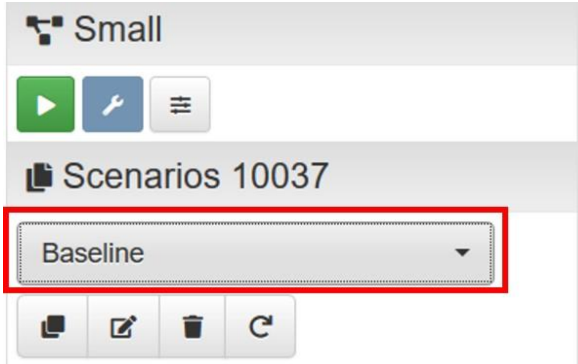
The results confirm that some of the demand has been curtailed.



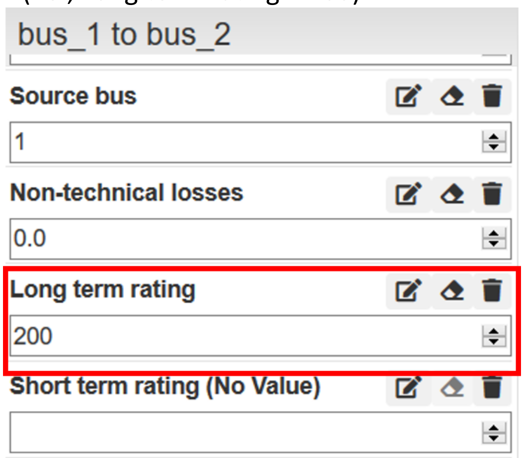
Several actions can be taken to address this issue and supply the full demand, such as reinforcing the network. To explore this option, it is convenient to first clone the current study in a new scenario. For that purpose, clone the "Baseline" and call the new scenario "Original results"



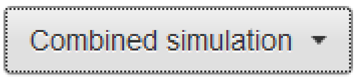
Return to the "Baseline" scenario to continue editing the network.



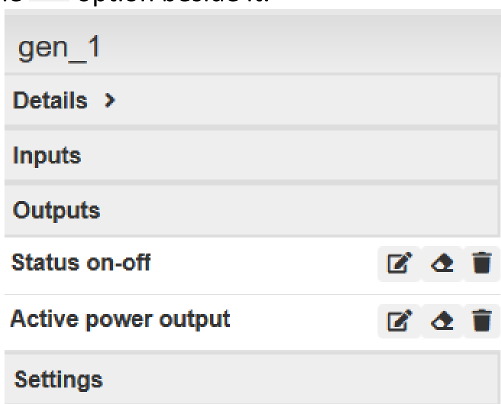
In this example, the impacts of a line reinforcement is explored by increasing the capacity of line "bus_1 to bus_2" to 200 MVA (i.e., Long term rating = 200).



Perform a second "Combined simulation" study ( ) using the new settings to explore if the line reinforcement solved the issue.

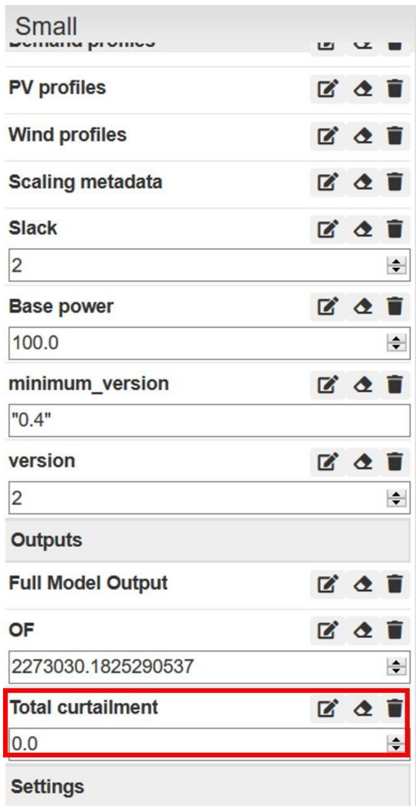


Once the study is successful, double click on the generator to access its "Outputs" and select "Active power output" and click on the option beside it.



The results show that the generation profile is no longer flat at around 18:00h, which suggests that the full demand is being supplied now. Note that the "Original results" with the previous results can be displayed in the figure if it is selected as shown in the figure below.

The conclusion that there is no curtailment can be validated by using once again the system level data option ( ) to access the monthly "Total curtailment" which is zero this time.

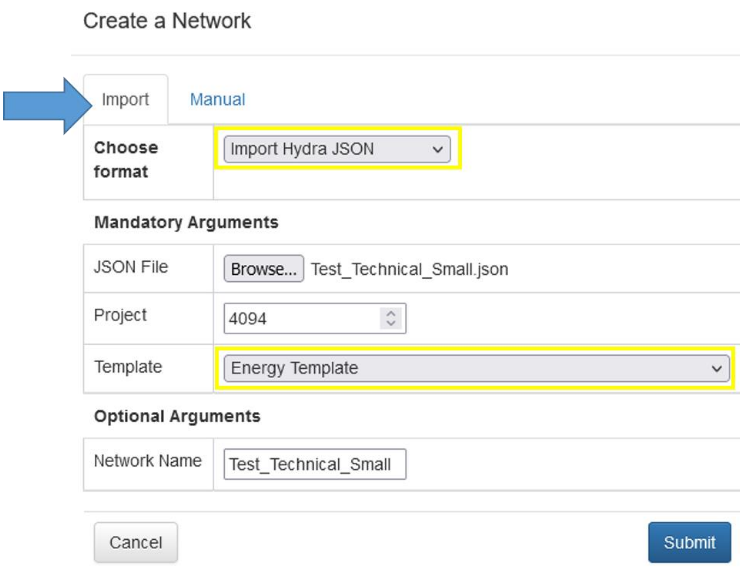


3.3.Technical characteristics of the networks

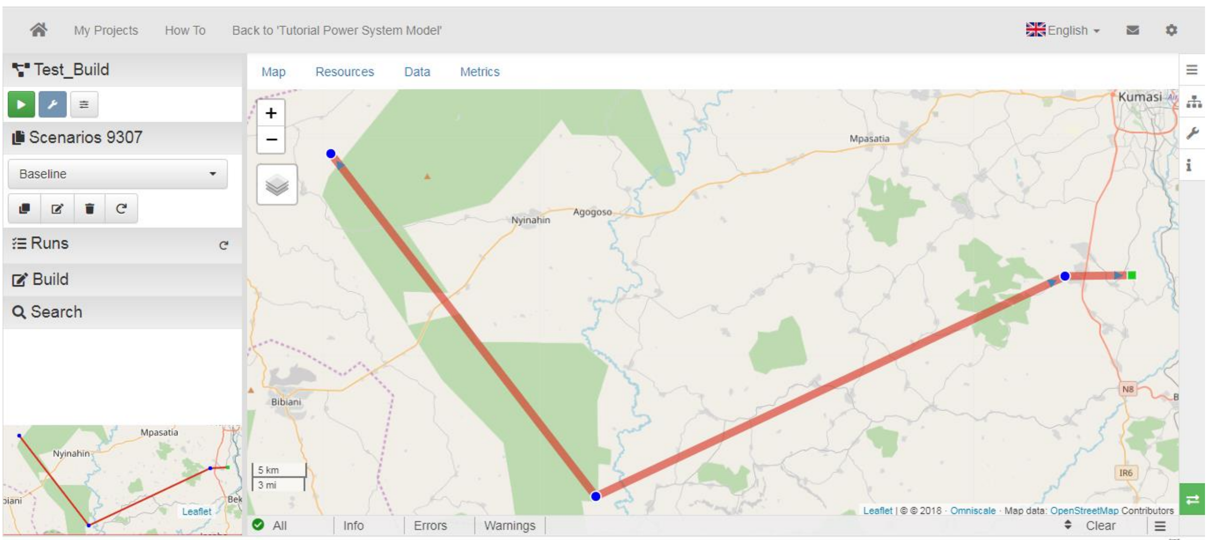
This section provides step-by-step guidance to load, edit and visualise technical changes on a 3 bus power network model. The technical changes that will be analysed include changes in line parameters, demand values and non-technical losses. The network model file used in this example includes energy profiles for two representative days with hourly resolution. If some steps seem unclear, please revise Section 2 on “The modelling interface”.

To begin this example, access the modelling dashboard by login in https://hydra.org.uk/login. If the “Test_Technical_Small” network model has already been shared with you, it will appear in the dashboard. In that case, select the test to open the modelling interface.

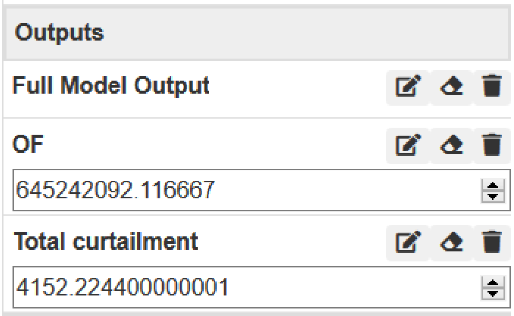
Alternatively, if you have downloaded the “Test_Technical_Small.json” file, click on the “Create a Network” option (+) to open a new menu and select the Import Tab. Create a new model named “Test_Technical_Small” and locate the “Test_Technical_Small.json” file to create the model.



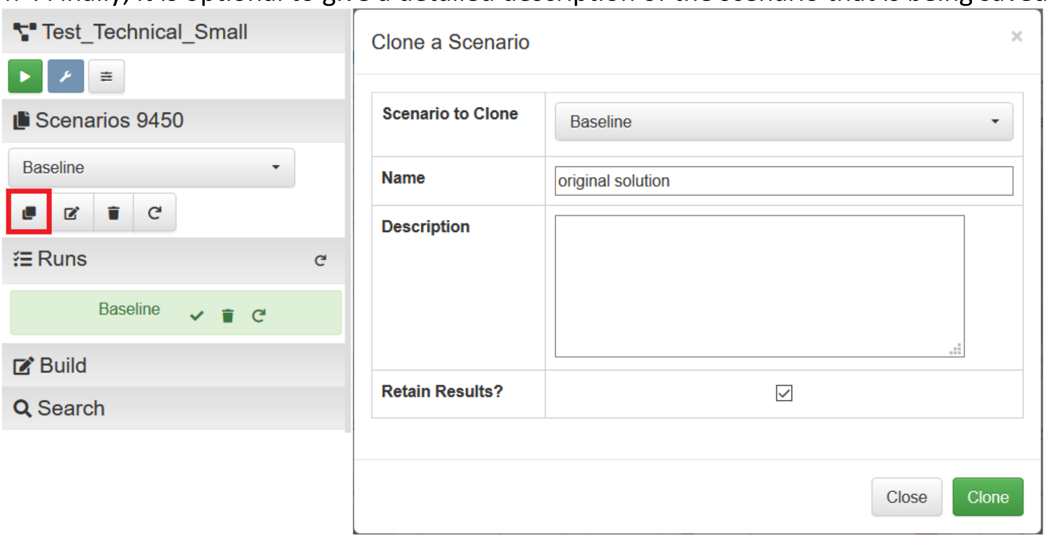
The “Test_Technical_Small” example will be created in the dashboard. Click on the example to open the modelling interface.



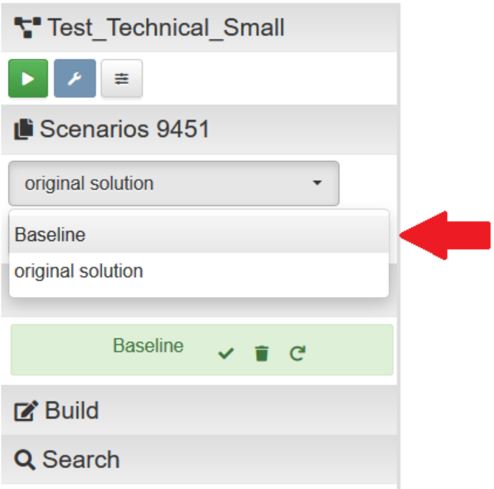
Run the network model by selecting , and then running a time series analysis, i.e., "Combined simulation". Once the study successfully concludes (i.e., green run), check the system level results by selecting ( ) to access the monthly "Total curtailment" and objective function "OF".



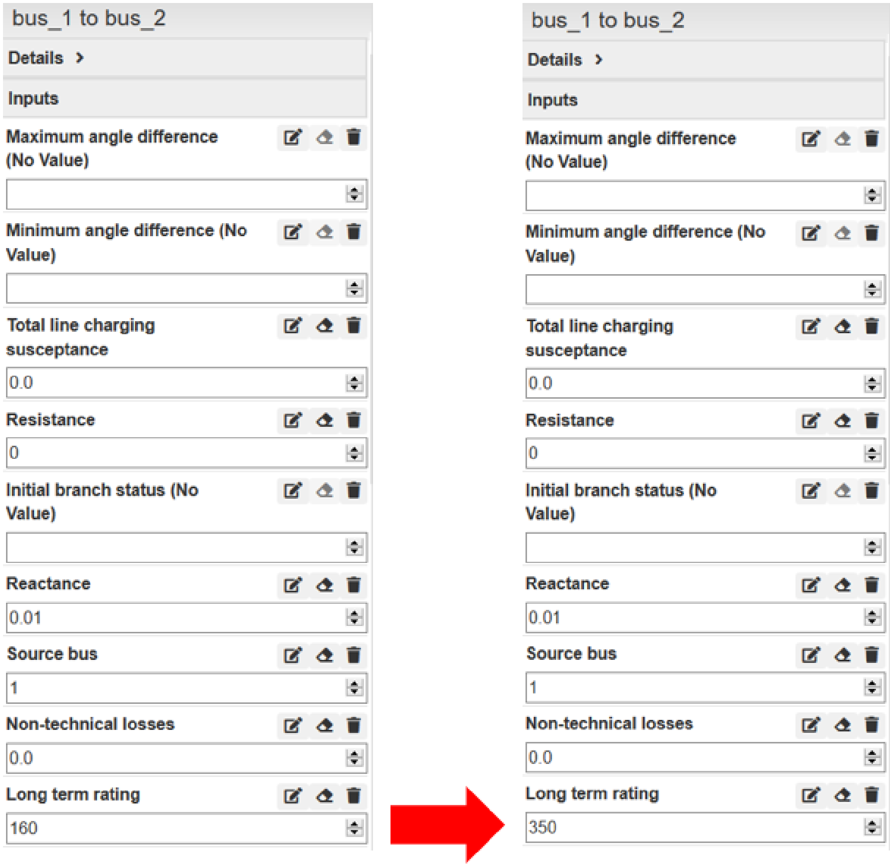
You should save the results for comparison by clicking on the icon clone scenario ( ). You should select the scenario that you want to clone, in this case you should clone the scenario "Baseline". Furthermore, you should give a name to this new scenario. For this example we will name it as "original solution". Finally, it is optional to give a detailed description of the scenario that is being saved.



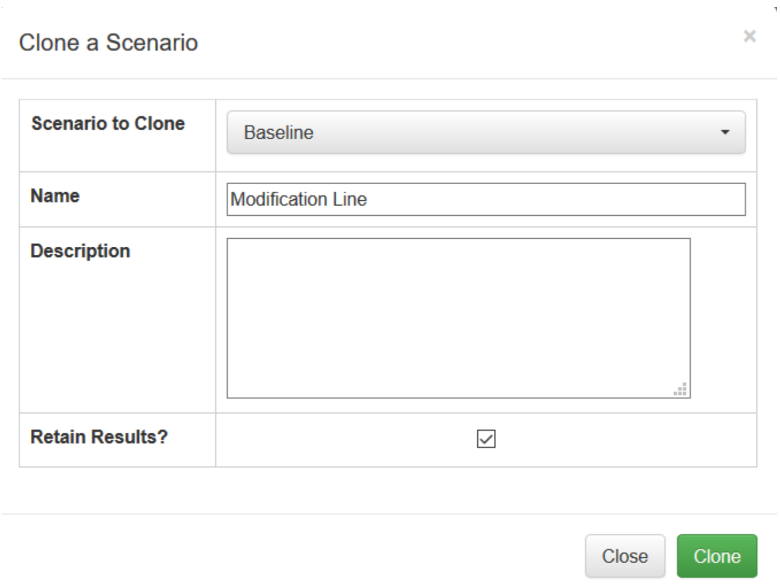
Once the results are cloned, you have to select manually the Baseline scenario. This is necessary because only modifications made in the Baseline scenario are accepted by the interface.



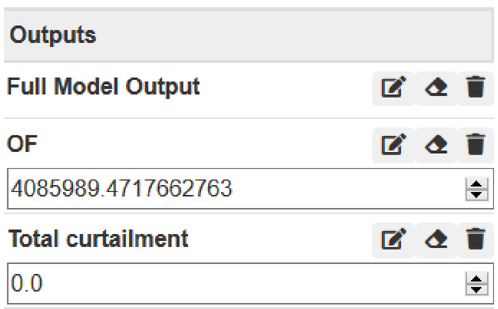
The original solution has load shedding and the next step is to modify the network to eliminate the load shedding. In this case the problem is caused by the line that connects the buses 1 and 2. The thermal capacity of the line is 160 MVA which is not enough to transport the necessary generation from node 1 to the loads at nodes 2 and 3 (100 MW and 200 MW respectively). Therefore, you should change the thermal limit of the line by double clicking the line that connects buses 1 and 2, and then modifying the "RATE_A" value from 160 MVA to 350 MVA.



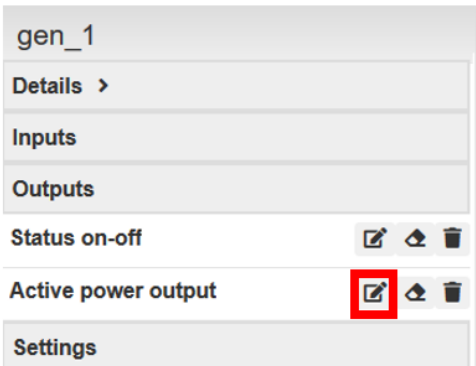
Now, run the network model again and after it concludes, clone the results and save them with the name "Modification Line".



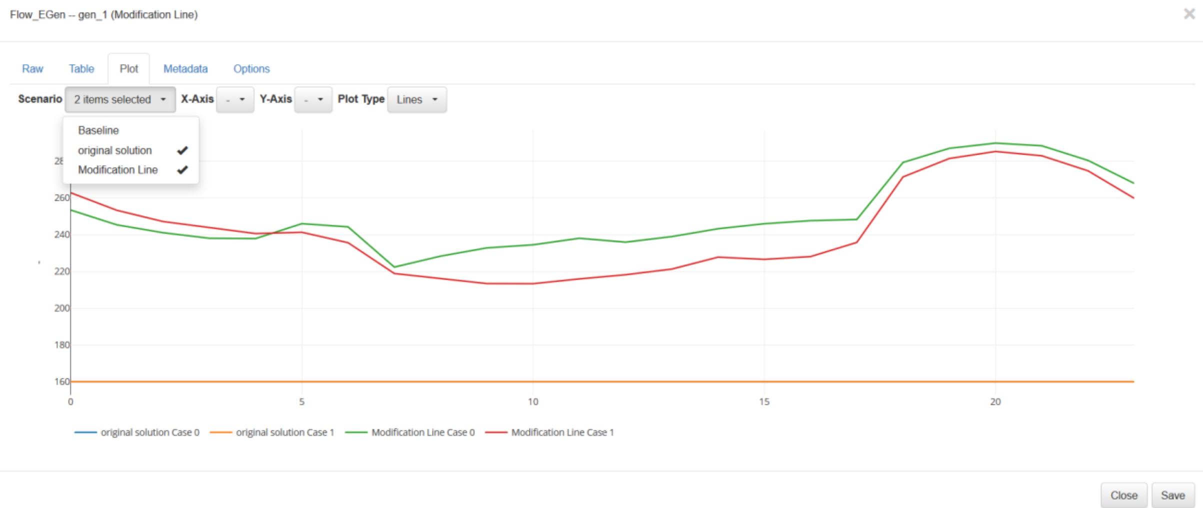
Check the system level results and you will notice that both the objective function and load curtailment have changed. Now the solution has zero load curtailment, which means that the power system has enough generation and transmission capacity to meet all demand and losses. You can also see that the value of the objective function has changed significantly and this is because the load curtailment is included and penalised in the objective function. Therefore, this significant reduction corresponds to the elimination of the generation curtailment in the system.



The interface also provides tools to visualise and compare results for different scenarios. We will use the hourly generation for both scenarios as an example. First you need to double click on the generator, select "Outputs", "Active power outputs" and click on the icon.

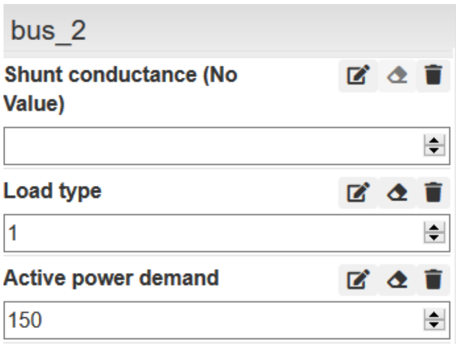


Click on tab Plot on the new window and then select the scenarios "original solution" and "Modification Line". This will display a figure with the generation for both scenarios.

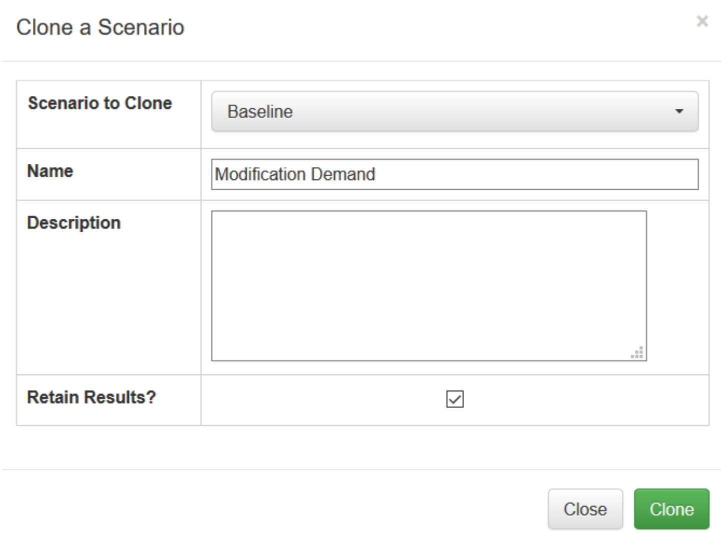


The results show that for the "original solution" the generation was a constant value of 160 MW, this makes sense considering that the previous thermal limit for line 1-2 was 160 MVA. We can see that the scenario "Modification Line" allows the generator to follow the changes of the demand at every period.

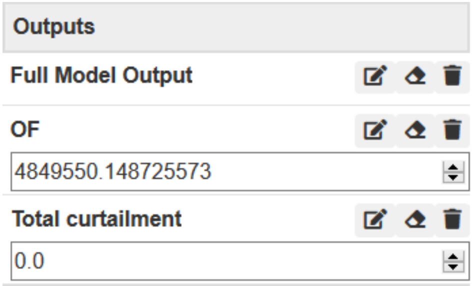
For the next example you will modify the value of the demand at bus 2 from 100 MW to 150 MW. To do so, first you need to select the "Baseline" scenario on the left hand menu. After, you need to double click on bus 2 and modify "Active power demand" with the abovementioned value.



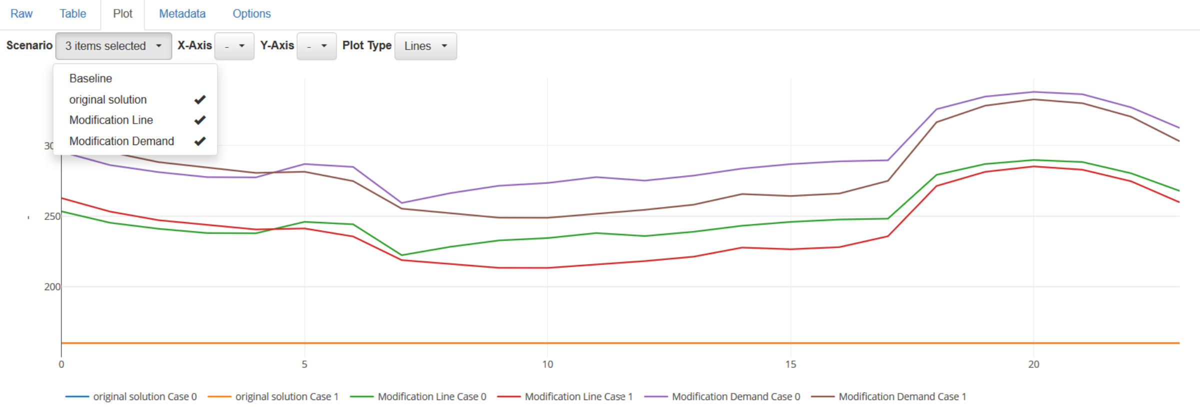
Now, run the network model again and after it concludes, clone the results and save them with the name "Modification Demand".



Now, you can compare the results of this scenario with the previous scenarios. To do so, first compare the value of the objective function with the previous scenarios.

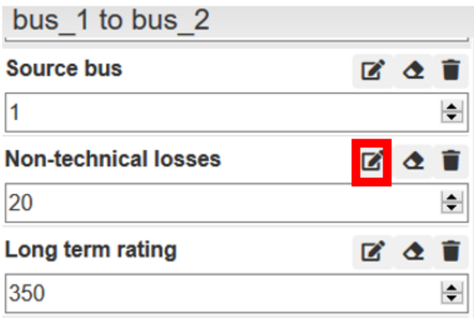


As you can see, the objective function has increased in value compared to the previous scenario. This is expected since the value of the demand at bus 2 has been increased. Furthermore, the load curtailment remains in zero, which is also expected considering that the increment in the demand did not surpass the transmission and generation capacity. You can also compare the generation for different scenarios by double clicking on the generator, selecting Outputs, "Active power outputs" and clicking on the icon. In the window that comes into view, select the tab plot and the palette select the three scenarios that you have studied.

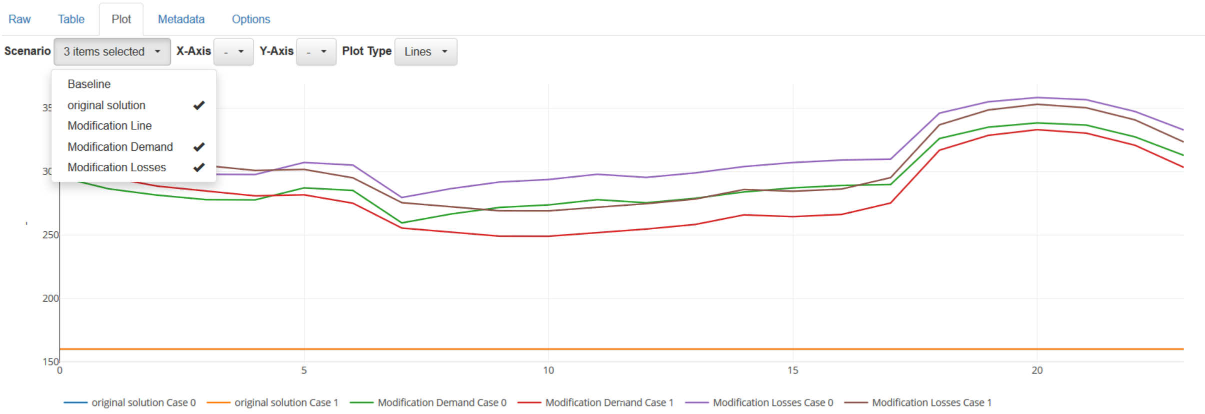


The curve at the top of the figure corresponds to the generation dispatch for the last scenario that was analysed. The result is again expected since an increase in the demand produces an increase in the generation.

Another feature that is included in the interface is the possibility to include non-technical losses to the model. To use this feature, first select the "Baseline" scenario and, afterwards, double click on line "bus_1 to bus_2". In the right side menu we must change the value of "Non-technical losses" by a specific amount of expected losses in MW. In this case, a value of 20 MW has been chosen for non-technical losses.



Now, run the network model again and after it concludes, clone the results and save them with the name "Modification Losses". Now we can again compare the objective function and the generation with the other scenarios. Only three scenarios will be selected to compare to avoid overcrowding the figure, which can difficult the visualisation of the results. The scenarios to be analysed in this case are “original solution”, “Modification Demand” and “Modification Losses”.



Outputs

Full Model Output

OF

5235058.690008001

Total curtailment

0.0

You can now compare the results of this scenario with the others. There is again an increase in the value of the objective function as expected for the higher power losses. This increase in the objective function is also reflected in a higher power generation for this scenario.

One final feature that will be explored is the modification of demand values for two sub-periods in a 24-hour period. To do so, we need to: 1) change to scenario “Baseline”, 2) select the system level data ( ), 3) Select inputs, 4) click on the icon in demand values. After taking those steps a new window should emerge containing a table of 7 rows and 25 columns. The columns represent number of hours and the rows represent different daily profiles. The model has been set up to use the first two profiles (rows) corresponding to winter weekday and winter weekend profiles.

Raw | Table | Plot | Metadata | Options

− ROWS + | − COLUMNS + | DATA▾ | FIX▾ | ADD INDEX | Dimensions 7,25 | Apply

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2	Values_1	0.8283	0.8019	0.7879	0.778	0.7775	0.804	0.7983	0.7267	0.7462	0.7609	0.7664	0.778	0.7711	0.781	0.795	0.8039	0.8094	0.8114	0.913	0.9381	0.9474	0.9427	0.9166	0.8757
3	Values_2	0.8591	0.8278	0.8078	0.7973	0.7864	0.7887	0.7701	0.7153	0.7061	0.6974	0.6972	0.7057	0.7131	0.7232	0.7444	0.7405	0.7454	0.7706	0.8872	0.92	0.9325	0.9249	0.8981	0.8492
4	Values_3	0.8788	0.8548	0.8401	0.8232	0.8258	0.8432	0.8078	0.7646	0.7907	0.8097	0.8199	0.8285	0.8244	0.8346	0.8434	0.8464	0.8502	0.8705	0.9717	0.9954	1	0.9944	0.9644	0.9194
5	Values_4	0.885	0.8533	0.8321	0.8178	0.8093	0.807	0.7567	0.7302	0.7269	0.7222	0.7236	0.7392	0.7493	0.765	0.776	0.7788	0.7824	0.8265	0.9364	0.9734	0.9886	0.9839	0.9543	0.9043
6	Values_5	0.8049	0.7834	0.7668	0.7566	0.7633	0.788	0.7679	0.7439	0.7592	0.7696	0.7713	0.7753	0.7749	0.7795	0.7984	0.8056	0.8089	0.8109	0.9439	0.9707	0.9703	0.9606	0.9199	0.8587
7	Values_6	0.8135	0.7887	0.7701	0.7621	0.7559	0.7582	0.7264	0.7052	0.7027	0.6898	0.6836	0.6803	0.6829	0.698	0.7084	0.716	0.7257	0.7511	0.8926	0.9303	0.9378	0.9272	0.8893	0.8256

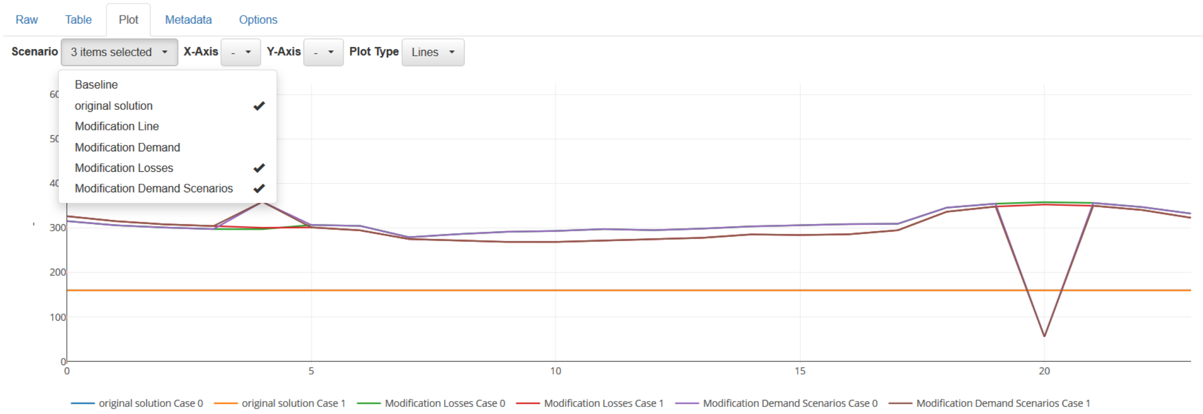
You should now modify two columns with the values 0.95 and 0.1. For this example, you should modify the column “F” or “4” with 0.95 and the column “V” or “20” with 0.1. It is only necessary to modify the first two rows.

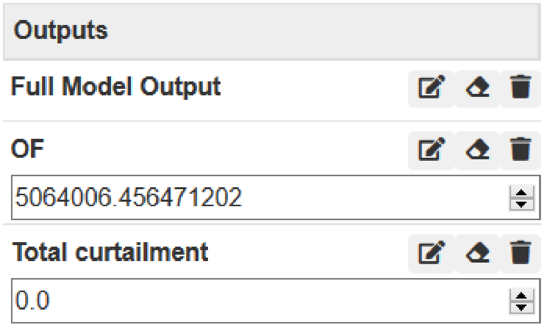
Raw | Table | Plot | Metadata | Options

− ROWS + | − COLUMNS + | DATA▾ | FIX▾ | ADD INDEX | Dimensions 7,25 | Apply

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
1		0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23
2	Values_1	0.8283	0.8019	0.7879	0.778	0.95	0.804	0.7983	0.7267	0.7462	0.7609	0.7664	0.778	0.7711	0.781	0.795	0.8039	0.8094	0.8114	0.913	0.9381	0.1	0.9427	0.9166	0.8757
3	Values_2	0.8591	0.8278	0.8078	0.7973	0.95	0.7887	0.7701	0.7153	0.7061	0.6974	0.6972	0.7057	0.7131	0.7232	0.7444	0.7405	0.7454	0.7706	0.8872	0.92	0.1	0.9249	0.8981	0.8492
4	Values_3	0.8788	0.8548	0.8401	0.8232	0.8258	0.8432	0.8078	0.7646	0.7907	0.8097	0.8199	0.8285	0.8244	0.8346	0.8434	0.8464	0.8502	0.8705	0.9717	0.9954	1	0.9944	0.9644	0.9194
5	Values_4	0.885	0.8533	0.8321	0.8178	0.8093	0.807	0.7567	0.7302	0.7269	0.7222	0.7236	0.7392	0.7493	0.765	0.776	0.7788	0.7824	0.8265	0.9364	0.9734	0.9886	0.9839	0.9543	0.9043
6	Values_5	0.8049	0.7834	0.7668	0.7566	0.7633	0.788	0.7679	0.7439	0.7592	0.7696	0.7713	0.7753	0.7749	0.7795	0.7984	0.8056	0.8089	0.8109	0.9439	0.9707	0.9703	0.9606	0.9199	0.8587
7	Values_6	0.8135	0.7887	0.7701	0.7621	0.7559	0.7582	0.7264	0.7052	0.7027	0.6898	0.6836	0.6803	0.6829	0.698	0.7084	0.716	0.7257	0.7511	0.8926	0.9303	0.9378	0.9272	0.8893	0.8256

Now, run the network model again and after it concludes, clone the results and save them with the name “Modification Demand Scenarios”. The results for this scenario are as follows.





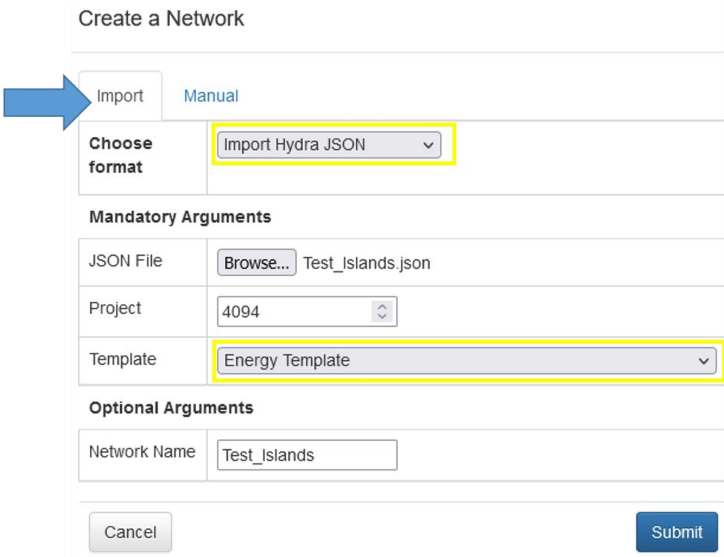
The result shows a decrease in the value of the objective function compared to the previous scenario. This is reasonable since one period was increased by a little percentage (i.e. column F) but the other period (i.e. column V) was decreased by a big percentage. This is also reflected in the generation curve for all periods.

3.4.Energy Islands

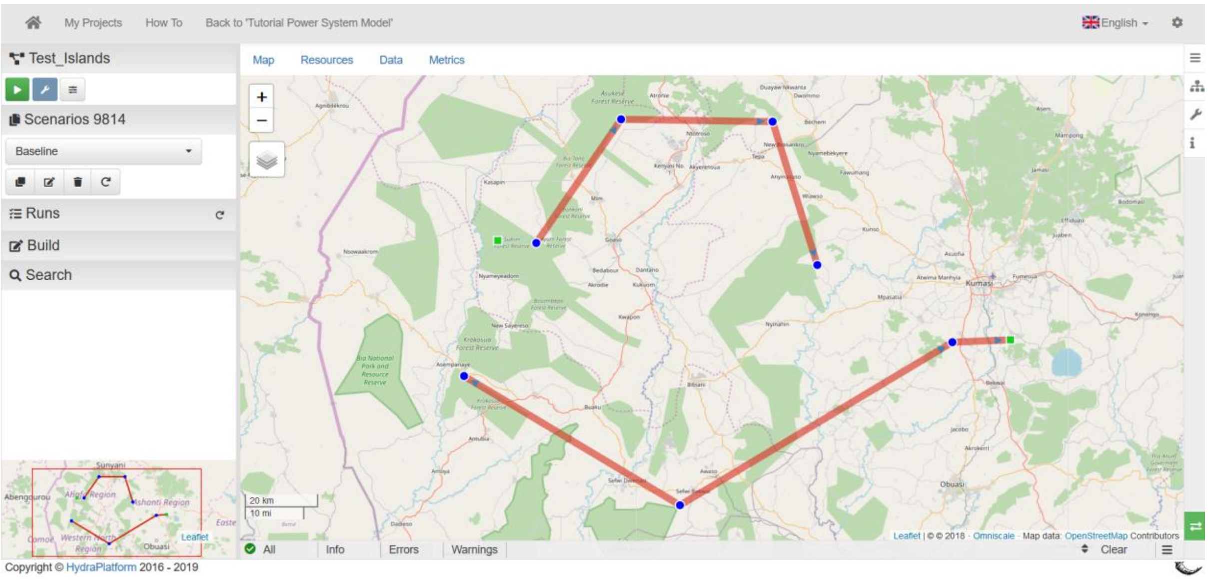
This section provides step-by-step guidance to load, edit and solve a power system with islands (disconnected portions of the network). Additional changes such as the addition of new lines, the increase of the generation cost and the increase of the linear technical losses will be illustrated in this section. This example will illustrate the capability of the energy engine to be used for on-grid and off-grid applications. The network model file used in this example includes energy profiles for two representative days with hourly resolution. If some steps seem unclear, please revise Section 2 on “The modelling interface”.

To begin this example, access the modelling dashboard by login in https://hydra.org.uk/login. If the “Test_Islands” network model has already been shared with you, it will appear in the dashboard. In that case, select the test to open the modelling interface.

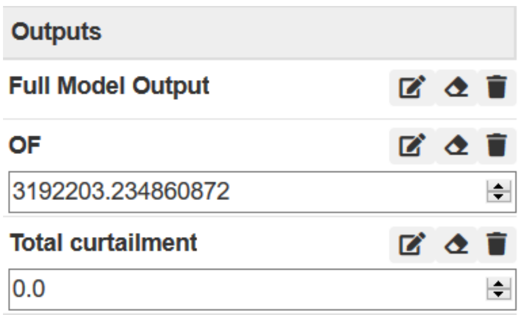
Alternatively, if you have downloaded the “Test_Islands.json” file, click on the “Create a Network” option () to open a new menu and select the Import Tab. Create a new model named “Test_Islands” and locate the “Test_Islands.json” file to create the model.



The “Test_Islands” example will be created in the dashboard. Click on the example to open the modelling interface.

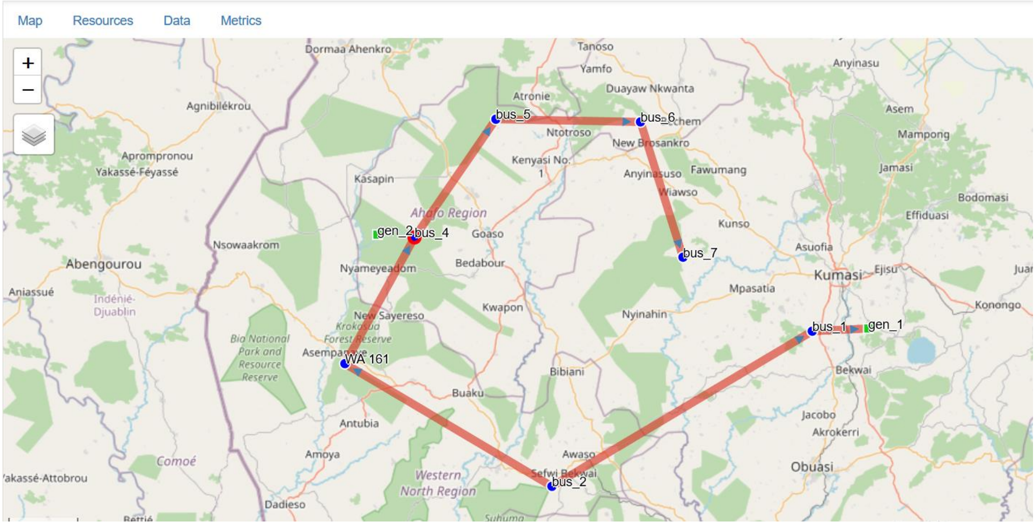


Run the network model by selecting , and then running a time series analysis, i.e., “Combined simulation”. Once the study successfully concludes (i.e., green run), check the system level results by selecting () to access the monthly “Total curtailment” and objective function “OF”.

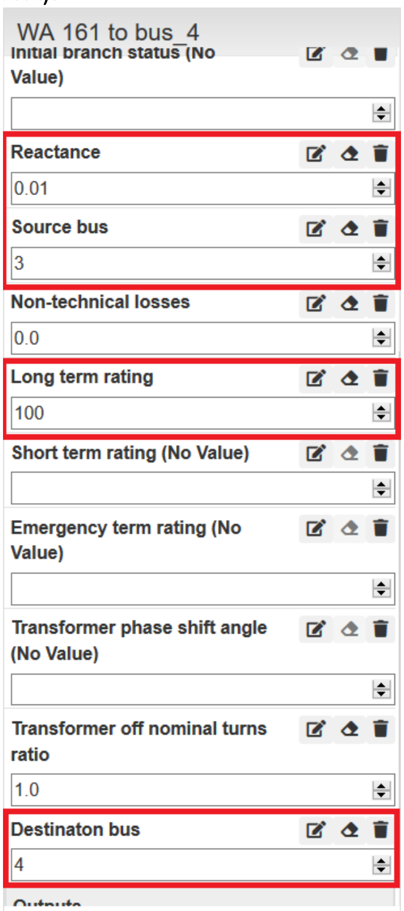


You should save the results with the name "original solution" for comparison with other scenarios. Once the results are saved, select the "Baseline" case in the dropdown menu in the left side. The procedure is the same as with the previous example.

The first modification that will be made in this example is to connect the two islands. To do so, a new line that connects nodes 3 and 4 is installed in the system.

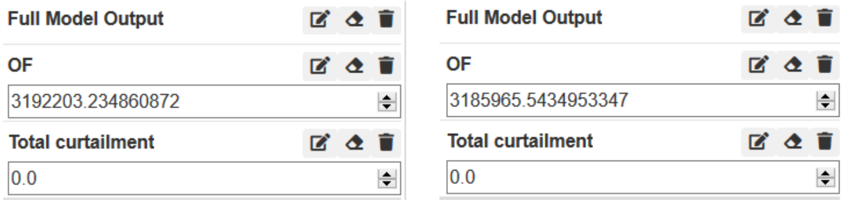


The data that have to be manually included are the reactance of the new line (Reactance = 0.01 pu), the buses that are connected by the line (Source bus = 3 and Destination bus = 4), and the capacity of the line (Long term rating = 100 MVA).



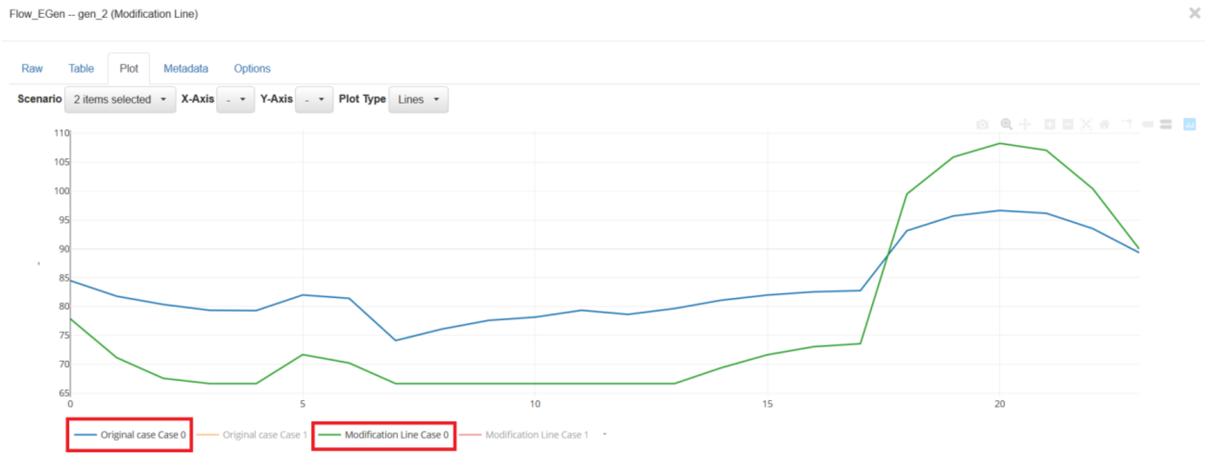
Now, run the network model again and after it concludes, clone the results and save them with the name "Modification Line". The first difference between the two scenarios can be observed in the value of the objective function as shown below.

a. Original Solution b. Modication Line



This decrease in the objective function is caused by a change in the generation pattern that directly affects the quadratic generation cost of each generator. If the generation cost function were linear then the objective function would not have any change. This improvement in the operational cost is a consequence of the interconnection of the independent systems. It is important to note that these results are case specific and, in practice, connecting two or more independent systems does not necessarily lead to a reduction in operational cost for all interconnected systems. That said, interconnecting and meshing different systems can bring benefits in terms of economies of scale, use of the most cost-effective generation technologies, reduction of losses, and so forth.

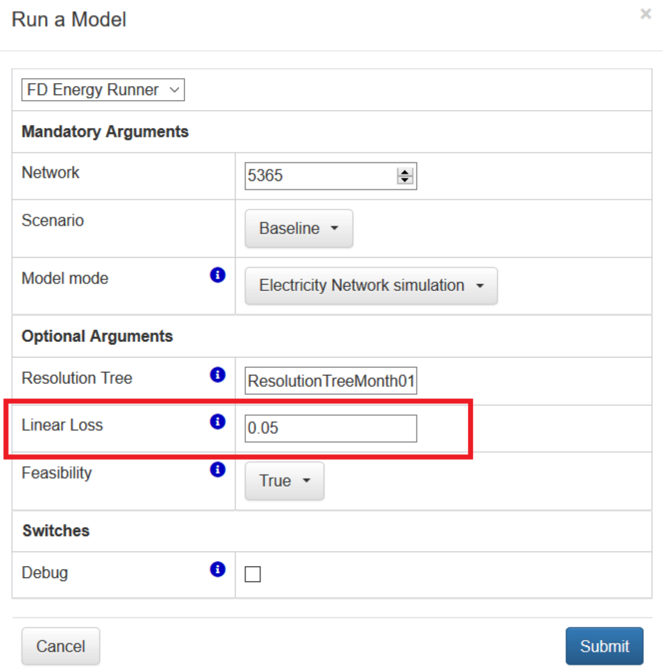
a. Generation output at generator 1



b. Generation output at generator 2

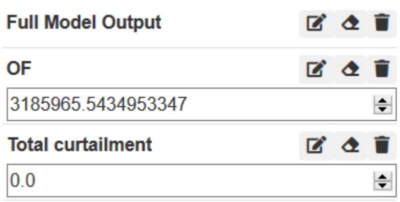
Only generation patterns of “case 0” for scenarios “original case” and “Modification Line” are shown in the figures above for the sake of simplicity. If you want to show or hide one specific case then you just need to click on the label of the case at the bottom of the image.

The second modification that will be made in this example is to modify the technical losses of the system. This modification is done in the “Run a Model” menu. The initial technical losses were set in 2% of the total demand of the system and in this example you will change the value to 5%. To do so, change the value of Linear Loss in the "Run a Model" menu to 0.05 (5%). Now run a combined simulation of the model. Clone the results and save them with the name "Technical Losses".

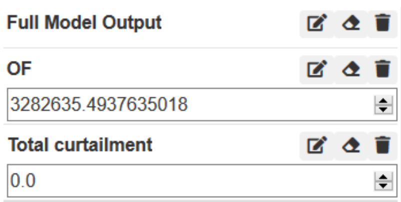


The first difference between the two scenarios can be observed in the value of the objective function as shown below.

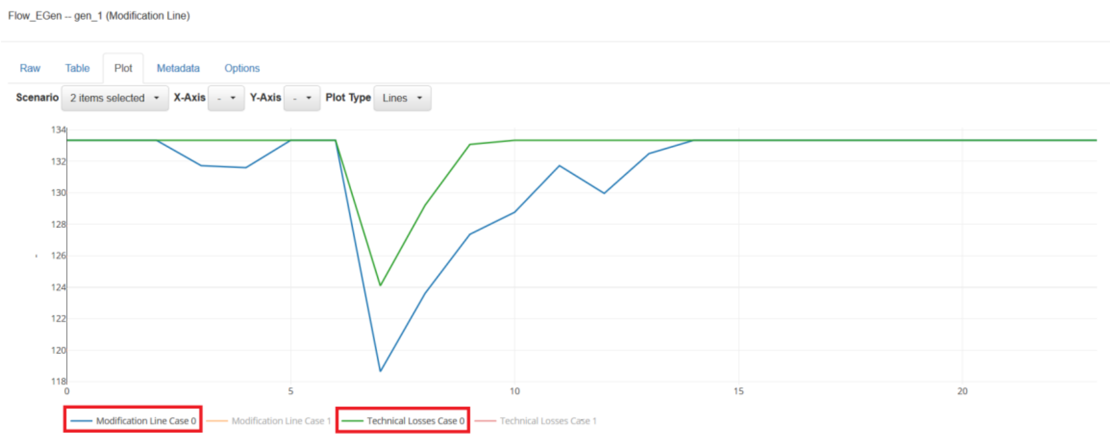
a. Modification Line



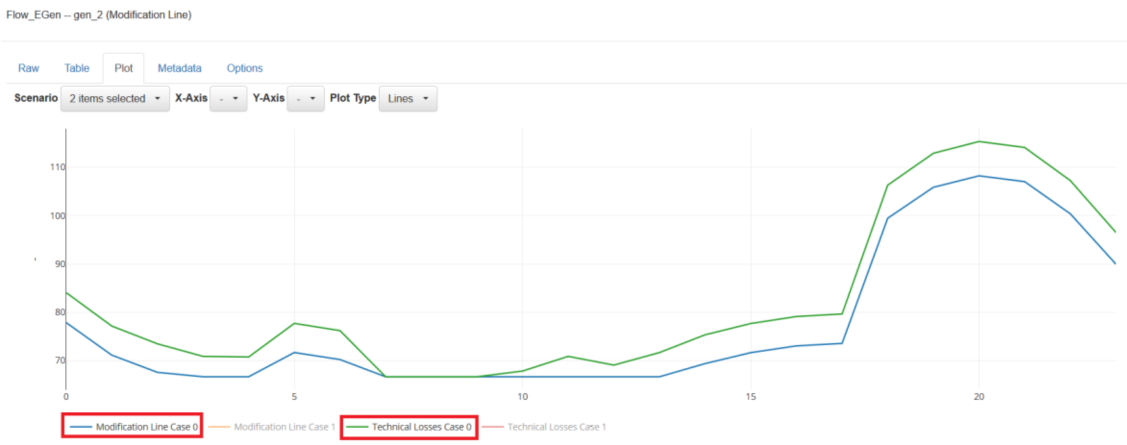
b. Technical Losses



The objective function has increased in value as a consequence of increasing the value of the technical losses in the system. The generation outputs of both generators are shown in the figures "a" and "b" below. you can observe in the figures that the generation of both generators has increased in the new scenario compared to the previous one.

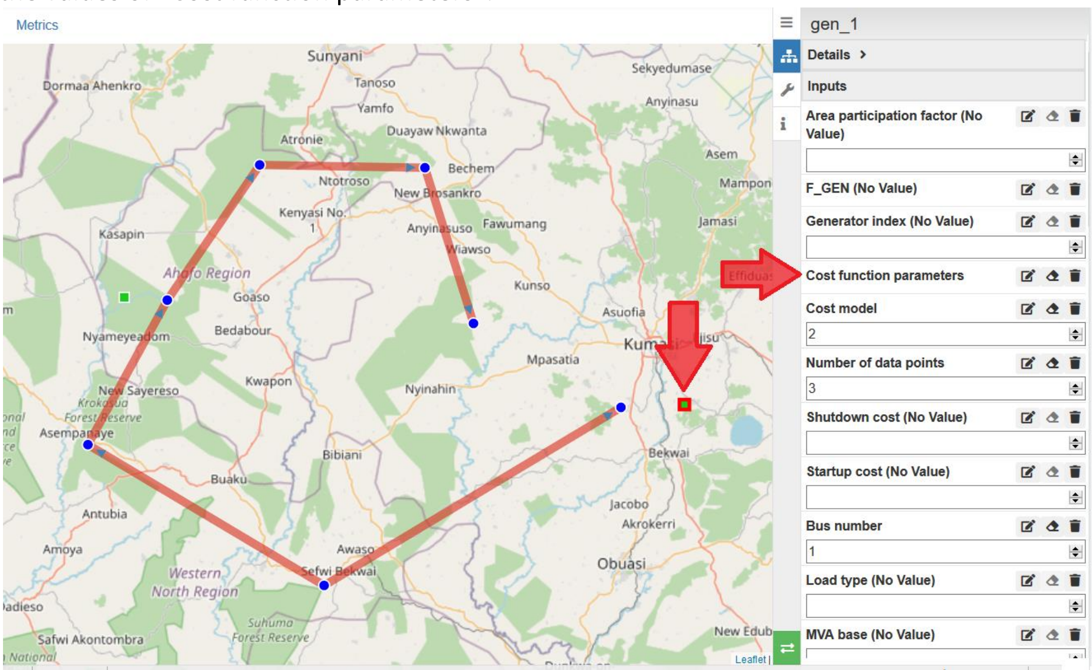


a. Generation output at generator 1

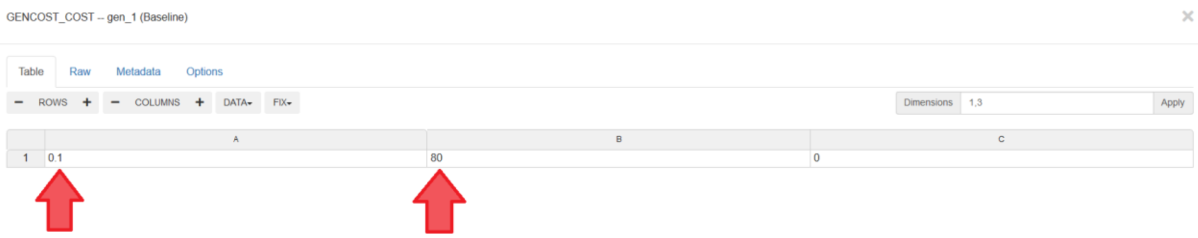


b. Generation output at generator 2

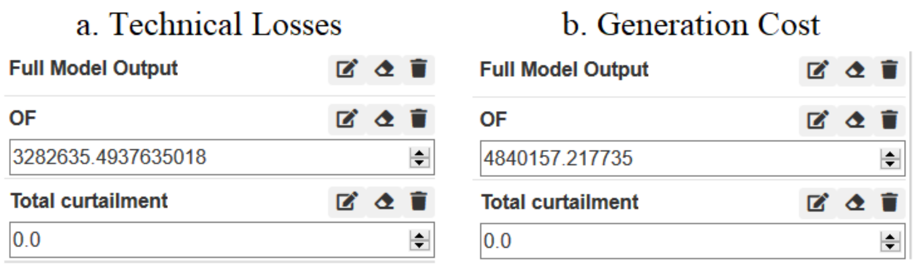
The last modification that will be made in this example is to modify the cost coefficients of the generation cost function of generator 1. You need to click in generator 1 and then after you need to edit the values of “Cost function parameters”.



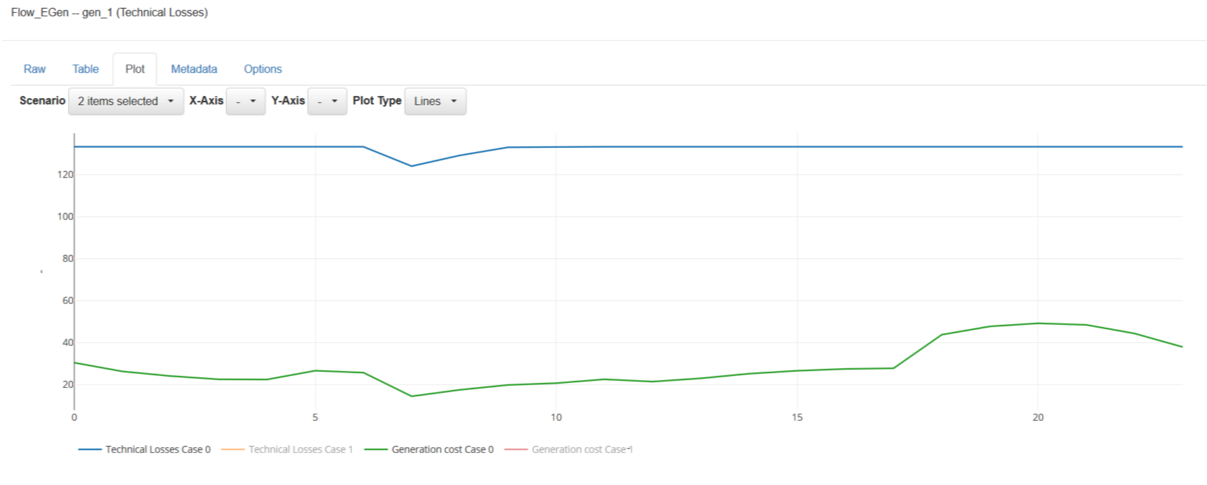
You need to change the values to “A=0.1, B=80, C=0” As shown in the figure below. Now run a combined simulation of the model and clone the results with the name “Generation Cost”.



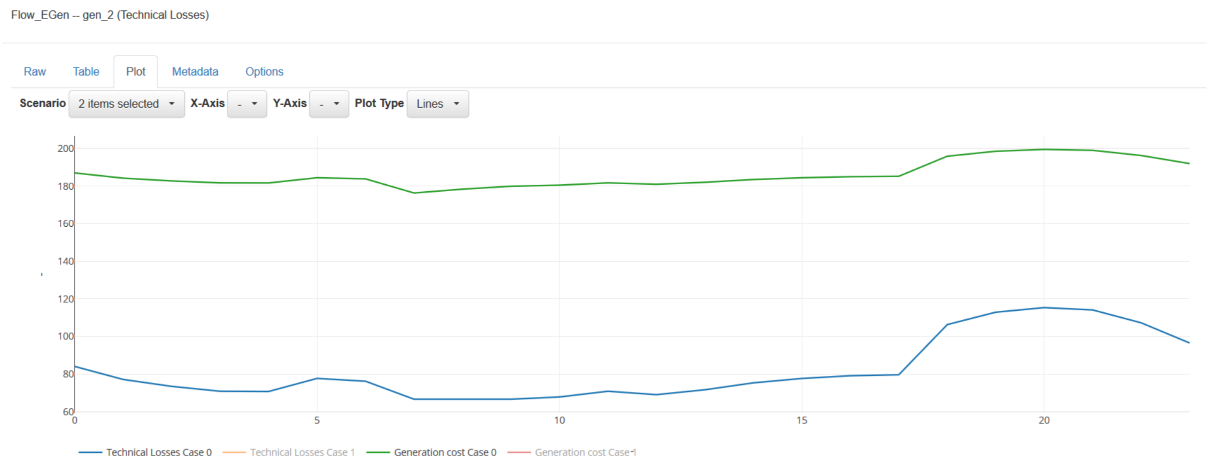
You can observe in the figure below that the previous and current scenario have again a difference in the value of the objective function. This is expected considering that the generation cost of one of the generators was increased.



You can observe in the figures below that the generation output of generator 1 (figure a) has decreased substantially due to the increase of the generation cost. The opposite just happened is generator 2 because it has cheaper generation.



a. Generation output at generator 1



b. Generation output at generator 2

4.Additional reading materials

The following list of literature provides more information about the FutureDAMS and the power network and other models, as well as different studies that are relevant to the project.

Main links:

1. FutureDAMS official website, http://www.futuredams.org/
2. Links to available publications: http://www.futuredams.org/publications/

Recommended reading:

1. E. A. Martínez Ceseña, J. Mutale, M. Panteli and, P. Mancarella, " How data collected from mobile phones can help Electricity planning," The Conversation, March, 2019. https://theconversation.com/how-data-collected-from-mobile-phones-can-help-electricity-planning-110803
2. J. M. Gonzalez, et al, Spatial and Sectoral Benefit Distribution in Water-Energy System Design", Applied energy, in Press.
3. M. Etichia, E. A. Martínez Ceseña, J. Harou, M. Panteli, "Assessment of Soft and Hard Linking Approaches for Integrated Water-Energy Simulation," EGU 2020
4. E. A. Martínez Ceseña, N. Good, M.Panteli, J. Mutale and P. Mancarella, "Flexibility in Sustainable Electricity Systems: Multivector and multisector nexus perspectives," IEEE Electrification magazine, vol. 7, no. 2, 2019.
5. Y. Zhou, M. Panteli, B. Wang and P. Mancarella, "Quantifying the System-Level Resilience of Thermal Power Generation to Extreme Temperatures and Water Scarcity," IEEE Systems Journal, vol 14, 2019. https://ieeexplore-ieee-org.manchester.idm.oclc.org/document/8840870
6. E. A. Martínez Ceseña, M. Panteli, J. Mutale, P. Mancarella, J. Tomlison and J. J. Harou, "Integrated Energy-Water Tool to Model Interdependent Storage, Run-of-River and Pump Hydropower," in PowerTech, Milan, Italy, 23 - 27 June, 2019. https://ieeexplore-ieee-org.manchester.idm.oclc.org/document/8810468
7. J. M. Gonzalez-Cabrera, J. Tomlinson, E. A. Martínez Ceseña, J. J. Harou, M. Panteli, "A integrated water-energy simulation and multi-objective optimisation framework," EGU General Assembly 2019, 07 – 12 April, Vienna, Austria, 2019.